"By hammer and hand, all things do stand"

ROGERS MACHINISTS GUIDE

A PRACTICAL ILLUSTRATED TREATISE
ON
MODERN MACHINE SHOP PRACTICE

BY

WILLIAM ROGERS

AUTHOR OF "PUMPS AND HYDRAULICS"
"MECHANICAL DRAWING AND DESIGN"
"ERECTING AND OPERATING
MACHINERY"

PUBLISHERS
THEO. AUDEL & COMPANY
72 FIFTH AVENUE
NEW YORK, U. S. A.

PRINTED IN THE U. S.

PART ONE

INDEX

TO THE PROGRESSIVE MACHINIST.

PART TWO

INDEX

FOR THE ADVANCED MACHINIST.

A

B

C

D

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

R

S

S

T

T

U

V

W

PLAN OR OUTLINE OF THE WORK.

Every author has a preconceived plan upon which his work is based and it is essential that his plan shall be known to the student so that he may, to advantage, follow the instruction of the writer.

How many read the "preface" to their books? Again, how many know into how many divisions the book is divided and where they may find a certain subject, upon which they need information? It is in view of these facts that the following lines have been prepared, to aid in the better understanding, the scope and outline of the book.

In a work necessarily so limited as this many topics must be treated with extreme conciseness, but where space has been lacking for a free discussion of a subject, the elementary principles have had the preference, leaving the reader to continue what may be called a wider and philosophic observation, to a complete comprehension of the particular study.

The subject of this work relates to a true science, and the author has planned the work accordingly, *i. e.*, the orderly arrangement of all miscellaneous information into a classification that will permit the careful reader the ready use of the contents.

It has been the desire of the author to render the work attractive by illustrating the general principles and practice of the art by the use of language easy to be understood, as well as by many helpful cuts and diagrams.

Mathematical elements are woven into the whole work throughout as a foundation; tables, rules and examples are inserted wherever these can make the reading matter plainer.

To be a good mechanical draftsman is a long step in the path of scientific improvement, and skillful artists in this line are seldom out of employment; hence the part of the Progressive Machinist devoted to this subject will, it is to be hoped, be taken as meant, as an aid, cheerfully imparted and of permanent value.

In the preparation of the contents of the work the author has had two objects constantly in view: first, to make the Student thoroughly acquainted with the leading principles of the art underlying Machine Shop Practice; and secondly, to furnish him as much useful information as possible.

PREFACE.

The author has before him five photographic groups of machinists' societies and the large group of American and English mechanical engineers, as they were to be seen at one of their recent annual reunions.

A study of these scores and scores of faces suggests a thought or two: 1, but few of them seem to equal "the days of the years of the life" of the author; 2, each and every man has undoubtedly stored in the recesses of his brain one or many items of useful knowledge pertaining to the mechanic arts, unknown to the author of this work which, notwithstanding, is aimed to be educational; 3, that if every art of mechanism were for the time obliterated and known on earth no more, these men, modest as they are, could restore in a few brief years every useful art and manufacture; 5, throughout the groups appears a wise gravity born of the combined brain and muscle work going with the higher class of mechanicians.

It is to men represented by these photographic groups that the author appeals with profound respect for a kindly consideration of the contents of the work.

It is narrated of the good sculptor, Michael Angelo, that when at work, he wore over his forehead, fastened to his cap, a lighted candle, in order that no shadow of himself might fall on his work. It was a beautiful custom, and spoke a more eloquent lesson than he knew. For the shadows that fall on our work—how often they fall from ourselves.

So, it will be the aim of the editor and compiler of these succeeding pages to keep in the shaded background allusions to those long years of personal experience which have gone never to return but upon whose gathered and garnered experience the value of the work must rest.

The contents of the book must, perforce, be its own justification; to be thorough and accurate is to be also honest, and to be all three, is worthy of the highest ambition, and such has been the endeavor of the author.

A book requires as much labor and careful thought as a complicated machine, and it often takes longer to produce it, and then, too, a reader wishes to know, first of all, what it contains, what ground it covers and what are its scope and limitations.

The Progressive Machinist is issued in the interest of those (1) who as yet are uninformed and are at the beginning of a career devoted to mechanic arts. (2) those who have once known the rules and practices of the machinist's art and have forgotten much of that they once painfully acquired. (3) For all whose extensive knowledge of machines and machine shop practice will be rendered more available by a classification or scientific arrangement.

Let it not be forgotten that "the man stands strongest who stands on his head," and that head is best filled that knows the most of the principles which underlie his life's calling.

Certain principles are fundamental; although knowledge has advanced natural laws have remained and will remain; application may have changed, but nature's decrees are lasting; a straight line is the nearest distance between two points no matter what comes in between or what means are used to connect them. That is the principle; that is the law. Cohesion of matter always remains. Gravity is everywhere and instantaneous.

To quote from a distinguished and well-known author:

"I have always divided men into two classes, professional and non-professional, to the disparagement of neither.

"Among non-professional men, I class those who carefully treasure every scrap of past experience, and who are guided by their accumulations of experience.

"Among the professional men, I class those, who, without any special attempt to gain experience themselves, are constantly and forever absorbing the experience of others. If the non-professional never did a certain thing he knows nothing about it. After he has done it, he gets one man's experience. . . . The professional man without intending to do a certain thing may have a thorough knowledge of the world's experience in that thing. To him the books bring the life-time experience of ten thousand lives. Knowledge of others' failures will divert his thoughts and acts into original channels. The non-professional leaves on record the experience of one short life and the professional man gathers in thousands of these."

It is to be hoped that in the educational lines attempted to be followed in *The Progressive Machinist,* each of these two classes will be benefited.

The term machinist signifying a builder of machinery is now of less scope of meaning than formerly; at no distant period the machinist was to-day a lathe hand, to-morrow a vise hand; he was required to be alike skillful in working upon both wood and metal, a pattern maker and a founder;

he was both engineer and a millwright, but it is not so in this age of specialization.

But it is true now as always that the skill which is exercised by a machinist is an art which is taught from man to man, and it is a fact that there is always more or less interchange of experience and moving about of workmen, which enables others in other lines of work to know what is being done, and thus permanent improvement is made year by year.

The most expensive machine is the man himself; the saving in labor is the chief item in economical shop practice. "The man behind the gun" wins the victory; the man behind the machine is a captain of modern achievement; an epic of our times might well be, as Carlyle wrote, "not arms and the man, but tools and the man."

"The human body is an epitome in Nature of all mechanics, all hydraulics, all architecture, all machinery of every kind. There are more than three hundred and ten mechanical movements known to mechanics to-day, and all of these are but modifications of those found in the human body. Here are found all the bars, levers, joints, pulleys, pumps, pipes, wheels and axles, ball and socket movements, beams, girders, trusses, buffers, arches, columns, cables and supports known to science. At every point man's best mechanical work can be shown to be but adaptations of processes of the human body, a revelation of first principles used in Nature." *

NOTE.—This is a quotation from William George Jordan.

"Make the most of time," says Goethe, "it flies so fast. Yet method will teach you to win time." Talleyrand remarks "Methods are the masters of masters."

If one desires to get on he will have to work, and if the work is to be a success it must be done in an orderly, systematic manner; the proverb has it, "Raw haste is half-sister to delay."

"Adopt the pace of Nature," says Emerson, "her secret is patience." "Everything comes if a man will only wait," is a saying of Lord Beaconsfield, England's great Prime Minister. "Imitate time," wrote the French essayist, Joubert. "It destroys slowly; it undermines, wears, loosens, separates; it does not uproot."

Dr. Le Bon says, "Century after century our departed ancestors have fashioned our ideas and sentiments, and in consequence all the motives of our conduct. The generations that have passed away do not bequeath us their physical constitution merely; they also bequeath us their thoughts. We bear the burden of their mistakes, we reap the reward of their virtues." It is thus with shop management; we are the inheritors of a hundred generations of such men as Newcomen, Watt, Stephenson, Arkwright, Maudslay, Fairburn, Whitworth, and thousands of others.

Hence, 1, work with thoughtful system; 2, work with patient deliberation; 3, work in the place where one is providentially living; 4, learn underlying principles; 5, remember what Ben Franklin said one hundred and fifty years ago, "He that idly loses five shillings' worth of time, loses five shillings and might as prudently throw five shillings into the river."

In closing the author has yet to repeat a well-approved shop adage, "A grain of showing is worth an ounce of telling."

INTRODUCTION.

Machinists must know the elements of several trades in order to be masters. No one man can be expert in all branches, and while it is now universally admitted that a man does well to excel in one, the steps which lead to the top are built of those simple things which are of service, alike to the student and to the master. It is almost a necessity to be posted upon the history of the development of machines and their inventors; still more is it to be thoroughly instructed in the meaning and use of shop words and terms.

There are but five sources of original power: 1, Water power; 2, Wind power; 3, Tide power; 4, The power of Combustion; 5, The power of Vital Action. Gravitation, Electricity, Galvanism, Magnetism and Chemical Affinity can never be practically employed as original sources of power.

Machines are divided into *simple* and compound; the former are six in number: 1, The Lever; 2, The Wheel and Axle; 3, The Pulley; 4, The Inclined Plane; 5, The Screw; 6, The Wedge.

Compound machines are formed from two or more simple machines. *Tools* are the simplest implements of art; these when they become complicated in their structure become *machines;* and machines, when they act with great power, take the name, generally speaking, of *engines*—as the pumping engine.

There are ten arithmetical figures—how small their number—1, 2, 3, 4, 5, 6, 7, 8, 9, 0; observe the small space it takes to print them.

There are twenty-six letters in the alphabet—a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z; how insignificant they are when put down in order.

There are, too, only some sixty or eighty elementary or simple substances—such as iron and copper— in the world, under it, or in the air. These are arranged in alphabetical order:

Aluminium
Antimony
Arsenic
Barium
Beryllium
(See Glucinum)
Bismuth
Boron
Bromine
Cadmium
Cæsium
Calcium
Carbon
Cerium
Chlorin
Chromium
Cobalt
Columbium
(See Niobium)
Copper
Didymium
Erbium
Fluorin
Gallium
Germanium
Glucinum
Gold
Hydrogen
Indium
Iodine
Iridium
Iron
Lanthanum
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Neodymium
Nickel
Niobium
Nitrogen
Osmium
Oxygen
Palladium
Phosphorus
Platinum
Potassium
Praseodymium
Rhodium
Rubidium
Ruthenium
Samarium
Scandium
Selenium
Silicon
Silver
Sodium
Strontium
Sulphur
Tantalum
Tellurium
Terbium
Thallium
Thorium
Tin
Titanium
Tungsten
Uranium
Vanadium
Ytterbium
Yttrium
Zinc
Zirconium

And yet:—

From the ten figures all the vast and varied processes of calculation may be made.

From the twenty-six letters may be formed books, periodicals and writings sufficient to fill the world.

Now, too, from these sixty or eighty elementary substances are made not only the solid earth, but every minute body alive or without life, all trees and fruits, water, the gases, and all machines and materials used in and about them.

The first lesson to be learned from these examples is this—that every one capable of thought may learn the names and some of the leading uses of figures, of the alphabet and of the simple substances of which the earth, and perhaps the vast universe, is formed and exists.

The second lesson is the rather unpleasant truth that no human intellect ever had the power of compassing the innumerable details to which, by combination, they may be extended.

Other lessons—of humility and such like—from a contemplation of the conditions named may be drawn, but one other will suffice; (3) that success in the brief span of a single human life lies along the line of concentration of thought and effort in special endeavors, united with an honest and truthful judgment of the elementary knowledge open to all aspirants for learning.

A million years of prolonged life and study allowed to a million of scholars, each pursuing a separate path of research, would not compass a millionth part of the knowledge to be acquired in the development to their full extent of the ten numerals, of the twenty-six letters and the sixty or eighty elementary substances.

Thus, a traveller visiting a town, could take in a second of time a general survey, so that he could ever after say with truth, I have seen Paris or New York or Yokohama; this would be true, especially if the view was first had from an eminence which allowed the whole sweep of horizon to be embraced in the flash of an eye-lid.

But the traveller to the cities named would need months and years to gain the knowledge necessary to become thoroughly an active, useful citizen of either of them.

In addition, there are to be considered what are called the Laws of Nature, the practical adoption of the law of Demand and Supply and the general fitness of things, leaving out of the question the chapter of accidents so evident in all human endeavor, so we are to be forgiven if in the preparation of these volumes we keep prudently within safe and simple limits in explaining, for the advantage of the student the subjects selected, but—

Always keeping in view the order of progression natural to healthy advancement.

MATERIALS

MATERIALS.

PRELIMINARY DEFINITIONS.

The earth may be regarded in the light of a vast physical machine and knowledge of it may be conveniently divided into two branches, 1, what is known of its structure—including the composition, its material parts; 2, its method of working.

Much of the work will be devoted to the latter, but first it is essential to know as much as possible of the matter entering into all work; hence the following definitions.

In the accompanying sections, some of the properties of iron and steel, as employed in the construction of machinery and tools are given. It is, therefore, desirable that the meanings applied to the various terms used should be clearly understood. Some of the definitions are briefly as follows:

MATTER OR SUBSTANCE may be defined as whatever occupies space as metals, water, air; or again, matter is any collection of substance existing by itself.

Matter appears to us in various shapes, which, however, can all be reduced to two classes, namely, solids or fluids.

Whatever is composed of matter may be termed material; raw material is unmanufactured substance, as iron ore is the raw material of pig iron and pig iron is that of cast iron.

ELEMENT—This word denotes a substance incapable of being resolved by any known process into simpler substances.

MATERIALS.

A PROPERTY OF A THING is what belongs especially to it as its own peculiar possession, in distinction from all other things; when we speak of the qualities or properties of matter, *quality* is the more general; *property* the more limited term.

A quality is inherent; a property may be transient; those qualities manifested by all bodies (such as impenetrability, extension, etc.,) may be called general properties of matter, while those peculiar to certain substances or to certain states of those substances (as fluidity, malleability, etc.,) are termed specific properties.

A SOLID offers resistance both to change of shape and to change in bulk; *a fluid* is a body which offers no resistance to change of shapes; fluids, again, can be divided into liquids and vapors or gases.

A LIQUID can be poured in drops while gas or vapor cannot. It is important to note that experiment proves that nearly every substance becomes a gas or vapor, at a sufficiently high temperature; example, when iron is "burnt" a part of it has gone into vapor.

A METAL is a simple or elementary, shining, opaque body or substance having a peculiar lustre, known as the metalic lustre, insoluble in water, fusible by heat and a good conductor of heat and electricity. Many of the metals are also malleable or extensible by the hammer and some of them extremely ductile.

NOTE.—"A Metal is an Elementary Substance, or one which, in the present state of Chemical Science is one undecomposable, and which possesses Opacity, Lustre, Conductivity for heat and electricity and plasticity, or capability of being drawn, squeezed or hammered with change of shape but no loss of continuity. Metals which possess all these qualities, although in varying degree, are Gold, Silver, Copper, Iron, Lead and Tin. These metals have a high specific gravity; the lightest of the above, tin, is over seven times as dense as water.'
—(C. D.)

MATERIALS

TENSILE STRENGTH is equivalent to the amount of force which, steadily and slowly applied in a line with the axis of the test piece, just overcomes the cohesion of the particles, and pulls it into separate parts.

CONTRACTION OF AREA is the amount by which the area, at the point where the specimen has broken, is reduced below what it was before any strain or pulling force was applied.

ELONGATION is the amount to which the specimen stretches, between two fixed points, due to a steady and slowly applied force, which pulls and separates it into parts. Elongation is made up of two parts; one due to the general stretch, more or less, over the length; the other, due to contraction of area at about the point of fracture.

SHEARING STRENGTH is equivalent to the force which, if steadily and slowly applied at right angles, or nearly so, to the line of axis of the rivet, causes it to separate into parts, which slide over each other, the planes of the surface at the point of separation being at right angles, or nearly so, to the axis of the rivet.

ELASTIC LIMIT is the point where the addition to the permanent set produced by each equal increment of load or force, steadily and slowly applied, ceases to be fairly uniform, and is suddenly, after the point is reached, increased in amount. It is expressed as a percentage of the tensile strength.

TOUGH.—The material is said to be "tough" when it can be bent first in one direction, then in the other, without fracturing. The greater the angles it bends through (coupled with the number of times it bends), the tougher it is.

MATERIALS.

DUCTILE.—The material is "ductile" when it can be extended by a pulling or tensile force and remain extended after the force is removed. The greater the permanent extension, the more ductile the material.

ELASTICITY is that quality in a material by which, after being stretched or compressed by force, it apparently regains its original dimensions when the force is removed.

FATIGUED is a term applied to the material when it has lost in some degree its power of resistance to fracture, due to the repeated application of forces, more particularly when the forces or strains have varied considerable in amount.

MALLEABLE is a term applied to the material when it can be extended by hammering, rolling, or otherwise, without fracturing, and remains extended. The more it can be extended without being fractured, the more malleable it is.

WELDABLE is a term applied to the material if it can be united, when hot, by hammering or pressing together the heated parts. The nearer the properties of the material, after being welded, are to what they were before being heated and welded, the more weldable it is.

COLD-SHORT is a name given to the material when it cannot be worked under the hammer or by rolling, or be bent when cold without cracking at the edges. Such a material may be worked or bent when at a great heat, but not at any temperature which is lower than about that assigned to dull red.

HOT-SHORT is when the material cannot be easily worked under the hammer, or by rolling at a red-heat at any temperature which is higher than about that assigned to a

MATERIALS.

red-heat, without fracturing or cracking. Such a material may be worked or bent at a less heat.

TENACITY OR THE POWER OF COHESION is that resistance which bodies exhibit when force or weight is applied to tear asunder, in the direction of their length, the fibres or particles of which they are composed. Tenacity results from the attraction of cohesion which exists between the particles of bodies, and the stronger this attraction is the greater is the tenacity of the body; tenacity primarily means to "hold fast;" cohesion "to stick."

RESISTANCE may be understood as meaning the act of "springing back" or rebounding or the work given back by a spring after being strained.

COEFFICIENT is that which unites in action with something else to produce a given effect; that which unites its action with the action of another.

STRESS AND STRAIN—Any breaking or bending pressure applied to a body or substance is called *a stress,* its effect on the piece *a strain;* briefly, then, the strength of a solid piece or body is the total resistance it can oppose to strain in that direction.

Materials are exposed to four different kinds of strain.

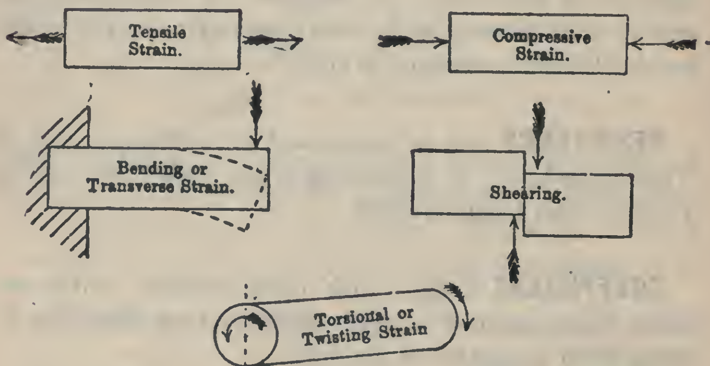
1. They may be torn asunder; the strength of a body to resist this kind of strain is called its resistance to tension, or absolute strength.

2. They may be crushed or compressed in the direction of their length as in the case of columns.

MATERIALS.

3. They may be broken across; the strength of a body to resist this kind of strain is called its lateral strength.

4. They may be twisted or wrenched as in the case of axles or screws.



IRON, STEEL

AND

METALS

IRON, STEEL, ETC.

IRON is one of the elementary metals, and too well known to require a lengthy description; of all metals none plays so important a part in civilizing, mechanical advance, as iron; it is obtained from ores in which it is combined with earthy or stony substances and frequently with carbon, phosphorus, sulphur, arsenic, magnesia, etc.; in fact, iron is never found in its native condition, chemically pure, nor is any iron manufactured in a large way found to be free from impurities.

IRON is put upon the market in three forms:

1. Cast iron.
2. Wrought iron.
3. Steel.

VARIOUS IRONS—Different names are given to iron as needed to describe its size, form, quality or use; thus—gossamer iron—sponge iron—hoop, band, scroll, tee, groove, plate, bar, angle, flat, rod, sheet, hexagon, galvanized, horse shoe, nailrod, scrap iron.

CAST IRON, is iron which has been melted and cast; that is run into a mold in which it assumes the desired form; it is inflexible, unyielding in its nature, it melts at 1960° Fahrenheit, and its specific gravity is 7.21; when broken it shows a granular fracture.

Historical Note.—Iron was first made in Asia and North Africa and its use and manufacture can be traced to the earliest ages of antiquity. Tubal Cain, who was born in the seventh generation from Adam, is described in the Revised Version of the Scriptures as "the forger of every cutting instrument of brass and iron."

Gossamer Iron, the wonderful product of the Swansea Iron Mills, is so thin that it takes 4,800 sheets piled one on the other to make an inch in thickness.

IRON, STEEL, ETC.

PIG IRON is distinguished in "the trade" by numbers, according to their relative hardness.

No. 1 is the softest iron, possessing in the highest degree the qualities described as belonging to gray iron. It has not much strength, but on account of its fluidity when melted, and of its mixing advantageously with other kinds of iron, it is of great use to the foundry.

No. 2 is harder, closer grained, and stronger than No. 1. It has a gray color and considerable lustre.

No. 3 is still harder. Its color is gray but inclined to white. It has considerable strength, but is principally used for mixing with other kinds of iron.

No. 4 is bright iron. No. 5 is mottled iron. No. 6 is unfit for general use by itself.

The quality of iron, in the pig, is decided by breaking the pig and examining the fracture. A medium-sized grain, bright gray color, lively aspect, fracture sharp to the touch, and a close compact texture, indicates a good quality of iron. A grain either very large or small, a dull, earthy aspect, loose texture, dissimilar crystals mixed together, indicate an inferior quality.

MALLEABLE IRON is made from pig iron low in silicon, sulphur and phosphorus, and from which the carbon has

NOTE.—Pig iron, according to the proportion of carbon which it contains, is divided into Foundry iron, and Forge iron.

There are many varieties of cast iron, differing from each other by almost insensible shades. The two principal divisions are gray and white, so called from the color of the fracture, when recent.

Gray iron is softer and less brittle than white iron. It is to a slight degree malleable and flexible, can be easily drilled and turned in the lathe, and does not resist the file. It has a brilliant fracture, of a gray, or sometimes a bluish-gray color; the color is lighter as the grain becomes closer, and its hardness increases at the same time.

White iron is very brittle and resists the file and the chisel. The fracture presents a silvery appearance, generally fine-grained and compact.

subsequently been largely removed by annealing at a red heat in iron ore, mill scale or some other porous or infusible substance.

WROUGHT-IRON is iron which can be worked into form by rolling or forging; it can be welded, it is flexible and malleable; it melts at 2912° Fah.; it has a specific gravity of 7.74; when fractured it shows a fibrous nature; it is weldable at 1500 or 1600° Fah.

There is an enormous wrought-iron pillar in India, near Delhi, which weighs 10 tons, and is said to be 1,800 years old. The manufacture of cast steel in India can be traced back for over 2,000 years.

STEEL—The term steel has always been more or less indefinite in meaning, so that it is generally necessary to add some qualifying adjective, in order that the nature of the material under consideration may be understood. Within recent years, however, the causes of the differences between the various kinds of steel have been studied in a manner which has enabled metallurgists to speak with some degree of precision concerning them.

The shortest definition of steel is to say it is refined or nearly pure iron, with a certain per cent. of added carbon. Steel may be made by two methods: (1) by adding carbon to wrought-iron, called *cementation process,* and (2) by removing carbon from cast iron as in the Bessemer process.

The name steel includes all varieties of iron except malleable iron, containing less than 1.5 per cent. of carbon; it may have been fused as in crucible steel and mild steel.

NOTE.—A bar of iron that contains flaws, blisters, etc., or for any other reason is not of uniform structure or density throughout, though no foreign substance be mixed with the iron, is said to be *non-homogeneous* or *unhomogeneous.*

IRON, STEEL, ETC.

Or it may have been prepared in the solid condition, as in blister steel. When the steel has less than .5 per cent. of carbon it is called mild steel, when more, hard steel. When fractured the appearance is from granular to fibrous as the steel is of every variety from hard to mild or soft. Its specific gravity also varies from 7.70 to 7.90, and it melts at 2500° Fah.

Steel may be distinguished from iron by its fine grain, and its susceptibility of hardening, by immersing it when hot in cold water.

The best steel possesses the following characteristics: heated to a redness and plunged into cold water, it becomes hard enough to scratch glass and to resist the best files; the hardness is uniform throughout the piece. After being tempered, it is not easily broken, welds readily and does not crack or split. It also bears a very high heat, and preserves the capability of hardening after working; the grain is fine, even and homogeneous, and it receives a brilliant polish.

BESSEMER STEEL is made by pouring melted cast iron into a vessel called a "converter," through which a blast of air is forced; by this means the impurities are burnt out, and comparatively pure iron remains. To this then is added a certain quantity of *spiegeleisen,* which is a compound of iron, carbon and manganese; after this is done, the converter is tilted up, and the molten metal is cast into ingots.

SIEMEN-MARTIN STEEL is made by melting cast iron and wrought iron, or cast iron and certain kinds of iron ore together on the hearth of a reverberating gas furnace.

IRON, STEEL, ETC.

CAST STEEL is the finest kind of steel. It is known by a very fine, even, and close grain, and a silvery and homogeneous fracture. It is very brittle, and acquires extreme hardness, but is difficult to weld without the use of flux. Other kinds of steel have a coarser grain and are less homogeneous, are softer, less brittle and weld more easily.

CRUCIBLE CAST STEEL is used for tools, *i. e.,* tool steel—so-called—is cast from a crucible. A crucible is a melting pot generally made from plumbago.

MANGANESE-STEEL is an alloy of iron and manganese, containing a high percentage of carbon; it has great tensile strength and toughness combined with great hardness which cannot be softened and therefore limits its use; it can only be machined with great difficulty.

NICKEL STEEL is used with much success as a material for parts of marine engines and boilers. Owing to its ability to resist the action of salt water it is found to be superior to other kinds of steel for marine construction. Hollow shafts in the ocean "greyhounds" are found to be much stronger when made of this alloy than when made of any other kind of steel.

BLISTERED STEEL is prepared by the direct combination of iron and carbon. The process is to take the best bars and plates of wrought iron and expose them in a converting furnace for seven or eight days, to a medium temperature, while in contact with powdered charcoal so as to

---

NOTE.—In reading the percentages of carbon, phosphorus, etc., as given in technical papers and books of instruction, the reader is supposed to know that 1.5 per cent. means 1½ parts in 100 or say again, .05 per cent. makes five parts in 100 or 1 1/20 part. This is told in decimals in arithmetic, but repeated here for the guidance of the incautious student.

totally exclude the air. The bars, on being taken out, exhibit in the fracture a uniform crystalline appearance. The degree of carbonization is varied according to the purpose for which the steel is intended.

SHEAR STEEL is generally made from blistered steel, refined by piling into fagots which are brought to a welding heat in a reverberatory furnace, hammered and rolled again into bars. This operation is repeated several times to produce the finest kind of shear steel. The name is derived from the fact that this variety of steel was used in England for shears.

THE PROCESS of converting cast into malleable iron consists in melting the pig metal in a reverberatory furnace, where the flame is made to act directly on the metal, keeping it exposed to a great heat, and constantly stirring the mass, thus bringing every part of it evenly under the action of the flame until it loses its carbon. It then loses its fluidity, and is formed into a puddler's ball. This is the point or connecting link between cast and malleable iron. After the puddler's ball has been formed, it is passed to a heavy squeezer, or steam hammer,—most frequently the former, the object being to press out, as perfectly as possible, the liquid cinder which the ball contains, when it is ready to be rolled or hammered.

NOTE.—*Attractive and Repellent Forces.*—If we take a piece of iron and attempt to pull it to pieces, we find that there is a force which holds the molecules together and resists our efforts. If we try to compress the metal we find that there is a force which holds the molecules apart and resists our efforts as before. If, however, we apply heat, the iron expands and finally melts. So, also, if we heat a bit of ice, the attractive force is gradually overpowered, the solid becomes a liquid, and at last the repellent force predominates and the liquid passes off in vapor. In turn, we can cool the vapor, and convert it back successively into water and ice. We thus see that there are two opposing forces which reside in the molecules—an attractive and repellent force, and that the latter is heat.

IRON, STEEL, ETC.

While hot, it is generally passed between the rolls several times, and drawn into a bar about 5 inches wide and 3 inches long; this is called muck bar.

To refine it they are cut with a strong pair of shears into such lengths as are best adapted to the size of the bar or sheet required. The sheared bars are then piled one on the other, according to the quantity of metal necessary to make the finished piece. They are then brought to a welding heat in the heating furnace, and passed between the finishing rolls until drawn to the proper size.

NOTE.—"*Cast iron usually contains over 3 per cent. of carbon; cast steel anywhere from 0.06 per cent. to 1.50 per cent., according to the purpose for which it is used; wrought iron from 0 02 per cent. to 0.10 per cent. The quality of hardening and tempering which formerly distinguished steel from wrought iron is now no longer the dividing line between them, since soft steels are now produced which, by the ordinary blacksmith's tests, will not harden. All products of the crucible, Bessemer, and open-hearth processes are now commercially known as steel.*"—W. KENT.

VARIOUS METALS, ALLOYS, ETC.,
ARRANGED ALPHABETICALLY.

ALLOY is an artificial compound of two or more metals combined while in a state of fusion, as of copper and tin which form an alloy called bronze.

ALUMINUM is a metal of white silver color and brilliant luster, very malleable, ductile and a good conductor of heat and electricity. It melts at about 1160° Fah. Its most remarkable features are, (1) its low specific gravity, about ⅓ that of iron, (2) its strength, and (3) it does not tarnish in the air; it is non-poisonous; it is used in machinery and alloys, and in apparatus where lightness and strength are required. Nickel-aluminum is the term used to describe an alloy of these two metals.

Five per cent. of copper, nickel or manganese or 30 per cent. of zinc added to aluminum make strong metals, as rigid as bronze, yet only one-third as heavy. Such light, strong, good casting and machining alloys have an extremely large field of usefulness.

Aluminum is the coming metal; it is found in inexhaustible quantity in common clay. When the iron fields and copper districts have yielded their last ton of metal, the world will progress with ease and comfort with this now rare product. Few of the readers of this book will, it is almost certain, reach the "Aluminum Age."

VARIOUS METALS, ALLOYS, ETC.

AMALGAM—This term signifies a mixture of metals, as a compound of quicksilver with another metal. Amalgams are used for cold-tinning, water gilding and for the protection of metals from oxidation or rusting, etc.

ANTIMONY is a metal of a white color and bright luster, and does not readily tarnish; it is a less perfect conductor of heat and electricity than most true metals and also differs from them in being brittle. It melts at 842° Fah., and is 6.7 heavier for the same bulk than water; it is largely used in alloys, particularly type metal, Babbitt and various anti-friction metals.

ASBESTOS is a fibrous mineral which resists heat, moisture and generally acids; its fibres are flexible and elastic; it is used for packing steam joints, piston-rods, etc. Reduced to a powder it is soft to the touch and makes a good cement for protecting heated surfaces.

BABBITT—This is an alloy composed of tin, copper and antimony. Any anti-friction metal has now come to be known as "Babbitt metal." Formerly the alloy originated by Isaac Babbitt was used for all purposes, but there is no one composition that will bring equally good results in all kinds of machinery. A metal designed to do the best service under heavy pressure will not be the best metal for bearings subjected to high speed.

BISMUTH is a metal of a peculiar light reddish color, highly crystalline, and very brittle; it is used in alloys with tin and lead, which fuse at a temperature less than that of boiling water and steam, under pressure, *i. e.,* such an alloy as is used in what are called "Safety Plugs," put in the shells of steam boilers to indicate low water.

VARIOUS METALS, ALLOYS, ETC.

BRASS is an alloy composed of copper and zinc in different proportions; it is generally harder than copper and wears better than that metal; it can be rolled into sheets or hammered into any shape, and drawn into fine wire; it turns easily in the lathe; it melts at 1650° Fah. Brass is of different degrees of hardness, according to the proportion of the alloys.

BRONZE—This is the name given to alloys which contain about 80 to 90 per cent. of copper, thus: Manganese Bronze contains 88 per cent. of copper. Phosphor Bronze contains 80 per cent. of copper.

CORUNDUM is a mineral substance found native in a crystalline state; in hardness it is next to the diamond; it is of various colors, the transparent varieties being prized as gems. Emery is granular corundum more or less impure. As an abrasive corundum is unexcelled. Its diamond-like hardness, brittleness and sharpness give it its long lasting qualities.

COPPER is a well-known metal, distinguished from all others by its red color; it is one of the most widely diffused metals. In two regions this metal is mined in its native state, namely, on the south shore of Lake Superior, and in Bolivia, South America. Copper is used for electrical purposes, on account of its high conductivity; it melts at 1996° Fah., and its specific gravity is 8.8; copper can be rolled, drawn or wrought; it turns easily in the lathe.

DELTA is an alloy of three metals; delta signifies three-sided or triangular. Its component parts are copper, zinc and iron. Delta is non-corrosive, and capable of high polish; it can be cast, forged, stamped and rolled; it has great strength and toughness; when rolled it considerably exceeds the tensile strength of rolled bar iron. For mines it presents advantages from its resistance to acid waters.

DROSS is the name generally used to define the impurities or foreign matter or refuse which separates from molten metal and rises to the surface.

EMERY is a granular mineral substance and belongs to the species corundum; it is not, however, pure corundum, but is mixed with magnetic or hematite ores; it is principally used in grinding and polishing stone, metal and glass surfaces; for this purpose the stone is crushed into powder and attached to paper, cloth, wood.

GLASS is an inorganic substance, the result of the fusion of silica, soda, lime, potash, etc. Glass, such as used for window panes, is produced by the fusion at a very high temperature of purified white sand, lime, sulphate of soda, arsenic, manganese, salt cake and cullet or broken glass.

GOLD is a precious metal, remarkable for its unique yellow color, luster, high specific gravity and freedom from liability to rust or tarnish; it melts at 2000° Fah., and its specific gravity is 19.2; it resists the action of all ordinary acids.

GUN METAL or *Bronze* is an alloy of 8 parts copper and 1 part tin; principally used in making bells, in the manufacture of cannon and also machinery requiring extra strength.

VARIOUS METALS, ALLOYS, ETC.

LEAD is a metal remarkable for its softness and durability; it belongs to the white metals, but has a decided bluish gray tinge; the fresh cut surface is lustrous, but soon becomes dull from exposure. Lead is easily cut with a knife and is very malleable; it can be rolled into sheets, but will not draw into wire; it is largely used for pipes and steam joints. It melts at 618° Fah., and its specific gravity is 11.38.

LIMESTONE is a rock used largely in purifying cast iron in the cupola or furnace.

MANGANESE is a metal not used in its pure state. When alloyed with iron it is called spiegeleisen or ferro-manganese.

MINERALS—This word is derived from mine, hence primarily, minerals are metallic or other ores procured by digging.

A mineral is in almost every case a solid body and besides its chemical composition has other characteristics, as specific gravity, hardness, fracture, tenacity, luster, color and fusibility.

MERCURY is a metal of a silver white color and brilliant metallic luster, unique in that it is fluid at all ordinary temperatures; its chief use is in treating gold and silver ores, and its peculiar qualities are availed of in the thermometer and barometer. Mercury freezes and becomes solid at about, *i. e.*,—40° Fah.

MUNTZ METAL is an alloy of three parts copper, two parts zinc; it is largely used for sheathing timber ships' bottoms to preserve them from the action of salt water; it can be easily rolled or forged, and differs from common brass in being malleable when hot.

VARIOUS METALS, ALLOYS, ETC.

NICKEL is a metal which is closely allied to iron and is of a slightly lighter color; the ore of nickel is diffused generally throughout the world but nowhere in abundance; nickel is an ingredient in valuable alloys such as German silver, coinage, nickel steel, nickel plating, etc.

Nickel is very difficult of fusion, melting at about 3000° Fah. Nickel is attracted to the magnet and may be made magnetic like iron.

ORE is a name or term used to define rock or metallic mineral which is of economical or mercantile value.

PLATINUM is an important although rare metal; it is not found as an ore, but is alloyed with other metals in its native state; it is only surpassed in ductility by gold and silver; it is infusible in the strongest heat of a blast furnace, and is used for the connecting wires in incandescent electric lamps. The annual world's supply of this metal is reckoned in ounces. Over 90 per cent. of the total comes from the Russian placers, the output of which in a single recent year was approximately 153,000 ounces.

PLUMBAGO is black lead graphite, one of the forms in which carbon occurs in nature; it has an iron gray color and metallic luster, chiefly used in pencils, crucibles and portable furnaces; it is used to counteract friction in rubbing surfaces, and is used as a lubricant, dry, in powder form, or mixed with oil or grease, etc.

PHOSPHOR BRONZE is an alloy of copper, tin, lead and phosphorous; it is generally used for bearings requiring strength and durability; it has been adopted by some prominent railways, and is spoken of frequently as "standard metal."

PHOSPHOR TIN is an alloy used for making castings.

VARIOUS METALS, ALLOYS, ETC.

PHOSPHORUS is a solid, non-metalic, combustible substance not found by itself in nature. When pure it is semi-transparent and colorless, and is exceedingly inflammable. Probably no element of itself weakens cast iron as much as phosphorus when present in large quantities; most irons contain more than is beneficial. One part out of one hundred or less add to the quality of cast iron—above 1½ parts to the 100 weakens it.

PLASTER is a composition of lime, sand, hair and water; hair is used to give it cohesion and prevent its breaking apart. Plaster made with a particular kind of calcined gypsum is called plaster of paris; it sets quickly but does not obtain much hardness.

SILVER is a metal of a white color; it is harder than gold and softer than copper. It is remarkable for its whiteness of color. Silver occurs in a great variety of ores all over the world. Native silver is of frequent occurrence; it is liable to tarnish, and is never used without alloy, as it is too soft.

SOLDER is an alloy of tin, bismuth and lead, extremely fusible; it is generally used for joining or binding together metallic joints or surfaces.

SPELTER is the name by which ingot zinc is called, and is seldom used except in commerce.

SULPHUR is an elementary substance which occurs in nature as a brittle crystalline solid; it melts at 238° Fah.; it occurs in great abundance in the neighborhood of extinct volcanoes. In the manufacture of iron sulphur is a great drawback, on account of making the metal difficult to work.

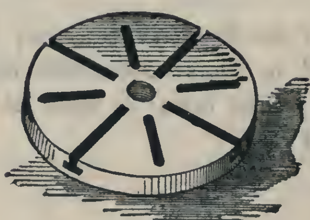
VARIOUS METALS, ALLOYS, ETC.

THALLIUM is a rare metal; it is malleable and very soft; it has a bluish white tinge.

TIN is a metal nearly resembling silver in whiteness and lightness and luster; it is highly malleable and takes a high polish; native tin occurs very rarely; it melts at 442° Fah.; its chief uses are for coating sheet iron, and for making alloys with copper and other metals.

TUNGSTEN is a rare metal, the ore of which is found in Cornwall, Eng.; it is used to improve the quality of steel. A certain per cent. of tungsten in steel makes it very hard.

ZINC is one of the chemical elements; its ore has long been known, and in combination with copper forms the well-known alloy called brass; it melts at 780° Fah.; its specific gravity is 7.19.



GRAVITY.

Our English word "gravity" is derived from a Latin word meaning "heavy;" hence its primary definition is "weight" or "heaviness."

We can not well say what gravity is, but may say what it does,—namely, that it is something which gives to every particle of matter a tendency toward every other particle. This influence is conveyed from one body to another without any perceptible interval of time. If the action of gravitation is not instantaneous, it moves more than fifty millions of times faster than light.

Gravity extends to all known bodies in the universe, from the smallest to the greatest; by it all bodies are drawn toward the center of the earth, not because there is any peculiar property or power in the center, but because, the earth being a sphere, the *aggregate* effect of the attractions exerted by all its parts upon any body exterior to it, is such as to direct the body toward the center.

This property discovers itself, not only in the motion of falling bodies, but in the *pressure* exerted by one portion of matter upon another which sustains it; and bodies descending freely under its influence, whatever be their figure, dimensions or texture, are all *equally accelerated* in right lines perpendicular to the plane of the horizon. The apparent *inequality* of the action of gravity upon different species of matter near the surface of the earth arises entirely from the resistance which they meet with in their passage through the air. When this resistance is removed (as in the exhausted receiver of an air-pump), no such inequality is perceived;

GRAVITY.

bodies of all kinds there descend with equal velocities; and a coin, a feather, and the smallest particle of matter, if let fall together, are observed to reach the bottom of the receiver exactly at the same instant.

The *weight* of a body is the force it exerts in consequence of its gravity, and is measured by its mechanical effects, such as bending a spring. We weigh a body by ascertaining the force required *to hold it back,* or to keep it from descending. Hence, weights are nothing more than *measures of the force of gravity* in different bodies.

It has been ascertained, by experiment, that a body falling freely from rest, will descend $16\frac{1}{12}$ feet in the first second of time, and will then have acquired a velocity, which being continued uniformly, will carry it through $32\frac{1}{6}$ feet in the next second. Therefore, if the first series of numbers be expressed in seconds, 1″, 2″, 3″, &c., the velocities in feet will be $32\frac{1}{6}$, $64\frac{1}{3}$, $96\frac{1}{2}$, &c.; the spaces passed through as $16\frac{1}{12}$, $64\frac{1}{3}$, $144\frac{3}{4}$, &c., and the spaces for each second, $16\frac{1}{12}$, $48\frac{1}{4}$, $80\frac{5}{12}$, &c.

TABLE

Showing the Relation of Time, Space and Velocity.

Time in seconds of the body's fall	Velocity acquired at the end of that time.	Squares.	Space fallen through in that time.	Space.	Whole space fallen through in the last second of the fall.
1	32.16	1	16.08	1	16.08
2	64.33	4	64.33	3	48.25
3	96.5′	9	144.75	5	80.41
4	128.66	16	257.33	7	112.58
5	160.83	25	402.08	9	144.75
6	193.	36	579.	11	176.91
7	225.17	49	788.08	13	209.08
8	257.33	64	1029.33	15	241.25
9	289.5	81	1302.75	17	273.42
10	321.66	100	1946.08	19	305.58

THE THREE LAWS OF MOTION

Gravity operates under three great principles of motion, called the Laws of Motion.

First Law.—*A body continues in the state in which it is, whether of rest or motion, until compelled by some external force to change its state.*

Second Law.—*Motion, or change of motion, is proportioned to the force impressed, and is in the direction of that force.*

Third Law.—*When bodies act on each other, action and reaction are equal and in opposite directions.*

SPECIFIC GRAVITIES OF BODIES.

Every substance in nature has, under the same circumstances, a weight *specific* or peculiar to itself.

The Specific Gravity of a body is its weight compared with the weight of another body taken as a standard.

Water is the standard for all solids and liquids, and common air is the standard for gases.

The heaviest of all known substances is platinum, whose specific gravity, in its state of greatest condensation, is 22, water 1; and the lightest of all weighable bodies is hydrogen gas, whose specific gravity is $\frac{073}{1000}$, common air being 1, but air is 818 times lighter than water. Hence by calculation it will be found that platinum is about 247,000 times as heavy as hydrogen, and a wide range is thus allowed to the various bodies which lie between these extremes.

SPECIFIC GRAVITIES OF BODIES.

In taking the specific gravity of solids, advantage is taken of the important fact that when a solid is wholly immersed in water, it displaces a bulk of that liquid exactly equal to its own, and the solid appears to lose its weight; that is, it is supported by the surrounding water with a force exactly equal to the weight of the water displaced; hence, the difference of its weight in water from that of its weight in air must be the weight of an equal bulk of water.

These paragraphs relating to gravity, or the weight of bodies, are inserted after the subject of *Materials* because, in all practical mechanics, every particle of matter used or handled by the workman is instantly and constantly affected by this mysterious force, and it must be intelligently reckoned with to arrive at proper results.

Historical Note.—One of the most valuable discoveries made by Archimedes, the famous scholar of Syracuse, in Sicily, relates to the weight of bodies immersed in water.

Hiero, king of Syracuse, had given a lump of gold to be made into a crown, and when it came back he suspected that the workmen had kept back some of the gold, and had made up the weight by substituting silver; but he had no means of proving this, because they had made it weigh as much as the gold which had been sent.

Archimedes, puzzling over this problem, went to his bath. As he stepped in he saw the water, which his body displaced, rise to a higher level in the bath, and to the astonishment of his servants he sprang out of the water, and ran home through the streets of Syracuse almost naked, crying, "*Eureka! Eureka!*" ("I have found it! I have found it!")

What had he found? He had discovered that any solid body put into a vessel of water displaces a quantity of water equal to its own bulk, and therefore that equal weights of two substances, one light and bulky, and the other heavy and small, will displace different quantities of water.

This discovery enabled him to solve his problem. He procured one lump of gold and another of silver, each weighing exactly the same as the crown. Of course, the lumps were not the same size, because silver is lighter than gold, and so it takes more of it to make up the same weight. He first put the gold into a basin of water, and marked on the side of the vessel the height to which the water rose.

Next, taking out the gold, he put in the silver, which, though it weighed the same, yet, being larger, made the water rise higher; and this height he also marked. Lastly, he took out the silver and put in the crown.

Now, if the crown had been pure gold, the water would have risen only up to the mark of the gold; but it rose higher, and stood between the gold and silver marks, showing that silver had been mixed with the gold, making the crown more bulky; and by calculating how much water was displaced, Archimedes could estimate how much silver had been added.

This was the first attempt to measure the *specific gravity* of different substances; that is, the weight of any particular substance compared to an equal bulk of some other substance taken as a standard.

TABLE OF SPECIFIC GRAVITIES.

Iron, (cast)	7.207	Gold (22 carats)	17.481
" (wrought)	7.688	" (20 ")	15.709
Steel (soft)	7.780	Silver (pure, cast)	10.474
" (tempered)	7.840	" (hammered)	10.511
Lead (cast)	11.400	Mercury (60°)	13.580
" (sheet)	11.407	Pewter	7.248
Brass (cast)	8.384	Tin	7.293
" (wire drawn)	8.544	Zinc (cast)	7.215
Copper (sheet)	8.767	Platinum	21.500
" (cast)	8.607	Antimony	6.712
Gold (cast)	19.238	Arsenic	5.763
" (hammered)	19.361	Bronze (gun metal)	8.700

Stones and Earth.

Coal (Bituminous)	1.256	Lime	2.720
" (Anthracite)	1.436 1.640	Granite	2.625
		Marble	2.708
Charcoal	.441	Mica	2.800
Brick	1.900	Millstone	2.484
Clay	1.930	Nitre	1.900
Common Soil	1.984	Porcelain	2.385
Emery	4.000	Phosphorus	1.770
Glass	3.248	Pumice Stone	.915
Ivory	1.822	Salt	2.130
Grindstone	2.143	Sand	1.800
Diamond	3.521	Slate	2.672
Gypsum	2.168	Sulphur	2.033

Woods.

Ash	.845	Cherry	.715
Beech	.852	Cork	.240
Birch	.720	Elm	.67.

TABLES OF STRENGTH OF MATERIALS.

1.—METALS.

Materials.	Limits of tensile strength.	Materials.	Limits of tensile strength.
Steel, best tempered	134,000—153,000	Iron, ship plates, average	44,000
Steel, cast, maximum	142,000	" cast	14,000 45,970
" shear	118,000	" cast, mean of American	31,800
" blister	104,000	Copper, wire	61,200
" puddled	67,200	" wrought	34,000
" plates, lengthwise	96,300	" cast, American	24,250
" plates, breadthwise	73,700	Platinum, wire	53,000
" razor	150,000	Silver, cast	40,000
Iron, wire	73,000—103,000	Gold, cast	20,000
" best Swed. bar	72,000	Tin, cast block	3,800
" bar, mean by Barlow	56,560	" Banca	2,122
" bar, inferior	30,000	Zinc	2,600
" boiler plates, average	51,000	Bismuth	2,900
		Lead, wire	2,580
		" cast	1,800

2.—OTHER MATERIALS.

Glass, plate	9,400	Mortar, of 20 years	52
" flint	4,200	Roman cement, to blue stone	77
Hemp fibres, glued	9,200	Wood, box	14,000—24,000
Hemp fibres, twisted (rope)	6,400	" oak	10,000—25,000
Manila rope	3,200	" locust tree	20,100
Marble, different species	9,000 5,200	" elm	13,200
Stone, different species	1,000 350	" ash	12,000
Brick, well burned	750	" fir	8,330
		" cedar	4,880

STRENGTH OF MATERIALS.

This is a general expression for the measure of capacity of resistance, possessed by solid masses or pieces of various kinds, to any causes tending to produce in them a permanent and disabling change of form or positive fracture.

As a matter of calculation its principal object is to determine the proper size and form of pieces which have to bear given loads, or, on the other hand, to determine the loads which can be safely applied to pieces whose dimensions and arrangement are already given.

The materials used in construction are chiefly four kinds.

1. Timber.
2. Rock or natural stones.
3. Brick, concrete, etc. (artificial stones).
4. Metals, especially iron.

All these resist fracture in whatever way, but the capability of resistance in a given case varies with chiefly the following: 1, the nature of the material and its quality; 2, the shape and dimensions of the piece used; 3, the manner of support from other parts; 4, the lines and direction of the force tending to produce rupture.

In the tables of strength which precede, the piece experimented on is (unless otherwise specified) always one the transverse section of which presents an area of 1 square inch; and the limits of strength found, known by the loads required to secure fracture, are expressed in pounds weight avoirdupois.

Tensile strength means the resistance to a *direct pull;* for illustration, see page 34.

STRENGTH OF MATERIALS.

Materials of all kinds *owe their strength* to the action of these forces residing in and about the molecules of bodies (the molecular forces), but mainly to that one of these known as *cohesion;* certain modified results of cohesion, as toughness or tenacity, hardness, stiffness, and elasticity are also important elements and the strength is in the relation of the toughness and stiffness combined.

A piece of iron or timber may be subjected to strain or fracture in four ways: 1, it may be stretched, pulled or torn asunder, as a tie-rod or a steam boiler. This is called tensile strain or tension, and is a direct pull; resistance to this force is called *tensile strength.* 2, the iron or timber may be crushed in the direction of the length as in columns and truss beams. This is direct thrust, direct pressure or compression; and the resistance to it, *the crushing strength.* An example of this is found in the force tending to collapse the flues of a steam boiler. 3, it may be bent or broken across by a force perpendicular or oblique to its length, as in common beams and joists. This is transverse strain or flexion; resistance to it *the transverse strength.* 4, it may be twisted or wrenched off, in a direction about its axis, as in case of shafting. This is torsion; resistance to it *the torsional strength.* (See figures on page 34.)

Let it be noted, that any bending or breaking pressure is *a stress;* its effect on the piece *a strain;* briefly, then, the strength of a solid piece or body is the total resistance it can oppose to strain in that direction.

IMPORTANT PRINCIPLES RELATING TO STRENGTH OF MATERIALS.

A rod, rope or any body being pulled in the direction of its length, its cohesion can come into play only by reason of the opposite length being fixed; and the amount of cohesion excited is a reaction against the strain applied; up to the limit

STRENGTH OF MATERIALS.

of strength the amount of cohesion is always exactly equal to the acting strain; at every moment the strain and reaction are equal throughout the whole length of the piece acted upon.

Where weight does not (as it must in any hanging rope or piece) come in to modify the result the piece must, when the limit of strength is exceeded, always part or yield at its weakest portion; that the tensile strength can never exceed that of such weakest portion.

Two fibres of like character equally stretched must exhibit double the strength of one. Generalizing this result, we say that the tensile strength of beams, rods, ropes, wires, etc., is, for each material, proportional to the area of the cross-section of the piece used. This is, accordingly, also termed the absolute strength.

When allowance for modifying influences is made, the laws of tensile strength become safe guides in practice, though the behavior of different materials in yielding to tension may vary considerably.

Any material, under a considerable tensile strain, becomes slightly elongated, not returning when the strain is taken off. This result is expressed by saying that the body possesses *extensibility*. It is doubtful whether in all materials, or in most, a result of this kind can be often or indefinitely repeated. But over this, the body lengthens a little by every pull in consequence of its elasticity; and this effect is not permanent, at least its whole amount is not so; the piece shortens again, when the strain is removed, by quite or nearly the amount of this lengthening.

If the body possesses *ductility*, when the limit of its extensibility and elasticity is reached, the particles upon the surface at the weakest point begin to slip upon each other; the body is by this action both permanently and sensibly lengthened or drawn out, and as this extension does not, as in wire-drawing proper, take place under circumstances favorable to increase of toughness, the strength is with the first yielding impaired; while, if the load be not then diminished, the yielding portion must be drawn rapidly smaller until it parts completely. Thus, for ductile materials, the load beyond which permanent change must occur is *the limit of strength.*

In metallic bars or links, timbers, etc., a considerable proportion of the actual strength is gained by means of the firm hold of the fibres laterally one upon another; as is proved by the fact that, of two ropes of like material and containing in their sections a like number of fibres, in one of which the fibres are twisted and in the other glued together, the strength of the latter is greater by at least one-third.

FATIGUE OF METALS.

A matter of great practical interest is the weakening which materials undergo by repeated changes in their state of stress. It appears that in some if not all materials a limited amount of stress variation may be repeated time after time without apparent reduction in the strength of the piece; on the balance wheel of a watch for instance, tension and compression succeed each other for some 150 millions of times in a year, and the spring works for years without showing signs of deterioration. In such cases the stresses lie well within the elastic limits; on the other hand the toughest bar breaks after a small number of bendings to and fro when these pass the elastic limits.

MELTING POINTS OF SOLIDS.

The metals are solid at ordinary temperatures, with the exception of mercury, which is liquid down to —39° F. Hydrogen it is believed, is a metal in a gaseous form.

All the metals are liquid, at temperatures more or less elevated, and they probably turn into gas or vapor at very high temperatures. Their melting points range from 39 degrees below zero of Fahrenheit's scale (the melting or rather the freezing point of mercury), up to more than 3,000 degrees, beyond the limits of measurement by any known pyrometer. Certain metals, such as iron and platinum, become pasty and adhesive at temperatures much below their melting points. Two pieces of iron raised to a welding heat, are softened, and readily unite under the hammer; and pieces of platinum unite at a white heat.

MELTING POINTS OF SOLIDS.

VARIOUS SUBSTANCES.	Melting Points.
Sulphurous acid	—148° F.
Carbonic acid	—108
Bromine	9. 5
Turpentine	14
Hyponitric acid	16
Ice	32
Nitro-glycerine	45
Tallow	92
Phosphorus	112
Acetic acid	113
Stearine	109 to 120
Margaric acid	131 to 140
Wax, rough	142
" bleached	154
Iodine	225
Sulphur	239

Melting Points of Solids.—(*Continued.*)

METALS.	Melting Points.
Mercury	−39° F
Potassium	144
Sodium	208
Lithium	356
Tin	442
Bismuth	507
Lead	617
Zinc	680 to 773
Antimony	810 to 1150
Bronze	1692
Silver	1832 to 1873
Copper	1996
Gold, standard	2156
Cast Iron, white	1922 to 2012
" " gray	2012 to 2786
Steel	2372 to 2552
Wrought Iron	2732
Hammered Iron	2912

SUNDRY ALLOYS OF TIN, LEAD, AND BISMUTH.	Melting Points.
3 Lead, 2 Tin, 5 Bismuth	199°
1 " 1 " 4 "	201
5 " 3 " 8 "	212
1 " 4 " 5 "	246
1 " 3	334
2 " 1 "	334
1 " 2 "	360 to 385
3 " 1 "	392
3 " 1 "	552

It must be understood that these tables exhibit only to a degree, of accuracy, the results of very many attempts to arrive at the difficult although approximate results.

USEFUL WEIGHTS AND MEASURES.

A *measure* is a standard unit, established by law or custom, by which quantity is measured or estimated.

Unit is a work which denotes a single thing—the least whole number. The unit of numbers is the figure one (1).

The foot rule is the *unit* or measure *of length* most used; the foot is divided into twelve inches and the inch is subdivided in half inches, quarter inches, eighths and sixteenths. It is plain that into whatever number of parts the inch is divided, we shall equally have the whole inch if we take the whole of the parts of it; if it were divided into ten equal parts, then ten of these parts would make an inch.

The *unit of surface* is represented by the square inch, etc.

These references to the different measures, or units, are made because they enter into calculations in connection with Tables to be found elsewhere.

CIRCULAR MEASURE.

60 seconds (″),	make	1 minute,	′
60 minutes,		1 degree,	°
360 degrees,		1 circum.,	C.

The circumference of every circle, whatever, is supposed to be divided into 360 equal parts, called *degrees*.

A degree is $\frac{1}{360}$ of the circumference of any circle, small or large.

A *quadrant* is a fourth of a circumference, or an arc of 90 degrees.

A degree is divided into 60 parts, called minutes, expressed by sign (′), and each minute is divided into 60 seconds, expressed by (″), so that the circumference of any circle contains 21,600 minutes, or 1,296,000 seconds.

USEFUL WEIGHTS AND MEASURES.

ROMAN TABLE.

I. denotes	One.	XVII. denotes	Seventeen.
II.	Two.	XVIII.	Eighteen.
III.	Three.	XIX.	Nineteen.
IV.	Four.	XX.	Twenty.
V.	Five.	XXX.	Thirty.
VI.	Six.	XL.	Forty.
VII.	Seven.	L.	Fifty.
VIII.	Eight.	LX.	Sixty.
IX.	Nine.	LXX.	Seventy.
X.	Ten.	LXXX.	Eighty.
XI.	Eleven.	XC.	Ninety.
XII.	Twelve.	C.	One hundred.
XIII.	Thirteen.	D.	Five hundred.
XIV.	Fourteen.	M.	One thousand.
XV.	Fifteen.	$\overline{\text{X}}$.	Ten thousand.
XVI.	Sixteen.	$\overline{\text{M}}$.	One million.

A bar (¯) placed over a letter increases its value a thousand times. Thus, $\overline{\text{X}}$ represents ten thousand; $\overline{\text{M}}$, one million.

TIME.

60 seconds,	make	1 minute.
60 minutes,		1 hour.
24 hours,		1 day.

365 days 5 hrs. 48 min, 48 seconds = 1 year.

Every year divisible by 4 is a leap year, and contains 366 days—the other years 365 days.

TROY WEIGHT.

24 grains (gr.),	make	1 pennyweight,	pwt.
20 pennyweights,		1 ounce,	oz.
12 ounces,		1 pound,	lb.

A *carat*, for gold-weight, is 4 grains; for diamond-weight, is 3.2 grains.

USEFUL WEIGHTS AND MEASURES.

LONG MEASURE—MEASURES OF LENGTH.

12 inches,	=	1 foot.
3 feet,	=	1 yard.
5½ yards,	=	1 rod.
40 rods,	=	1 furlong.
8 furlongs,	=	1 common mile.
3 miles,	=	1 league.

The *mile* (5,280 feet) of the above table is the legal mile of the United States and England, and is called the statute mile.

Additional measures of length in occasional use: 3 inches = 1 palm; 4 inches = 1 hand; 6 inches = 1 span; 2½ feet = 1 military pace; 3 feet = common pace; $\frac{1}{48}$ of an inch = a hair's breadth.

SQUARE MEASURE—MEASURES OF SURFACE.

144 square inches,	=	1 square foot.
9 square feet,	=	1 square yard.
30¼ square yards,	=	1 square rod or perch.
160 square rods or perches,	=	1 acre.
640 acres,	=	1 square mile.

An *acre* equals 4,840 square yards or a square whose side is $208\frac{71}{100}$ feet.

Surface or Square Measures are used in computing areas or surfaces, as of land, lumber, painting, paving, etc.

A *Surface* has two dimensions, length and breadth.

A *Square* is a plane figure, bounded by four equal sides, and having four right angles.

A *Circular inch* is a circle whose diameter is one inch =0.7854. A Square inch=1.2732 Circular inches.

NOTE.

The difference between one square foot and one foot square. One foot square means one foot long and one foot wide, but one square foot can be of any shape, providing the area equals one square foot or one hundred and forty-four square inches.

USEFUL WEIGHTS AND MEASURES.

AVOIRDUPOIS WEIGHT.

16 drams, or 437½ grains,	=	1 ounce.
16 ounces, or 7,000 grains,	=	1 pound.
25 pounds,	=	1 quarter.
4 quarters, or 100 lbs.,	=	1 hundred-weight.
20 hundred-weight,	=	1 net ton.
2240 hundred-weight,	=	1 long ton.

In the United Kingdom 28 lbs. = 1 quarter.
4 quarters = 1 hundred-weight = 112 lbs.
1 stone = 14 lbs. 1 quintal = 100 lbs.

This table is used for nearly all articles estimated by weight, except gold, silver and jewels, for which the "Troy weight" table is used.

DRY MEASURE.

2 pints,	=	1 quart.
8 quarts,	=	1 peck.
4 pecks,	=	1 bushel.

This measure is used in measuring grain, fruit and other articles not liquid.

The standard U. S. bushel is the Winchester bushel = 18½ inches in diameter × 8 inches deep = 2,150$\frac{42}{100}$ cubic inches.

IMPORTANT NOTE.

In a fairly long experience in mechanical pursuits in both Europe and America, the author has found the "data" printed on pages 65 to 72 of frequent service; hence he strongly recommends the study of the rules, measures and explanations given in these closing pages of the PROGRESSIVE MACHINIST.

USEFUL WEIGHTS AND MEASURES.

SOLID OR CUBIC MEASURE.

1728 cubic inches,	=	1 cubic foot.
27 cubic feet,	=	1 cubic yard.
128 cubic feet,	=	1 cord.

A pile of wood 4 feet wide, 4 feet high, and eight feet long, contains 1 cord; and a cord foot is 1 foot in length of such a pile.

This table is used in measuring bodies, or things having length, breadth and height or depth.

A *Solid* is a body, volume, or space, that has three dimensions, length, breadth and thickness. A Cube is a body bounded by six equal squares, called Faces. The sides of these squares are called the Edges of the cube. A Cubic Inch is a cube, each edge of which is 1 inch in length. A Cubic Foot is a cube, each of whose edges are 1 foot in length.

LIQUID MEASURE.

4 gills (gi.),	=	1 pint.
2 pints,	=	1 quart.
4 quarts,	=	1 gallon.
31½ gallons,	=	1 barrel.
42 gallons,	=	1 tierce.
63 gallons,	=	1 hogshead.

The *barrel* and *hogshead* are not fixed measures, but vary when used for commercial purposes. The capacity of these is found by actual measurement.

The U. S. gallon = 231 cubic inches.

British Imperial gallon = $277\frac{274}{1000}$ inches.

7½ gallons (U. S.) nearly = 1 cubic foot.

USEFUL WEIGHTS AND MEASURES.

TABLE OF ALIQUOT PARTS.

Of a $.		Of a Ton.		Of a cwt.		Of an Acre.		Of a Month.	
cts.	$	cwt.	ton.	lb.	cwt.	rd.	A.	d.	m.
50	= ½	10	= ½	50	= ½	80	= ½	15	= ½
33⅓	= ⅓	5	= ¼	25	= ¼	40	= ¼	10	= ⅓
25	= ¼	4	= ⅕	20	= ⅕	32	= ⅕	7½	= ¼
16⅔	= ⅙	2½	= ⅛	12½	= ⅛	20	= ⅛	6	= ⅕
12½	= ⅛	2	= 1/10	10	= 1/10	16	= 1/10	5	= ⅙
10	= 1/10	1	= 1/20	5	= 1/20	8	= 1/20	3	= 1/10

An aliquot part of a number is an exact divisor of it; thus, 2, 4 and 8 are exact divisors of 16.

TRAVELLERS' NAUTICAL MEASURES.

TABLE.

60 Geographic, or 69.16 Statute Miles = 1 Degree of Latitude on a Meridian, or of Longitude on the Equator.
360 Degrees = the Circumference of the Earth.
1.15⅕ Common Miles = 1 Geo. Mi. Used to meas. distances at sea.
3 Geographic Miles = 1 Nautical League.

Miles and Knots.—A statute mile is 5,280 feet long. It is our standard of "long" measure adopted from the English, who in turn adopted it from the Romans. A Roman military pace, by which distances were measured, was the length of the step taken by the Roman soldiers. A thousand of these paces were called in Latin a mile.

The English mile is therefore a purely arbitrary measure, enacted into a legal measure by a statute passed during the reign of Queen Elizabeth: it has no connection with any scale in nature. A nautical mile, on the other hand, is equal in length to one-sixtieth part of the length of a degree of a great circle of the earth.

But the circumference of the earth is nowhere a true circle; its radius or curvature is variable; hence the nautical mile, as a matter of fact, depends for its length upon the shape as well as the size of the globe sailed over; and hence, strictly speaking, the length of the nautical mile should vary with the latitude, from 6,046 feet at the equator to 6,109 feet at the pole. Such extreme accuracy is not necessary in navigating and cannot be well attained without undue labor.

The British Admiralty therefore have adopted 6,080 feet as the length of a nautical mile, which corresponds with the length of one-sixtieth of a degree—of one minute of arc—of a great circle in latitude 48°.

USEFUL WEIGHTS AND MEASURES.

TABLE.

Showing relative value of French and English measures of length.

FRENCH.		ENGLISH.
Milimetre,	=	0.03937 inches.
Centimetre,	=	0.39371 "
Decimetre,	=	3.93710 "
Metre,	=	39.37100 "

In the French system of weights and measures, which has been legalized by special act of the U. S. Congress, the *metre, litre, gramme,* etc., are increased or decreased by the following words prefixed to them:

Milli	expresses	the	1,000th	part.	
Centi	"	"	100th	"	
Deci	"	"	10th	"	
Deca	"	10	times	the	value.
Hecto	"	100	"	"	"
Kilo	"	1,000	"	"	"
Myria	"	10,000	"	"	"

APOTHECARIES WEIGHTS.

SOLID MEASURE.

20 grains (gr.),	=	1 scruple (sc.).
3 scruples,	=	1 dram (dr.),
8 drams,	=	1 ounce (oz.).
12 ounces,	=	1 pound (lb.).

FLUID MEASURE.

60 minims or drops,	=	1 fluid dram.
8 fluid drams,	=	1 fluid ounce.
16 fluid ounces,	=	1 pint.
8 pints,	=	1 gallon.

USEFUL WEIGHTS AND MEASURES.

MONEY.

STERLING OR ENGLISH MONEY.

TABLE.

4 farthings (qr. or far.) make	1 penny,	d.
12 pence,	1 shilling,	s.
20 shillings,	1 pound or sovereign,	£.
10 florins (fl.),	1 pound,	£.

FRENCH MONEY.

TABLE.

10 centimes = 1 decime.
10 decimes = 1 franc.

The unit of French money is the franc, the value of which in U. S. money is 19.3 cents, or about 1/5 of a dollar.

UNITED STATES MONEY.

TABLE.

10 mills are	1 cent,	ct.
10 cents are	1 dime,	d.
10 dimes, or 100 cents are	1 dollar,	dol. or $.
10 dollars are	1 eagle,	E.

The *dollar* is the unit; hence dollars are written with the *sign* $ prefixed to them and *the decimal point* placed after them.

Cents occupy hundredths place on the right of the decimal point and occupy two places, hence if the number to be expressed is less than 10 a cipher must be prefixed to the figure denoting them; one dollar and nine cents is written $1.09.

DRAWING

FREE-HAND DRAWING.

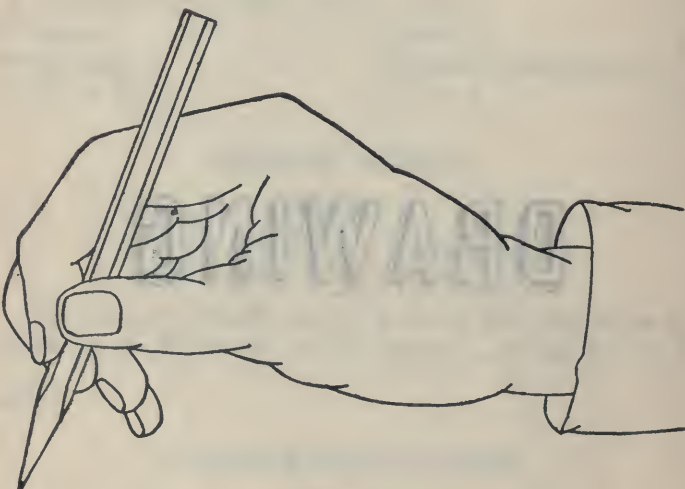
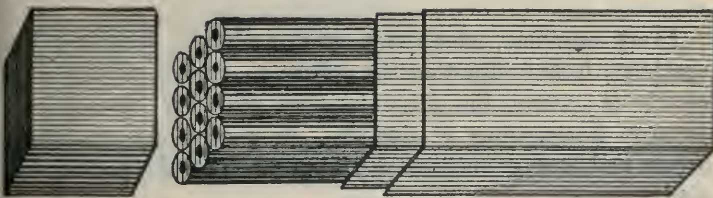


Fig. 8.



FREE-HAND DRAWING.

Fig 11.

A free-hand drawing is executed with the unaided hand and eye, without guiding instruments or other artificial help. It is necessary to be known that all the drawing required in the office and shop cannot possibly be done by rule and compass, but that some portion must be drawn "free-hand," trusting to the eye alone.

Hence, it is important that the student should be able to sketch at sight from objects he may see, or to draw roughly with a piece of chalk or a pencil pieces of mechanism required to be represented.

Practice in free-hand should go along, little by little, as progress is made in mechanical drawing, in order to cultivate both branches equally. "A simple sketch will often," as it has been rather roughly said, "express more than yards of talk."

Even a slight sketch refreshes the memory, and in the case of a preparation of a complete set from a finished machine, with a view to the making of a mechanical drawing, the proper course to pursue is, in the first instance, to make a general sketch, letter the various parts for reference, and then prepare a series of de-

FREE-HAND DRAWING.

tailed sketches, similarly lettered, and diffuse with dimensions.

Every engineer, electrician and mechanic, whatever his specialty, feels to-day that the ability to sketch rapidly and clearly is among the absolute necessities for correct and prompt transactions of business, in giving and executing orders and doing business with persons outside his profession.

Mistakes and misunderstandings may be averted by means of rough sketches taken at the time and shown for confirmation; this also saves assistants from getting into trouble, especially if they pin the sketch to the order, for reference in case of any dispute arising.

Such are a few of the advantages of knowing how to sketch quickly and correctly.

In "free-hand" any sort of pencil is better than none, but there is a considerable advantage in having a good serviceable article—a pencil not too soft nor too hard, and one which will retain its point for some little time.

Fig. 8 shows the approved position in which the pencil should be held while sketching. See note relating to holding and using the pencil.

NOTE.—The pencil should be held firmly between the thumb and first finger of the right hand; press the second finger against the pencil at the opposite side to the thumb pressure, so that the pencil is firmly held by the contact of the thumb and two fingers—the third and fourth fingers just coming into easy reach of the paper surface—the wrist or ball of the hand resting lightly on the surface of the work—the arm resting on the desk or drawing-board for steadiness.

The motion of the pencil is produced from the movement of the fingers and thumb, principally in the vertical strokes, and the horizontal strokes are produced by fingers and thumb, combined with a wrist or elbow motion; the oblique lines and curves are produced with a free movement, with nothing cramped or confined about the finger joints.

FREE-HAND DRAWING.

SKETCH-BOOKS, with paper bound in cloth covers, are utilized for bold, off-hand sketches by experienced draughtsmen, but a single sheet of paper, used on both sides, is not unworthy of service in an emergency—or even the blank side of a letter may be available. Sketching-blocks, or paper "pads," 4 x 6, or more, in size, and containing 48 sheets, are sold by stationers, and are found to be most convenient to have in hand and for practical use. Portfolio-envelopes, made of extra length paper (manila) are useful in filing away sketches and drawings. The size 10½ x 15 are used for United States Patent Office drawings.

BLACKBOARD DRAWING.—The use of a blackboard comes under the head of free-hand drawing, as the work on it is mostly done by hand, without aid from instruments; a few "tools," however, are useful—such as, 1, large wooden blackboard compasses holding a crayon, which are made and sold by the trade in size twelve inches to thirty inches in length; 2, a straight-edge; and 3, some crayons. With the compasses circles and part of the circle can be made, and with the straight-edge the larger lines can be drawn.

Again, the board should be entirely free from grease; cloths, sponges or chamois skin rubbers may be used to erase or change the chalk marks; vertical lines should be drawn

NOTE.—In making a drawing of an object from the model it is well to observe the following order: Look the model over carefully and determine the number of views necessary to illustrate it fully, drawing the same, *free-hand*, in their proper relation to each other, on sketching paper. Look the sketch over carefully to see that nothing has been omitted, and put on dimension lines, after which scale the model carefully and put on dimensions. Do not put in the dimensions at the same time the dimension lines are drawn; have all the dimension lines in place before attempting to insert dimensions."

Follow the same order in making the drawing with instruments as was used in making the sketch; that is, draw the views in their proper relation to each other, put in dimension lines, then dimensions, and lastly notes and title. If section drawing is made, do not draw section lines in pencil.—AMERICAN MACHINIST.

FREE-HAND DRAWING.

from above downward; the draughtsman should stand with his right shoulder opposite the vertical line to be drawn, and the weight of the hand and the arm should be allowed to fall naturally; very rapid drawing upon the board should not be encouraged, as it is likely not to be accurate enough. Chalk lines have this advantage—they are easily altered or rubbed out when not needed any longer.

Many a man can chalk out on a blackboard, or on a piece of sheet-iron, or on the floor, just what he wants to show, and make his meaning very plain; many things are wanted at once of which it would be needless to make a paper drawing, and where a pencil or chalk outline, with dimensions, will answer every purpose; hence, in every workshop, and many other places, a blackboard is more than useful, and it has been said that no draughting office is complete without one.

Practice in this should alternate with sketching in the sketch-book and with geometrical drawing—to be hereafter described—as drawing on the blackboard is indeed the most perfect illustration of the term free-hand drawing. A learner should practice a short time on the board, at least once a week; large sizes are the most profitable for the representations to be made; when drawing in different directions the hand should be turned, not the paper or board; never allow the hand to obstruct the sight, hence the hand and fingers should be held in a position of freedom—with fingers not nearer than 1½ or 2 inches from the board.

Short lines should be drawn with the fingers alone, those somewhat longer with the hand, using the wrist-joint; the still longer lines draw with the forearm, using the elbow-joint; those longer yet, which will be usually on the black-board, draw with the whole arm, using the shoulder-joint.

Draw lines always with a uniform motion, slow enough for the eye to follow.

DRAWING MATERIALS AND INSTRUMENTS.

Drawing tools or instruments are contrived solely for mechanical drawing; aside from this use they are perfectly worthless, hence the quality of these special utensils is a matter of the first consideration to the earnest student.

There are several degrees of excellence to be found in the make-up of drawing instruments and materials; it may be remarked with truth that "any kind are good enough, and the best none too good," i. e., a learner in this delightful art should not stop at the lack of goodness or the low grade existing in his "tools," but rather do the best work possible with the means at hand.

However, in order that acceptable work may be accomplished, fairly good instruments should be procured. The advice of some one experienced in draughting tools should be sought before purchasing, so important is the matter in results.

A drawing board, a sheet of paper and a pencil, and this first scrap of paper, it may be noted, *has two sides, which can be used in early practice*—is the "simplest outfit" possible; to this small beginning may be added, soon afterwards, a cheap pair of compasses, a T-square and a couple of triangles; a vast range of work can be executed with these few tools.

Nothing more will be positively needed to do fine work except, perhaps, one or two pairs of better compasses and a few sweeps or means of drawing irregular curves; all these had best be purchased separately; for in buying a "box of instru-

DRAWING MATERIALS.

ments," it may contain some articles which are not desired, or that are of a wrong size, or even duplicates of those already possessed.

An outfit recommended by the author of "Reed's Hand Book" is as follows:

Large compasses with movable leg.
A pair of dividers.
Bow pencil.
Bow pen.
Pencil leg for large compasses.
Pen leg for large compasses.
Drawing pen.

Louis Rouillion, B. S., Instructor of Drawing in Pratt Institute, Brooklyn, N. Y., recommends the following drawing outfit:

Compasses, 5½ inches, with needle point; pen, pencil and lengthening bar.
Drawing pen, 4½ inches.
T-square, 24-inch blade.
45-degree triangle, 9 inches.
30 and 60 degree triangle, 9 inches.
1 Scroll.
Dixon's V. H. pencil.
12-inch boxwood scale, flat, graduated to 1-16 inch the entire length.
Bottle of liquid India ink, four tacks, pencil and ink eraser.
20 sheets drawing paper, 11x15 inches, and a drawing-board about 16x23 inches will also be necessary; students can usually make these themselves for less money.

NOTE.—The purchasing of drawing tools is one of the most difficult points to settle that can present itself to a person about to buy a drawing outfit for the first time. Nothing can be so productive of distress to a person drawing as to have his tools getting out of order, joints one day too tight, next day too slack, points getting blunt or perhaps turning up altogether; if needle points, then the needles slip up, and drawing spoiled; in fact the purchaser can be annoyed in numberless different ways.—W. H. THORN.

Fig. 12.

THE DRAWING BOARD.

The board should be made of well seasoned pine of a convenient size, say 23x16, which will take half a sheet of imperial paper, leaving ½-inch margin all round.

The working surface of the board—or its front side—should be perfectly smooth, but instead of being flat it should have a very slight camber, or rounding, breadthways, this latter feature in its construction being to prevent the possibility of a sheet of paper when stretched upon its surface having any vacuity beneath it.

The *four edges* of the board need not form an exact rectangle, as much valuable time is often wasted in the attempts to produce such a board; but it will answer every purpose of the draughtsman so long as the adjacent edges at the lower left-hand corner of the square are at right angles to each other.

An English authority recommends the use of two drawing-boards, 42 inches long and 30 inches wide, made of plain stuff, without cleets, 1¼ inches thick—seasoned—with edges perfectly straight and at right angles to each other. With two boards, one may be used for sketching and drawing details and the other for the finished drawing.

NOTE.—The board should be ¾ inches in thickness, and fitted at the back, at right angles to its longest side, with a couple of hardwood battens, about 2 inches wide and ¾ inch thick; the use of these battens being to keep the board from casting or winding and to allow of its expansion or contraction through changes of temperature. This latter purpose, however, is only effected by attaching the battens to the back of the board in the following manner: . . . At the middle of the length of each batten—which should be one inch less than the width of the board—a stout, well-fitted wood screw is firmly inserted into it, and made to penetrate the board for about ½ inch, the head of the screw being made flush with the surface of the batten; on either side of the central screw, two others, about 3½ inches apart, are passed through oblong holes in the battens, and screwed into the body of the board until their heads are flush with the central one; fitted in this way the board itself can expand or contract lengthwise or crosswise, while its surface is prevented from warping or bending.

THE TEE-SQUARE.

This is an instrument in the form of a letter T, as shown in the figure,—see below— the two parts are known as *stock*

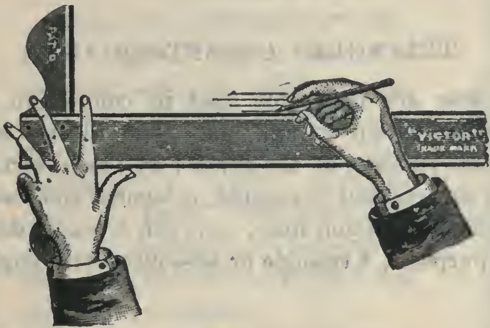


Fig 13

and *blade;* the horizontal part of the latter (T) is the stock, and the vertical part the blade—hence the name, T-square.

To form the square, the two parts are joined together in such a way as to make them exactly at right angles to each

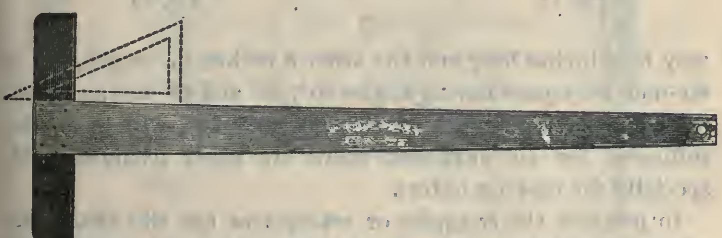


Fig. 14.

NOTE.—DRAWING-PINS, OR THUMB-TACKS.—For mechanical drawing the invariable practice is to secure the paper on which the drawing is to be made to the drawing board by pinning it; this is effected by various kinds of *drawing pins.* The only kind of pins a mechanical drawer should use, should have a head as thin as possible, without cutting at its edges, slightly concave on the under side next the paper, and only so much convex on its upper side as will give it sufficient thickness to enable the pin to be secured to it; better use four or more small pins along the edge of a sheet of paper, than use one clumsy, badly made pin at each end—projecting or thick heads; milled edges damage the squares.

THE TEE-SQUARE.

other; the stock, which is applied to the working edge of the drawing board, being about one-third the length of the blade, and about three times its thickness.

TRIANGLES OR SET-SQUARES.

Set-squares are invariably used in connection with the tee-square as shown in fig. 14. The illustrations below show several patterns of the device; by these, vertical lines, triangles, squares and hexagonal, octagonal and twelve-sided figures, diagonal section lines, etc., can be easily drawn. For ordinary purposes, a triangle or set-square with angles of 45°

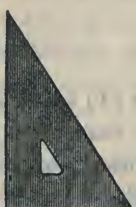


Fig. 15.

Fig. 16.

may be 4 inches long and the other 8 inches in length, but a six-inch set-square having angles 90°, 45° and 45° and an eight-inch one having angles of 90°, 60° and 30°, will be found sufficient for all purposes; there are other triangles used specially for making letters.

In practice the triangles or set-squares are slid along the edge of the blade, and need not be any thicker than it.

Fig. 17

Fig. 18.

DIVIDERS AND COMPASSES.

These two instruments, while they appear alike, have a separate use; the dividers are used to space off distances and dimensions; especially are they necessary in reading drawings made to scale. *Compasses* are used for describing circles, curves, etc., and *dividers* are used for marking out spaces.

Two forms of the dividers are shown in figs. 19 and 20; the simplest, plainest form is shown in fig. 19; these are used for rough spacings; fig. 20 represents a pair of dividers fitted with an adjustable screw controlled by a steel spring in one leg; by this a very exact measurement can be made. Fig. 20 is intended to exhibit what is called "a hair-spring divider."

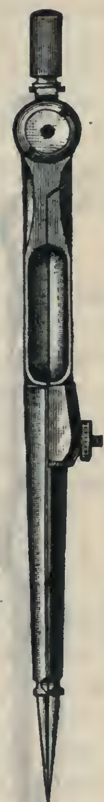


Fig. 19. Fig. 20

COMPASSES.

Compasses consist of two pointed legs; they are instruments for describing circles or for—sometimes—measuring figures, in absence of dividers. Fig. 21 represents compasses fitted as dividers.

Compasses should have jointed legs, which will allow the points to be placed at right angles to the paper, whatever

COMPASSES

the size of the circle to be drawn. Compasses should not be used for circles which are too large to allow the

Fig. 21.

Fig. 22.

Fig. 23.

Fig. 24.

Fig 25.

points to be thus placed; a lengthening bar is generally provided. which greatly increases the diameters of circles

COMPASSES.

which may be drawn by this attachment, is shown in fig. 22.

One leg of the compasses is usually provided with a socket to which are fitted three points; a divider point, fig. 25; a pencil point, fig. 23, and a point, fig. 24, carrying a special pen for the inking of circles. Each of these points is generally provided with a joint, so that it may be placed at right angles to the paper.

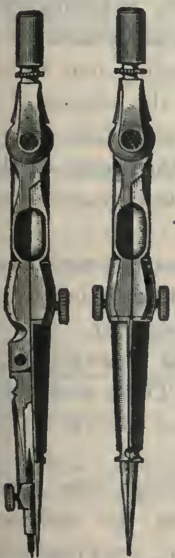


Fig. 26. Fig. 27.

The other leg should be jointed; it is often provided with a socket which receives two points, one a divider point, and the other carrying a needle point. Such an instrument may be used as dividers for spacing, or as compasses for penciling or inking circles.

The joint at the head of the compasses, see fig. 21, is the most important feature. It should hold the legs firmly in any position, so that in going over a circle several times only one line will result. It should allow the legs to move smoothly and evenly, and should be capable of adjustment.

As shown in fig. 21 one leg has a hinge or joint, and a needle point, which can be regulated by a thumb screw; the

---

NOTE.—Compasses specially used for putting in fine circles and dimensions are called "bows." When a pen point it is a "bow pen," with a pencil point a "bow pencil," and if with needle point a "bow dividers." Fig. 26 is a "bow dividers"; this fitted with screw for fine adjustment in one leg, fig. 27, is called a "hair-spring bow dividers"; for small details, bows with steel spring legs without any joint are used; these are called "steel-spring bows."

DRAWING SCALES.

Scales are proportioned rules or mathematical instruments of wood, metal, etc., on which are marked lines and figures for the purpose of measuring sizes and distances. It is usual to make scales in the proportion of *parts of an inch* equalling a foot; the most generally adopted scale for machine drawing is one and a half inches, equalling one foot; that is, twelve-eighths of an inch (each eighth of an inch representing one inch); there is no fixed rule in the choice of a scale, as they are varied according to the coarseness or fineness of the parts of the machine to be drawn and the space or surface of paper to be utilized.

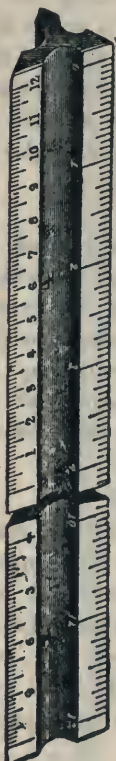


Fig. 28.

When objects are of moderate proportions they may be represented full size; but when large, the drawings must be smaller. Standard scales for mechanical drawings are $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, and $\frac{1}{16}$ full size. These scales are often written $6''=1$ ft.; $3''=1$ ft.; $1\frac{1}{2}''=1$ ft. and $\frac{3}{4}''=1$ ft.

Instead of selecting one of the scales named or one found upon the ordinary scales used by draughtsmen, drawings may be made to any scale whatever. Thus, if any object is to be represented in a certain space, a scale should be constructed which will cause the whole of the object to be shown.

DRAWING TO SCALE.—The meaning of this is, that the drawing when done bears a definite proportion to the full size of the particular part, or in other words, is precisely the same as it would appear if viewed through a diminishing glass.

THE TWO-FOOT RULE shown in fig. 29 is the most useful instrument for the comparison of linear dimensions—it can be used as a scale of one-twelfth, or 1 inch equal to a foot, 12 inches = 12 feet, it being divided into portions or

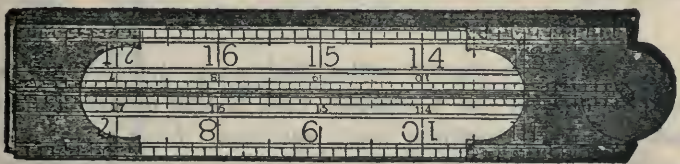


Fig. 29.

spaces, each of which is subdivided into halves, quarters, eighths and sixteenths; frequently in the latter class of 2 ft. rules there are graduations of scales, and it is then also called a draughting scale. Fig. 30 represents a flat scale, graded so that one inch represents a foot—$\frac{1}{12}$th size—etc., as shown. Fig. 28 represents a triangular scale (broken). The

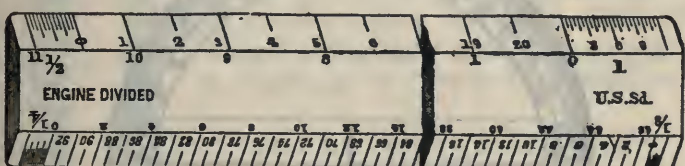


Fig. 30.

triangular scale should read on its different edges as follows: Three inches and 1½″ to one foot, 1″ and ½″ to one foot, ¾″ and ⅜″ to one foot, ¼″ and ⅛″ to one foot, $\frac{3}{16}$″ and $\frac{3}{32}$″ to one foot, and one edge read sixteenths the whole 12″ of its length. Fig. 30 shows such a scale broken. An explanation of the 1″ and ½″ side will suffice for all. Where it is used as a scale of 1″ to one foot, each large space, as from 0 to 12 or 0 to 1, represents a foot, and is a foot at that scale. There being 12″ in one foot, the twelve long divisions at the left represent inches; each inch is divided into two equal parts, so from 0 to one division at the left of 9 is 9½″ and so on. The 1″ and ½″ scales being at opposite ends of the same edge, it is obvious that one foot on the 1″ scale is equal to two feet on the ½″ scale, and conversely, one foot on ½″ scale is equal to six inches on the 1″ scale; and 1″ being equal to one foot, the total feet in length of scale will be 12; at ½″ to one foot the total feet will be 24.

In working to regular scales, such as ½, ⅛, or $\frac{1}{16}$ size, a good plan is to use a common rule, instead of a graduated scale. There is nothing more convenient for a mechanical draughtsman than to be able to readily resolve dimensions into various scales, and the use of a common rule for fractional scales trains the mind, so that computations come naturally, and after a time almost without effort.

Fig. 31.

THE PROTRACTOR.

The protractor shown in fig. 31 is an instrument for laying down and measuring angles on paper; it is used in connecting with a scale to define the inclination of one line to another.

Protractors have the degrees of a half circle marked upon them; as the whole circle contains 360 degrees, half of it will contain 180, one quarter 90, etc. Hence, protractors showing 180° exhibit all that is needed. To protract means to extend, so this instrument is also useful in "extending" the lines of inclination at the circle.

DRAWING-PENS.

A special pen called a drawing-pen, and also special ink, are required to ink a drawing; figs. 32 and 33 represent two sizes of drawing-pens—one being best adapted for fine work, and the other for coarse or heavy line work. The points, as will be observed in the illustration, are made of two steel blades which open and close as required for thickness of lines by a regulating screw.

Fig. 32. Fig. 33.

In practice the flat side of the drawing-pen is laid against the tee-square or ruler; the taper of the blade of the pen is sufficient to throw the point enough away from the edge to prevent blotting; the pen is drawn from left to right and from the bottom to the top of the board.

This is shown in fig. 34, intended to represent "short work" with the drawing-pen. The wrist is shown resting upon the blade of the square.

In a similar figure, 35, the position of the hand holding the pen indicates the best relative posture for inking long lines. In one of these illustrations the work is executed principally

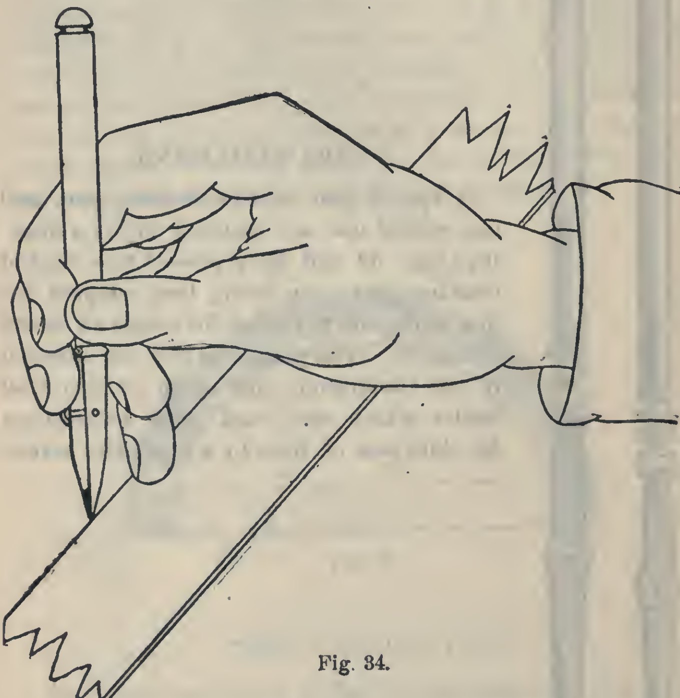


Fig. 34.

by the wrist—in the other by the arm and fingers working together.

The pen should be held with even pressure against the straight edge or curve. If the pressure varies, the blades will spring and the width of the line will change. The blades should be of such length that both will bear equally upon the paper when the pen is inclined slightly, so as to bring the inner blade near the straight edge; the angle of the pen should not be changed while drawing any line.

NEEDLE POINTS.—In marking off distances, centers, etc., a fine needle point is required; the hole should not be punctured through the paper, merely a prick point, so that it will leave an impression, which will not be obliterated by the use of rubber; drawing-pens are often equipped with such a needle point in the end of the handle, that is visible only when the pen is unscrewed from the handle; but in the absence of one of this kind the point of the divider leg will be of use.

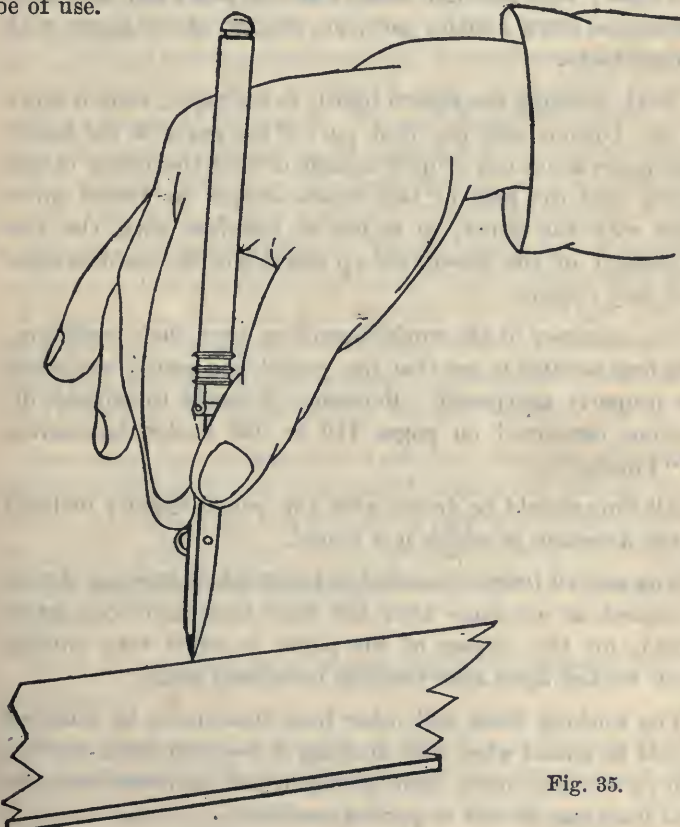


Fig. 35.

If the pen is not in use, even for a short time, the ink should be taken out, as it evaporates quickly and clogs the pen. For this purpose, pass the corner of a piece of chamois skin between the nibs of the pen.

PENCILLING.

With all necessary materials in hand, and in good order for the beginning of a drawing, the first thing to do is to pin the paper on the board quite square.

To do this effectively, lay the paper flat and put on the T-square with its head at the left side of the board; slide the square up nearly to the top, and arrange the paper level with the blade; with the right hand hold the paper still and move the square down a little; now, pin the top of the paper with thumb tacks.

Next, pressing the square lightly to the paper, slide it down to the bottom and pin that part of the paper to the board. The paper must not project outside or over the edges of the board, and the pins or tack-heads should be forced down flush with the paper, so as not to interfere with the free movement of the tee-square up and down the board as occasion may require.

The accuracy of the work depending upon their condition, it is first needful to see that the pencil and pencil compasses are properly sharpened. Reference is made to valuable directions contained on pages 119 to 123 under the heading of "Points."

All lines should be drawn with the pencil slightly inclined in the direction in which it is moved.

Any and all lines not needed in the finished drawing should be erased at one time after the final lines have been determined, for the surface of the paper is soiled very quickly when worked upon after erasures have been made.

The working lines and other lines that are to be removed should be erased when the drawing is ready to finish and before its outlines have been strengthened, in order that the final lines may be left in perfect condition.

NOTE.—To show where the lines meet or terminate it is needful that *all pencil lines* pass the actual ending place, making a distinct intersection. This does not apply to "inking in" the lines, but rather to prevent the over-drawing of the ink lines, because the edge of the rule and the pen itself obstruct or partly cover the view of the line, it is very liable to pass over or beyond the required point in inking the lines, which must not occur.

INKING.

When a drawing is completely finished in penciling, it should next be "inked in" for preservation. Something has been said on this subject, page 119, under another head to which these directions for the performance of the work apply.

Care should be used that the pen may be perfectly clean; the pen should be held nearly vertical, leaning just enough to prevent it from catching on the paper; the pen should be held between the thumb and first and second fingers, the knuckles being bent, so that it may be at right angles with the length of the hand. The ink should be rubbed up fresh whenever it is about to be used, for it is better to waste a little time in preparing ink slowly than to be at a continual trouble with pens, which will occur if the ink is ground too rapidly or on a rough surface. To test ink, a few lines can be drawn on the margin of a sheet, noting the shade, how the ink flows from the pen, and whether the lines are sharp. After the lines have dried, cross them with a wet brush; if they wash readily, the ink is too soft; if they resist the water for a time and then wash tardily, the ink is good.

Care must be exercised not to overload the pen with ink, and, like the pencil, the pen should always be moved from left to right and from the bottom to the top of the board. When inking both "nibs" of the pen point must rest evenly on the paper and the pen pressed only lightly against the T-square.

Never ink any portion of a drawing until the penciling is complete.

In inking long, fine lines it is well to go over each line twice, without moving the T-square, trying not to widen the

---

Note.—To produce finished drawings, it is necessary that no portion should be erased, otherwise the color applied will be unequal in tone; thus, when highly finished mechanical drawings are required, it is usual to draw an original and to copy it. Where sufficient time cannot be given to draw and copy, a very good way is to take the surface off the paper with fine sand-paper before commencing the drawing; if this be done, the color will flow equally over any erasure it may be necessary to make afterwards.

INKING IN DRAWINGS.

line on the second passage; also see that the pen contains ink enough to finish a line, as it is difficult to continue with the same width of line after re-filling.

When the inking is finished the whole drawing may be cleaned by rubbing it with bread, which is not greasy or so fresh as to stick to the paper. If the paper is much soiled it may be necessary to use an eraser. A soft pencil eraser should be used and great care taken that the ink lines are not lightened and broken by it.

To avoid the necessity of using an eraser upon a finished drawing, instruments and paper must be kept free from dust and dirt. The triangles and T-square should be cleaned often, by rubbing them vigorously upon rough, clean paper.

LETTERING DRAWINGS.

Lettering a drawing is a very important part of the work, the object aimed at being to identify any portion by reference letter or letters; thus in fig. 36 the line A C describes the line extending from A to C.

Fig. 36.

For easy reference, letters should not be crowded nor allowed to interfere with one another; they should be drawn neatly, avoiding all lines of the drawing. Plain letters and figures are always used on mechanical drawings, whether for title, scale, reference, etc.

Note.—Any information which cannot be expressed in the drawing is always expressed by lettering, and it is desirable to confine the lettering of drawings to one or two standard alphabets that are plain and distinct, and the principles of which are easily acquired. These conditions are fulfilled in the Gothic fonts shown.

LETTERING DRAWINGS.

A B C D E F G H I
J K L M N O P Q R
S T U V W X Y Z

a b c d e f g h i
j k l m n o p q r
s t u v w x y z

1 2 3 4 5 6 7 8 9 0

A B C D E F G H I
J K L M N O P Q R
S T U V W X Y Z

a b c d e f g h i
j k l m n o p q r
s t u v w x y z

1 2 3 4 5 6 7 8 9 0

LETTERING.

Neat, well-lettered drawings go far towards establishing a high standing for the aspiring draughtsman. All lettering should be done free-hand, first with the pencil, sharpened to a fine round point, and afterwards done in ink. For this purpose common writing pens are best to be used; fig. 37 represents the several numbers of the approved Gillott's pens adapted to this purpose.

Arrow-heads, figures and letters should be in black, and made with a writing pen. A pen with a ball point is preferable, giving an equal thickness of line, no matter in which direction the stroke is made.

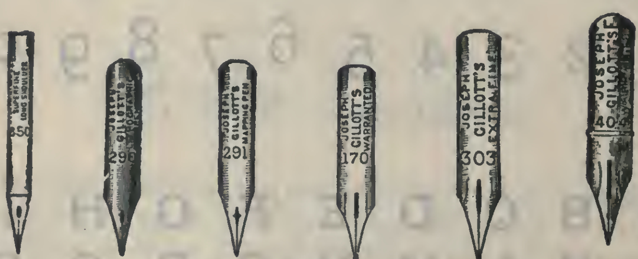


Fig. 37.

Letters should not be less than one-eighth of an inch in height and pencilled carefully before inking.

Both letters and figures must be carefully made and of uniform proportion; it is well to "lay out" these by regular measurement before permanently inking them.

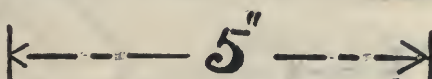
On page 97 are printed two forms of numerals and letters of the alphabet; it is recommended that these be used both for practice in lettering and for office work.

DIMENSIONING.

To "dimension" working drawings is to place measurements upon the parts represented, to enable the workman to proceed without measuring the drawing itself.

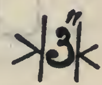
These dimensions should be placed so as not to interfere with nor crowd the lines of the drawing, nor yet interfere with one another.

Arrow-heads are used at the extreme points of measurement, the figures are generally inserted midway between the arrows; a dot and dash line reaches from the figure to the arrow-heads, as shown below.



When the dimension is short these lines are omitted and the dimension is placed outside the drawing, thus

and connected by a curved line; at other times it is found needful to place arrow-heads outside the drawing and the measurement inside.



When the dimension is long and narrow it is usual to carry the dimensions under the drawing by dotted and dash lines, as shown in last figure of example.

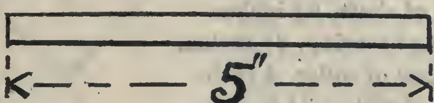


Fig. 38.

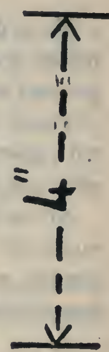
Arrow-heads and figures should be drawn free-hand with a common writing pen.

NOTE.—Usually dimensions are given in inches, up to 24 inches, as it is found less confusing; for instance, if written 1′ 1″ it may be mistaken for 11″; if written 13″ no mistake could be made.

Again, 1′ 0″ may be mistaken for 10″; if written 12″ it would not; in addition to being more distinct, it occupies less space on the drawing. In large measurements there is more room for the figures and, therefore, they can be spaced further apart—in feet and inches.

DIMENSIONING.

All figures should be made of a fairly large size. Vertical dimensions should read from the right hand, thus, as shown:



Measurements of importance, such as the diameter of a circle, the pitch or distance apart of rivets and bolts, etc., should be marked in figures on the drawing. When rough or unfinished work is mixed with machined or finished portions, it is usual to mark F or "fin." after the latter dimension.

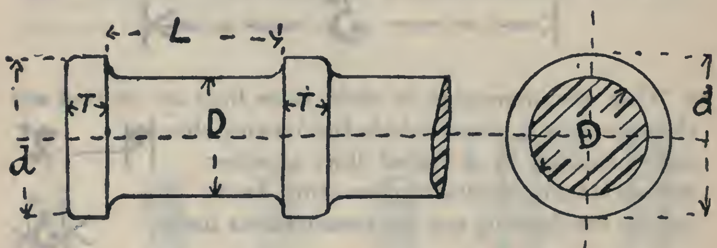


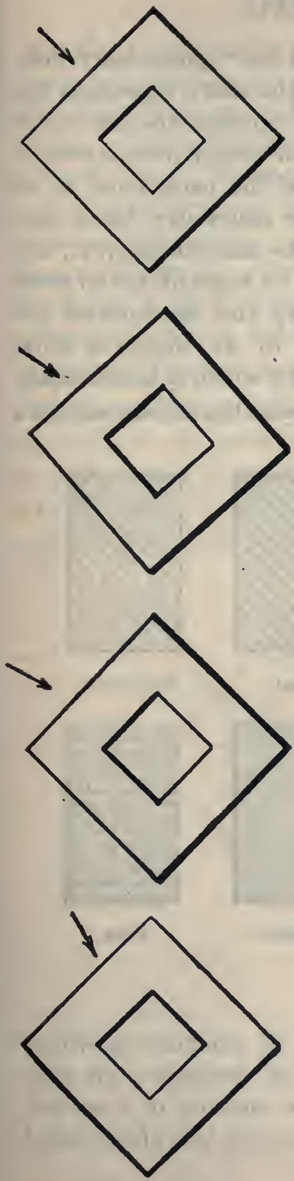
Fig. 39.

In practice, at times, instead of dimensions reference letters are used, thus:

D=diam. of shaft, 2½ inches.
L=length of bearing, 3¾ inches.
T=thickness of collar, ⅞ inch.
D=diam. of collar, 3½ inches.

Generally it is preferable to give the diameters of turned and bored work on a section, instead of an end drawn separately; confusion is sometimes caused by a number of radial dimensions.

NOTE.—"Now, one of the important matters in connection with dimensioning a drawing is the location of the figures. One rule, whose utility cannot be gainsaid, is that they should be so located that they can be altered or erased without damage to the lines of the drawing, as changes may be necessitated either by original errors in writing down the figures or by changes in the design being found desirable during the construction of the machine."



SHADING DRAWINGS.

To produce an effect, drawings are shaded; that is, shadow lines about twice the width of the regular line are drawn according to a recognized rule, which always represents the same peculiarity of form in the same way.

In working drawings light lines only are permitted; shade lines are wider than the working lines, and in reading scale measurements the extra thickness of line would make a difference.

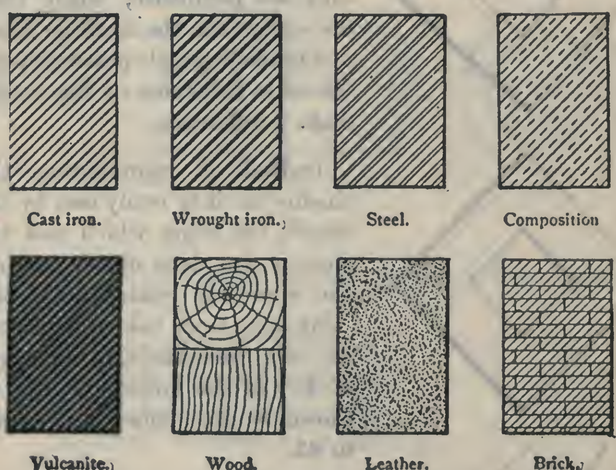
Instead of representing the shadow as it is really cast by the object, the edges which cast the shadow are determined, and all the views are treated as if the ight came from behind and from the left, downwards, at an angle of 45° to the horizontal line, as shown by the arrows in figs. 40 to 43.

The lower and right-hand outlines of projecting parts will cast shadows, and the student should make them of extra width.

Figs. 40-43.

SECTION LINING.

Cross-hatching has been defined in the "preliminary definitions" to drawing; this term, like the above, represents the practice of drawing diagonal lines to represent the interior of a piece, shown as a piece cut in half or when a piece is broken away. This is done to make more of the parts show, or to show more clearly the nature of the materials; hence section lining and cross-hatching tell the same thing, *i. e.*, the drawing of diagonal lines, usually at an angle of 45° to show clearly that the object is broken away and the interior designed to be represented. Figs. 44 to 51, inclusive, show the section lining and cross-hatching by which it is customary for experienced draughtsmen to represent the various materials entering into a construction.



Figs. 44-51.

Sections are necessary in nearly all machine drawings; they are usually taken horizontally or vertically, but they may be taken in any direction; the position of a section should be shown by a line upon the object; this line is called the cutting plane.

SECTION LINING.

Sectioning is done by drawing a series of parallel lines about $\frac{3}{32}$ inches apart. Lay the 45° triangle or the upper edge of the T-square and draw the topmost line of the sectioning. Then slide the triangle along the T-square for each successive line. The sectioning should be inked in without previous penciling and the lines should be finer than the lines of the general drawing. Various devices are in use for mechanically equalizing the distances in section lining, but the trained eye is the most practical method. When two abutting pieces are sectioned, the section-lining on one piece slants in an opposite direction to that on the other.

In practice, when an object to be sectioned is the same on both sides of its center line, only one side is sectioned while the other side is drawn in full.

In fig. below, is to be seen in the hub of the wheel, a fine sample of work very suitable for practice.

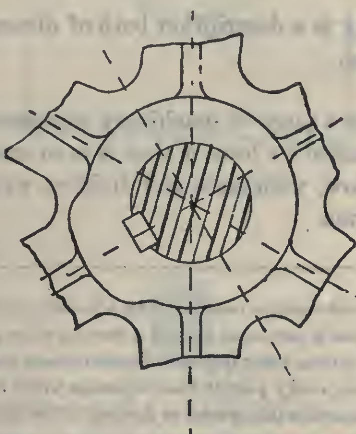


Fig. 52.

TO READ WORKING DRAWINGS.

To readily and correctly utilize a working drawing, is a matter of experience and practice. *A little showing* for the beginner is something for which he may be thankful.

In this work much is made of definitions; these are, first, to be carefully studied and committed to memory; second, the simplest examples given for exercise should be executed, and the principles they are designed to illustrate should be learned.

In studying a drawing, the object it is intended to represent should be made familiar as possible to the mind of the student, so that he may fill out in imagination the parts designedly left incomplete—as in a gear wheel where only two or three teeth are drawn in, that he may see, mentally, the whole.

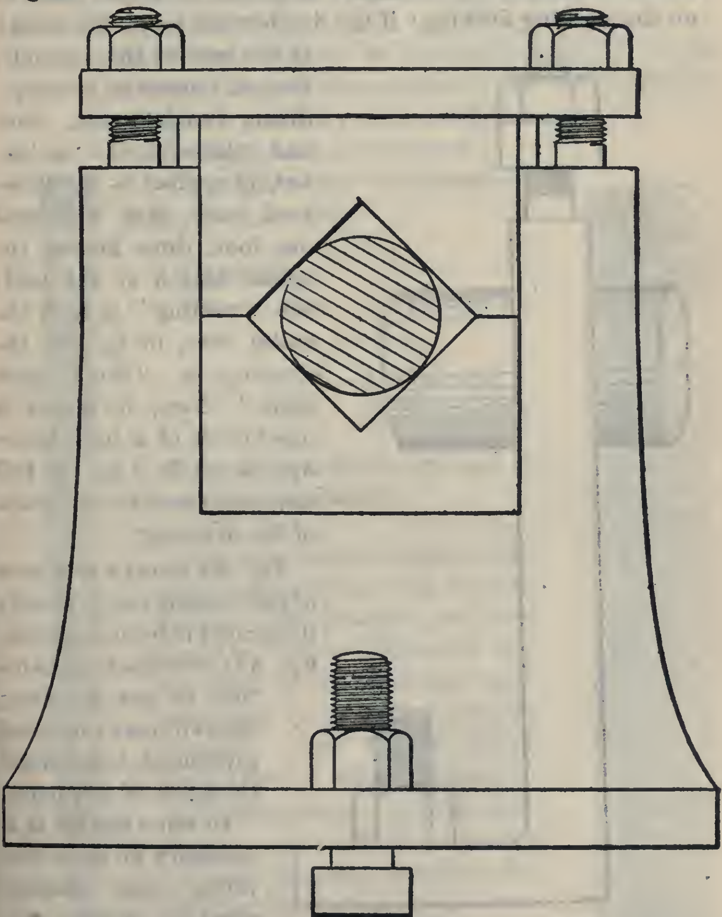
The following is a description both of dimensioning and of reading drawing.

Here we have a piece of machinery represented by fig. 53 and the information we have is that it is to scale, three inches =one foot. Now, with scale and dividers, we can arrive at its actual dimensions.

Note.—One of the advantages resulting from a knowledge of practical draughting is, that it enables a mechanic to *read* a drawing when given him as a guide for his work. It is getting every day more general among draughtsmen to figure exactly and minutely every part of their drawings which are drawn to a scale. Even in full size drawings this system of figuring is not objectionable. It is a system which should be followed whenever a drawing is made "to work to," for it allows the workman to comprehend at a glance the size of his work and the pieces he has to get made. Figuring makes a drawing comprehensible even to those who cannot make drawings. Drawings are almost always made "finished size," that is, the dimensions are for the work when it is completed. Consequently all the figures written on the different parts indicate the exact size of the work when finished, without any regard to the size of the drawing itself, which may be made to any reduced and convenient scale.

TO READ WORKING DRAWINGS.

A working drawing should be made, primarily, as plain as possible by the draughtsman ; second, the workman should patiently and carefully study it, so that it is thoroughly understood, before the executing of the object delineated is begun. Figs. 53 and 54 may be considered "working drawings."



Scale 3 in. = 1 ft. Fig. 53. Front View.

NOTE.—A working drawing, so called, is made in the office to a certain "scale" or proportion, *i. e.*, in the example three inches on the drawing equals one foot of the object represented, a steady rest.

TO READ WORKING DRAWINGS.

The machinist is required to do the work according to the scale marked on the drawing.

Measurements should be first taken *with the dividers from the drawing,* and then the dividers are applied to the scale, to which the drawing is made; this scale is always marked on the working drawing; if the dividers are set to the length of the base of the example, they will measure, on an ordinary two-foot rule, three and three-fourths inches, *but, if applied to the three-inch scale they will read* one foot, three inches, the actual length of the part; the "reading" is from the scale; thus, in fig. 196, the drawing is "three inch scale." Now, 3 inches is one-fourth of a foot, hence $3\frac{3}{4}'' \times 4 = 1$ ft. 3 in., the full size, and so on for all parts of the drawing.

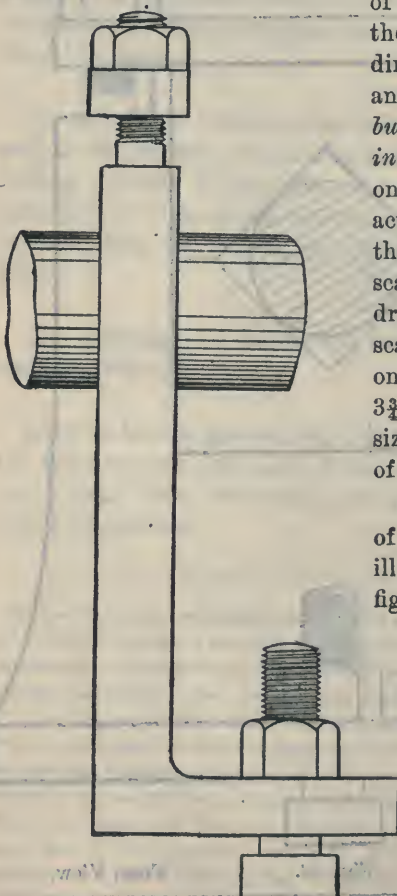


Fig. 54. Side View.
Scale, 3 in. = 1 ft.

Fig. 54 shows *a side view* of the "steady rest," already illustrated in front elevation, fig. 53; from the scale as before we get the sizes; the two views combined give length, breadth and thickness of the parts.

In some figures it is necessary to show end views, also section views, as in page 125, to enable all measurements to be read from the drawing.

PROBLEMS IN GEOMETRICAL DRAWING.

The following examples are to be solved by the use, only, of dividers and rule.

A problem is something to be done, and geometry may be defined as the science of measurement; hence, the relation between geometry and mechanical drawing is very close indeed.

The elementary conceptions of geometry are few:

1.—A point.

2.—A line.

3.—A surface.

4.—A solid, and

5.—An angle.

All of which elements are used in mechanical drawing.

The importance of a knowledge of geometrical drawing is paramount. The student will find that the figures delineated and explained in the next few pages constantly occur in mechanical drawing. Says Walter Smith, State Director of Art Education in Massachusetts, "I have never known a case where a student did not progress more satisfactorily in his studies after a course of practical geometry."

PROBLEMS IN GEOMETRICAL DRAWING.

Fig. 60.

EXAMPLE 1.—*To bisect* (cut in two) *a straight line, or an arc of a circle,* Fig. 60. From the ends of *A B* as centers, describe arcs cutting each other at *C* and *D*, and draw *C D*, which cuts the line at *E* or the arc at *F*.

Ex. 2.—*To draw a perpendicular to a straight line, or a radial line to a circular arc,* Fig. 60. Operate as in the foregoing problem. The line *C D* is perpendicular to *A B*; the line *C D* is also radial to the arc *A B*.

Ex. 3.—*To draw a perpendicular to a straight line, from a given point in that line,* Fig. 61. With any radius from any given point *A* in the line *B C*, cut the line at *B* and *C*. Next, with a longer radius describe arcs from *B* and *C*, cutting each other at *D*, and draw the perpendicular *D A*.

Fig. 61.

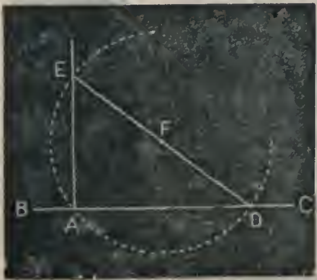


Fig. 62.

Second Method, Fig. 62. From any center *F* above *B C*, describe a circle passing through the given point *A*, and cutting the given line at *D*; draw *D F*, and produce it to cut the circle at *E*; and draw the perpendicular *A E*.

PROBLEMS IN GEOMETRICAL DRAWING.

Third Method, Fig. 63. From *A* describe an arc *E C*, and from *E* with the same radius, the arc *A C* cutting the other at *C;* through *C* draw a line *E C D* and set off *C D* equal to *C E*, and through *D* draw the perpendicular *A D*.

Fig. 63.

Fig. 64.

Ex. 4.—*To draw a perpendicular to a straight line from any point without it*, Fig. 64. From the point *A* with a sufficient radius cut the given line at *F* and *G;* and from these points describe arcs cutting at *E*. Draw the perpendicular *A E*.

NOTE.

If there be no room below the line, the intersection may be taken above the line; that is to say, between the line and the given point.

Second Method, Fig. 65. From any two points *B C* at some distance apart, in the given line, and with the radii *B A*, *C A*, respectively, describe arcs cutting at *A D*. Draw the perpendicular *A D*.

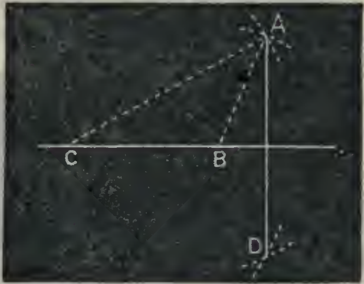


Fig. 65.

Ex. 5.—*To draw a parallel line through a given point*, Fig. 66. With a radius equal to the given point *C* from the given line *A B*, describe the arc *D* from *B* taken considerably distant from *C*. Draw the parallel through *C* to touch the arc *D*.

Fig. 66.

Second Method, Fig. 67. From *A,* the given point describe the arc *F D,* cutting the given line at *F;* from *F* with the same radius, describe the arc *E A,* and set off *F D,* equal to *E A.* Draw the parallel through the points *A D.*

Fig. 67.

When a series of parallels are required perpendicular to a base line *A B,* they may be drawn as in fig. 68. through points in the base line set off at the required distances apart. This method is convenient also where a succession of parallels are required to a given line *C D,* for the perpendicular may be drawn to it, and any number of parallels may be drawn on the perpendicular.

Fig. 68.

Ex. 6.—*To divide a line into a number of equal parts,* Fig. 69.

To divide the line *A B* into, say, five parts. From *A* and *B* draw parallels *A C, B D* on opposite sides; set off any convenient distance four times (one less than the given number), from *A* on *A C,* and on *B* on *B 1;* join the first on *A C* to the fourth on *B D,* and so on. The lines so drawn divide *A B* as required.

Fig. 69.

Fig. 70.

Second Method, Fig. 70. Draw the line at *A C,* at an angle from *A,* set off, say, five equal parts; draw *B 5,* and draw parallels to it from the other point of division in *A C.* These parallels divide *A B* as required.

PROBLEMS IN GEOMETRICAL DRAWING.

Ex. 7.—*Upon a straight line to draw an angle equal to a given angle,* Fig. 71. Let *A* be the given angle and *F G* the line. With any radius from the points *A* and *F*, describe arcs *D E, I H,* cutting the sides of the angle *A* and the line *F G*.

Fig. 71.

Set off the arc *I H* equal to *D E* and draw *F H*. The angle *F* is equal to *A* as required.

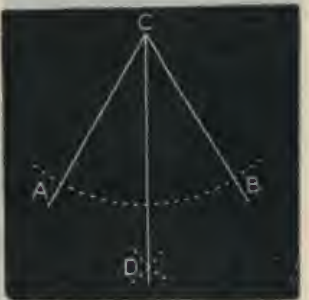


Fig. 72.

Ex. 8.—*To bisect an angle,* Fig. 72. Let *A C B* be the angle; on the center *C* cut the sides at *A B*. On *A* and *B* as centers describe arcs cutting at *D* dividing the angle into two equal parts.

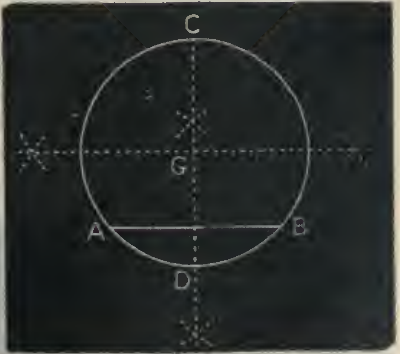


Fig. 73.

Ex. 9.—*To find the center of a circle or of an arc of a circle.* Fig. 73. Draw the chord *A B*, bisect it by the perpendicular *C D*, bounded both ways by the circle; and bisect *C D* for the center *G*.

PROBLEMS IN GEOMETRICAL DRAWING.

Ex. 10.—*Through two given points to describe an arc of a circle with a given radius,* Fig. 74. On the points *A* and *B* as centers, with the given radius, describe arcs cutting at *C;* and from *C,* with the same radius, describe an arc *A B* as required.

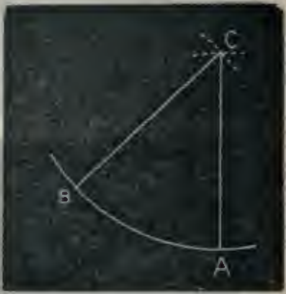


Fig. 74.

Fig. 75.

Second, for a circle or an arc, Fig. 75. Select three points *A B C* in the circumference, well apart; with the same radius; describe arcs from these three points cutting each other, and draw two lines *D E, F G,* through their intersections according to Fig. 68. The point where they cut is the center of the circle or arc.

Ex. 11.—*To describe a circle passing through three given points,* Fig. 75. Let *A B C* be the given points and proceed as in last problem to find the center *O,* from which the circle may be described.

This problem is variously useful: in finding the diameter of a large fly wheel, or any other object of large diameter when only a part of the circumference is accessible; in striking out arches when the span and rise are given, etc.

Ex. 12.—*To draw a tangent to a circle from a given point in the circumference,* Fig. 76. From A set off equal segments *A B, A D,* join *B D* and draw *A E,* parallel to it, for the tangent.

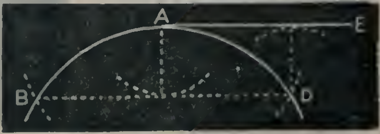


Fig. 76.

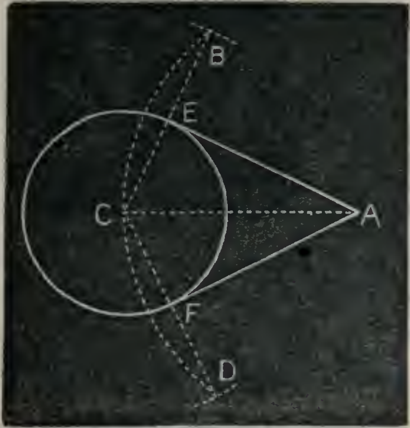


Fig. 77.

Ex. 13.—*To draw tangents to a circle from points without it,* Fig. 77. From A with the radius $A\ C$, describe an arc $B\ C\ D$, and from C with a radius equal to the diameter of the circle, cut the arc at $B\ D$, join $B\ C$, $C\ D$, cutting the circle at $E\ F$, and draw $A\ E$, $A\ F$, the tangents.

Ex. 14.—*Between two inclined lines to draw a series of circles touching these lines and touching each other,* Fig. 78. Bisect the inclination of the given lines $A\ B$, $C\ D$ by the line $N\ O$. From a point P in this line draw the perpendicular $P\ B$ to the line $A\ B$, and on P describe the circle $B\ D$, touching the lines and cutting the center line at E. From E draw $E\ F$ perpendicular to the center line, cutting $A\ B$ at F, and from F describe an arc $E\ G$, cutting $A\ B$ at G. Draw $G\ H$ parallel to $B\ P$, giving H, the center of the next circle, to be described with the radius $H\ E$, and so on for the next circle $I\ N$.

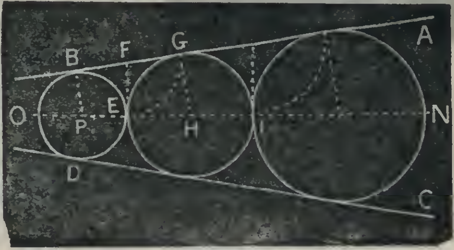


Fig. 78.

Ex. 15.—*To construct a triangle on a given base, the sides being given.*

First. An equilateral triangle, Fig. 79. On the ends of a given base $A\ B$, with $A\ B$ as a radius describe arcs cutting at C, and draw $A\ C$, $C\ B$.

Fig. 79.

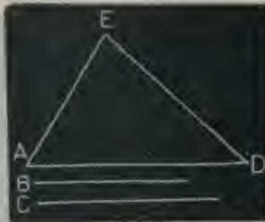


Fig. 80.

Second. Triangle of unequal sides, Fig. 80. On either end of the base *A D* with the side *B* as a radius, describe an arc; and with the side *C* as a radius on the other end of the base as a center describe arcs cutting the arc at *E*. Join *A E, D E*.

This construction may be used for finding the position of a point *C* or *E* at given distances from the ends of a base, not necessarily to form a triangle.

Fig. 81.

Ex. 16.—*To construct a square rectangle on a given straight line.*

First. A square, Fig. 81. On the ends *B A* as centers, with the line *A* B as radius, describe arcs cutting at *C;* on *C* describe arcs cutting the others at *D E;* and on *D* and *E* cut these at *F G*. Draw *A F B G* and join the intersections *H I*.

Fig. 82.

Second. A rectangle, Fig. 82. On the base *E F* draw the perpendiculars *E H, F G,* equal to the height of the rectangle and join *G H*.

Ex. 17.—*To construct a parallelogram of which the sides and one of the angles are given,* Fig. 83. Draw the side *D E* equal to the given length *A*, and set off the other side *D F* equal to the other length *B*, forming the given angle *C*. From *E* with *D F* as radius, describe an arc, and from *F*, with the radius *D E* cut the arc at *G*. Draw *F G, E G*. Or, the remaining sides may be drawn as parallels to *D E, D F*.

Fig. 83.

PROBLEMS IN GEOMETRICAL DRAWING.

Ex. 18.—*To describe a circle about a triangle*, Fig. 84.

Bisect two sides *A B*, *A C* of the triangle at *E F*, and from these points draw perpendiculars cutting at *K*. On the center *K*, with the radius *K A* draw the circle *A B C*.

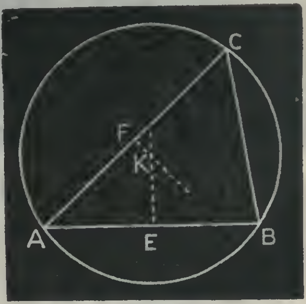


Fig. 84.

Ex. 19.—*To describe a circle about a square, and to inscribe a square in a circle*, Fig. 85.

First. To describe the circle. Draw the diagonals *A B*, *C D* of the square, cutting at *E*; on the center *E* with the radius *E A* describe the circle.

Second. To inscribe the square. Draw the two diameters *A B*, *C D* at right angles and join the points *A C B D* to form the square.

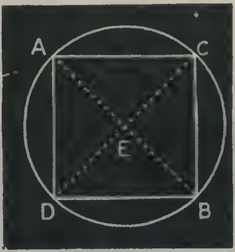


Fig. 85.

NOTE.

In the same way a circle may be described about a triangle.

Ex. 20.—*To inscribe a circle on a square, and to describe a square about a circle*, Fig. 86.

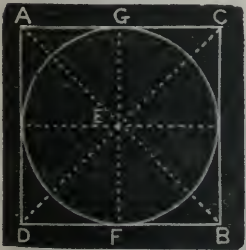


Fig. 86.

First. To inscribe the circle. Draw the diagonals *A B*, *C D* of the square, cutting at *E*; draw the perpendicular *E F* to one side, and with the radius *E F* describe the circle.

Second. To describe the square. Draw two diameters *A B*, *C D* at right angles, and produce them; bisect the angle *D E B* at the center by the diameter *F G*, and through *F* and *G* draw perpendiculars *A C*, *B D*, and join the points *A D* and *B C* where they cut the diagonals to complete the square.

Fig. 87.

Ex. 21.—*To inscribe a circle in a triangle,* Fig. 87. Bisect two of the angles *A C* of the triangle by lines cutting at *D,* from *D* draw a perpendicular *D E* to any side, and with *D E* as radius describe a circle.

Ex. 22.—*To inscribe a pentagon in a circle,* Fig. 88. Draw two diameters *A C, B D* at right angles cutting at *O;* bisect *A O* at *E,* and from *E* with radius *E B* cut *A C* at *F;* from *B* with radius *B E* cut the circumference at *G H,* and with the same radius step round the circle to *I* and *K;* join the points to form the pentagon.

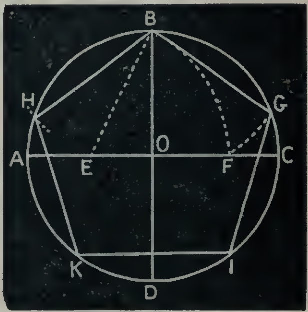


Fig. 88.

Fig. 89.

Ex. 23.—*To construct a hexagon upon a given straight line,* Fig. 89. From *A* and *B* the ends of the given line describe arcs cutting at *G;* from *G* with the radius *G A* describe a circle. With the same radius set off the arcs *A C, C F* and *B D, D E.* Join the points so found to form the hexagon.

Ex. 24.—*To inscribe a hexagon in a circle,* Fig. 90. Draw a diameter *A C B;* from *A* and *B* as centers with the radius of the circle *A C,* cut the circumference at *D, E, F, G,* and draw *A D, D E,* etc., to form the hexagon.

The points *D E,* etc., may be found by stepping the radius (with the dividers) six times round the circle.

Fig. 90.

Ex. 25.—*To describe an octagon on a given straight line,* Fig. 91. Produce the given line *A B* both ways and draw perpendiculars *A E, B F;* bisect the external angles *A* and *B* by the lines *A H, B C,* which make equal to *A B.* Draw *C D* and *H G* parallel to *A E* and equal to *A B;* from the center *G D,* with the radius *A B,* cut the perpendiculars at *E F,* and draw *E F* to complete the hexagon.

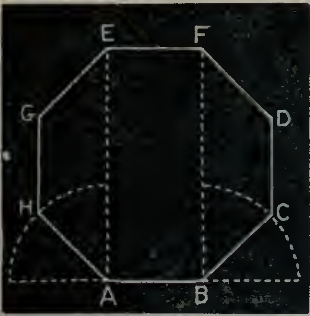


Fig. 91.

Ex. 26.—*To convert a square into an octagon,* Fig. 92.

Draw the diagonals of the square cutting at *e;* from the corners *A B C D,* with *A e* as radius, describe arcs cutting the sides at *G, H,* etc., and join the points so found to complete the octagon.

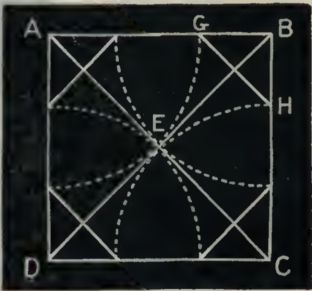


Fig. 92.

Ex. 27.—*To inscribe an octagon in a circle,* Fig. 93.

Draw two diameters *A C, B D,* at right angles; bisect the arcs *A B, B C,* at *E, F,* etc., to form the octagon.

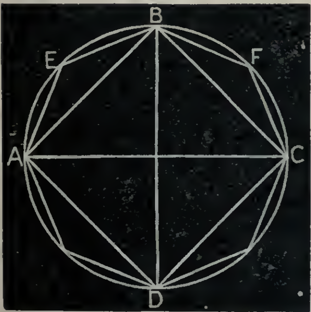


Fig. 93.

Ex. 28.—*To describe an octagon about a circle,* Fig. 94.

Describe a square about the given circle *A B,* draw perpendiculars *H* and *K,* to the diagonals, touching the circle, to form the octagon. Or, the points *H, K,* etc., may be found by cutting the sides from the corners, by lines parallel to the diagonals.

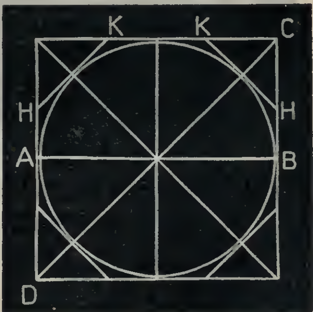


Fig. 94.

PROBLEMS IN GEOMETRICAL DRAWING.

Ex. 29.—*To describe an ellipse when the length and breadth are given*, Fig. 95. On the center *C* with *A*, *E*, as radius, cut the axis *A B* at *F* and *G*, the foci; fix a couple of pins into the axis at *F* and *G*, and loop on a thread or cord upon them equal in length to the axis *A B*, so as when stretched to reach the extremity *C* of the conjugate axis, as shown in dot-lining. Place a pencil or drawpoint inside the cord, as at *H*, and guiding the pencil in this way, keeping the cord equally in tension, carry the pencil round the pins *F*, *G*, and so describe the ellipse.

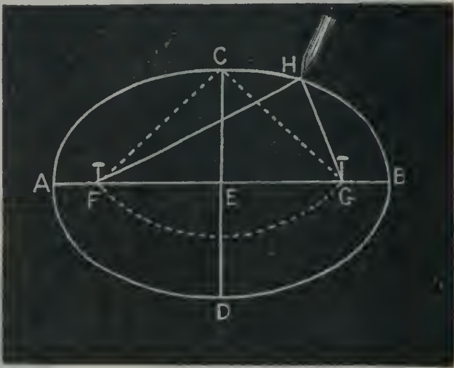


Fig. 95.

Second Method. Along the straight edge of a piece of stiff paper mark off a distance *a c* equal to *A C*, half the transverse axis; and from the same point a distance *a b* equal to *C D*, half the conjugate axis. Place the slip so as to bring the point *b* on the line *A B* of the transverse axis, and the point *c* on the line *DE;* and set off on the drawing the position of the point *a*. Shifting the slip, so that the point travels on the transverse axis, and the point *c* on the conjugate axis, any number of points in the curve may be found, through which the curve may be traced. See fig. 96.

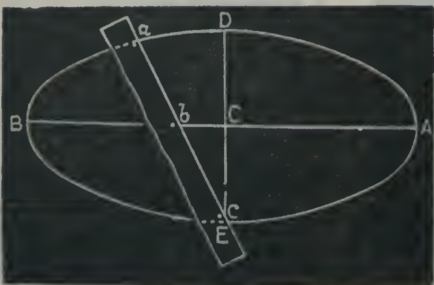


Fig. 96.

NOTE.—The ellipse is an oval figure, like a circle in perspective. The line that divides it equally in the direction of its great length is the *transverse axis*, and the line which divides the opposite way is the *conjugate axis*.

"POINTS" RELATING TO FREE-HAND AND MECHANICAL DRAWING.

The application of the science of geometry to the drawing-board is absolutely necessary to success, for the reason that the whole fabric of mechanical drawing rests on the principles of geometry, which is well termed the Science of Measurements.

A good draughtsman leaves his work in such a state that any competent person can without difficulty ink in what he has drawn.

The criterion of a good set of drawings is that with a properly prepared specification they are complete in themselves and require no explanation.

A "break" in a figure or object in a drawing is shown in rough irregular lines as in fig. 134 on page 131; this is useful when the paper is not large enough to show the whole.

Never use a sloping line in writing fractions on a drawing. The objection arises from the fact that such a dimension as $1\frac{3}{16}$, if written with the inclined line, unless very distinctly executed, may be read as $\frac{1}{1}\frac{3}{6}$.

In inking do not draw the lines further than you wish them to go, but in penciling it is well to extend the lines, free up.

Never use a scale for a ruler.

Do not overload the pen with ink.

Having filled the pen, nearly close the nibs and try the width of the line on a piece of paper or the margin of the drawing.

Never refill or lay the pen aside without first cleaning it.

NOTE.—Many of these "points" are repetitions, with but little variation from the way they have been previously stated; they are thus repeated, to emphasize their practical worth.

"POINTS" RELATING TO DRAWING.

Section lines should be the last inked and always without previous penciling.

Center lines are necessary in working drawings.

In choosing T-squares, care should be exercised to see that the head slides up and down the *left* hand side of the board easily, and that when pressed against the board with the left hand there is no "slogging" of the blade up or down, or in other words, that the head is bearing firmly for its whole length against the board.

The best place for the title of a drawing is said to be the upper left hand corner; this facilitates the filing of the sheet.

Never use a soft pencil except for finishing in shadow lines.

The rubber should always be kept clean.

Great care should be taken to keep drawing boards out of the way of heat or damp, as these cause the wood to warp.

Circles and curves are to be "inked in" first. Ink the smallest and afterwards the larger ones.

Do not press heavily on the pencil so as to cut the paper, but draw lightly, so that the mark can be erased and leave no trace, especially if the drawing is to be inked.

The draughtsman should commence his work at the top of the paper, keeping the lower part covered over until he needs to use it.

Shade lines should be avoided in all working drawings, as their use interferes with accurate measurements.

To make ink stick to the tracing cloth, with a woolen cloth rub some powdered chalk or pounce over the surface on which the ink lines are to be drawn, then wipe the surface clean and use a good quality of ink.

For striking small circles a small bow pen should be used.

"POINTS" RELATING TO DRAWING.

To fix led pencil marks or sketches so that they cannot be readily erased, sponge them with milk carefully skimmed, then lay blotting paper over them and iron with a hot flat-iron.

To have the ink preserve its fluidity and to keep out all dirt and dust, keep the cover on the ink slab; the mistake is often made of putting too liberal a supply of water in ink well, which causes a waste of both time and ink; no more should be prepared than to meet immediate requirements.

Always draw on the right side of the sheet, which can be found by holding the sheet up to the light and looking across its surface with the eye nearly in the same plane as the paper; note which side is the smoothest and has the least number of blemishes on it; this is the right side to draw on.

As to sharpening pencils, it is always best to cut a chisel point on the pencil used for drawing, and put a circular point on the pencils in the bow pencil and pencil leg. The chisel point makes a finer line and lasts much longer than a round point.

The varnish used in many large drawing rooms is simply white shellac dissolved in alcohol; it requires a little experience to mix these to a proper consistency, but this is soon acquired.

Never sharpen your pencil over the drawing.

The T-square belongs to the left side of the drawing-board, and is operated by the left hand. The right hand should be kept free for the purpose of picking up pencil, pen and bows, adjusting and marking off. The left hand controls the T-square and the triangle that slides along the upper edge of the square; the right hand is for the instruments.

A center line of a drawing is the line upon which the figure

"POINTS" RELATING TO DRAWING.

is to be constructed; the center line is the first line to be drawn.

The advantage of a paper rule or scale is that the paper will expand and contract under varying degrees of atmospheric moisture the same as the drawing does.

Avoid rubbing out and constantly cleaning the drawing with india rubber; if wrong lines are made or it is desired to make alterations the part to be changed should be rubbed out and completely re-drawn.

When using the bows see to it that the steel-pointed leg that is put down first on the paper, to secure a center for a curve or a circle, is a trifle longer than the pencil or pen leg.

To clearly indicate the position of a center which is to be used again, lightly pencil a small circle about it; never put the point of a pencil in the center hole to enlarge or blacken it; the prick point made by the dividers and needle points should be no more than can be just seen, hence the circle to be made as advised above.

Be particular in having the legs of the dividers exactly the same length, and sharp, so that in pricking off distances, and dimensions, and centers, the indent or hole made in the paper is as small as possible.

The term "plane" means a perfect flat surface; that is, something which has length and breadth but no thickness.

The best way to indicate on the drawing the surfaces which are to be finished is to write on the lines which represent the finished surfaces "finished," tool-finish, or "faced," according to the degree of finish required. The single letter *f* is frequently used.

Avoid fingering the drawing sheet as much as possible; in pointing to any part of the drawing use a pencil and not the finger.

"POINTS" RELATING TO DRAWING.

Remember that a drawing is made to be read.

The skill in inking does not depend on the fineness of the line, but on its clearness.

A soft pencil should never be used on a mechanical drawing unless in rare cases when it is used for pencil shading; the hardness or softness of pencils are denoted by letters.

Never ink any portion of a drawing until the penciling is entirely finished.

Stretching or pasting the paper to the board is very seldom resorted to, for the reason that the mechanical drawings are *to scale* and the paper is natural when pinned to the board and more correct than if under a strain. Mechanical drawings are always required in practice *right away*, and time would be wasted and lost in damping and pasting and drying again.

GEAR WHEELS.

A gear is primarily a toothed wheel; gearing is a train of toothed wheels for transmitting motions; there are two chief sorts of toothed gearing, viz., spur gearing and bevel gearing.

A spur wheel has teeth around the edge pointing to the center; commencing at the center, a spur wheel may be said to consist of a hole, square, octagonal or round for its axle or shaft; a hub; the web, body or arms; a rim, and the teeth; fig. **111**.

A spur wheel has teeth on its circumference which run parallel to its shaft, see fig. 102; wheels as shown in fig. 109 are termed *helical wheels;* these are similar to spur wheels except their teeth are arranged upon different angles to the shaft.

A bevel is a slant or inclination of a surface from a right line, hence a bevel gear wheel is one whose teeth stand beveling or at an oblique angle to the shaft, or towards the center. Fig. 104.

The addendum circle of a toothed wheel, is as shown in illustration, fig. 100; *addendum* means "something added," and as shown in the figure, it is the part added beyond the "pitch line."

The pitch line is the most important one in gearing; the "pitch line" or "pitch circle" is supposed to be the working circle. P—P in fig. **111**.

The periphery of a wheel is the extreme circumference. N in fig. 111.

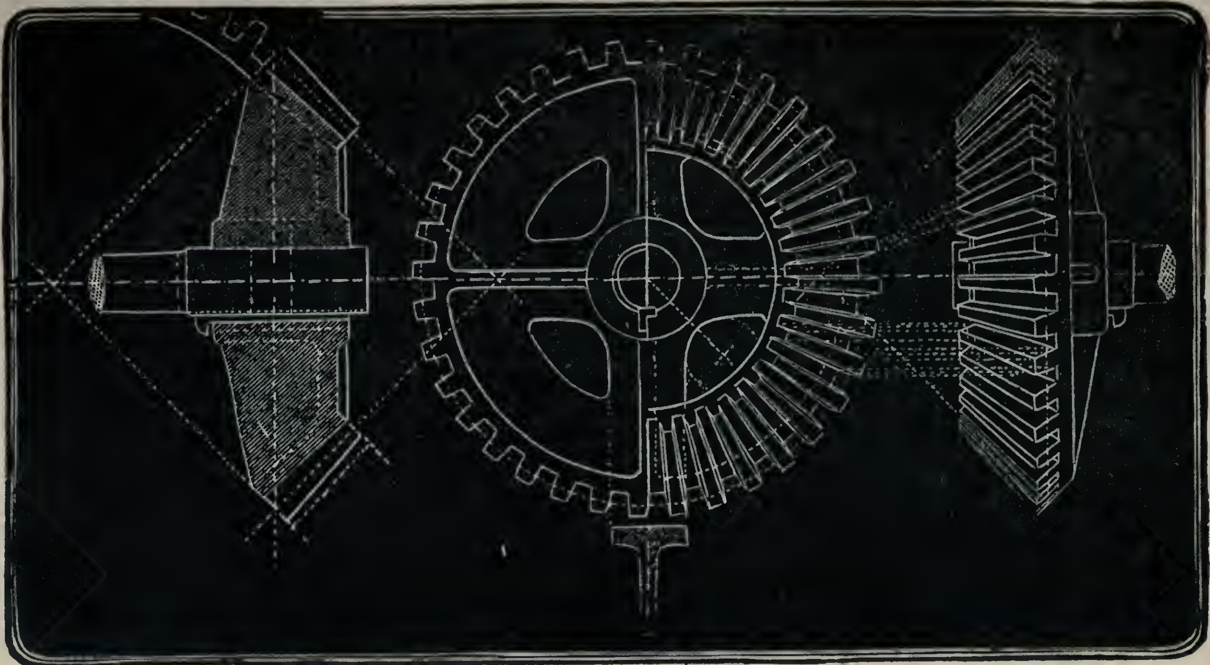


Fig. 97. Fig. 98. Fig. 99.

GEARING.

The diameter of both spur and bevel wheels is measured and calculated neither from the outside nor from the bottom of the teeth, but on the pitch circle. When we speak of the diameter of a spur or bevel wheel, we mean the diameter of the pitch circle, without any reference to the form of tooth.

A cog wheel is the general name for any wheel which has a number of cogs placed around its circumference.

When the teeth of a wheel are made of the same material and formed of the same piece as the body of the wheel, they are called *teeth;* when they are made of wood or some other material, and fixed to the circumference of the wheel, they are called *cogs.*

A pinion is a small wheel. When two toothed wheels act upon one another, the smallest is generally called the pinion. The terms *trundle* and *lantern* are applied to small wheels having cylindrical bars instead of teeth. The teeth in pinions are sometimes termed *leaves;* in a trundle, *staves.*

The wheel which acts is called a *leader* or *driver;* and the wheel which is acted upon by the former is called a *follower,* or the *driven.* When a screw or *worm* revolves in the teeth of a wheel, the latter is termed a *worm wheel* or *worm gear.*

NOTE.—The number of teeth, their proportions, pitch and diameter of pitch circle are frequently determined on the "Manchester" principle. This system originated in Mancnester (Eng.), and is now generally used in the United States for determining diameters and number of teeth, which, of course, regulate speeds. The principle is not applicable to large wheels, but is limited in its application to small wheels, or wheels having "fine pitch," as will be seen in the following explanation, which we introduce as very useful and indispensable knowledge for the acquisition of the student in mechanical drawing.

The "pitch" of teeth has already been stated to be the distance from center of one tooth to the center of another on the "pitch line," measured on the chord of the arc. In determining the number of teeth or pitch of wheels on this principle, the pitch is reckoned on the *diameter* of the wheel, in *place of the circumference*, and distinguished as wheels of "4 pitch." "6 pitch," "8 pitch." etc. In other words, this means that there are four, six, or eight teeth in the circumference of the wheel for every inch of diameter.

GEARING.

See fig. 108. When a pinion acts with a rack having teeth, we speak of *rack* and *pinion*. When the teeth are on the inside of the rim, and not on the periphery, the wheel is termed an *internal gear*, see fig. 110. Two wheels acting upon one another in the same plane are called *spur gear;* the teeth are parallel with the axis. When wheels act at an angle, they are called *bevel gear*.

Fig. 100.

All parts of gear-wheel consist of portions, to which have been given generally accepted names. Fig. 100 shows the "addendum circle" and the "pitch line" as marked. The teeth and rim are shown in white.

Miter wheels are bevel wheels of the same size, working at right angles with one another, see fig. 106.

Diametral means pertaining to a diameter or the length of a diameter; hence a diametral pitch is a system of measures or enumeration based upon the diameter instead of the circular pitch line; it is used very generally in spacing for fine tooth gear. Wheels of this description usually have their teeth cut in a gear-cutting machine, *i. e.*, medium and fine tooth gears.

The circular pitch line, as opposed to the diametral pitch, is the same as the pitch circle. It is a line which bisects all the teeth of a toothed wheel.

The rolling circle is the same as the circular pitch line.

GEARING.

In fig. 101 is shown the halves of a wheel and pinion in gear; *A B* is the line of centers and *C C* and *C C* are the pitch circles touching at *C;* the divisions *A c* and *B c,* of the line of centers, being the pitch-radii of the wheels. The arc of the pitch circle, between *P* and *P*, is the pitch of the teeth, and it comprises a tooth and a space.

The difference between the width of a space and the thickness of a tooth is called clearance or side clearance.

The play or movement permitted by clearance is called the backlash; clearance is necessary to prevent the teeth of one wheel becoming locked in the spaces of the other.

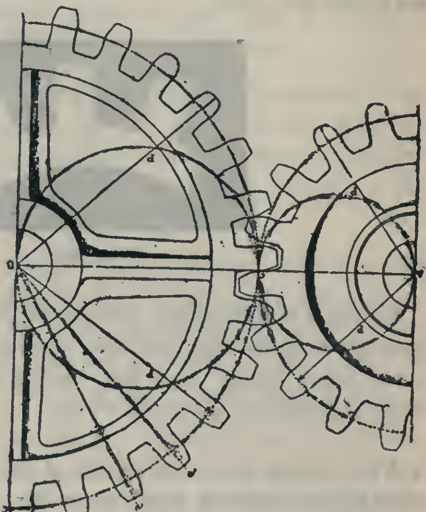


Fig. 101.

Wheels are in gear or geared together when their pitch lines engage, *i. e.*, when the pitch circles meet.

Wheels to be geared together must have their teeth spaced the same distance apart, or in other words, of the same pitch.

The teeth of spur wheels are arranged on its periphery parallel to the wheel axis, or shaft on which it is hung.

The teeth of a bevel wheel or bevel gears are always arranged at an angle to the shaft.

When the *teeth* of bevel gears form an angle of 45° they are called mitre wheels.

Mitre wheels to gear must be of equal sizes.

A crown wheel is a disc that has teeth which are radial to the shaft; that is, teeth on a flat circular surface all pointing to the center of the wheel.

SPUR-WHEELS.

A rack has teeth on a flat surface or plane all parallel to one another.

A *trundle wheel* has no teeth, properly speaking. Instead of teeth, as shown on illustration of a rack, it has rungs arranged like the rungs of a ladder between two walls, or pins fixed in one end only. See page 137.

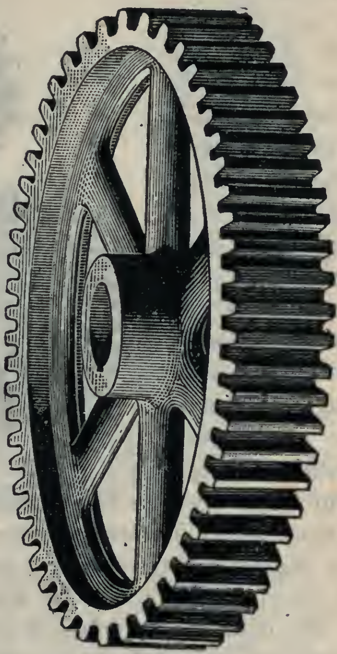


Fig. 102.

A bevel wheel and pinion must be made to suit one another by both having teeth forming together an angle of 90°, therefore they are pairs, or proportioned in the number of teeth one to the other. Any other proportion used would not exactly gear and would be termed a "Bastard" gear.

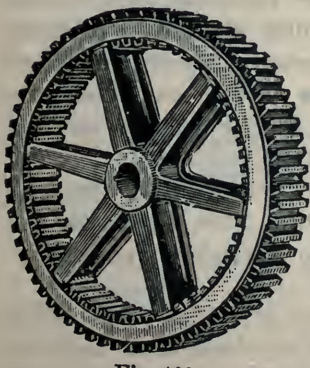


Fig. 103.

A flange or addition to the end of a tooth and the rim connecting them together is used to strengthen the teeth. This extends from the root to pitch line when the wheel and pinion are both flanged; if only one is flanged it extends from the root to the addendum.

BEVEL-GEAR.

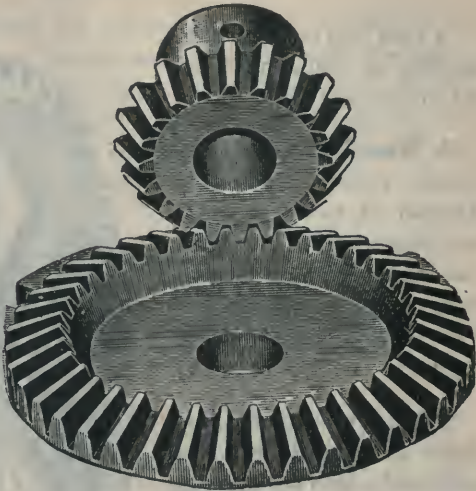


Fig. 104.

A gear cut by machine is called a *cut gear.* It has teeth with less clearance than cast wheels, which are not so true or perfect, and therefore require more clearance.

A worm gear is a spur wheel with teeth at an angle to the axis, so as to work with a worm which is a *screw,* or has teeth shaped in the form of a spiral wound round its circumference; the screw or worm is called an endless screw, because it never comes to a stopping place in the circumference of the wheel.

The diameter of a wheel or pinion is invariably the diameter measured on pitch-circle, except it is specially described otherwise, thus the diameter "over all" etc.

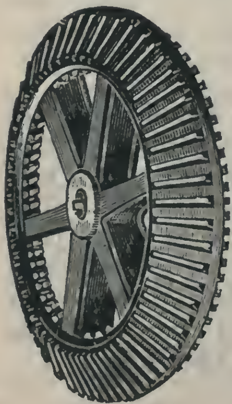


Fig. 105.

The shape of the curved face of the teeth of gears extending from the root to the addendum is the curve conforming to the passage of the teeth described on its fellows entering and leaving, as they rotate or roll together on their pitch circles.

The curve of teeth outside the pitch circle is called "the face," and the curve from pitch circle to root is called "the flank."

An internal or annular gear wheel is one in which the faces of the teeth are within and the flank without the pitch

MITRE-GEAR.

circle, hence the pinion operates within the wheel. See fig. 110 page 133.

In internal geared wheels there is almost an entire absence of friction and consequent wear of the teeth, as compared to ordinary spur gearing.

A worm with even a light load is liable to heat and cut if run at over 300 feet of rubbing surface travel. The wheel teeth will keep cool, as they form part of a large radiating surface; the worm itself is so small that its heat is dissipated slowly.

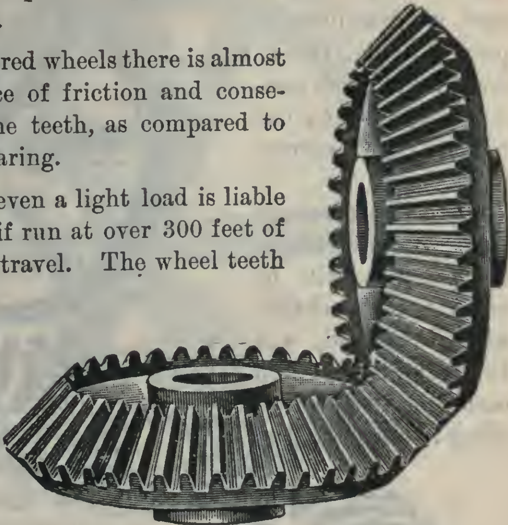


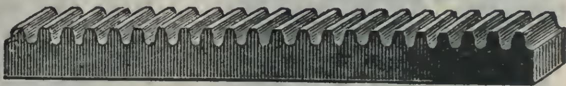
Fig. 106.

A worm throws a severe end thrust or strain on its shaft.

Fig. 102 shows a spur-wheel, a general perspective view which is not a working drawing, but conveys a good idea of this numerous class of gears.

A *spur mortise wheel* is similarly shown in fig. 103; it is very like in appearance to the spur-wheel shown, but it differs essentially in that the teeth of the latter are separate cogs, fixed in singly to the rim.

Fig. 107.



NOTE.—The teeth of spur-wheels cast from a pattern must of necessity be larger at one side than at the other, because the teeth must have taper to permit the extraction of the pattern from the mould; therefore, in fixing wheels to gear, the large side of one should meet the smaller side of the other; should the two large sides come together the teeth will meet only at the large side, and the teeth will probably break away from the excessive strain on that point.

GEARING.

Fig. 104 shows a pair of bevel wheels in gear as described on page 129; fig. 105 illustrates a bevel mortise wheel; *i. e.*, one having cogs inserted in its rim.

Fig. 106 represents a pair of miter-wheels in gear; it will be noted that the shafts, when connected, will be at right angles to each other, the wheels being in all particulars

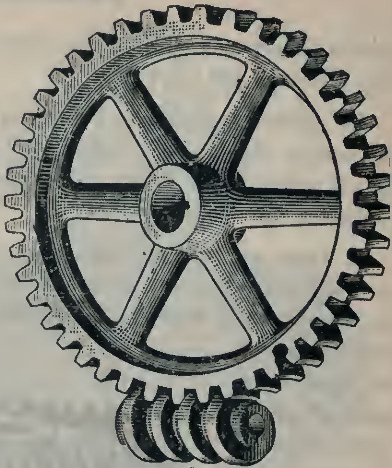


Fig. 108.

of the same dimension; the figure answers the purpose of a much longer description if given in words.

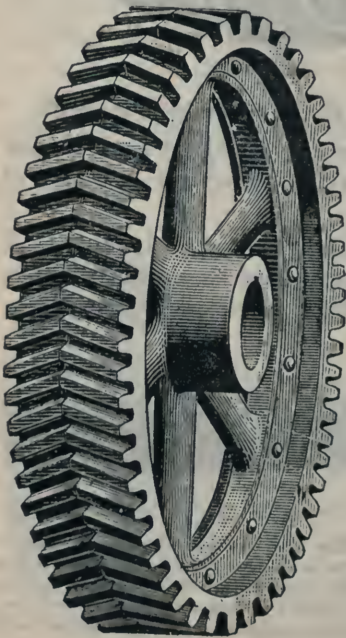


Fig. 109.

A mitre-wheel can easily be known by putting a square upon the face of the teeth, which are always at an angle of 45° with one another, irrespective of size.

Fig. 107 represents a rack; the teeth in this form of gear are shaped similarly to those in the spur-wheel, shown on page 128, with the difference that the teeth of one are on a circle and on the other made on a straight line.

INTERNAL GEAR WHEEL.

Fig. 110.

Figs. 97, 98 and 99, page 125, represent three views of a mitre-wheel. *The plan* shows the outline in one half and the finished teeth in the other half. The *sectional* elevation is shown above the plan, projected from the center line, looking down upon the plan. The lower figure represents *a side elevation* projected from the plan.

It will be observed that at the left of the plan is shown a section of the arm of the wheel.

Fig. 108 illustrates a worm and a worm wheel, sometimes called screw gears. This is a slow but powerful method of transmitting power, one revolution of the worm only moving the wheel the distance of one tooth and space.

Fig. 109 represents a gear with helical teeth. It is similar to a spur-wheel, and is used in place of same in heavy and slow moving machinery, the formation of teeth preventing—in large measure—the jar or concussion noticeable in common spur-gears.

GEARING.

Friction gearing-wheels are those which communicate motion one to the other by the simple contact of their surfaces.

In frictional gearing the wheels are toothless and one wheel drives the other by means of the friction between the two surfaces which are pressed together.

Grooved friction wheels are used to give greater cohesion than can be obtained by the plain surface.

Gear wheel teeth should be lubricated or greased.

Friction gear should not be lubricated or greased.

DESIGNING GEARS.

To accurately divide the pitch circle of a gear wheel by hand requires both patience and skill. On the accuracy of spacing lies the essential requisite of a good gear wheel.

The drawing in this plate, fig. 111, illustrates a pair of spur-wheels, shown in gear, the office instructions for which being:

"Required, *a detail plan* of a pair of spur-wheels; dimensions: wheel, 76 teeth, $3\frac{1}{2}$ inches pitch, 7-inch eye, 6 arms; pinion, 19 teeth; scale, $1\frac{1}{2}$ inches = 1 foot."

The drawing, as illustrated, is the result of the above instructions, all pencil lines being removed, and this result is worked out as follows:

76 teeth $\times 3\frac{1}{2}$ inches, pitch = 266 inches in circum. = 7 ft. $.0\frac{11}{16}$ in. diam. = 3 ft. $6\frac{11}{32}$ in. radius; with this measurement as represented on scale draw line *P P* on drawing. This is called the pitch line.

Draw next diameter line, produce or extend this diameter line for pinion, and with radius of $10\frac{19}{32}$ (19 teeth $\times 3\frac{1}{2}$) from pitch line of wheel, draw pitch line of pinion.

NOTE.—Friction gear may be used where the speed is so high that noise would be caused by toothed gearing; they may be used when the motion is intermittent, or often put into or out of gear without stopping the machinery

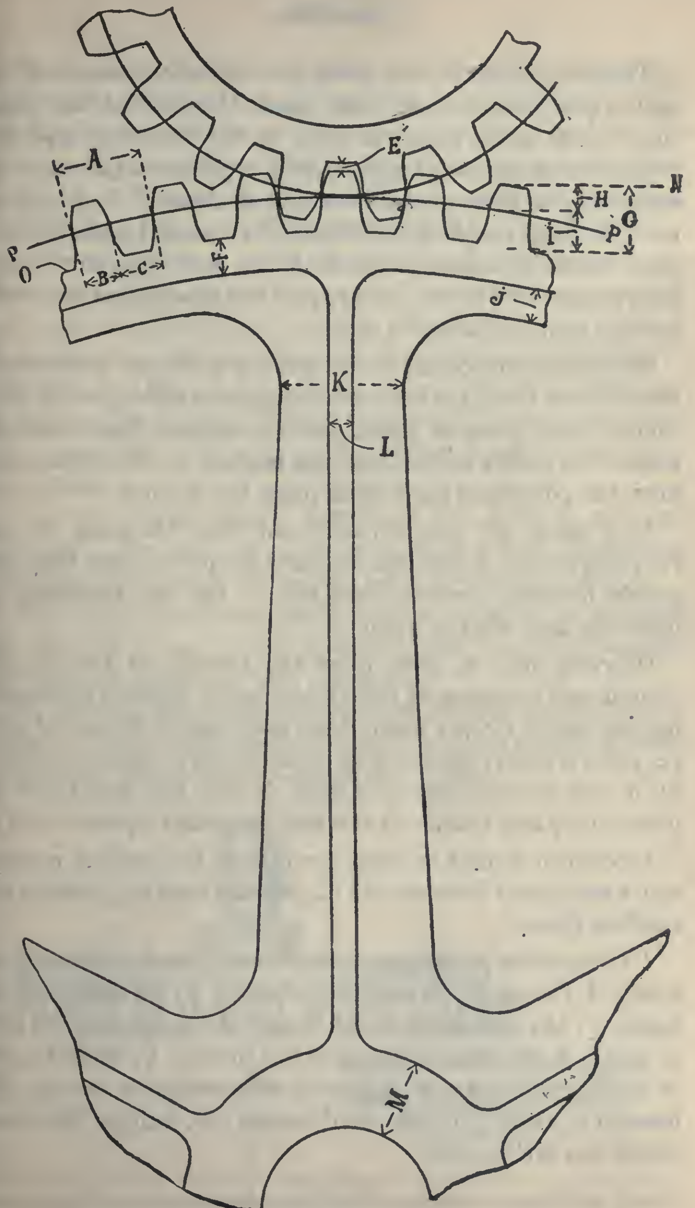


Fig. 111.

GEARING.

Take any point in this pitch line of wheel, mark off $3\frac{1}{2}$ inches as represented on scale, mark this around the pitch line, it will be the center of each of the 76 teeth; then the breadth or thickness of each tooth ($=$ pitch $\times 0.475$) must be marked from these centers, then mark from *P I*, length of tooth to point ($=$pitch$\times 0.35$) and *P I* to root ($=$pitch$\times 0.4$) draw circles for outside of teeth *N* and root of tooth *O;* now with compass set to the pitch ($3\frac{1}{2}$) of the wheel, draw the outer portion from pitch line of tooth.

The radius will center in the pitch line of next tooth where thickness of tooth has been marked; after finishing outer portion of both sides of teeth, set the compass from *center* of tooth with radius to the thickness marked on pitch line and draw the portion of tooth from pitch line to root.

Now mark off with dividers and draw thickness of rim ($=$ pitch$\times 0.5$), divide this line into six parts, draw radii for centers of arms; draw the bore hole 7″ and the thickness of metal for hub same as pitch.

On radii lines of arms, draw the breadth of arm at rim —pitch and thickness of tooth—increase in breadth approaching the center (1″ per foot), draw thickness of feather of arm ($=$ pitch$\times 0.35$); draw web on inside of rim ($=$pitch$\times 0.375$); fill in arcs for the joining of arms in rim and hub (radii $=$ pitch$\times 0.8$) and feather to rim and hub (radii$=$pitch$\times 0.37$).

Proceed in similar manner, completing the teeth of pinion, and when pencil lines are all in, ink the drawing, erasing all needless lines.

P P shows the pitch line; *B,* thickness of tooth; *c,* breadth of space; *A,* the pitch; *E,* clearance of teeth; *N,* the addendum of tooth; *O,* the root of tooth; *H,* length of tooth from pitch line to point; *I,* length of tooth pitch line to root; *G,* whole length of tooth; *F,* thickness of rim; *J,* web or feather on rim; *K,* breadth of arm; *L,* thickness of feather; *M,* hub, or thickness round the eye.

Note.—But it must be remembered that no fixed standard has ever been agreed on for these proportions and workshops differ considerably in practice.

GEARING.

In designing gears to transmit power the stress on a tooth is calculated; it determines the breadth or width also and the thickness of the tooth on pitch line; the space between the teeth is in proportion to the thickness of tooth, and the thickness of both combined (one tooth and one space), measured on the pitch line or circle, is the pitch of the wheel.

From the pitch all the proportions and measurements for the sizes and strength of the parts of the wheel are taken *by rule,* and a symmetrical form is produced.

In machine drawing the practice is to represent wheels by circles only; the teeth are never shown except on enlarged details and then only in very rare instances; the circles drawn are always the *pitch lines* or the rolling points of contact of the wheels.

The addendum circle is seldom if ever used in practical drawing. Should it be necessary to show it in an exceptional case the circle would be represented by "dotted" line.

The shape of tooth and mode of constructing it, as practiced in drawing offices, differs from the true curve theoretically of the tooth, although very minutely.

In all calculations for the speed of toothed gears the estimates are based upon the pitch line, the latter standing in the same place as the circumference of a pulley.

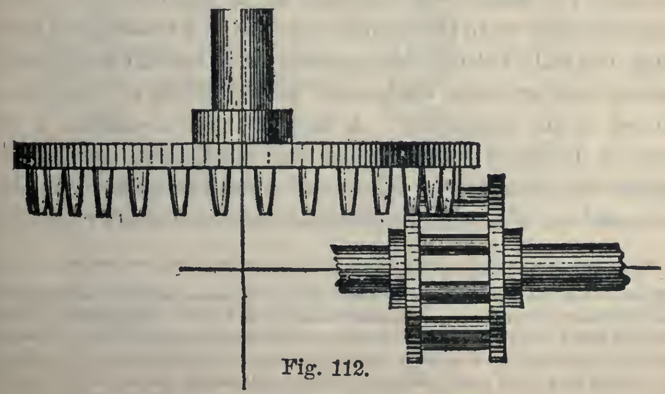


Fig. 112.

Trundle-Wheel. See page 129

GEARING.

The decimal proportions already given in example, page 134, are adopted in many workshops. Many others use the proportions approved of by Sir William Fairbairn, which are:

Table of proportion of gears:

Depth of tooth above pitch line....	.35	of the pitch.
" below pitch line....	.40	"
Working depth of tooth...........	.70	"
Total depth of tooth..............	.75	"
Clearance at root..................	.05	"
Thickness of tooth.................	.45	"
Width of space.....................	.55	"

Steel Gears.—There is great economy in the use of cast-steel over cast-iron in gears; the average life of the former is nearly twice as great as that of cast-iron gears. And, apart from their longer life and efficiency, there is less danger of breaking.

The most accurate teeth, strongest and most uniform in wearing, are to be found in steel gears cut from solid stock, or made by cutters of proper shape.

Skew gearing are bevel wheels working out of center; the teeth do not form radial lines from wheel center.

Covers for Gears.—Experience of a painful and costly nature has shown in thousands of cases the advantage of covering, not only belting, but gearing, with special safeguards against contact with the person and clothing of those employed in its operation. A factory act, so-called, is in force in England to safeguard the public and employees against this danger. A feature of American practice is the increased use of covers for gears that were formerly exposed.

NOTE.—This factory act is the outcome of labor agitation, and it is administered in a peremptory way; great precautions being taken to have all gearing perfectly safe, and cased about, in lathe, drill and wood-working machinery; the gears are enclosed in malleable iron or brass cases or covering, which fit close to the wheels and occupy very little room; they are found an advantage instead of an encumbrance, and protect the gears from chippings, etc.

GEARING.

Train of Gears.—When two wheels mesh—that is, engage with each other—as in fig. 101, one axle revolves in the opposite direction to the other; but when internal gears mesh as shown in fig. 110, the shafts revolve in the same direction; three or more gears running together are often called *a train of gears.*

Fig. 113.

When the teeth of gear wheels become worn it is well to thin down the edges with a smooth file, thereby bringing the strain along the center of the tooth; then they will not break unless the strain is sufficient to break off the whole tooth.

Maximum speed of gears under favorable conditions for safety are comparatively—

Ordinary cast-iron wheels....	1,800	feet per minute.
Helical " "	2,400	"
Mortise wood cog "	2,400	"
Ordinary cast-steel wheels...	2,600	"
Helical " " ..	3,000	"
Cast-iron machine cut wheels.	3,000	"

It is not, however, advisable to run gears at their maximum speeds, as great noise and vibration are caused.

NOTE.—*Helical Teeth*—In recent years the speed at which gearing is run has been greatly increased. A striking instance is that of a pair of *cast-iron* helical wheels, 6 ft. 3 in. diameter, 12 in. wide, making 220 revolutions per minute, the speed of the pitch line being 4,319 ft. per minute; these wheels are running continuously and with little noise. There is also a *cut* gear in a mill in Massachusetts 30 ft. in diameter, and the speed of pitch line is 4,670 ft. per minute. This is probably the highest speed ever regularly run.

WORK BENCHES.

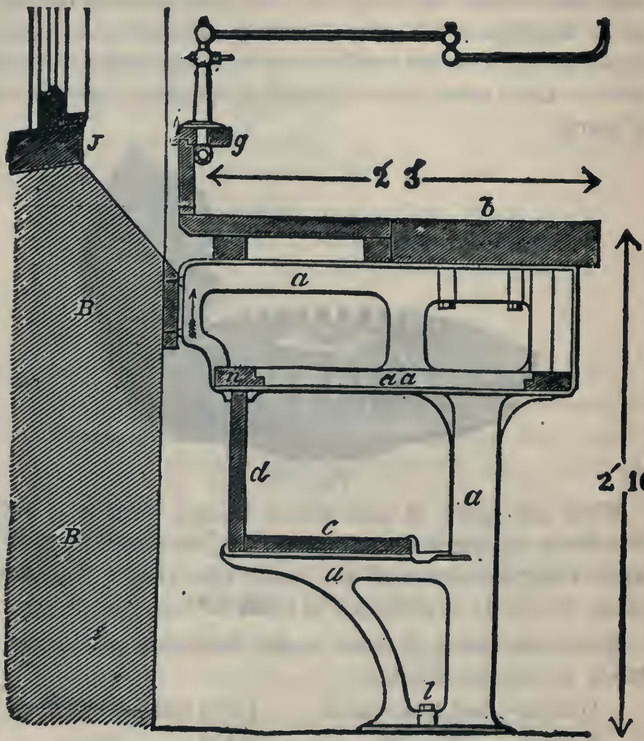


Fig. 114.

NOTE.—"The correct manipulation of metal-working too s comes natural to many; but where one such man is found, there will be a dozen others who can acquire the necessary skill to be called good machinists only after careful study and close application of the most thorough instruction. The time required to accomplish this will depend entirely on the man and the conditions under which he works. Under favorable circumstances two to six years will be required."—W. H. VAN DEVOORT.

BENCH

AND

VISE

TEMPERING AND HARDENING METALS.

To temper steel or other metal is to bring it to a proper degree of hardness and elaciticity for use; the reason tempered steel cuts common steel or iron is because it is harder.

Steel is said to be *hardened* when it is as hard as it is practicable to make it, and to be *tempered* when, after having been hardened, it is subjected to a less degree of heat, which partly but not altogether destroys or removes the hardness.

Steel plunged into cold water when it is itself at a red heat becomes excessively hard. The more suddenly the heat is extracted the harder it will be. This process of "hardening," however, makes the steel very brittle, and in order to make it tough enough for most purposes it has to be "tempered."

Steel is tempered by being first heated to a high temperature and then rapidly cooled; it is then reheated to the desired temperature and cooled again.

The process of tempering depends upon a characteristic of steel, which is that if (after hardening) the steel be reheated, as the heat increases, the hardness diminishes.

In order to produce steel of a certain degree of toughness, without the extreme hardness which causes brittleness, it is gradually reheated, and then cooled when it arrives at that temperature which experience has shown will produce the limited degree of hardness required. Advantage is taken of this change of color in the process of tempering, which for ordinary tools is conducted as follows: The workman places the point or cutting-end of the tool in the fire till it is of a cherry-red heat, then hardens it by dipping the end of the tool suddenly into cold water.

TEMPERING AND HARDENING METALS.

The art of properly hardening tool-steel is a trade secret which many who obtain their livelihood by it are very reticent in speaking about. Steel edge-tool hardening is a matter of study and practice which, when acquired, secures the highest remuneration and steadiness of employment. An expert in this craft replied thus to an inquiry: "A good steel edge-tool hardener knows his value. I have made the study of edge-tool steel hardening a special feature. I can harden and temper tool-steel, from a very fine drill upwards. My turning tools are made from old files, which are doing excellent work, through proper hardening and tempering. I put tools to-rights for many mechanics in my district."

"The art of steel-hardening properly does not consist of heating to cherry-red and plunging in the water bucket. I have received many offers in money from tool-makers for my secret in tool-steel hardening. I refuse to sell it," writes a second expert.

Another experienced master in this difficult "trick of the trade," J. Matthewson, gives the summary for tempering:

1. Good steel.
2. No over-heating.
3. Cutting out all cracked pieces.
4. Avoidance of final blows edgewise of the tools when getting rather cold.
5. Clean water with all frosty chill removed.
6. Do not "plunge" too hot.

The above directions are given by one who claims to have tempered thousands of tools, but a novice undertaking to temper tools by it for a shopful of workmen would soon be replaced by another who had no rule to go by, but could temper, having learned by experience, the tools brought to him as they were needed in the shop.

H. Woodruffe kindly informs the inquiring student, "Try the following way of tempering tools; heat the tools to a dull redness, then plunge them two or three times into a mixture made by dissolving 10 parts by weight of rosin in 5

TEMPERING AND HARDENING METALS.

parts of fish oil; stirring in 2½ parts of melted tallow. The tools are then reheated to dull redness and plunged into cold water.

In answer to an inquiry "How can I harden cast steel so that it will hold an edge and not crumble?" the able editor of the *American Machinist* replies: "The method of procedure would depend on the kind of steel and the purpose for which it is to be used. For ordinary lathe and planer tools, heat the tools in a charcoal fire to a cherry red, and quench them in a hardening solution consisting of one gallon of soft water and one-half pint of salt."

There are two classes of steel: *Hard* steel, which contains *over* a half of one per cent. of carbon; this becomes hard when it is heated to redness and quenched in water.

Mild steel contains *less* than a half of one per cent. of carbon; this does not harden sensibly when so treated.

The two classes pass gradually one into the other, so that it is impossible to draw an exact line of separation.

Hard steel is almost always made by cementation, with or without subsequent melting. Mild steel is made either by the Bessemer or the Siemens process.

When steel is heated to redness and suddenly cooled, as by quenching in water, it becomes very hard, whilst if slowly cooled it becomes soft. After the steel has been hardened, the hardness can be reduced or the metal tempered by heating to a moderate temperature and cooling, the rate of cooling having little influence.

While the cause of hardening and tempering is not yet fully known, it is, however, intimately connected with changes in the condition in which the carbon exists in the metal. The hardness which can be imparted to steel depends on the

NOTE.—Cementation is a metallurgical process in which two substances are heated in contact to effect a chemical change in one of them.

TEMPERING AND HARDENING METALS.

amount of carbon present, and on the rate at which the temperature falls over the critical point. Three cooling agents are used—mercury, which is the most rapid; then water, which is almost always used in practice, and lastly oil.

Saws are hardened in oil, or in a mixture of oil with suet, wax, etc. They are then heated over a fire till the grease inflames. This is called being "blazed." After blazing the saw is flattened while warm, and then ground. Springs are treated in somewhat the same manner, and small tools after being hardened in water are cooled with tallow, heated till the tallow begins to smoke, and then quenched in cold tallow.

Carbon exists in steel in two forms:

(1.) In *soft steel* it is present in the form of a definite compound, scattered through the metal. In this form it is called carbide carbon.

(2.) In *hardened steel* it is present apparently in combination with, or in solution in, the whole of the iron. In this form it is called hardening carbon.

Hardened steel is usually too brittle for use, and must, therefore, have its hardness let down by tempering; the higher the temperature of tempering the more will the hardness be reduced. For articles which are required to take a very keen edge the hardness must be very little reduced. In all cases, of course, a suitable steel must be used.

NOTE.—When the steel is heated to redness the carbon passes into the condition of hardening carbon, which is the stable form at high temperatures, and on slow cooling, as the temperature reaches about 1,500° F., it passes into the carbide condition, the stable form at low temperatures, and if the cooling be slow enough the whole may change its form. The passage from the one form to the other takes time, and if the metal be suddenly cooled over the critical temperature the carbon cannot change its condition before the metal is too solid to allow of further molecular change, and the metal remains hard. The carbon in the hardening condition is at ordinary temperatures in a state of stress, and when the metal is heated so as to allow molecular freedom, some of it will pass into the carbide condition, and the steel will be softened to some extent, the amount of softening depending on the temperature to which the metal is heated.

GRADES OF TOOL-STEEL.

The grades of hard steel made are:

RAZOR TEMPER.—Contains one and a half per cent. of carbon. This steel becomes very hard, and is very difficult to work. Articles made of it take a very keen edge.

SAW FILE TEMPER.—Contains one and three-eighths per cent. carbon. This steel hardens well, and tools made of it take a very keen edge. It is easier to work than the razor temper, and with care can be welded.

TOOL TEMPER.—Contains one and a quarter per cent. carbon. This steel does not become so hard as those above, but is hard enough to take a keen edge. It is easier to work and can be welded with care.

SPINDLE TEMPER.—Contains one and one-eighth per cent. carbon; this is a very useful steel for large tools, but requires care in welding.

CHISEL STEEL.—Contains one per cent. carbon. This is a very useful steel. It hardens well, though it becomes less hard than the steels containing more carbon, and when hardened is very tough. It is used for cold chisels and other tools which require strength and a moderately sharp cutting edge.

COLD-SET TEMPER.—Seven-eighths of one per cent. carbon. This is a very tough steel, but does not harden well. It is used for cold sets and other tools which have to stand heavy blows. It welds fairly well.

CASE-HARDENING.

Case-hardening is a process by which the surface of wrought iron is turned into steel, so that a hard exterior, to resist wear, is combined with the toughness of the iron in the interior. This is effected by placing the article to be case-

NOTE.—A more rapid method of case-hardening is conducted as follows: The article to be case-hardened is polished, raised to a red heat, sprinkled with finely powdered prussiate of potash. When this has become decomposed and has disappeared, the metal is plunged into cold water and quenched. The case-hardening in this way may be made local by a partial application of the prussiate.

CASE-HARDENING.

hardened in an iron box full of bone-dust or some other animal matter, and subjecting it to a red heat for a period varying from one-half hour to eight hours, according to the depth of steel required.

The iron at the surface combines with a proportion of carbon, and is turned into steel to the depth of $\frac{1}{16}$ to $\frac{3}{8}$ inches. The principal materials used in effecting the hardening are: granulated raw bone, hydro-carbonated bone black, black oxide of magnesia, sal soda, charcoal, and salt. These materials are commonly used and give much satisfaction if they be carefully and properly handled.

The work which is to be hardened can be packed in cast or wrought-iron boxes, sealing with fire-clay or mud, so as to prevent the gases from escaping as much as possible. The pieces to be hardened should be placed about two inches apart in the box. The vacant spaces are well filled and packed with the material used for the case-hardening purpose. Should the box be supplied with heavy work, as crank-pins, guides, etc., fifteen to twenty hours of steady heat are necessary in order to secure the best results. If, on the other hand, you have light pieces, as link blocks and pins, eight to ten hours will be sufficient to subject them to a good heat.

The work may be placed in the furnace about 8 o'clock in the morning and heated all day. At night close up the furnace, letting the box remain over night; if the surface of the article is to be hardened all over, it is quenched in cold water upon removal from the furnace. If parts are to remain malleable it is allowed to cool down, the steeled surface of those parts is removed, and the whole is then reheated and quenched, by which the portions on which the steel remains are hardened.

Malleable castings are sometimes case-hardened in order that they may take a polish; malleable iron may be case-hardened by heating it red-hot, rubbing cyanide of potassium over it, or by immersing it in melted cyanide, again heating and quenching in water.

TEMPERING SCALE.

The temperature to which the steel is heated for tempering is usually judged by the color of the oxide.

Heated steel becomes covered with a very thin film of oxidation, which grows thicker and changes in its color as the temperature rises; this color is an indication of the temperature of the steel on which it appears.

Oxide Tint.	Temp. Fah.	
	Deg.	
1. Pale yellow......	428	Very small tools requiring the keenest cutting edge.
2. Straw yellow.....	446	Razors.
3. Golden yellow....	469	Hammers, taps, reamers, etc.
4. Brown...........	491	Cold chisels, shears, etc.
5. Brown, with purple spots........	509	Axes, planes, etc.
6. Purple...........	531	Wood turning tools, etc.
7. Bright blue......	550	Watch springs, etc.
8. Full blue........	559	Fine saws, augers, etc.
9. Dark blue........	600	Hand and pit saws, etc.

The above table shows the temperature at which the steel should be suddenly cooled in order to produce the hardness required for different descriptions of tools. It also shows the colors which indicate that the required temperature has been reached.

ANNEALING.

This is the art or process of removing the brittleness of steel, and at the same time retaining its toughness and elasticity. In general, these results are obtained by heating to a high temperature and then cooling very gradually.

BENCHMAN'S TOOLS.

The most elementary division into which mechanical devices and appliances can be resolved are two:

1. Hand-tools.
2. Machine-tools.

The first includes those which are or can be utilized without any force other than manual labor. The second division embraces all new as well as old machines, designed to be employed in combination with the various original powers, such as are derived from steam, water and other sources of energy, helpful to mankind.

While no day now passes without adding to the already great number of useful and more or less complicated machines, it is true that long before human history began, hand-tools such as are described and illustrated in the few following pages were in wide and constant use. It is true, also, that skill in manipulating the latter will always take first rank as compared to the former; fortunate the workman who has a chest full of the highest quality of hand-tools such as are described.

WORK BENCHES.

A machinist's bench is the most "homelike spot" in the shop. The "vise-man" has usually this coveted place with its appropriate tools and drawer, to which he has the exclusive key; the lathe-hand generally owns his own "box," which is usually placed under or at the foot of his lathe, or otherwise he may use a tray or stand.

Fig. **115** shows a bench two feet ten inches in height and two feet three inches in breadth, with drawer.

Benches are usually constructed in longer or shorter lines, with the best light obtainable, to aid in seeing the work. A

WORK BENCHES.

vise and a drawer are put about every ten to twelve feet, according to the work, large work requiring the greater space for ease of execution.

The qualities to be desired in a work bench are stability, hence extra thickness in outer plank, as shown, supported by

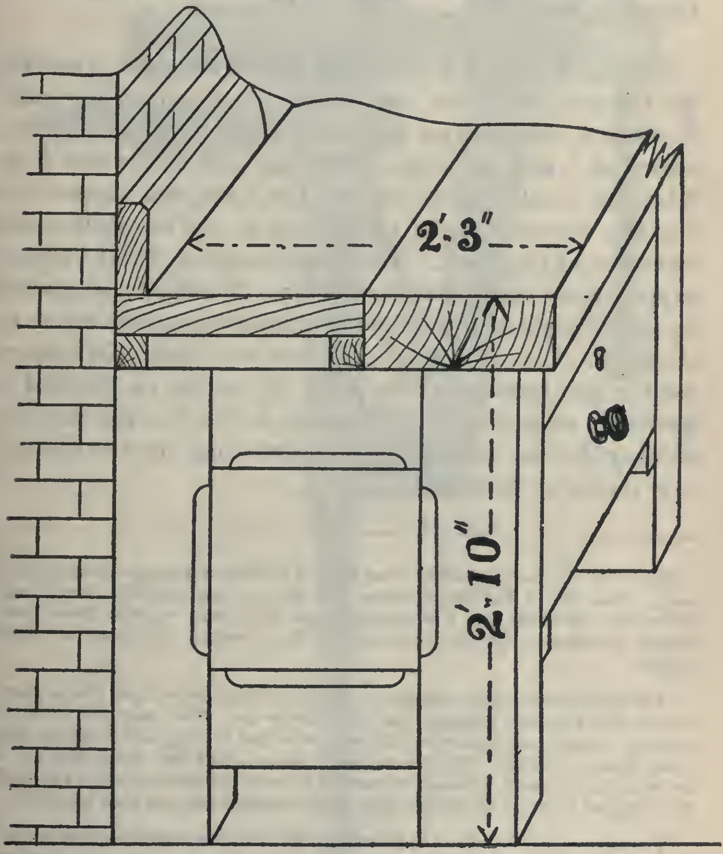


Fig. 115.

substantial wood or cast-iron legs, suitably arranged according to each shop's requirement. A well-built drawer of sufficient size to accommodate the workman's hammers, chisels, etc., without crowding. The drawer fitted with a large slid-

WORK BENCHES.

ing shelf, to separate the files and lighter instruments from the heavier tools. An improved work bench is shown in fig. 114, designed for both iron and wood work; construction drawings and castings for this are furnished by Messrs. Brown & Sharp, Providence, R. I., to whom credit is due for the following description:

The leg or casting *a* consists of a rigid standard, a bracket for the support of the shelf *c*, and its accompanying back. The legs or standards are fastened to the floor by coach screws, shown at *l*, and are supported at the back by the wall *B B*. They are usually placed about 4 feet apart, and support the bench *b*, the shelf *g*, the frame-work *n*, and the shelf *c*, and its accompanying back. The frame-work *n n*, forms a strong support upon which slide the drawers. The shelf *c*, supported by the brackets is held in place by the cast-iron clip, shown at the front. The shelf *g*, affords a neat and substantial support for the gas brackets. The front of the leg or standard is provided, when desired, with a hole to receive the bolt for holding the vise, and this construction brings the vise directly over the leg or standard.

NOTE.—"I am studying about what kind of benches to put into the new North shop. I am sick of the usual things; they are too convenient to throw things under, for one thing, and I have about made np my mind to have them wainscoted, or sealed up, letting the bottom of the 'sealing' drop back, say eight inches.

"I am prejudiced against drawers in benches. Our men will pile files in them, and do the files more damage than their regular use. Then they will throw in chipping chisels, and hammers and wrenches, and squares, and scrap iron, and scrap brass, and odd pipe fittings, and sheet rubber, and I don't know what all. I am studying on a wall cupboard to take the place of the drawers, and if I succeed in getting up anything to suit my ideas of the proper thing, you shall hear of it.

"I mentioned my objections to drawers to Mr. Viall, the superintendent, and he got the keys from the men and we made the grand rounds. Yale locks to start on—think of that, you who use padlocks!—and drawers that you could actually draw right open without any hammering or fussing.

"And when those drawers are opened, they looked as nice and clean inside as any apprentice's tool box. Here a neat, clean, sliding tray for scales and calipers, and small tools generally; here a division for chisels, and here another one for files."—CHORDAL, in *American Machinist*.

THE VISE.

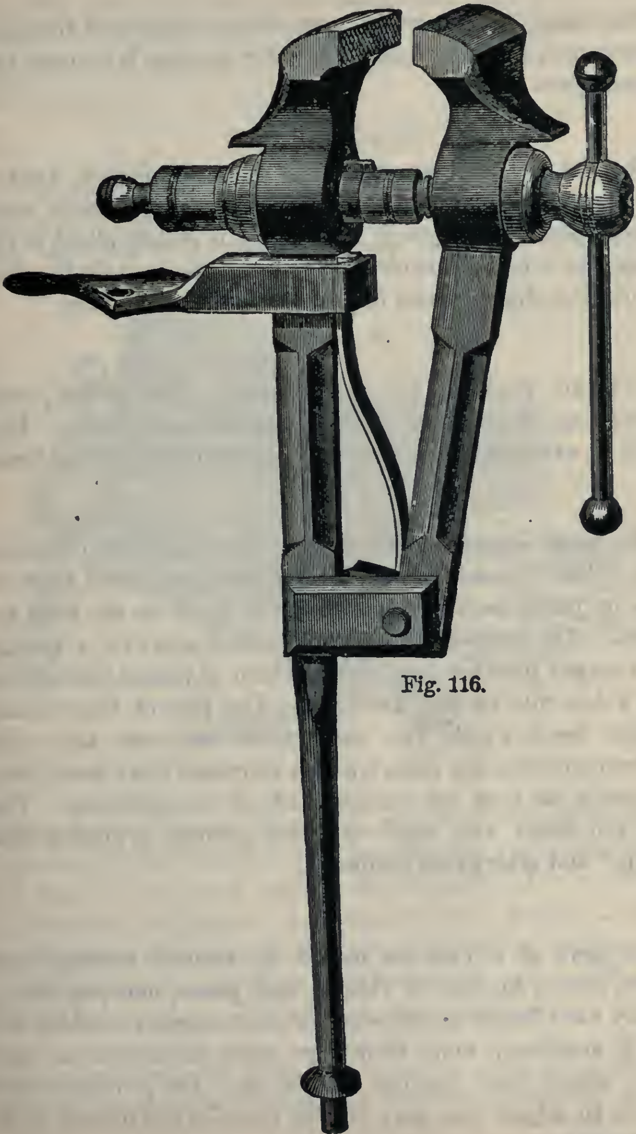


Fig. 116.

THE VISE.

The name of this well-known device is derived from the French, *vis*, a screw; hence the screw portion is its most important part.

The *vise* is a gripping or holding tool or appliance, fixed or portable, used to hold an object firmly in position while work is being performed upon it. The vise is closely allied to the *clamp;* both have movable jaws that may be brought together to hold any object placed in position between the jaws.

Vises are made in two parts forming jaws either joined by a spring, or arranged to move upon slides or guides. Fig. 116 is an example of the first, and fig. 117 of the second form.

The large engraving shows the common form of bench vises. This consists of a fixed vertical leg pivoted between arms or plates secured some distance down on the fixed leg shown. The jaws of the device are held apart by a spring, and brought together by a screw, which is passed through or into a box-nut in the fixed leg. The jaws of this vise are parallel bench-wise. The shop term for these is "solid box wrought-iron leg vises," which expresses their main characteristics, as they are usually made of wrought-iron. The jaws are faced with steel cut with grooves, to allow a firm "grip," and afterwards tempered.

The jaws of a vise are moved by various methods—by screws, levers, toggles, or ratchet and pawls, one jaw being usually fixed firmly to the bench or other support to which the vise is attached; some forms are made adjustable at any angle; others have parallel motions and are provided with swivels to adjust the jaws to the shape of the objects to be held by them.

THE VISE.

This device receives several names derived from the use to which it assigned, thus: bench-vise, saw-vise, parallel-vise, pipe-vise; an illustration of the latter is shown elsewhere in this volume.

THE HAMMER.

The *hammer* was probably the first tool used by mankind; hammers of stone are found among the remains of antiquity, and they are still common among barbarous races. The

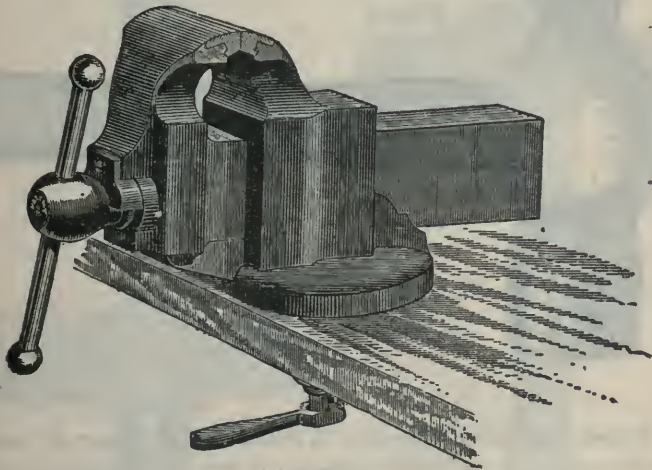


Fig. 117.

hammer, in common every-day service is an instrument, or tool, consisting of a solid head, usually of metal but sometimes of wood or prepared leather, set cross-wise to the handle. The machinist's hammer, as generally used, weighs from one to two and one-quarter pounds, exclusive of the handle.

The *peen* of a hammer is the opposite end to the head, which terminates in a rounded or cone-shaped point.

NOTE.—"The Century Dictionary spells it peen, but gives also four alternative spellings, pean, pene, pein and piend, either of which may be assumed to be permissible. The word may originally have been pin, which was sometimes used for a peak or pinnacle, which the peen of a hammer often is."

THE HAMMER.

The *eye* of the hammer is the center opening through which the handle is inserted. The eye is left soft as to temper, as it will in that condition better resist the shock of the blows; the hammer is made of high-grade steel, carefully tempered on head and peen; the head is usually made cylindrical with flat face.

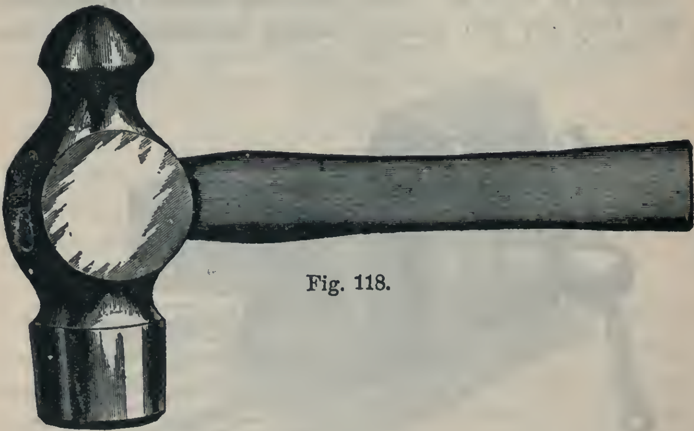


Fig. 118.

Copper hammers are also in use, the body being of malleable iron, and the ends or tips are of pure bar copper; these are driven into cavities provided with a slight taper, or inserted in parallel recesses and fixed with set screws, which permits the tip being rotated as the edge at one side wears away on account of the soft material used.

Timber mallets are used on sheet iron, as the blow covers a large surface and does not leave a recess, which would be the case if struck by a steel hammer. A decided improvement on the timber mallet is the hide-faced hammer; the raw-hide mallet has a core or strip of soft metal in the center, round which is rolled or compressed the raw-hide, making a weighty and yet not bulky implement.

THE HAMMER.

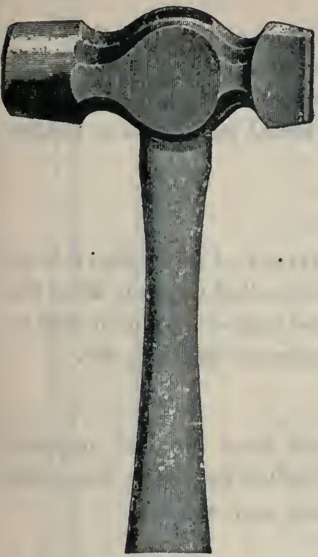


Fig. 119.

Fig. 120.

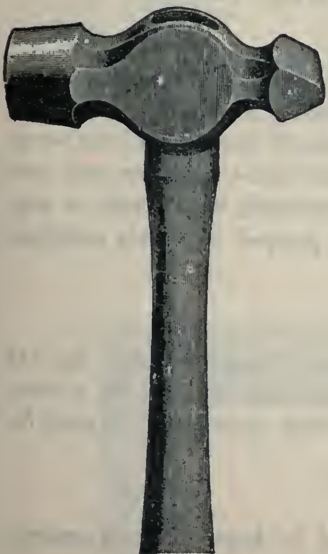


Fig. 121

THE HAMMER.

The "lead hammer" is used to avoid "upsetting" of machine parts needing to be hammered, and too finely finished to be roughly treated; the heavy wooden mallet has been, in shop work, superseded by the soft ended lead, brass or leather hammer.

The hammer is made in such a variety of forms that it is almost impossible to classify it; it is called not only after the use to which it is put, but after the trade-class which uses it, as the machinist-hammer, the blacksmith-hammer, etc.

Hammers are principally named from the end opposite the face of the hammer; this is called the peen; the claw-hammer gets its name from the peen end, etc.

A *ball-peen hammer* is shown in fig. 118.

In its use the hammer should be grasped near the end of the handle, giving it a free arm swing, and carrying the head through a nearly vertical plane. If the plane of the swing approaches a horizontal the weight of the hammer will produce a twisting effort on the fore-arm, which will be very wearing. The handle should be grasped with only sufficient force to safely control the blow.

On the previous page are shown three hammers: fig. 119 is a straight-peen, fig. 120 is a ball-peen, and fig. 121 a cross-peen, hammer. These are the three principal tools used for general service.

The face of the hammer should be kept true and smooth, by careful grinding and polishing.

SCRIBERS.

A *scriber* or marker, of which two forms are shown in figs. 122 and 123, is a rather important tool in machine and engineering practice, as it is used to assure the close fitting of one piece or part of the work to the other part.

The scriber, fig. 123, is used upon inside work, and the other, fig. 122, for surface work.

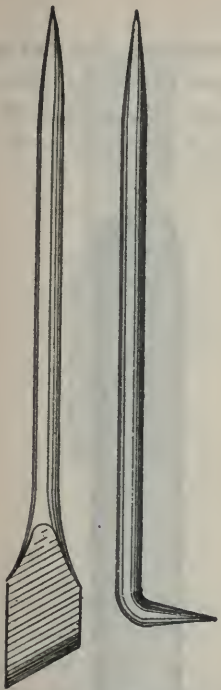


Fig. 122. Fig. 123.

KEY-SEAT RULE.

This is an instrument made in the form of angle iron and used in connection with the scriber in marking parallel lines on round shafts; such lines as are necessary in cutting key-seats.

THE STEEL SQUARE.

The *steel try-square* is an instrument used by machinists, draughtsmen and others for trying or describing right angles. It consists of two rules or branches, as shown in fig. 124, fastened perpendicularly at one end of their extremities, so as to form a right angle.

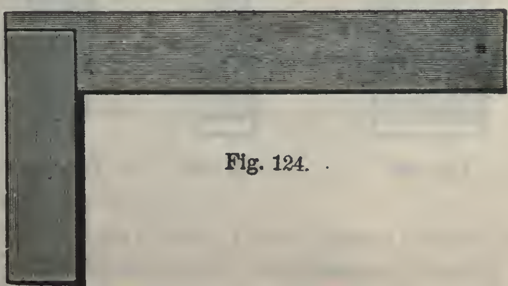


Fig. 124.

THE CHISEL.

This is a tool consisting of a blade, commonly flat, having a beveled or sloping cutting edge at one extremity, and a handle at the other, designed to cut under the impulse of a blow from a mallet or hammer or under *pressure*, as in a lathe.

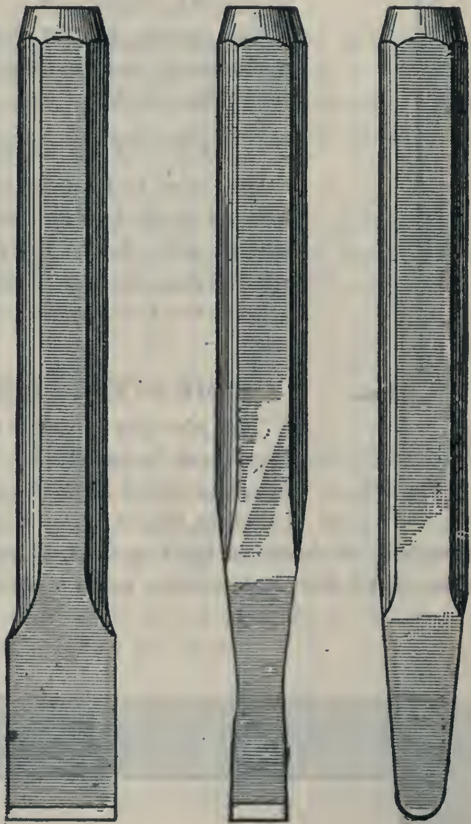


Fig. 125. Fig. 126. Fig. 127.

A *cold-chisel* is a chisel with a cutting edge formed entirely of steel, properly tempered for cutting metals.

THE COLD-CHISEL.

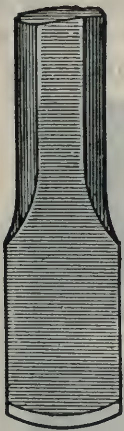


Fig. 128.

Fig. 129.

Fig. 130.

In common hand use, the cold-chisel is a cutting tool principally used for "chipping" or cutting out metals; chisels are used as well for working in stone, wood and other materials, but in this volume relating to working in steel, iron and brass, all reference to the chisel, in any way, means its work in metals.

Fig. 125 represents the common flat cold-chisel.

A *cape-chisel* is shown in fig. 126; this chisel has clearance on the sides and is deep on edge view.

A *round-nose chisel* is shown in fig. 127.

A *curved cold-chisel* is shown in fig. 128.

The *cow-mouth chisel* is shown in fig. 129; this form of chisel is called *a gouging-chisel.*

The *diamond-point chisel* is shown in fig. 130.

FILES.

A *file* is a metal (usually steel) tool, having a round, triangular, rectangular or irregular section, and either tapering or of uniform width and thickness, covered on one or more of its surfaces with teeth or transverse or oblique ridges.

Fig. 131.

Fig. 132.

Fig. 133.

Fig. 134.

Fig. 135.

Fig 136.

The *tag* end of a file is the point or taper part intended for attaching the file to the handle; it is the part left untempered.

The *shoulder* is the abutment where the tag meets the body of the file; the "point" of a file is the end opposite the handle.

A file is used for scraping off, reducing or smoothing metals, ivory, etc.; before the days of modern machinery, FILES.

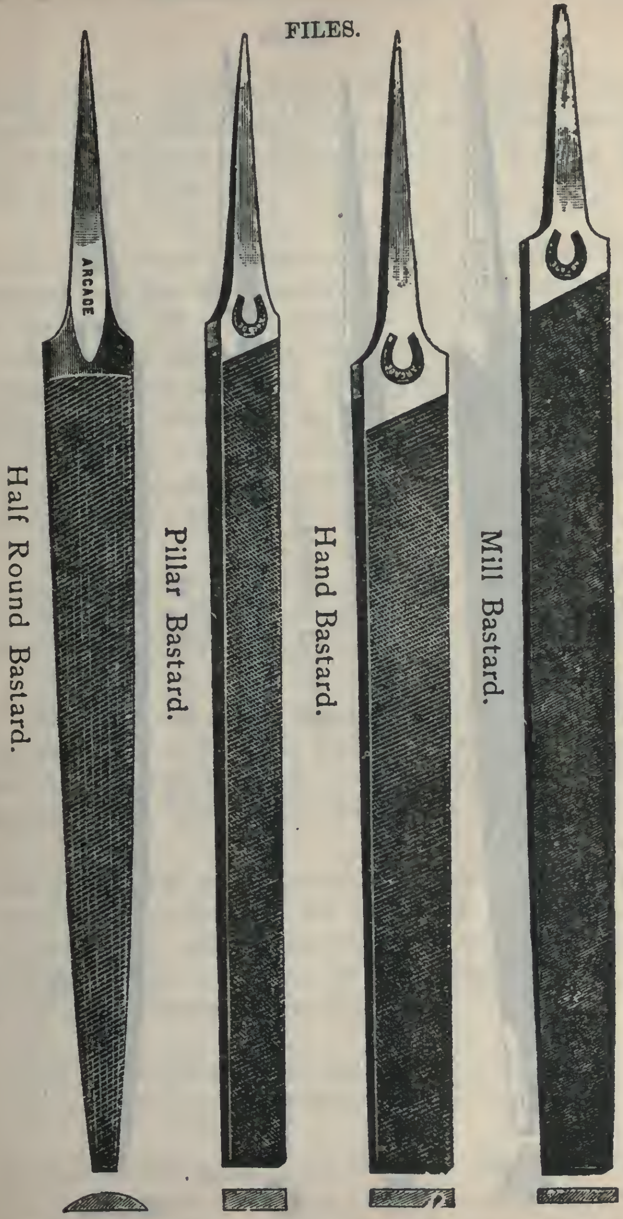


Fig. 137. Fig. 138. Fig. 139. Fig. 140.

FILES.

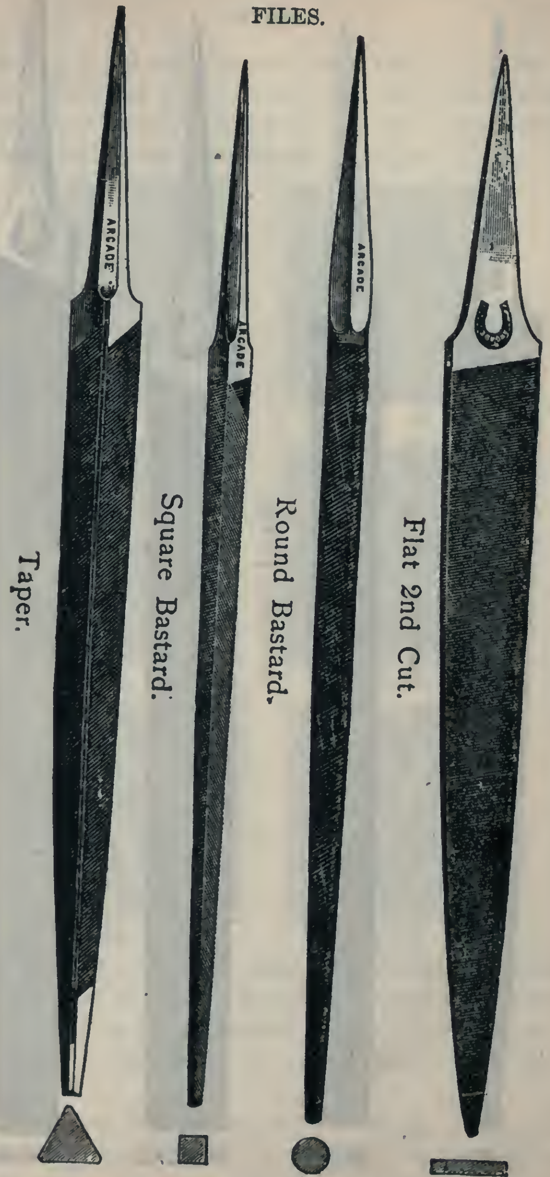


Fig. 141 Fig. 142. Fig. 143. Fig. 144

FILES.

"chipping," or "chiseling," and "filing," composed a large proportion of the mechanical work, and to-day it is difficut to think how work could be executed without the file and the chisel—perhaps it may not!

A very clear idea of the shape and section views of the most commonly used files are given in the following illustrations. The figs. from **131** to **136** represent the differcnce in the character or coarseness of the "cut" of the files, described hereafter. Fig. **131** is a coarse, double-cut surface. Fig. **132** is the "bastard" double-cut; fig. **133** is the "second double-cut" file; fig. **134** is the "smooth double-cut" file; fig. **135** is the "dead smooth double-cut" file, and fig. **136** is the "mill bastard," a single-cut file.

These full-size representations are taken from twelve-inch files; the sixteen-inch file is coarser in proportion, and the shorter files are still finer in proportion.

It will be seen that there are single-cut and double-cut files in the above list; in the single-cut files the diagonals are parallel to one another; in the double-cut files the diagonals cross each other—all as shown in the illustrations.

Fig. **137** is a half-round bastard file, as shown in the sectional view at the bottom of the illustration. The same observation applies to all the representations of the files, *i. e.*, the sectional views are shown to more clearly explain the make of the instruments, or tools.

This is a combination of the flat and round file in one. It files curved work and angles better than the flat file.

The *pillar bastard* file is shown in fig. **138**; this is also called a "slot" file or "cotter" file, it being parallel and generally used for these purposes.

FILES.

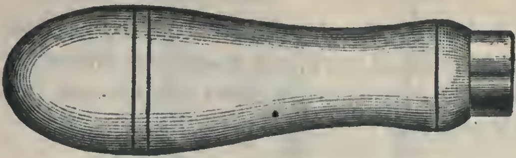


Fig. 145.

Fig. **139** represents the hand bastard file; this file is very similar to the flat bastard, but differs in this respect, the latter is taper in its breadth, the hand file being parallel.

The *mill bastard* is shown in fig. **140**; this differs from the bastard file, in that the bastard is cross hatched, or cross cut; the mill file is plain diagonal cut only, one way in straight ridges, for use on hard steel saws and such like work.

Fig. **141** shows the "taper-file," called also the "three-square file"; this is used for filing out corners, etc.

The square bastard file is exhibited in fig. **142**; this is used largely for squaring round holes after the drill; for enlarging mortises, or key ways, etc.

Fig. **143** shows the round bastard file; this file is in general use for shaping fillets or angles, finishing half-round ended slot holes, enlarging round holes, etc.

The flat "second-cut" file is shown in fig. **144**; this is a file for general work and more particularly for lathe and extra fine finished surfaces.

Fig. **146** shows the file which is in general use by machinists, whether flat, round, or half-round, in cross section, *i. e.*, "bastard file"; its teeth are between coarse and second cut.

Flat Bastard.

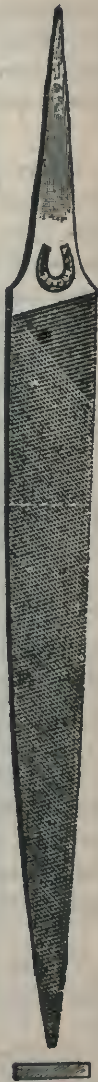


Fig. 146.

FILES.

A *file handle* is represented in fig. 145; this is made of hard wood, having a ferrule or ring on its end outside of the hole provided for *tag* of file; the end for hand should not be pointed, but bluff, to take large surface of hand, as if small or pointed it may blister the hand.

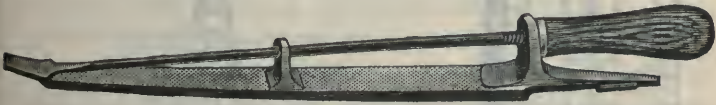


Fig. 147.

Fig. 147 shows a *surface file holder;* this holder is used when the surface is broad and cannot be reached by an ordinary length of file on account of the handle; as will be seen the rod has provision on the end for the left hand to grasp the point of file with a downward pressure; the handle screws the rod tight against the shoulder and the point, and the center support forms a slight curve in the file, an advantage of considerable importance in filing plane surfaces.

A *scratch gauge* is shown in fig. 148; this gauge is made of round steel, graduated to parts of an inch; on this bar slides a bushing which can be clamped or fixed by the action of the fly nut; the "marker" is a square or circular piece of thin, tempered steel, which is firmly held against the end of the bar, usually by a set screw.

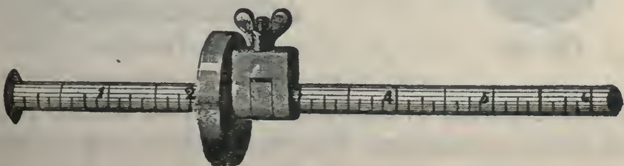


Fig. 148

TWO-FOOT RULE.

Fig. 149 shows a *boxwood two-foot rule;* this is "four fold"; that is, the two feet comprise four pieces. The common rule is graduated into inches marked with numerals,

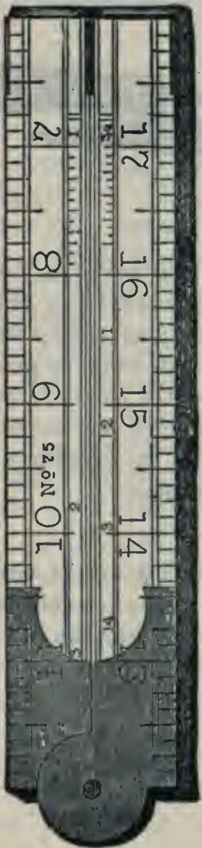


Fig. 149.

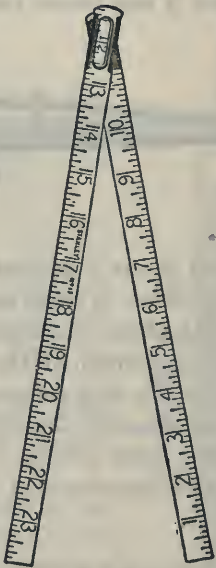


Fig. 150.

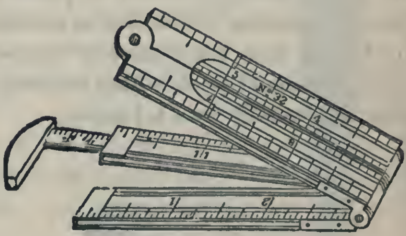


Fig. 151.

half inches marked by long lines between the inches; quarter of an inch marked shorter than the half inch, and one-eighth of an inch marked shorter than the quarter inch; again, one-

CALIPERS, ETC.

sixteenth is shorter than the one-eighth; these are the gradations on a common rule, and should be carefully learned by the student.

Special rules are marked as fine as the one-hundredth part of an inch; these are usually made of steel, as the wood will not stand close markings. The ends of common rules are tipped with brass to prevent wear, yet it is usual for the experienced workman to take his spacings or short measurements for greater accuracy with dividers from the inside graduations on the rule and not from the brass end.

The *two-fold rule* shown in fig. 150 is seldom used, on account of its unhandy length, being liable to fracture.

Fig. 151 shows a caliper rule, generally made one foot long, four fold; it is useful for rough measurements, but not sufficiently accurate on account of the joint in the fulcrum of the rule, which is liable to spring and wear from use.

Fig. 152.

Fig. 152 is a *steel straight-edge.* This is constantly used for marking, scribing, and as a telltale for hollow or curved work; it is also used with the aid of the rule to measure depth of holes, etc.

Outside calipers are shown in fig. 153; these are used for measuring diameters and outside dimensions of circular work; the essential portion for correct work is the rivet or connecting pin, which should be extra large, with a wide washer fitted with the utmost accuracy.

DIVIDERS AND PUNCH.

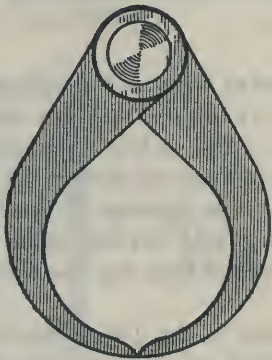


Fig. 153.

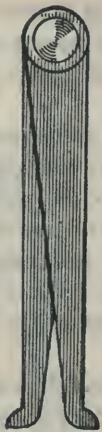


Fig. 154.

Fig. 155.

Fig. 156

CENTER PUNCH, ETC.

Inside calipers are shown in fig. 154; these are used for ascertaining internal diameters and are useful instead of dividers for measuring the distance between lines and points.

The *spring dividers,* fig. 155, are used for setting out work, marking exact points and distances; great accuracy can be attained by the use of the screw movement, by which the instrument is adjusted.

Fig. 156 shows the well-known "center-punch"; this is made of steel with a hardened end, and is used for marking centers in lathe work, etc. The center-punch should always be formed to an angle of 60°; a fine center-punch for making indelible lines after being scribed on surfaces, is called a prick or "bob" punch; this punch is in general use on template work after the scribe or scratch gauge has been used; there are many other forms of hand punches and markers used for transferring and special work.

The *monkey-wrench,* shown in fig. 157, is an adjustable tool, too well known to need description; its right name is "Moncky," as described in note below.

NOTE.—In his interesting article upon the genesis of machine design, Mr. W. H. Sargent spoke of the slide which moves up and down in the handle of a monkey wrench as resembling a toy monkey, and thereby drew an analogy. To this Mr. H. E. Madden writes: "The wrench is not named from this, neither is it so called because it is a handy thing to 'monkey' with. The right name is 'Moncky.' Charles Moncky, the inventor of it, sold his patent for $2,000, and invested the money in a house in Williamsburg, Kings County, N. Y., where he afterward lived."

WRENCHES.

The *Stillson wrench,* shown in fig. 158, is an improvement on the monkey wrench; the pressure on the handle or lever

Fig. 157

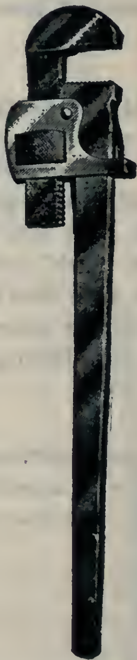


Fig. 158.

tends to close the holding jaws together; for this reason it is sometimes called a pipe wrench, because it will grip a pipe, or round surface, which the monkey wrench will not.

SLEDGE AND ANVIL.

Fig. 159 shows a *striking hammer* or light sledge, handy in every shop.

Fig. 159.

Fig. 160 exhibits an *anvil*, one of which, although a blacksmith tool, is generally found most useful in the machine shop.

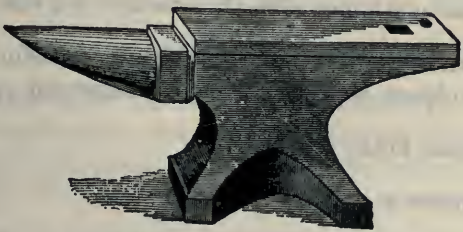


Fig. 160.

VISE AND BENCH PRACTICE.

Vise or bench-work include all operations performed by the machinist that are not included in the work performed by machine tools.

Again, in a general way vise work may be sub-divided into two branches, viz., Fitting and Erecting; fitting requires more skill than does boring, turning, or, as the operation of machine tools is termed, machining.

The work of "fitting" embraces the preliminary operations necessary to be done before that properly allotted to the machine tool, and the machinist doing it is called a "fitter."

Erecting is the final operation; it is the combining of these pieces in their relative and proper positions one to the other, the result being an engine or machine; it is apparent that the operation of erecting must include greater skill and experience than fitting, hence the term "Erecter," denoting a superior "fitter."

USE OF THE VISE.

The advantages aimed at in the selection of a vise are:

1. Quickness in operation, especially in fastening and releasing the objects requiring work to be executed upon them.

2. Firmness in the grip or hold.

3. Steadiness in resisting strains or blows.

4. Strength to allow chipping or filing the work without the possibility of the vise breaking.

5. The jaws should move parallel and freely, and should be arranged so as to get the full power of the screw.

USE OF THE VISE.

Improvements in the vise, for particular purposes, have been invented, such as swivel jaws, ratchet, eccentric and wedge grip motion, etc., but the plain screw-vises shown in fig. 116 and fig. 117 are the most extensively employed.

In manipulating the vise the right hand is generally used to operate the lever, the left hand at the same time adjusting the work in the position required; when the work is well gripped in the jaws the left hand is disengaged from the object and a sudden strong strain, with both hands, is applied to the lever of the vise, thus assuring the firmest possible hold to be obtained.

In releasing the object from the jaws of the vise, the reverse order is followed; the two-hand strain is first employed, the right hand giving the final turns to the lever, while the left hand supports and guides the object about to be freed from the grip of the vise.

Vise-caps or *jaw protectors* are designed to save the steel jaws of the vise while subject to the action of the file; at the same time the caps act also as a soft medium between the hard, serrated face of the jaws of the vise and the finished portions of the work held.

Vise attachments are contrivances applied to parallel vises to adapt them to special varieties of work; pipe-holding attachments are an example, and there are many more.

THE USE OF THE HAMMER.

The *hammer* in an expert's hand is practically a part of himself; it is sensitive, and communicates intuitively to him by "the feel" and sound, the different conditions it is acting against, and the mechanical effect its blows accomplish.

The hammer, as a simple contrivance, used to drive, stretch or straighten, is the most important tool used in vise and bench work; it enters as well into almost all kinds of mechanical manipulations. Great skill and judgment are required to become properly expert in its use.

USE OF THE HAMMER.

The extreme difference often noted between workmen from artist to artisan depends upon the judgment shown in the velocity and energy of the blow delivered by the hammer.

A good hammer is one that has a long hole to provide a good bearing for the handle, and which has the metal round the hole tapered or curved with punching and drifting, called bell-mouthed; the hole itself should be an oval; the handle hole of a hammer being tapered at both ends, the shaft and in the metal is made to resemble a rivet which is thickest at the two ends; one end is fitted by paring the wood, and the other end by spreading the wood with wedges.

The wood of the shaft is preferably ash, and should be fitted when dry, the overlength outside being cut off and the wedges of iron driven in, causing the wood to fill the hole.

In using a hammer it is essential to study the difference in effect between a sharp blow with a light hammer, and a slow blow with a heavy one; the former penetrates farthest and gives least lateral pressure, while the latter penetrates less and spreads more outwardly.

The machinist's hammer is made heavier at the face than at the peen end, so that the hammer will naturally assume a position in the hand with the face downwards, this being the position generally required, the peen end only being used for riveting or for straightening or expanding.

Note.—The length of time a hammer remains in contact with the material it strikes is called "the duration of the blow." The duration depends on, one, the velocity of the impact; two, the weight of the hammer, and three, the hardness of the material operated on.

Thus within certain limits, 1, the duration of the blow is decreased, with increased velocity; 2, the duration of the blow increases with the weight of the hammer; 3, the duration of the blow increases with the less hard material; in other words, *the greater the rebound*, the shorter the duration of the blow, and when the energy of the blow is expended in bruising or permanently altering the form *the contact is prolonged.*

USE OF THE HAMMER.

The length of handle for heavy chipping should be thirteen inches, and the weight of the hammer with this length of shaft is one and three-quarter pounds.

When *chipping,* the handle is held at its end in the right hand, grasped firmly by the thumb and second and third fingers, the other fingers being lightly closed about it. This mode of holding the hammer distributes the strain and jar without tiring the hand. In striking one should stand well away from the vise, swinging the hammer back nearly vertically over the shoulder before each blow.

All hammers for hand use should be made entirely of steel; the practice of welding steel faces to an iron body, in order to avoid using all steel, produces an inferior tool; a soft, fibrous steel that will bear handling is preferable.

PROPER METHOD OF USING FILES.

The most important point to be decided before commencing filing is the fixing the vise to the correct height and perfectly square, so that when the work to be operated on is placed in the vise it will lie level. As to what is really the correct height some difference of opinion exists, but the height which is generally thought right is such that the "chops" or jaws of the vise come just below the elbow of the workman when he is at his place in front of the vise; it will be found that the average height of the elbow is from forty to forty-four inches, therefore forty-two inches may be the average. But

---

NOTE.—The handle of a machinist's hammer should be of straight-grained dry ash or hickory, twelve to sixteen inches long, depending on the weight of the hammer. The handle should not be too stiff in the shank, as too rigid a connection between hammer and hand causes undue shock; it should be so set in the eye that its length is at right angles to the axis of hammer head, and its long cross section parallel with this axis. The eye should be enlarged slightly at each end, as the handle can then be fitted in from one side and wedged to fill the enlargement of the eye on the other side. Hard, smooth wedges are not suitable for this purpose, as they jar loose too easily—soft wood or roughed metal wedges serve the purpose well.

USING FILES.

there is large economy in making the height of the vise suit each workman by raising or lowering the vise, or by the use of a platform; this enables the workman to get the full, free swing of his arms from the shoulder.

If the work to be filed is small and fragile, a movement of the arms, or of one arm alone being required, the vise should be higher, so that the workman may stand more erect and can more easily scrutinize his work. Should the stock to be filed be heavy and solid, needing great muscular effort, its surface should be beneath the level of the elbow joint and the operator should stand farther from it, with his feet from ten to thirty inches apart, one being in advance of the other, with the knees slightly bent, which will lower his stature, at the same time throwing his weight upon the file, causing it to penetrate the stock with but a slight movement of the arms, depending largely on the movement of the body to shove the file.

When filing, the operator should stand with the left foot about six inches to the left of the vise leg, and about six inches away from the bench; the right foot being thirty inches away from the vise leg or bench and in a straight line—at right angles to it. This position gives command over the tool, and is at once characteristic of a good workman.

The art of filing a flat surface is not to be learned without considerable effort, and long and attentive practice is necessary ere the novice will be able to creditably accomplish one of the most difficult operations which fall to every-day work, and one which even the most professionally taught workman does not always succeed in.

The file must be used with long, slow and steady strokes, taken right from point to tang, moderate pressure being brought to bear during the forward stroke; but the file must be relieved of all pressure during the return stroke, otherwise the teeth will be liable to be broken off, just in the same manner that the point of a turning tool would be broken if the lathe were turned the wrong way.

USE OF FILES.

It is not necessary to lift the file altogether off the work, but it should only have its bare weight pressing during the back stroke. One of the chief difficulties in filing flat is that the arms have a tendency to move in arcs from the joints, but this will be conquered by practice. A piece of work which has been filed up properly will present a flat, even surface, with the file marks running in straight parallel lines from side to side; each stroke of the file will have been made to obtain a like end.

There is beauty in well-finished work, perfectly square and smooth, as left by the file, untouched by any polishing materials; in such work the filing must be got gradually smoother by using progressively files of finer cut, and, when the work is deemed sufficiently finished for the purpose, the lines should be carefully equalized by "draw-filing," that is, the file is held in both hands, in a manner similar to a spoke-shave, and drawn over the work in the same way, producing a series of fine parallel lines.

When it is necessary to file up a small surface—say 2 in. or 3 in. square—the file must be applied in continually changing directions, not always at right angles to the jaws of the vise.

When the surface is fairly flat, the file should be applied diagonally both ways; thus any hollow or high places otherwise unobservable will be at once seen, without the aid of straight-edges, etc. This method of crossing the file cuts from corner to corner is recommended in all cases, and the file should invariably travel right across the work, using the whole length of the file.

The file must be held firmly, yet not so rigid that the operator cannot *feel* the work as it progresses; the sense of touch is brought into use to a far greater extent than would be imagined, and a firm grasp of the tool, at the same time preserving a light touch to feel the work, is an essential attribute of a good filer.

In filing out mouldings and grooves which have sections resembling, more or less, parts of a circle, a special mode of handling the file becomes requisite. The files used are generally half-rounds, and these are are not used with the straightforward stroke so necessary in wielding the ordinary hand-files, but a partial rotary motion—a sort of twist axially—is given to the file at each stroke, and this screw-like tendency, given alternately from right to left, and *vice versa*, serves to cross the file cuts and regulate the truth of the hollow.

To sharpen or cut the file it is advisable to hold it in an acid bath, consisting of seven parts of water, three parts sulphuric acid and one part nitric acid, after which a clear water and milk-of-lime bath cleans it. Then brush the file with a mixture of olive oil and turpentine, and afterward dry it with fine pulverized coke.

To clean used files it is recommended to hold them for a minute in a steam current with a pressure of 40 pounds per square inch, when the file is said to be absolutely clean.

When files have become clogged up with oil and grease, another plan is to boil them for a few minutes in strong soda water; this will dissolve the grease and, as a rule, set most of the dirt and filings free; a little scrubbing with an old brush will be beneficial before rinsing the files in boiling water and drying them before the fire. These methods will prove effective in removing the ordinary accumulation of dirt, etc., but those "pins" which are so much to be dreaded in files, when finishing work, can only be removed by being picked out with a scriber point, or, what is better, a piece of thin, very hard, sheet brass, by means of which they can be pushed out very easily.

NOTE.—With regard to cleaning tools which have become clogged up with minute particles of metal, the following directions will enable one to keep them in proper order. The most generally used tool for cleaning files is the scratch brush; but this is not very efficient in removing those little pieces which get firmly embedded and play havoc with the work. File cards are also used; they are made by fixing a quantity of cards—such as a pack of playing cards—together by riveting, or screwing to a piece of wood. These file cards are used in the same way as the scratch brushes, *i. e.*, transversely across the file in the direction of its "cuts."

THE USE OF THE CHISEL.

The *chisel* in machine shop practice is essentially a hand tool; the accumulation of energy imparted to the blow of the hammer enables the sharp, tempered edge or end of the chisel to accomplish work much beyond that done by a push of the tool by hand power.

It is claimed that all machine work could be accomplished by a skillful workman by the sole use of the chisel and hammer. This cannot be said to-day, yet it is true of all exterior surfaces; the introduction of many machines is but the desire for economical production, and not because the hammer and cold-chisel cannot accomplish the work.

To acquire expertness in the use of the chisel is a matter of gradual development, the beginner only being allowed to do those parts of the "chipping" where the material runs no risk of loss, such as cutting sheet-iron, etc.; in other cases even special blocks of metal have been cast for apprentices to practice upon, for improvement, before being intrusted with any regular work. A study of the six figs., 125 to 130, is recommended in connection with the reading matter on page 182; in figs. 161 and 162 are shown the flat and cape chisels in actual practice, referred to hereafter.

Chisels are made of different widths, according to the material to be operated on; the broader the chisel the easier it is to hold its edge fair with the work surface, and cut smooth chips, and leave a more even surface; the usual breadth of a flat chisel, fig. 125, for iron and steel chipping, is seven-eighths of an inch.

Chisels vary in many particulars, but the hammer used is generally the same; if the same force of blow is applied to a narrow surface as to a wide one, it will cut differently; for instance, a narrower chisel can be used with a full blow on iron or steel than can be used on material like brass, which is more brittle; therefore to enable the workman to exert his full energy the chisel is made wide for the brittle material.

USE OF THE CHISEL.

The important point in practice with the chisel is the angle at which the cutting edge meets the stock; this varies according to the depth of cut and the nature of the material; the angle of the cutting end of a flat or cape chisel is usually about 60°, as shown in figs. 161 and 162; the angle of the long taper portion is about 6° in the flat chisel, fig. 161, and about 30° in the cape chisel, fig. 162.

The angle of these chisels, designed to work brass or gun metal, should be made a little less than for iron or steel, both in the taper part and the cutting edge.

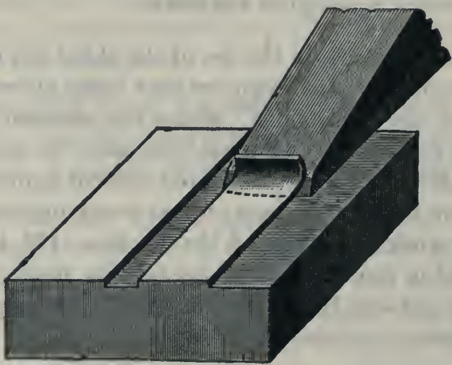


Fig. 161.

In practical use the chisel is not only held by the hand, but also is steadied by the "chip" in the work, as shown in figs. 161 and 162; the nearer the chisel is held by the hand to the head end the steadier it can be grasped when the hammer imparts the blow, and the chipped surface will be smoother.

In taking off a heavy chip one should stand well away from the vise, instead of close to it; in the one case the body is lithe and supple, having a slight motion in unison with the hammer, while in the other it is constrained and looks awkward. If, now, a light chip is to be taken, one may stand nearer to the work, so that he can watch the chisel's action and keep its depth of cut level. In both cases the chisel is

USE OF THE CHISEL.

to be pushed forward to its cut, and held as steadily as possible. It is a mistake to move it at each blow, because it cannot be so accurately maintained at the proper height. Light and quick blows are always necessary for the finishing cuts, whatever the kind of metal may be.

The use of a slightly curved cold-chisel is necessary when joining two planes, or when taking a very fine cut off a surface, as

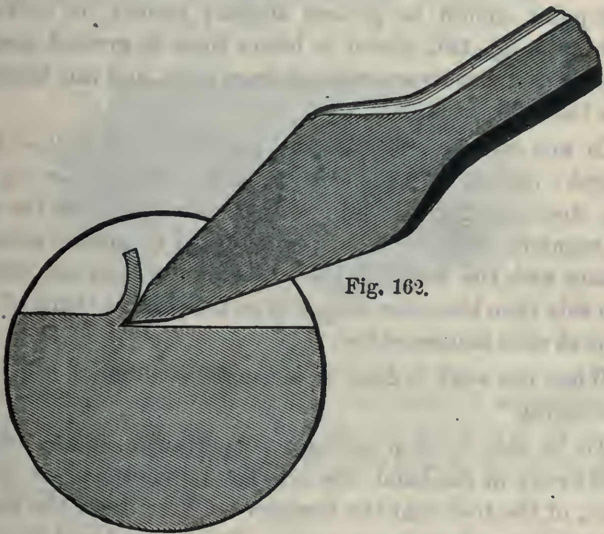


Fig. 162.

it will not show a ridge or groove, which the corners of a straight ground flat chisel would leave after it; a very slight rounding is enough, see fig. 161. A cow-mouthed chisel is necessary to chip bored holes, or the inside of hollow surfaces. For cutting out corners or the inside angles a diamond-point chisel is used, see fig. 130.

The *cape chisel* is used for cutting shafting, bars, etc., as shown in fig. 162. On account of its shape and great strength it is used in broad, heavy surface chipping, to cut grooves a little less distance apart than the flat chisel, which is then used to cut away the stock or ridge left between the

USE OF THE CHISEL.

grooves, as in fig. 161; should the flat chisel in heavy chipping be used on the solid surface without cutting these grooves, its corners are liable to break away. The point must be made as thin as possible, and, for ordinary purposes, it should be ground flat; grinding rounded, as fig. 128, is to be avoided.

Sharpening chisels ready for use is effected on ordinary grindstones, or an emery tool-grinder. For heavy chipping the point should be ground slightly convex, or curved, as shown in fig. 161, which is better than if ground straight, because the corners are relieved from duty, and are, therefore, less liable to break.

In any case the chisel should not be ground hollow in its length; in that case the corners will "inbed" or dig into the stock, and render it impossible either to guide the chisel or regulate the cut. The faces should be ground alike and square with the body of the chisel; if the faces are wider on one side than the other they will be inclined to "jump" sideways at each hammer-blow.

When the work is done by a round-nosed chisel it is called "fullering."

To be able to chip surfaces properly the chisel should be held firmly in the hand, the eyes fixed upon the *point*, not the *head*, of the tool, and the hammer held far down the handle, so that it may have a fair swing. One thing should be noted: Never chip towards an edge, but away from it.

A good fitter will always take off in this manner as much extraneous metal as he can, and only have recourse to the file to finish his work, for files are expensive, and soon worn out; while the chipping chisel is inexpensive, and easily repaired.

All fitters' work should be set out by the aid of the surface-plate, the scribing-block, the compasses and straight-edge. All lines should be delineated with small center punch-marks, which cannot easily be obliterated.

The *round-nose chisel* is used to finish fillets and cut oil grooves. See fig. 127.

SURFACING.

Surface plates, as shown in fig. 163, are made of fine-grained metal, of considerable weight and thickness; the portion machined and finished is cast "face down," so as to have a solid surface free of air or blow-holes; they are made with ribs or strengthening battens on the under side, to prevent any tendency to warp or spring; the face is planed, filed and scraped to a high degree of perfection, on account of the importance of the service they are intended to perform.

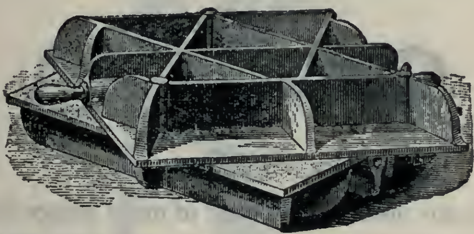


Fig. 163.

Surface plates are made three at one time for standards or originals; these are not applied to the usual run of work directly, but are kept to test the shop plates, so-called, and keep them accurate.

In shop practice in connection with the surface plates, a very fine coat of color, generally red lead mixed with oil, is applied to the plate by the use of a sponge or waste. The composition is then carefully rubbed off, leaving a slight trace on the plate, just sufficient to discolor the surface.

Next the hand should be passed over the surface, first of the plate, and next over the surface of the work to be "trued up"; this is done to make sure that no grit or foreign substance remains attached to either surface, as such would cause false markings and, consequently, imperfect execution of the work.

SURFACING.

When the work is very uneven the markings will be few and of small size; on these being "filed" down the work becomes more even and the markings extend in number and size; the file is finally discarded for the "scraper," which finishes the work, when the markings show all over the surface regularly and the surfacing is completed.

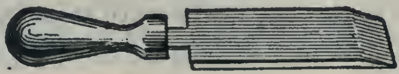


Fig. 164.

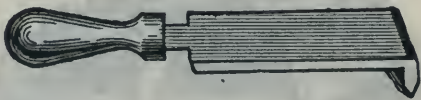


Fig. 165.

Scrapers are made of steel and of many shapes and forms; for interior circular work they are steel discs with a center rod; for corners they are shaped triangular; the most usual shape in every-day use are the flat surface scrapers, as shown above, i.e., the "straight" scraper and the "bent" scraper. These and all similar devices are used to give the finish to high-class surface work on steel, brass, etc., and for accurately fitting together the parts of machinery.

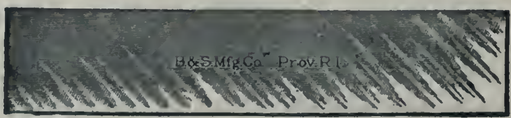


Fig. 166.

The file is used up to a certain state of accuracy; then the scraper comes into play and removes the markings of the surface plate, etc., making a smooth, fine surface, closing the grain of the material and giving it a fine polished appearance. A fine file would not give the same appearance, nor would it act on the exact spot as well as a scraper.

Fig. 167.

SURFACING.

The steel straight-edge shown in fig. 166 is an instrument in constant use to show the viseman irregularity in surfaces; the "turner" uses it to see that the machining is being correctly done. The straight-edge is also used with the rule to measure depth of holes, and with a square to line interior holes, and with a steel scriber, in drawing lines, etc.

A straight-edge laid on the internal surface of a hole will mark a true line parallel to its axis, such as marking a key slot in the eye of a wheel.

Fig. 167 shows a *surface gauge* or *scriber*. This is an instrument used generally in vise, drill and planer work, and erecting; it marks accurately the centers of holes, points and lines, parallel or equidistant to the surface upon which it rests.

This instrument is generally made of metal; the base, shown round in the sketch, is also made square, oblong, etc., so as to be more readily adjustable to the work; the stem is fixed firmly in the base, and carries a split, movable bush or sliding-block, which can be regulated to any height and fixed by fly-nut; this sliding-block has a regulating or set screw, which engages with a block sliding on the stem; this block carries the scriber, or marking steel point, fixed firmly by fly-nut.

When in use the surface gauge is set as follows: See that the base rests firm and level; unscrew both fly-nuts and roughly adjust the point of scriber to the height required; tighten the upper fly-nut on the stem; this will probably alter the height of scriber point a little; with the adjusting screw regulate the scriber point to the exact measurement required, and at the same time tighten the fly-nut on the scriber to retain or hold it in position.

HAND-DRILLING.

A *drill* is a steel cutting-tool fixed to a drill-stock or drilling machine.

There are hand-drills and power-drills; many derive their names from the distinctive uses for which they are designed, thus:

A *centrifugal drill* is a drill which carries a fly-wheel upon the stock to maintain steady motion.

A *double-drill* is a drill with two cutters, used for making counter-sunk holes, as for screw or rivet-heads.

An *expanding drill* is a drill with a pair of adjustable bits, which can be spread apart at any given depth, to increase the width of the hole at that point.

A *finishing drill* makes a smooth cut, and is used to follow a drill doing rapid but rough work.

A *lip-drill* is a flat drill upon the cutting edge of which a lip is formed, either by grinding or during the process of forging; the lip adds to the speed and cleanness of working.

A *roughing drill* is a form of drill adapted for speedy working, but producing a rough cut.

A *teat drill* is a square-face, cylindrical drill with a sharp projection like a pyramid or teat issuing from the center of the cutting face; this is used to flatten or finish the bottom of holes.

A *twist drill* is a round drill around the body of which is carried a deep spiral groove, so that the tool appears as though twisted from a flat bar; the point is sharpened to an obtuse angle. Such drills are used in all sizes, from a diameter of three inches down.

A *vertical drill* is a drill with a vertical or upright spindle.

A *wall drill* is a drilling machine set up against a wall, and not fitted with a table to receive the work.

HAND DRILLING.

A ratchet drill.—A ratchet is a pivoted piece designed to fit into the teeth of a ratchet-wheel, permitting the wheel to

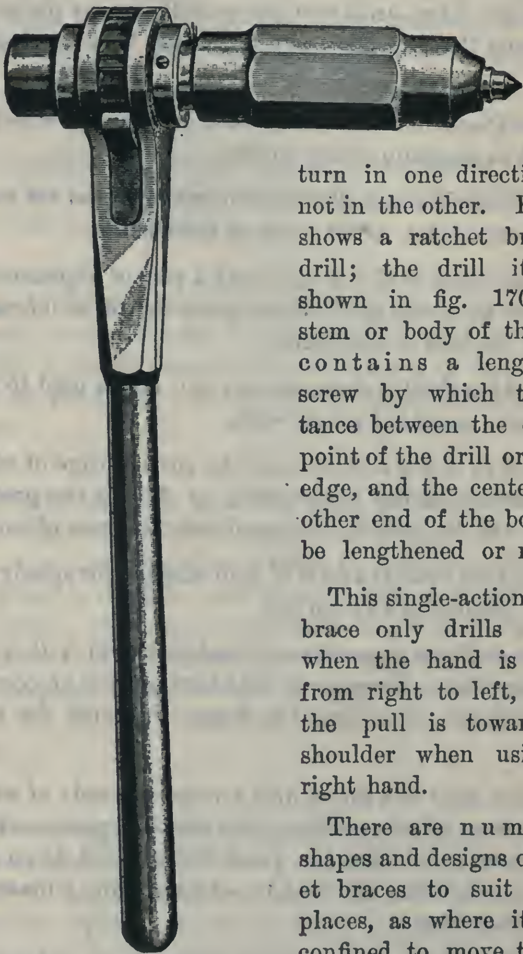


Fig. 168.

turn in one direction but not in the other. Fig. 168 shows a ratchet brace, or drill; the drill itself is shown in fig. 170. The stem or body of the brace contains a lengthening screw by which the distance between the extreme point of the drill or cutting edge, and the center at the other end of the body, can be lengthened or reduced.

This single-action ratchet brace only drills or acts when the hand is moving from right to left, or when the pull is towards the shoulder when using the right hand.

There are numerous shapes and designs of ratchet braces to suit special places, as where it is too confined to move the arm in a circle. Some are self-acting in feed; somo double-acting in the cut, having bevel gear, etc. The single action is the general shop appliance.

HAND DRILLING.

In operating the ratchet-drill or brace, it is necessary to have a fulcrum to work from. The sketch, fig. 169, shows such a device, which is composed of a strong standard with a

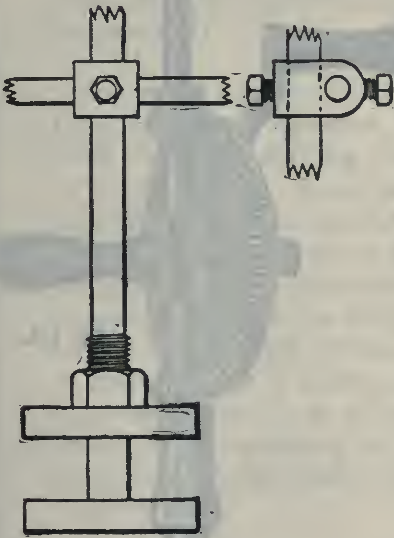


Fig. 169.

sliding-block, which carries a sliding-arm or cross bar, fixed by screws; the arm can be swivelled into any position and the base is clamped to the work, and fixed firmly by action of the nut on the top—all as shown by the two views given in the sketch.

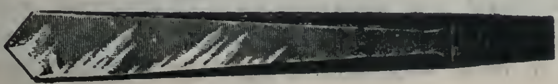


Fig. 170.

HAND DRILLING.

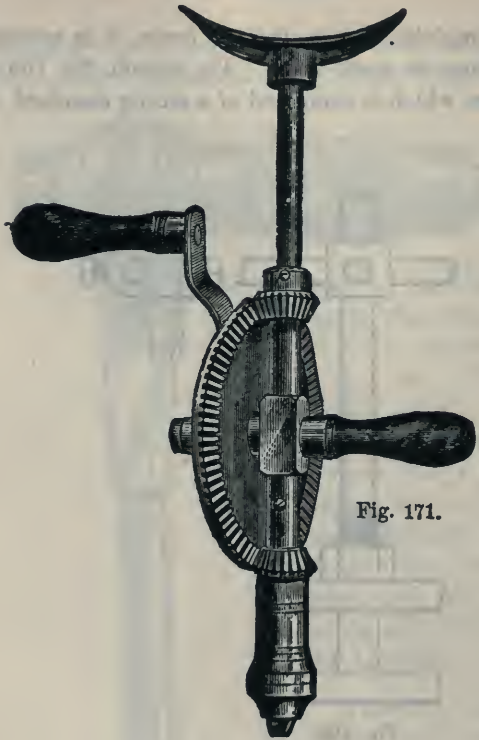


Fig. 171.

As ratchet-braces are generally used in confined places difficult to get at otherwise, the drills used with them are usually plain, flat drills, easily forged, and which can be cut quickly in the forge to the length required, and they are usually made as short in length as possible for stiffness.

When drilling between parallel surfaces with the ratchet-drill, blocking or packing is inserted to make the correct space and act as a fulcrum; at other times a bent piece of flat iron, like the letter *Z*, is used as a fulcrum.

The *breast drill*, shown in fig. 171, is a most convenient shop tool; it is used to drill centers in lathe work, and small holes in brass work, and is especially "handy" in repair-work.

BROACHING OR DRIFTING.

A *broach* is a steel tool with file teeth designed for pressing or driving through irregular holes in metal that cannot be dressed by revolving tools.

Fig. 172.

This operation requires considerable experience in preparing suitable-shaded cutting tools for the various operations to be performed.

The socket-spanner end shown in fig. 173 illustrates the operation, which comprises marking or scribing a square hole on the stock; as much as possible of the material is then removed as can be done by drilling; this is shown in the illustration by circles, one large and four small holes as dotted; then the drift, or broach, as shown in fig. 172, is forced through by repeated blows of a heavy hammer, or by pressure applied by a screw or hydraulic press, completing the making of the square opening needed to be formed in the spanner.

Broaches or drifts are made of various forms. Some are smooth on the outside, as fig. 172, the cutting part being at

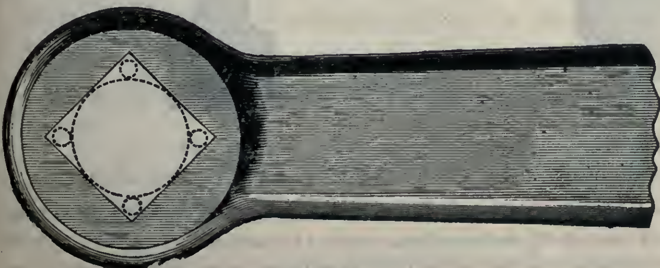


Fig. 173.

BROACHING.

the end similar to a punch; others are cut on all four sides, like a square file; another kind is shown in fig. 174, this being intended to cut slots or keyways; the blind socket or box-wrench, fig. 175, is an example of work specially suited for and which can be performed more economically and of better finish by broaching than by any other method.

In drifting or broaching it is essential that the work rests evenly on a solid block of iron or similiar foundation; lead is often used when the material is fragile; in striking the punch, the blow must be fair and even; the great aim in using drifts is to drive them true.

Drifts should be freely lubricated when used upon steel or wrought iron.

Care must be exercised in broaching that the drift is kept upright on entering the hole in the work.

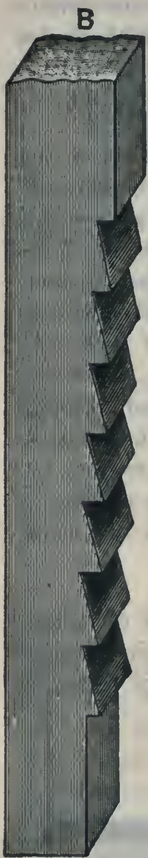


Fig. 174.

Fig. 175.

NOTE.—There are two kinds of drifts: 1, the *cutting drift* described above; 2, the *smooth taper drift;* the latter is the one used by boiler-makers to make the holes in boiler plates come fair, so that the rivet will enter, being in effect a "stretching drift."

SCREW CUTTING.

The screw forms one of the six mechanical powers, and is virtually a spiral inclined plane, only the inclined plane is commonly used to overcome gravity, while the screw is more often used to overcome some other resistance.

Screws are *right* or *left*, according to the direction of the spiral. A right-handed screw is advanced by turning from left to right, or clockwise; a left-handed screw is advanced by turning from right to left.

A *right and left screw* is a screw of which the threads upon the opposite ends run in different directions.

A *setting-up screw* is a screw for taking up space caused by wear in journal-boxes, etc.

A *screw thread* is a single turn of the spiral ridge of a male or female screw, commonly called simply *thread*.

A *screw-gauge* is a device for testing the diameter, the pitch and the accuracy of the thread of screws.

Screw-blank.—This is a piece of metal cut from a bar preparatory to forming it into a screw.

Milled Screw.—This is a screw with a flat, broad head, fluted or roughened to afford a firm hold for the fingers.

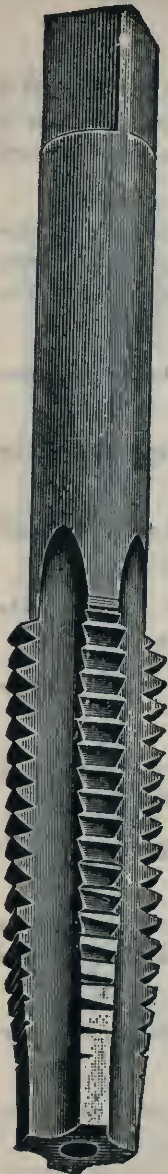
Screw-eye.—This is a screw having a loop or eye for its head.

Screw-feed.—This is any feed governed or operated by a screw, as the feeding mechanism driving the lead screw of a lathe.

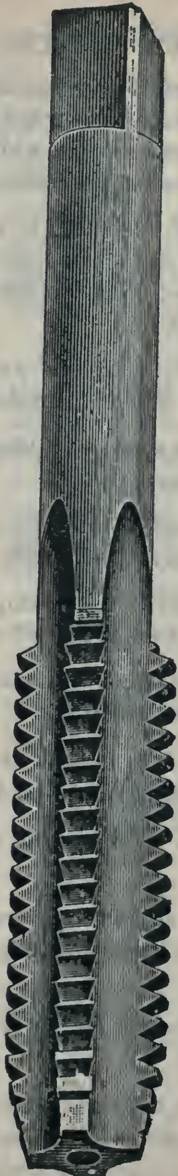
Screw-plate.—This is a tool for use in cutting small screw-threads.

Screw-press.—This is a simple form of press, producing pressure by the direct action of a screw.

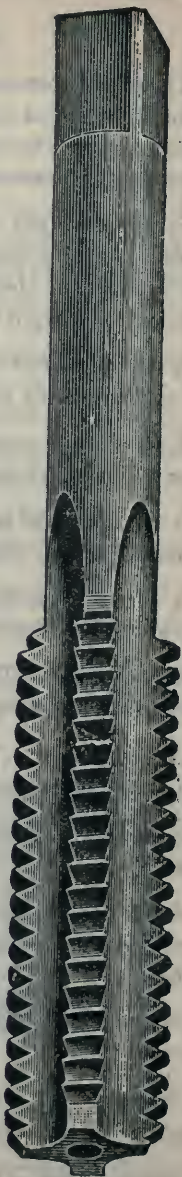
Screw-punch.—This is a punch in which the operating pressure is applied to a screw.



TAPER
Fig. 176



PLUG
Fig. 177.



BOTTOMING
Fig. 178.

SCREW CUTTING.

Screw-tap.—This is a tool for cutting screw-threads on the inside of pipes, etc.

Screw-wrench.—This is a wrench of which the jaws are opened or drawn together by means of a screw.

Screw-cutting Lathe.—This is a lathe with slide-rests with change gears, by which screws of different pitch may be cut.

Screw-cutting is the general term applied to the operation of cutting threads, V shape or square, when performed by a machine, whether the thread is cut on the surface or the interior.

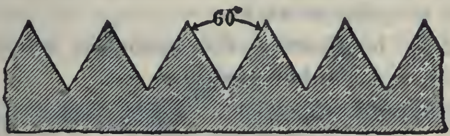


Fig. 179.

The *common screw-thread* is a V thread; the angle is 60°; see fig. 179.

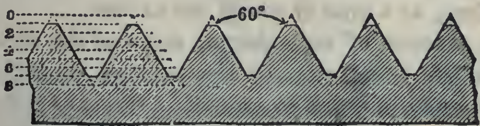


Fig. 180.

The *standard thread* used in America is this V thread, with one-eighth part in height cut square off the top and bottom, as shown in fig. 180.

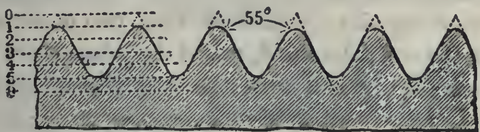


Fig. 181.

The *Whitworth's thread* is the English standard; it has a V thread at an angle of 55°; the bottom and top are rounded for one-sixth of the height of the thread, as shown in fig. 181.

NOTE.—The three figures are shown in section.

SCREW CUTTING.

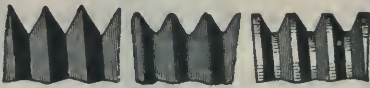


Fig. 182.

Fig. 182 shows portion of these three threads as they appear on the round surface of a bolt; the center figure shows the rounded Whitworth thread.

The terms *tapping* and *screwing,* used in hand or bench-work, are not confined to hand-work, but are used also on machine-work; the term screw-cutting, on the contrary, is only applied to machine-work.

In hand or bench-work the operation is confined to V threads only, and is subdivided into

1. Tapping.
2. Screwing.

Tapping is the process effected when the thread is formed on the interior of a hole, which is done with a tap; and *screwing* when the thread is formed on the surface or outside of a cylindrical surface, as a pipe or round bar of iron.

A ***tap*** consists of an external screw of the required size, formed of steel and more or less tapered, part of the thread being cut away in order to present a series of cutting edges; this being screwed into the nut in the manner of an ordinary bolt forms the thread required.

Taps are usually made in sets of three. The first, called the *entering tap* or *taper tap,* generally tapers regularly throughout its length; the second, or *middle tap,* sometimes tapers, but is usually cylindrical with two or three tapering threads at the end; the third, called the *plug-tap* or *finishing-tap,* is always cylindical, with the full thread carried to the point.

In fig. 176 to fig. 178 are shown three taps; these are made of steel, the main portion being threaded in a lathe or chaser, the grooves, four in number, being cut out with a milling machine to give room for the cuttings to escape; the round shank on the tap is made the exact size that the hole in the stock should be drilled, thus making a sliding-

SCREW CUTTING.

fit; the square part made for the handle or wrench should not have the corners or angles in line with the cutting edges, but between them.

The entering or taper tap is also called *first tap,* as it is the first used; the taper portion is smaller than the size of hole,

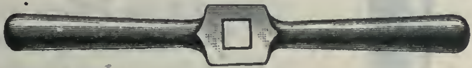


Fig. 183.

so that it enters it a distance equal to nearly its own diameter; this helps to keep the tap straight with the hole; in practice it is usual to test the tap on two sides with a square off the work surface, to make quite sure of its entering straight.

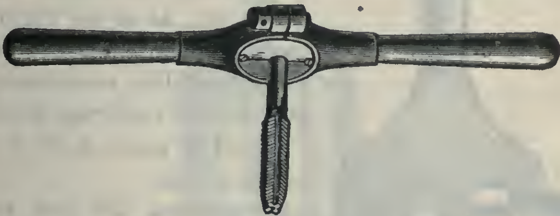


Fig. 184.

The plug or *second tap* is used after the taper tap, as, after the first has entered sufficiently to cut a full thread it becomes very laborious to work, on account of the long taper cutting surfaces acting together.

Fig. 185.

Tap-wrenches, so called, are shown in figs. 183 to 185; these are made solid, double-handled, with square hole in center to fit the square of tap; they are also made adjustable with dies, which open to admit several sizes of the tap-ends.

NOTE.—The finishing or *third tap* is seldom used except in holes which are shallow and blind; it requires great care, as, if too much leverage or pressure is used, the first thread has all the strain of the full cut, and is liable to break off; it requires judgment and practice to put enough strain on and yet not overdo it, so that the thread will bear safely when it reaches the bottom.

STOCKS AND DIES.

A *stock and die* is a tool used for cutting screw-threads, or, in other words, a screw-cutting die in its holder; or, again, an adjustable wrench with two handles of equal radius for holding screw-cutting dies, as shown in fig. 186.

The stock is very often used with blank dies to suit the square on the end of a tap, as shown in fig. 184.

Stocks and dies are arranged in sets with three assorted dies to accompany a large-size stock, and six or more dies to fit a smaller stock; but, as in all engineering tools, there are endless varieties of stocks and dies, some being very delicate and requiring great care.

Fig. 187 shows a set or pair of common dies.

In practice the dies are not closed on the bolt or work sufficient to form the thread in one cut, but by gradually working the dies back and forward, closing them gradually until the full thread is formed; if dies are closed too quickly there is fear of stripping off or abraiding the thread.

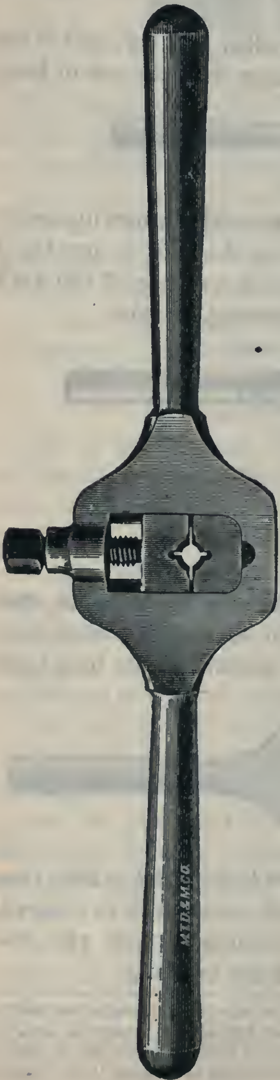


Fig. 186.

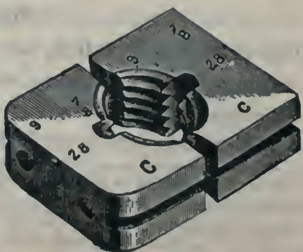


Fig. 187.

PIPE-VISE.

Oil, or soap-water and oil, should be used liberally when threading with dies.

Care must be used with the pressure put on the dies in starting the thread correctly in the first turn, and also in finishing against the shoulder, or the threads will be broken off where they come in contact with the full size of bar at the end of the screwed portion.

Special cutters or dies are used which will finish a screw-thread in a single cut; these are called *screw-plates.* They are solid or non-adjustable and arranged in sets of several in one plate, and for sizes they cut three-sixteenths or less.

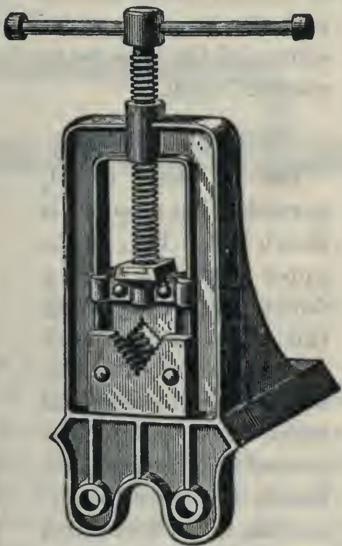


Fig. 188.

PIPE VISE.

The vise shown in fig. 188 is especially a bench tool; it is known as a pipe vise, and is designed to "grip" pipes of various sizes while they are being threaded, cut off or otherwise operated upon.

A parallel or ordinary bench vise will only grip a pipe on two points, and, if tightened, the strain will easily collapse it, owing to its hollow form; but a pipe vise is so made that it presses upon four points, as the jaw or holding portion is formed V shaped instead of parallel.

Some pipe vises are formed of two pivoted discs instead of jaws, having semicircles or recesses, which fill all diameters of pipes up to two inches, and bear on the outside of the pipe all around.

It is an improvement to have the upper portion of the vise hinged at one end or side, and fixed with a pin or collar at the other, as it renders more convenient the removal or insertion of the pipe to be operated upon.

Fig. 189.

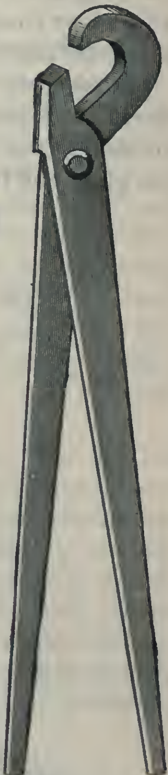


Fig. 190.

PIPE CUTTERS.

One of these useful, portable hand-tools is shown in fig. 189; in the upper portion a cutting device will be observed; this is a hardened steel, adjustable, circular cutter, designed to be rotated round the pipe; it is compressed into the pipe surface by the screw handle, and has two rollers which rotate on the pipe surface, to lessen the friction, etc.

In cutting the larger sizes of pipe sometimes a special cutting-tool is introduced in place of the circular cutter to accomplish the more difficult work; in shop practice it is customary to cut the large sizes of pipe in the lathe or screwing machine; when a quantity of this work is required, a special power cutter is provided.

PIPE-TONGS.

The *gripping tongs,* for handling and holding pipe, in common use are shown in fig. 190; they are composed of a holder or circular portion and a "tong" or grip part hinged together; when the correct size is used on a pipe the grip meets the pipe at an angle, and the handles are apart nearly as much as shown in fig. 190; the pull being on the grip portion, the greater the pull the more the grip bears on the pipe surface; if too small a tongs is used the grip is tangent to the pipe and inclined to slip.

Fig. 191.

THE HACK-SAW.

A *hack-saw* is a hand-machine, as shown in fig. 191; it is a saw blade with little set, close teeth, and well tempered; it has a small, stout frame, and is used for sawing metal, as in cutting off bolts, nicking heads of hand-made screws, etc.; so very useful is this tool that many machine shops have a power-driven hack-saw, self-feeding and always ready for use, which is a necessity for cutting shafts and bars to length, preparatory to the operation in the lathe.

WRENCHES.

The word which gives this term to the tools here described is one of the strong words of the English language; wrench means, primarily, "a violent twist or turn given to something," hence, as derived, any instrument almost that causes

WRENCHES.

a twist or torsion strain comes under the above heading. A wrench is a tool used by hand to turn or rotate other tools, nuts or bolts. A solid wrench, shown in fig. 192, is formed of a single piece of metal, having a notch or opening of suitable shape and size to fit on the objects to be grasped.

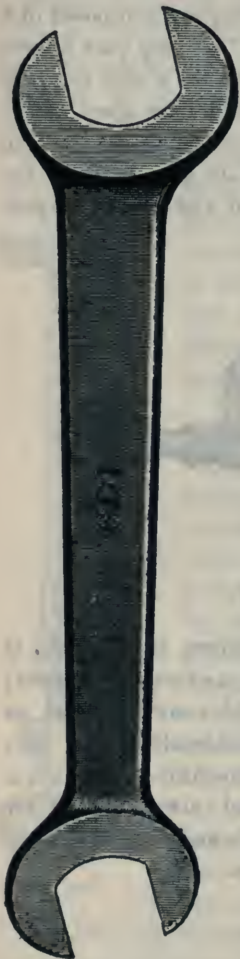


Fig. 192.

Fig. 193.

A wrench is specifically designated according to the shape of the recess or aperture, as a square wrench, hexagon wrench, etc. If the opening is at one end, it is termed a single-ended wrench; if it is in the middle, a double-handled wrench, such as fig. 183 If the recess is open, it is termed an open-ended wrench; if closed, forming an aperture through the metal, a box-wrench. A solid wrench having an angular recess notched on its sides, so that any nut or bolt which will enter the jaws can be grasped, is called an alligator-wrench, fig. 194, and is one of the most convenient forms. To illustrate, fig. 193 is a double-ended square wrench.

ALLIGATOR WRENCH.

Again, different kinds of wrenches are called by the name of the inventor, or patentee, or shape—thus, in the shop, "Where is the Stillson ?" not Stillson wrench.

Screw or monkey-wrenches are those which have a movable

Fig. 194.

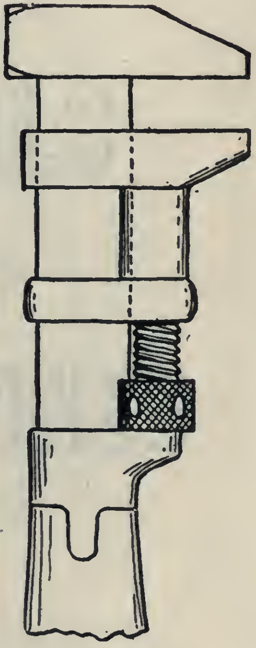


Fig. 195.

jaw, so that the tool may be adjusted to fit any sized nut within its compass; as shown in fig. 195.

A *spanner* is a special form of wrench, which circles or spans round, generally for twisting a round or circular-shaped portion provided with holes in its circumference.

TOOLS

AND

MACHINES


STANDARD
Screw Thread
GAUGE
4 4½ 5 5½ 6 7 8 9 10 11 12 13 14 16 18 20

TOOLS AND MACHINES.

Tool, the word, comes probably from toil, signifying the thing with which one toils or labors, as a hammer, file or wrench.

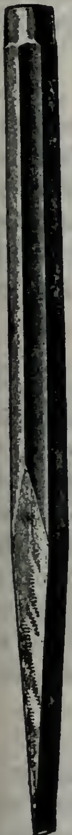


Fig. 197.

A *tool* is that which is brought to bear directly on the work; again, it is any implement used by a craftsman at his work; it is any instrument employed for performing, or aiding to perform, mechanical operations by means of striking, penetration, separation, abrasion, friction, etc.

In practical mechanics the word tool has a restrictive meaning; a single device, as a chisel, crowbar or saw, or a very simple combination of moving parts, as tongs, shears, pincers, etc. These, for manual use, are always called *tools,* although comprised in the strict technical definition of machine.

These implements in shop practice are called "hand-tools," to distinguish them from cutting-tools.

Fig. 198.

A portable tool is a tool or machine tool which can be taken from place to place; example, a riveting machine.

TOOLS AND MACHINES.

A tool never ceases to be a tool, *i. e.*, something which is applied directly to the work; generally tools in machine practice cut, abrade, like a file, or strike—as a hammer.

The distinction between the words *tool* and *machine* becomes indefinite with increased complications of parts, but the difference may be generally defined as follows:

A *machine* is an aggregation of parts whose combined action makes the work of the tool more effective. *Tools* are the simplest implements of art; these, when they are complicated in their structure, become machines; and machines, when they act with great power, take the name, generally speaking, of engines—as the pumping-engine, the engine-lathe, etc.

A Machine Tool.—In the foregoing paragraphs the words tool and machine have been explained; the two combined have a separate meaning. A machine tool is a tool actuated by a mechanism; example, a drill is a tool, but one or more when arranged to do work become a machine tool; although designated as a "drilling machine" the combination belongs to the classification of machine tools; the cutter in a lathe is a tool, but the whole mechanism is a machine tool. Hence a tool operated by machinery becomes part of an aggregation of another class, *i. e.,* machine tools.

Such machines as are used in shaping materials in the construction of the parts of other machines, and also many of those which perform work, such as boring, planing, riveting, etc., formerly only done by hand, and still performed manually to a greater or less extent, are nearly always called machine tools; the term, engine tool, is more in accord with general usage when referring to large and complicated machines.

TOOLS AND MACHINES.

Special machine tools comprise a large family designed for a thousand uses, the names of which, given mostly to designate their particular service, would fill a large volume.

It is extremely difficult to classify machine tools on a strictly scientific basis, but the great family easily subdivides itself into two great sections:

First, machines for general engineering workshops, each designed to take a variety of work; and,

Second, special machine tools designed for specific purposes, among which we may put the automatic machines, though these take numerous objects of similar design.

An automatic machine, to define an often repeated term, is a self-acting mechanism—the modern lathe is probably as good an example as can be given of an automatic machine. The steam engine is automatic.

Machines are divided into *simple* and *compound*. The simple machines, or what are commonly called mechanical powers, are six in number, viz.:

1, the lever; 2, the wheel and axle; 3, the pulley; 4, the inclined plane; 5, the screw; 6, the wedge.

These can in turn be reduced to three classes:

I. A solid body turning on an axis.
II. A flexible cord.
III. A hard and smooth inclined surface.

For the mechanism of the wheel and axle and of the pulley merely combines the principle of the lever with the tension of the cords; the properties of the screw depend entirely on those of the lever and the inclined plane; and the case of the wedge is analogous to that of a body sustained between two inclined planes.

TOOLS AND MACHINES.

The parts of a machine may be distinguished into two principal divisions—1, the frame or fixed parts, and, 2, the mechanism or moving parts. The frame is a structure which supports the pieces of the mechanism, and in a measure determines the nature of their motions.

The form and arrangement of the pieces of the frame depend upon the arrangements and motions of the mechanism; the dimensions of the pieces of the frame required in order to give it stability and strength are determined from the pressures applied to it by means of the mechanism.

It appears, therefore, that in general the mechanism is to be designed first and the frame afterwards—care being taken to adapt the frame to the most severe load which can be thrown upon it at any period of the action of the mechanism.

In the action of a machine the following three things take place:

FIRST.—Some natural source of energy communicates motion and force to a piece or pieces of the mechanism called *the receiver of power* or *prime mover.*

SECONDLY.—The motion and force are transmitted from the prime mover through *the train of mechanism* to *the working piece* or *pieces,* and during that transmission the motion and force are modified in amount and direction, so as to be rendered suitable for the purpose to which they are to be applied.

THIRDLY.—The working piece or pieces, by their motion, or by their motion and force combined, produce some useful effect.

MACHINERY.

Machinery.—This is a term which easily comes from the word machine, and denotes the parts of the latter taken as a whole; its secondary meaning is where a number of machines and tools are to be considered as a group, *i. e.*, the machinery in a watch factory, the machinery in a shop, etc. The machinist gets his designation also from the word machine; in the rating of the U. S. navy an engine-room artificer is called "a machinist" of different grades.

Most machines are combinations of some or all of the mechanical powers. Thus the lever is combined with the screw in a common press; the wheel and axle with pulleys in various ways, and with the endless screw; pulleys are combined with pulleys, and wheels with wheels. The wedge is the only one among the mechanical powers that does not admit of combination with others. In wheels with teeth, the number of teeth that play together in two wheels ought to be *prime* to each other, that the same teeth may not meet at every revolution, but as seldom as possible.

The strength of every part of a machine ought to be made proportional to the stress it is to bear; and no part must be stronger or heavier than is necessary, for all superfluous matter is nothing but a dead weight upon the machine, and serves for nothing but to clog its motion. The accomplished mechanic contrives all the parts to last equally well, so that when the machine fails, every part shall be worn out.

Every machine ought to be made of as *few parts,* and as simple as possible, to answer its purpose; not only because the expense of making and repairing will be less, but it will be less liable to get out of order. Any useless motions also waste some portion of the power. Uniformity or steadiness of motion is carefully to be preserved. All these advantages are more easily attained in large than in small machines.

CLASSIFICATION OF MACHINE WORK.

An excellent description of the processes effected by machine tools has been made by a well-known writer,* which is most admirable; the general subdivisions of the work commonly performed are briefly outlined as follows:

First—*Turning and Boring;* as performed in the lathe, screw-machine, turret-machine, vertical boring mill, etc., in which the work is usually made to rotate to a cutting tool or tools which, aside from feeds, are stationary. This operation usually produces curved or circular surfaces, both internal and external, but may, as in facing, produce a plane surface.

Second—*Planing Operations;* as performed on the planer, shaper, slotting machine or key-way cutter, where the work is given a straight line motion to a stationary tool, or, as in the three latter types of machines, the tool is given a straight line motion over stationary work. In the former case the feeds are given to the tool while in the latter the work usually receives one or both of the feeds. In the case of the traverse head shaper, however, the tool is given both feeds over perfectly stationary work.

Third—*Milling Operations;* as performed on the various types of milling machines where a rotating cutter produces plain, curved or formed surfaces on the work, the latter usually receiving the feeds.

Fourth—*Drilling;* the forming of circular holes in solid stock by means of a revolving tool at one operation, the tool usually receiving the feed. Drilling differs from boring in that the latter term applies to the enlarging and truing of a hole already formed.

---

* W. H. Van Dervoort, M.E., in *Machinery.*

CLASSIFICATION OF MACHINE WORK.

Fifth—*Grinding;* these operations involve the removal of metal and finishing of the surface by an abrasive process, the material being ground rather than cut away. The universal and surface grinding machines correspond with the lathe and planer, a rotating wheel of emery or corrundum taking the place of the cutting tool in the latter machines. Grinding operations, although necessarily slow, make possible the accurate finishing of the hardest metals.

Sixth—*Punching and Shearing;* under this heading may be included all tools used for the punching and shearing of metals, and although not strictly in this class, we may include presses used for stamping and forming purposes.

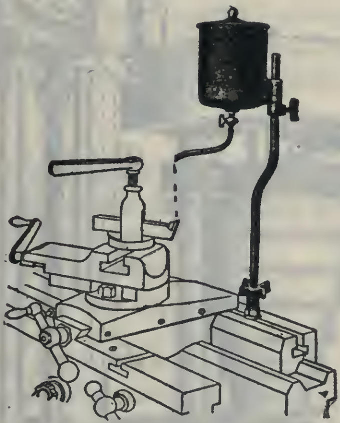


Fig. 199.

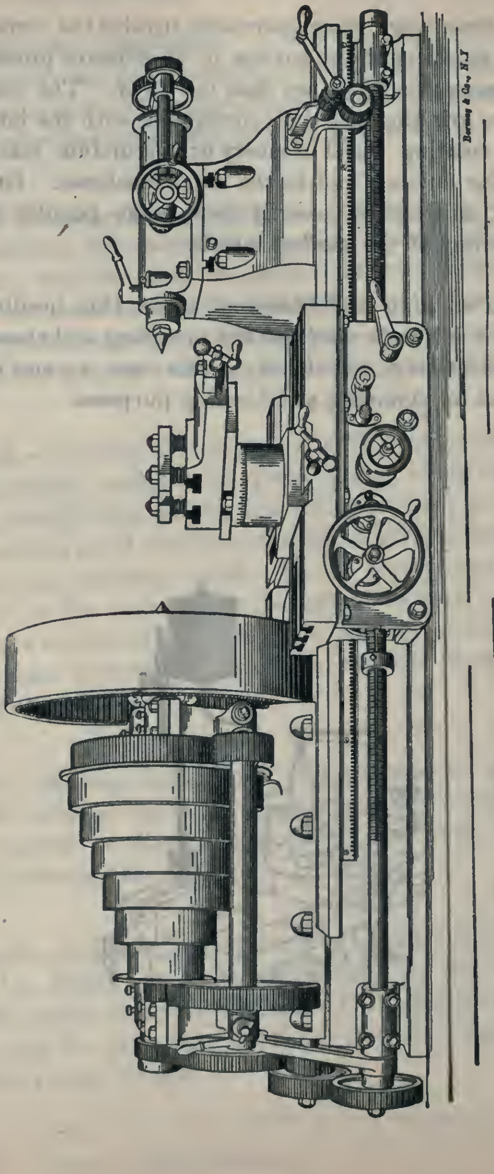


Fig. 200. See page 303.

THE LATHE.

The *lathe* is a machine for working metals, wood or other substances by causing the material to revolve with greater or less speed, according to the nature of the material and the work to be performed, before a tool which is held at rest, although for special work and in exceptional instances the lathe is used to rotate the cutting tool, the work being fixed stationary on feed carriage, etc.

The lathe is made in a greater variety of forms than any other machine tool, and at what exact point of its development, from the simple foot lathe, it first became entitled to rank as a machine tool is involved in much obscurity, but, as far as any tools laying claims to precision are concerned, it appears to have first come into existence.

Lathes are used for boring, turning, cutting, chasing, polishing, screw-cutting, shaping, etc.; the lathe may be justly termed the most important of all metal cutting machine-tools.

It is generally understood that an expert lathe hand, or turner, "is deemed capable of operating a planer, drilling machine or any of the ordinary machine-tools, whereas those who have learned to operate any or all of these machines would prove altogether inefficient if put to operate a lathe."

All the forms of cutting-tools employed in the planer, drilling machine, shaping machine, boring machine, etc., are found amongst lathe tools, while the holding devices employed to fix the work on the lathe include very nearly all those employed on all other machines, and in addition a great many that are peculiar to itself, hence the description of lathes and

THE LATHE.

cutting tools in the following pages will answer the double purpose of describing lathe tools specially, and in general machine cutting-tools of nearly all kinds.

The multiplicity of forms in which lathes exist may be reduced to a simple classification, viz.:

1. Foot-lathes.
2. Hand-lathes.
3. Self-acting slide lathes, and,
4. The chuck or surfacing lathe, designed to carry heavy or large work, fastened to the face plate.

Below will be found a brief description of several lathes and parts of lathes useful to be noted by the student.

The *foot-lathe* signifies that the lathe driving is done by the foot by means of a treadle.

The *hand-lathe* is one that has no sliding rest, the cutting tool being held by the hand.

The *single-geared lathe* signifies that the spindle is attached to or driven direct by the cone without any intermediate gear to reduce the speed.

The *back-geared lathe* has gear-wheels at the back of the headstock by which the rotation of the cone (which runs loose) is transmitted to the spindle and reduced in speed.

The *self-acting lathe* is one that has a slide rest, the feed travel or traverse of the cutting tool being automatic or actuated by the rotation of the spindle in the headstock.

The *screw-cutting lathe* is one that has a self-acting slide rest, the traverse of which can be adjusted by change-wheels or gearing to cut any kind of screw thread.

When a screw-cutting lathe has two motions for the traverse, one being the ordinary slide feed and the other one for the screw cutting, it is said to be *a screw-cutting lathe with independent feed.*

PARTS OF THE LATHE.

Engine-lathe is a term that varies in its application, being used by some to denote that the lathe is engine-driven, that is, by power, as its prime mover, and they call all other lathes foot-lathes; others apply the term engine-lathe to lathes in which the tool or cutter motion is actuated by power in its traverse, and term hand-lathes all lathes which have the feed motion actuated by hand; others again only apply the term engine-lathe to lathes in which the tool motion is actuated by power both in its traverse and cross feeds.

A single-gear lathe is one that has no gearing between the cone and the live spindle.

A double-geared lathe is provided with a loose revolving cone on the line spindle, and an intermediate gearing, to reduce the speed and increase the power of the live spindle. This gearing can be dispensed with if desired, the cone being fastened to the live spindle in such a way that it acts as a single-gear lathe.

A triple-gear-lathe is provided with two sets, or a train, of gears, which increases the power three-fold, reducing the speed in proportion; this lathe can be operated as a double or single tool at will.

PARTS OF THE LATHE.

The parts common to nearly all standard lathes are as follows:

1. The bed, or shears.
2. The legs, or supports.
3. The head-stock.
4. The tail-stock, or poppet.
5. The carriage.

In addition to the above there are many subdivisions of each, and also various specially-designed parts, which will be given hereafter with some details of the work effected by their addition to the regular type of the lathe.

PARTS OF THE LATHE.

THE BED.

Fig. 201 shows a very simple end view of a lathe-bed; it will be understood that the drawing represents the part upon which the carriage travels or slides.

A is a metal rib or cross-girt, connecting the sides and the shears or top slides; this rib, or web, forms the two ends of the bed. When the latter is of unusual length additional ribs are spaced at intervals between the ends.

B B are projecting ribs on which the head-stock is fixed; on these grooves also the poppet or tail-stock slides, or is moved in position as required.

C is a flat rib on the under side of the shears, to prevent the carriage lifting; *D D* are ribs on which the carriage slides.

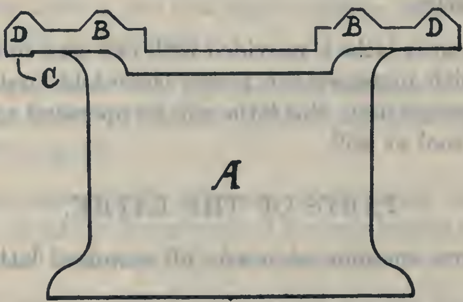


Fig. 201.

THE HEAD-STOCK.

This portion of the lathe is shown in fig. 202; the head-stock, as a whole, is shown in illustration; the details are indicated by the lettering, as follows:

A. Head-stock casting, which is firmly fixed to shears.
G. Front bearing-box; there is a similar one at back.
L. Bearings in which the live spindle rotates.

PARTS OF THE LATHE.

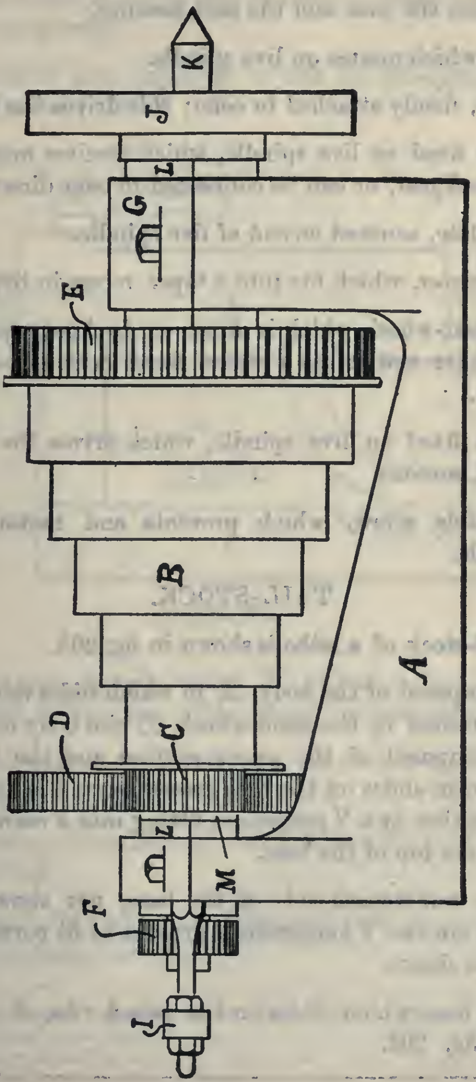


Fig. 202.

PARTS OF THE LATHE.

M. Steel anti-friction washer; this is loose on the live spindle between the cone and the back bearing.

B. Cone, which rotates on live spindle.

C. Pinion, firmly attached to cone; this drives the backgear.

E. Wheel fixed on live spindle, which receives motion from the backgear, or can be connected to cone direct.

J. Face-plate, screwed on end of live spindle.

K. Live-center, which fits into a taper recess in live spindle.

D. Backgear-wheel, which is fixed on backgear spindle; on the other end it has a pinion fixed, which gears into *E* wheel.

F. Pinion fixed on live spindle, which drives the different speed motions.

I. Adjustable screw, which prevents end motion to live spindle.

TAIL-STOCK.

The tail-stock of a lathe is shown in fig. 203.

It is composed of the body, *A*, in which slides the tail spindle, *F*, actuated by the hand-wheel, *C;* the body of the tail-stock is composed of the upper portion and the base; the upper portion slides on the base crosswise, and is kept in the desired position by a V projection fitting into a corresponding groove in the top of the base.

On the underneath side of the base, not shown in fig. 203, there are two V longitudinal grooves to fit corresponding ribs on the shears.

B is the base which slides on the raised ribs, *B B*, on the bed, fig. 201.

NOTE.—The object of the backgear is to reduce the speed of rotation, thereby increasing the power and enabling a heavier cut to be taken.

PARTS OF THE LATHE.

C is a handwheel fixed on the tail-screw which operates in the tail-spindle.

D is a handled nut, employed to lock the tail-spindle, *F*, in its adjusted position.

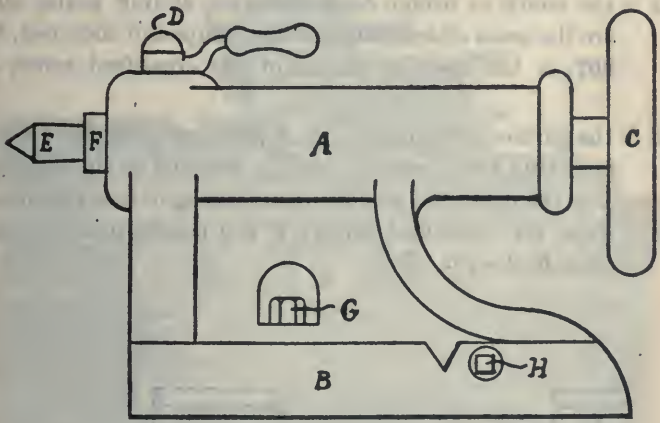


Fig. 203.

E is the center, usually called the "dead center," to distinguish it from the "live center" of head-stock.

F is the tail-spindle or mandril, in which is fixed the dead center, *E*.

G is the nut or threaded-bolt which screws the body and base to the bed.

H is the regulating screw for sliding the body crosswise to the bed, for taper turning.

NOTE.—If the running or live spindle of a lathe revolved absolutely true in its bearing, if the tail-stock and slide-rest were in perfect contact with the bed, if the tail-stock were in true line with head-stock, and if the slide-rest moved parallel with the line of centers of the head and tail-stock, there being no lost motion in any of the working parts, or spring to the tool, the work would be cut perfectly clean and geometrically true. Therefore, in precise proportion as these conditions are fulfilled in the construction of a lathe will its performance approach perfection.

THE LATHE CARRIAGE.

Fig. 204 represents the sliding carriage, which is provided with grooves on its underneath surface, which slide on the ribs of bed, *D*, in fig. 201.

A is the saddle or bridge connecting the sliding parts; on it are the cross slides on which the compound slide-rest, fig. **207**, is traversed by means of the cross-feed screw, *D*.

B is the surface of carriage; it is provided with slot grooves for fixing bolts, used for bolting material to the carriage; *D* is the cross-feed screw; *E*, a bearing or bracket on carriage for cross-feed screw; *F* is a handle to actuate the cross-feed screw, *D*.

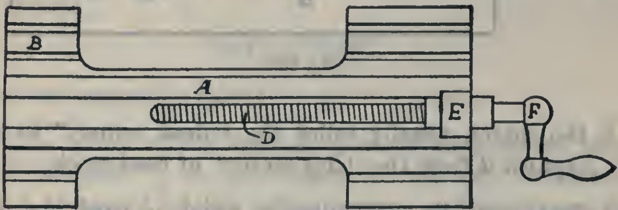


Fig. 204.

Fig. **205** is a front view of a portion of the lathe-carriage; it is called the "apron," and contains the bearings and mechanism by which the hand moves the carriage.

When the lathe is "self-acting," the gearing between the feed spindle, which communicates the motion, and the rack, which is shown on the under side of the shears, is contained in this apron, as is also the reverse motion for the feed.

PARTS OF THE LATHE.

The *apron* is tongued and grooved into the carriage, to which it is firmly bolted.

Fig. 206 shows the back or interior view of an apron; the bevel wheels show the reverse motion for the feeds, the screw-

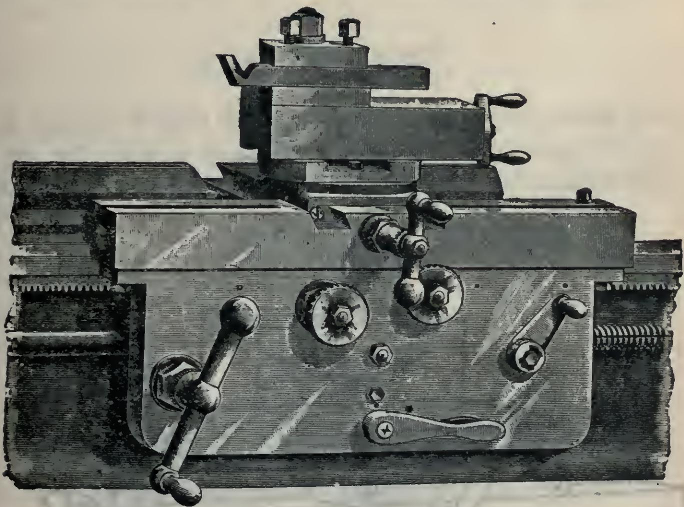


Fig. 205.

cutting feed being actuated through the half-nuts shown open; the longitudinal and cross-feeds are actuated by friction.

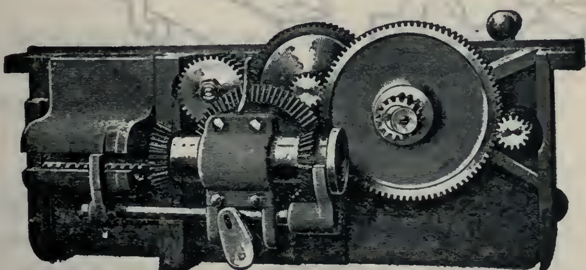


Fig. 206.

The reverse for the feeds is extremely simple, and is always at the hand of the operator. The half-nuts are planed

THE SLIDE-REST.

to fit directly into substantial bearings in the apron; they are operated by a cam, having its grooves carefully milled; the half-nuts are cut from the solid metal and are fitted with a

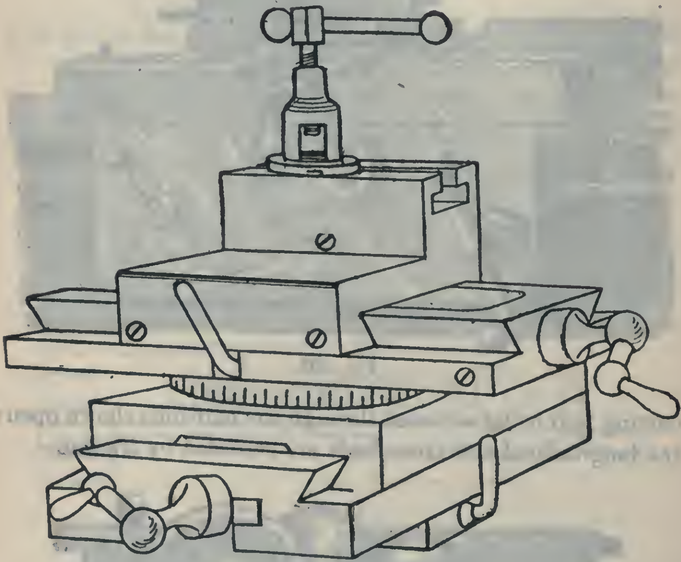


Fig. 207.

device which connects a cam with the reverse lever, which cam is thrown in the path of the half-nuts when open and the feed is engaged, so that the half-nuts can not be closed until the feed is thrown out.

PARTS OF THE LATHE.

The friction cross-feed is so designed and constructed that if the cross-feed is allowed to run beyond its limit either way no harm will be done.

THE SLIDE-REST.

A compound hand slide-rest is shown in a perspective view in fig. 207; this is virtually a part of the carriage; it consists of a lower slide fixed in the carriage, and another slide

Fig. 208.

which swivels on the lower one and carries the tool-post; this carries the cutting-tool, which can be manipulated in any direction by the hand, as shown in the illustration.

Fig. 208 shows a raise-and-fall rest particularly adapted for lathes used on small work which requires constant adjustment of the height of the cutting tool; this can be quickly accomplished by the hand-screw at the end of the rest, as shown in figure; the other end is hinged to the sliding carriage.

This description of lathe rest is designed for hand feed only

LATHE COUNTERSHAFT.

Countershafts are separate sections of shafting generally used for controlling or varying the motion of a particular machine without interfering with the speed of the main shafting.

Lathe countershafts are constructed in a variety of designs; fig. 209 shows a simple form; it consists of a pair of pulleys, one fixed and one running loose, on a short shaft, supported by two bearings; a cone is fixed on this shaft, and is connected to the lathe-cone by a belt; four alterations of speed are provided for on the cone, and the motion can be entirely stopped by moving the main driving belt from the fixed pulley to the loose one.

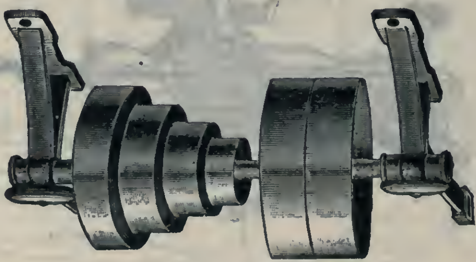


Fig. 209.

An improved form of the countershaft consists of two wide, loose pulleys, with a narrow, fixed pulley between them, and two belts, one of them crossed or twisted, so that the loose pulleys revolve in different directions, and the movement of either belt on to the fixed pulley will give a reverse motion to the countershaft; this plan as usually employed in screw-cutting lathes is an improvement adopted by which the reversing of the travel of the carriage is accomplished by an arrangement of wheels in the carriage itself, the lathe always revolving in one direction.

PARTS OF THE LATHE.

Fig. 210 shows a countershaft in which the driving consists of two loose pulleys, with a sliding friction clutch between them, through which their motion is transferred to the countershaft; both inner and outer pulleys travel in the same direction, giving two speeds of the countershaft from the different sized driving pulleys on the main line, and sixteen speeds of spindle with four-step cone.

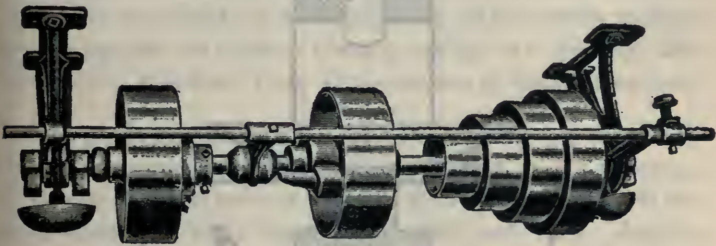


Fig. 210.

All reversing of the carriage, both for thread-cutting and feeding, is done with the handle at right-hand side of the apron. This can be used with the lathe in motion except when running on the fastest speeds or cutting very coarse threads at high speeds, in which case the speed should be slackened at reversal.

In special cases, where it is desirable or necessary to run the lathe backwards, the outer friction pulley may be driven, as in ordinary practice, with a crossed belt.

TOOL-POST.

A portion of a tool-post or tool-holder is shown in section, in fig. 211.

A is the top of the slide-rest in which is a T-groove; *B* is a circular post, and is designed to turn in the T-groove.

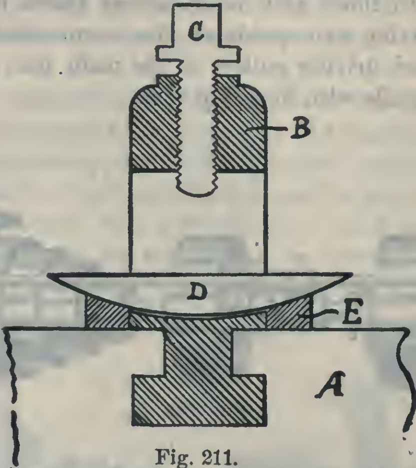


Fig. 211.

E is a cupped washer, moving easily around *B;* on this washer rests a curved gib, *D*, moving endwise in the slot in post; the tool rests on this gib, and its point can be raised or depressed by moving the gib; the tool is fixed by set screw, *C*.

Fig. 212 is a side view or plan of tool-post,

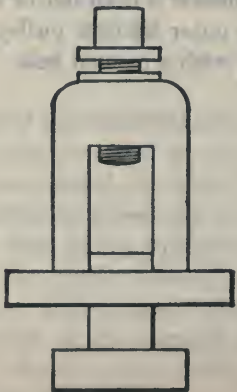


Fig. 212

STEADY REST.

Fig. 213 is a "steady rest"; it is used when turning shaftings fixed on the shears.

It consists of a single casting, in which are spaced three sliding-blocks actuated by screws; the steady rest when bolted to the sliding carriage and traveling with it is called a follow rest.

The piece of shafting is passed through the steady rest, and the three slide-blocks in it are adjusted by the screws to press evenly against its surface, thereby acting as a bearing, and preventing vibration from the operation of the cutting-tool.

The producing of satisfactory results in the use of the follow rest requires good judgment on the part of the operator. It should be set as soon as possible after the cut has left the dead center and while the work is rigid and true. Any irregularities in the work surface on which the follow rest passes serve to reproduce these same irregularities throughout the length of the work, and it is, therefore, very important to start exactly right. In the cutting of threads on long, light rods the follow rest is indispensable. It is also of value in steadying work that is being operated upon by a cutting-off tool. It is superior to the steady rest for this purpose, inasmuch as it can be set so much closer to the point where the cut is being taken.

Fig 213

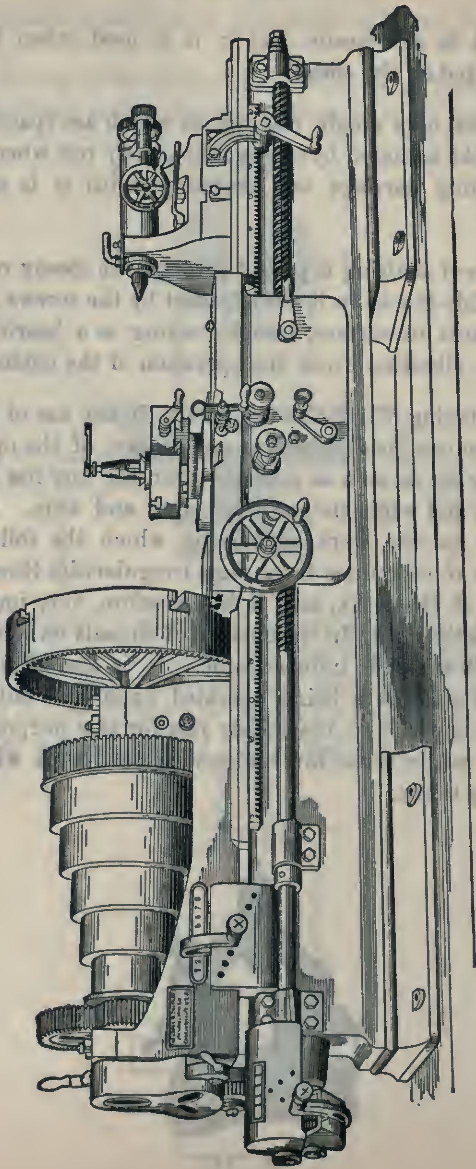


Fig. 214. See page 304.

CUTTING-TOOLS.

Cutting-tools for lathes, planing machines, etc., are made of a special grade of cast steel known as tool steel; this is first forged to shape as nearly as possible; next, the tools are of necessity filed up more or less, after the forging, on account of their shape.

When the desired form is attained, whether by forging or filing, the tool is heated to red heat, dipped into water and then tempered, as described in pages 143 to 149, and afterwards ground to sharpen the edge; too much grinding will alter the form and the temper of the edge, wearing away the tool needlessly.

The shape given to any particular tool is determined partly by the kind of metal to be turned, and partly by the nature of the work the tool has to do. The chief points to be borne in mind are that the cutting angle should be keen enough to cut well, while strong enough to stand the strain of cutting without breaking.

NOTE.—In connection with this subject, reference is made to the important discussion of "Tempering and Hardening Metals," beginning on page 143; to this is added a quotation from an article in the *American Machinist* of a recent date, contributed by Mr. Tecumseh Swift, M.E.

"The hardening, tempering and annealing of our tools is the most responsible operation of the shop; the heating and cooling of steel, the two simple but responsible operations involved in all our hardenings and temperings and annealings, are the two operations of the shop which we need to perform with the most precise accuracy and with the most perfect control. The anomalous fact is the precise reverse of this. We put a piece of steel through a long process of careful shaping and finishing; we provide means for most accurately gauging it, and set to ourselves limits of inaccuracy beyond which we may not go. We bring the piece to the last and most important process of all, with the work up to this point done precisely according to the most exacting requirements, and then we do the last thing of all upon it, the one thing upon which the success and value of all the previous work entirely rests, *by almost pure guesswork*, and it is more by luck than by skill that it is only occasionally that we actually spoil a piece.

"It is not out of place to call attention to the very unsatisfactory state of affairs in this important operation or the shop, *because it seems to be possible to do much better than we are now generally doing, and the gas furnace* and *the pyrometer* seem to offer vast possibilities in the line of improved practice."

CUTTING-TOOLS.

Rake Cutting-angle and Clearance.—The angles are generally referred to as "top rake," the "cutting angle," and "clearance," and also "side rake," as shown in fig. 215; *B* is the angle of top rake, *C* is the "cutting angle," and *A* is the angle of clearance.

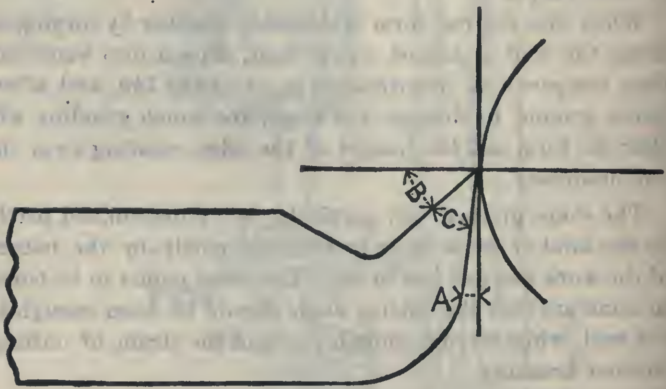


Fig. 215.

Increasing the "top rake," or "side rake," relieves the pressure on the tool, but this is done at the expense of the strength of the tool point.

A correctly shaped tool properly applied to the work will cut cleanly and well, and will leave a smooth, even surface behind it; it should be so applied to the work as to afford sufficient "clearance" underneath, to prevent it rubbing instead of cutting, and sufficient relief, or "top rake," as it is termed, to enable the cuttings to easily come away from the metal.

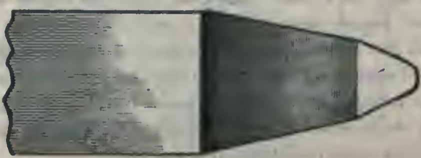


Fig. 216.

CUTTING-TOOLS.

The outline of the tool shown above is well suited for turning wrought iron or mild steel. Fig. 216 shows the plan of a straight-turning tool. Fig. 217 shows a perspective view of this tool in which *AA*, *BB*, represent the top and bottom levels of the tool steel; *C* is the top face, *D* is the bottom face; *E* is a line at right angles to *A* or *B*. Referring to the top face, *C*, its angle or rake is its incline in the direction of the arrow; in many cases it is impracticable to give top rake, the necessary keenness must be given by side rake, which is done by reducing the cutting angle formed by the top and side faces.

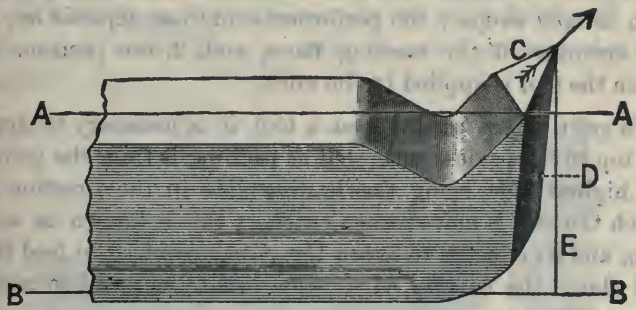


Fig. 217.

The angle *C*, fig. 215, varies slightly, according to the metal which is being turned, certain cutting angles having proved by experience to be the best suited to different metals. For example, for wrought iron and mild steel, an angle of about 55 degs. gives the best results, while for cast iron a somewhat more obtuse angle, from 58 degs. to 60 degs., is best.

Differences so exact as this, however, may be disregarded in practical work, and it may be taken that an angle of about 58 degs. will be found satisfactory for all-round work on the above-named metals. For heavy cuts on cast iron a more obtuse cutting angle may occasionally be required to give the necessary strength to the point of the tool.

The cutting angle being thus determined, the "clearance" and the top rake have still to be provided for. The object of the clearance is to enable the tool to cut without rubbing

CUTTING-TOOLS.

against the work. For this purpose a very small angle, 3 degs. or 4 degs., is sufficient; and, indeed, an excess of clearance is injurious, as it weakens the point of the tool.

While dealing with the subject of "clearance" it may be well to emphasize the necessity of grinding the side faces of the tool, which form the cutting edge, perfectly flat; this requires skill to accomplish, and neglect of this matter will cause trouble; a slightest rounding at the edge will cause the tool to rub, and destroys its efficiency.

The top and side faces, taken one in conjunction with the other, form a wedge, and all machine tools are nothing more than *cutting wedges;* the performance of these depends on, 1, the keenness of the meeting faces, and, 2, the position in which the tool is applied to the work.

To get the best results from a tool it is necessary to slope the top surface sideways as well as backwards from the point, the highest side being the leading side in the direction in which the tool is moved when cutting; this is known as side rake, and its effect is to lessen the power required to feed the tool along, the cutting edge penetrating the metal so much more easily.

A tool with side rake is suitable only for traversing in one direction; this is no real disadvantage, as nearly all turning is performed with the tool moving from right to left.

When possible all turning tools are forged with a swan-neck on the top surface of the tool, as shown in fig. 322; it will be apparent that this form can be reground or sharpened, and retain the original rake, which could not be done with a flat tool.

Variation of Rake with Height of Tool.—With the same tool the top rake varies with the position, the rake being greater for the same cutting angle the higher it is above the center; hence when sliding, and the heavier the cut, the more the tool should be packed up; in heavy roughing the tool is often considerably above the center.

CUTTING-TOOLS.

Fig. 218 shows a tool, with little top rake, placed at the center; this tool, as shown, will not properly cut the material but will scrape it off; now if the tool is raised above the center, the angle of contact will be changed, and it will cut the material.

A few actual trials in the lathe with the position of the tool altered in various ways, will soon enable the student to grasp the importance of these facts.

For surfacing work, *i. e.*, going over a face at right angles to the axis, the tool must obviously be on a level with the axis, or it would leave a circle of metal untouched at the center.

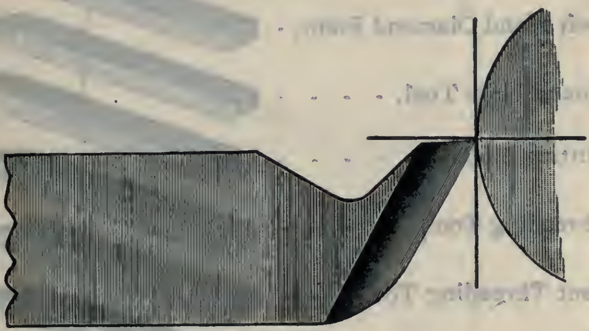


Fig. 218.

Influence of Material on Cutting Angle.—The angles of cutting tools vary with the metals operated on; wrought iron being tough, requires a good top rake, as in fig. 215, and abundance of lubricant to turn away the cutting, otherwise the metal will crowd or stick on the tool face, and the material is torn instead of cut. On brass or cast iron, which are brittle, the top rake needs to be less keen, fig. 218, is approximately correct for brass and cast iron; when a very smooth cut is required on brass work, the top face of the tool is ground quite flat, without any "top" or side rake.

CUTTING-TOOLS.

A set of ***slide-rest tools,*** which are sufficient for all ordinary work, will now be described; the most generally used tool is the front turning or roughing tool, shown in fig. 217, which

Left Hand Side Tool, - -

Right Hand Side Tool, - -

Right Hand Bent Tool, - -

Right Hand Diamond Point.

Left Hand Diamond Point, -

Round Nose Tool, - - - -

Cutting off Tool, - - - -

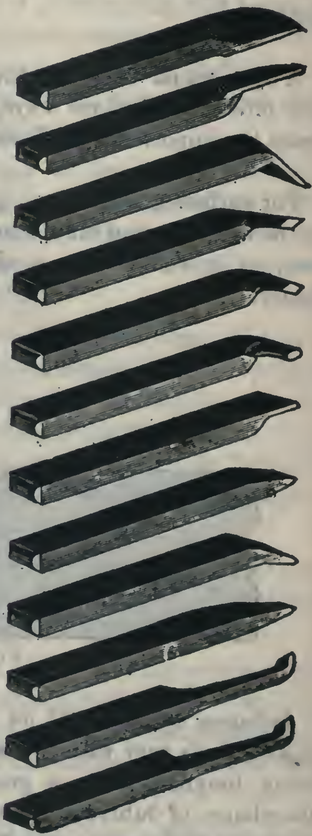
Threading Tool, - - - -

Bent Threading Tool, - -

Roughing Tool, - - - - -

Boring Tool, - - - - - -

Inside Threading Tool, - -



Figs. 219-230.

will serve for turning work between centers, and also for facing work held in the chuck. Occasionally, however, surfaces have to be turned which cannot be reached with a straight tool of this kind, and for which side-tools have to be used. A

CUTTING-TOOLS.

right-hand side-tool and a left-hand side-tool are illustrated in figs. 231 and 231a. They are ordinary swan-neck tools, with a top rake, and having side rake to the right or left, as they are

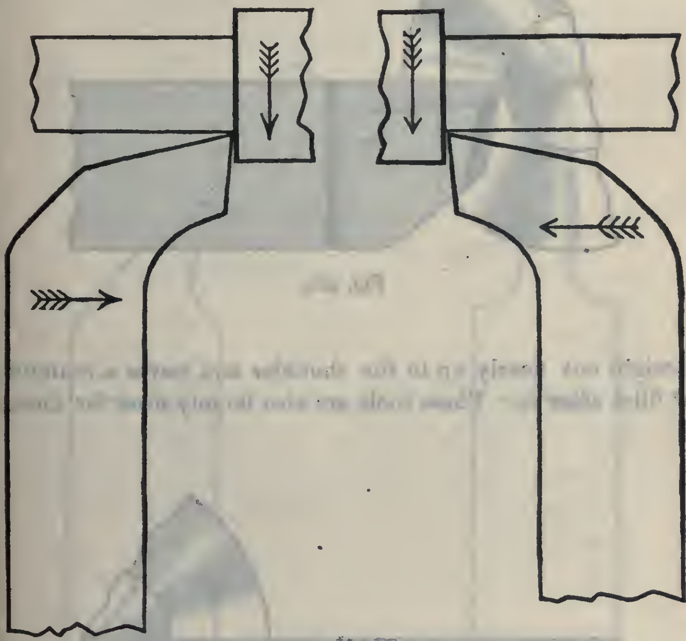


Fig. 231. Fig. 231a.

intended to travel, as shown by arrows; they are used as illustrated in figs. 231 and 231a, and also with the cutting point rounded off, when used with a coarse traverse feed.

This tool occupies considerable breadth of space, as clearly shown above; when the work is confined and there is but little room for the tool to pass, a knife-edge side-tool is used,

CUTTING-TOOLS.

as shown in figs. 232 and 233; this tool is used to finish the shoulder after the "front" tool is used, which only takes the

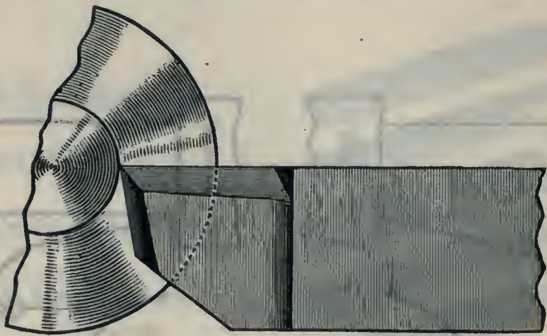


Fig. 232.

straight cut nearly up to the shoulder and leaves a rounding or fillet after it. These tools are also largely used for facing

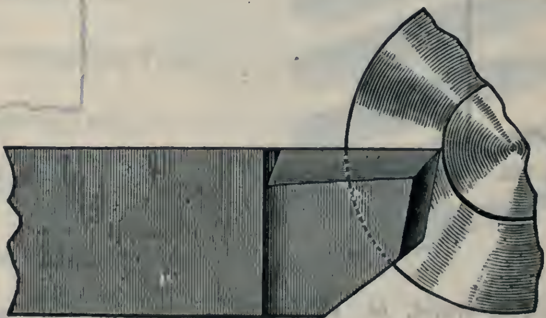


Fig. 233.

bolt-heads, collars and shoulders, and it is important that there should be sufficient clearance to the cutting edge.

CUTTING-TOOLS.

Fig. 234 shows a bent parting tool, which is used near the surface plate, where it would not be possible to reach with the straight tool.

Fig. 235 shows a plan of a very important tool for cutting-off work in the lathe; it is called a parting tool, and it will

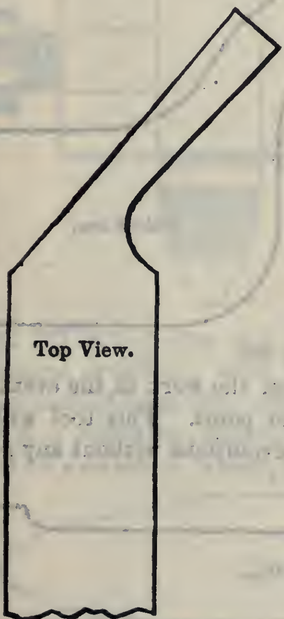


Fig. 234.

Fig. 235.

be seen that the front of the tool—its cutting edge—is wider than the back, to give it clearance sideways and to prevent it rubbing at the sides, as it advances into the work; this tool is generally flat, on the top, which must not be higher at the cutting point than the center of the lathe, as it is intended to cut the way into the center of the work operated on.

CUTTING-TOOLS.

The Roughing Cut.—In heavy cutting the tool springs in or out according to the weight of the cut, and copies more or less the unevenness of the forging. Hence, in "finishing," the tool should be set down as much as convenient, so that if it meets any extra weight the tool will spring away and remove the difference at the next turn. This is carried to a greater extent in the "spring" tool, fig. 236, which yields about

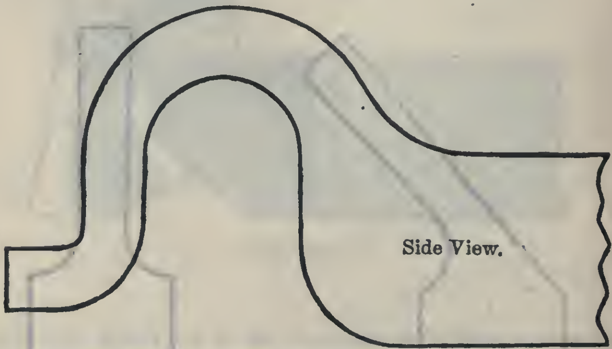


Fig. 236.

the bend, and comes away from the work in the event of excessive pressure coming on the point. This tool will often keep cutting three or four revolutions without any advance of the top slide.

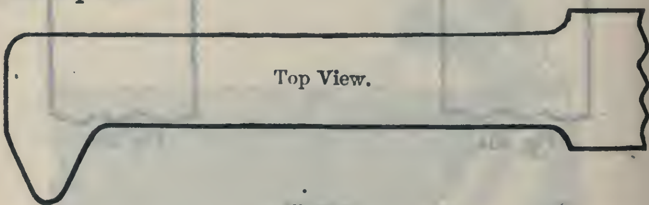


Fig. 237.

Boring in the Lathe.—Boring in the lathe is done generally by means of flat drills, which are centered at one end and ground at the other into either "point," "rougher," or "finisher." Great care is taken in setting these drills, especially the "finisher," as, when once set, it lasts a long time, and can always be relied on. If one corner is in advance of the

CUTTING-TOOLS.

other it will catch the cut first, and will be pushed away, with the result that the hole is bigger than the drill. Their accuracy is generally gauged by resting the centered end on a coned point fixed to a table, and with one corner making a mark. On turning the drill to the other corner it should come on the same mark.

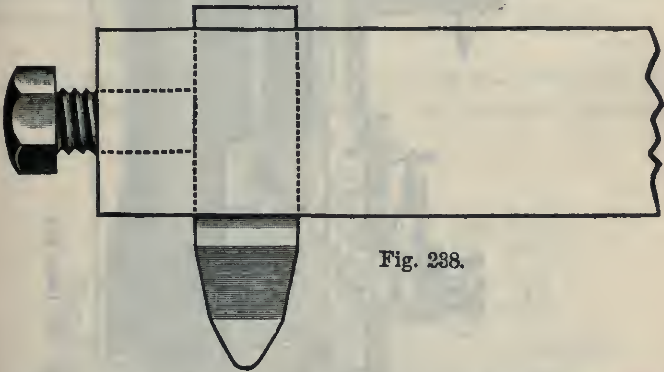


Fig. 238.

Fig. 237 is a boring tool, used in the lathe for enlarging holes cored or drilled; when the size of the hole permits the tool is made of large size; and when the hole is deep and will allow it, a strong bar, having a cutting-bit fixed in a slot, or hole with a set screw, is used, as shown in fig. 238.

Fig. 239.

The tools so far described are intended for turning either cast or wrought iron or steel. For brass and gun-metal, tools of other shapes are necessary, the principal difference being that no top rake is required. If a brass turning tool is too keen, it will rip the surface of the metal instead of cutting smoothly.

A suitable front tool for brass is illustrated in fig. 218 and fig. 239, from which it will be noticed that rather more clearance is allowed than with tools for iron.

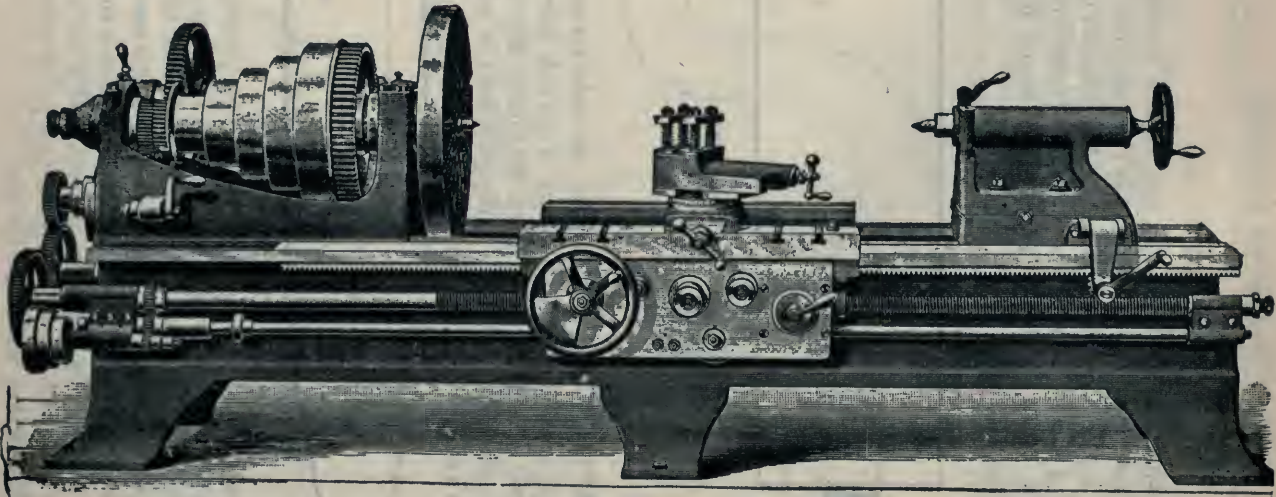


Fig. 240. see page 304.

TOOL-ROOMS.

An eminent engineer has said: "Show me your tool-room, and I will tell you the character of the work which you turn out."

A tool-room is part of every well-organized machine-shop; many tools and instruments are so important that they must, perforce, when not in use, be kept under lock and key.

One man, usually the foreman, has charge of the tools and materials contained in the tool-room; as the size of the shop,

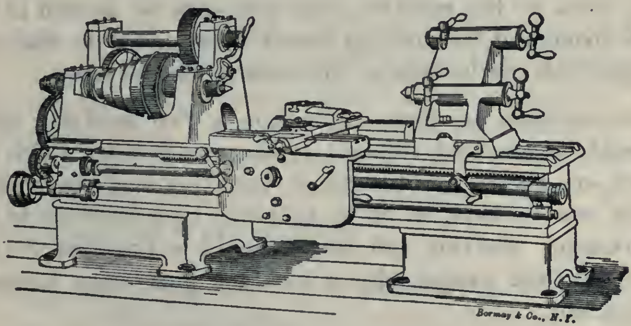


Fig. 241. See page 304.

number of men and variety of work are increased, the tool-room becomes a distinct department, with many classifications and men employed to carry on the work arising from the system adopted.

The location for the tool-room depends largely on the general arrangement of the shop, but the tool-room should always be located so as to have good light, and the location should be a central one, taking into consideration where the men work who use the tools to the greatest extent. If there

TOOL-ROOMS.

is sufficient space, the tool-room should be located outside of the shop proper, with a large opening between them. A tool-room should be equipped with shelving and racks, not located against the wall, the shelving being inclined at such an angle as will permit each tool to be readily seen.

The shelving should be neatly divided up by strips, so that each tool will have its own particular place, and prevent damage on account of the tools striking together. The tools should be arranged in the pockets made by the strips, so that tools of about the same size will be kept together. The racks should be so arranged that they are readily accessible from either side, and can be reached without interfering with the work at the machine tools that may be located in the tool-room, and the shelving should be arranged so that the larger tools can be kept on the lower portion of same.

In addition to these racks, one or two revolving racks should be provided adjacent to the window from which the tools are handed out, on which revolving rack the smaller tools can be kept, so as to facilitate their delivery to the workmen. Shelving and hooks should be provided, for the templets and gauges, also a rack for pipe-tongs, straight-edges, etc.

The machine tools to be placed in a tool-room depend largely upon the size of the shop and the policy of the management as to manufacturing taps, reamers, etc., or buying them outside.

NOTE.—In order that the tool-room may be a success, the man placed in charge of same should be carefully selected. He should have had considerable experience—the more the better—in the making of tools, neat and orderly in all that he does, and a man who thoroughly appreciates the necessity for preserving standards, as the preservation of many standards depends largely upon the proper maintenance of the tools ordinarily kept in a well-regulated tool-room. A tool-room, if well handled by such a man, will insure that the tools have proper care and can be found when required. It also makes it possible to collect together tools that have become obsolete, so that they can be condemned, or altered, to suit the standard requirements.

TOOL-ROOMS.

All standard tools that are in general use and are required to be kept to standard sizes, should have a place in the tool-room. This would naturally include taps, reamers, drills, dies, templets, jigs, ratchets, clamps, callipers, etc. In addition, all tools in general use, that require special adjustment, should be kept in the tool-room, such as hydraulic jacks and pneumatic tools. The tool-room is the proper place for lathe tools, planer tools and chisels, over and above a certain number to be kept at each machine, or by each floor hand, as may be determined upon by the master mechanic of the shop. The tool-room is also the proper place for all test gauges.

Each shop in practical operation makes its own rules for the delivery and return of tools to the tool-room; in order to prevent delay, the workmen should not wait until they actually want a tool, but should anticipate their wants, so that the tool can be brought to them by the time it is required. The returning of the tools to the tool-room can be handled in the same way as the delivery.

If the size of the plant will warrant it, it is advisable that there shall be a tool dressing fire near the tool room, together with a small power hammer, at which fire the dressing of all tools should be done; also, a list of all workmen entitled to obtain tools from the tool-room should be printed alphabetically, and each name should be numbered in consecutive order. The list should be neatly framed and hung up in the tool-room near the delivery window.

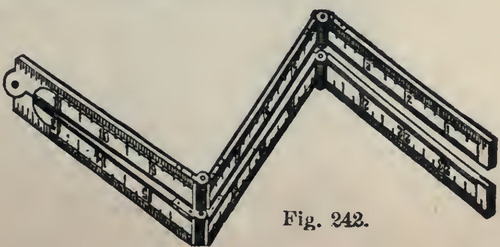


Fig. 242.

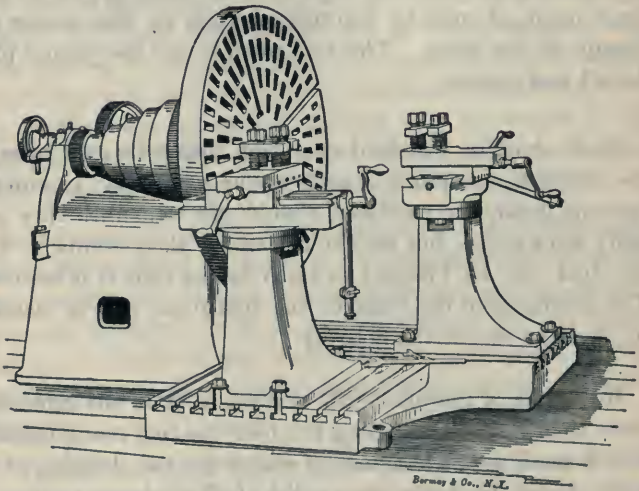


Fig. 243. See page 305.

LATHE

AND

SHOP

RULE FOR TEMPERING TOOLS.

Heat from two to three inches of the end of the tool to a cherry red, and hold it vertically in a pair of tongs, quickly dip about one inch into cold water, holding it under the water for several seconds; this makes the point dead hard; then withdraw it from the water and rub the end of the tool with a piece of sandstone or emery cloth, until the surface is clean and bright. Watch this end; it will change color as the heat travels down from the heated upper portion which was not cooled; a band of colors will be noticed traveling down to the point very slowly; the front of this band is a pale yellow, which merges into a deep yellow, then to a brown, then to a plum color, then to a purple and, lastly, to a blue; when the dark yellow color has reached the point of the tool, the latter should at once be dipped deep under the surface of the cold water, and allowed to remain there until quite cool; the rule is, the darker the color the softer the tool—the pale yellow being the hardest, and the blue color the softest.

TUBAL CAIN,
THE FIRST TOOL MAKER.

LATHE PRACTICE.

Lathe tools of the kind shown in the foregoing sketches should be made of the fine grain cast steel known as tool steel. The steel should be heated and hammered out nearly to the shape of the required tool, care being taken not to make the steel too hot when heating it, or it will become brittle and the point will chip and crumble away when the tool is applied to its work.

A bright cherry red is the best heat to work at, and it should be borne in mind that the thinnest parts of the tool will get hottest first, and if not carefully watched may overheat and get "burnt" before the thicker parts are properly hot.

When the tool has been hammered out to something like its proper shape it should be allowed to cool slowly, so as to get thoroughly soft; it may next be filed or ground to the exact shape required. When the correct shape is obtained the tool must be hardened and tempered. This may be done by the rule printed on the opposite page.

MEASURING APPLIANCES.

The *measuring appliances* required for metal turning are comparatively few in number, and simple in construction; first, a 12-inch steel rule should be obtained, divided into eighths, sixteenths and thirty-seconds of an inch; a shorter steel rule, either 4 or 6 inches long, divided in the same way, will also be useful.

Steel rules are much better than wooden ones, as the graduations are finer and more accurate, and a steel rule is frequently very useful as a straight-edge.

LATHE PRACTICE.

Fig. 153, page 170, shows a pair of outside calipers, used for measuring the external diameter of round shafting, etc.; the legs are opened until they just touch on both sides of the work with but little pressure being applied; if they are then placed on the steel rule, as shown in fig. 349, the diameter of the work can be closely and correctly ascertained.

Similarly, if it is required to turn a piece of work to a given diameter, say one inch, the caliper's legs are applied to the rule, as shown, and opened out until the right leg touches the one-inch mark; the work can then be reduced in size until the calipers just pass over it.

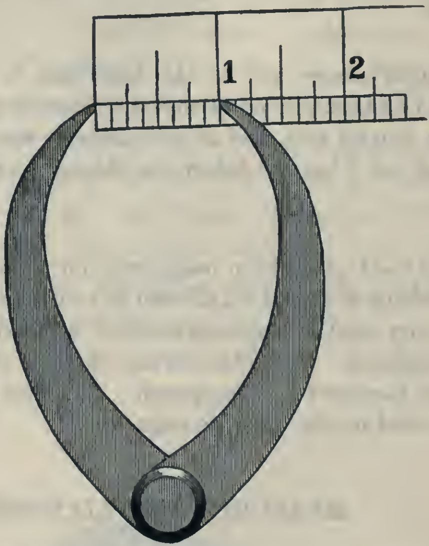


Fig. 244.

Fig. 154 shows a pair of inside calipers as used for measuring internal diameters; these can be set "to size" on a steel rule, in the same way as described for outside calipers; the end of the rule should, however, butt up against the face plate or other flat surface, to keep the point of the caliper leg perfectly level with the rule end.

LATHE PRACTICE.

Fig. 245 shows the inside calipers testing a hole; one point or leg should be kept stationary, while the other is oscillated to and fro, as indicated by the dotted curve line *AB;* the legs should be opened out until the point which moves in the curve just touches the surface of the metal; this will then give the exact diameter of the hole as required.

Caliper legs should never be adjusted by knocking on the points, as these will thereby become bruised, and so render them useless for accurate work; they should be set by tapping gently the *upper portion* of the leg only.

When it is desired to turn a piece of metal to fit a hole, the inside calipers should first be set to the exact size of the hole,

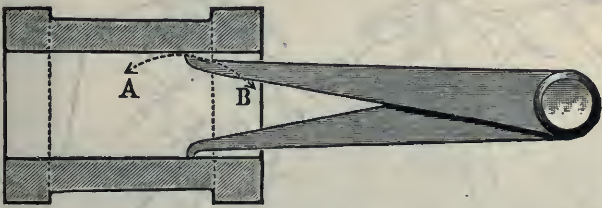


Fig. 245.

and then the outside calipers set to just touch over their points, as shown in fig. 246. The hands show the most convenient way of holding the calipers for this purpose. It will be noted that the lower points of the calipers are supported in contact with each other by one of the fingers of the left hand, while the other points are tried together until the required degree of touch is obtained. If a "working" or "sliding" fit is required, the spindle to be turned must be slightly smaller than the hole in which it is to run, and the larger the diameter of the hole the greater must this difference be.

NOTE.—It may vary from nearly one-two-thousandth part of an inch in small spindles of about a quarter of an inch diameter, to one-one-hundredth part of an inch in twelve inches diameter.

LATHE PRACTICE.

A knowledge of the proper allowances to make in size for obtaining a "sliding" fit, "driving" fit, "shrinking" fit or "forced on" fit, can be obtained only from practical experience, like a great many other useful items of knowledge.

A "sliding" fit is a working fit of perfect cylindrical form, of sufficient difference in sizes in the diameters as will permit one surface to revolve within the other freely.

A "driving" fit is a fit between two true cylindrical forms, of such a difference in their diameters that they only come together by driving with a hammer, sledge or a ram, in proportion to the work.

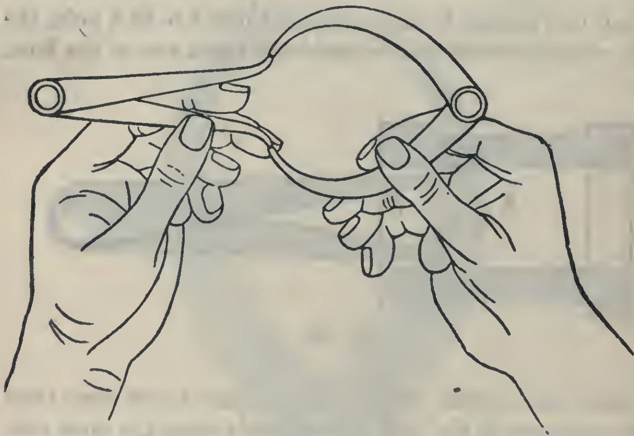


Fig. 246.

A "shrinking" fit is a fit between cylindrical forms, of such differences in diameter that the outer surface or ring requires expanding by heat to permit it occupying its intended position on the inner cylinder; a "shrinking" fit is a considerably tighter fit than a "driving" fit.

A "forced" fit is used only in very heavy work; it requires hydraulic force to put the parts into the desired position.

NOTE.—The student should practice with a pair of calipers until he can readily detect the smallest differences in the size of work by the "feel" of the points when touching the work.

LATHE PRACTICE.

While very minute differences in size can be detected with a pair of calipers, it is obvious that they cannot be set to a given size with absolute accuracy by measuring from a steel rule, yet with a good rule and keen eyesight on the part of the user, it is possible to set them to within $\frac{1}{64}$th of an inch of the required size. Where greater accuracy than this is desired, vernier calipers or micrometer calipers (see fig. 247) must be used; with the latter instrument a measurement to the thousandth part of an inch can easily be made.

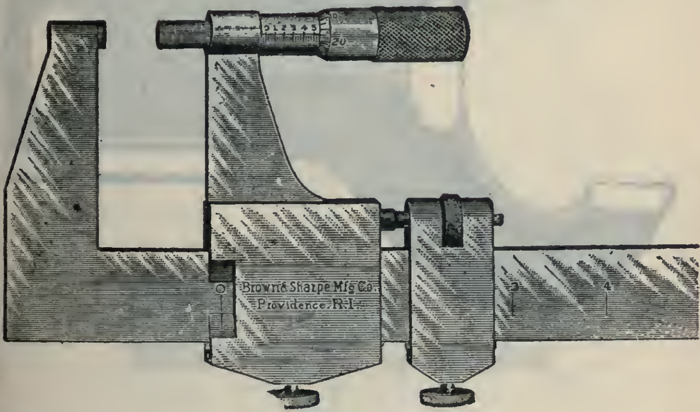


Fig. 247.

Figs. 249 and 250 show a "plug and collar gauge"; these are made a sliding fit, and are used to test the size of internal and external cylindrical surfaces; the plug or internal gauge is sometimes called the male gauge, and the collar or ring the female gauge; these are very costly gauges, being made of hardened steel; they are only used up to a certain size, because of their weight.

Fig. 248 shows a form of caliper-gauge which can be applied without removing the work from between the centers; one end of this gauge is internal and the other external; it is usual to have different sizes in the one piece, thus a two-inch outside gauge would have a two-and-one-eighth-inch internal end; in this way the two-inch internal end would be on a

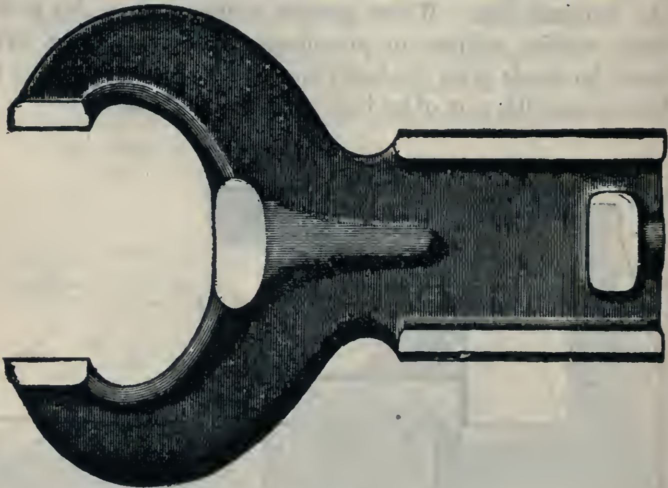


Fig. 248.

separate piece to its mate; thus they can be compared together, which could not be accomplished with the two in one piece.

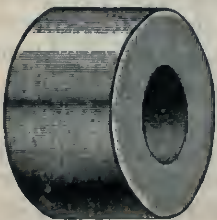


Fig. 249.

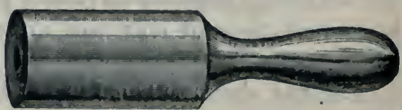


Fig. 250.

LATHE PRACTICE.

A *depth-gauge,* as shown in fig. **251,** is useful for ascertaining the depth of a hole or recess and for other purposes; it consists of a stock or straight-edge, *A,* in which a graded standard, *B,* slides up or down, being fixed when set to the required depth by the set screw, *C;* a groove, *D,* is also provided so that the rod, *B,* may be used close to the end, as well as in the middle, when convenient.

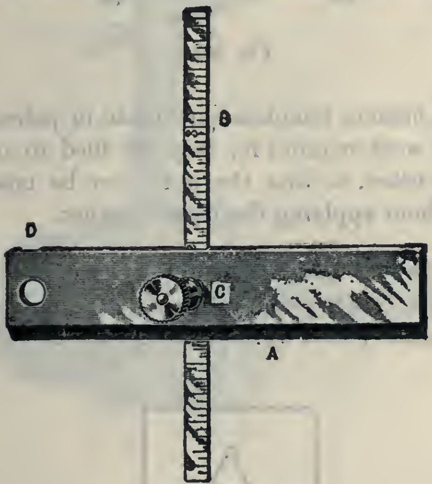


Fig. 251.

NOTE.—A gauge is a standard of measure; an instrument for determining the dimensions, capacity, quantity, force, etc., of anything; hence any standard of comparison or estimation, as a gauge for the thickness of wire, steam-gauge, sheet-metal gauge, vacuum-gauge, water-gauge, recording-gauge, etc.

LATHE PRACTICE.

When a curve, projection or a hollow, is required to be turned on a round piece of work, the exact form should be marked out on a piece of sheet-iron, and a template or gauge should be made by filing away the metal to the line thus marked; the accuracy of the work can then be tested by applying the template from time to time to the work, as shown in fig. 252.

Fig. 252.

Inside and outside templates are made in pairs, when the nature of the work requires it; they are filed to exactly conform to each other, so that the work can be machined accurately, without applying the parts together.

Fig. 253 shows a gauge which every one should make for himself; it is a center gauge which shows the exact angle to which the center points of the lathe should be turned; both

Fig. 253.

center points should be of exactly the same angle, and whenever a center point wears and has to be re-turned, it can by means of this gauge be turned to exactly the same angle as before; for lathe centers an angle of 60° is the one generally used, although in England "Whitworth" adopts an angle of 55°.

CHUCKS AND MANDRELS.

A *chuck* is an attachment to the lathe, designed for holding or gripping the cutting tool or the work itself. A chuck-plate is the large surface plate to which the work may be attached. The utility of a lathe is greatly enhanced by the possession of an assortment of chucks.

A *mandrel* is a cylindrical piece which is driven into hollow work, and holds it while it is turned in the lathe.

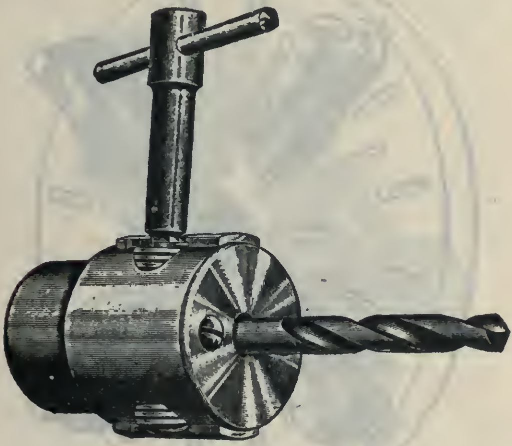


Fig. 254.

A *self-centering chuck*, fig. 254, is one in which the jaws, usually three in number, are opened or closed simultaneously by the turning of one screw only. As each jaw moves through exactly the same distance towards or from the center, it is obvious that a drill or any piece of work fixed between them will be held truly central. For holding twist drills, metal rods, bolts and small castings, these chucks are particularly useful.

CHUCKS AND MANDRELS.

An *independent-jaw chuck* is one in which each jaw (see fig. 256) is moved in or out by its own screw, and works independently of the other jaws. In this device the work is chucked by the moving, either inwards or outwards, of the stepped roughened jaws which, controlled by screws, slide in the blocks; the latter are bolted against the chuck-plate of the lathe, as shown in fig. 255.

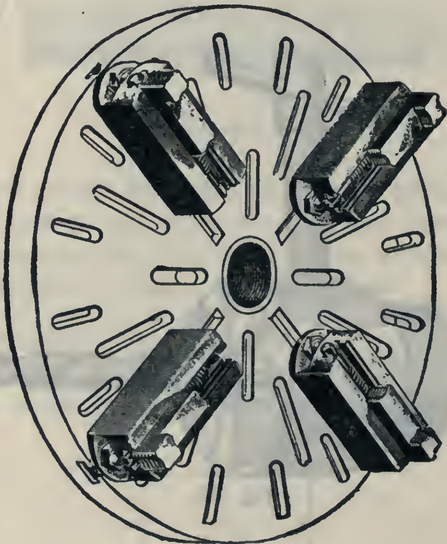


Fig. 255.

A face plate is shown above; this is another view of *J*, in fig. 202, to which reference is made; this is one of very many designs, and when fitted with jaws shown in sketch is called "Cushman's chuck."

In example shown the jaws are independent—simply bolted to the face plate, and are reversible.

CHUCKS AND MANDRELS.

A *dog* is a work-holding device; in shop language "it is a tool which bites like a dog—it holds to its grip—you can't shake it off."

A *dog-chuck* is one containing independent jaws or chucks. Many lathes are supplied by the makers with a four-jaw chuck of this kind. These are, as a rule, much larger and stronger than the self-centering chucks, being of as great a diameter as the lathe will conveniently take. They are very useful for holding heavy castings, such as cylinders, cylin-

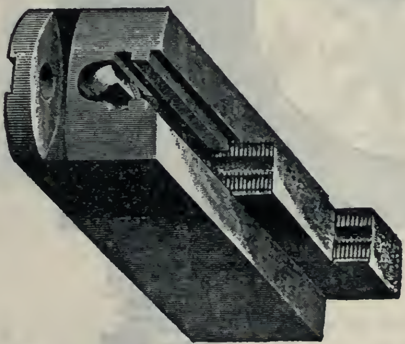


Fig. 256.

der covers, wheels, couplings, pulleys, etc., which have to be bored or faced. Moreover, as each jaw can be moved in or out independently of the others, these chucks enable the work to be held so that, if desired, holes may be bored in out-of-center positions, as in the case of an eccentric for a steam engine.

NOTE.—Work held between the lathe centers is said to run true when a fixed point set to touch its outside rim will have an equal degree of contact all around the circumference; and when the work is cylindrical at any part of the length of the same when it is rotated.

CHUCKS AND MANDRELS.

A modification of this independent-jaw chuck is found useful in chucking irregular work; four "dogs" of the form shown in fig. 257 are used, bolted by the nutted stud to the chuck-plate; the operation of the long set-screw holds the work.

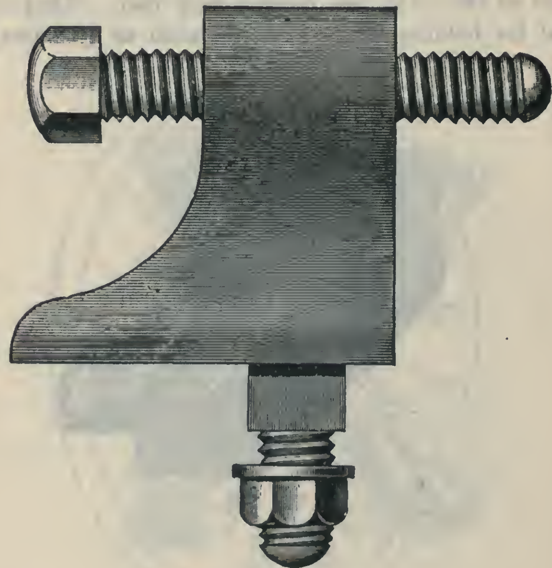


Fig. 257.

A very useful chuck is formed by bolting an angle plate, such as shown in fig. 308, to the face plate, as work which cannot be secured in the other forms of chucks may be bolted to the angle plate, and adjusted to the position desired.

Another form of chuck which depends upon adjustable screws for holding the work is the bell chuck, shown in fig. 258; this is a casting made in the shape of a bell, which at the back is bored and screwed to fit the lathe spindle; the

CHUCKS AND MANDRELS.

work is held by the screws *AAAA*, which are placed at intervals round the bell portion of the casting; these are generally four in number, although sometimes three are used.

In the sketch two sets of screws are shown, one set behind the other; this enables work of considerable length to be adjusted centrally, while the work is more securely held than it could be by one set of screws.

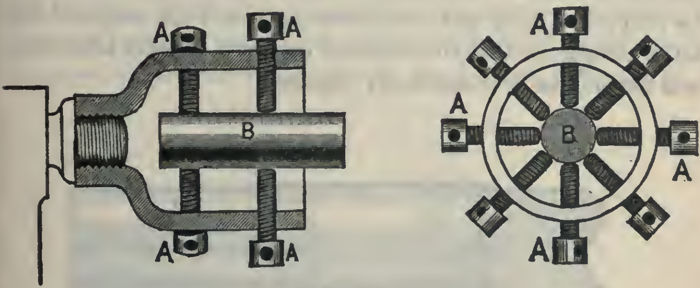


Fig. 258.

When work is heavy at one side, or when an angle plate is used in chucking, it is necessary to bolt a counterbalance on the face plate opposite the heavy part; the distance from the center of the lathe to the heaviest part of the work should be the same distance to the center of the counterbalance, otherwise the work will run "out of true," and will not be round.

Note.—The main points to be looked to in construction of a lathe are, that the tail-stock shall fasten to the bed in true line with the counter-line of the live spindle, and that the locking of the dead center spindle shall not cause that spindle to deviate from that true line. The slide-rest must be so fitted to the shears that it will, in traversing along the latter, move parallel to the same lines. As the head and tail-stock of the lathe are firmly bolted to the bed, it follows that the weak point in the connection of the parts lies in the manner of adjusting the carriage, or saddle, as it is sometimes called, to the bed.

CHUCKS AND MANDRELS.

Fig. 259 is a mandrel. This consists of a round turned bar, correctly centered at the ends, and turned to size so as to run perfectly true between the lathe centers. The two ends of the bar are rounded, or turned to a smaller diameter than the body, to suit the carrier and to prevent the blows used in driving the mandrel into work bruising the edges; it is well also to file a flat on each of these end portions, to receive the point of the carrier screw. The central portion of the mandrel is made slightly tapering, so that it may drive tightly into the hole in the work. It is important that the centers at each end be properly drilled and countersunk, to suit the angle of the lathe centers, so that the mandrel may run equally true when end for end, as is occasionally required.

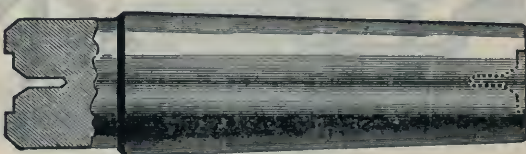


Fig. 259.

Cast steel is the best metal to use for mandrels, as the ends may then be hardened, and so keep the center holes from wearing out of truth. If this plan is adopted, the central portion should be left rather large at first, and should be turned down to size after the ends are hardened, to insure its running perfectly true; failing this, however, mild steel answers very well for most purposes. The length is not very important, provided that they are long enough to allow comfortable room for the slide-rest to be manipulated, but not so long as to bend when being driven into the work, or as to spring when the cutting pressure of the tool is applied.

Mandrels should be treated very carefully if they are required to retain their truth, and they are of little value unless perfectly true.

CHUCKS AND MANDRELS.

The surface of the mandrel which fits the hole in the work should be rubbed with a little oil to prevent it binding too tightly, and the mandrel may then be driven in with a hammer. It is important that the blows of the hammer should not bruise the end of the mandrel, and so spoil the center hole; this may be avoided by using either a lead or copper hammer, or by placing a piece of brass or copper between the hammer and the mandrel end to receive the blow.

When it is required to remove the mandrel after the turning has been done, it may be driven out from the opposite end in a similar way, but a piece of lead should be placed under the work to prevent any injury to the finished surface. If a

Fig. 260.

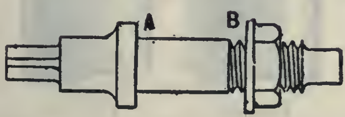


Fig. 261.

mandrel is being driven in or out of a pulley with light arms, or any other job liable to be damaged by the blows, care should be taken to support it close round the hole through which the mandrel passes, so as not to allow the strain of the blows to come on the fragile parts.

Fig. 260 shows another type of mandrel on which the work is held tight, not by being driven on the mandrel, but by being clamped between the shoulder, *A*, and the adjustable nut and washer, *B*. Fig. 261 shows a mandrel which is useful for holding work through which a threaded hole passes, or for holding nuts for facing and chamfering. If the threaded portion of the mandrel be made sufficiently long, the work may be locked in position by a nut screwed up against it on the outside; though this is not usually necessary, as the work can be screwed hard up against the mandrel shoulder, and the cutting pressure only tends to tighten it. The mandrel shoulders in the types shown in figs. 260 and 261 should be accurately faced up true to insure good work.

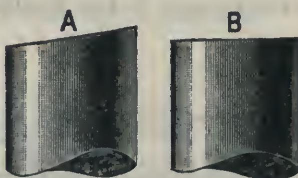


Fig. 262. Fig. 263.

CENTERING FOR THE LATHE.

The operation of preparing a piece of iron or steel for running properly between the lathe-centers requires a provision in the objects to be rotated to receive the center-points of the lathe, *i. e.*, the live and dead centers; these are conical holes, made to fit exactly the lathe "points" or centers.

In "centering," the following method should be adopted: Supposing the work to be centered is a round piece cut off a bar, the first thing is to file both ends practically square, as shown in fig. 263; on no account should the ends be left as at *A*, fig. 262; then fix the piece end up in the vise, and rub the top end over with a piece of chalk; next take a pair of odd leg

LATHE PRACTICE.

calipers, open them approximately half the diameter of the bar to be centered, and scribe or mark from opposite sides; these markings will act as a guide to the center-punch in pricking for the center hole.

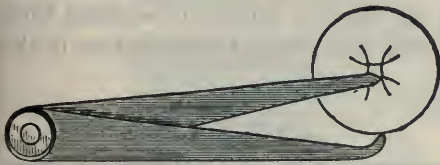


Fig. 264.

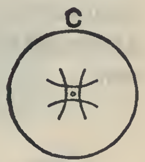


Fig. 265.

A *center-square* is shown in fig. 266; this instrument is made of sheet steel, about one-quarter inch thick, forming a right angle, having a longer blade riveted to it, in such a position that one edge exactly divides the right angle into two equal angles of 45° each; this device is used as shown; the dotted circles represent the ends of any size of circles.

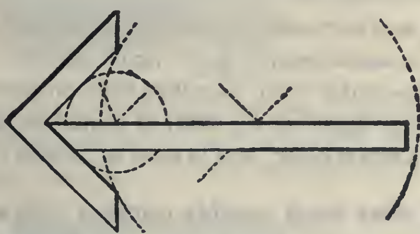


Fig. 266.

The work having been roughly centered up, it should be placed rather loosely between the centers without a carrier, and lightly spun round by the fingers. It will at once be apparent whether the centering has been correctly done or not. If the work runs out of truth, a piece of chalk should be held close to it while it is being spun round, so as to touch the side which runs farthest out from the center.

LATHE PRACTICE.

The work should then be fixed again in the vise, and the center-pop drawn over by careful use of the center-punch towards the side marked by the chalk. The work should again be placed in the lathe and the process repeated until the desired accuracy is obtained. If, however, the center has been carefully marked out with the calipers or scribing block as already indicated, it will need little or no correction in this way.

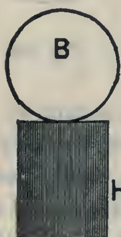


Fig. 267.

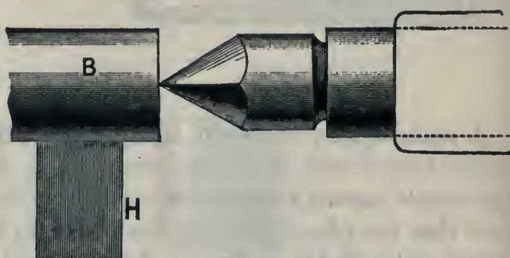


Fig. 268.

In rapidly and accurately centering a number of pieces of work, the "square-center" is of much service. This is an ordinary lathe-center with four flats filed on the point, so as to form cutting edges, see fig. 268; it should be hardened and tempered to a straw color, and is used as follows:

The work, after being roughly centered with a punch, the marking out process not being necessary, is fitted with a carrier and placed between the centers, the ordinary dead center of the lathe being replaced by the square center; a square end bar, *H*, is fixed in the slide-rest, and is then gradually brought to bear against the work, *B*, while the latter is running round as in fig. 268; at the same time the square-center is fed up against the work, and as the latter is being forced to run true by the pressure of the bar in the slide-rest, a correct center hole is cut.

Fig. 267 is an end view showing work, B, and square bar, H.

CENTERING FOR LATHE.

Some prefer to use a fork-ended bar to press against the work, as keeping it under better control, but with ordinary care the plain end is quite sufficient.

The work having been correctly centered, the next process

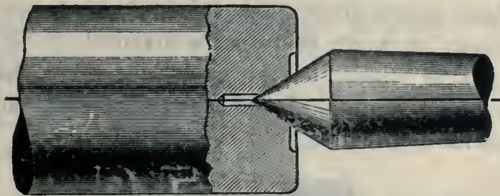


Fig. 269.

is to drill at each center "pop" a small hole about one-sixteenth inch diameter; this hole should be larger or smaller than the size mentioned, according to the work, and should

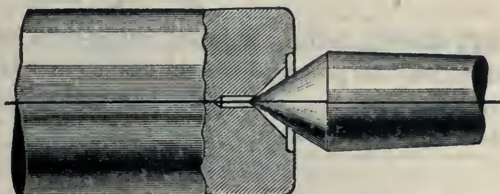


Fig. 270.

not be more than one-fourth inch deep; the object of this hole is to allow the extreme point of the lathe center to clear at the bottom; next, each of these holes should be countersunk

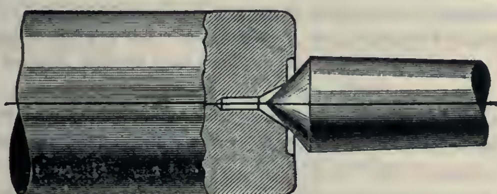


Fig. 271.

to the exact angle of the lathe center, say 60°, as shown in fig. 269, which represents the centering correctly done, and the work being evenly on the lathe center.

CENTERING FOR LATHE.

Fig. 270 shows the countersink at a greater angle than the lathe center; this is not right, and would soon wear untrue. Fig. 271 is too small an angle, and should not be permitted; it will cause heating of the center and will wear out of truth.

The best way to accomplish this is by means of a countersunk center bit to fit in the lathe mandrel; it is simply an ordinary lathe center filed away to slightly less than half its diameter, and then hardened and tempered; an ordinary countersunk drill will answer the purpose.

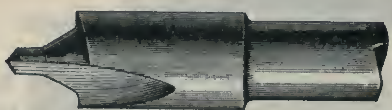


Fig. 272.

Fig. 272 shows a useful combined center-drill and countersink, which may be procured of tool dealers at a trifling cost; it fits in the chuck, and will both drill and countersink the center-hole at one operation.

NOTE.—Very many machinists when centering up a piece of work simply smooth up the end with a file and make a "center-pop" with a hammer and center-punch as near the middle of each end as they think correct. This method of procedure may give rise to one or more of the following troubles when the job is being turned: (1) The work may be a good deal out of truth when first starting turning, which makes the first cut very uneven in character, or prevents the work from cleaning up to the proper diameter; (2) the work may run out of truth after being partially turned; (3) the work may not run true when changed end for end between centers; (4) the turned portions may be oval, instead of being truly round.

The first of these troubles is obviously due to the "center-pop" being incorrectly placed; the second will be due to the fact that the point of the lathe center rests at the bottom of the "center-pop," and is not supported at the sides, thus not having a proper bearing, and consequently being free to shift about as the cutting pressure is applied; the third trouble will arise if the "center-pop" at the dead center wears, as above suggested; if the fourth trouble is found to exist, the cause will be because the end of the work has not been filed at right angles to the axis before centering up, thus causing the lathe center to have more bearing on one side than the other.

DRIVING WORK BETWEEN LATHE CENTERS.

Before the work is put between the centers, observe whether the live center runs true in its place; if not, take it out and replace it again; if it cannot be got to run true, it must be trued up in its place.

The centers for turning straight work must be "in line"; they can be set in line by sliding up the tail-stock and bringing the centers together, and adjusting the dead center; now, clean the ways and slides, oil the bearings thoroughly, and the lathe is ready for service.

When a piece of work has been centered and placed in the lathe ready for turning, it is obvious that some sort of contact

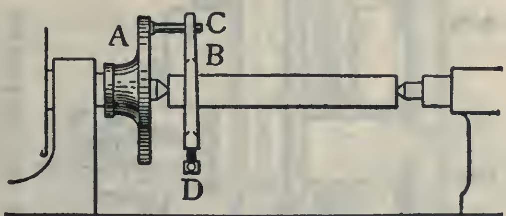


Fig. 273.

or connection must be established between the work and the lathe mandrel, so that the latter can "drive" or carry round the former as it revolves. This connection is usually provided by means of the face-plate or "driver-plate" of the lathe, and a "carrier" or "dog" on the work.

Such an arrangement is shown in fig. 273.

Fig. 274 is a perspective view looking down on a lathe in operation.

Fig. 275 shows an end view of a lathe with the cutting tool in operation on a round shaft; the cutting tool is held firmly in a tool-post in an upper sliding rest, as shown in sketch; there is a lower slide-rest with a travel at right angles

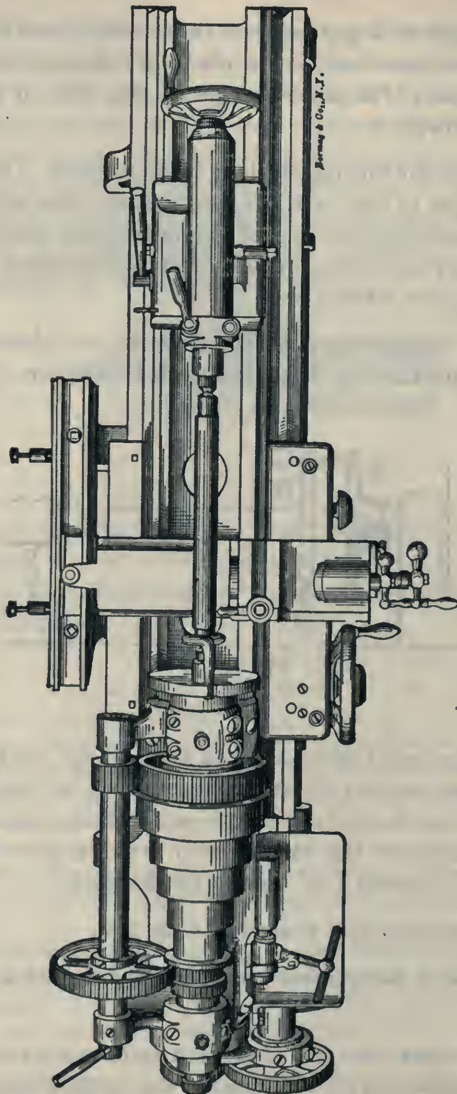


Fig. 274. See page 305.

DRIVING WORK BETWEEN LATHE CENTERS.

to the upper one, which is attached or bolted to the carriage, and has V-grooves on its under side, by which it slides on the parallel V-ribs on the bed. The construction of the shears and bed of the lathe is shown in section.

An example of an "elevating-rest" is shown in fig. 208;

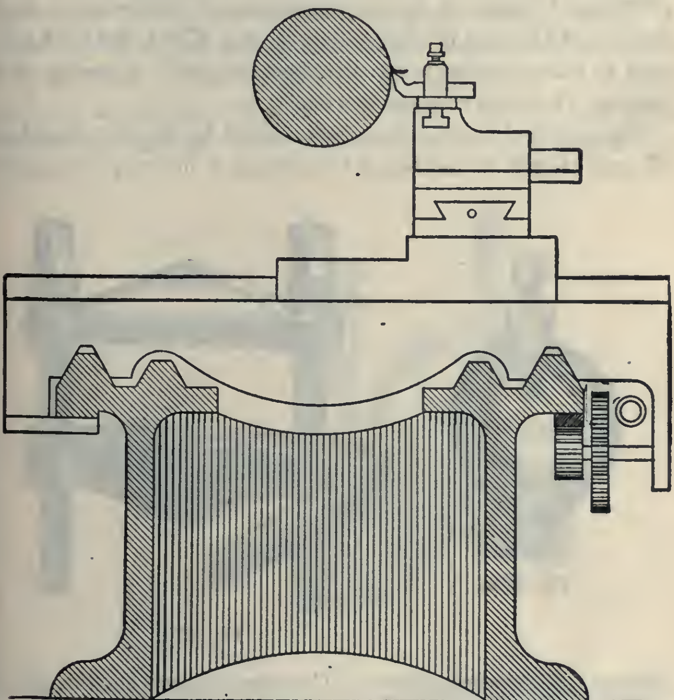


Fig. 275.

the object aimed at in this form or addition to the carriage of a lathe is to raise or lower the end of the rest by a screw, and thus to regulate the cutting point of the tool to the height required by the work being operated upon.

Fig. 273 shows a side view of the work between the lathe centers; *A* is simply a small circular plate which screws on to the live spindle, and has a driving pin, *C*, screwed or riveted into it at right angles near its outer edge. The car-

DRIVING WORK BETWEEN LATHE CENTERS.

rier or dog, *B*, is firmly fastened to the end of the piece of work to be turned by means of the set screw, *D*. It will be seen that the pin, *C*, catches the projecting tail of the carrier, and thus drives the work round as the mandrel revolves. The shape of the "dog" shown will be more clearly seen on referring to page 6, in the beginning of this book; a modification of the dog is often used, see fig. 275a; the bent tail is used in direct connection with the face-plate *A* (see fig. 273), the pin, *C*, being dispensed with.

The point of the carrier screw should be slightly chamfered off, and should be hardened to prevent it burring over by the

Fig. 275a.

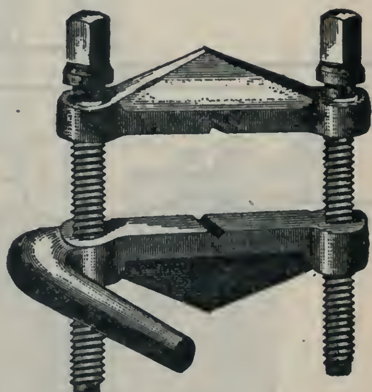


Fig. 276.

constant tightening down. Carriers such as shown in this sketch should be of various sizes, and, of course, each size of carrier will accommodate different sizes of work within its limits.

When turning long, thin shafts or spindles, the pressure of the driving pin, being exerted only at one end of the carrier, tends to bend the work. This may be overcome by the use of a face-plate having two driving pins, one pressing at each end of the carrier.

For very small and also for large work, the form of carrier described has its disadvantages; thus, not only is it difficult

DRIVING WORK BETWEEN LATHE CENTERS.

to properly grip very small work, but the carrier is heavy and unwieldly in proportion to the size of the work; in such cases a pair of wrought or malleable cast iron clips, as shown in fig. 276, are useful; the work is gripped in the V-shaped notches, pressure being applied by tightening the screws, the holes in the upper bar in the sketch being plain clearing holes, the screws being tapped into the corresponding holes in the lower bar; the bars should be made of wrought iron or mild steel, and of a size in proportion to the work. One of the straps should be provided with a projection or horn to act as a driver.

Fig. 277.

Fig. 277 shows an improvement on the above; the tightening screws are pivoted to one of the clamps, and the pressure is applied by the nuts, as shown.

The advantage of this arrangement is that a taper cone or irregular piece of work can be held with the jaws, which accommodate themselves to the work, which cannot be done by the arrangement in fig. 276.

For light work of a large diameter which has not to be subject to a very heavy cut, an ordinary collar with a set screw makes a convenient form of carrier, as the driving is

DRIVING WORK BETWEEN LATHE CENTERS.

done through the set screw, which has all the strain; this is not suited for heavy work, but for light jobs it is frequently of service.

When a large job has to be driven between centers, which though small enough to easily clear the lathe bed will not

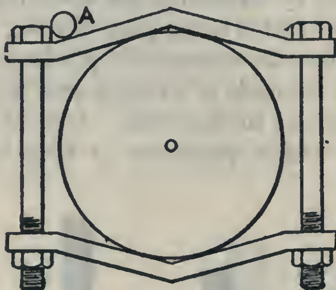


Fig. 278.

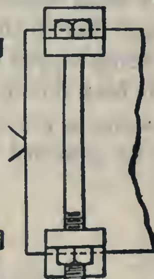


Fig. 279.

admit of much projection of the carrier, the usual device is a pair of "straps," as they are termed, as shown in fig. 278.

The driving pin of the chuck-plate will then fit against the strap next one of the bolt heads, as shown at *A*. It will probably be found that the ordinary chuck-plate is too small for a job

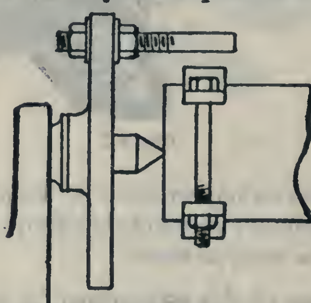


Fig. 280.

of this size, in which case one must be improvised by using the face plate. This can be done by inserting an ordinary bolt through one of the slots, or holes, in the face plate, and fixing it up in place with nuts and washers, as in fig. 280. The head of the bolt should be previously cut off with a hack-

DRIVING WORK BETWEEN LATHE CENTERS.

saw, so that the body of the bolt may engage directly against the strap.

A neat method of driving, for bolts with hexagonal or square heads, is shown in fig. 281. An iron plate, *B*, bent as shown, is fastened to the face-plate, *A*, by the bolt *C*. The lower end of the plate is cut out to fit over the head of the bolt, as shown in the end view, fig. 282.

It often happens that the screwed part of a bolt, or that finished work, has to be held by a carrier, while the operation

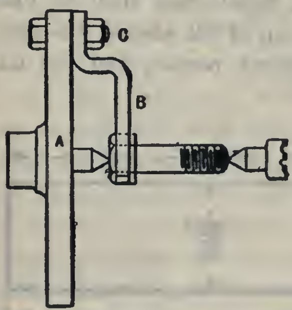


Fig. 281.

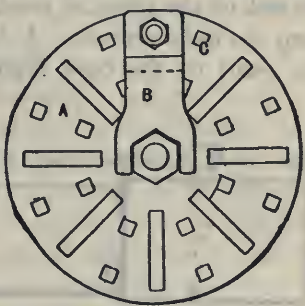


Fig. 282.

is performed on the other end, then a piece of sheet-brass or copper should be bent into a ring, and placed between the end of the screw in the dog and the work, to prevent damage to the latter.

TURNING WORK BETWEEN CENTERS.

Taking, as a practical example in lathe turning, a plain wrist-pin suitable for an engine cross-head, as shown in fig. 283, the operator-machinist should proceed as follows: He

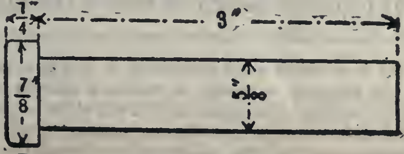


Fig. 283.

TURNING WORK BETWEEN CENTERS.

should select a piece of mild steel or wrought iron somewhat longer than the finished wrist-pin required; the diameter of the piece of steel chosen should also be slightly larger than the diameter of the head of the wrist-pin; as the latter is seven-eighths inch, a piece of steel 1 inch in diameter should be used.

The first operation is to square up the ends with a file, and mark off, drill, and countersink the center holes as described on page 269; this done, a suitable carrier should be affixed to one end of the piece of steel, which may then be placed between the lathe centers. A drop of oil should be applied to the point of the dead headstock center, and the latter

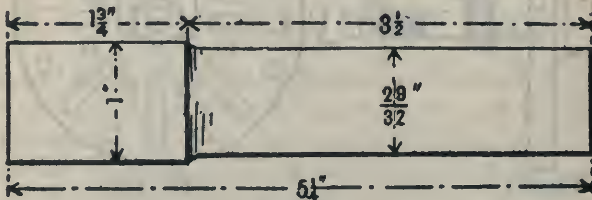


Fig. 284.

should then be tightened up until the work can be easily moved round with the fingers without there being any vibration. A front turning tool, preferably of the swan-neck form, shown in fig. 217, should then be fixed in the slide-rest, and the lathe started.

Now, take a cut along the work for a distance of about three and one-half inches, as shown in fig. 284, that is about one-fourth inch longer than the wrist-pin is to be when finished; this cut should be deep enough to reduce the diameter of the

NOTE.—If economy in material is not important, it will be found convenient, in making a pin of the dimensions shown, to choose a margin of one and three-fourths inches, in the length. This extra length will allow ample space between the centers to manipulate the slide-rest without interfering with the carrier, and will avoid reversing the work, end for end, in order to reach the various portions of the job with the tools.

TURNING WORK BETWEEN CENTERS.

work to one-thirty-second over seven-eighths inch, thus leaving enough material to enable a light finishing cut to be afterwards taken over the portion forming the head of the wrist-pin; then run the tool back to the end again and take another cut along for a distance of three and one-eighth inches, as shown in sketch—fig. 285; this cut should be repeated until

Fig. 285.

the diameter of this part of the work is reduced to about one-thirty-second inch over five-eighths inch, the finished size. A light finishing cut, with plenty of soap and water applied to the cutting edge of the tool, should then be taken, to reduce it to an exact five-eighths inch diameter. The head of the piece may then also be finished to its exact diameter. The front tool should now be removed from the slide-rest, and a right-hand, knife-edge side-tool, fig. 233, inserted, with which the shoulder "*a*" in sketch, fig. 286, may be cut out, square.

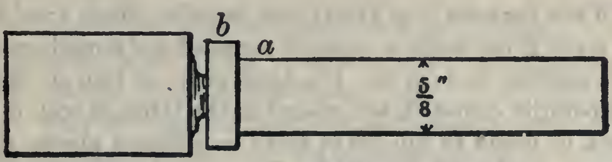


Fig. 286.

Now, substitute a parting tool, fig. 235, for the side-tool, and cut down the head of the wrist-pin, as shown at "*b*" to its correct thickness, one-fourth inch; this cut should not be taken too deep at first, as it will weaken the work, and may cause it to fracture.

Note.—When finishing wrought iron or steel plenty of soap and water may well be applied to the tool, as it imparts a bright, smooth finish to the work aside from its cooling property

TURNING WORK BETWEEN CENTERS.

Now, round the head of the piece at the corner, according to the drawing, fig. 283; a straight tool will do this well; now, use the right-hand side-tool to cut the body of the pin to its exact length, three inches, as in drawing, fig. 287; a small portion of metal should be left round the center hole at *c*, whereby to support the work until finished.

The parting tool is now again brought into use, and the metal at "*d*," see fig. 287, cut down until it almost breaks off; the work may then be removed from the lathe, and the piece is broken away from, or cut off, with a hacksaw; the portions of metal at "*c*" and "*d*" can be easily removed with a file, or, as is more usual, the work is placed in a self-centering chuck, and finished off at the ends with a side tool.

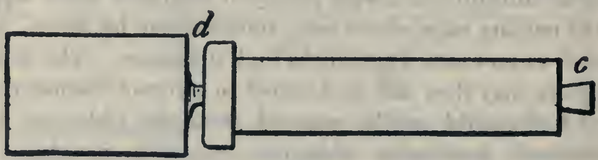


Fig. 287.

When turning long shafts and spindles, much trouble will be saved if the work is properly centered and straightened before starting to turn it. If a long piece of iron or steel be temporarily centered, and placed in the lathe, it will, in most cases, be found to run out of truth in different places; should it run out of truth equally throughout its length, it is obvious that the reason is that the center holes are not correctly placed at the ends. In some cases, however, the ends may run true, but the shaft may still be out of truth at other places; this is because it is bent, and therefore it will be necessary to straighten it before commencing the actual turning.

NOTE.—The object of cutting the work back at "c" in this case is to avoid retaining the center hole in the end of the pin; in work of this kind it would look unfinished if the center marks appeared.

TURNING WORK BETWEEN CENTERS.

When dealing with such a shaft the first thing is to center the ends so that they may run true, then to ascertain which way the shaft is bent.

Now, take a piece of chalk between the fingers of the right hand and hold it steady, close to the surface of the shaft, the shaft being meanwhile spun round between the centers by the left hand, or if too heavy for the hand rotate it, by a carrier or driver in the ordinary way; if held close enough, as the shaft revolves the chalk will touch that side of the shaft which is farthest away from the line of centers, thus indicating that the shaft is bent outwards at that point.

Two such bends are shown, slightly exaggerated, at *A* and *B* in the shaft drawn in fig. 288. These points being marked, the shaft should be taken out of the lathe and laid over two

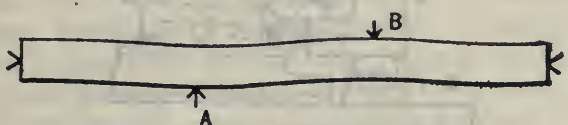


Fig. 288.

blocks of iron, placed a few inches apart, one of the chalk marks on the shaft being uppermost and over the space between the blocks. Two or three smart blows on this mark from a hammer will tend to straighten this particular bend, and, the other bends having been similarly treated, the shaft may be replaced between centers and again tested with the chalk. Very few trials of this kind are generally sufficient to correct the inaccuracies, and the turning may then be proceeded with.

A long thin shaft or spindle will bend or spring considerably under the pressure of the cutting tool unless it be provided with some other support in addition to the lathe centers. In self-acting lathes, where the slide-rest is carried on a saddle which slides along the bed, a "follow rest," as illustrated in fig. 289, is usually provided. This consists of a pillar fastened

NOTE.—Belt-driven, screw and hydraulic devices are especially designed and used with great efficiency for straightening shafting and round iron.

TURNING WORK BETWEEN CENTERS.

to the lathe saddle, and carrying in a recess two hardwood or gun-metal blocks, *C C*, which are bored out to suit the diameter of the shaft being turned. These blocks are fastened in place by set screws and cap, *D*.

Fig. 53 shows an enlarged view of the plan of a "steady rest," as described, and fig. 54 is a side view of the same device.

It will be noticed that the shaft revolves in V-shape bearing, as shown in fig. 53; this shape has an advantage over a round hole, because the V-bearing can be adjusted to accommodate several different sizes of shafts.

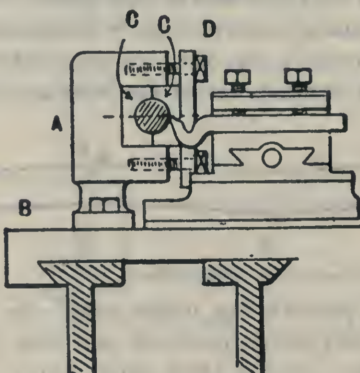


Fig. 289.

To use this appliance, the end of the shaft is first turned to the right diameter for a distance of two or three inches. The turned portion is then passed through the blocks, *C C*, and is also supported by the back center in the usual way. As the saddle carrying the turning tool travels along the lathe bed, so this bearing, as it really is, travels with it, and thus forms a constant support, immediately behind (*i.e.*, to the right-hand side of) the cutting tool.

NOTE.—It is frequently desirable to leave the center holes in the work, as at some future time it may be necessary to again put the work in the lathe to effect a repair or an alteration. It is very usual to leave the centers in such work as three throw-cranks, etc. As a guide for re-turning them, in some work of this class it would be very difficult to re-center the work should the original centers be removed.

TURNING WORK BETWEEN CENTERS.

The turning of crank pins, on crank shafts, presents more difficulty than the ordinary run of lathe work; in fig. 290, to turn a crank pin, *A*, in the lathe, it is obvious that it should revolve in line with the lathe centers, *B B;* provision for this is made by fixing plates, *c c*, on the ends of the crank shaft, and drilling center holes in the plates in line with the center of the crank pin to be turned.

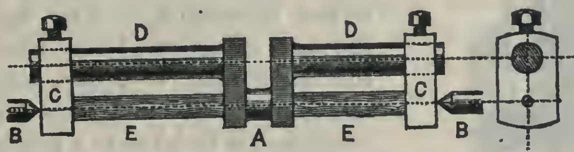


Fig. 290.

The main portions of the crank shaft, *D D*, must first be turned, though not necessarily to their finished size; the plates, *c c*, must be bored out to be a tight fit on the ends of the crank shafts to which they are each further secured by a set-screw; the crank shaft is then laid on a surface plate or on the lathe bed, which will answer this purpose very well. If the sides of the crank webs have been truly planed, the crank may rest on these; but if not, it should be supported on the portions already turned, in the V-blocks, *A A*, as shown in fig. 291. The crank should be placed so that the webs lie in a horizontal position. A scribing block, *B*, with the scriber

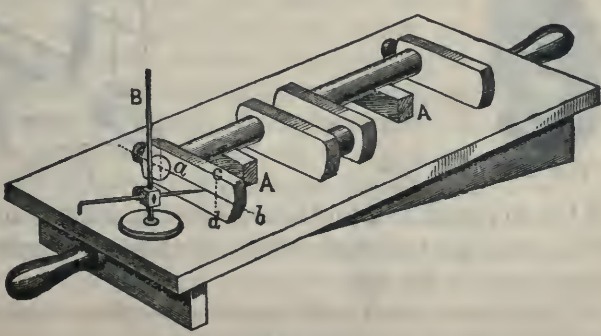


Fig. 291.

TURNING WORK BETWEEN CENTERS.

set exactly to the height of the center of the crank shaft, should then be used to make a horizontal center line, *a b*, across the outside face of each end plate. Care should be taken that the crank remains unmoved till this center line has been marked at each end.

Fig. 292.

It would be well to test the height of the centers at each end of the crank shaft with the point of the scriber beforehand, to make sure that the shaft is perfectly level. When both the center lines, *a b*, have been thus marked, the exact "throw" of the crank should be taken in a pair of compasses, and an arc, *c d*, described from the center hole in the crank end. The point of intersection of the lines, *a b* and *c d*, will then give the exact centers at each end from which the crank pin is to be turned. Center holes should be drilled and countersunk in the usual way at these points. The crank shaft may then be mounted in the lathe on these centers, and the crank pin turned.

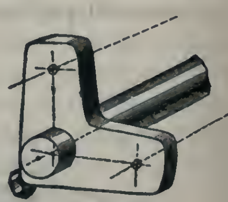


Fig. 293.

When the crank is a double one, with one crank in advance of the other, or at an angle with it, the plates are made with angular arms, as fig. 293.

A three-throw crank will require end plates with three arms placed at the angle of 120° apart.

TURNING WORK BETWEEN CENTERS.

When crank shafts are being turned between centers they are apt to spring under the pressure of the centers and of the cutting tool; this may be overcome by wedging in stout pieces of hardwood, *E E*, fig. 290, between the end plates and the faces of the crank webs. Large cranks, as a rule, are strong enough to be turned without extra supports.

In turning crank shafts the work as a whole is very much out of balance, and will require a counter balance weight on the opposite side of the driving plate of the lathe, and the crank itself must be prevented from rotating unevenly or jerking round between the centers by driving the end plate, which serves also as a carrier between two driving pins, one of which does the actual driving, and the other supports the weight when the crank overbalances in coming round.

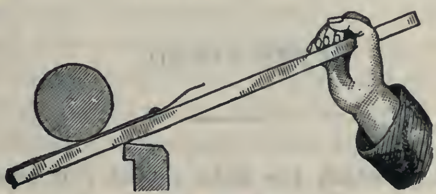


Fig. 294.

The surface of a fly-wheel, or pulley, may be finished off by using a hand scraper, or a " smooth " flat file. In the latter case, the speed of the lathe should not be too great, or the teeth of the file will be worn away very rapidly. Although the lathe may only be making a comparatively few number of revolutions per minute, the circumferential speed of the fly-wheel or pulley being turned may be considerable on account of its large diameter. On the other hand, spindles and other jobs of small diameter should be run at a high speed when being filed in the lathe, or there will be a danger of the file taking more off the work at one part of its circumference than at another, and thus spoil the roundness of the work; the final polish is usually obtained with a stick and a piece of emery cloth, used as shown in fig. 294. Here the stick, *A*, is supported on the tool rest, *B*, and presses the emery cloth, *C*, against the under side of the work, the leverage thus secured making it easy to apply sufficient pressure while the work revolves at a high speed. A coarse piece of emery cloth should be used to commence with, and this should be changed for a finer piece as soon as the file or tool marks are removed; for polishing wrought iron, cast iron, or steel, plenty of oil should be applied to the emery cloth; brass and gun metal are best polished dry. Very fine emery powder is sometimes used to give an exceptionally high degree of polish, but it is rarely necessary; a fine finish on brass or gun metal may be obtained by using polishing paste, spread over a piece of cotton waste; this should be held against the work while it is running at a considerable speed.

LATHE SPEED.

The speed at which the lathe should run when turning must, of course, vary with the size of the work, the depth of the cut and the nature of the metal.

Cast iron and cast steel require the slowest speeds; wrought iron and mild steel require medium speeds, and brass and gun metal the highest speeds.

If the work is run at too high a speed it will unduly heat the point of the cutting tool, and, by thus destroying its temper, will will make it too soft to cut; it is better practice to take moderately heavy cuts, at moderate speeds, than to take light cuts at high speeds or heavy cuts at very slow speeds.

Mild steel and wrought iron are best turned with the aid of a plentiful supply of soapy water, especially when taking finishing cuts. Cast iron, brass and gun metal should be turned dry. Oil is very useful as a lubricant for turning cast steel, while turpentine is a great help when using spring tools

LATHE SPEED.

with broad cutting edges. When turning castings of any description, the first cut should get right under the skin of the casting all round. If this is not done, the hard surface of the skin, and the sand which is always present therein, will speedily spoil the cutting edge of the tool, and necessitate its being re-ground. An old file may sometimes be used with advantage to remove the skin of the casting at the place where the tool starts its cut.

For the above reason special care should be taken, when boring castings, to get the hole as central in relation to the outer circumference as is allowable, so as to have the job run fairly true when mounted on a mandrel for turning. Their largest diameter on a job is usually turned first, and the smallest part last. If the diameter of the smallest part be turned down first, the strength of the job is reduced, and it is not so well able to stand the strain which results when the larger portions are being turned. It is easier to turn a cylindrical piece of work to exactly fit a hole, than it is to bore a hole to exactly fit a turned piece of work.

Where possible, therefore, the hole should be bored first, and the pin or spindle turned to fit afterwards. Always keep the loose headstock center well oiled, and always have both lathe centers turned to the same angle. When placing a piece of work between centers, see that the center hole and the center point are both free from grit or dirt; otherwise the work will not run true; the center in the mandrel revolves with the work; it therefore has no wear, and need not be hardened; each center should always be kept to its own end of the lathe, and always put it in the same position. One center-pop should be placed on the mandrel end, and another on the body of the center; by taking care that these marks are brought opposite one another when the center is inserted, the right position will be insured. A similar precaution should be observed with the tail stock or dead center.

CHUCK AND FACE PLATE WORK.

The face plate and the various chucks are largely used for holding jobs which have to be drilled or bored in the lathe; but in addition to this it frequently happens that a piece of turning has to be done which cannot conveniently be accomplished between centers, and which, therefore, has to be mounted on the face plate or in a chuck.

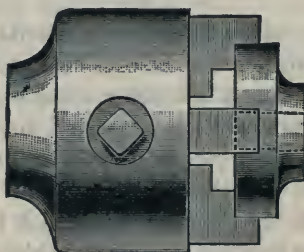


Fig. 295.

Fig. 295 shows the method of holding a small casting in the jaws of a self-centering chuck, upon which boring or end facing work has to be executed. Fig. 296 shows a similar chuck holding a ring or collar which has to be turned on the outside; in this lattter case the position of the jaws is reversed, and the work is gripped from the inside.

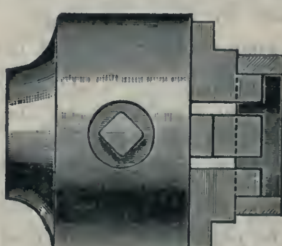


Fig. 296.

Fig. 297 shows a gland for the stuffing-box of a steam engine cylinder, held in a four-jaw dog-chuck.

CHUCK AND FACE PLATE WORK.

Fig. 299 is a front view, and fig. 300 is a side view, which shows a simple example of a face plate job; it represents a cylinder, *A*, fastened to a face plate, ready for bor-

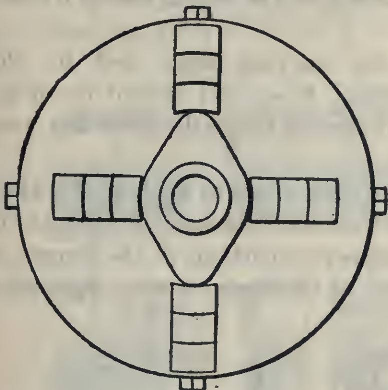


Fig. 297.

Fig. 298.

ing; *B B* are clamps, or clamping plates, *c c* are packing pieces which support the outer ends of these plates; these packing pieces should not be placed too close to the bolts, as the pressure of the screws will then act on the packing pieces

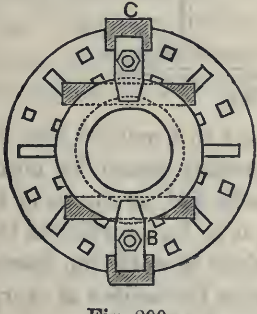


Fig. 299.

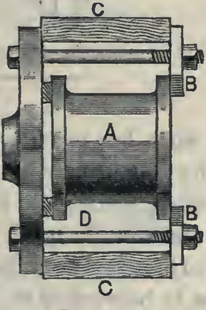


Fig. 300.

instead of on the cylinder, in which event it would be liable to slip and alter its position.

It will be observed that the cylinder itself is resting on two

NOTE.—The lathe bed must not be used for an anvil, nor yet as a resting place for tools, spanners, chucks, etc.; have a shelf, a cupboard, and a tool rack for this purpose. A good machinist never ill-treats his lathe, and always keeps it tidy, clean, and well adjusted.

CHUCK AND FACE PLATE WORK.

other packing strips, *D D*, which are used in order to keep the cylinder a short distance away from the surface of the face plate, so as to provide clearance for the boring tool as it comes through.

It is important that the packing strips used for this purpose should have parallel faces, and should be of exactly equal thickness, or otherwise they will throw the work out of truth.

When arranging the clamping plates in a job of this kind, care should be taken that they rest on a solid portion of the work, and not on the unsupported portions of the flanges, or the latter may be fractured by the pressure when tightening up.

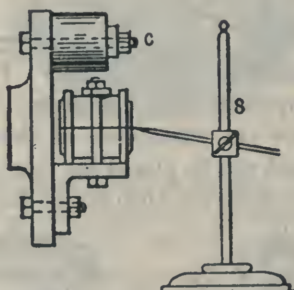


Fig. 301.

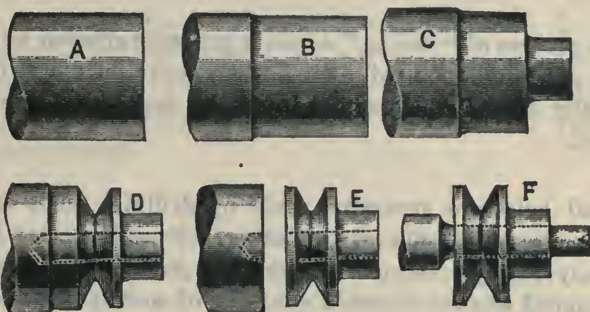
When work has to be bored out to a marked line, its position in the chuck may be accurately tested by means of a scribing block resting on the lathe bed, as shown in fig. 301. Another and equally good plan is to fix a scriber in the slide-rest and adjust the work in the chuck until the marked line which has to be worked to, touches the scriber at every point, as the chuck is slowly turned round by hand.

Fig. 302 to fig. 307 illustrates the method of boring and turning a small V-groove sheave from a solid piece of metal held in a chuck; sketch *A* shows the end of the metal to be used; *B* shows largest diameter turned; at *C* the diameter of the boss is roughed out and the hole bored; *D* shows the V-groove roughed out, and *E* the sheave cut off by means

CHUCK AND FACE PLATE WORK.

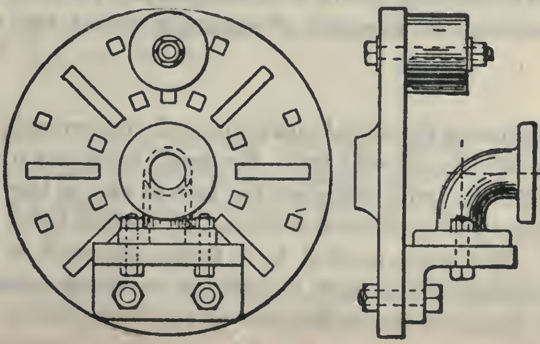
of the parting tool, and *F* shows it mounted on a mandrel for taking a light finishing cut.

Figs. 308 and 309 illustrate the use of an angle plate for mounting jobs for boring, which cannot conveniently be



Figs. 302—307.

clamped to the face plate in the usual way. The job to be bored and faced is bolted to the horizontal surface of the angle plate, and the latter is bolted to the face plate; work of this description requires a counterbalance, which is shown in the figure bolted to the face plate.



Figs. 308—309

DRILLING AND BORING IN THE LATHE.

The term "drilling" is usually applied to the making of a hole in solid metal by a drill which forms an aperture of the desired diameter at one operation.

The process of "boring" a hole is generally effected by the action of a single-pointed tool, the successive cuts of which gradually enlarge the opening until the desired diameter is reached.

Small holes are generally made by drilling, while large holes are usually produced by boring. To drill a large hole not only requires considerable driving power, but involves the removal of a considerable quantity of metal; whereas, if the method of boring is adopted, a rough hole may be "cored" through the casting when the latter is made in the foundry, and this can be subsequently enlarged to the required size by the application of a boring tool. Thus, if a certain size bore were required in a steam engine cylinder, the casting will be "cored" out a little smaller than the required size, and will be finished by boring, effecting a saving both in labor and material over the alternative method of drilling the hole out of the solid metal. Another advantage of boring is that a hole can be made to any odd size or to exactly fit any piece of turned work, without the necessity of making a special tool for the job.

In discussing the actual operations and appliances involved, drilling will be dealt with first. For small holes, say up to one inch diameter, twist drills are the best to use, as they can be depended upon to produce accurate and smooth holes, exactly to size. The usual method is to fasten the drill in a self-centering drill chuck, and to feed the work up against the drill by means of the back-center of the lathe or the sliding carriage.

DRILLING AND BORING IN THE LATHE.

The exact place for the hole should be marked off on the work, and a heavy center-pop should be made, so as to guide the point of the drill at starting; with large holes, a circle the size of the hole to be drilled should be marked with compasses, and four center-pops should be made at opposite points on the line; these are necessary to act as guides in case the line gets effaced; a start is then made, but before the point of the drill has fully entered the metal, an examination must be made to see if it is cutting truly with the circle marked out; if it is so doing the work may be proceeded with and the hole drilled.

It frequently happens, however, that the drill will have run slightly to one side; to remedy this a narrow groove must be cut down one side of the hole; this may be done with a narrow diamond-pointed chisel, and the groove should be made on the side towards which the hole requires to go, to be in the correct position; the drill may then be applied again, when the effect of the groove will be to draw the hole over towards the center of the circle. After a few turns of the drill the hole should be again examined, and, if necessary, the "drawing-over" process repeated, until the hole is truly central, when the work may be completed; it must be understood that this "drawing-over" should be done before the full diameter of the drill commences to cut, as the grooving plan can have no further effect in drawing over the hole after the full diameter of the drill enters the hole.

It more frequently happens that the relative positions of the parts described are reversed, and the work to be drilled is held in the chuck, and the drill is fed up to it.

In such a case the drill may be gripped in a guide to prevent it turning round, and the drill can be advanced or fed up to the work by means of the dead center; twist-drills are

DRILLING AND BORING IN THE LATHE.

provided with center holes at the shank, and for this especial purpose. When drilling a hole in this manner, it is very necessary to give the drill a true start, and this may be done either by the point of a tool in the slide-rest or by putting in the square center in the tail-stock, and feeding it up against the work, when it will readily cut a true starting center for

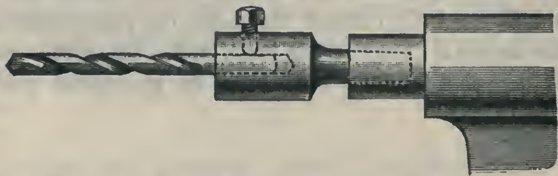


Fig. 310.

the drill; another method of drilling from the back-center is shown in fig. **310**, which represents a small drill chuck with a taper shank to fit in the place of the ordinary dead center.

When it is desired to enlarge a "cored" hole by means of a drill, it is essential that the drill be firmly held; this is usually done by fixing it in the tool holder of the slide rest; a cored hole never runs very true, and if the drill is not firmly

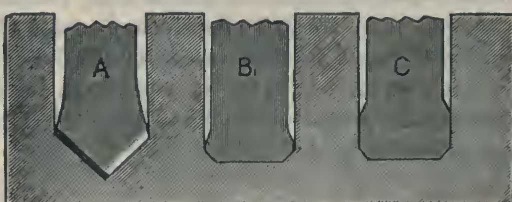


Fig. 311. Fig. 312. Fig. 313.

fixed in a central position the point will simply follow the course of the cored hole, and therefore the finished hole will be just as much out of truth. For work of this kind flat drills are usually employed; fig. 311 shows the "pointed" or first drill, used in solid work; fig. 312 is the "rougher," or enlarging drill, and fig. 313 is the "finisher."

DRILLING AND BORING IN THE LATHE.

The *rougher* and *finisher* have a short part past the corner parallel which guides the drill for a straight hole, whereas if the point drill were used to a cored hole it would follow the bend of the core.

The point is ground to an angle varying from 95° to 100°, and when used for wrought iron it is lipped a little, to make it keener.

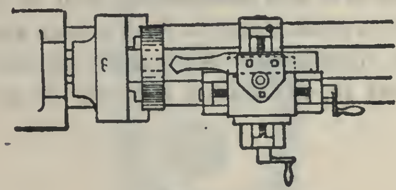


Fig. 814.

These drills work well at 20 ft. per minute, and a traverse of 150 down to 30 revolutions per inch.

The drill, when fixed in the slide-rest, where it must be "packed up" to the exact height of the lathe-centers, can be fed up to the work, either by means of the back center in the case of a saddle slide-rest, or by the feed screw of the rest itself in the simpler form of slide-rest. Fig. 314 shows a view in plan of the latter arrangement.

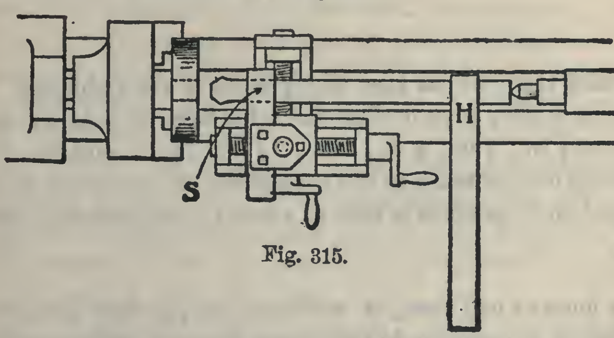


Fig. 315.

Another method of boring out cored holes, or enlarging drilled holes, is shown in fig. 315; here a flat drill, as used in the plan last described, is again employed, but is held in a different manner; instead of being firmly fixed in the slide-

DRILLING AND BORING IN THE LATHE.

rest, it passes through a slotted holder, *S*, which may be made in either of the two forms, *A* or *B*, shown in fig. 316. A center hole is made in the back end of the drill to receive the point of the back center of the lathe, which is used to feed the drill forward while cutting. The drill is kept steady by means of the hooked holder, *H*, the shape of which is shown in figs. 315 and 316, this holder being held in the left hand and pressed downwards while the back center wheel is turned round with the right hand. With drills of this kind a hole can be bored out to any desired diameter at one operation,

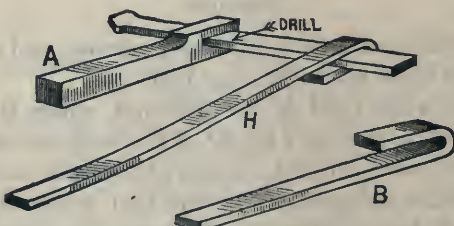


Fig. 316.

provided the drill has been first ground to the right size. It is usual to keep a set of these drills for holes of standard sizes, such as $\frac{1}{2}$ in., $\frac{5}{8}$ in., $\frac{3}{4}$ in., 1 in., $1\frac{1}{4}$ in., $1\frac{1}{2}$ in., and so on, as once the drill is made to the correct size it can always be depended on to produce a hole of exactly corresponding diameter.

In holes of odd sizes, or where an exceptionally good fit is desired, it is better to do the boring with an ordinary slide-rest boring tool, as shown in fig. 237.

When boring holes of small diameter, care must be taken that there is proper clearance at the under part of the cutting

DRILLING AND BORING IN THE LATHE.

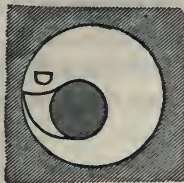


Fig. 317.

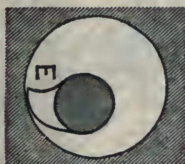


Fig. 318.

tool, as at *D,* fig. 317; otherwise, the tool will rub against the side of the work, as at *E,* fig. 318, and interfere with the proper execution of the work.

The first cut taken through the hole should be a fairly heavy one, so as to clean up the hole perfectly true all round. One or more lighter finishing cuts may be afterwards run through to bring the hole to the exact size required. Care should be taken to set the slide-rest perfectly true, so as to insure a parallel hole being bored. The hole should be carefully tested with a pair of inside calipers after the first cut has been run through, to make certain that this has been done. If the hole is found to taper either way, the slide-rest should be altered accordingly. With a self-acting feed, the hole ought to be perfectly parallel, provided the headstock and lathe bed are set true, the position of the slide-rest not affecting the work at all in this case.

Work which is too awkward in shape, or too heavy to be chucked or bolted to the face plate, may sometimes be bolted down to the saddle of the lathe and bored with a boring bar running between the lathe-centers. Engine and pump cylinders, field magnets for dynamos and motors, and the bearings of engine bed-plates, are examples of work which can be done with advantage in this way. It is, of course, necessary to have a lathe with a saddle and self-acting feed motion, unless a complicated boring bar fitted with its own screw-feeding motion is used.

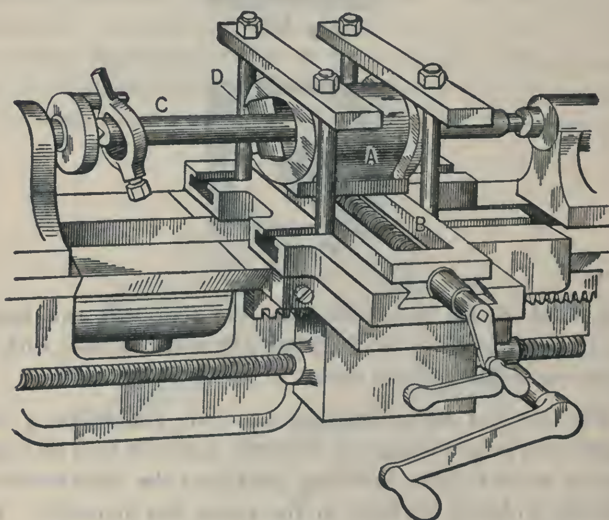


Fig. 319.

An engine cylinder fixed for boring in the above way is shown in the sketch (fig. 319). Here the slide-rest is removed from its usual place, and the cylinder, *A*, is bolted down to the lathe saddle, *B*. A cutter bar, *C*, carrying a cutter, *D*, revolves between the centers in the usual direction, while the cylinder is slowly carried along the lathe bed towards the fast headstock by the self-acting feed motion applied to the saddle.

It is obvious that the cylinder must be bolted down in correct position before the process of boring is commenced, and to facilitate this a circle should first be marked off with a

DRILLING AND BORING IN THE LATHE.

pair of compasses round the cored hole in the cylinder, showing the exact size and position of the bore when finished. This should be done at each end of the cylinder, a temporary plug of wood being inserted, on which the center for describing the circle from can be marked. The cylinder is then placed temporarily on the saddle, and the boring bar put between the centers and through the cylinder, as in fig. 320. A pointed scriber, *S*, is wedged on the cutter slot in the bar, so that when the bar revolves the point, *S*, describes a circle of the same diameter as that marked on the cylinder. The cylinder

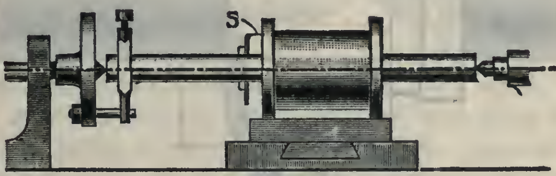


Fig. 320.

is then adjusted in position until the scriber point exactly touches the circle on the cylinder at every point.

For the purpose of trying this the cutter-bar may be revolved by hand. The same test should be applied to each end of the cylinder until it is adjusted to the exact position desired, and the holding-down bolts may then be finally tightened up.

A scribing-block is made of special construction which can be bolted to the boring-bar and rotated with it, while the scriber tests the position of the circle drawn on the cylinder.

A side view of the arrangement of the cutter-bar generally used is shown in fig. 321; this should be made of cast steel, and should be hardened and tempered to a deep straw color.

DRILLING AND BORING IN THE LATHE.

The cutting edges are at *B B*, and proper clearance angles should be given, as shown in the drawing, the cutting edges sloping away in the opposite directions on each side; the extreme diameter, *A*, of the cutter exactly corresponds with the size of the hole it will produce; the cutter is fixed in a slot in the cutter-bar by means of the steel keys, or wedges, *c c*.

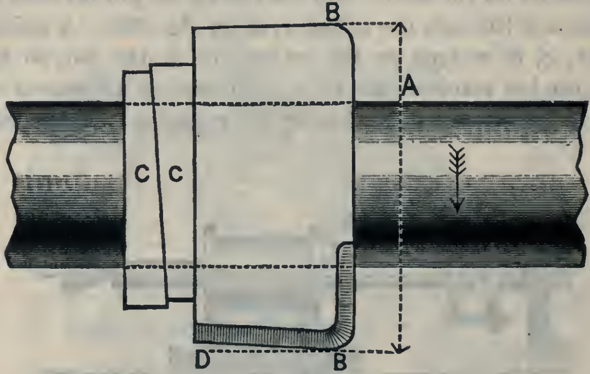


Fig. 321.

Fig. 322.

Fig. 322 shows an end view of cutter-bar in operation.

A more simple form of cutter is shown in fig. 323; this is made from a piece of round tool steel, fitting into a round hole in the cutter-bar, and it is fastened in place by a small set screw, *S*.

DRILLING AND BORING IN THE LATHE.

As the cutter-bar should be as large as possible, to secure adequate strength, and the cutter should not project more than necessary to provide proper cutting edges and clearance enough to prevent the cuttings clogging round the bar, there is not sufficient room left for a screw head to the set screw. This should therefore be cut off flush with the surface of the cutter-bar, and provided with a saw-slot to receive a screw-driver.

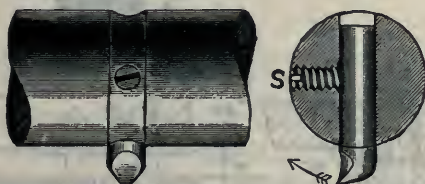


Fig. 323.

Fig. 324 shows a modification of this plan, which is applicable to cases where the hole to be bored is of large diameter compared to the cutter-bar. Here a cast-iron cutter-block, or collar, is keyed on to the cutter-bar, and the cutter itself is fastened into the collar by means of a small set-screw, as shown.

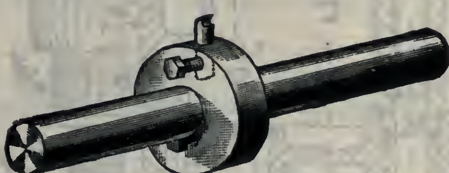


Fig. 324.

Cutters of the kind shown in figs. 323 and 324 have an advantage over the kind illustrated in fig. 321, inasmuch as the same cutter can be adjusted to bore holes of different diameters, or the cutter can first be set to take a rough cut through the job, and, after being nicely ground up, a second cut can be taken to finish. The fig. 321 type of cutter is very rigid in its action, and does excellent work; it produces holes of great smoothness and accuracy, but answers better for cast iron and brass than for wrought iron or steel, for which a somewhat keener cutting edge is necessary.

LATHE PROPORTIONS.

Fig. 325 is an illustration (partly in section) showing the construction, the proportions and measurements of the parts of a double-geared headstock, to swing eighteen inches diameter, nine inches center; the back gear, as shown in the figure, is operated by an eccentric shaft.

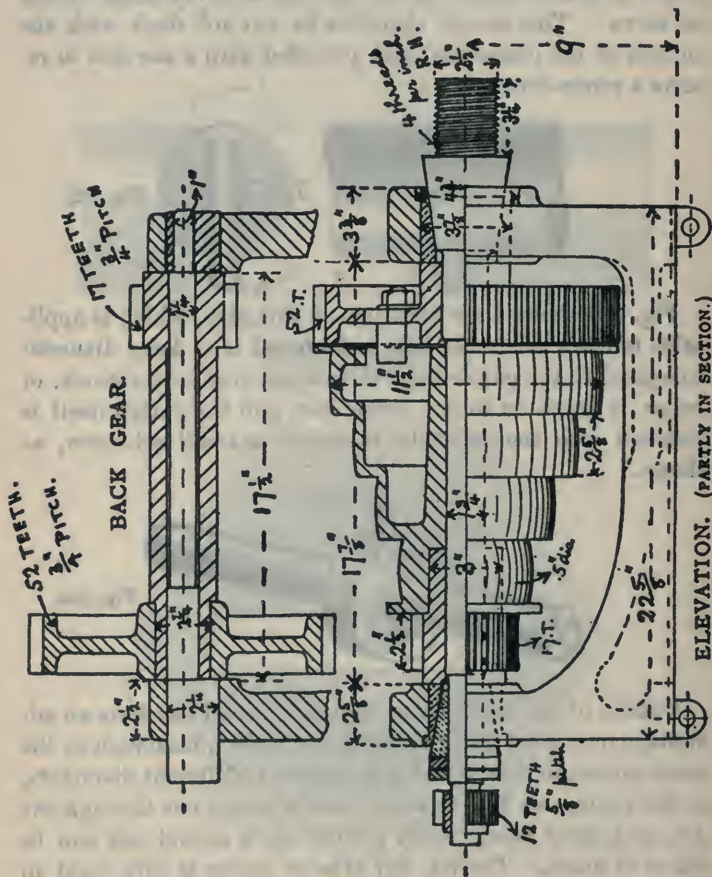


Fig. 325.

The sliding stud, or connection, which is used to fix the cone when driving the lathe direct, without the back gear, is also shown in the drawing.

SUMMARY RELATING TO THE LATHE.

Something more than one hundred pages of this volume have been given to the subject of the lathe and its operation; several full-page illustrations have been used which need a few words of explanation, which are added in the following paragraphs to which reference has been already made under the figures.

A triple-geared, self-acting, screw-cutting and automatic cross-feed lathe is shown in fig. 200, page 216. This is a tool intended principally for turning large diameters and surfaces, yet it is adapted for general boring, turning, screw-cutting, etc., and is provided with compound swivel tool-rest, with clamps for holding tools; in England the tool is described as a triple-geared, self-acting, sliding, surfacing and screw-cutting lathe.

A special characteristic of this machine is found in the application to the tail-stock or poppet-head of,

1. Gearing, in connection with the rack to slide the tail-stock by hand into position on the shears.

2. A geared adjustment, to operate the dead center in tightening or releasing work.

3. A sliding cross traverse to the upper portion, to permit of fine adjustment of out-of-line-of-centers, for taper turning—all as shown in the figure.

These attachments are only used on the largest lathes; the work operated on being heavy, the surface of shears is fixed close to the ground level.

SUMMARY RELATING TO THE LATHE.

Fig. 214, page 232, shows a triple-geared, self-acting, screw-cutting and automatic feed lathe, with revolving tool post and cupped washer, for regulating height of cutting tool.

This is a powerful lathe, although not as powerful as shown in fig. 200; the tailstock is actuated by a direct action pinion on hand lever; the shears rest on legs, or stools, raised above the ground level; all as shown in the illustration.

Fig. 240, page 244, represents a double-geared, self-acting, screw-cutting and automatic feed-lathe.

This is a general lathe for turning, boring and screw-cutting; has self-acting, longitudinal and cross-feeds, actuated by the splined spindle in front, on which is a worm, gearing into a screw wheel on carriage . It is also screw-cutting, being actuated by the long screw or shears in front of the rack; in England the same style of machine is called a self-acting, slide-surfacing and screw-cutting lathe.

The principal distinguishing feature of this tool is the fact that it has two automatic feed motions: 1, for ordinary traverse and cross-feed; 2, an independent feed for screw-cutting, both as shown on the front of the figure.

A double-spindle lathe, or elevated-spindle lathe, is shown in fig. 241, page 245; the arrangement of an elevated spindle in the lathe enables work of a large diameter to be performed in a comparatively small swing lathe; hitherto, when necessity occurred for performing work of a larger diameter than the lathe could swing, it was usual to block or pack under the heads and raise them up from the shears or bed; this necessitated the abandonment of the automatic feed screw, etc.; the substitution of the improvement of the extra elevated spindle enables the screw-cutting or feed motions to

SUMMARY RELATING TO THE LATHE.

be retained; thus a twenty-six-inch ordinary swing lathe, when provided with the improvement, will swing forty-eight inches.

This lathe is suitable for executing work of large diameters and of light weight; it is not suitable for heavy work or heavy cuts.

Fig. 243, page 248, illustrates a boring and surfacing lathe, arranged with duplex, compound hand slide-rests on pedestals or standards which are bolted to base plate.

This description of lathe is generally used for boring and turning pulleys, wheels of large dimensions, etc.

Fig. 274, page 272, shows a view looking down on a lathe.

In operation the workman stands with his face towards the lathe, the head-stock being on his left-hand side and the tail-stock at his right hand.

The left hand actuates the cross feed of the slide rest, the traverse feed being attended to by the right hand; the feed for the screw is thrown in and out of gear with the left hand, and the automatic traverse feed, when used, is generally operated by the left hand, the right hand adjusting the automatic cross feed.

The right hand is also used in adjusting the center of the tail stock, the left hand generally operating the left lever or countershaft.

It may be further explained, that this figure shows a double-geared, self-acting, screw-cutting and automatic feed lathe, as seen in side-view on page 244.

TABLES

AND

INDEX

USEFUL TABLES OF WEIGHTS OF IRON AND COMPARISONS OF GAUGES.

Weight of a Superficial Foot of Plate and Sheet Iron

Plate Iron.		Sheet Iron. United States Standard Gauge. Adopted by Congress, to take effect July 1st, 1893.			
Thickness.	Weight per square foot.	Number of Gauge.	1000's of an inch.	Weight per square foot.	Nearest fraction of an inch.
INCHES.	POUNDS.			OUNCES	
1/16 in.	2½	No. 1	.281	180 oz.	9/32 in.
1/8 "	5	" 2	.265	170 "	17/64 "
3/16 "	7½	" 3	.250	160 "	1/4 "
1/4 "	10	" 4	.234	150 "	15/64 "
5/16 "	12½	" 5	.218	140 "	7/32 "
3/8 "	15	" 6	.203	130 "	13/64 "
7/16 "	17½	" 7	.187	120 "	3/16 "
1/2 "	20	" 8	.171	110 "	11/64 "
9/16 "	22½	" 9	.156	100 "	5/32 "
5/8 "	25	" 10	.140	90 "	9/64 "
11/16 "	27½	" 11	.125	80 "	1/8 "
3/4 "	30	" 12	.109	70 "	7/64 "
13/16 "	32½	" 13	.093	60 "	3/32 "
7/8 "	35	" 14	.078	50 "	5/64 "
15/16 "	37½	" 15	.070	45 "	9/128 "
1 "	40	" 16	.062	40 "	1/16 "
		" 17	.056	36 "	9/160 "
		" 18	.050	32 "	1/20 "
		" 19	.043	28 "	7/160 "
		" 20	.037	24 "	3/80 "
		" 21	.034	22 "	11/320 "
		" 22	.031	20 "	1/32 "
		" 23	.028	18 "	9/320 "
		" 24	.025	16 "	1/40 "
		" 25	.021	14 "	7/320 "
		" 26	.018	12 "	3/160 "
		" 27	.017	11 "	11/640 "
		" 28	.015	10 "	1/64 "
		" 29	.014	9 "	9/640 "
		" 30	.012	8 "	1/80 "

USEFUL TABLES.

Weight of One Foot of Flat Rolled Iron.

Width.	THICKNESS.								
	¼	5/16	⅜	7/16	½	⅝	¾	⅞	1
½	.422	.528	.634	.738	.845				
⅝	.528	.660	.792	.923	1.056	1.320			
¾	.633	.792	.950	1.108	1.265	1.584	1.901		
⅞	.738	.923	1.108	1.294	1.477	1.840	2.217	2.588	
1	.845	1.056	1.267	1 478	1.690	2.112	2.534	2.956	3.380
1⅛	.950	1.187	1.425	1.663	1.901	2.375	2.850	3.326	3.802
1¼	1.056	1.320	1.584	1.848	2.112	2.640	3.168	3.696	4.224
1⅜	1 161	1.452	1.742	2.032	2.325	2.904	3.484	4.065	4.646
1½	1 266	1.584	1.900	2.217	2.535	3.168	3.802	4.435	5.069
1⅝	1.372	1.716	2.059	2.402	2.746	3.432	4.119	4.805	5.492
1¾	1.497	1.848	2.218	2.589	2 957	3.696	4.435	5.178	5.914
1⅞	1.584	1 980	2.376	2.772	3 168	3.960	4.752	5.544	6.336
2	1 689	2.112	2.534	2.957	3 379	4.224	5 069	5.914	6.758
2⅛	1.795	2 244	2.693	3.141	3.591	4 488	5.386	6.283	7 181
2¼	1.900	2.376	2.851	3.326	3.802	4.752	5 703	6.653	7 604
2⅜	2.006	2.508	3.009	3.511	4.013	5 016	6.019	7.022	8.025
2½	2.112	2.640	3.168	3.696	4.224	5.280	6.336	7.392	8 448
2¾	2.323	2.904	3.485	4 066	4.647	5.808	6.970	8.132	9 294
3	2.535	3.168	3.802	4.435	5.069	6.337	7.604	8.871	10.138
3¼	2.746	3.432	4.119	4.805	5.492	6.865	8.237	9 610	10.983
3½	2.957	3.696	4.436	5.175	5.914	7.393	8.871	10 350	11 828
3¾	3.168	3.990	4.752	5.544	6.336	7.921	9 505	11 089	12.673
4	3.380	4.224	5.069	5.914	6.759	8 448	10 138	11.828	13.518
4½	3.802	4.752	5.703	6.653	7.604	9 504	11.406	13.306	15.208
5	4.224	5.280	6.330	7.392	8.449	10.560	12.673	14.784	16.897
5½	4.647	5.808	6.970	8.132	9.294	11.616	13.940	16.264	18.587
6	5.070	6.337	7.604	8.871	10.138	12.674	15.208	17.742	20.276

USEFUL TABLES.

Weight of One Foot of Round Iron.

SIZE.	Weight pr. Foot.	SIZE.	Weight pr. Foot.	SIZE.	Weight pr. Foot.
	LBS.		LBS.		LBS.
1/8 in.	.041	1 7/16 in.	5.41	3 1/2 in.	32.07
3/16 ..	.092	1 1/2 ..	5.89	3 5/8 ..	34.40
1/4 ..	.164	1 9/16 ..	6.39	3 3/4 ..	36.82
5/16 ..	.256	1 5/8 ..	6.91	3 7/8 ..	39.31
3/8 ..	.368	1 11/16 ..	7.45	4 ..	41.89
7/16 ..	.501	1 3/4 ..	8.02	4 1/8 ..	44.55
1/2 ..	.654	1 13/16 ..	8.60	4 1/4 ..	47.29
9/16 ..	.828	1 7/8 ..	9.20	4 3/8 ..	50.11
5/8 ..	1.02	1 15/16 ..	9.83	4 1/2 ..	53.01
11/16 ..	1.24	2 ..	10.47	4 5/8 ..	56.00
3/4 ..	1.47	2 1/8 ..	11.82	4 3/4 ..	59.07
13/16 ..	1.73	2 1/4 ..	13.25	4 7/8 ..	62.22
7/8 ..	2.00	2 3/8 ..	14.77	5 ..	65.45
15/16 ..	2.30	2 1/2 ..	16.36	5 1/8 ..	68.76
1 ..	2.62	2 5/8 ..	18.04	5 1/4 ..	72.16
1 1/16 ..	2.95	2 3/4 ..	19.80	5 3/8 ..	75.64
1 1/8 ..	3.31	2 7/8 ..	21.64	5 1/2 ..	79.19
1 3/16 ..	3.69	3 ..	23.56	5 5/8 ..	82.83
1 1/4 ..	4.09	3 1/8 ..	25.57	5 3/4 ..	86.56
1 5/16 ..	4.51	3 1/4 ..	27.65	5 7/8 ..	90.36
1 3/8 ..	4.95	3 3/8 ..	29.82	6 ..	94.25

Weight of One Foot of Square Iron.

SIZE.	Weight pr. Foot	SIZE.	Weight pr. Foot.	SIZE.	Weight pr. Foot
	LBS.		LBS.		LBS.
1/8 in.	.052	1 7/16 in.	6.89	3 1/2 in.	40.83
3/16 ..	.117	1 1/2 ..	7.50	3 5/8 ..	43.80
1/4 ..	.208	1 9/16 ..	8.14	3 3/4 ..	46.88
5/16 ..	.326	1 5/8 ..	8.80	3 7/8 ..	50.05
3/8 ..	.469	1 11/16 ..	9.49	4 ..	53.33
7/16 ..	.638	1 3/4 ..	10.21	4 1/8 ..	56.72
1/2 ..	.833	1 13/16 ..	10.95	4 1/4 ..	60.21
9/16 ..	1.06	1 7/8 ..	11.72	4 3/8 ..	63.80
5/8 ..	1.30	1 15/16 ..	12.51	4 1/2 ..	67.50
11/16 ..	1.58	2 ..	13.33	4 5/8 ..	71.30
3/4 ..	1.87	2 1/8 ..	15.05	4 3/4 ..	75.21
13/16 ..	2.20	2 1/4 ..	16.88	4 7/8 ..	79.22
7/8 ..	2.55	2 3/8 ..	18.80	5 ..	83.33
15/16 ..	2.93	2 1/2 ..	20.83	5 1/8 ..	87.55
1 ..	3.33	2 5/8 ..	22.97	5 1/4 ..	91.88
1 1/16 ..	3.76	2 3/4 ..	25.21	5 3/8 ..	96.30
1 1/8 ..	4.22	2 7/8 ..	27.55	5 1/2 ..	100.80
1 3/16 ..	4.70	3 ..	30.00	5 5/8 ..	105.50
1 1/4 ..	5.21	3 1/8 ..	32.55	5 3/4 ..	110.20
1 5/16 ..	5.74	3 1/4 ..	35.21	5 7/8 ..	115.10
1 3/8 ..	6.30	3 3/8 ..	37.97	6 ..	120.00

USEFUL TABLES.

Weight per Running Foot of Cast Steel.

Size.	Lbs.	Size.	Lbs.	Size.	Lbs	Size.	Lbs.
¼ in. Sq.	.213	¼ in. Rd.	.167	1 × ¼	.852	½ in. Oct.	.745
½	.855	½	.669	1⅛ × ⅜	1.43	⅝	1.16
¾	1.91	¾	1.50	1¼ × ½	2.13	¾	1 67
1	3.40	1	2.67	1½ × ⅝	3.19	⅞	2.28
1¼	5.32	1¼	4 18	1¾ × ¾	4.46	1	2.98
1½	7.67	1½	6.02	2 × ½	3 40	1⅛	3.77
2	13.63	2	10.71	.. × ⅝	4.25	1¼	4.65

Comparison of Principal Gauges in Use.

Number.	United States Standard.		Stubbs' Birmingham.		Brown & Sharp.	
	1000's of an inch.	Pounds per square foot. IRON.	1000's of an inch.	Pounds per square foot. IRON.	1000's of an inch.	Pounds per square foot. IRON.
No. 1	.281	11.25	.300	12.04	.289	11.61
" 2	.265	10.62	.284	11.40	.257	10.34
" 3	.250	10.	.259	10.39	.229	9.21
" 4	.234	9.37	.238	9.55	.204	8.20
" 5	.218	8.75	.220	8.83	.181	7.30
" 6	.203	8.12	.203	8.15	.162	6.50
" 7	.187	7.50	.180	7 22	.144	5.79
" 8	.171	6.87	165	6 62	.128	5.16
" 9	.156	6.25	.148	5.94	.114	4 59
" 10	.140	5.62	.134	5.38	.102	4.09
" 11	.125	5.00	.120	4.82	.091	3.64
" 12	.109	4.37	.109	4.37	.080	3 24
" 13	.093	3.75	.095	3.81	.072	2.89
" 14	.078	3.12	.083	3 33	.064	2.57
" 15	.070	2.81	.072	2.89	.057	2.29
" 16	.062	2.50	.065	2.61	.050	2 04
" 17	.056	2.25	.058	2.33	.045	1.82
" 18	.050	2.00	.049	1.97	.040	1.62
" 19	.043	1.75	.042	1.69	.036	1 44
" 20	.037	1.50	.035	1 40	.032	1.28
" 21	.034	1.37	.032	1.28	.028	1.14
" 22	.031	1.25	.028	1.12	.025	1.02
" 23	.028	1.12	.025	1.00	.022	.90
" 24	.025	1.00	.022	.88	.020	.80
" 25	.021	.87	.020	.80	.018	.72
" 26	.018	.75	.018	.72	.016	.64
" 27	.017	.68	.016	.64	.014	.57
" 28	.015	.62	.014	.56	.012	.50
" 29	.014	.56	.013	.52	.011	.45
" 30	.012	.50	.012	.48	.010	.40

DECIMAL EQUIVALENTS OF AN INCH.

1/64	.015625	33/64	.515625
1/32	.03125	17/32	.53125
3/64	.046875	35/64	.546875
1/16	.0625	9/16	.5625
5/64	.078125	37/64	.578125
3/32	.09375	19/32	.59375
7/64	.109375	39/64	.609375
1/8	.125	5/8	.625
9/64	.140625	41/64	.640625
5/32	.15625	21/32	.65625
11/64	.171875	43/64	.671875
3/16	.1875	11/16	.6875
13/64	.203125	45/64	.703125
7/32	.21875	23/32	.71875
15/64	.234375	47/64	.734375
1/4	.250	3/4	.750
17/64	.265625	49/64	.765625
9/32	.28125	25/32	.78125
19/64	.296875	51/64	.796875
5/16	.3125	13/16	.8125
21/64	.328125	53/64	.828125
11/32	.34375	27/32	.84375
23/64	.359375	55/64	.859375
3/8	.375	7/8	.875
25/64	.390625	57/64	.890625
13/32	.40625	29/32	.90625
27/64	.421875	59/64	.921875
7/16	.4375	15/16	.9375
29/64	.453125	61/64	.953125
15/32	.46875	31/32	.96875
31/64	.484375	63/64	.984375
1/2	.500	1	1

TABLE

CONTAINING THE DIAMETERS, CIRCUMFERENCES AND AREAS OF CIRCLES

Diam.	Area.	Circum.	Diam.	Area.	Circum.
0.0			3.0	7.0686	9.4248
.1	.007854	.31416	.1	7.5477	9.7389
.2	.031416	.62832	.2	8.0425	10.0531
.3	.070686	.94248	.3	8 5530	10.3673
.4	.12566	1.2566	.4	9.0792	10.6814
.5	.19735	1.5708	.5	9.6211	10.9956
.6	.28274	1.8850	.6	10.1788	11.3097
.7	.38485	2.1991	.7	10.7521	11.6239
.8	.50266	2.5133	.8	11.3411	11.9381
.9	.63617	2.8274	.9	11.9456	12.2522
1.0	.7854	3.1416	4.0	12.5664	12.5664
.1	.9503	3.4558	.1	13.2025	12.8805
.2	1.1310	3.7699	.2	13.8544	13.1947
.3	1.3273	4.0841	.3	14.5220	13.5088
.4	1.5394	4.3982	.4	15.2053	13.8230
.5	1.7671	4.7124	.5	15.9043	14.1372
.6	2.0106	5.0265	.6	16.6190	14.4513
.7	2.2698	5.3407	.7	17.3494	14.7655
.8	2.5447	5.6549	.8	18.0956	15.0796
.9	2.8353	5.9690	.9	18.8574	15.3938
2.0	3.1416	6.2832	5.0	19.6350	15.7080
.1	3.4636	6.5973	.1	20.4282	16.0221
.2	3.8013	6.9115	.2	21.2372	16.3363
.3	4.1548	7.2257	.3	22.0618	16.6504
.4	4.5239	7.5398	.4	22.9022	16.9646
.5	4.9087	7.8540	.5	23.7583	17.2788
.6	5.3093	8.1681	.6	24.6301	17.5929
.7	5.7256	8.4823	.7	25.5176	17.9071
.8	6.1575	8.7965	.8	26.4208	18.2212
.9	6.6052	9.1106	.9	27.3397	18.5354

TABLE—(*Continued.*)

CONTAINING THE DIAMETERS, CIRCUMFERENCES AND AREAS OF CIRCLES.

Diam.	Area.	Circum.	Diam.	Area.	Circum.
6.0	28.2743	18.8496	10.0	78.5398	31.4159
.1	29.2247	19.1637	.1	80.1185	31.7301
.2	30.1907	19.4779	.2	81.7128	32.0442
.3	31.1725	19.7920	.3	83.3229	32.3584
.4	32.1699	20.1062	.4	84.9487	32 6726
.5	33.1831	20.4204	.5	86.5901	32.9867
.6	34.2119	20.7345	.6	88.2473	33.3009
.7	35.2565	21.0487	.7	89.9202	33.6150
.8	36.3168	21.3628	.8	91.6088	33.9292
.9	37.3928	21.6770	.9	93.3132	34.2434
7.0	38.4845	21.9911	11.0	95.0332	34.5575
.1	39.5919	22.3053	.1	96.7689	34.8717
.2	40.7150	22.6195	.2	98.5203	35.1858
.3	41.8539	22.9336	.3	100.2875	35.5000
.4	43.0084	23.2478	.4	102.0703	35.8142
.5	44.1786	23.5619	.5	103.8689	36.1283
.6	45.3646	23.8761	.6	105.6832	36.4425
.7	46.5663	24.1903	.7	107.5132	36.7566
.8	47.7836	24.5044	.8	109 3588	37.0708
.9	49.0167	24.8186	.9	111.2202	37 3850
8.0	50.2655	25.1327	12.0	113.0973	37 6991
.1	51.5300	25.4469	.1	114.9901	38 0133
.2	52.8102	25.7611	.2	116.8987	38.3274
.3	54.1061	26.0752	.3	118.8229	38.6416
.4	55.4177	26.3894	.4	120.7628	38.9557
.5	56.7450	26.7035	.5	122.7185	39 2699
.6	58.0880	27.0177	.6	124.6898	39.5841
.7	59.4468	27.3319	.7	126.6769	39.8982
.8	60.8212	27.6460	.8	128.6796	40.2124
.9	62.2114	27.9602	.9	130.6981	40.5265
9.0	63.6173	28.2743	13.0	132.7323	40 8407
.1	65.0388	28.5885	.1	134.7822	41 1549
.2	66.4761	28.9027	.2	136.8478	41.4690
.3	67.9291	29.2168	.3	138.9291	41.7832
.4	69.3978	29.5310	.4	141.0261	42.0973
.5	70.8822	29.8451	.5	143.1388	42.4115
.6	72.3823	30.1593	.6	145.2672	42.7257
.7	73.8981	30.4734	.7	147.4114	43.0398
.8	75.4296	30.7876	.8	149.5712	43.3540
.9	76.9769	31.1018	.9	151.7468	43.6681

TABLE—(Continued.)

CONTAINING THE DIAMETERS, CIRCUMFERENCES AND AREAS OF CIRCLES

Diam.	Area.	Circum.	Diam.	Area.	Circum.
14.0	153.9380	43.9823	18.0	254.4690	56.5486
.1	156.1450	44.2965	.1	257.3043	56.8628
.2	158.3677	44.6106	.2	260.1553	57.1770
.3	160.6061	44.9248	.3	263.0220	57.4911
.4	162.8602	45.2389	.4	265.9044	57.8053
.5	165.1300	45.5531	.5	268.8025	58.1195
.6	167.4155	45.8673	.6	271.7164	58.4336
.7	169.7167	46.1814	.7	274.6459	58.7478
.8	172.0336	46.4956	.8	277.5911	59.0619
.9	174.3662	46.8097	.9	280.5521	59.3761
15.0	176.7146	47.1239	19.0	283.5287	59.6903
.1	179.0786	47.4380	.1	286.5211	60.0044
.2	181.4584	47.7522	.2	289.5292	60.3186
.3	183.8539	48.0664	.3	292.5530	60.6327
.4	186.2650	48.3805	.4	295.5925	60.9469
.5	188.6919	48.6947	.5	298.6477	61.2611
.6	191.1345	49.0088	.6	301.7186	61.5752
.7	193.5928	49.3230	.7	304.8052	61.8894
.8	196.0668	49.6372	.8	307.9075	62.2035
.9	198.5565	49.9513	.9	311.0255	62.5177
16.0	201.0619	50.2655	20.0	314.1593	62.8319
.1	203.5831	50.5796	.1	317.3087	63.1460
.2	206.1199	50.8938	.2	320.4739	63.4602
.3	208.6724	51.2080	.3	323.6547	63.7743
.4	211.2407	51.5221	.4	326.8513	64.0885
.5	213.8246	51.8363	.5	330.0636	64.4026
.6	216.4243	52.1504	.6	333.2916	64.7168
.7	219.0397	52.4646	.7	336.5353	65.0310
.8	221.6708	52.7788	.8	339.7947	65.3451
.9	224.3176	53.0929	.9	343.0698	65.6593
17.0	226.9801	53.4071	21.0	346.3606	65.9734
.1	229.6583	53.7212	.1	349.6671	66.2876
.2	232 3522	54.0354	.2	352.9894	66.6018
.3	235.0618	54.3496	.3	356.3273	66.9159
.4	237.7871	54.6637	.4	359.6809	67.2301
.5	240.5282	54.9779	.5	363.0503	67.5442
6	243.2849	55.2920	.6	366.4354	67.8584
.7	246 0574	55.6062	.7	369.8361	68.1726
.8	248.8456	55.9203	.8	373.2526	68.4867
.9	251.6494	56.2345	.9	376.6848	68.8009

TABLE—(Continued.)

CONTAINING THE DIAMETERS, CIRCUMFERENCES AND AREAS OF CIRCLES.

Diam.	Area.	Circum.	Diam.	Area.	Circum.
22.0	380.1327	69.1150	26.0	530.9292	81.6814
.1	383.5963	69.4292	.1	535.0211	81.9956
.2	387.0706	69.7434	.2	539.1287	82.3097
.3	390.5707	70.0575	.3	543.2521	82.6239
.4	394.0814	70.3717	.4	547.3911	82.9380
.5	397.6078	70.6858	.5	551.5459	83.2522
.6	401.1500	71.0000	.6	555.7163	83.5664
.7	404.7078	71.3142	.7	559 9025	83.8805
.8	408.2814	71.6283	.8	564 1044	84.1947
.9	411.8707	71.9425	.9	568.3220	84.5088
23.0	415.4756	72.2566	27.0	572.5553	84.8230
.1	419.0993	72.5708	.1	576.8043	85.1372
.2	422.7327	72.8849	.2	581.0690	85.4513
.3	426.3848	73.1991	.3	585.3494	85.7655
.4	430.0526	73.5133	.4	589.6455	86.0796
.5	433.7361	73.8274	.5	593.9574	86.3938
.6	437.4354	74.1416	.6	598.2849	86.7080
.7	441.1503	74.4557	.7	602.6282	87.0221
.8	444.8809	74.7699	.8	606.9871	87.3363
.9	448.6273	75.0841	.9	611.3618	87.6504
24.0	452.3893	75.3982	28.0	615.7522	87.9646
.1	456.1671	75.7124	.1	620.1582	88.2788
.2	459.9606	76.0265	.2	624.5800	88.5929
.3	463.7698	76.3407	.3	629.0175	88.9071
.4	467.5947	76.6549	.4	633.4707	89.2212
.5	471.4352	76.9690	.5	637.9397	89.5354
.6	475.2916	77.2832	.6	642.4243	89.8495
.7	479.1636	77.5973	.7	646.9246	90.1637
.8	483.0513	77.9115	.8	651.4407	90.4779
.9	486.9547	78.2257	.9	655.9724	90.7920
25.0	490.8739	78.5398	29.0	660.5199	91.1063
.1	494.8087	78.8540	.1	665.0830	91.4203
.2	498.7592	79.1681	.2	669.6619	91.7345
.3	502.7255	79.4823	.3	674.2565	92.0487
.4	506.7075	79.7965	.4	678.8668	92.3628
.5	510.7052	80.1106	.5	683.4928	92.6770
.6	514.7185	80.4248	.6	688.1345	92.9911
.7	518.7476	80.7389	.7	692.7919	93.3053
.8	522.7924	81.0531	.8	697.4650	93.6195
.9	526.8529	81.3672	.9	702.1538	93.9336

TABLE—(*Continued.*)

CONTAINING THE DIAMETERS, CIRCUMFERENCES AND AREAS OF CIRCLES.

Diam.	Area.	Circum.	Diam.	Area.	Circum.
30.0	706.8583	94.2478	34.0	907.9203	106.8142
.1	711.5786	94.5619	.1	913.2688	107.1283
.2	716.3145	94.8761	.2	918.6331	107.4425
.3	721.0662	95.1903	.3	924.0131	107.7566
.4	725.8336	95.5044	.4	929.4088	108.0708
.5	730.6167	95.8186	.5	934.8202	108.3849
.6	735.4154	96.1327	.6	940.2473	108.6991
.7	740.2299	96.4469	.7	945.6901	109.0133
.8	745.0601	96.7611	.8	951.1486	109.3274
.9	749.9060	97.0752	.9	956.6228	109.6416
31.0	754.7676	97.3894	35.0	962.1128	109.9557
.1	759.6450	97.7035	.1	967.6184	110.2699
.2	761.5380	98.0177	.2	973.1397	110.5841
.3	769.4467	98.3319	.3	978.6768	110.8982
.4	774.3712	98.6460	.4	984.2296	111.2124
.5	779.3113	98.9602	.5	989.7980	111.5265
.6	784.2672	99.2743	.6	995.3822	111.8407
.7	789.2388	99.5885	.7	1000.9821	112.1549
.8	794.2260	99.9026	.8	1006.5977	112.4690
.9	799.2290	100.2168	.9	1012.2290	112.7832
32.0	804.2477	100.5310	36.0	1017.8760	113.0973
.1	809.2821	100.8451	.1	1023.5387	113.4115
.2	814.3322	101.1593	.2	1029.2172	113.7257
.3	819.3980	101.4734	.3	1034.9113	114.0398
.4	824.4796	101.7876	.4	1040.6212	114.3540
.5	829.5768	102.1018	.5	1046.3467	114.6681
.6	834.6898	102.4159	.6	1052.0880	114.9823
.7	839.8185	102.7301	.7	1057.8449	115.2965
.8	844.9628	103.0442	.8	1063.6176	115.6106
.9	850.1229	103.3584	.9	1069.4060	115.9248
33.0	855.2986	103.6726	37.0	1075.2101	116.2389
.1	860.4902	103.9867	.1	1081.0299	116.5531
.2	865.6973	104.3009	.2	1086.8654	116.8672
.3	870.9202	104.6150	.3	1092.7166	117.1814
.4	876.1588	104.9292	.4	1098.5835	117.4956
.5	881.4131	105.2434	.5	1104.4662	117.8097
.6	886.6831	105.5575	.6	1110.3645	118.1239
.7	891.9688	105.8717	.7	1116.2786	118.4380
.8	897.2703	106.1858	.8	1122.2083	118.7522
.9	902.5874	106.5000	.9	1128.1538	119.0664

TABLE—(*Continued.*)

CONTAINING THE DIAMETERS, CIRCUMFERENCES AND AREAS OF CIRCLES

Diam.	Area.	Circum.	Diam.	Area.	Circum.
38.0	1131.1149	119.3805	42.0	1385.4424	131.9469
.1	1140.0918	119.6947	.1	1392.0476	132.2611
.2	1146.0844	120.0088	.2	1398.6685	132.5752
.3	1152.0927	120.3230	.3	1405.3051	132 8894
.4	1158.1167	120.6372	.4	1411.9574	133.2035
.5	1164.1564	120.9513	.5	1418.6254	133.5177
.6	1170.2118	121.2655	.6	1425.3092	133.8318
.7	1176.2830	121.5796	.7	1432.0086	134.1460
.8	1182.3698	121.8938	.8	1438.7238	134.4602
.9	1188.4724	122.2080	.9	1445.4546	134.7743
39.0	1194.5906	122.5221	43.0	1452.2012	135 0885
.1	1200.7246	122.8363	.1	1458.9635	135.4026
.2	1206.8742	123.1504	.2	1465.7415	135.7168
.3	1213.0396	123.4646	.3	1472.5352	136.0310
.4	1219.2207	123.7788	.4	1479.3446	136.3451
.5	1225.4175	124.0929	.5	1486.1697	136.6593
.6	1231.6300	124.4071	.6	1493.0105	136.9734
.7	1237.8582	124.7212	.7	1499.8670	137.2876
.8	1244.1021	125.0354	.8	1506.7393	137.6018
.9	1250.3617	125.3495	.9	1513.6272	137.9159
40.0	1256.6371	125.6637	44.0	1520.5308	138.2301
.1	1262.9281	125.9779	.1	1527.4502	138.5442
.2	1269.2348	126.2920	.2	1534.3853	138.8584
.3	1275.5573	126.6063	.3	1541.3360	139.1726
.4	1281.8955	126.9203	.4	1548.3025	139.4867
.5	1288.2493	127.2345	.5	1555.2847	139.8009
.6	1294.3189	127.5487	.6	1562.2826	140.1153
.7	1301.0042	127.8628	.7	1569.2962	140.4292
.8	1307.4052	128.1770	.8	1576.3255	140.7434
.9	1313.8219	128.4911	.9	1583.3706	141.0575
41.0	1320.2543	128.8053	45.0	1590.4313	141.3717
.1	1326.7024	129.1195	.1	1597.5077	141.6858
.2	1333.1663	129.4336	.2	1604.5999	142.0000
.3	1339.6458	129.7478	.3	1611.7077	142.3142
.4	1346.1410	130.0619	.4	1618.8313	142.6283
5	1352.6520	130.3761	.5	1625.9705	142.9425
.6	1359.1786	130.6903	.6	1633.1255	143.2566
.7	1365.7210	131.0044	.7	1640.2962	143.5708
.8	1372.2791	131.3186	.8	1647.4826	143.8849
.9	1378.8529	131.6227	.9	1654.6847	144.1991

TABLE—(Continued.)

CONTAINING THE DIAMETERS, CIRCUMFERENCES AND AREAS OF CIRCLES.

Diam.	Area.	Circum.	Diam.	Area.	Circum.
46.0	1661 9025	144.5133	50.0	1963.4954	157.0796
.1	1669.1360	144.8274	.1	1971.3572	157 3938
.2	1676.3853	145.1416	.2	1979.2348	157.7080
.3	1683.6502	145.4557	.3	1987.1280	158.0221
.4	1690.9308	145.7699	.4	1995.0370	158.3363
.5	1698.2272	146.0841	.5	2002.9617	158.6504
.6	1705.5392	146.3982	.6	2010.9020	158.9646
.7	1712.8670	146.7124	.7	2018.8581	159.2787
.8	1720.2105	147.0265	.8	2026.8299	159.5929
.9	1727.5697	147.3407	.9	2034.8174	159.9071
47.0	1734.9445	147.6550	51.0	2042.8206	160.2212
.1	1742.3351	147.9690	.1	2050.8395	160.5354
.2	1749.7414	148.2832	.2	2058.8742	160.8495
.3	1757.1635	148 5973	.3	2066.9245	161.1637
.4	1764.6012	148.9115	.4	2074.9905	161.4779
.5	1772.0546	149.2257	.5	2083.0723	161.7920
.6	1779.5237	149.5398	.6	2091.1697	162.1062
.7	1787.0086	149.8540	.7	2099.2829	162.4203
.8	1794.5091	150.1681	.8	2107.4118	162.7345
.9	1802.0254	150.4823	.9	2115.5563	163.0487
48.0	1809.5574	150.7964	52.0	2123.7166	163.3628
.1	1817.1050	151.1106	.1	2131.8926	163.6770
.2	1824.6684	151.4248	.2	2140.0843	163.9911
.3	1832.2475	151.7389	.3	2148.2917	164.3053
.4	1839.8423	152.0531	.4	2156 5149	164.6195
.5	1847.4528	152.3672	.5	2164.7537	164.9336
.6	1855.0790	152.6814	.6	2173.0082	165 2479
.7	1862.7210	152.9956	.7	2181.2785	165.5619
.8	1870.3786	153.3097	.8	2189.5644	165.8761
.9	1878.0519	153.6239	.9	2197.8661	166.1903
49.0	1885.7409	153.9380	53.0	2206.1834	166.5044
.1	1893.4457	154.2522	.1	2214.5165	166.8186
.2	1901.1662	154.5664	.2	2222.8653	167.1327
.3	1908.9024	154.8805	.3	2231.2298	167.4469
.4	1916.6543	155.1947	.4	2239.6100	167.7610
.5	1924.4218	155.5088	.5	2248.0059	168.0752
.6	1932.2051	155.8230	.6	2256.4175	168.3894
.7	1940.0042	156.1372	.7	2264.8448	168.7035
.8	1947 8189	156.4513	.8	2273.2879	169.0177
.9	1955.6493	156.7655	.9	2281.7466	169.3318

TABLE—(Continued.)

CONTAINING THE DIAMETERS, CIRCUMFERENCES AND AREAS OF CIRCLES.

Diam.	Area.	Circum.	Diam.	Area.	Circum.
54.0	2290.2210	169.6460	58.0	2642.0794	182.2124
.1	2298.7112	169.9602	.1	2651.1979	182.5265
.2	2307.2171	170.2743	.2	2660.3321	182.8407
.3	2315.7386	170.5885	.3	2669.4820	183.1549
.4	2324.2759	170.9026	.4	2678.6476	183.4690
.5	2332.8289	171.2168	.5	2687.8289	183.7832
.6	2341.3976	171.5310	.6	2697.0259	184.0973
.7	2349.9820	171.8451	.7	2706.2386	184.4115
.8	2258.5821	172.1593	.8	2715.4670	184.7256
.9	2367.1979	172.4735	.9	2724.7112	185.0398
55.0	2375.8294	172.7876	59.0	2733.9710	185.3540
.1	2384.4767	173.1017	.1	2743.2466	185.6681
.2	2393.1396	173.4159	.2	2752.5378	185.9823
.3	2401.8183	173.7301	.3	2761.8448	186.2964
.4	2410.5126	174.0442	.4	2771.1675	186.6106
.5	2419.2227	174.3584	.5	2780.5058	186.9248
.6	2427.9485	174.6726	.6	2789.8599	187.2389
.7	2436.6899	174.9867	.7	2799.2297	187.5531
.8	2445.4471	175.3009	.8	2808.6152	187 8672
.9	2454.2200	175.6150	.9	2818.0165	188.1814
56.0	2463.0086	175.9292	60.0	2827.4334	188.4956
.1	2471.8130	176.2433	.1	2836 8660	188.8097
.2	2480.6330	176.5575	.2	2846.3144	189.1239
.3	2489.4687	176.8717	.3	2855.7784	189.4380
.4	2498.3201	177.1858	.4	2865.2582	189.7522
.5	2507.1873	177.5000	.5	2874.7536	190.0664
.6	2516.0701	177.8141	.6	2884.2648	190.3805
.7	2524.9687	178.1283	.7	2893.7917	190.6947
.8	2533.8830	178.4425	.8	2903.3343	191.0088
.9	2542.8129	178.7566	.9	2912.8926	191.3230
57.0	2551.7586	179.0708	61.0	2922.4666	191.6372
.1	2560.7200	179.3849	.1	2932.0563	191.9513
.2	2569.6971	179.6991	.2	2941.6617	192.2655
.3	2578.6899	180.0133	.3	2951.2828	192.5796
.4	2587.6985	180.3274	.4	2960.9197	192.8938
.5	2596.7227	180.6416	.5	2970.5722	193.2079
.6	2605.7626	180.9557	.6	2980.2405	193.5221
.7	2614.8183	181.2699	.7	2989.9244	193.8363
.8	2623.8896	181.5841	.8	2999.6241	194.1504
.9	2632.9767	181.8982	.9	3009.3395	194.4646

TABLE—(*Continued.*)

CONTAINING THE DIAMETERS, CIRCUMFERENCES AND AREAS OF CIRCLES

Diam.	Area.	Circum.	Diam.	Area.	Circum.
62.0	3019.0705	194.7787	66.0	3421.1944	207.3451
.1	3028.8173	195.0929	.1	3431.5695	207.6593
.2	3038.5793	195.4071	.2	3441.9603	207.9734
.3	3048.3580	195.7212	.3	3452.3669	208.2876
.4	3058.1520	196.0354	.4	3462.7891	208.6017
.5	3067.9616	196.3495	.5	3473.2270	208.9159
.6	3077.7869	196.6637	.6	3483.6807	209.2301
.7	3087.6279	196.9779	.7	3494.1500	209.5442
.8	3097 4847	197.2920	.8	3504.6351	209.8584
.9	3107.3571	197.6062	.9	3515.1359	210.1725

Diam.	Area.	Circum.	Diam.	Area.	Circum.
63.0	3117.2453	197.9203	67.0	3525.6524	210.4867
.1	3127.1492	198.2345	.1	3536.1845	210.8009
.2	3137.0688	198.5487	.2	3546.7324	211.1150
.3	3147.0040	198.8628	.3	3557.2960	211.4292
.4	3156.9550	199.1770	.4	3567.8754	211.7433
.5	3166.9217	199.4911	.5	3578.4704	212.0575
.6	3176.9043	199.8053	.6	3589.0811	212.3717
.7	3186.9023	200.1195	.7	3599.7075	212 6858
.8	3196.9161	200.4336	.8	3610.3497	213.0000
.9	3206.9456	200.7478	.9	3621.0075	213.3141
64.0	3216.9909	201.0620	68.0	3631.6811	213.6283
.1	3227.0518	201.3761	.1	3642.3704	213.9425
.2	3237.1285	201.6902	.2	3653.0754	214.2566
.3	3247.2222	202.0044	.3	3663.7960	214.5708
.4	3257.3289	202.3186	.4	3674.5324	214.8849
.5	3267.4527	202.6327	.5	3685.2845	215.1991
.6	3277.5922	202.9469	.6	3696.0523	215.5133
.7	3287.7474	203.2610	.7	3706.8359	215.8274
.8	3297.9183	203.5752	.8	3717.6351	216.1416
.9	3308.1049	203.8894	.9	3728.4500	216.4556
65.0	3318.3072	204.2035	69.0	3739.2807	216.7699
.1	3328.5253	204.5176	.1	3750.1270	217.0841
.2	3338.7590	204.8318	.2	3760.9891	217.3982
.3	3349.0085	205.1460	.3	3771.8668	217.7124
.4	3359.2736	205.4602	.4	3782.7603	218.0265
.5	3369.5545	205.7743	.5	3793.6695	218.3407
.6	3379.8510	206.0885	.6	3804.5944	218.6548
.7	3390.1633	206.4026	.7	3815.5350	218.9690
.8	3400.4913	206.7168	.8	3826.4913	219.2832
.9	3410.8350	207.0310	.9	3837.4633	219.5973

TABLE—(*Continued.*)

CONTAINING THE DIAMETERS, CIRCUMFERENCES AND AREAS OF CIRCLES

Diam.	Area.	Circum.	Diam.	Area.	Circum.
70.0	3848.4510	219.9115	74.0	4300.8403	232.4779
.1	3859.4544	220.2256	.1	4312.4721	232.7920
.2	3870.4736	220.5398	.2	4324.1195	233.1062
.3	3881.5084	220.8540	.3	4335.7827	233.4203
.4	3892.5590	221.1681	.4	4347.4616	233.7345
.5	3903.6252	221.4823	.5	4359.1562	234.0487
.6	3914.7072	221.7964	.6	4370.8664	234.3628
.7	3925.8049	222.1106	.7	4382.5924	234.6770
.8	3936.9182	222.4248	.8	4394.3341	234.9911
.9	3948.0473	222.7389	.9	4406.0916	235.3053
71.0	3959.1921	223.0531	75.0	4417.8647	235.6194
.1	3970.3526	223.3672	.1	4429.6535	235.9336
.2	3981.5289	223.6814	.2	4441.4580	236.2478
.3	3992.7208	223.9956	.3	4453.2783	236.5619
.4	4003.9284	224.3097	.4	4465.1142	236.8761
.5	4015.1518	224.6239	.5	4476 9659	237.1902
.6	4026.3908	224.9380	.6	4488.8332	237.5044
.7	4037.6456	225.2522	.7	4500.7163	237.8186
.8	4048.9160	225.5664	.8	4512.6151	238.1327
.9	4060.2022	225.8805	.9	4524.5296	238.4469
72.0	4071.5041	226.1947	76.0	4536.4598	238.7610
.1	4082.8217	226 5088	.1	4548.4057	239.0752
.2	4094.1550	226.8230	.2	4560.3673	239.3894
.3	4105.5040	227.1371	.3	4572.3446	239.7035
.4	4116.8687	227.4513	.4	4584.3377	240.0177
.5	4128.2491	227.7655	.5	4596.3464	240.3318
.6	4139.6452	228.0796	.6	4608.3708	240.6460
.7	4151.0571	228.3938	.7	4620.4110	240.9602
.8	4162.4846	228.7079	.8	4632.4669	241.2743
.9	4173.9279	229.0221	.9	4644.5384	241.5885
73.0	4185.3868	229.3363	77.0	4656.6257	241.9026
.1	4196.8615	229.6504	.1	4668.7287	242.2168
.2	4208.3519	229.9646	.2	4680.8474	242.5310
.3	4219.8579	230.2787	.3	4692.9818	242.8451
.4	4231.3797	230.5929	.4	4705.1319	243.1592
.5	4242.9172	230.9071	.5	4717.2977	243.4734
.6	4254.4704	231.2212	.6	4729.4792	243.7876
.7	4266.0394	231.5354	.7	4741.6765	244.1017
.8	4277.6240	231.8395	.8	4753.8894	244.4159
.9	4289.2243	232.1637	.9	4766.1181	244.7301

TABLE—(Continued.)

CONTAINING THE DIAMETERS, CIRCUMFERENCES AND AREAS OF CIRCLES.

Diam.	Area.	Circum.	Diam.	Area.	Circum.
78.0	4778.3624	245.0442	82.0	5281.0173	257.6106
.1	4790.6225	245.3584	.1	5293.9056	257.9247
.2	4802.8983	245.6725	.2	5306.8097	258.2389
.3	4815.1897	245.9867	.3	5319.7295	258.5531
.4	4827.4969	246.3009	.4	5332.6650	258.8672
.5	4839.8189	246.6150	.5	5345.6162	259.1814
.6	4852.1584	246.9292	.6	5358.5832	259.4956
.7	4864.5128	247.2433	.7	5371.5658	259.8097
.8	4876.8828	247.5575	.8	5384.5641	260.1239
.9	4889.2685	247.8717	.9	5397.5782	260.4380
79.0	4901.6699	248.1858	83.0	5410.6079	260.7522
.1	4914.0871	248.5000	.1	5423.6534	261.0663
.2	4926.5199	248.8141	.2	5436.7146	261.3805
.3	4938.9685	249.12-3	.3	5449.7915	261.6947
.4	4951.4328	249.4425	.4	5462.8840	262.0088
.5	4963.9127	249.7566	.5	5475.9923	262.3230
.6	4976.4084	250.0708	.6	5489.1163	262.6371
.7	4988.9198	250 3850	.7	5502.2561	262.9513
.8	5001.4469	250.6991	.8	5515.4115	263.2655
.9	5013.9897	251.0133	.9	5528.5826	263.5796
80.0	5026.5482	251.3274	84.0	5541.7694	263.8938
.1	5039.1225	251.6416	.1	5554.9720	264.2079
.2	5051.7124	251.9557	.2	5568.1902	264.5221
.3	5064.3180	252.2699	.3	5581.4242	264.8363
.4	5076.9394	252.5840	.4	5594.6739	265.1514
.5	5089.5764	252.8982	.5	5607.9392	265.4646
.6	5102.2292	253.2124	.6	5621.2203	265.7787
.7	5114 8977	253.5265	.7	5634.5171	266.0929
.8	5127.5819	253.8407	.8	5647.8296	266.4071
.9	5140.2818	254.1548	.9	5661.1578	266.7212
81.0	5152.9973	254.4690	85.0	5674.5017	267.0354
.1	5165.7287	254.7832	.1	5687.8614	267.3495
.2	5178.4757	255.0973	.2	5701.2367	267.6637
.3	5191.2384	255.4115	.3	5714.6277	267.9779
.4	5204.0168	255.7256	.4	5728.0345	268.2920
.5	5216.8110	256.0398	.5	5741.4569	268.6062
.6	5229.6208	256.3540	.6	5754.8951	268.9203
.7	5242.4463	256.6681	.7	5768.3490	269.2345
.8	5255.2876	256.9823	.8	5781.8185	269.5486
.9	5268.1446	257.2966	.9	5795.3038	269.8628

TABLE—(*Continued.*)

CONTAINING THE DIAMETERS, CIRCUMFERENCES AND AREAS OF CIRCLES.

Diam.	Area.	Circum.	Diam.	Area.	Circum.
86.0	5808.8048	270.2770	90.0	6361.7251	282.7433
.1	5822.3215	270.4911	.1	6375.8701	283.0575
.2	5835.8539	270.8053	2	6390.0309	283.3717
.3	5849.4020	271.1194	.3	6404.2073	283.6858
.4	5862.9659	271.4336	.4	6418.3995	284.0000
.5	5876.5454	271.7478	.5	6432.6073	284.3141
.6	5890.1407	272.0619	.6	6446.8309	284.6283
.7	5903.7516	272.3761	.7	6461.0701	284.9425
.8	5917.3783	272.6902	.8	6475.3251	285.2566
.9	5931.0206	273.0044	.9	6489.5958	285.5708
87.0	5944.6787	273.3186	91.0	6503.8822	285.8849
.1	5958.3525	273.6327	.1	6518.1843	286.1991
.2	5972.0420	273.9469	.2	6532.5021	286.5133
.3	5985.7472	274.2610	.3	6546.8356	286.8274
.4	5999.4681	274.5752	.4	6561.1848	287.1416
.5	6013.2047	274.8894	.5	6575.5498	287.4557
.6	6026.9570	275.2035	.6	6589.9304	287 7699
.7	6040.7250	275.5177	.7	6604 3268	288.0840
.8	6054.5088	275.8318	.8	6618.7388	288.3982
.9	3068.3082	276.1460	.9	6633.1666	288.7124
88.0	6082.1234	276.4602	92.0	6647.6101	289.0265
.1	6095.9542	276.7743	.1	6662.0692	289.3407
.2	6109.8008	277.0885	.2	6676.5441	289.6548
.3	6123.6631	277.4026	.3	6691.0347	289.9690
.4	6137.5411	277.7168	.4	6705.5410	290.2832
.5	6151.4348	278.0309	.5	6720.0630	290.5973
.6	6165.3442	278.3451	.6	6734.6008	290.9115
.7	6179.2693	278.6563	.7	6749.1542	291.2256
.8	6193.2101	278.9740	.8	6763.7233	291.5398
.9	6207.1666	279.2876	.9	6778.3082	291.8540
89.0	6221.1389	279.6017	93.0	6792.9087	292.1681
.1	6235.1268	279.9159	.1	6807.5250	292.4823
.2	6249.1304	280.2301	.2	6822.1569	292.7964
.3	6263.1498	280.5442	.3	6836.8046	293.1106
.4	6277.1849	280.8584	.4	6851.4680	293.4248
.5	6291.2356	281.1725	.5	6866.1471	293.7389
.6	6305.3021	281.4867	.6	6880.8419	294.0531
.7	6319.3843	281.8009	.7	6895.5524	294.3672
.8	6333.4822	282.1150	.8	6910.2786	294.6814
.9	6347.5958	282.4292	.9	6925.0205	294.9956

TABLE—(Concluded.)

CONTAINING THE DIAMETERS, CIRCUMFERENCES AND AREAS OF CIRCLES.

Diam.	Area.	Circum.	Diam.	Area.	Circum.
94.0	6939.7782	295.3097	97.0	7389.8113	304.7345
.1	6954.5515	295.6239	.1	7405.0559	305.0486
.2	6969.3106	295.9380	.2	7420.3162	305.3628
.3	6984.1453	296.2522	.3	7435.5922	305.6770
.4	6998.9658	296.5663	.4	7450.8839	305.9911
.5	7013.8019	296.8805	.5	7466.1913	306.3053
.6	7028.6538	297.1947	.6	7481.5144	306.6194
.7	7043.5214	297.5088	.7	7496.8532	306.9336
.8	7058.4047	297.8230	.8	7521.2078	307.2478
.9	7073.3033	298.1371	.9	7527.5780	307.5619
95.0	7088.2184	298.4513	98.0	7542.9640	307.8761
.1	7103.1488	298.7655	.1	7558.3656	308.1902
.2	7118.1950	299.0796	.2	7573.7830	308.5044
.3	7133.0568	299.3938	.3	7589.2161	308.8186
.4	7148.0343	299.7079	.4	7604.6648	309.1327
.5	7163.0276	300.0221	.5	7620.1293	309.4469
.6	7178.0366	300.3363	.6	7635.6095	309.7610
.7	7193.0612	300.6504	.7	7651.1054	310.0752
.8	7208.1016	300.9646	.8	7666.6170	310.3894
.9	7223.1577	301.2787	.9	7682.1444	310.7035
96.0	7238.2295	301.5929	99.0	7697.6893	311.0177
.1	7253.3170	301.9071	.1	7713.2461	311.3318
.2	7268.4202	302.2212	.2	7728.8206	311.6460
.3	7283.5391	302.5354	.3	7744.4107	311.9602
.4	7298.6737	302.8405	.4	7760.0166	312.2743
.5	7313.8240	303.1637	.5	7775.6382	312.5885
.6	7328.9901	303.4779	.6	7791.2754	312.9026
.7	7344.1718	303.7920	.7	7806.9284	313.2168
.8	7359.3693	304.1062	.8	7822.5971	313.5309
.9	7374.5824	304.4203	.9	7838.2815	313.8451
			100.0	7853.9816	314.1593

TABLE

OF SQUARES, CUBES, SQUARE AND CUBE ROOTS OF NUMBERS.

Number.	Square.	Cube.	Square Root.	Cube Root.
1	1	1	1.0	1.0
2	4	8	1.414213	1.25992
3	9	27	1.732050	1.44225
4	16	64	2.0	1.58740
5	25	125	2.236068	1.70997
6	36	216	2.449489	1.81712
7	49	343	2.645751	1.91293
8	64	512	2.828427	2.0
9	81	729	3.0	2.08008
10	100	1000	3.162277	2.15443
11	121	1331	3.316624	2.22398
12	144	1728	3.464101	2.28942
13	169	2197	3.605551	2.35133
14	196	2744	3.741657	2.41014
15	225	3375	3.872983	2.46621
16	256	4096	4.0	2.51984
17	289	4913	4.123105	2.57128
18	324	5832	4.242640	2.62074
19	361	6859	4.358898	2.66840
20	400	8000	4.472136	2.71441
21	441	9261	4.582575	2.75892
22	484	10648	4.690415	2.80203
23	529	12167	4.795831	2.84386
24	576	13824	4.898979	2.88449
25	625	15625	5.0	2.92401
26	676	17576	5.099019	2.96249
27	729	19683	5.196152	3.0
28	784	21952	5.291502	3.03658
29	841	24389	5.385164	3.07231
30	900	27000	5.477225	3.10723
31	961	29791	5.567764	3.14138
32	1024	32768	5.656854	3.17480
33	1089	35937	5.744562	3.20753
34	1156	39304	5.830951	3.23961
35	1225	42875	5.916079	3.27106
36	1296	46656	6.0	3.30192
37	1369	50653	6.082762	3.33222
38	1444	54872	6.164414	3.36197
39	1521	59319	6.244998	3.39121
40	1600	64000	6.324555	3.41995

TABLE—(Continued.)

OF SQUARES, CUBES, SQUARE AND CUBE ROOTS OF NUMBERS.

Number	Square.	Cube.	Square Root.	Cube Root.
41	1681	68921	6.403124	3.44821
42	1764	74088	6.480740	3.47602
43	1849	79507	6.557438	3.50339
44	1936	85184	6.633249	3 53034
45	2025	91125	6.708203	3.55689
46	2116	97336	6.782330	3.58304
47	2209	103823	6.855654	3.60882
48	2304	110592	6.928303	3.63424
49	2401	117649	7.0	3.65930
50	2500	125000	7.071067	3.68403
51	2601	132651	7.141428	3.70843
52	2704	140608	7.211102	3.73251
53	2809	148877	7.280109	3.75628
54	2916	157464	7.348469	3.77976
55	3025	166375	7.416198	3.80295
56	3136	175616	7.483314	3.82586
57	3249	185193	7.549834	3.84850
58	3364	195112	7.615773	3.87087
59	3481	205379	7.681145	3.89299
60	3600	216000	7.745966	3.91486
61	3721	226981	7.810249	3.93649
62	3844	238328	7.874007	3.95789
63	3969	250047	7.937253	3.97905
64	4096	262144	8.0	4.0
65	4225	274625	8.062257	4.02072
66	4356	287496	8.124038	4.04124
67	4489	300763	8 185352	4.06154
68	4624	314432	8.246211	4.08165
69	4761	328509	8.306623	4.10156
70	4900	343000	8.366600	4.12128
71	5041	357911	8.426149	4.14081
72	5184	373248	8.485281	4.16016
73	5329	389017	8.544003	4.17933
74	5476	405224	8.602325	4.19833
75	5625	421875	8.660254	4.21716
76	5776	438976	8.717797	4.23582
77	5929	456533	8.774964	4.25432
78	6084	474552	8.831760	4.27265
79	6241	493039	8.888194	4.29084
80	6400	512000	8.944271	4.30887

TABLE—(Continued)

OF SQUARES, CUBES, SQUARE AND CUBE ROOTS OF NUMBERS.

Number.	Square.	Cube.	Square Root.	Cube Root.
81	6561	531441	9.0	4.32674
82	6724	551368	9.055385	4.34448
83	6889	571787	9.110438	4.36207
84	7056	592704	9.165151	4.37951
85	7225	614125	9.219544	4.39683
86	7396	636056	9.273618	4.41400
87	7569	658503	9.327379	4.43104
88	7744	681472	9.380831	4.44796
89	7921	704969	9.433981	4.46474
90	8100	729000	9.486833	4.48140
91	8281	753571	9.539392	4.49794
92	8464	778688	9.591663	4.51435
93	8649	804357	9.643650	4.53065
94	8836	830584	9.695359	4.54683
95	9025	857375	9.746794	4.56290
96	9216	884736	9.797959	4.57785
97	9409	912673	9.848857	4.59470
98	9604	941192	9.899494	4.61043
99	9801	970299	9.949874	4.62606
100	10000	1000000	10.0	4.64158
101	10201	1030301	10.049875	4.65701
102	10404	1061208	10.099504	4.67233
103	10609	1092727	10.148891	4.68754
104	10816	1124864	10.198039	4.70266
105	11025	1157625	10.246950	4.71769
106	11236	1191016	10.295630	4.73262
107	11449	1225043	10.344080	4.74745
108	11664	1259712	10.392304	4.76220
109	11881	1295029	10.440306	4.77685
110	12100	1331000	10.488088	4.79142
111	12321	1367631	10.535653	4.80589
112	12544	1404928	10.583005	4.82028
113	12769	1442897	10.630145	4.83458
114	12996	1481544	10.677078	4.84880
115	13225	1520875	10.723805	4.86294
116	13456	1560896	10.770329	4.87699
117	13689	1601613	10.816653	4.89097
118	13924	1643032	10.862780	4.94086
119	14161	1685159	10.908712	4.91868
120	14400	1728000	10.954451	4.93242

TABLE—(Continued)

OF SQUARES, CUBES, SQUARE AND CUBE ROOTS OF NUMBERS.

Number.	Square.	Cube.	Square Root.	Cube Root.
121	14641	1771561	11.0	4.94608
122	14884	1815848	11.045361	4.95967
123	15129	1860867	11.090536	4.97319
124	15376	1906624	11.135528	4.98663
125	15625	1953125	11.180339	5.0
126	15876	2000376	11.224972	5.01329
127	16129	2048383	11.269427	5.02652
128	16384	2097152	11.313708	5.03968
129	16641	2146689	11.357816	5.05277
130	16900	2197000	11.401754	5.06579
131	17161	2248091	11.445523	5.07875
132	17424	2299968	11.489125	5.09164
133	17689	2352637	11.532562	5.10446
134	17956	2406104	11.575836	5.11723
135	18225	2460375	11.618950	5.12992
136	18496	2515456	11.661903	5.14256
137	18769	2571353	11.704699	5.15513
138	19044	2628072	11.747344	5.16764
139	19321	2685619	11.789826	5.18010
140	19600	2744000	11.832159	5.19249
141	19881	2803221	11.874342	5.20482
142	20164	2863288	11.916375	5.21710
143	20449	2924207	11.958260	5.22932
144	20736	2985984	12.0	5.24148
145	21025	3048625	12.041594	5.25358
146	21316	3112136	12.083046	5.26563
147	21609	3176523	12.123455	5.27763
148	21904	3241792	12.165525	5.28957
149	22201	3307949	12.266555	5.30145
150	22500	3375000	12.247448	5.31329
151	22801	3442951	12.288205	5.32507
152	23104	3511808	12.328828	5.33680
153	23409	3581577	12.369316	5.34848
154	23716	3652264	12.409673	5.36010
155	24025	3723875	12.449899	5.37168
156	24336	3796416	12.489996	5.38323
157	24649	3869893	12.529964	5.39469
158	24964	3944312	12.569805	5.40612
159	25281	4019679	12.609520	5.41750
160	25600	4096000	12.649110	5.42883

TABLE—(Continued)

OF SQUARES, CUBES, SQUARE AND CUBE ROOTS OF NUMBERS.

Number.	Square.	Cube.	Square Root.	Cube Root.
161	25921	4173281	12.688577	5.44012
162	26244	4251528	12.727922	5.45136
163	26569	4330747	12.767145	5.43255
164	26896	4410944	12.806248	5.47370
165	27225	4492125	12.845232	5.48480
166	27556	4574296	12.884098	5.49586
167	27889	4657463	12.922848	5.50687
168	28224	4741632	12.961481	5.51784
169	28561	4826809	13.0	5.52877
170	28900	4913000	13.038404	5.53965
171	29241	5000211	13.076696	5.55049
172	29584	5088448	13.114877	5.56129
173	29929	5177717	13.152946	5.57205
174	30276	5268024	13.190906	5.58277
175	30625	5359375	12.228756	5.59344
176	30976	5451776	13.266499	5.60407
177	31329	5545233	13.304134	5.61467
178	31684	5639752	13.341664	5.62522
179	32041	5735339	13.379088	5.63574
180	32400	5832000	13.416407	5.64621
181	32761	5929741	13.453624	5.65665
182	33124	6028568	13.490737	5.66705
183	33489	6128487	13.527749	5.67741
184	33856	6229504	13.564660	5.68773
185	34225	6331625	13.601470	5.69801
186	34596	6434856	13.638181	5.70826
187	34969	6539203	13.674794	5.71847
188	35344	6644672	13.711309	5.72865
189	35721	6751269	13.747727	5.73879
190	36100	6859000	13.784048	5.74889
191	36481	6967871	13 820275	5.75896
192	36864	7077888	13.856406	5.76899
193	37249	7189057	13.892444	5.77899
194	37636	7301384	13.928388	5.78896
195	38025	7414875	13.964240	5.79889
196	38416	7529536	14.0	5.80878
197	38809	7645373	14.035668	5.81864
198	39204	7762392	14.071247	5.82847
199	39601	7880599	14.106736	5.83827
200	40000	8000000	14.142135	5.84803

CLOSING WORDS.

To progress means primarily a steady and constant forward movement, admitting of pause but not retreat; we speak of slow or rapid progress—thus one may say without limitation, "I am an advocate of progress."

The aim of this volume is to illustrate the above thought and to advocate a constant advancement; it must be remembered that experience teaches that no enterprise can stand still, and the wise student will make a firm resolve to seek constant development of new powers and greater proficiency both in personal character and in the mechanic arts.

Furthermore, a regular review of first principles, as aimed to be taught in this volume, is not only wise but safe for the reader, as, owing to the varying conditions of trade which necessarily make fluctuations in the "output" of the shop, the article which is the product of the shop cannot remain marketable over long periods without constant improvement in design,—

Again, as to equipment, tools which are modern and best suited to the work to-day, not only depreciate, but become an actual source of loss in doing their work when compared with the tools of later date, hence, the necessity of a constant progression along new lines founded upon the elementary and unchangeable laws of nature.

Last of all, it may be kindly added, there is a constant going and coming among the personnel of all shops of industry, and in the shifts and changes among men of all grades, is found the opportunity for permanent advance to the well read and capable "coming man."

The author, in closing, wishes a progressive improvement, as indicated by the title of this book, to be the happy outcome of the reader and student.

PART TWO

GENERAL CONTENTS.

For special index, alphabetically arranged, see front of book.

SUMMARY OF ARITHMETIC.

The following abridgment of several of the rules of arithmetic, often referred to in elementary books on mechanical science, are here inserted for the convenience of reference. These rules and examples are given merely to refresh the memory, it being taken for granted that the reader has already acquainted himself with the principles of common arithmetic. They will, however, be found serviceable, both as a convenience of reference and to give some insight to the subjects on which they treat.

Arithmetic is the science of numbers, and numbers treat of magnitude or quantity. Whatever is capable of increase or diminution is a magnitude or quantity.

The processes of arithmetic are merely expedients for making easier the discovery of results which every man of ordinary ingenuity would find a means for discovering himself. Roger Bacon lived eight centuries ago; in the great roll of modern scientists, his name stands first; these are his

NOTE.—Calculation is the art, practice or manner of computing by numbers: the use of numbers by addition, subtraction, multiplication or division, for the purpose of arriving at a certain result.

Upon this art—of calculation—rest not only the mechanical arts, but the whole structure of modern civilization. Consider the solar system, a time-piece, a well-equipped modern factory—the characteristic of each is its "calculability." Everything comes at last to correct figuring for assured success.

SUMMARY OF ARITHMETIC.

words: "For he who knows not mathematics cannot know any other sciences; and, what is more, he cannot discover his own ignorance or find its proper remedies."

In every branch of science, our knowledge increases as the power of measurement becomes improved; it is very generally true that the one ignorant of useful numbers is the one who serves, while the leader in all departments is the one who calculates.

A glossary is a collection of words not in general use, especially of an art or science; the ordinary use of a glossary is to explain in some detail many of the more difficult words used in the text, hence the following—

SYMBOLS, ABBREVIATIONS AND DEFINITIONS.

= *Equal to.* The sign of equality; as 100 cts. = $1, signifies that one hundred cents are equal to one dollar.

— *Minus* or *Less.* The sign of subtraction; as 8—2 =6; that is, 8 less 2, is equal to 6.

+ *Plus* or *More.* The sign of addition; as 6+8=14; that is, 6 added to 8 is equal to 14.

× *Multiplied by.* The sign of multiplication; as 7×7 =49; that is, 7 multiplied by 7 is equal to 49.

÷ *Divided by.* The sign of division, as 16÷4=4; that is, 16 divided by 4 is equal to 4.

SYMBOLS, ABBREVIATIONS AND DEFINITIONS.

∴ Signifies then or therefore.

∵ Since or because.

d^2 = diameter squared, or is a number multiplied by itself, thus $2 \times 2 = 4$.

d^3 = diameter cubed, or is a number multiplied by itself twice, thus $2 \times 2 \times 2 = 8$.

d^4 = diameter to the fourth power, or is a number multiplied by itself thrice, thus $2 \times 2 \times 2 \times 2 = 16$.

A single accent (′) signifies feet; *a double accent* (″) inches; thus 3′ 6″ = 3 feet 6 inches.

Dia. = diameter. ° Degrees.

Revs. per min. = revolutions per minute.

Lbs. per sq. in. = pounds per square inch.

Brackets ( ) or [ ] are employed to denote that several numbers are to be taken collectively. Thus $4(a + b)$ signifies that the number represented by $a + b$ is to be multiplied by 4; again $(a + b) \times (c - d)$ denotes that the number represented by $a + b$ is to be multiplied by the number which is the result of subtracting d from c.

The Greek Letter π denotes the ratio of the circumference of a circle to its diameter. In the English alphabet, this letter stands in place of *p*, and is called *pi;* it is very frequently met with in mechanical literature.

The Decimal Point.—In both France and Germany, one-fourth (¼) reduced to a decimal is always written as 0,25; in England it is written 0·25, and in the United States in this way, 0.25.

SYMBOLS, ABBREVIATIONS AND DEFINITIONS.

A formula is an arithmetical rule in which all words are omitted, all the quantities represented by letters and figures, and all the operations indicated by signs, and by the position of the different characters; the word "formula" is another name for "form."

The following 10 formulas include the elementary operations of arithmetic and follow from the succeeding illustrations.

1. *The Sum = all the parts added.*
2. *The Difference = the Minuend − the Subtrahend.*
3. *The Minuend = the Subtrahend + the Difference*
4. *The Subtrahend = the Minuend — the Difference.*
5. *The Product = the Multiplicand × the Multiplier.*
6. *The Multiplicand = the Prodnct ÷ the Multiplier.*
7. *The Multiplier = the Product ÷ the Multiplicand.*
8. *The Quotient = the Dividend ÷ the Divisor.*
9. *The Dividend = the Quotient × the Divisor.*
10. *The Divisor = the Dividend ÷ the Quotient.*

A number is exactly divisible by—2, when the number ends in an even number or in 0; *3*, when the sum of the digits is exactly divisible by 3; *4*, when the number formed by the last two digits is exactly divisible by 4; *5*, when the number ends in 5 or 0.

Ratio is the relation of one number to another, as obtained by dividing one by the other; hence, ratio means the same as the word quotient.

SYMBOLS, ABBREVIATIONS AND DEFINITIONS.

Log. This is the abbreviation of the term *logarithm;* these are auxiliary numbers, by means of which the simple operations of addition and subtraction may be substituted for the more cumbrous operations of multiplication and division, and easy cases of multiplication and division for involution and evolution.

The use of logarithms reduces multiplication to addition, division to subtraction; raising powers or extracting roots to multiplication and division, respectively.

Logarithms of numbers are arranged in tables, running to four and six figures, beginning with one and going to so high as to fill entire books with the columns.

Algebra is that science which deals with formulas; it is a mathematical science which teaches the art of making calculations by letters and signs instead of figures. The name comes from two Arabic words, *al gabron*, reduction of parts to a whole. The letters and signs are called *Symbols. Quantities* in Algebra are expressed by *letters*, or by a combination of *letters* and *figures;* as a, b, c, $2x$, $3y$, $5z$, etc. The first letters of the alphabet are used to express *known* quantities; the last letters, those which are *unknown.*

The operations to be performed are expressed by the same signs as in Arithmetic; thus + means Addition, — expresses Subtraction, and × stands for Multiplication.

NOTE.—A machinist has little or no use for algebra in his every-day work; but if he wants to find out more about the how and why of things and study into general principles, it is the most important subject that he can take up, next to arithmetic and mechanical drawing.

SYMBOLS, ABBREVIATIONS AND DEFINITIONS.

A NUMBER is a unit or collection of units; as two, five, six feet, etc.

An INTEGER is a number that represents whole things.

An ABSTRACT NUMBER is one which does not refer to any particular object.

A CONCRETE NUMBER is a number used to designate objects or quantities.

An ODD NUMBER is a number which cannot be divided by two.

An EVEN NUMBER can be exactly divided by two.

FACTORS of a number are those numbers which, when multiplied together, make that number.

A PRIME NUMBER is a number exactly divisible by one.

A COMPOSITE NUMBER is a number which can be divided by other integers besides itself and one.

An EXACT DIVISOR of a number is a whole number that will divide that number without a remainder.

The GREATEST COMMON DIVISOR of two or more numbers is the greatest number that will divide each of them exactly.

A MULTIPLE of a number is any number exactly divisible by that number.

The LEAST COMMON MULTIPLE of two or more numbers is the least number that is exactly divisible by each of them.

A PRIME FACTOR is any prime number used as a factor.

NOTE.—*Quantity* is the amount of anything considered, or of any commodity bought, or sold. *Price* is the value in money of one, or of a given unit of any commodity. *Cost* is the value in money of the entire quantity bought, or sold.

NOTATION AND NUMERATION.

NOTATION is a system of representing numbers by symbols. There are two methods of notation in use, the *Roman* and the *Arabic*. NUMERATION is a system of naming or reading numbers.

THE ARABIC METHOD OF NOTATION employs ten characters or figures, viz:

1	2	3	4	5	6	7	8	9	0
One,	***Two,***	***Three,***	***Four,***	***Five,***	***Six,***	***Seven,***	***Eight,***	***Nine,***	***Zero.***

The nine figures are called *digits* or significant figures. The character 0 has no value when standing alone.

The nine digits have each a *simple* and a *local value.* The simple value of a figure is the one expressed by it when standing alone or in the units place. The local value of a figure is that which depends upon the place which the figure occupies in a number.

There must be three figures in every period, except the one at the left, which may have one, two or three. Every order of a number not occupied by a significant figure must be filled with a cipher, or 0.

NOTE.—By means of these ten figures or characters we can represent any number. When one of the figures stands by itself, it is called a unit; but if two of them stand together, the right-hand figure is still called a unit, but the left-hand figure is called tens; thus, 79 is a collection of 9 units and 7 sets of ten units each, or of 9 units and 70 units, or of 79 units, and is read as seventy-nine. If three of them stand together, then the left-hand figure is called hundreds; thus, 279 is read two hundred and seventy-nine.

NOTATION AND NUMERATION.

Rule for Notation.—*Beginning at the left, write the hundreds, tens and units of each successive period in their proper order, filling all vacant orders and periods with ciphers.*

Numeration Table.

Names of periods:	Billions.			Millions.			Thousands.			Units.						
Order of Units:	Hundred-billions	Ten-billions	Billions	Hundred-millions	Ten-millions	Millions	Hundred-thousands	Ten-thousands	Thousands	Hundreds	Tens	Units	Decimal point	Tenths	Hundredths	Thousandths
	8	7	6,	5	4	3,	2	0	1,	2	8	2	.	4	8	9

The number in the table is read "eight hundred and seventy-six billion, five hundred and forty-three million, two hundred and one thousand, two hundred and eighty-two, decimal point, four, eight, nine."

In the table given, it will be observed that the long row of figures is divided into groups of three figures, called periods. This is to aid in their ready reading. The first set is called *units*, the second *thousands*, the third *millions*, etc.

Beginning at units place, the orders on the right of the decimal point express tenths, hundredths, thousandths, etc.

The Reading of Decimals.—In reading decimals, it is well to omit, even in thought, the idea of a denominator, and to say, thus—example, .25; to read, say "point, 2, 5"; in reading .48437, say "point, 4, 8, 4, 3, 7."

Example.—Write sixty-four thousandths in decimals.

Since there are only two figures in the numerator 64, and the right-hand figure of the decimal must occupy the

NOTATION AND NUMERATION.

third decimal place to express thousandths, it is necessary to prefix a cipher to bring the right-hand figure into its proper place. Therefore write *point*, *oh*, *six*, *four* (.064), in the order named.

It is well also to say "oh" (this is the letter O).

THE ROMAN NOTATION is the method of notation by letters, and is illustrated as follows:

I,	V,	X,	L,	C,	D,	M,
1,	5,	10,	50	100,	500,	1,000.

Repeating a letter repeats its value; thus: I = 1, II = 2.

Placing a letter of less value before one of greater value diminishes the value of the greater by the less; thus, IV = 4, IX = 9, XL = 40.

Placing the less after the greater increases the value of the greater by that of the less; thus, VI = 6, XI = 11, LX = 60.

Placing a horizontal line over a letter increases its value a thousand times; thus, $\overline{\text{IV}}$ = 4,000 $\overline{\text{M}}$ = 1,000,000.

ROMAN TABLE.

I	denotes	One.	XVII	denotes	Seventeen.
II	"	Two.	XVIII	"	Eighteen.
III	"	Three.	XIX	"	Nineteen.
IV	"	Four.	XX	"	Twenty.
V	"	Five.	XXX	"	Thirty.
VI	"	Six.	XL	"	Forty.
VII	"	Seven.	L	"	Fifty.
VIII	"	Eight.	LX	"	Sixty.
IX	"	Nine.	LXX	"	Seventy.
X	"	Ten.	LXXX	"	Eighty.
XI	"	Eleven.	XC	"	Ninety.
XII	"	Twelve.	C	"	One hundred.
XIII	"	Thirteen.	D	"	Five hundred.
XIV	"	Fourteen.	M	"	One thousand.
XV	"	Fifteen.	$\overline{\text{X}}$	"	Ten thousand.
XVI	"	Sixteen.	$\overline{\text{M}}$	"	One million

ADDITION.

Addition is uniting two or more numbers into one. The result of the addition is called the Sum or Amount. In addition, the only thing to be careful about except the correct doing of the sum, is to place the unit figures under the unit figure above it, the tens under the tens, etc.

RULE.

After writing the figures down so that units are under units, tens under tens, etc.:

1. *Begin at the right hand, up and down row, add the column and write the sum underneath if less than ten.*

2. *If, however, the sum is ten or more, write the right-hand figure underneath, and add the number expressed by the other figure or figures with the numbers of the next column.*

3. *Write the whole of the last column.*

EXAMPLES FOR PRACTICE.

7,060	248,124	13,579,802
9,420	4,321	83
1,743	889,876	478,652
4,004	457,902	87,547,289
22,227 Ans.		

Use care in placing the numbers in vertical lines; irregularity in writing them down is the cause of mistakes.

RULE FOR PROVING THE CORRECTNESS OF THE SUMS.—*Add the columns from the top downward, and if the sum is the same as when added up, the answer is right.*

Add and prove the following numbers:

684 32 257 20. Ans. 993.

SUBTRACTION.

Subtraction is taking a lesser sum from a greater one.

As in addition, care must be used in placing the units under the units, the tens under the tens, etc.

The answer is called the remainder or the difference.

The sign of subtraction is (—) Example: 98—22=76.

Subtraction is the opposite of addition: one "takes from," while the other "adds to."

RULE.

1. *Write down the greater number first, and then under it the lesser number, so that the units stand under the units, the tens under the tens, etc., etc.*

2. *Begin with the units, and take the under from the upper figure, and put the remainder beneath the line.*

3. *But if the lower figure is the larger, add ten to the upper figure, and then subtract and put the remainder down: this borrowed ten must be deducted from the next column of figures where it is represented by* 1.

EXAMPLES FOR PRACTICE.

892	89,672	89,642,706
46	46,379	48,765,421
846 remainder.		

NOTE.—In the first example, 892—46, the 6 is larger than 2; borrow 10, which makes it 12, and then deduct the 6; the answer is 6. The borrowed 10 reduces the 9 to 8, so the next deduction is 4 from 8=4 is the answer.

SUBTRACTION.

RULE FOR PROVING THE CORRECTNESS OF SUBTRACTION.—*Add the remainder, or difference, to the smaller amount of the two sums, and if the two are equal to the larger, then the subtraction has been correctly done.*

EXAMPLE.	898		246
	246	Now then,	652
	652		898 Ans.

MULTIPLICATION.

MULTIPLICATION is finding the amount of one number increased as many times as there are units in another.

The number to be multiplied or increased is called the MULTIPLICAND.

The MULTIPLIER is the number by which we multiply. It shows how many times the multiplicand is to be increased.

The answer is called the PRODUCT.

The multiplier and multiplicand which produce the product are called its FACTORS. This is a word frequently used in mathematical works, and its meaning should be remembered.

The sign of multiplication is $\times$ and is read "times," or multiplied by; thus, 6×8 is read, 6 times 8 is 48, or, 6 multiplied by 8 is 48.

The principle of multiplication is the same as addition: thus, $3\times8=24$ is the same as $8+8+8=24$.

MULTIPLICATION.

Rule for Mutiplying.

1. *Place the unit figure of the multiplier under the unit figure of the multiplicand, and proceed as in the following:*

Examples. Multiply 846 by 8, and 487,692 by 143.

Arrange them thus:

```
                         487,692
                             143
    846                  -------
      8                  1463076
   ----                 1950768
  6,768                487692
                       ---------
                       69,739,956
```

2. *But if the multiplier has ciphers at its end, then place it as in the following:*

Multiply 83,567 by 50, and 898 by 2,800.

```
                            898
    83567                     2800
         50                   ------
  ----------                718400
  4,178,350               1796
                          --------
                          2,514,400
```

The product and the multiplicand must be in like numbers. Thus, 10 times 8 gallons of *oil* must be 80 gallons of *oil*; 4 times 5 *dollars* must be 20 *dollars*; hence, the multiplier must be the *number* and not the *thing* to be multiplied.

In finding the cost of 6 tons of coal at 7 dollars per ton, the 7 *dollars* are taken 6 times, and not multiplied by 6 tons.

MULTIPLICATION.

When the multiplier is 10, 100, 1000, etc., the product may be obtained at once by annexing to the multiplicand as many ciphers as there are in the multiplier.

EXAMPLE.

1. Multiply 486 by 100. Now 486 with 00 added = 48,600.

2. 6,842 × 10,000 = how many? Ans. 68,420,000.

TO PROVE THE RESULT IN MULTIPLICATION.

RULE.—*Multiply the multiplier by the multiplicand, and if the product is the same in both cases, then the answer is right.*

DIVISION.

Division is a word derived from the Latin, *divido* meaning to separate into parts. In arithmetic, it may be defined as the dividing of a number or quantity into any number of parts assigned.

When one number has to be divided by another number, the first one is called the DIVIDEND, and the second one the DIVISOR, and the result is the QUOTIENT.

1. TO DIVIDE BY ANY NUMBER UP TO 12.

RULE.—*Put the dividend down with the divisor to the left of it, with a small curved line separating it, as in the following*

EXAMPLE.—Divide 7,865,432 by 6.

```
6)7,865,432
  ---------
  1,310,905—2
```

DIVISION.

Here at the last we have to say, "6 into 32 goes 5 times and 2 over"; always place the number that is over as above, separated from the quotient by a small line, or else put it as a fraction, thus, $\frac{2}{6}$, the top figure being the remainder, and the bottom figure the divisor, when it should be put close to the quotient; thus, $1,310,905\frac{2}{6}$.

2. TO DIVIDE BY ANY NUMBER UP TO 12, WITH A CIPHER OR CIPHERS AFTER IT, as 20, 70, 90, 500, 7,000, etc.

RULE.—*Place the sum down as in the last example, then mark off from the right of the dividend as many figures as there are ciphers in the divisor; also mark off the ciphers in the divisor; then divide the remaining figures by the number remaining in the divisor; thus:—*

EXAMPLE.—Divide 9,876,804 by 40.

```
40)9,876,804
   ---------
   246,920—4.
```

The 4 cut off from the dividend is put down as a remainder, or it might have been put down as $\frac{4}{40}$ or $\frac{1}{10}$.

3. TO DIVIDE BY ANY NUMBER NOT INCLUDED IN THE LAST TWO CASES.

RULE.—*Write the divisor at the left of the dividend and proceed as in the following*

EXAMPLE.

Divide 726,981 by 7,645.

```
7,645)726981(95
      68805
      -----
       38931
       38225
       -----
         706  Ans. 95 706/7645.
```

DIVISION.

EXAMPLES FOR PRACTICE.

1.—Divide 76,298,764,833 by 9.
2.— " 120,047,629,817 " 20.
3.— " 9,876,548,210 " 48.
4.— " 3,247,617,219 " 63.

Multiplying the dividend, or dividing the divisor by any number, multiplies the quotient by the same number.

Dividing the dividend, or multiplying the divisor by any number, divides the quotient by the same number.

Dividing or multiplying both the dividend and divisor by the same number does not change the quotient.

RULE FOR PROVING DIVISION.

Division may be proved by multiplying the quotient by the integral part of the Divisor, and adding to the product the remainder, if there is any. The result will be equal to the dividend if the work is correct.

EXAMPLE. 12)48679
4056—7
12
48679 Proof.

QUOTATION.—"As long ago as the days of ancient Greece, Aristotle said: 'I find the young men who study mathematics quick and intelligent at other studies.' But, apart from the value of mathematical studies as a mental training, the modern engineer, whatever branch of the science he may pursue, will find mathematics one of the necessary tools of his profession."

REDUCTION.

A DENOMINATE NUMBER is a number applied to an object; thus, 40 inches and 3 feet 5 inches are denominate numbers; the first is a *simple* and the latter a *compound denominate number.*

REDUCTION is changing these numbers from one denomination to another without altering their values. It is of two kinds, DESCENDING and ASCENDING.

Reduction Descending is changing higher denominations to lower, as tons to pounds. Reduction Ascending is changing lower to higher denominations, as cents to dollars.

Reduction of Denominate Numbers is the process of changing the denomination of a number without changing the value. Thus, 3 yards may be expressed as 9 feet, or 108 inches.

TO CHANGE DENOMINATE NUMBERS TO LOWER DENOMINATIONS is done by multiplication and by the following

RULE.—1. *Multiply the number of the highest denomination given by the number of units of the next lower denomination required to make one of that higher, and to the product add the given number of the lower denomination, if any.*

2. *Proceed in like manner with this result and each successive denomination obtained, until the given number is reduced to units of the required denomination.*

NOTE.—*A simple number* is one which expresses one or more units of the same denomination. *A compound number* expresses units of two or more denominations of the same kind, as 5 yards, 1 foot, 4 inches—or example, page 36, 6 T., 8 cwt., 3 qrs.—these are compound numbers; but *ten oxen*, or *five dollars*, are simple numbers.

REDUCTION.

EXAMPLE.

Reduce six tons, eight hundred weight, three quarters, to lbs.

```
    6  T. 8 cwt. 3 qrs.
   20
  ---
  120
    8 add above.
  ---
  128
    4
  ---
  512
    3 add above.
  ---
  515 qrs.
   25
 ----
 2575
1030
-----
12875 lbs.   Answer.
```

TO REDUCE LOWER DEMOMINATIONS TO HIGHER IS DONE BY DIVISION.

RULE.—1. *Divide the given number by the number of units of the given denomination required to make a unit of the next higher denomination.*

2. *In the same manner, divide this and each successive quotient until the required denomination is reached. The last quotient, with the remainders annexed, will be the required result.*

Ex.—Bring 98,704,623 lbs. to tons and lbs.

```
2000)98704623
     --------
        49352 Tons, 623 lbs.
```

REDUCTION.

Ex.—76,245 gills to gallons, etc.

4)76245

2)19061—1 gill

4)9530—1 pint.

2382—2 quarts.

Ans., 2382 gallons, 2 quarts, 1 pint and 1 gill.

PROOF.—Reduction Ascending and Descending *prove* each other; for one is the reverse of the other.

FRACTIONS.

A fraction means a part of anything. A vulgar fraction is always represented by two numbers (at least), one over the other and separated by a small horizontal line. The one above the line is always called the NUMERATOR, and the one below the line the DENOMINATOR.

The denominator tells us how many parts the whole thing has been divided into, and the numerator tells us how many of those parts we have. Thus, in the fraction $\frac{3}{8}$ the eight is the denominator, and shows that the object has been divided into eight equal parts; and three is the numerator, and shows that we have three of those pieces or parts of the object.

A PROPER FRACTION is one whose numerator is less than the denominator, as $\frac{3}{8}$ or $\frac{2}{5}$.

AN IMPROPER FRACTION is one whose numerator is more than its denominator, $\frac{8}{3}$ or $\frac{5}{2}$.

NOTE.—$\frac{8}{3}$ means more than a whole one, because $\frac{3}{3}$ must be a whole one. Thus $\frac{8}{3}$ will be three-thirds+three-thirds+two-thirds, or $2\frac{2}{3}$, and this form of fraction is called *a mixed number*.

REDUCTION OF FRACTIONS.

TO REDUCE AN IMPROPER FRACTION TO A MIXED NUMBER.

RULE.—*Divide the numerator by the denominator; the quotient is the whole number part, and the remainder is the numerator of the fractional part.*

EXAMPLES: $\frac{16}{7}=2\frac{2}{7}$. $\frac{15}{3}=5$. $\frac{27}{8}=3\frac{3}{8}$.

TO REDUCE A MIXED NUMBER TO AN IMPROPER FRACTION.

RULE.—*Multiply the whole number part by the denominator, and add on the numerator; the result is the numerator of the improper fraction.*

EXAMPLES: $2\frac{2}{7}=\frac{16}{7}$. $5\frac{1}{3}=\frac{16}{3}$. $3\frac{3}{8}=\frac{27}{8}$.

TO REDUCE A FRACTION TO ITS LOWEST TERMS.

RULE.—*Divide both numerator and denominator by the same number; if by so doing there is no remainder.*

EXAMPLE.—Reduce $\frac{8}{12}$. Here 4 will divide both top and bottom without a remainder. Divide by 4.

$$4)\frac{8}{12}=\frac{2}{3}.$$

The meaning of this is, that if you divide a thing into 12 equal parts, and take 8 of them, you will have the same as if the thing had been divided into 3 equal parts and you had two of them.

TO REVERSE THE LAST RULE, TO BRING A FRACTION OF ANY DENOMINATOR TO A FRACTION HAVING A GREATER DENOMINATOR.

RULE.—*See how often the less will go into the greater denominator and multiply both numerator and denominator by it. The result is the required fraction.*

REDUCTION OF FRACTIONS.

EXAMPLES.

Bring $\frac{1}{2}$ to a fraction whose denominator is 8.

Here 2 goes in 8 four times; then multiply the numerator and denominator of $\frac{1}{2}$ by 4—$\frac{4}{8}$, which is the required fraction.

Bring $\frac{2}{3}$ to a fraction whose denominator is 15.

Here 3 goes into 15 five times; then $\frac{2}{3}$ becomes $\frac{10}{15}$.

In case of a fraction of a fraction, as $\frac{1}{2}$ of $\frac{1}{4}$, it is called a compound fraction, and should always be reduced to a simple fraction *by multiplying all the numerators together for a new numerator, and all the denominators together for a new denominator; then, if necessary, reduce this fraction to its lowest terms.*

EXAMPLE.—$\frac{3}{4}$ of $\frac{2}{3}$ of $\frac{4}{9}$. Reduce to a single fraction: 3×2×4—24; and 4×3×9—108.

Thus, $\frac{24}{108}$ is the fraction. Reduce this 12)$\frac{24}{108}$—$\frac{2}{9}$.

TO REDUCE TWO OR MORE FRACTIONS TO EQUIVALENT FRACTIONS HAVING THEIR LEAST COMMON DENOMINATOR.

RULE.—*Find the least common multiple of the given denominators for the least common denominator, and reduce the given fractions to this denominator.*

EXAMPLE.

Reduce $\frac{2}{3}$, $\frac{3}{4}$, $\frac{5}{6}$ and $\frac{9}{10}$ to equivalent fractions having their least common denominator; then $\frac{2}{3}$—$\frac{40}{60}$, $\frac{3}{4}$—$\frac{45}{60}$, $\frac{5}{6}$—$\frac{50}{60}$, $\frac{9}{10}$—$\frac{54}{60}$.

CANCELLATION.

This is a method of shortening problems by rejecting equal factors from the divisor and dividend.

The sign of cancellation is an oblique mark drawn across the face of a figure, as $\not 4$, $\not 6$, $\not 2$.

Cancellation means to leave out; if there are the same numbers in the numerator and the denominator they are to be left out.

Ex.—$\frac{3}{4}$ of $\frac{2}{3}$ of $\frac{4}{9}$. Here the 3 in the first numerator and the 3 in the second denominator are left out; also 4 of the first denominator and the last numerator, thus:

$$\text{Ans.}\ \frac{\not 3}{\not 4}\times\frac{2}{\not 3}\times\frac{\not 4}{9}=\frac{2}{9}$$

Ex.—$\frac{2}{9}$ of $\frac{3}{8}$ of $\frac{14}{18}$ of $\frac{90}{170}$—by cancellation **thus:**

$$\underset{3}{\frac{\not 2}{\not 9}}\text{ of }\underset{\underset{2}{\not 4}}{\frac{\not 3}{\not 8}}\text{ of }\frac{\overset{7}{\not 1\not 4}}{\not 1\not 8}\text{ of }\underset{34}{\frac{\overset{5}{\not 9\not 0}}{\not 1\not 7\not 0}}=\frac{7}{3\times2\times34}=\frac{7}{204}$$

See note.

NOTE.—The process is as follows: The first numerator, 2, will go into 8, the denominator of the second fraction, 4 times; the denominator of the third fraction, 18, will go into 90, the numerator of the last quantity, 5 times. The numerator of the second fraction, 3, will go into the denominator of the first fraction 3 times; 5 will go into 170, 34 times; 2 will go into 4 twice, and 2 into 14, 7 times, and as we cannot find any more figures that can be divided without leaving a remainder, we are at the end, and the quantities left must be collected into one expression. On examination, we have 7 left on the top row; this is put down at the end as the final numerator; on the bottom we have 3, 2 and 34; these multiplied together give us 204, which is the final denominator.

USEFUL DEFINITIONS.

RULES FOR CANCELLING.

1. *Any numerator may be divided into any denominator, provided no remainder is left, and vice versa,* ***thus:***

$$\frac{\cancel{3}}{5} \text{ of } \frac{4}{\underset{3}{\cancel{9}}} = \frac{4}{15} \qquad \Big| \qquad \frac{\cancel{3}}{\cancel{5}} \text{ of } \frac{\overset{3}{\cancel{15}}}{\underset{\underset{2}{\cancel{6}}}{\cancel{18}}} = \frac{1}{2}$$

2. *Any numerator and denominator may be divided by the same number, provided no remainder is left, and the decreased value of such numerator and denominator be inserted in the place of those cancelled.*

$$\frac{3}{\underset{2}{\cancel{8}}} \text{ of } \frac{\overset{5}{\cancel{20}}}{31}$$

Here 8 is divided by 4, and 20 can also be divided by the same number without leaving any remainder. Answer, $\frac{15}{62}$.

Ex.—

$$\frac{\cancel{8}}{\underset{3}{\cancel{15}}} \text{ of } \frac{\cancel{5}}{\underset{\underset{2}{\cancel{4}}}{\cancel{32}}} \text{ of } \frac{\overset{7}{\cancel{14}}}{17} = \frac{7}{3 \times 2 \times 17} = \frac{7}{102}$$

DEFS.—A COMMON DENOMINATOR of two or more fractions is a denominator to which they can all be reduced, and is the common multiple of their denominators.

THE LEAST COMMON DENOMINATOR of two or more fractions is the least denominator to which they can be reduced, and is the least common multiple of their denominators.

A MULTIPLE of a number is a number that is exactly divisible by it; or it is any product of which the given number is a factor.

Thus, 12 is a multiple of 6; 15 of 5, etc.

A COMMON MULTIPLE of two or more numbers is a number that is exactly divisible by each of them.

Thus, 12, 24, 36 and 48 are multiples of 4 and 6.

THE LEAST COMMON MULTIPLE of two or more numbers is the *least* number that is exactly divisible by each of them.

Thus, 12 is the least common multiple of 4 and 6.

ADDITION OF FRACTIONS.

Addition of fractions is the process of finding the sum of two or more fractions. In order that fractions may be added, they must have like denominators and be parts of like units.

RULE.—*Bring all the fractions to the same common denominator, add their numerators together for the new numerator, and reduce the resulting fraction to its simplest form.*

EXAMPLES.

What is the sum of $\frac{1}{4}+\frac{1}{2}=\frac{1}{4}+\frac{2}{4}=\frac{3}{4}$. Ans.

What is the sum of $\frac{3}{4}+\frac{1}{2}+\frac{3}{8}+\frac{6}{8}=\frac{19}{8}=2\frac{3}{8}$. Ans.

SUBTRACTION OF FRACTIONS.

Bring the fractions to others having a common denominator, as in addition, and subtract their numerators.

EXAMPLES.

From $\frac{7}{8}$ subtract $\frac{3}{8}=\frac{4}{8}=\frac{1}{2}$.

From $\frac{1}{2}$ take $\frac{1}{6}$. $\frac{3-1}{6}=\frac{2}{6}=\frac{1}{3}$.

$\frac{7}{16}-\frac{3}{8}=\frac{7-6}{16}=\frac{1}{16}$.

What is the difference between $\frac{1}{2}$ of $\frac{3}{4}$ and $\frac{1}{4}$ of $1\frac{1}{2}$?

$\frac{1}{2}$ of $\frac{3}{4}=\frac{3}{8}$; and $\frac{1}{4}$ of $1\frac{1}{2}=\frac{1}{4}$ of $\frac{3}{2}=\frac{3}{8}$.

Therefore, it is $\frac{3}{8}-\frac{3}{8}=0$.

MULTIPLICATION OF FRACTIONS.

First bring each fraction to its simplest form; then multiply the numerators together for the new numerator, and the denominators together for the new denominator. Reduce the fraction to its simplest form.

MULTIPLICATION OF FRACTIONS.

EXAMPLES.

1. Multiply $\frac{4}{7} \times 1\frac{5}{16}$; that is, $\frac{4}{7} \times \frac{21}{16} = \frac{84}{112} = \frac{21}{28} = \frac{3}{4}$, or by canceling

$$\frac{\overset{1}{\not 4}}{\underset{1}{\not 7}} \times \frac{\overset{3}{21}}{\underset{4}{\not{16}}} = \frac{3}{4}$$

The 4 cancels into the 16 four times, and the 7 into the 21 three times. Thus $1 \times 3 = 3$, and $1 \times 4 = 4$. Answer $\frac{3}{4}$.

2. $2\frac{1}{10}$ of $3\frac{4}{7} \times 6\frac{1}{8}$ of $\frac{8}{21}$.

$$\frac{\overset{3}{\not{21}}}{\underset{2}{\not{10}}} \text{ of } \frac{\overset{5}{\not{25}}}{\underset{1}{\not 7}} \times \frac{\overset{7}{\not{49}}}{\underset{1}{\not 8}} \text{ of } \frac{\overset{1}{\not 8}}{\underset{3}{\not{21}}}$$

$$\frac{\overset{5}{\not{15}}}{2} \times \frac{7}{\underset{1}{\not 3}} = \frac{35}{2} = 17\tfrac{1}{2} \text{ Answer.}$$

DIVISION OF FRACTIONS.

Reverse the divisor and proceed as in multiplication.

The object of inverting the divisor is convenience in multiplying.

After inverting the divisor, cancel the common factors.

EXAMPLES.

$\frac{3}{4} \div 1\frac{1}{8}$, that is, $\frac{3}{4} \div \frac{9}{8}$, reverse the $\frac{9}{8}$ and it becomes $\frac{8}{9}$; then the question is $\frac{3}{4} \times \frac{8}{9} = \frac{24}{36} = \frac{2}{3}$ Ans.

$4\frac{2}{7}$ of $\frac{14}{15} \div 3\frac{3}{4}$ of $3\frac{1}{5}$, that is, $\frac{30}{7}$ of $\frac{14}{15} \div \frac{15}{4}$ of $\frac{16}{5}$; canceling reduces the dividend to $\frac{4}{1}$ and the divisor to $\frac{12}{1}$ and we have $\frac{4}{1} \div \frac{12}{1}$, that is, $\frac{4}{1} \times \frac{1}{12} = \frac{4}{12} = \frac{1}{3}$ Ans.

DECIMALS.

A decimal fraction derives its name from the Latin *decem*, "ten," which denotes the nature of its numbers. It has for its denominator a UNIT, or whole thing, as a pound, a yard, etc., and is supposed to be divided into ten equal parts, called tenths; those tenths into ten equal parts, called hundredths, and so on.

The denominator of a decimal being always known to consist of a unit, with as many ciphers annexed as the numerator has places, is never expressed, being understood to be 10, 100, 1000, etc., according as the numerator consists of 1, 2, 3 or more figures. Thus: $\frac{2}{10}$, $\frac{24}{100}$, $\frac{125}{1000}$, etc., the numerators only are written with a dot or comma before them, thus: .2, .24, .125.

The use of the dot (.) is to separate the decimal from the whole numbers.

The first figure on the right of the decimal point is in the place of tenths, the second in the place of hundredths, the third in the place of thousandths, etc., always decreasing from the left towards the right in a tenfold ratio, as in the following

TABLE.

Etc., Etc.	Tens of Millions.	Millions.	Hundreds of Thousands.	Tens of Thousands.	Thousands.	Hundreds.	Tens.	Units.	Decimal point.	Tenths.	Hundredths.	Thousandths.	Ten Thousandths.	Hundred Thousandths.	Millionths.	Ten Millionths.	Etc., Etc.
	5	5	5	5	5	5	5	5	.	5	5	5	5	5	5	5	

Ascending. **Descending.**

DECIMALS.

A cipher placed on the left hand of a decimal decreases its value in a tenfold ratio by removing it farther from the decimal point. But annexing a cipher to any decimal does not alter its value at all. Thus 0.4 is ten times the value of 0.04, and a hundred times 0.004. But 0.7=0.70=0.700 =0.7000, etc., as above remarked.

0.2	is equal to			two-tenths.
0.25	"	"	"	twenty-five hundredths.
0.1876	"	"	"	one thousand eight hundred and seventy-six ten thousandths, and so on.

Mixed numbers consist of a whole number and a decimal, as 4.25 and 3.875.

TO REDUCE A FRACTION TO A DECIMAL.

RULE.—*Annex decimal ciphers to the numerator, and divide by the denominator, pointing off as many decimal places in the quotient as there are ciphers annexed.*

EX.—Reduce $\frac{3}{4}$ to a decimal.

EX.—4) 3.00
·75

TO REDUCE A DECIMAL TO A FRACTION.

RULES.—1, *Omit the decimal point;* 2, *Supply the proper denominator;* 3, *Reduce the fraction to its lowest terms.*

EX.—Reduce .075 to an equivalent fraction.

$.075 = \frac{75}{1000} = \frac{3}{40}$.

NOTE.—"It is not merely the ability to calculate that constitutes the utility of mathematical knowledge to the engineer; it is also the increased capacity for understanding the natural phenomena on which the engineering practice is based."

ADDITION OF DECIMALS.

RULE.—*Place the quantities down in such a manner that the decimal point of one line shall be exactly under that of every other line; then add up as in simple addition.*

EXAMPLE.

Thus:—Add together 36.74, 2.98046, 176.4, 31.0071 and .08647.

```
 36.74
  2.98046
176.4
 31.0071
   .08647
----------
247.21403
```

SUBTRACTION OF DECIMALS.

RULE.—*Place the lines with decimal point under decimal point, as in addition. If one line has more decimal figures than another, put naughts under the one that is deficient till they are equal, then subtract as in simple subtraction.*

EXAMPLES.

From 146.2004 take 98.9876.

```
146.2004
 98.9876
--------
 47.2128 Answer.
```

From 4.17 take 1.984625.

```
4.170000
1.984625
--------
2.185375 Ans.
```

MULTIPLICATION OF DECIMALS.

RULE.—*Place the factors under each other, and multiply them together as in whole numbers; then point off as many figures from the right hand of the product as there are decimal places in both factors, observing, if there be not enough, to annex as many ciphers to the left hand of the product as will supply the deficiency.*

EXAMPLE.—Multiply 3.625 by 2.75.

$$3.625 \times 2.75 = 9.96875 \text{ Ans.}$$

DIVISION OF DECIMALS.

RULE.—*Prepare the decimal as directed for multiplication; divide as in whole numbers; cut off as many figures for decimals in the quotient as the number of decimals in the dividend exceeds the number in the divisor; and if the places in the quotient be not so many as the rule requires, supply the deficiency by annexing ciphers to the left hand of the quotient.*

EXAMPLE.—Divide 173.5425 by 3.75.

```
3.75)173.5425(46.27+
     1500
     ----
      2354
      2250
      ----
       1042
        750
       ----
        2925
        2625
        ----
         300
```

RATIO, PROPORTION, RULE OF THREE.

THE RULE OF THREE, so called because there are always *three* numbers to find a fourth.

The solving of this problem, *i. e.*, having three numbers, to find the fourth, is the most important part of proportion. On account of its great utility and extensive application, it has been called *the golden rule.*

RATIO is the relation of two numbers as expressed by the quotient of the first divided by the second. Thus, the ratio of 6 to 3 is 6÷3, or 2.

THE RATIO BETWEEN TWO NUMBERS *is expressed by placing a colon between them*; *thus, the ratio of* 8 *to* 4 *is expressed* 8 : 4.

A SIMPE RATIO IS A RATIO BETWEEN TWO NUMBERS, as 4 : 5.

A COMPOUND RATIO is a ratio formed by the combination of two or more simple ratios.

Thus, $\begin{matrix}4:5\\3:2\end{matrix}$ is a compound ratio, and is equivalent to $4\times3 : 5\times2$, or 12 : 10.

The numbers whose ratio is expressed are *the terms of the ratio.* The two terms of a ratio form *a couplet*, the first of which is *the antecedent* and the second *the consequent.*

PROPORTION IS AN EQUALITY OF RATIOS. The first and fourth terms of a proportion are called *the extremes*, and the second and third *the means.*

The product of the means is equal to the product of the extremes.

RATIO AND PROPORTION.

A missing mean may be found by dividing the product of the extremes by the given mean.

A missing extreme may be found by dividing the product of the means by the given extreme.

SIMPLE PROPORTION is an equality of two simple ratios, as,

9 lb. : 18 lb. : : 27 cents : 54 cents.

Ex.—If 24 wrenches cost $27, what will 32 wrenches cost?

ANS.—36 dollars. See note.

RULE.—*For convenience, take for the third term the number that may form a ratio with, or is of the same denomination as, the answer. If, from the nature of the example, the answer is to be greater than the third term, make the greater of the two remaining terms (which must be of the same denomination) the second term; when not, make the smaller the second term. Then multiply the means (the second and third) together, and divide their product by the given extreme (the first term).*

EXS.—The missing term, x, in the examples below, can be found by applying the principles given on page 48).

16 : x : : 24 : 18. Ans. 12.
x : 27 : : 18 : 54. Ans. 9.
32 : 27 : : x : 135. Ans. 160.
16 : 12 : : 24 : x. Ans. 18.

NOTE.—For convenience in working this example make the fourth term the missing term, or the required answer. Since the third and fourth terms must be of the same denomination and the denomination of the answer will be dollars, take $27 as the third term. From the nature of the example the answer will be more than $27, the third term; therefore, make 32 wrenches the second term and 24 wrenches the first term. The proportion will then be stated as follows: 24 wrenches : 32 wrenches : : $27 : x (Let x represent the unknown term). Multiplying 32 by 27, and dividing the product by 24, the fourth or missing term will be $36.

EVOLUTION OR SQUARE ROOT.

The SQUARE ROOT of a number is one of the two equal factors of a number. Thus, the square root of 25 is 5. $5 \times 5 = 25$.

TO FIND THE SQUARE ROOT OF A NUMBER.

RULE.—*Beginning at units' place, separate the given number into periods of two figures each.*

Find the greatest square in the left-hand period, and write its root at the right in the form of a quotient in division. Subtract this square from the left-hand period, and to the remainder annex the next period to form a dividend.

Double the part of the root already found for a trial divisor. Find how many times this divisor is contained in the dividend, exclusive of the right-hand figure, and write the quotient as the next figure of the root. Annex this quotient to the right of the trial divisor to form the complete divisor. Multiply the complete divisor by the last figure of the root, and subtract the product from the dividend.

To the remainder annex the next period, and proceed as before.

When the given number is a decimal, separate the number into periods of two figures each, by proceeding in both directions from the decimal point.

EXAMPLE.

Find the square root of 186624.		Proof
	18,66,24(432	432
	16	432
83	266	864
	249	1296
862	1724	1728
	1724	186624

EXAMPLE.

Find the square root of 735.

```
         7,35(27.11 etc.          Proof  2711
          4                              2711
        ------                           ----
   47  | 335                             2711
       | 329                            2711
        ------                         18977
  541  |  600                          5422
       |  541                          ---------
        -------                        734.9521
 5421  |   5900
       |   5421
        --------
            etc.
```

We proceed as before till we get the remainder 6, and we see it is not a perfect square; we wish the root to be taken to two or three places of decimals; there are no more figures to bring down, therefore bring down two ciphers and proceed as in the first example; to the remainder attach two more ciphers and proceed as before, and by attaching two ciphers to the remainder you may carry it to any number of decimal places you please. In the above example the answer is 27.11, etc.

The following important note is to be studied in connection with example at the bottom of the opposite page.

NOTE.—Begin at the last figure 4, count two figures, and mark the second as shown in the example; count two more, and mark the figure, and so on till there are no more figures; take the figures to the left of the last dot, 18, and find what number multiplied by itself will give 18 There is no number that will do so, for $4 \times 4 = 16$, is too small, and $5 \times 5 = 25$, is too large; we take the one that is too small, viz , 4, and place it in the quotient, and place its square, 16, under the 18, subtract and bring down the next two figures, 66. To get the divisor, multiply the quotient 4 by $2 = 8$, place the 8 in the divisor, and say 8 into 26 goes 3 times, place the 3 after the 4 in the quotient and also after the 8 in the divisor; multiply the 83 by the 3 in the quotient, and place the product under the 266 and subtract, then bring down the next two figures, 24. To get the next divisor, multiply the quotient 43 by $2 = 86$; see how often 8 goes into 17, twice; place the 2 after the 43 of the quotient, and also after the 86 of the divisor; multiply the 862 by the 2, and put it under the 1724, then subtract. Answer, 432.

EVOLUTION.

In expressing the square root it is customary to use simply the mark ($\sqrt{}$), the 2 being understood.

All roots as well as powers of *one* are 1, as $\sqrt{1}=1$.

EXAMPLE.

Find the square root of 588.0625.

```
          5,88.06,25(24.25
          4
          -----
  44  |   188
      |   176
          -----
 482  |   1206
      |    964
          ------
4845  |  24225
      |  24225
```

In a decimal quantity like the above, the marking off differs from the former examples. Instead of counting twos from right to left, we begin at the decimal point and count twos toward the left and toward the right. The rest of the work is similar to the other examples.

Notice, that when the .06 is brought down, the figure for a quotient is a decimal.

To familiarize oneself with the extracting of the square root, it is well first to square a number and then work backward according to the examples here given, and by long and frequent practice become expert in the calculation. But in first working square root, it is undoubtedly better to secure the services of a teacher.

INVOLUTION

Is the raising a number (called the root) to any power. The powers of a number are its square, cube, 4th power, 5th power, etc.

$2 \times 2 = 4$	4 is the square or 2nd power of 2.
$2 \times 2 \times 2 = 8$	8 is the cube or 3d power of 2.
$2 \times 2 \times 2 \times 2 = 16$	16 is the 4th power of 2.
Etc.	Etc.

RULE.—*To square a number multiply it by itself.*

EXAMPLE.

What is the square of 27 (written 27^2)?

```
   27
   27
  ---
  189
  54
  ---
  729 Answer.
```

RULE.—*To cube a number, multiply the square of the number by the number again.*

EXAMPLE.—What is the cube of 50 (written 50^3)?

```
     50
     50
    ---
   2500 the square
     50
   ----
 125000 the cube.
```

A *power* of a quantity, is the product arising from multiplying the quantity by itself one or more times. When the quantity is taken *twice* as a factor, the product is called the *second* power; when taken *three* times, the *third* power, and so on.

INVOLUTION.

SIGNS THAT REPRESENT THE ROOTS OF NUMBERS.

The sign common to all roots is $\surd$ or $\sqrt{}$ and is known as the Radical Sign. If we require to express the square root of a number we simply put this sign before it, as $\sqrt{16}$, but if the number is made up of two or more terms, then we express the square root by the same in front, but with a line as far as the square root extends, as $\sqrt{9+7}$ or $\sqrt{4\,(19+6)}$.

The cube root is expressed by the same sign, with a 3 in the elbow, as $\sqrt[3]{8}$ or $\sqrt[3]{7\,(100—51.)}$

All other roots in the same manner, the number of the root being put instead of the 3. As fifth root $\sqrt[5]{}$, and sixth root $\sqrt[6]{}$, etc.

In the above examples, $9+7 — 16$, and the square root of 16 is 4.

The $4\,(19+6)—4\times25—100$, and the square root of 100 is 10.

The other way of expressing that the root is required, is by putting a fraction after and above the quantity, as $16^{\frac{1}{2}}$, which means the square root of 16, $(19+17)^{\frac{1}{2}}$, or $\{4\ (19+6)\}^{\frac{1}{2}}$ all of which means the square root of the quantities to which they are attached.

The cube root, 4th root, 5th root, etc., are written in the same way, as $729^{\frac{1}{3}}=9$; $256^{\frac{1}{4}}=4$; $3125^{\frac{1}{5}}=5$, etc.

THE POWERS OF NUMBERS.

Signs Representing the Power of Numbers.

6^2 is equal to 6×6—36; that is, 36 is the square of 6.

5^3 is equal to 5×5×5—125; that is, 125 is the cube of 5.

4^4 is equal to 4×4×4×4—256; that is, 256 is the fourth power of 4.

The power and the root are often combined, as $4^{\frac{3}{2}}$; this is read as the square root of 4 cubed. So the numerator figure represents the power, and the denominator figure represents the root. In this case the square root of 4 is 2, and the cube of 2 is 2×2×2—8 Answer.

Perhaps the most common form that the student will meet with this sign is in the following:

$8^{\frac{2}{3}}$, which is read the cube root of 8 squared. Now, 8 squared = 64, and the cube root of 64 is 4 Answer.

Find the value of $20^{\frac{3}{2}}$.

20 cubed = 8000, and square root of 8000 = 89.4, etc.

Example.

What is the value of $\frac{8^{\frac{2}{3}}+81}{3^{\frac{3}{2}}}$?

$$8^{\frac{2}{3}} = \sqrt[3]{8^2} = \sqrt[3]{64} = 4;\ 81^{\frac{1}{2}} = 9;\ 3^{\frac{3}{2}} = \sqrt{3^3} = \sqrt{27} = 5.2 \text{ nearly.}$$

Hence, $\frac{4+9}{5.2} = \frac{13}{5.2} = 2.5$ or $2\frac{1}{2}$. Answer.

( ) are called *brackets*, and mean that all the quantities within them are to be put together first; thus, 7 (8—6+4×3) means that 6 must be subtracted from 8 = 2, and 4 times 3 = 12 added to this 2 = 14; and then this 14 is to be multiplied by 7 = 98.

THE METRIC SYSTEM.

In the Metric or French system of weights and measures, the *Meter* is the basis of all the units which it employs. The *Meter* is the unit of length, and is equal to one ten-millionth part of the distance measured on a meridian of the earth from the equator to the pole, and equals about 39.37 inches, or $39\frac{1}{3}$ inches nearly.

The standard meter is a bar of platinum carefully preserved at Paris. Exact copies of the meter and the other units have been procured by the several nations (including the United States) that have legalized the system.

In this system, weights and measures are increased or decreased by the following words prefixed to them:

Milli	expresses	the	1,000th	part.	
Centi	"	"	100th	"	
Deci	"	"	10th	"	
Deka	"	10	times	the	value.
Hecto	"	100	"	"	"
Kilo	"	1,000	"	"	"

TABLE.

		1 Millimeter......($\frac{1}{1000}$ of a meter)	=	.03937	*in.*
10 *mm.*	=	1 Centimeter .....($\frac{1}{100}$ of a meter)	=	.3937	*in.*
10 *cm.*	=	1 Decimeter......($\frac{1}{10}$ of a meter)	=	3.937	*in.*
10 *dm.*	=	1 METER.........(1 meter)	=	39.37	*in.*
10 *m.*	=	1 Dekameter......(10 meters)	=	32.8	*ft.*
10 *Dm.*	=	1 Hectometer.....(100 meters)	=	328.09	*ft.*
10 *Hm.*	=	1 Kilometer......(1000 meters)	=	.62137	*mile.*

NOTE.—A gramme is the weight of a cubic centimeter of distilled water; a decigramme contains $\frac{1}{10}$ of a gramme; a dekagramme contains 10 grammes.

MENSURATION

USEFUL MEASUREMENTS.

A measurement is an ascertained dimension, as the length, breadth, thickness, depth, extent, quantity, capacity, etc., of a thing as determined by measuring.

Mensuration is the art of measuring things which occupy space; the art is partly mechanical and partly mathematical.

There are three kinds of quantity in space, viz., length, surface and *solidity;* and there are three distinct modes of measurement, viz., *mechanical measurement, geometrical construction* and *algebraical calculations.* The last two modes are done by calculations, while in mechanical measurements they are made by the direct application of rules and special measuring instruments.

Lengths are measured on lines, and the measure of a length of a line is the ratio or relation which the line bears to a recognized unit of length—the inch, foot or mile determined by reference to brass rods kept by the United States Government at Washington as a standard. The use of the "rules" is called *direct measurement.*

The second kind of quantity to be measured is surface. This sort of measurement is never done directly or mechanically, but always by the measurement of lines, as will be seen both under this division and under the sections relating to geometry.

The third species of quantity is solidity. Direct measurement of solid quantities consists simply in filling a vessel of known capacity, like a bushel or gallon measure, until all is measured. The geometrical mode of computing solids is the one hereafter shown by examples and illustrations.

SURFACES.

A surface is the exterior part of anything that has length and breadth, as the surface of a cylinder. *The area* of any figure is the measure of its surface or the space contained within the bounds of that surface, without any regard to the thickness.

TO FIND THE AREA OF A TRIANGLE.

A Triangle is a figure bounded by three sides, and is half a parallelogram; hence the

RULE.—*Multiply the base by half the perpendicular height.*

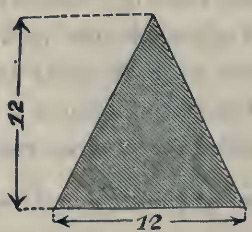


Fig. 6.

EXAMPLE.—The base of the triangle is 12 feet, and it is also 12 feet high; what is its area?

Half the height = 6 feet; and $12 \times 6 = 72$ square feet area.

SURFACES.

To find the area of a Trapezium.

A Trapezium is any four-sided figure that is neither a rectangle, like a square or oblong, nor a parallelogram.

Rule.—1. *Join two of its opposite angles, and thus divide it into two triangles.*

2. *Measure this line and call it the base of each triangle.*

3. *Measure the perpendicular height of each triangle above the base line.*

4. *Then find the area of each triangle by the previous rule; their sum is the area of the whole figure.*

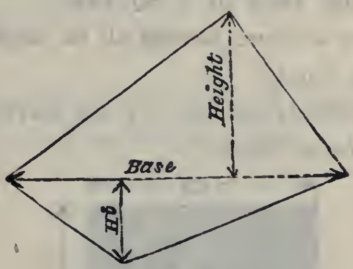


Fig. 7.

To find the area of a Trapezoid.

A Trapezoid is a trapezium having two of its sides parallel.

Rule.—*Multiply half the sum of the two parallel sides by the perpendicular distance between them.*

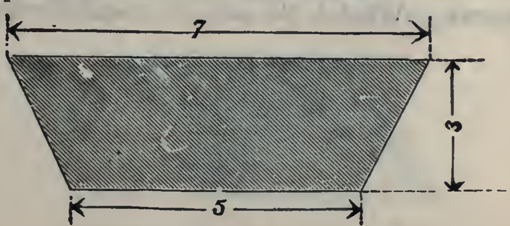


Fig. 8.

USEFUL MEASUREMENTS.

Let the figure be the trapezoid, the sides 7 and 5 being parallel; and 3 the perpendicular distance between them.

EXAMPLE.—Find the area of the above trapezoid, the parallels being 7 feet and 5 feet, and the perpendicular height being 3 feet.

$$\begin{array}{r} 7 \\ 5 \\ \hline 2)12 \\ \hline 6 \end{array} \text{ And } 6 \times 3 = 18 \text{ square feet.}$$

TO FIND THE AREA OF A SQUARE.

A Square is a figure having all its angles right angles and all its sides equal.

RULE.—*Multiply the base by the height; that is, multiply the length by the breadth.*

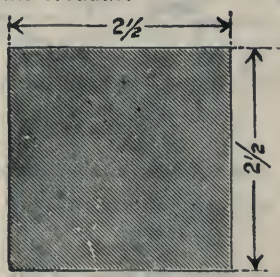


Fig. 9.

EXAMPLE.—What is the area of a square whose side is 2½ feet?

$$\begin{array}{r} 2.5 \\ 2.5 \\ \hline 125 \\ 50 \\ \hline \end{array}$$

Answer, 6.25 square feet.

SURFACES.

TO FIND THE AREA OF A RECTANGLE.

A rectangle is a figure whose angles are all right angles, but whose sides are not equal; only the opposite sides are equal.

RULE.—*Multiply the length by the breadth.*

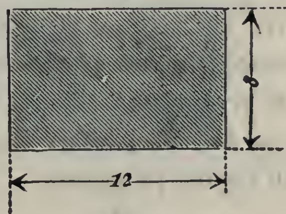


Fig. 10.

EXAMPLE.—What is the area of a rectangular figure whose base is 12 feet and height 8 feet?

$$\begin{array}{r} 12 \\ 8 \\ \hline \end{array}$$

Answer, 96 square feet.

TO FIND THE AREA OF A PARALLELOGRAM.

A Parallelogram is a figure whose opposite sides are parallel, the square and oblong are parallelograms; so also are other four-sided figures whose angles are *not* right angles. It is these latter whose area we now want to find.

RULE.—*Multiply the base by the perpendicular height.*

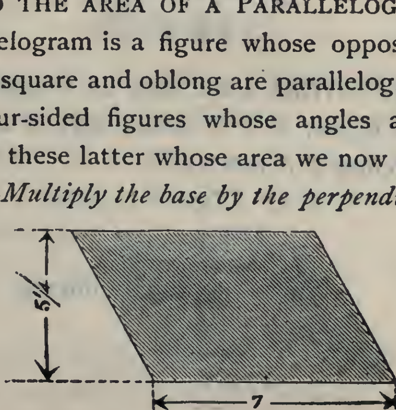


Fig. 11.

USEFUL MEASUREMENTS.

EXAMPLE.—Find the area of a parallelogram whose base is 7 feet and height $5\frac{1}{4}$ feet?

$$\begin{array}{r} 5.25 \\ 7 \\ \hline \end{array}$$

Answer, 36.75 square feet.

TO FIND THE AREA OF A POLYGON.

RULE.—*Multiply the sum of the sides, or perimeter of the polygon, by the perpendicular dropped from its center to one of its sides, and half the product will be the area.* This rule applies to all regular polygons.

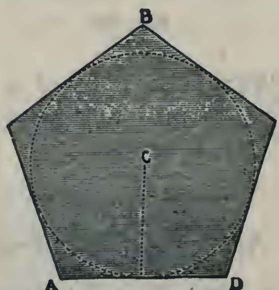


Fig. 12.

EXAMPLE.—What is the area of a regular pentagon, or five-sided figure, *B A D* whose side *A D* is 9 feet and the perpendicular *C E* is 6 feet?

$$\begin{array}{r} 9 \\ 5 \\ \hline 45 \text{ the perimeter.} \\ 6 \\ \hline 2\,)\,270 \\ \hline \end{array}$$

Answer, 135 feet.

THE CIRCLE.

The circle is a plane figure, comprehended by a single curve line, called its *circumference*, every part of which is equally distant from a point called the *center*. Of course, all lines drawn from the center to the circumference are equal to each other.

.7854

"Why is the decimal .7854 used to ascertain the area of a circle or round opening?" is a question frequently asked. Now, if you will divide a square inch into 10,000 parts, then describe a circle one inch in diameter and divide that into ten thousandths of an inch, you will find that you have 7854 of such squares, each one-thousandth of an inch, hence the decimal .7854 is used as a "constant" or multiplier, after squaring the diameter, and the result is the area of the circle.

3.1416

The Greek letter π, called pi, is used to represent 3.1416, the circumference of a circle whose diameter is 1. The circumference of a circle equals the diameter multiplied by 3.1416, nearly. Another approximate proportion is $\frac{22}{7}$, and another still nearer is $\frac{355}{113}$.

This decimal has been worked out to 36 places, as follows:

3.14159265358979323846264338327950288 4+

and called the Ludolphian number, because calculated by Ludolph Van Ceulen, a long time ago.

USEFUL MEASUREMENTS.

To find the length of the curve line, called the Circle; that is, to find the Circumference of a Circle.

Rule.—*Multiply* 3.1416 *by the diameter.*

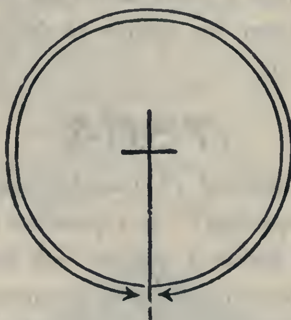


Fig. 13.

Example.—What is the circumference of a circle whose diameter is 3 inches?

$$\begin{array}{r} 3.1416 \\ 3 \\ \hline \end{array}$$

Answer, 9.4248 inches.

To find the Diameter of a Circle.

Rule.—(1) *Multiply the circumference by* 7 *and divide by* 22; or, (2) *Divide the circumference by* 3.1416.

Example.

A pulley has a circumference of 50.30″, find its diameter?

$$\frac{50.30 \times 7}{22} = 16'' \text{ diameter. Answer.}$$

THE CIRCLE.

TO FIND THE AREA OF A CIRCLE.

RULE.—*Multiply the square of the diameter by .7854*

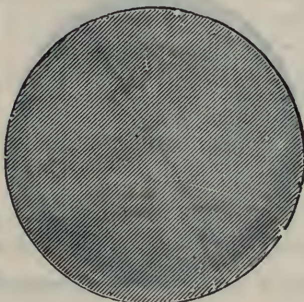


Fig. 14.

EXAMPLE.—The diameter of a circle is 3 inches, find its area.

```
 3            .7854
 3                9
--          -------
 9    Answer, 7.0686 square inches.
```

EXAMPLE.—The diameter of a circle is 3.5 inches, find the area.

```
  3.5          .7854
  3.5          12.25
  ---         ------
  175          39270
 105          15708
 ----        15708
12.25        7854
             -------
    Answer, 9.621150 square inches.
```

NOTE.—"In every branch of science our knowledge increases as the power of measurement becomes improved."

USEFUL MEASUREMENTS.

TO FIND THE SECTIONAL AREA OF A RING OR PIPE.

RULE.—*From the area of the greater circle subtract that of the lesser.*

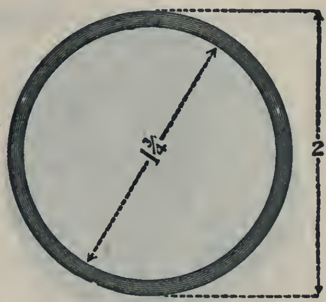


Fig. 15.

EXAMPLE.—A pipe has an external diameter of 2″ and an internal diameter of $1\frac{3}{4}$″, find its sectional area in square inches.

Thus area of 2″ — $2^2 \times .7854$ — 3.1416
" $1\frac{3}{4}$″ — $1\frac{3}{4}^2 \times .7854$ — 2.4053

Answer, .7363 square inches.

TO FIND THE AREA OF AN ELLIPSE.

RULE.—*Multiply* .7854 *by the product of the diameters.*

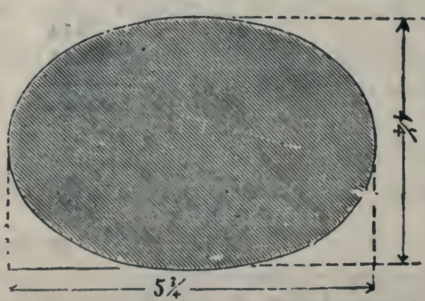


Fig. 16.

THE CIRCLE.

EXAMPLE.

What is the area of an ellipse whose diameters are $5\frac{3}{4}$ and $4\frac{1}{4}$?

```
   5.75             24.4375
   4.25               .7854
  -----            --------
   2875              977500
  1150              1221875
 2300              1955000
 -------          1710625
 24.4375          ---------
                  19.19321250
```

TO FIND THE SURFACE OR ENVELOPE OF A CYLINDER.

RULE.—*Multiply* 3.1416 *by the diameter, to find the circumference, and then by the height.*

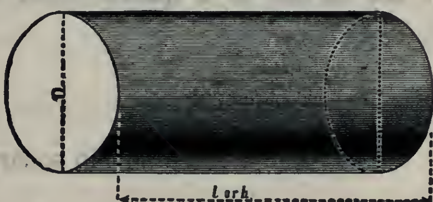


Fig. 17.

EXAMPLE.

What is the surface of a cylinder whose diameter is 9 inches and height 15 inches.

```
  3.1416
       9
 -------
 28.2744—circumference.
      15
 -------
 1413720
 282744
 -------
 424.1160 area of surface in square inches.
```

USEFUL MEASUREMENTS.

TO FIND THE SURFACE OR ENVELOPE OF A SPHERE.

The surface of a sphere is equal to the convex surface of the circumscribing cylinder; hence the

RULE.—*Multiply* 3.1416 *by the diameter of the sphere, and this again by the diameter; because in this case the diameter is the height of the cylinder;*

Or multiply 3.1416 *by the square of the diameter of the sphere.*

EXAMPLE.

What is the surface of a sphere whose diameter is 3 feet? See figure page 73.

$$\begin{array}{r} 3.1416 \\ 9 = 3^2 \\ \hline 28.2744 \end{array}$$ area of surface in square feet.

QUOTATION.—"Observe any of the best-known mechanics' pocket reference books after it has been used a few years, and there is always indisputable evidence that the arithmetical tables are used oftener than any other part of the contents. Though it may be well preserved in all other parts, the tables are worn to a useless condition."

SOLIDS.

A solid is a body or magnitude which has three dimensions—length, breadth and thickness—being thus distinguished from a *surface*, which has but two dimensions, and from a line, which has but one; the boundaries of solids are surfaces.

The measurement of a solid is called its solidity, capacity or content.

TO FIND THE SOLIDITY OR CAPACITY OF ANY FIGURE IN THE CUBICAL FORM.

RULE.—*Multiply the length by the breadth and by the depth.*

EXAMPLES.

A tank is 10 feet long, 6 feet broad and 3 feet deep; how many cubic feet of water will it hold?

$10 \times 6 \times 3 =$ Ans. 180 cubic feet.

A bar of iron is 24″ long, 6½″ broad, and 2¼″ thick; how many cubic inches does it contain?

$24 \times 6.5 \times 2.25 =$ Ans. 351 cubic ins.

Find the cubical contents in inches of a shaft 3″ diameter and 15′ 0″ long?

$3^2 \times .7854 = 7.0686 \times 15 \times 12 =$ Ans. 1272.348 cubic ins.

MEASUREMENTS OF SOLIDS.

A CUBE is a solid having six equal square sides. TO FIND THE CONTENTS—

RULE.—*Multiply the area of the base by the perpendicular height.*

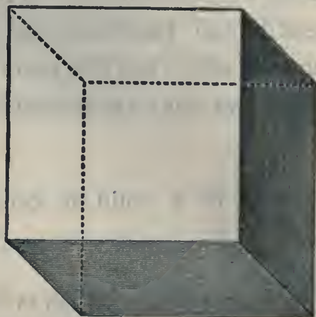


Fig. 18.

EX.—What is the contents of a cistern whose sides and depth are 3 feet 6 inches?

3′ 6″ × 3′ 6″ × 3′ 6″ = 42′ 10″ nearly (42.875 cubic feet)

TO FIND THE CONTENTS OF A RECTANGULAR SOLID

RULE.—*Multiply the length, breadth and height together.*

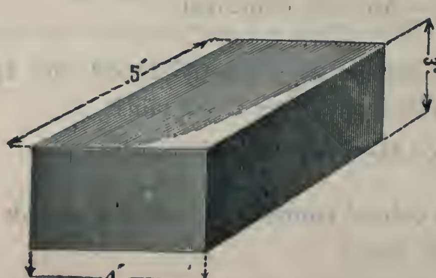


Fig. 19

EXAMPLE.

What is the contents of a rectangular solid whose length is 5 feet, breadth 4 feet and height 3 feet?

5 feet
4 feet
—
20 square feet of base
3 feet
—
60 cubic feet

TO FIND THE CUBIC CONTENTS OF A SPHERE.

RULE.—*Multiply* .7854 *by the cube of the diameter, and then take* $\frac{2}{3}$ *of the product.*

Fig. 20.

EX.—Find the cubic contents of a sphere whose diameter is 5 feet.

5	.7854
5	125
25	39270
5	15708
	7854
$125 = 5^3$	98.1750
	2
	3)196.3500

Answer, 65,4500 cubic feet.

USEFUL MEASUREMENTS.

The rule is only approximate, owing to the "repeating decimal" used in the calculations. Another rule is as follows:

Multiply the cube of the diameter by .5236, *or the cube of the circumference by* .016887, *and the product will be the solidity.*

TO FIND THE SOLIDITY OF A HEMISPHERE.

RULE.—*Multiply the square of the diameter by the radius, and multiply the product by* .5236, *which is the ratio between the solidity of a cube and that of a sphere, whose diameter is equal to one side of the cube.*

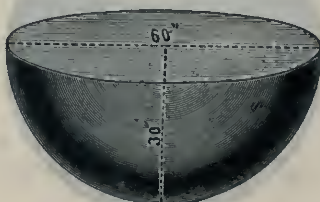


Fig. 21.

EXAMPLE.—How many cubic inches in a hemisphere whose diameter is 60 inches?

60×60×30×.5236=56548.8 cubic inches. Answer.

NOTE.—The convex surface of a sphere may be found by multiplying the circumference by the diameter. Or, multiply the square of the diameter by 3.1416, and the product will be the convex surface.

The solidity of a sphere is equal to two-thirds of the solidity of its circumscribing cylinder.

The surface of a sphere is equal to 4 times the area of a circle of the same diameter as the sphere; or to the area of a circle whose diameter is double that of the sphere; or to the convex surface of the circumscribing cylinder.

SOLIDITY OF A HEMISPHERE.

TO FIND THE SOLIDITY OF A SEGMENT OF A SPHERE.

RULE 1.—*To three times the square of the radius of the segment's base, add the square of the depth or height; then multiply this sum by the depth, and the product by* .5236.

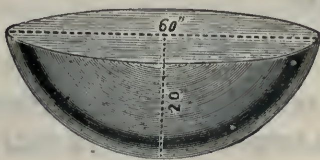


Fig. 22.

EXAMPLE.—How many cubic inches in a spherical segment which has a diameter of 60 inches and a depth of 20 inches?

$60 \div 2 = 30$ inches radius. $30 \times 30 \times 3 = 2700$; $2700 + (20 \times 20) = 3100$; $3100 \times 20 \times .5236 = 32463.2$, which is the number of cubic inches.

RULE 2.—*From three times the diameter of the sphere subtract twice the height of the segment; multiply the remainder by the square of the height, and that product by* .52361 *for the solidity.*

EXAMPLE.—If the diameter of a sphere be 3 feet 6 inches, what is the solidity of a segment whose height is 1 foot 3 inches? Ans. 6.545 feet.

$$\begin{array}{rl} \text{Now, } 3.5 \times 3 = & 10.5 \\ 1.25 \times 2 = & 2.5 \\ \hline & 8 \end{array}$$

$1.25 \times 1.25 = 1.5625 \times 8 = 12.5$ Product.

Then, $12.5 \times .52361 = 6.545$ cubic feet.

NOTE.—When the segment is greater than a hemisphere, find the solidity of the lesser segment and subtract the same from the solidity of the entire sphere.

USEFUL MEASUREMENTS.

TO FIND THE CUBIC CONTENTS OF A SOLID CYLINDER.

RULE.—*Find the area of the base, and multiply this by the height or length.*

EXAMPLE.

What is the cubic contents of a cylinder whose diameter is 4 feet, and height or length $7\frac{1}{2}$ feet?

```
 4        .7854
 4           16
——      ———————
16        47124
          7854
        ———————
        12.5664=area of base in square feet
            7.5=height or length in feet
        ———————
         628320
        879648
        ———————
```

Answer, 94.24800 cubic feet.

TO FIND THE SOLIDITY OF A CYLINDRICAL RING.

Fig. 23.

RULE.—*To the thickness of the ring, add the inner diameter; and this sum being multiplied by the square of the thickness, and the product again by 2.4674, will give the solidity.*

NOTE.—The surface of a cylindrical ring may be found by the following rule: To the thickness of the ring, add the inner diameter; and this sum being multiplied by the thickness, and the product again by 9.8696, will give the surface required.

SOLIDITY OF A CYLINDRICAL RING.

EXAMPLE.—What is the solidity of a cylindrical ring whose thickness *A B* or *C D* is 6, and the inner diameter *B C* 20 inches?

Here $(20+6)\times 6^2 \times 2.4674 = 26 \times 36 \times 2.4674 = 936 \times 2.4674 = 2309.4864$ inches, the solidity required.

TO FIND THE SOLIDITY OF A CONE.

RULE.—*Multiply the area of the base by the perpendicular height, and $\frac{1}{3}$ of the product will be the solidity.*

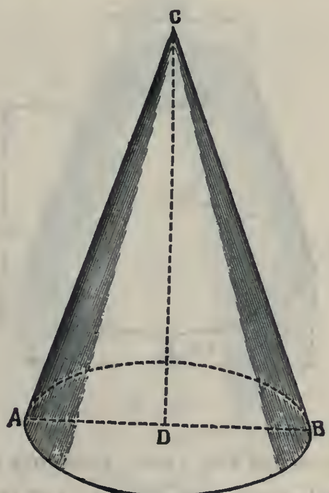


Fig. 24.

EXAMPLE.

1. Required, the solidity of the cone *A B C*; the diameter, *A B*, of the base being 12 feet, and the perpendicular altitude, *D C*, 18 feet 6 inches.

Here $.7854\times 12^2 = .7854\times 144 = 113.0976$, the area of the base; and $(113.0976\times 18.5)\div 3 = 2092.3056\div 3 = 697.4352$ feet, the solidity required.

USEFUL MEASUREMENTS.

TO FIND THE CUBIC CONTENTS OF A FRUSTRUM OF A CONE.

A frustrum of a cone is the lower portion of a cone left after the top piece is cut away.

RULE.—*Find the sum of the squares of the two diameters* (d, D), *add on to this the product of the two diameters multiplied by* .7854, *and by one-third the height* (h).

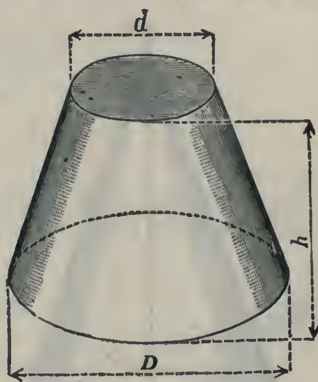


Fig. 25.

EXAMPLE.—Find the cubic contents of a safety-valve weight of the following dimensions: 12″ large diameter, 6″ small diameter, 4″ thick. Now:

$144+36+72\times.7854\times1.33$
$252\times.7854\times1.33=263.23$, etc., cubic inches.

TO FIND THE SOLIDITY OF A PYRAMID.

Pyramids may be trilateral, quadrilateral, pentagonal, hexagonal, heptagonal, octagonal, etc., having three, four, five, six, seven, eight triangular sides, respectively.

SOLIDITY OF A PYRAMID.

The trilateral pyramid has three triangles. The quadrilateral pyramid has four triangles, and the pentagonal pyramid has five triangles, and so on.

RULE.—*Multiply the area of the base by one-third of the perpendicular height, and the product will be the solidity.*

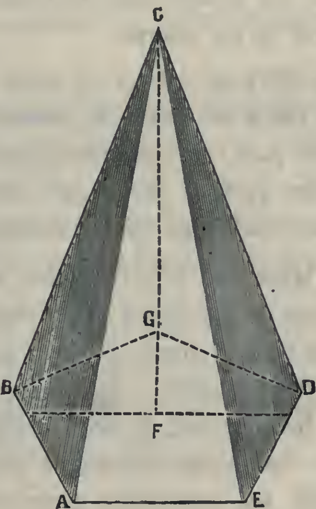


Fig. 26.

EXAMPLE.—What is the solidity of the regular pentagon pyramid *A B C D E*, each side of the base being 9 feet, and the perpendicular altitude, *F C*, 24 feet?

The area of the base, see page 64, is

$$\begin{array}{r} 135 \text{ feet} \times \tfrac{1}{3} \text{ of } 24 = 8 \\ 8 \\ \hline \end{array}$$

Answer, 1080 feet, the solid contents.

USEFUL MEASUREMENTS.

To find the solidity of an Irregular Solid.

Rule.

Divide the irregular solid into different figures; and the sum of their solidities, found by the preceding problems, will be the solidity required.

If the figure be a compound solid, whose two ends are equal plane figures, the solidity may be found by multiplying the area of one end by the length.

To find the solidity of a piece of wood or stone that is craggy or uneven, put it into a tub or cistern, and pour in as much water as will just cover it; then take it out and find the contents of that part of the vessel through which the water has descended, and it will be the solidity required.

If a solid be large and very irregular, so that it cannot be measured by any of the above rules, the general way is to take lengths, in two or three different places; and their sum divided by their number, is considered as a mean length. A mean breadth and a mean depth are found by similar processes. Sometimes the length, breadth and depth taken in the middle are considered mean dimensions.

There are five regular solids which are shown in Figs. below. A regular solid is bounded by similar and regular plane figures. Regular solids may be circumscribed by spheres, and spheres may be inscribed in regular solids.

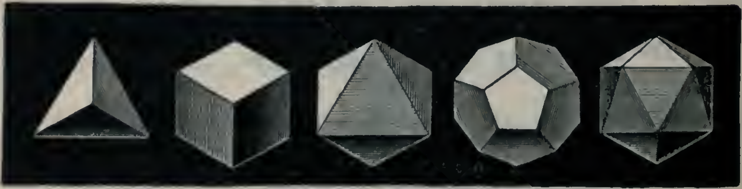


Fig. 27. Fig. 28. Fig. 29. Fig. 30. Fig. 31.

THE FIVE REGULAR SOLIDS.

The *Tetrahedron* (fig. 27) is bounded by four equilateral triangles.

The *Hexahedron*, or cube (fig. 28), is bounded by six squares.

The *Octahedron* (fig. 29) is bounded by eight equilateral triangles.

The *Dodecahedron* (fig. 30) is bounded by twelve pentagons.

The *Icosahedron* (fig. 31) is bounded by twenty equilateral triangles.

TO FIND THE SURFACE AND THE CUBIC CONTENTS OF ANY OF THE FIVE REGULAR SOLIDS.

RULE.—*For the surface, multiply the tabular area below, by the square of the edge of the solid.*

For the contents, multiply the tabular contents below, by the cube of the given edge.

TABLE OF CONSTANTS.

SURFACES AND CUBIC CONTENTS OF REGULAR SOLIDS.

Number of Sides	NAME	Area. Edge = 1	Contents. Edge = 1
4	......Tetrahedron........	1.7320	0.1178
6	......Hexahedron...... ..	6.0000	1.0000
8	......Octahedron.........	3.4641	0.4714
12	......Dodecahedron.....	20.6458	7.6631
20	......Icosahedron.........	8.6603	2.1817

A constant is a quantity or multiplier which is assumed to be invariable.

PARTS OF A CIRCLE.

The circumference of a circle is supposed to be divided into 360 degrees or divisions, and as the total angularity about the center is equal to four right angles, each right angle contains 90 degrees or 90°, and half a right angle contains 45°. Each degree is divided into 60 minutes, or 60′; and, for the sake of still further minuteness of measurement, each minute is divided into 60 seconds, or 60″. In a circle there are, therefore, $360 \times 60 \times 60 = 1{,}296{,}000$ seconds.

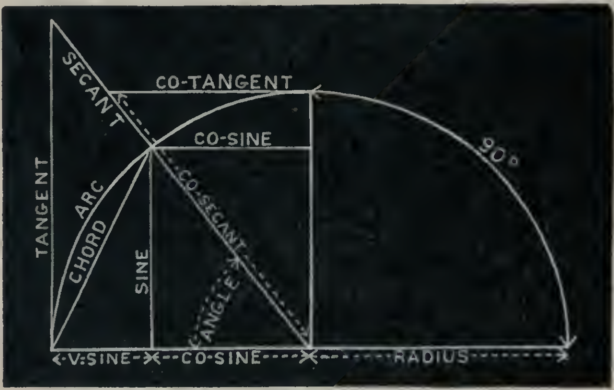


Fig. 32.

The above diagram exemplifies the relative positions of the

Sine, Tangent,
Cosine, Cotangent,
Versed sine, Secant, and
Cosecant

of an angle.

NOTE.—The circumferences of all circles contain the same number of degrees, but the greater the radius, the greater the absolute measures of a degree. The circumference of a fly-wheel or the circumference of the earth have the same number of degrees; yet the same number of degrees in each and every circumference is the measure of precisely the same angle.

DEFINITIONS OF PARTS OF A CIRCLE.

1. The *Complement* of an arc is 90° minus the arc.

2. The *Supplement* of an arc is 180° minus the arc.

3. The *Sine* of an angle, or of an arc, is a line drawn from one end of an arc, perpendicular to a diameter drawn through the other end.

4. The *Cosine* of an arc is the perpendicular distance from the center of the circle to the sine of the arc; or it is the same in magnitude as the sine of the complement of the arc

5 The *Tangent* of an arc is a line touching the circle in one extremity of the arc, and continued from thence to meet a line drawn through the center and the other extremity.

6. The *Cotangent* of an arc is the tangent of the complement of the arc. The *Co* is but a contraction of the word complement.

7. The *Secant* of an arc is a line drawn from the center of the circle to the extremity of the tangent.

8. The *Cosecant* of an arc is the secant of the complement.

9. The *Versed Sine* of an arc is the distance from the extremity of the arc to the foot of the sine.

For the sake of brevity these technical terms are contracted thus: for sine *AB*, we write *sin. AB;* for cosine *AB*, we write *cos. AB;* for tangent *AB*, we write *tan. AB*, etc.

NOTE.—*Trigonometry* is that portion of geometry which has for its object the measurement of triangles. When it treats of plane triangles it is called *Plane Trigonometry*, and as the engineer will continually meet in his studies of higher mathematics the terms used in plane trigonometry, it is advantageous for him to become familiar with some of the principles and definitions relating to this branch of mathematics.

MEASURING MACHINES, TOOLS AND DEVICES.

The accuracy of a man's workmanship can usually be determined from knowing the kind of measuring instruments he employs. It is an old saying among mechanics that a blacksmith's "hair's-breadth" is anything less than a quarter of an inch. There used to be good ground for this statement, the reason being that the blacksmith measured with a square, the graduations of which were $\frac{1}{4}$ inch.

When a man begins to use a scale graduated to hundredths he finds, as soon as he learns to distinguish the marks, that there is considerable space included in $\frac{1}{100}$ of an inch.

When a man has used a micrometer caliper for a short time he learns to determine $\frac{1}{2}$ of $\frac{1}{1000}$ of an inch quite readily, and then begins to appreciate the value of fine measurements and close fits. In considering modern methods and comparing them with older practice, we are at once struck by the definiteness with which the sizes of parts are now fixed. The fitting of one part to another is no longer a question of working to gauges of which the absolute sizes are unknown, but of working to sizes which

---

NOTE.—In a device consisting of a short steel rod fitting into a hollow cylinder, the rod being three-quarters of an inch in diameter, it was found that the fit was so perfect that it would slide freely in and out, but if the rod was taken out and held in the hand for a few seconds, the slight expansion caused by the warmth of the hand was enough to render it impossible to insert the rod until it had been allowed by gradual cooling to regain its normal size.

are definitely fixed and stated, and which are at any time capable of reproduction. To carry out this system means the general provision of instruments for accurate measurement which were formerly only to be found in a very few special establishments; it means the possession of skill in the use of such measuring appliances, and a cultivation of an appreciation of the value of small units.

Fig. 33 shows a side view of a standard End-Measuring Rod; these are formed of steel, hardened on the ends and accurately ground, so that the ends form sections of true spheres whose diameters are equal to those of the length of the rods. They are suitable for making internal measure-

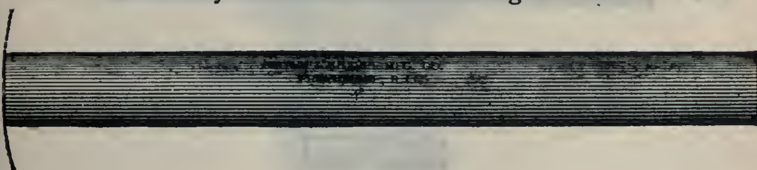


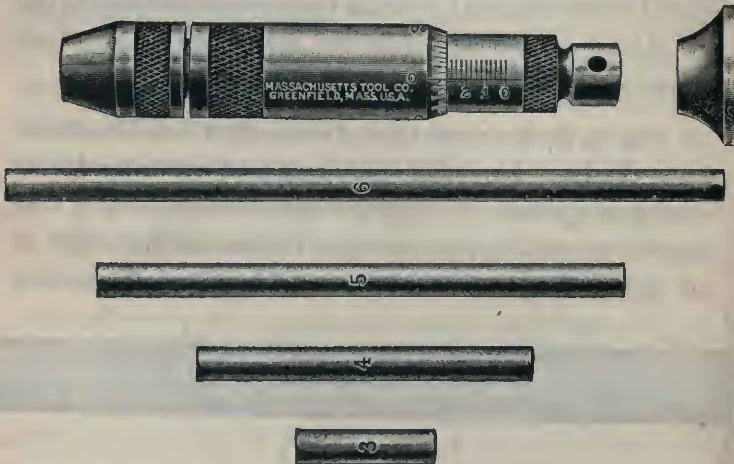
Fig. 33.

ments, as rings, cylinders, etc.; and, as reference tools, are particularly well adapted for setting calipers, comparing gauges, and work of a similar character. They are also suitable for measuring parallel surfaces, as the spherical ends will pass such surfaces without cramping, the same as spheres of like diameters.

Figs. 34 to 39 exhibit Inside Micrometer Gauges. These are adjustable, and designed for making internal measurements, and work of a similar character, and are also adapted for measuring parallel surfaces.

The device consists of a holder provided with a micrometer screw and thimble. The screw has a movement of $\frac{1}{8}''$; and, by the use of the extension rods fur nished, measurements from 3″ to 6″ can be made by the thousandths of an inch.

The extension rods vary by ½″, and each rod is provided with an adjusting nut and check-nut, which are set



Figs. 34 to 39.

to obtain the proper measurement of the given rod, and should be adjusted only when the point of that rod has become worn.

This instrument is provided with a micrometer screw and nut, and is graduated to read by half-thousandths.

Provision is made for adjustment to compensate for wear of the screw and measuring surfaces.

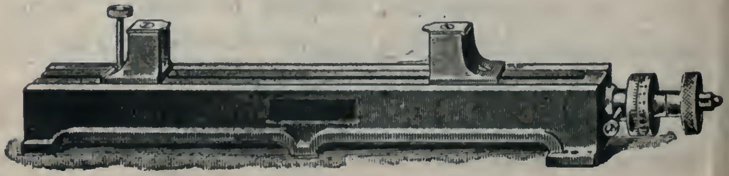


Fig. 40.

MEASURING MACHINES.

Fig. 40 shows a standard form of measuring machine for use in the tool room in preparing templates, reamers, mandrels, etc. It will measure differences of the $\frac{1}{10000}$ of an inch. Adjustments in the machine provide for the wear of measuring points.

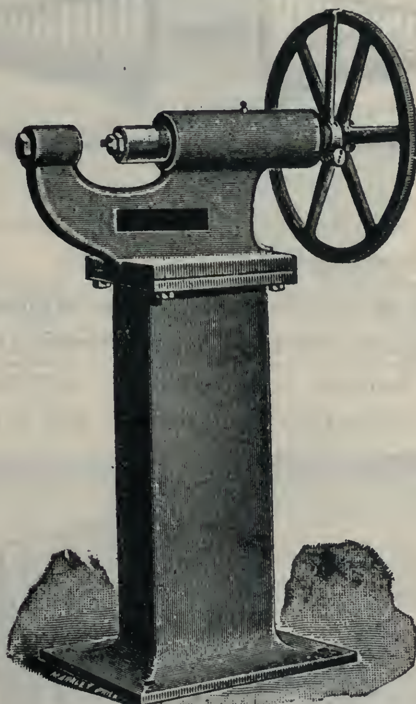


Fig. 41.

Calipering Machines are used to transmit sizes, and differ from fixed calipers in that they record as the size is approached, and show how much a piece is to be reduced.

Machines of this type are used in connection with standard sizes as an accurate pair of calipers, and have the features of a measuring machine, as they will measure accurately *above and below a certain size* after having been adjusted and the index, which is on the edge of the wheel, set for a standard size. The machine shown in fig. 41

Fig. 42.

will caliper to 6 inches. The index wheel is divided to read to ten-thousandths of an inch.

Fig. 42 shows corrective gauge standards. These discs are employed for testing and correcting fixed gauges, for setting calipers, and also as a reference to prove dimensions within their range. Each disc is separate and is ground independently to size.

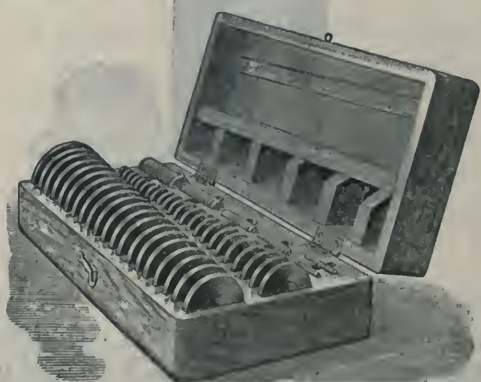


Fig. 43.

The introduction of accurate scientific methods into manufacturing and commercial processes involves the use ot a great variety of standards of far greater accuracy than formerly required. Fig. 42 is but one of very many measuring devices introduced to secure the essential accuracy.

Standard reference discs are shown in fig. 43. These are employed for testing and correcting fixed caliper gauges, for setting calipers, and also as a reference to

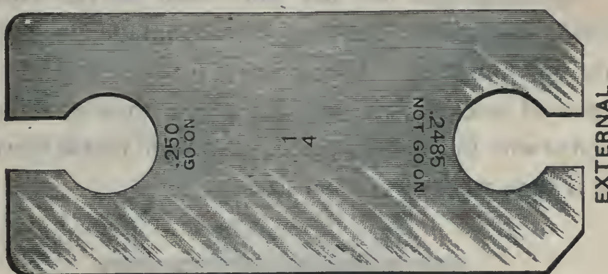


Fig. 44.

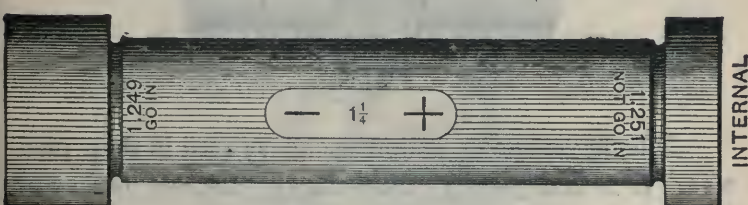


Fig. 45.

prove dimensions within their range. They are intended to serve principally as originals, not as working gauges.

The illustration represents "a set" of forty-five discs, ranging in size from ¼″ to 3″, inclusive, by 16ths, and four handles. The discs vary in width from ¼″ to ½″, according to the diameter, and afford ample contact surface.

The figures 44 and 45 represent the common form of internal and external limit gauges. Gauges of this type are stamped with the words "go on" and "not go on," for the external, and "go in" and "not go in" for the internal; and, as the two ends are of different shape, the workman is enabled to easily and quickly distinguish the large from the small end without looking at the sizes stamped upon the gauge.

These gauges are not only used as references for finishing operations, but are of advantage in roughing work for finishing. When used in this way the same amount of stock is left on each piece, thus enabling the operator who finishes the pieces to work to better advantage than if they were of various sizes.

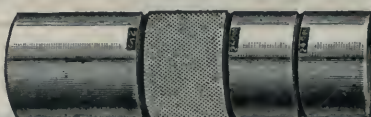


Fig. 46.

The fig. 46 shows a limit gauge as used in shop practice. It is stamped $2\frac{1}{2}$, 2.500, 2.4995; the end marked $2\frac{1}{2}$ is ground accurately to size, and is not used except as a reference standard, the calipers or measuring instruments being set by the ends marked 2.500, 2.4995. The difference between these is a limit of .0005, or the $\frac{1}{2000}$ part of an inch.

The advantages derived from the use of the limit gauges are being appreciated more and more; as, by their use the time consumed in testing and gauging is reduced to a minimum, and the duplication of parts is insured.

MEASURING DEVICES.

Fig. 47 shows an adjustable parallel measuring gauge. It measures from ¼ inch to 4 inches, and measurements over the above are got by placing a base beneath. The slide is tightened by the right-hand thumb nut and the scriber by the the left-hand one, by which both work independently of each other. It is graduated into 64 parts to the inch. The graduation on the tool is wider than the ordinary scale, it being on an incline, but the operator should read them just the same as a scale of 64ths, matching the line of the slide to the graduation on the incline.

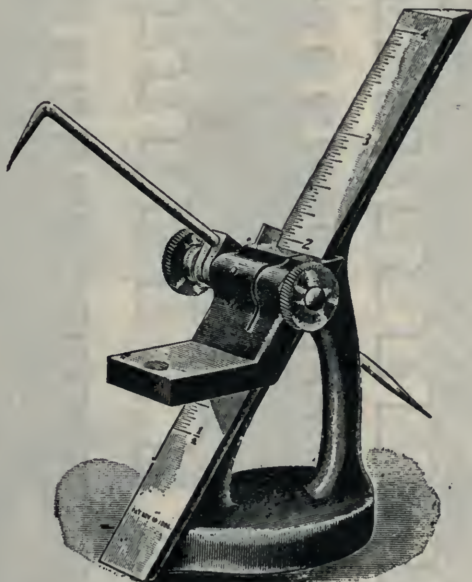


Fig. 47.

GAUGES.

English or Birmingham gauges, for sheet and plate steel and iron, are shown in figs. 48 and 49. The former indicates sizes from 1 to 32; the latter from 000 to 25. The illustrations are about two-thirds the real size.

Fig. 48.

Fig. 49.

Fig. 50.

Fig. 50 represents, two-thirds actual size, the United States Standard Gauge for sheet and plate steel and iron, adopted by Congress March 3, 1893.

GAUGES.

Figs. 51 and 52 are gauges for use in measuring twist drills and steel drill rods.

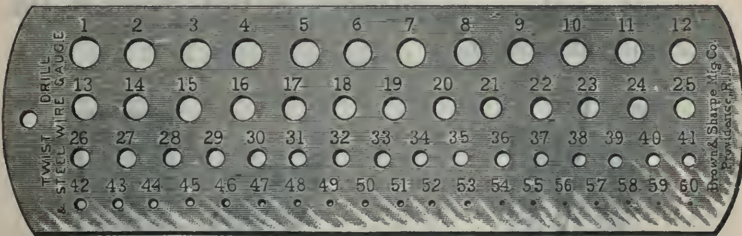


Fig. 51.

Gauge No. 51 is about $\frac{1}{16}''$ thick, $1\frac{5}{8}''$ wide, $5\frac{1}{4}''$ long, and contains gauge numbers from 1 to 60 inclusive.

Fig. 52.

Gauge No. 52 is about $\frac{1}{16}''$ thick, $\frac{3}{4}''$ wide, $2''$ long, and contains gauge numbers from 61 to 80 inclusive.

Fig. 53.

Fig. 53 shows an angle gauge, with the addition of a protractor and registering dial. It is a very useful tool for testing planed and finished parts.

ANGLE-GAUGES.

Fig. 54 shows a simple form of bevel protractor operated on the same principles as that shown in the preceding illustration.

Fig. 54.

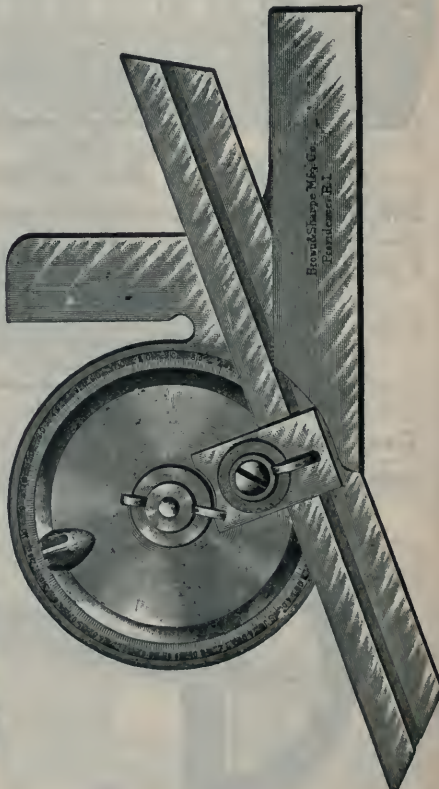


Fig. 55.

Fig. 55 shows still another form of the same device. In each of the above instruments the circles, or parts thereof, are divided into degrees.

USEFUL MEASUREMENTS.

This tool is well adapted for all classes of work where angles are to be laid out or established; one side of the stock is flat, thus permitting its being laid upon the paper or work. The dial is accurately graduated in degrees the entire circle. It turns on a large central stud, which is hardened and ground, and can be rigidly clamped by the thumb nut shown in cut.

The line of graduations is below the surface, thus protecting them from wear. The blade is about one-eighth inch thick, can be moved back and forth its entire length, and clamped independently of the dial, thus adapting the protractor for work where others cannot be used.

THE VERNIER AND ITS USE.

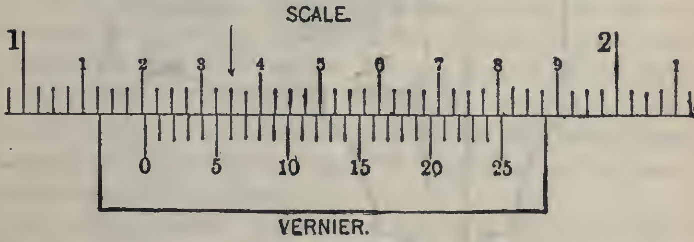


Fig. 56.

The Vernier is a small *movable scale* invented by Pierre Vernier in 1631, and used for measuring a fractional part of one of the equal divisions on the graduated *fixed scale*.

The Vernier consists, in its simplest form, of a small sliding scale, the divisions of which differ from those of the fixed or primary scale; the ingenuity of the invention has given a lasting and world-wide fame to the discoverer of its useful application.

THE VERNIER AND ITS USE.

On the scale of the tool is a line of graduations divided into inches and numbered 0, 1, 2, etc., each inch being divided into ten parts, and each tenth into four parts, making forty divisions to the inch.

On the sliding jaw is a line of divisions of twenty five parts, numbered 0, 5, 10, 15, 20, 25. The twenty-five divisions on the Vernier correspond, in extreme length, to twenty-four divisions, or $\frac{24}{40}$ of an inch, on the scale; each

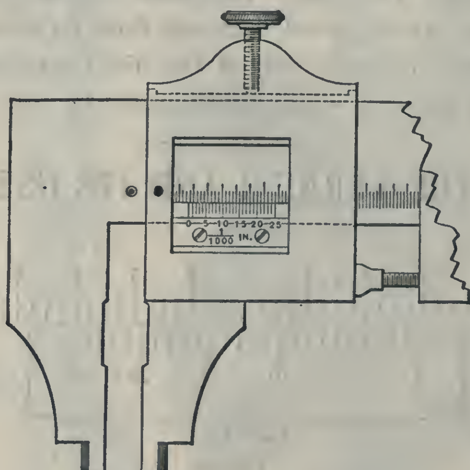


Fig. 57.

division on the Vernier is, therefore, $\frac{1}{25}$ of $\frac{1}{40}$, or $\frac{1}{1000}$ of an inch shorter than the corresponding division on the scale.

If the Vernier is moved until the line marked 0 on the Vernier coincides with that marked on the scale, then the next two lines to the right will differ from each other by $\frac{1}{1000}$ of an inch; and the difference will continue to increase $\frac{1}{1000}$ of an inch for each division, until the line 25 on the Vernier coincides with a line on the scale.

USEFUL MEASUREMENTS.

Fig. 56 represents a Vernier caliper, showing the two scales, and in the note is an admirable explanation of its use, for which credit is due to Brown & Sharpe Manufacturing Co.

NOTE.—On the bar of the instrument is a line of inches, numbered 0, 1, 2, etc., each inch being divided into ten parts, and each tenth into four parts, making forty divisions to the inch. On the sliding jaw is a line of divisions of twenty-five parts, numbered 0, 5, 10, 15, 20, 25. The twenty-five parts on the Vernier correspond, in extreme length, with 24 parts, or twenty-four fortieths of the bar; consequently, each division on the Vernier is smaller than each division on the bar by .001 part of an inch. If the sliding jaw of the caliper is pushed up to the other, so that the line marked 0 on the Vernier corresponds with that marked 0 on the bar, then the two next lines to the right will differ from each other by .001 of an inch, and so the difference will continue to increase, .001 of an inch for each division, till they again correspond at the line marked 25 on the Vernier. To read the distance the caliper may be open, commence by noticing how many inches, tenths and parts of tenths the zero point on the Vernier has been moved from the zero point on the bar.

Now, count upon the Vernier the number of divisions, until one is found which coincides with one on the bar, which will be the number of thousandths to be added to the distance read off on the bar. The best way of expressing the value of the divisions on the bar is to call the tenths one hundred thousandths (.100), and the fourths of tenths, or fortieths, twenty-five thousandths (.025). Referring to the cut shown above, it will be seen that the jaw is open two-tenths and three-quarters, which is equal to two hundred and seventy-five thousandths (.275). Now, suppose the Vernier was moved to the right, so that the tenth division would coincide with the next one on the scale, which will make ten thousandths (.010) more to be added to two hundred and seventy-five thousandths (.275), making the jaws to be open two hundred and eighty-five thousandths (.285).

USEFUL MEASUREMENTS.

Figs. 58 and 59 represent the entire calipers of which the head only is shown in fig. 57.

These instruments are graduated on the front side to

Fig. 58.

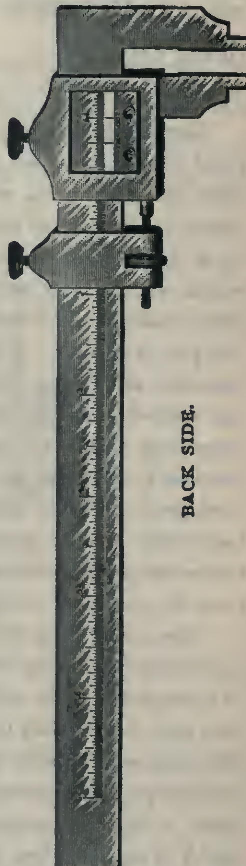


Fig. 59.

read, by means of the Vernier, to thousandths of an inch, and on the back to sixty-fourths of an inch; the jaws can be used for either outside or inside measurements; points

THE VERNIER AND ITS USE.

are placed on the bars and slide, so that dividers can be used to transfer distances. Verniers are applied to minute measuring instruments, as the sextant, barometer, etc.

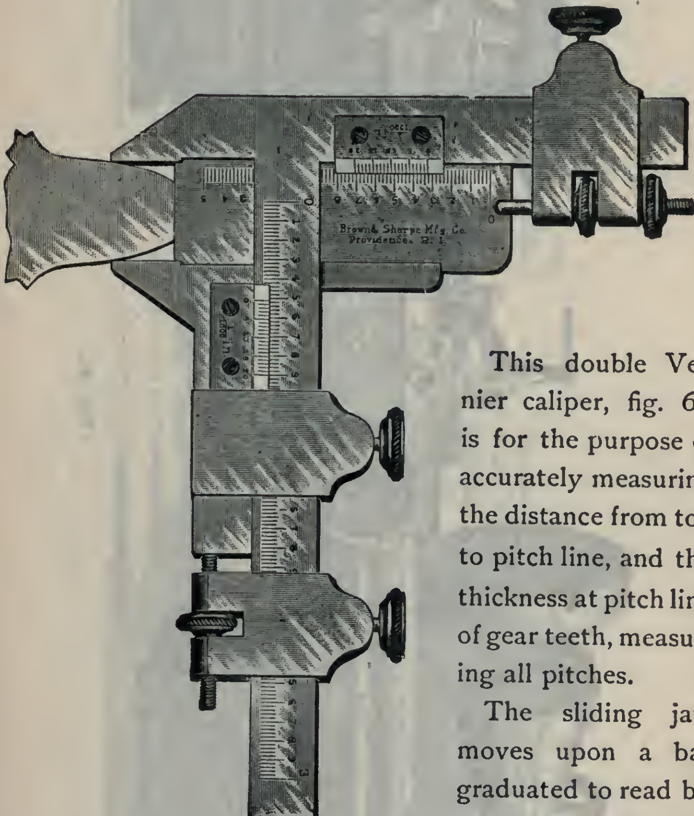


Fig. 60

This double Vernier caliper, fig. 60, is for the purpose of accurately measuring the distance from top to pitch line, and the thickness at pitch line of gear teeth, measuring all pitches.

The sliding jaw moves upon a bar graduated to read by means of the Vernier to thousandths of an inch. A tongue, moving at right angles with the jaws, is graduated in the same manner. Both the sliding jaw and tongue are provided with adjusting screws.

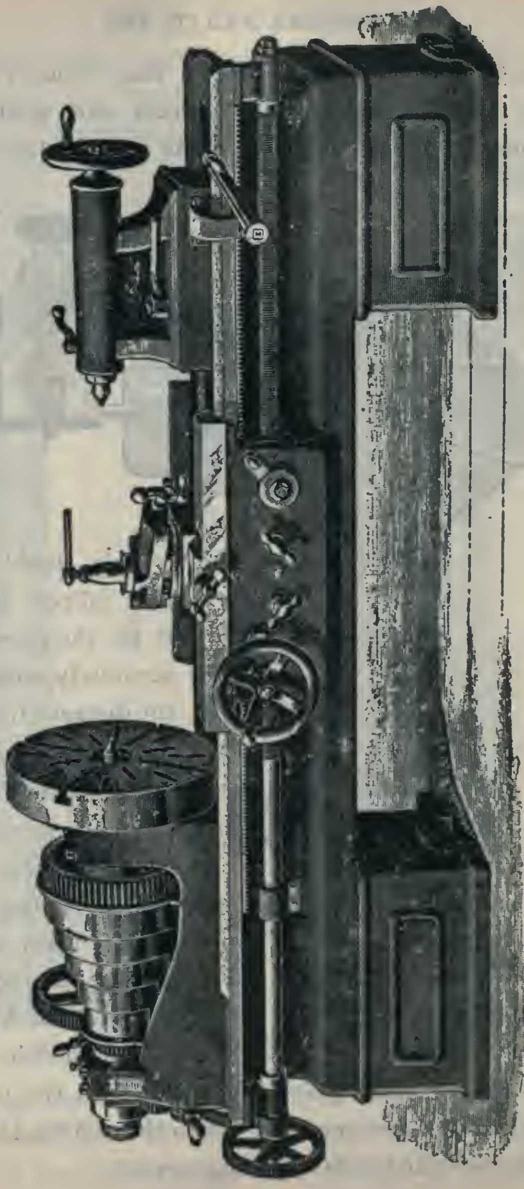


Fig. 61.

TURNING

AND

BORING

"There is a difference between 'cut' and 'wear'; tightening a *cut* journal will ruin it; steady, uniform, rotary *wear* upon a journal will outlast the lifetime of almost any machine."

"No man of any pretensions has any right to mix up the terms journal and bearing; a *journal* is that part of a shaft or axle that rests in the bearings; a *bearing* is the part, the contact with which, a journal moves, or the part of any piece where it is supported or the part of another piece where it is supported; a bearing is a guide to steady a shaft or rod and maintain it in position."

SCREW-CUTTING IN THE LATHE.

The operations of turning and boring are performed in the lathe, screw machine, boring mill, etc.; in these the work is usually made to rotate to a cutting tool, which, except for "the feeds," is stationary.

The movement of the work and the cutting of the tools, produce curved or circular, external or internal, and plane surfaces.

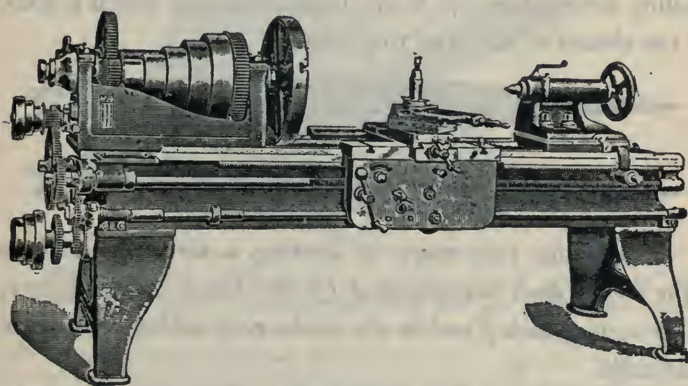


Fig. 62.

The lathe, with its two headstocks, is admirably adapted for all kinds of work supported by the two heads directly, or supplemented by supports or steady rests.

When boring and facing have to be done on the headstock, disadvantages and defects are encountered; the work must of necessity overhang when fixed on the hori-

TURNING AND BORING.

zontal spindle, causing vibration, etc. Another defect of the horizontal lathe, when used for boring, is the difficulty of setting and securing the overhang work to the face-plate.

The illustration, page 100, is a lathe designed for screw-cutting by the means of the lead-screw shown on the front.

Fig. 62 shows a lathe for turning, boring and screw-cutting; it has self-acting longitudinal and cross feeds, actuated by the spline feed spindle in front, on which is a sliding worm geared into a worm wheel on the carriage; the screw-cutting mechanism is actuated by the long leading screw shown in front, under the rack which is fixed to the shears or slides of the lathe.

Fig. 63.

Fig. 64.

There are two ways of cutting a screw-thread in a lathe: 1, *by tools manipulated by the hand, called chasers;* 2, *by cutting tools fixed in the lathe rest, which slides automatically.*

Chasers are of two kinds, the outside and the inside chaser; fig. 63 shows the outside or male chaser; it is the one which cuts the male thread, on a pipe, etc.; fig. 64 shows the inside, or female chaser; this cuts the interior thread on a pipe, etc.

The teeth of chasers are made to correspond to the number of threads per inch which they are intended to cut, and each size chaser can only be used to cut its own

SCREW-CUTTING IN THE LATHE.

number of threads, although the same chaser is equally suitable for different diameters of work; thus, an eight-thread-to-the-inch chaser would cut a thread of this pitch equally as well on a piece of work ¾ inch diameter as on a piece 1 inch diameter.

The mode of applying a chaser to cut an external thread is shown in fig. 65. Here *A* is the work between centers, *B* the tool rest, and *C* the chaser. If the tool rest, *B*, is placed with its upper surface level with the center of the work, then the chaser, *C*, must be tilted slightly, as shown in fig. 65, in order to bring the cutting angles of

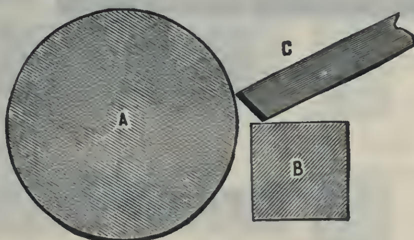


Fig. 65.

NOTE.—These hand tools or chasers would appear, at first acquaintance to many, to be old-fashioned, and not up-to-date devices for performing the very beautiful process of producing a perfectly uniform thread; nevertheless, chasers cannot be entirely superseded, even by the very perfect modern lathe, as a good workman can produce, with their aid and with ease and certainty, screws of the greatest cleanness and delicacy—the pressure required being very slight—threads can be cut by this method on the thinnest and the most fragile materials, which would be quite unable to resist the more violent treatment to which they would be subjected by any other process of screw-cutting; this system is used by manufacturers of brass fittings for telescopes and exceedingly light work, the thickness of the tube employed frequently exceeding only to a very small extent the depth of the screw thread which is cut upon them; it is not unusual to give the finishing touch to the threads of machine and engine work with the hand chaser when accurate and perfect threads are required.

TURNING AND BORING.

the tool into the right position. To start a thread, the end of the work should first be beveled off, as shown in fig. 66, and the points of the chaser teeth applied lightly to the work: if the chaser is held still in the one place, it is evident the teeth will simply cut a series of rings or circles on the surface of the work instead of a spiral thread; at the same time, therefore, as the teeth are applied to the work, a sliding motion towards the left hand must be given to the chaser; the exact rate at which the

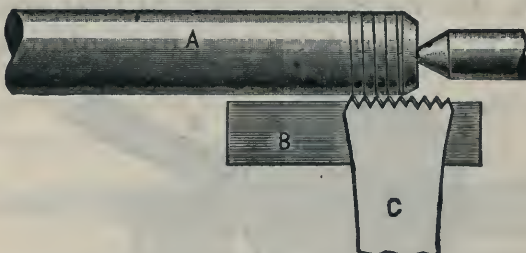


Fig. 66.

chaser is moved depends on the pitch of the screw to be cut, and also the speed at which the work is revolved in the lathe.

To cut a true thread, the chaser should move through a distance of one tooth for each revolution of the work, and this motion should be perfectly uniform; the speed of the lathe also should be constant and regular; if this operation be correctly performed the teeth of the chaser will produce one continuous spiral line, which should run quite true as the work revolves; the chaser is then brought back to the right-hand end of the work, and another cut taken, so as to deepen the line already made.

SCREW-CUTTING IN THE LATHE.

Great care is necessary for the first few cuts, to insure that the chaser-teeth engage in the same cuts each time, and that they do not start fresh threads; the line or groove is thus cut deeper and deeper, until it becomes a V-shaped groove, with, of course, the V-shaped ridge, or thread, between.

Fig. 67 shows a hand-chaser being used for cutting an internal thread. In this case the tool-rest, *B*, is placed across the mouth of the hole, and the chaser is inserted and gradually advanced, with its teeth against the interior surface, as shown.

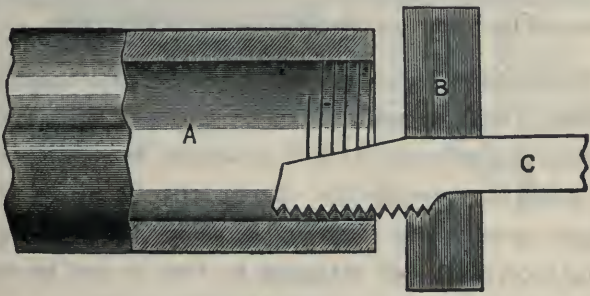


Fig. 67.

In chasing wrought iron or steel, plenty of soap and water or oil, preferably the former, should be used as a lubricant. If the chaser be moved along unevenly, or if the speed of the lathe fluctuate, an irregular thread will be produced, and this will be readily recognized by the "wobbling" appearance it has when running. A thread of this description is caused by incorrect speed of travel.

If the chaser-teeth be inserted in a true thread, without any cutting taking place, the screw will carry the chaser along at the proper speed. By trying this plan with the lathe

TURNING AND BORING.

running at various speeds, the reader will readily see how the speed at which the work revolves necessitates a faster or slower sliding motion of the chaser accordingly to produce a screw of the desired pitch.

When it is desired to cut a screw of, say, two or three inches, with a hand-chaser, the first inch or so should be well started before following up to the remaining portion of the screw; this, if correctly done, will then form a guide to lead the chaser up to the part as yet uncut.

The second method of screw-cutting in the lathe is performed by cutting-tools fixed in the lathe rest.

For cutting screws of any pitch by a tool fixed in the lathe rest, the lathe requires to be specially fitted with, 1, a leading or guide screw; 2, a quadrant fitted with one or more studs for carrying the change wheels; 3, a saddle or carriage upon which is fixed the slide rest carrying the cutting tools; 4, a nut attached so that it can be readily put into or out of gear with the leading screw.

The following illustration, fig. 68, shows the general arrangement of lathe for cutting a screw. *A* is the leading screw; the round metal bar, *B*, on which the screw is to be cut, is placed between the steel centers of the fast and movable headstocks of the lathe; a "carrier," or dog, *C*, is secured to the bar at the end next to the fast headstock, which engage with a driving stud, *D*, attached to the face-plate.

The cutting of a screw in a lathe, whether V-shape or a square thread, is an operation, the most important part of which is the selection of the proper change wheels. Every turn or revolution of the leading screw moves the carriage and cutting tool through a distance equal to the pitch of the leading screw. If the iron bar, *B*, fig. 68, revolves at the same rate as the leading screw, *A*, the pitch of the screw cut upon the bar will be

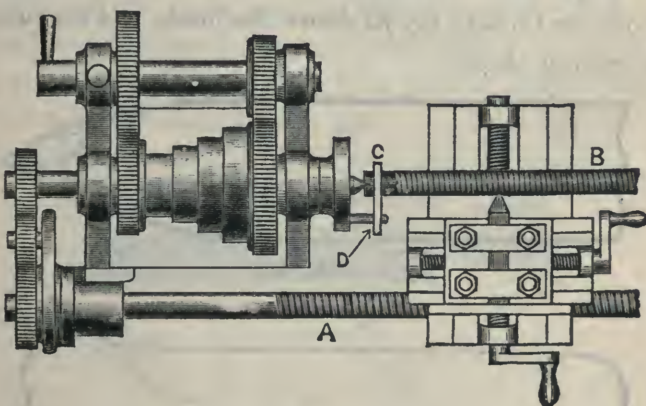


Fig. 68.

the same pitch as that of the leading screw; to cut the same thread as the leading screw, therefore, the driving wheel on the lathe mandrel must be the same size as the follower or driven wheel on the leading screw.

If the bar revolve faster than the leading screw, then the pitch of thread cut on the bar will be less than that on the leading screw; if the bar revolve slower than the leading screw, the thread cut upon the bar will be of greater pitch than that of the leading screw.

Fig. 68 shows the general arrangement *looking down on the work of a lathe* arranged for cutting screw threads,

SCREW-CUTTING IN THE LATHE.

with a cutting tool fixed in the tool-holder, which slides or travels automatically.

When V-threads are cut in a screw-cutting lathe by tools sliding automatically, a single-pointed tool is generally used.

Fig. 69 shows the front tool for cutting the male or outside thread; fig. 70 shows the inside tool for cutting the interior thread.

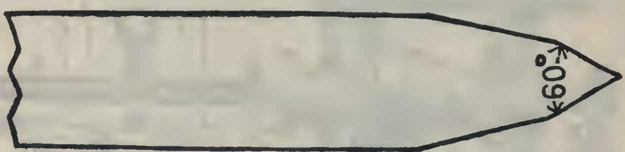


Fig. 69.

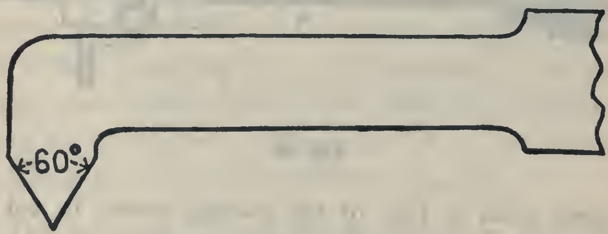


Fig. 70.

It will be noticed that the tools are very similar to the ordinary turning and boring tools, but with the points ground to a V-shape, the angle of the V corresponding exactly with the correct angle for the screw to be cut.

NOTE.—When cutting internal screw-threads it is important to remember that the diameter of the hole should be equal to the diameter at the *bottom* of the male screw-thread, which is to fit into it; thus the hole intended for an inch bolt, having eight threads per inch on it, would be bored out to just under seven-eighths inch diameter.

SCREW-CUTTING IN THE LATHE.

There is one important difference, however, between the shape of a turning tool and a screw-cutting tool; *i. e.*, that the tool point is canted or sloped over at an angle; this is necessary in the screw-cutting tool to prevent it rubbing against the sides of the thread, owing to the slope or "rake" of the latter; the rake of a thread depends on the pitch of the screw and the diameter of the work on which it is cut: thus, a screw of one-eighth pitch cut on a bolt of one-inch diameter, will have greater rake or slope than that of a thread of same pitch cut on a bolt of two inches diameter.

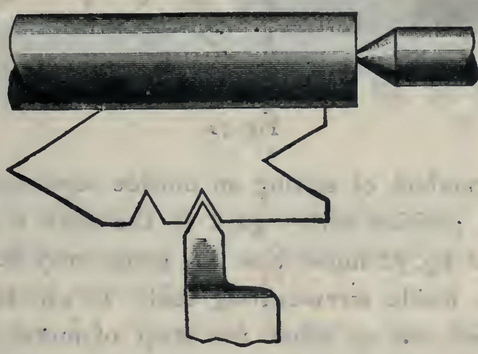


Fig. 71.

It may be said, however, that in actual practice it is not necessary to make a separate tool for each pitch of thread when cutting V-threads of reasonably small pitch and diameter, the clearance angle given to the cutting edges of the tool usually being sufficient to allow for slight variations in the rake of the thread.

It is necessary to have some gauge to which the tool can be ground to the correct shape; one way is to grind it to fit between the threads of an ordinary plug-tap, but a special screw-cutting gauge is more satisfactory; the one shown in fig. 71 is a useful form; the V-openings are cut out to the standard angle, 60°, and as it is made of light sheet steel, it can be readily applied to the tool when grinding, to test it.

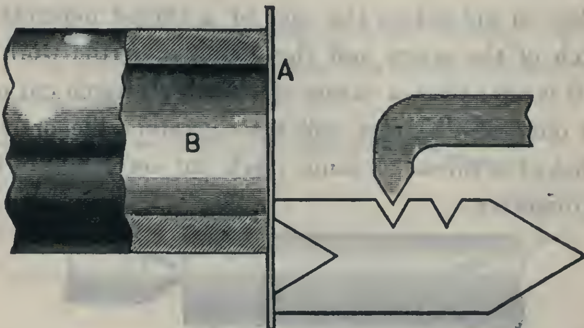


Fig. 72.

The method of setting an outside screw-cutting tool in correct position with regard to the work is shown in fig. 71, and fig. 72 shows how the gauge may be used for setting an inside screw-cutting tool. It will be noticed that a steel rule or other flat strip of metal, *A*, is laid across the end of the work, *B*, to form a surface for the end of the gauge to rest against.

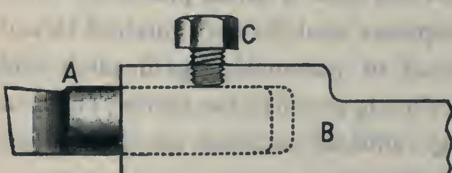


Fig. 73.

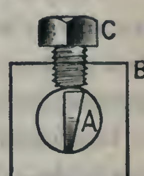


Fig. 74.

The form of tool used for cutting square threads is very similar to a parting tool, only that canting, or rake,

SCREW-CUTTING IN THE LATHE.

must be provided for in the portion that enters the work, to prevent side rubbing.

A tool holder of the kind shown in fig. 73 simplifies the making of square-thread tools very much. The tool itself is filed up out of a small round piece of tool-steel, *A*, which is then fixed in the holder, *B*, by means of the set-screw, *C*. The tool-steel being circular in section, can be turned round in the holder before the set-screw is tightened, so as to give any desired degree of rake.

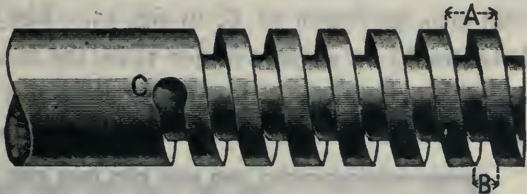


Fig. 75.

Fig. 74 shows the end view of the tool and its holder.

The width of a tool for cutting a single square thread must be equal to half the pitch of the thread. This will be seen from fig. 75, where *A* shows the pitch of the thread, which is equal to the thickness of a thread and a space. *B* shows the width the cutting tool should be, *i. e.* exactly half of *A*. In cutting a double or triple thread the case is different, as will be seen from fig. 76, which represents a double thread. Here the pitch, *A*, is equal to

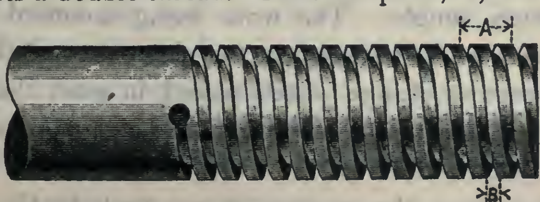


Fig. 76

the thickness of two threads and two spaces, so that the width of the cutting tool, *B*, must be exactly one-quarter of the pitch, *A*.

Fig. 77 shows a double-threaded screw with only the first groove cut. When the second groove is cut in the center of the intervening portions of the work, it leaves the double thread.

A neat way of finishing off a square thread is to drill a small hole into the work at the end of the thread for the tool to run into, as shown at *C*, in fig. 75. The diameter of the hole should be slightly larger than the thickness of the tool, and the depth a little greater than the depth of the thread. The lathe must be stopped just before the

Fig. 77.

tool reaches the hole, and pulled round by hand for the last half turn or so. As soon as the tool finishes its cut, it is withdrawn and run back again in readiness for taking a fresh cut.

The process of cutting a screw in the lathe is comparatively simple. The work being mounted between centers, the tool fastened in the slide-rest, and the proper screw-cutting change wheels placed in gear, the lathe is started and a preliminary cut taken along the work; the tool is then withdrawn, the clasp-nut disengaged from the leading screw, the carriage is run back to the starting

SCREW-CUTTING IN THE LATHE.

point, and the tool is set in a little deeper than before; the clasp being dropped into gear with the leading screw again, a second cut is taken along.

This series of operations is repeated until the screw is cut to a sufficient depth. There are, however, one or two precautions which must be observed; in the first place, a screw-cutting tool, by reason of its shape, is weak at the point, and is therefore easily broken; consequently, the depth of cut taken should not be greater than the tool can easily stand, and this should be regulated in a systematic manner. A simple plan is to mark, with a piece of chalk, the position of the cross-slide handle with which the tool is fed to the work, when the tool is withdrawn after a cut has been taken; it is wound in again before taking the next cut, so that the chalk mark is in exactly the same position as before; this shows the position of the tool during the previous cut, so that the operator can now readily judge how much further to turn the handle round to advance the tool sufficiently for the next cut.

This done, the old chalk mark is wiped out, and a fresh one substituted, the marking being repeated as each successive cut is taken.

The same guidance can be obtained in a neater way by placing a brass ring or clip over the handle of the slide rest, with a line marked across it, as shown in fig. 78; the ring is slipped back after each cut has been set in, so as to bring its mark again opposite to the arrow mark on the boss on the slide-rest, in readiness for the adjustment of the following cut.

Some lathes are provided with a small graduated disk

TURNING AND BORING.

on the handle which winds the tool in, a fixed pointer being attached to the lathe saddle; in this case, of course, the simpler expedients already described are not required.

There is another important precaution to be taken, viz., that the tool shall follow in the same path at each successive cut. There will be no trouble on this point when cutting any thread which is an exact multiple of the thread on the leading screw, or guide screw, of the lathe. If, for example, the guide screw has four threads per inch,

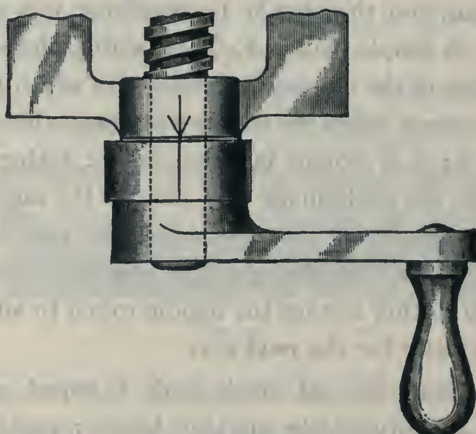


Fig. 78.

and the screw to be cut has twelve threads per inch, the work will always be in the right position for the tool to follow in the thread when the clasp-nut engages with the leading screw.

The same will be true if the screw to be cut has eight, sixteen, twenty or any number of threads per inch which is divisible by four.

The reason for this is that the change-wheel on the spindle and the change-wheel on the leading screw are in exactly the same proportion to each other as the threads on the leading screw and the screw being cut, and, since the number of teeth in one wheel is an exact multiple of the teeth in the other wheel, the smaller wheel of the two will always make an exact number of complete revolutions for each revolution of the larger.

To cut twelve threads per inch, as in the case mentioned above, a wheel with forty teeth would be placed on the spindle, and a wheel with 120 teeth on the leading screw; the spindle would therefore make three complete revolutions for each revolution of the leading screw, and the commencement of the screw-thread on the work would accordingly be brought to exactly the same position in relation to the tool each time the clasp-nut became engaged with the leading screw.

If, instead of twelve threads to the inch, a screw of ten threads to the inch is to be cut, the wheels required would be forty on the spindle and 100 on the leading screw; it will be apparent that for each turn of the leading screw the spindle will now make only 2½ revolutions, and the work will therefore be half a revolution behind its proper position, thus causing the point of the tool to come on top of the thread instead of in the groove between the threads, if the clasp-nut be engaged with the leading screw.

If the leading screw be allowed to make another complete revolution before engaging with the clasp-nut, the work will make another two and a half revolutions, which will bring it into the right position again for starting the tool in the proper groove. The work is therefore

TURNING AND BORING.

only in the correct position for starting a cut once during every two revolutions of the leading screw. Similarly, with other threads which are not exact multiples of the thread of the leading screw, it will be found that to bring the tool to the right position the clasp-nut must only be dropped in at certain intermediate positions of the change-wheels.

To prevent any mistake arising, the usual plan is to stop the lathe before the tool commences its first cut along the work, and chalk a tooth on the spindle wheel and a tooth on the leading screw wheel, placing another chalk mark on the headstock opposite the former and a chalk mark on the lathe bed opposite the latter, the clasp-nut being then engaged with the leading screw.

The saddle is run back to the starting point after each cut, and as soon as both chalk marks on the wheels come opposite to the stationary marks again at the same instant, the clasp-nut may be engaged with the leading screw, and another cut taken.

When cutting a double thread, a wheel with an even number of teeth should be selected for the spindle, and a chalk mark should be made on each of two exactly opposite teeth. The space into which one of these teeth falls in the wheel with which it gears should also be marked; when the first thread has been cut, the mandrel wheel should be disengaged and turned through half a revolution, so that the other marked tooth comes opposite the marked space; the wheels are then geared together again, and the second thread can be cut.

SCREW-CUTTING IN THE LATHE.

For a triple thread the spindle wheel should be divided into three, and for a quadruple thread into four, and so on.

For cutting a right-hand thread, the tool traverses from right to left, and for a left-hand thread it traverses from left to right.

In the latter case the necessary reversal in the direction of rotation of the leading screw is obtained by inserting an extra wheel in the train of gear wheels between the spindle and the leading screw; this extra wheel does not in any way affect the *speed* of rotation of the leading screw; it simply alters the *direction* in which it revolves.

A square thread must be finished to exact size with the tool. A V-thread can be finished off with a hand chaser.

All that is necessary to cut any pitch desired is to arrange gearing to revolve the screw as many times as it has threads to the inch, while the feed stud, or spindle, is making as many revolutions as the desired pitch.

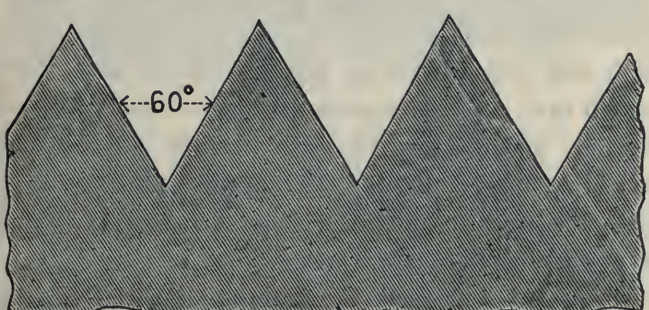


Fig. 79.

Fig. 79 shows an ordinary V-thread, of which the angle is 60°.

TURNING AND BORING.

Fig. 80 shows the American Standard thread; it is the V-thread, with one-eighth of its depth cut off the top and bottom, the angle being 60°.

Fig. 81 shows the Whitworth, or English Standard thread; it is a V-thread, with one-sixth of its depth rounded off the top and bottom the angle being 55°.

The following quotation from Low and Bevis' "Manual of Machine Drawing and Design" presents the relative merits of screw-threads shaped according to the Whit-

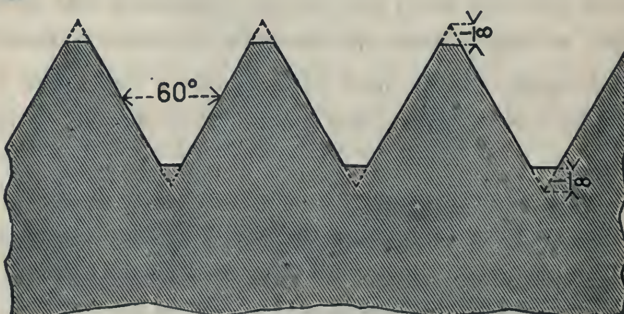


Fig. 80.

worth and Sellers system respectively, as seen through English eyes. The comparison, however, seems to be fair. Without underrating the good points of the Sellers thread, we believe that the Whitworth thread has its good points also, and that they are not as fully appreciated in this country as they might be:

"Comparing the 'Whitworth' and 'Sellers' screw-threads, the former is stronger than the latter because of the rounding at the root. The point of the Whitworth thread is also less liable to injury than the Sellers. The

SCREW-CUTTING IN THE LATHE.

form of the Sellers thread is, however, one which is more easily produced with accuracy, in the first place, because it is easier to get with certainty an angle of 60 degrees than an angle of 55 degrees, and, in the second place, because it is easier to make the point and root perfectly parallel to the axis than to ensure a truly circular point and root. The Sellers thread has also a slight advantage in that the normal pressure, and therefore the friction, at every point of the acting surface is the same; while in the Whitworth thread the normal pressure, and therefore the friction, is greater at the rounded parts. The surface of the Sellers thread will, therefore, wear more uniformly than the surface of the Whitworth thread. The total friction, and also the

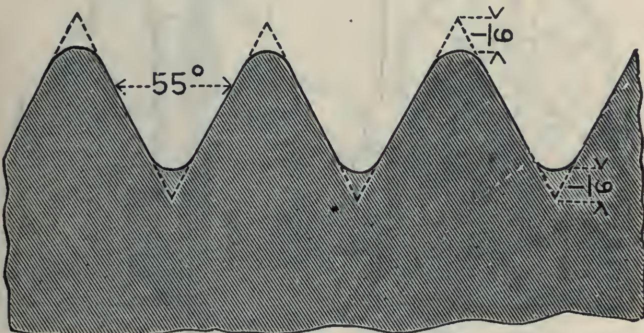


Fig. 81.

bursting action on the nut, are slightly greater in the Sellers thread than in the Whitworth, because of the greater angle of the V; it will be seen that for a given diameter of screw the diameter at the bottom of the thread is greater in the case of the Whitworth than in the Sellers. A bolt with a Sellers thread is, therefore, weaker than the same size of bolt with a Whitworth thread. The strength of the Sellers screw is still further reduced on account of the sudden change of the cross-section of the bolt at the bottom of the thread."

CHANGE-WHEELS.

Cutting a screw in the lathe is a mechanical operation, of which the most important part is the selection of the proper change-wheels. Change-wheels, or change-gears, are the gear-wheels employed to change the revolutions of a lead-screw, or feed motion.

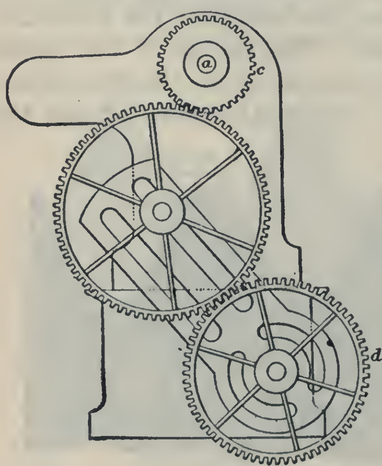


Fig. 82.

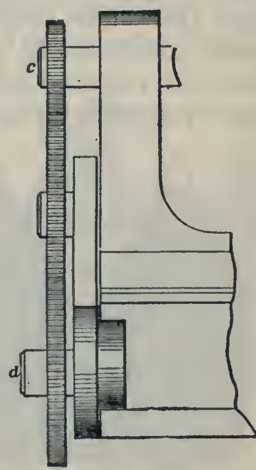


Fig. 83.

There are two ways of arranging the wheels: 1st, with two change-wheels; 2d, with four change-wheels.

Fig. 82 shows the two change-wheels, *c* and *d;* the middle wheel serves only to connect the two; *c* is the wheel on the spindle *a; d* is that on the leading screw.

Fig. 83 is a side view of this two-change-wheel.

The distance between the spindle and the leading screw of a lathe does not generally admit of cutting a

SCREW-CUTTING IN THE LATHE.

screw of more than ten threads to the inch, with *two* wheels, as the wheel on the leading screw would be too large, and that on the spindle too small.

In the same way, for cutting coarse-pitched screws, such as half a turn to the inch, the second method is generally used, or else the wheel on the leading screw would

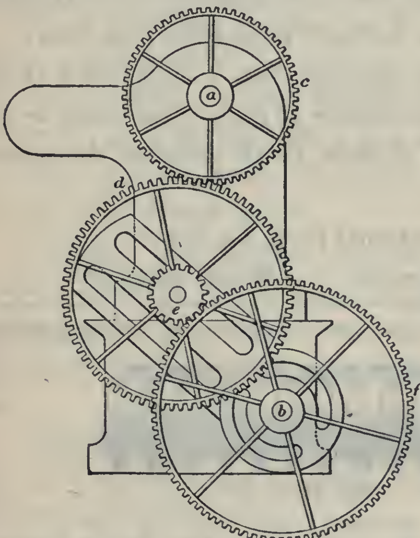


Fig. 84.

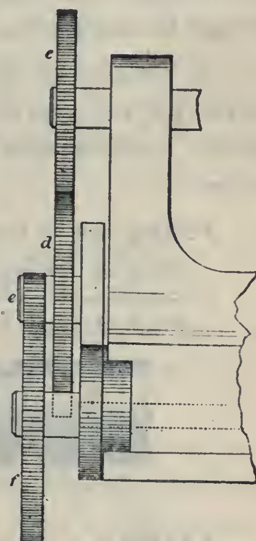


Fig. 85.

be too small, and that on the spindle too large. Thus the second method is employed for cutting screws of coarser pitch than one-half a thread, and finer than ten threads to the inch, and the first method for screws of a pitch intermediate between one-half a thread and ten threads to the inch.

Fig. 84 shows the second arrangement with four change-wheels, *c*, *d*, *e*, *f*; *c* is the wheel on the spindle, *d*

CHANGE-WHEELS.

and *e* are the wheels on the stud, *f* is the wheel on the leading screw *b*.

Fig. 85 is a side view of the arrangement with four change-wheels.

The rule for calculating the size of the change-wheels to cut threads of different pitches is really a very simple one, though frequently a source of difficulty to the student. It may be expressed as a simple proportion sum, thus:

As the pitch of the leading screw is to the pitch of the screw to be cut, so is the number of teeth in the wheel on the spindle to the number of teeth in the wheel on the leading screw.

Putting this in fractional form, we have:

$$\frac{\text{Pitch of leading screw}}{\text{Pitch of screw to be cut}} = \frac{\text{Wheel on spindle}}{\text{Wheel on leading screw.}}$$

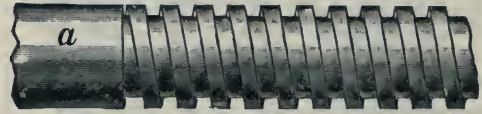


Fig. 86.

EXAMPLE 1.—Suppose that the lathe has a leading screw, *a*, with four threads to the inch; what wheels will be required to cut a screw, *b*, having eight threads per inch?

Fig. 87.

NOTE.—It simplifies matters by using the number of threads per inch in the two screws instead of the pitch, as in most cases it enables us to use whole numbers instead of fractions for figures.

SCREW-CUTTING IN THE LATHE.

Now, substituting these figures in the above fractions, we get

$$\frac{4}{8} = \frac{\text{Wheel on spindle}}{\text{Wheel on leading screw,}}$$

therefore, any two wheels in the proportions of four to eight will answer the purpose; if we multiply both these figures by the same number we do not alter the proportions at all; therefore, by multiplying both by five we get twenty and forty, as two suitable wheels, or multiplying by ten we get forty and eighty, or multiplying by fifteen we get sixty and one hundred and twenty, any of which pair will give the desired result.

Selecting the last pair, put the sixty wheel on the spindle and the one hundred and twenty wheel on the leading screw, and gear the two together by inserting an intermediate wheel, which may be whatever size will fit it best.

EXAMPLE 2.—Suppose a screw of eleven threads per inch is to be cut in the same lathe, the leading screw has four threads to the inch, as before, then the proportion required between the wheels is $\frac{4}{11}$, so that (multiplying by ten), a forty and a one hundred and ten wheel will be correct, or (multiplying by five), a twenty and a fifty-five wheel, or any wheels having the same ratio.

If a fractional number of threads is to be cut, such as $9\frac{1}{2}$ threads per inch, exactly the same plan is adopted. The proportion is $4 : 9\frac{1}{2}$; multiplying both by ten, we get forty and ninty-five as suitable wheels.

Similarly, if the leading screw have two threads per inch, and it is desired to cut twelve threads per inch, the proportion is 2:12. Multiplying both by ten, we get twenty and one hundred and twenty as being suitable wheels.

It is sometimes difficult to measure the exact number of threads per inch in places where there is a fractional part of a thread included, as, for instance, five and a quarter threads per inch. It is then better to measure such a length of the screw as contains an exact number of threads, and compare it with the number of threads in a similar length of the leading screw. A screw with five and a quarter threads per inch will have twenty-one complete threads in a distance of four inches. If the leading screw has four threads to the inch, it will clearly have sixteen complete threads in four inches. Therefore the relation between the two screws is 16:21. Multiplying both of these by five, we get eighty and one hundred and five as the wheels necessary to cut such a thread.

The calculations so far refer to a simple train of wheels. Cases frequently arise, however, especially with fine pitches, in which the wheels calculated in this way are not available. If the leading screw has four threads to the inch, and it is required to cut a screw of forty threads to the inch, the proportion is 4:40. Multiplying both by five, we get twenty and two hundred as the necessary wheels, but in all probality the lathe to be operated is not fitted with a two hundred wheel. A compound train of wheels, that is, four change-wheels, as shown in fig. 84, must therefore be selected.

To calculate these, proceed as follows: The proportion, as already stated is $\frac{4}{40}$. Split each number up into

SCREW-CUTTING IN THE LATHE.

two separate numbers, which, if multiplied together, will produce the original number, thus $\frac{4}{40}=\frac{2}{5}\times\frac{2}{8}$. Multiplying each of these numbers by 10, we get $\frac{20}{50}\times\frac{20}{80}$. This means that a wheel on the spindle, gearing into a 50 wheel on the intermediate stud, and another 20 wheel on the intermediate stud, gearing into an 80 wheel on the leading screw, will give the desired result.

It will be more easily understood if the student considers the fact that the first 20 wheel, *c*, gearing into the 50 wheel, *d*, reduces the speed in the proportion of 2½ to 1, and the second 20 wheel, *e*, gearing into the 80 wheel, *f*, on the leading screw again reduces this speed in the proportion of 4 to 1, making a total reduction in speed of 10 to 1, which is the proportion between the thread to be cut and the thread on the leading screw, *i. e.*, 4 to 40.

A few other examples are worked out to assist the reader to thoroughly grasp the rule.

EXAMPLE 1.—Leading screw two threads per inch, required the wheels to cut twenty-five threads per inch.

$$\frac{2}{25}=\frac{2\times 1}{5\times 5}$$

Multiplying each pair of numbers by the same figure, we get $\frac{20\times 10}{50\times 50}$ as one set of wheels, or using different multipliers we get $\frac{30\times 25}{75\times 125}$ as another set of wheels, either of which will cut the desired threads. The respective wheels may be identified by comparing the above fractions with the following:

$$\frac{\text{Driving wheel on spindle}\times\text{driving wheel on stud}}{\text{driven wheel on stud}\times\text{driven wheel on leading screw.}}$$

CHANGE-WHEELS.

The figures in the fractions of all the examples correspond to the wheel here indicated in the same position.

EXAMPLE 2.—Leading screw two threads per inch, required the wheels to cut nineteen threads per inch.

$$\frac{2}{19}=\frac{2\times 1}{9\frac{1}{2}\times 2}=\frac{20\times 40}{95\times 80}$$

as one set of wheels, or $\frac{20\times 35}{95\times 70}$ as another set of wheels.

EXAMPLE 3.—Leading screw four threads per inch, required the wheels to cut thirty-three threads per inch.

$$\frac{4}{33}=\frac{2\times 2}{3\times 11}=\frac{40\times 20}{60\times 110}$$

as one set of wheels, or $\frac{30\times 20}{45\times 110}$ as another set of wheels, either of which would do.

EX. 4.—Leading screw four threads per inch, required the wheels to cut seventeen and a half threads per inch.

If there are seventeen and a half threads in one inch of the screw to be cut, there are thirty-five threads in two inches. In two inches of the leading screw there are eight threads, so that the proportion is $\frac{8}{35}$

$$\frac{8}{35}=\frac{2\times 4}{5\times 7}=\frac{20\times 40}{50\times 70}$$

as one set of wheels, or $\frac{40\times 60}{100\times 105}$ as another set, which will cut the desired pitch.

If any doubts exist as to the correctness of the calculations for a set of wheels, the result may easily be tested by multiplying the number of teeth in the driving wheels together and the number of teeth in the driven wheels together, and placing these totals one above the other, in the form of a fraction. Then reduce this fraction to its lowest terms, and the figures obtained should correspond with the ratio of the leading screw to the screw to be cut, expressed in its lowest terms. Thus, to prove the second

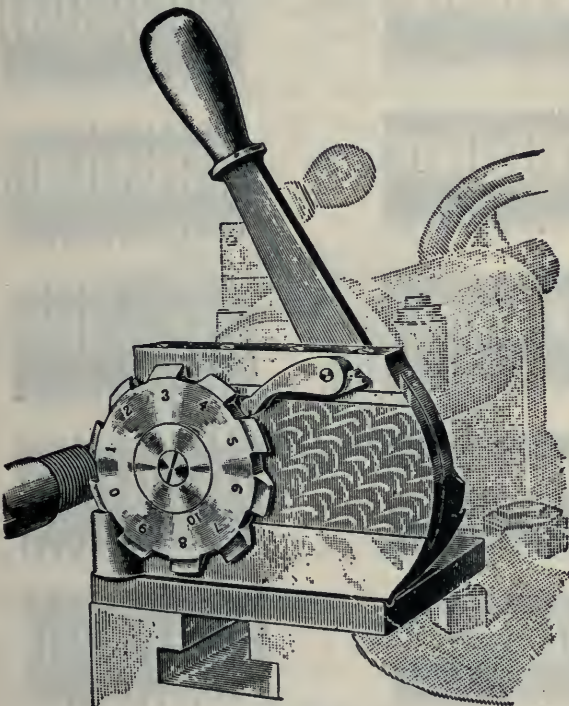


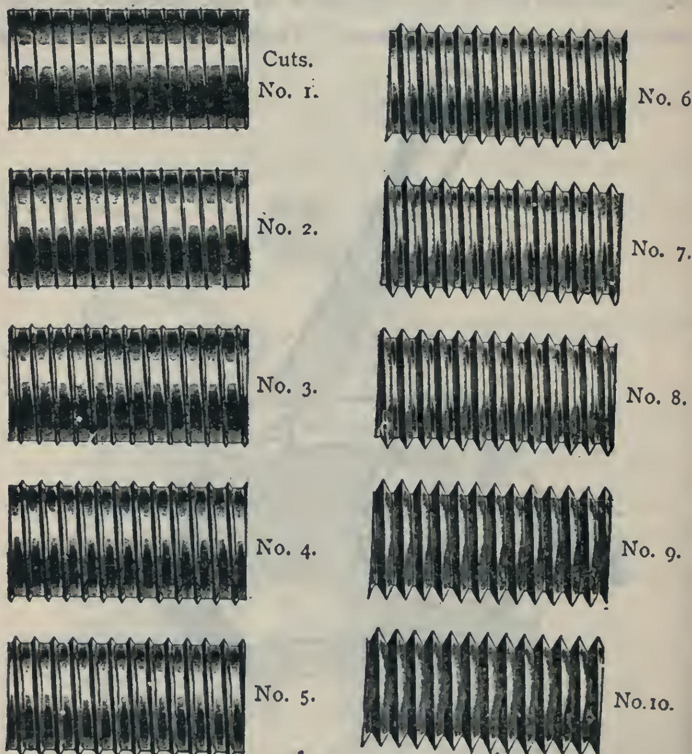
Fig. 88.

wheels obtained in example (1), we have thirty and twenty-five as drivers, and 75 and 125 as the driven wheels. $30 \times 25 = 750$, and $75 \times 125 = 9{,}375$. $\frac{750}{9375}$ reduced to its lowest term $= \frac{2}{25}$, which represents the ratio of the leading

CHANGE-WHEELS.

screw (two threads per inch) to the screw to be cut (twenty-five threads per inch).

It should be remembered that the "drivers" are those wheels which impart motion, and the "driven"



Figs. 89–98.

wheels are those which receive motion. The wheel on the spindle is a "driver," while the wheel on the leading screw is a "driven" wheel; the wheel on the intermediate stud, which gears with the spindle wheel, is a "driven" wheel, and the other wheel, on the intermediate stud,

SCREW-CUTTING IN THE LATHE.

which imparts motion to the wheel on the leading screw, is a "driver."

Fig. 88 shows a specially devised tool in operation, cutting a screw-thread on the lathe; the tool consists, as will be seen, of a disc of steel having ten distinct teeth on its rim, these teeth are graded for cutting the thread in distinct operations of the tool.

The cutter is mounted on a hand-sliding rest, which is bolted to the ordinary lathe carriage, and the tool is adjusted to each cut by the hand lever. Fig. 99 shows a separate view of the cutter.

Fig. 99.

Figs. 89–98 show a screw as it would appear after each cut has been performed. Commencing at No. 1, the thread is finished in ten trips, each of which removes an exact depth of stock. The first tooth, No. 1, makes a shallow cut the full width of the thread; each following tooth cuts deeper (as well as narrower), until the last one (No. 10), with its cutting point, does the finishing.

When fine work, such as for taps, etc., is required, the pawl is thrown back out of action, the micrometer adjustment used, and another trip taken across the thread. Advancing the lever one hole in the micrometer adjustment brings the cutting point a fraction of a thousandth of an inch forward. Successive trips with advance of lever will give the finest finish possible to a thread.

The heel of the tooth in action rests upon a stop, so that it can be ground until but an eighth of an inch in thickness, and still retain the full strength and power to do the work; a square is employed against the face of the cutting disc, and the thread angles are ground from this face.

When once set, neither tool nor cross-slide adjustment need to be changed in cutting the screw or any number of screws in exact duplication.

This form of tool requires very little grinding, as the point of the tool is reserved and only used in the finishing or last cut.

Ingenuity on the part of the lathe builders has resulted in the design of a simple contrivance by which the gears which are mounted under the head can be instantly set to cut any required thread at the will of the operator, without delay of calculating or of changing the gears. The mechanism consists of a set of gear wheels, usually ten, mounted on a shaft called the "change gear shaft," which is placed in the bed under the headstock of the lathe.

By an arrangement consisting of a sliding or tumbling gear, any of these ten fixed gears can be brought into operation; these combine with a set of intermediate gears located outside of the head, also varied in their arrangement by a lever mechanism, to vary the speed of the lead

SCREW-CUTTING IN THE LATHE.

screw to cut any of the following forty threads or feeds per inch.

Fig. 100 shows an index plate for the "change gear shaft"; this is usually attached to the front of the lathe, "handy" to the two levers to which reference is made.

THDS	KNOB	THDS	KNOB	THDS	KNOB	THDS	KNOB
18	2	9	2	4½	2	2	1
19	3	9½	3	4¾	3	2¼	2
20	4	10	4	5	4	2½	4
22	5	11	5	5½	5	2¾	5
23	6	11½	6	5¾	6	2⅞	6
24	7	12	7	6	7	3	7
26	8	13	8	6½	8	3¼	8
28	9	14	9	7	9	3½	9
30	10	15	10	7½	10	3¾	10
32	11	16	11	8	11	4	11
		FEEDS					
80 To 40		40 To 20		20 To 10		10 To 5	

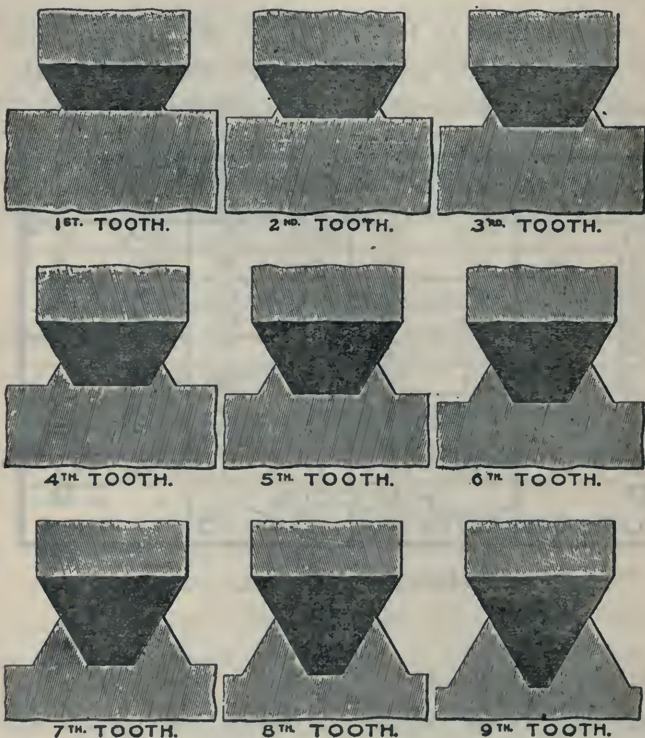
18-Inch Index Plate.

Fig. 100.

EXAMPLE.—Should the operator desire to cut 12 threads per inch, he engages the sliding gear on the lead screw intermediates, opposite the table showing 20 to 10 threads per inch, and then places the lever in front of the lathe head, which carries the sliding or tumbling gear into the hole marked "7," as indicated in the index plate opposite 12, the number of required threads; the tool is then ready for operation.

The gears required are obtained by moving two levers only; one being on the intermediate gear of the lead screw, the other being outside the headstock.

CHANGE-WHEELS.



Section of seven-pitch V-thread, enlarged four times, showing the regular ten cuts taken by the Rivet-Dock thread tool shown in fig. 88.

Figs. 101–110.

SCREW-CUTTING IN THE LATHE.

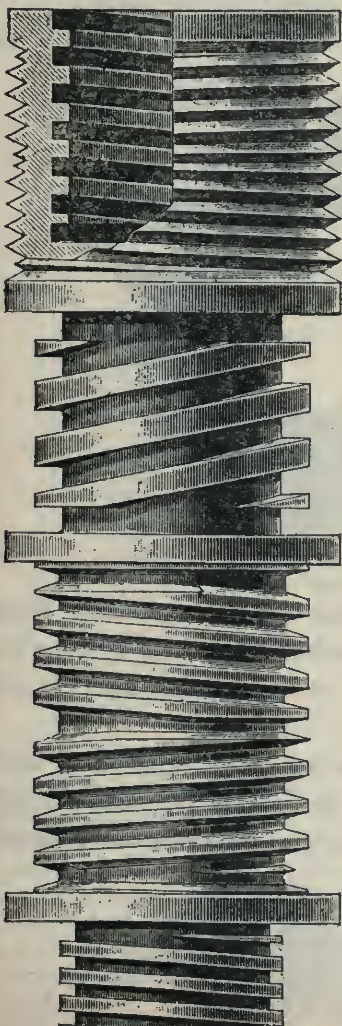


Fig. 111.

The above figure represents an external screw cut in a lathe without "change-wheels," and with the work constantly in motion and effected through the use of an automatic-stop on the carriage. No. 7 in the figure shows an internal thread cut to the shoulder by the same contrivance.

CHANGE-WHEELS.

The gauge, fig. 112, is used as a standard for grinding tools to cut threads according to the United States Standard.

The angles are 60 degrees, and the flat surfaces at top and bottom of threads are equal to one eighth of the pitch.

Fig. 112.

Fig. 113 shows a center gauge of United States Standard, 60 degrees; the method of setting a screw cutting tool by its use is shown in illustrations, figs. 114–116, on page 137.

This gauge is also used for a guide in grinding screw cutting-tools. The table on the gauge (see full size cut) is used for determining the sizes of tap drills for V-threads

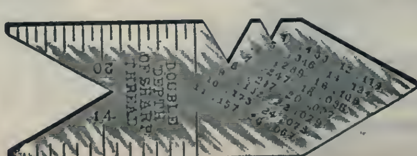
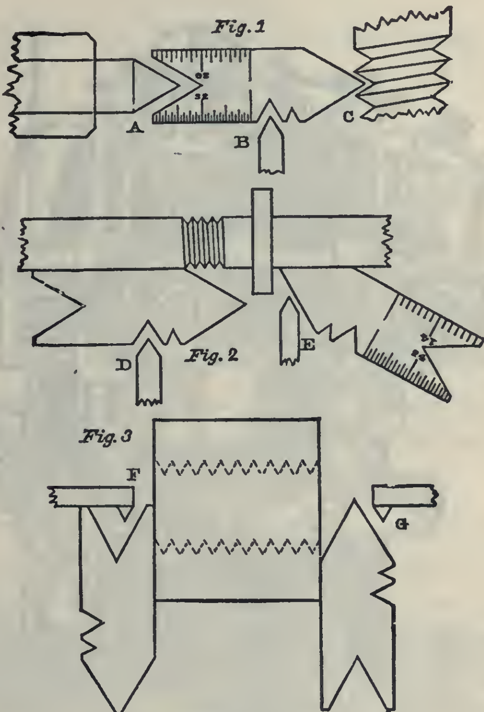


Fig. 113.

SCREW-CUTTING IN THE LATHE.

and shows in thousandths of an inch the double depth of thread of taps and screws of the pitches most commonly used.



Figs. 114-116.

NOTE.—In *Fig. 1*, at *A*, is shown the manner of gauging the angle to which a lathe centre should be turned; at *B*, the angle to which a screw thread cutting tool should be ground; and at *C*, the correctness of the angle of a screw thread already cut.

In *Fig 2* the shaft with a screw thread is supposed to be held between the centres of a lathe. By applying the gauge as shown at *D*, or *E*, the thread tool can be set at right angles to the shaft and then fastened in place by the screw in tool post, thereby avoiding imperfect or leaning threads.

In *Fig. 3*, at *F* and *G*, the manner of setting the tool for cutting inside threads is illustrated.

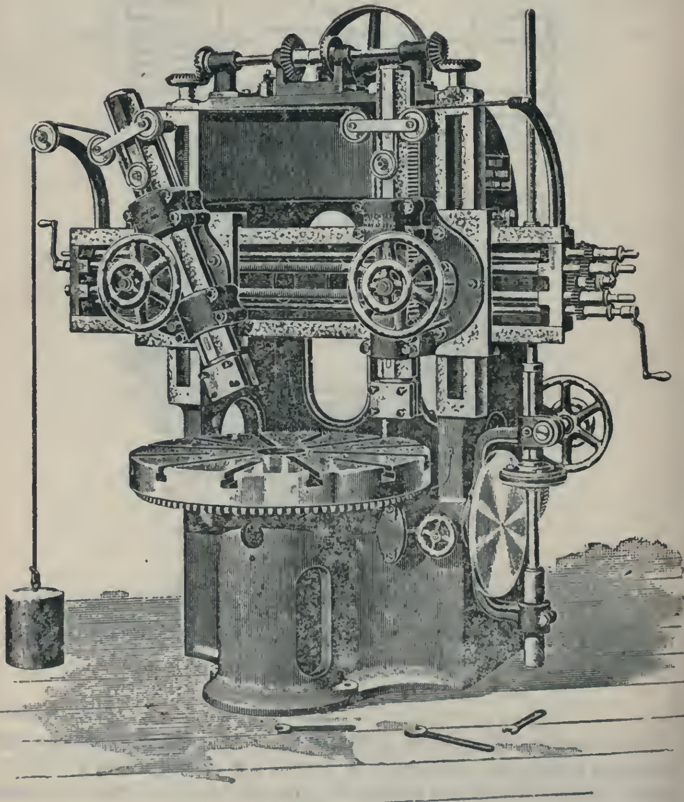


Fig. 117.

BORING OPERATIONS.

The operation of *boring* is the enlarging and trueing of holes already formed, and differs from *drilling*, which applies to making holes in solid stock.

Boring can be divided into two classes: 1, horizontal; 2, vertical Horizontal boring is done in a lathe in two ways: 1, the work rotates and the cutting tool is stationary; 2, the work is stationary and the cutting tool rotates.

Vertical boring is generally performed in special machines; in light work, *the cutting tool revolves*, as in drilling, the work being stationary; in heavy boring, *the work is revolved*, and the cutting tool is stationary except for feed motions.

Vertical boring machines having suitable automatic traverse for the cutting tool are largely used for turning and surfacing work which rotates; these machines are known as boring and turning mills, and may be described as revolving planing machines.

The most simple form of boring in a lathe is done on the chuck or face-plate, to which the work is fixed and rotated to a stationary tool in the saddle or carriage. When the hole is deep and the tool has to project beyond the holder, it is liable to spring, and the work itself, being overhung on the headstock, is liable to jar; in such cases, the work is more advantageously attached to the carriage of the lathe, and a bar used, as shown in fig. 118. This is designed to pass through the work and revolve between

BORING OPERATIONS.

the lathe centers, as shown in figs. 120 and 122, the carriage feeding the work to the rotating cutter.

In some cases, it is found needful to fix the work without any motion, the boring bar having both rotary and feed motion combined; such a boring bar is shown in fig. 119. *K* is a stout, strong bar, usually of cast-iron, because it does not "spring" as readily as wrought-iron; the cutting tool *L* is fixed to a sleeve *H* sliding on bar *K* by

Fig. 118.

means of the feed screw actuated by the handle *G*, or automatically by the provision *I* at the other end, as shown; the work to be operated on is securely fixed between the clamps or bearings *F* and *J*, the splined boring-bar *K* is rotated by the worm-wheel *E*, which is operated by the worm *D* connected to the driving-pulley or sheave *A*.

This is a portable tool, useful for boring cylinders, etc., without removing them from their beds, as it can be fixed at any angle or position; it may also be used between the centers of the lathe instead of the plain boring bar shown in fig. 118.

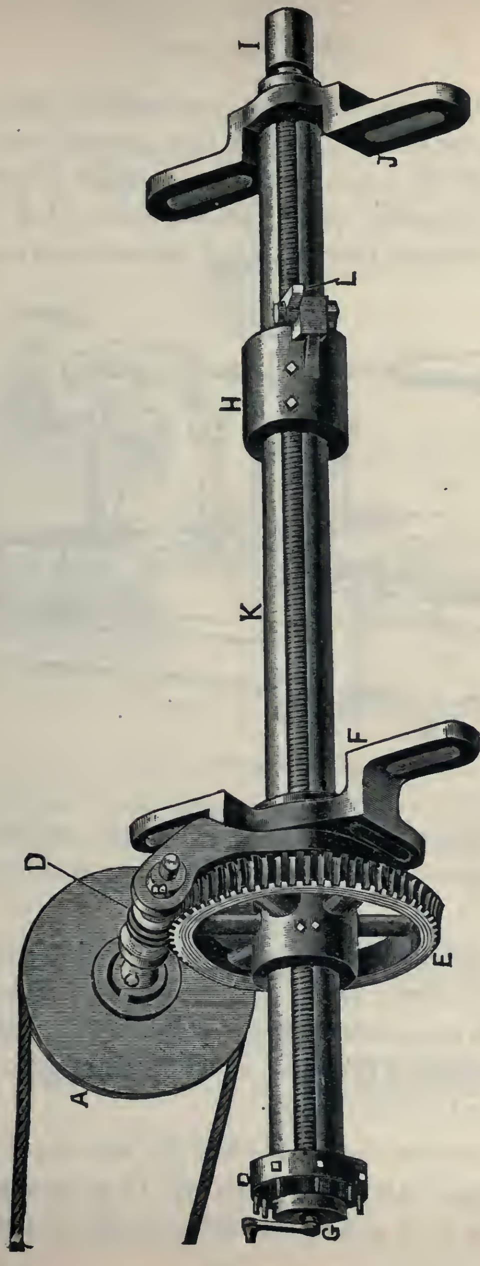


Fig. 119.

TURNING AND BORING.

Special horizontal boring machines are made which differ from the ordinary lathe in that the work-table is constructed with three movements, one being in a vertical and two in the horizontal plane; when the work has been set vertically, the work-table is moved crosswise and lengthwise

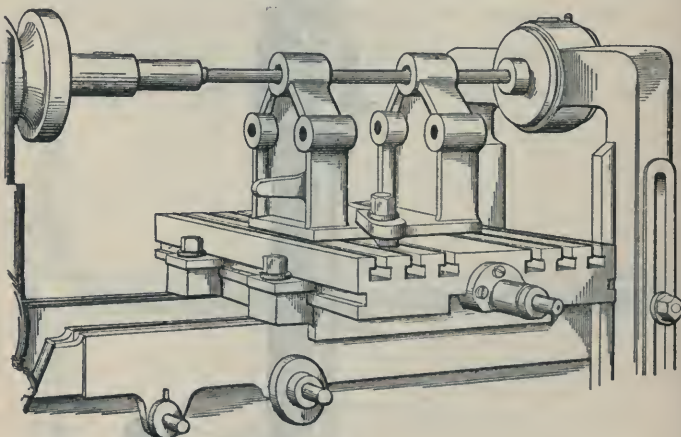


Fig. 120.

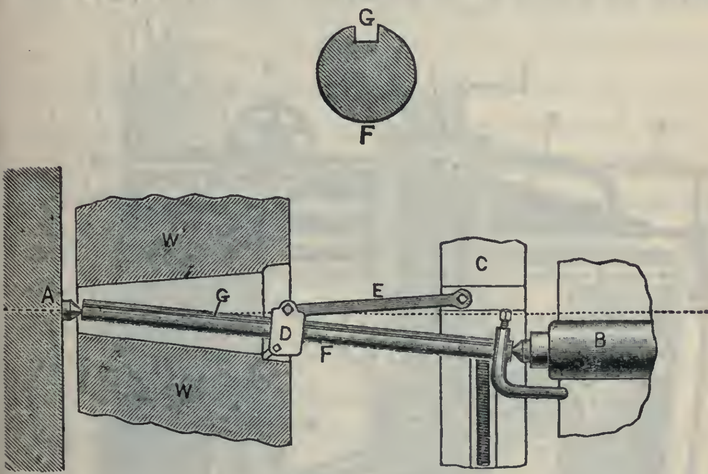
until the horizontal setting has been found; no blocking of any kind is needed; such an arrangement is shown in fig. 120.

Boring of taper holes in a lathe is illustrated by the arrangement shown in fig. 122; this is used when neither attachment, compound rest nor reamers are available; *A* is the headstock of the lathe, and *W W* the piece of work mounted on the face-plate.

Now, set over the tail-stock *B* the same as if turning, an outside taper the same as the hole to be bored. Fit up a boring-bar *F*, of as large diameter as practicable, with a

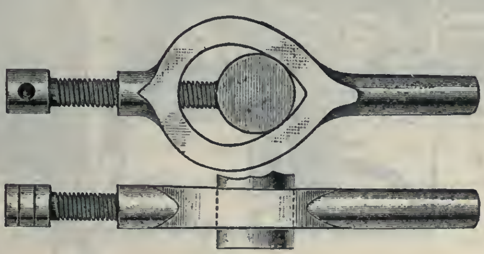
BORING OPERATIONS.

key-way *G*, and a traveling-head *D* carrying a cutter. Connect this traveling-head to the cross-carriage of the lathe *C* by the link *E*. Set a lathe-dog (see figs. 123 and 124) on



Figs. 121 and 122.

the outer end of the bar to prevent the bar from turning. Use the usual power longitudinal feed of the lathe, and adjust the cutter in the traveling-head for size the same as



Figs. 123 and 124.

for cylinder boring. This is a satisfactory way of taper boring where the conditions are suitable for the method.

THE BORING MILL.

The boring mill is essentially a vertical face-plate lathe, without the defects of the horizontal construction, *i. e.*, the

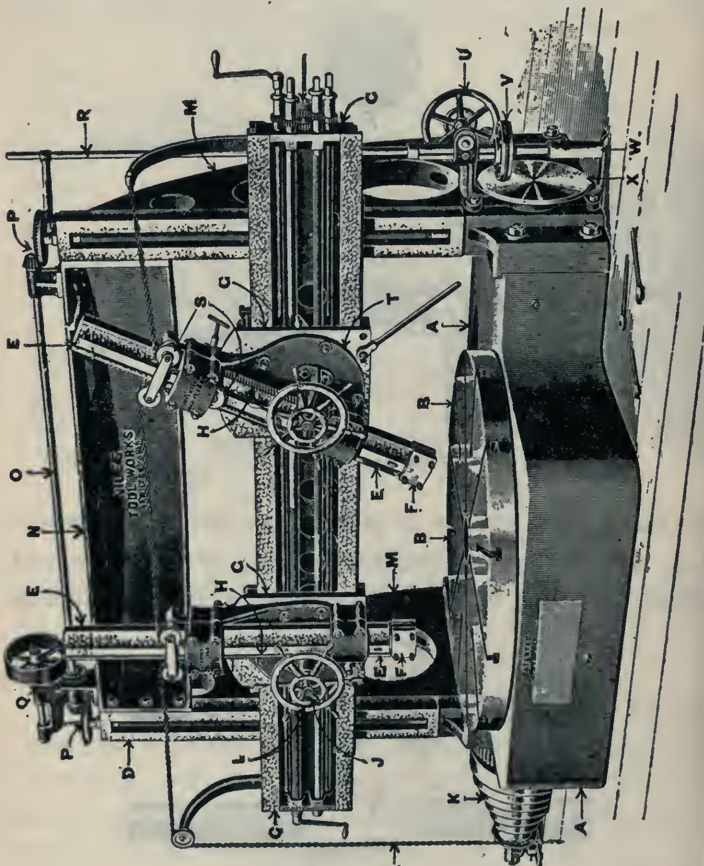


Fig. 125.

difficulty of setting and securing the work, and the necessity of heavy overhanging parts, etc.

BORING OPERATIONS.

Fig. 125 shows a boring mill, in which the horizontal table *B* is driven by internal bevel-gearing from a belt-cone *K*, the power being increased by external spur-gearing. The bed *A* is cast in one piece and well ribbed and braced for all stresses; the "housings" *M* are of hollow section, having wide palms where connected to the bed, to which they are fixed by bolts passing through reamed holes; a cross-brace *N*, at the top, stiffens the whole structure; the cross-rails *c*, *c*, are of box-girder form, having wide slide surfaces for the saddles *b*, *b*, and for the "housings;" power gears *Q* are used for elevating the cross-rails; the saddles *b*, *b*, are made "right" and "left," to permit the tool-bars *E*, *E*, to come close together; these tool-bars are octagonal in section, held in adjustable capped bearings, and will swing to any angle, being counter-weighted in all positions, and having convenient adjustment by racks *H*, *H*, and hand pinion wheel *I*, which have a power feed at all angles by friction nut *J*, *J*.

P, *P*, are the gears for elevating the cross-rails; the friction disc *X* communicates motion to rod *R* through the friction wheel *V*, which gives the quickest possible adjustment by handwheel *U* while running; a system of double gears at the end of the cross-rail gives vertical and horizontal traverse feeds to the tool; these are instantly reversible by sliding any one of the four slip gears shown in sketch.

The tool holders *F*, *F*, fig. 125, are solid steel forgings, held in the tool-bars by steel shanks and keys; these tool

NOTE.—The names of the parts and the above description are furnished by the makers of this admirable tool.

BORING MILL.

holders will grip tools in any position, and are easily removable for the insertion of cutter-bars or special tools, for which purpose the right-hand bar is set exactly central with the table; the counterweight acts at all angles through the wide bearing surface; in addition, the table has an annular, angular bearing which increases the bearing surface and

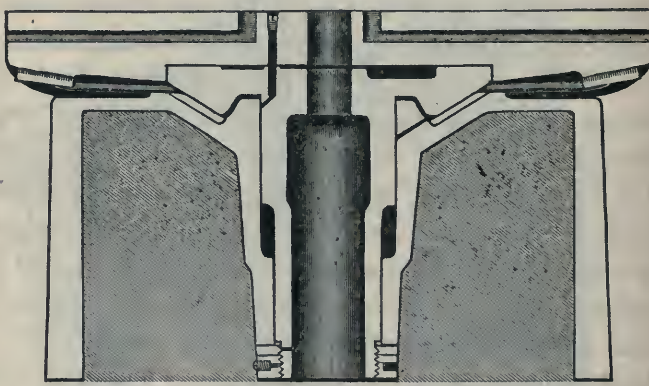


Fig. 126.

gives steadiness of motion; it has also a self-centering tendency, so that the combined weight of the table and spindle, as well as that of the work upon the table, tends to preserve and not destroy the alignment.

The advantages in the boring mill are that the work lies upon the horizontal table, and the total weight of the table and the work is distributed on a large angular bearing provided for that purpose, as shown in section, fig. 126, which gives rigidity and smooth cutting qualities, thus avoiding all jar or trembling, which occur in overhung lathes.

BORING MILLS.

Vertical boring machines are largely taking the place of planing machines for doing "surface" work. The continuous motion of the boring mill gives economy in time saved; an additional advantage is that a cutting-tool on a circular surface, when once it commences the cut, is continuous, whereas, in the planing machine, the tool gets into

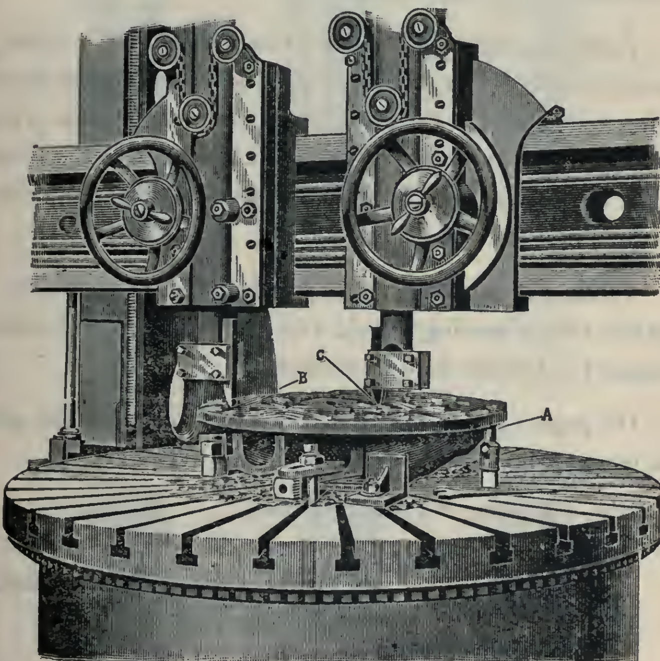


Fig. 127.

and out of the work at each stroke, often causing a ridge at the commencement, or a break-off at the termination, of the cut.

Fig. 127 shows a valve, held by angle-plates on the table, being faced or operated by two tools.

TURNING AND BORING.

Fig. 117 shows a boring mill driven by an external bevel-ring attached to the table. In many boring mills, an internal worm-wheel, geared into a worm on the cone spindle, is used, instead of chain *L* and the sheaves *S*, *S*, and does not pull the swinging tool-bar over, nor does it interfere with the moving saddles.

A section through the center of the revolving table is shown in fig. 126, the center spindle being of large diameter giving toothed gear the advantages claimed for the worm gearing, *i. e.*, steadiness in motion, and the table is closer to the floor level, thus being more convenient for handling heavy work.

When worm gearing is adopted, it is necessary that it and the thrust-bearing should run in a flood of oil, which reduces the friction to a minimum.

On page 149 are shown a set of turning tools for general use in a boring mill.

Fig. 128 being "a skiveing tool."

Fig. 129 is "a round-nose tool."

Fig. 130 is "a boring tool."

Fig. 131 is "a hog-nose roughing tool."

Fig. 132 is "a side tool."

Fig. 133 is "a broad finishing tool."

On page 150 are shown a set of boring tools for finishing cored-holes. Fig. 134 is an adjustable reamer with floating shank, the arrangement of which is shown in section in fig. 135. Fig. 136 is a boring bar with an adjustable cutter. Fig. 137 is a four-lipped roughing drill.

BORING-MACHINE TOOLS.

Fig. 128.

Fig. 129.

Fig. 130.

Fig. 131.

Fig. 132.

Fig. 133.

BORING MACHINE TOOLS.

A boring mill is practically an endless or continuous planer, that is, a planer without reversing. The convenience and facility with which work can be set on the vertical table, and the ease with which pieces can be secured, are apparent, the weight of the piece being on the machine and not on the securing device.

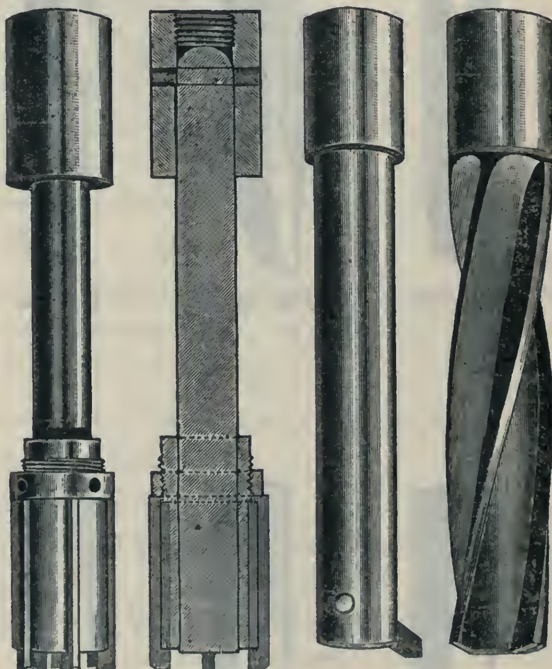


Fig. 134. Fig. 135. Fig. 136. Fig. 137.

Irregular shapes, such as eccentric discs, offset valves, brackets, etc., require no counterbalance in the boring mill, thus saving the time adjusting counterweights, which are seldom satisfactory on the overhung lathe, even when specially designed.

PLANING MACHINES

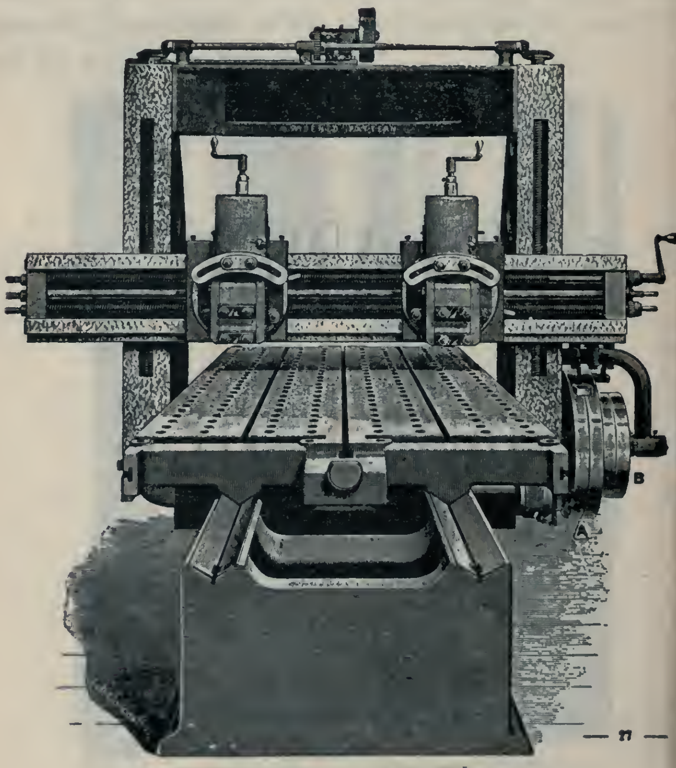


Fig. 138.

PLANING OPERATIONS.

The operation of planing constitutes straight-line cutting by means of a planer, a shaper, a slotting machine or a key-way cutter, with a steel cutting tool. In the planer, the piece to be planed is given a straight-line motion to a stationary tool; while in the shaper and slotting machine, the work is stationary and the cutting tool is given a straight-line motion over the surface of the former. The planer is a very important tool to the engine-builder, as well as others, being instrumental in the production of engine and lathe beds, slides, parallel pieces, etc.

The work to be planed is securely fixed to the table of the machine, and is moved backwards and forwards by means of suitable gear, the cutting tool being held in the tool box, mounted upon the cross-slide.

The devices feeding the cutting tool, and regulating the traverse of the table in planing machines, are of different forms; the general practice is 1, the employment of two driving belts, one for the forward and the other for the backward movement of the table; 2, the feeds are actuated by independent frictional devices, the tappets on the carriage being employed only to shift the belts; 3, narrow driving belts moving at a high speed to facilitate shifting on the pulleys.

Also, the rack and pinion movement is employed in nearly all planers to give the traverse to the table.

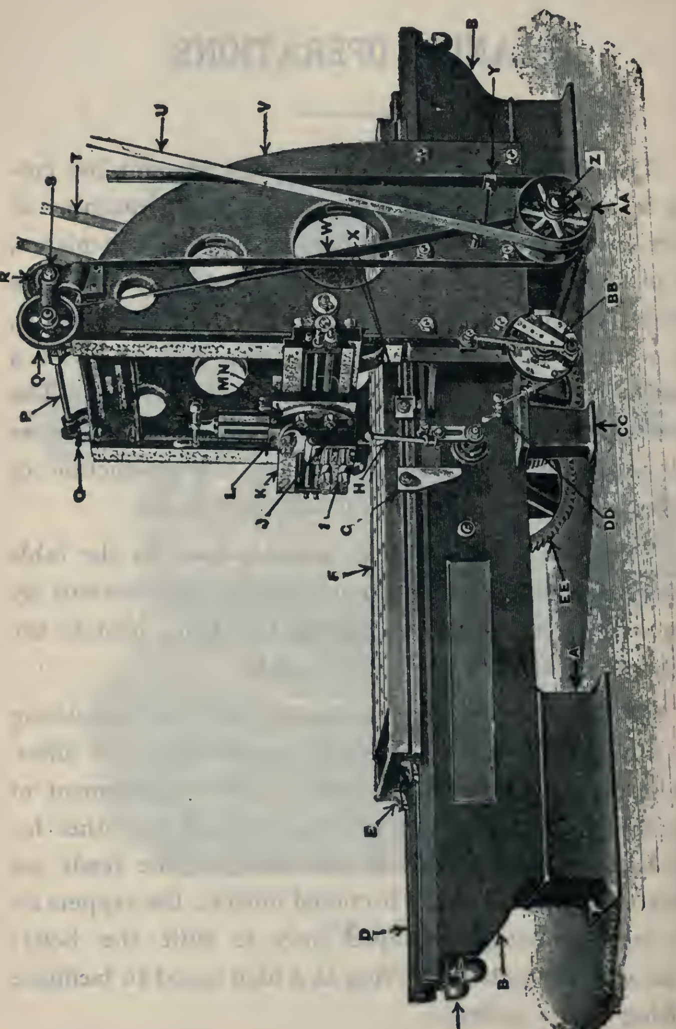


Fig. 139.

PLANING OPERATIONS.

Fig. 139 shows a heavy planer designed to plane 10 feet long, 34 inches high and 34 inches wide. The cabinets *A* support the bed *B*, which has parallel, V-shaped grooves *D*, on its upper side. Drip cups, to receive the overflow oil from these grooves, are shown at *C*. The table *F* is moved by rack and gear; on its under side are parallel V-shaped strips, which are fitted to slide smoothly in the similarly-shaped grooves *D*, on the bed; the wipers *E* contain felt to filter the oil entering the grooves, and also tend to keep them clean.

The long dog *G* strikes the rocker arm *H*, which has a removable arm for hand use; this rocker arm, through a system of mechanism, shifts the driving belts, reversing the motion of the table; *X* is the back or short dog; the cutter-head is on the cross-bar and consists of the tool-post *I*, where the cutting tool is clamped; *J* is the clapper or tool box, fastened to the vertical slide, or feed regulator, *L*, and swivels to any angle, being attached to the shoe *N*, which slides on the cross-bar *K*, thus giving the cross-feed or "advance" of the tool.

The down-feed or depth of cut is regulated by the handle shown over slide *L*. The head-lift bevel pinion *O* raises or lowers the cross-bar *K*, being geared to head-lift shaft *P*, on which is the spur-wheel *Q*, geared into pinion *S*, operated by the pulley *R* and belt *W*, driven from the pulley shaft *Z*.

The front post, or housings, *V*, are of box-form in section, and are bolted to the sides of the bed, being connected at the top by a substantial box-shaped cross-girt. The pulley-shaft *Z* is driven by two driving belts; the

PLANING MACHINES.

forward, or cutting belt, *T*, and the backward, or return belt, *U*; the belts being moved on the fast and loose pulleys by belt shifter *Y*. The backing pulleys *A A* are shown in the illustration; the forward, or cutting motion pulleys, are on the other side of the bed.

The friction box *B B* revolves through an angle which is varied by turning the worm shaft *D D*, which moves a segment having stop-lugs, so placed that the lugs on the back of the friction box strike them, thereby actuating the cross-feed. *E E* is the center gear which meshes with the table-rack.

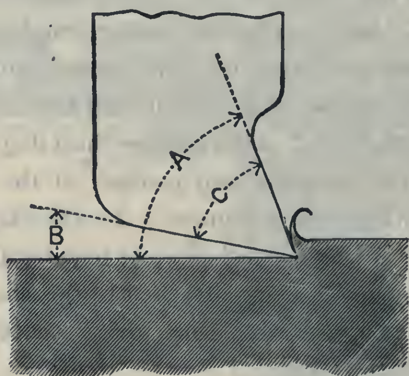


Fig. 140.

Planing machines run at a linear velocity of 15 to 20 feet per minute. The depth of cut depends on the material. The average cutting speeds for the various metals are as follows: Brass, 30 feet; gun metal, 25; cast iron, 15 to 20; wrought iron, 16: steel, 12. For general work the cross-feed, or advance of the tool should be from 12 to 14 cuts per inch for roughing cuts. The finishing cuts should be done with a broad tool, advancing from one-fourth to three-eighths of an inch with each cut.

PLANING OPERATIONS.

The tools used in planing are very similar in form to lathe-turning tools—a front tool used for roughing, a side tool for edge work, and a spring tool for flat work or surfacing. In fig. 140, *A* is the cutting angle, *B* the angle of relief or clearance, and *C* the tool angle.

The "cutting angle" for cast iron is 70°, for wrought iron, 65°, for brass, 80°, according to the table below.

TABLE.

	Cast Iron.	Wrought Iron.	Brass.
Cutting angle...........	70°	65°	80°
Clearance...............	3°	4°	3°
Tool angle..............	67°	61°	77°

One cutter head is shown in fig. 139, but it is quite common to have two cutter heads or clapper boxes, as shown in front view fig. 138, on the cross-bar, and in large machines there are, in addition, "side-heads," one on each housing, making four. All these heads will swivel to any angle.

Fig. 141 shows the arrangement of the cutter or cross-bar head which moves on the cross-bar parallel with the work table or platen.*

A is the tool-post-apron, sometimes called the clapper-box, being hinged so that the tool can lift upon the return or backward stroke; this prevents the tool edge rubbing on the work; *B* is the swivel apron; *C* the "slider" which carries the apron; *D* is the swing frame or swivel head; *E* is the saddle which slides on the cross-bar.

---

* *Platen* is a very old word meaning a covering plate; the more modern definition for this is "table."

PLANING MACHINES.

The cross-bar heads are operated by self-acting mechanisms both in the cross and angular feeding, the side-heads being fitted with vertical self-acting feed motions.

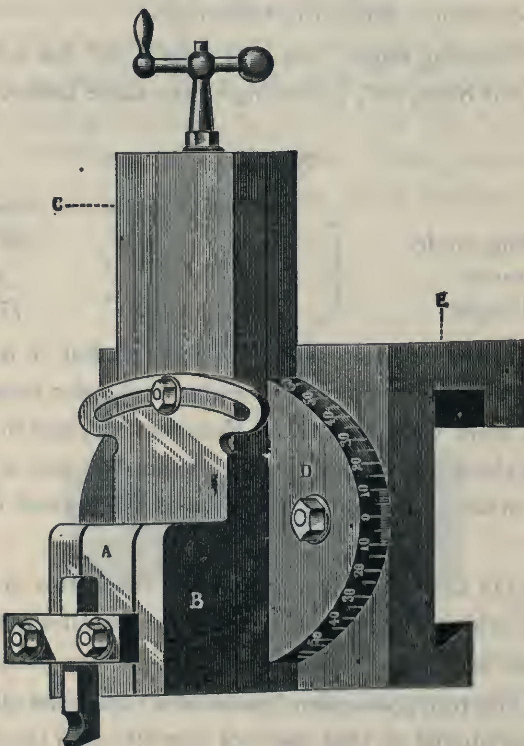


Fig. 141.

Planing machine tables are provided with bolt-holes and T-slots or grooves on the surface for fixing the work, which is usually bolted direct to the table. This cannot always be done, on account of the shape of the work.

PLANING OPERATIONS.

Fig. 142 shows an open-side planer; this tool is adapted to accommodate work when bolted to the table, of a greater width than the ordinary planer; the cross-vail or beam is a right-angle casting having a vertical leg with

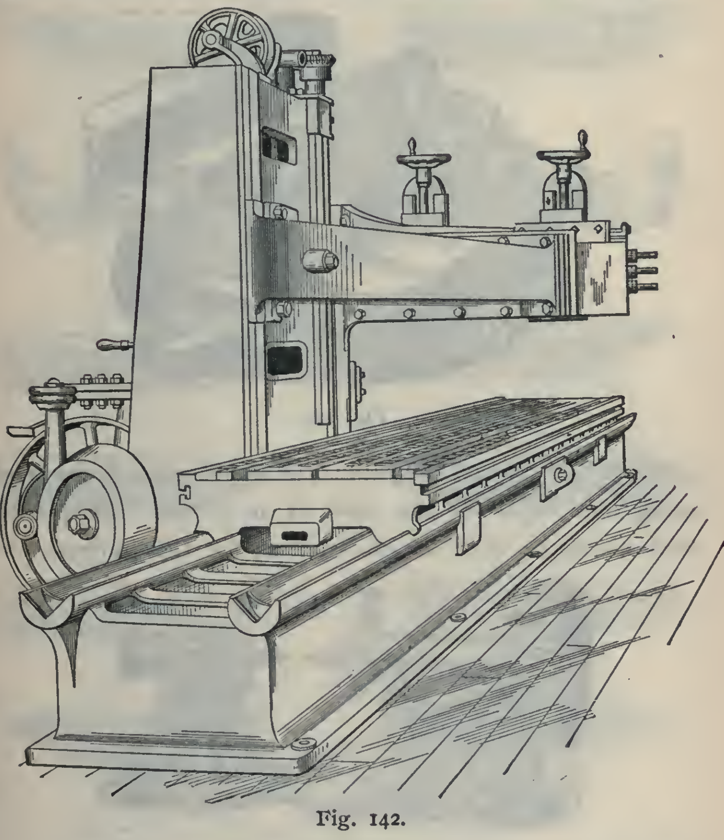


Fig. 142.

a very long bearing on the front face of the post; the horizontal arm is supported at the back by a heavy brace bolted securely to it, this arrangement insuring stiffness and stability; the brace has a sliding bearing on the side

CHUCKS.

and at the rear of the post, being rigidly clamped to it when set in position for planing. The beam and brace are raised and lowered by power.

Fig. 143 shows a swivel chuck which is sometimes

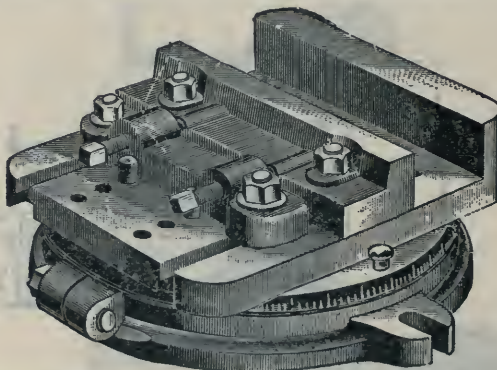


Fig. 143.

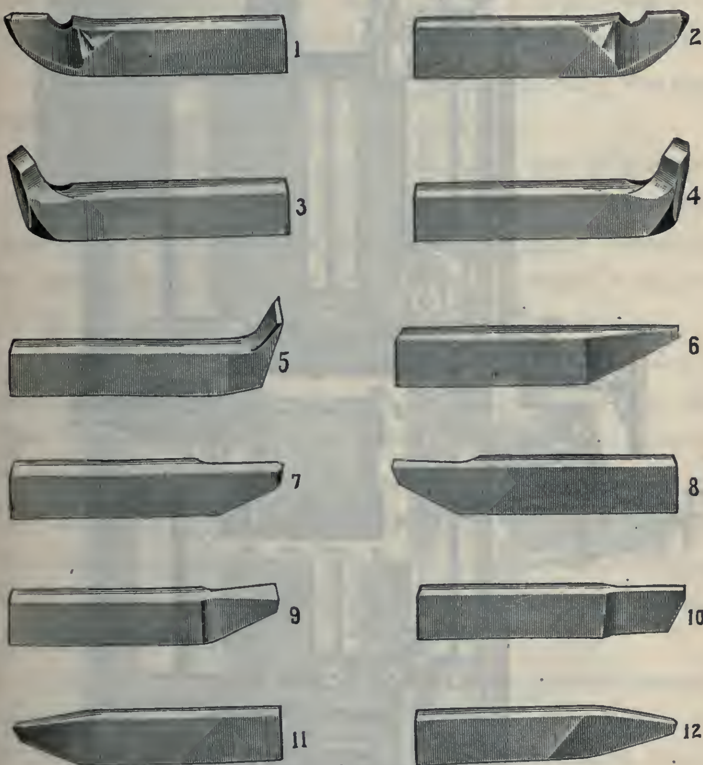
used; it is bolted on the table and travels with it, the work being held between the jaws as in a vise. Frequently work has to be held as on a lathe; for this purpose two

Fig. 144.

"planer centers" are used, as shown in fig. 144. These are bolted on the table; one of these is shown with a "dividing index."

PLANING MACHINE TOOLS.

The following illustrations show the tools in general use in planing machines. The name of each tool is given below in Note.



Figs. 145–156.

NOTE.—No. 1, Left-hand Side Tool; No. 2, Right-hand Side Tool; No. 3, Left-hand Diamond-point Tool; No. 4, Right-hand Diamond-point Tool; No. 5, Broad-nose, or Stocking Tool; No. 6, Scaling Tool; No. 7, Right-hand Siding Tool; No. 8, Left hand Siding Tool; No. 9, Finishing Tool, for corners; No. 10, Cutting-off Tool; No. 11, Left-hand Bevel Tool; No. 12, Right-hand Bevel Tool.

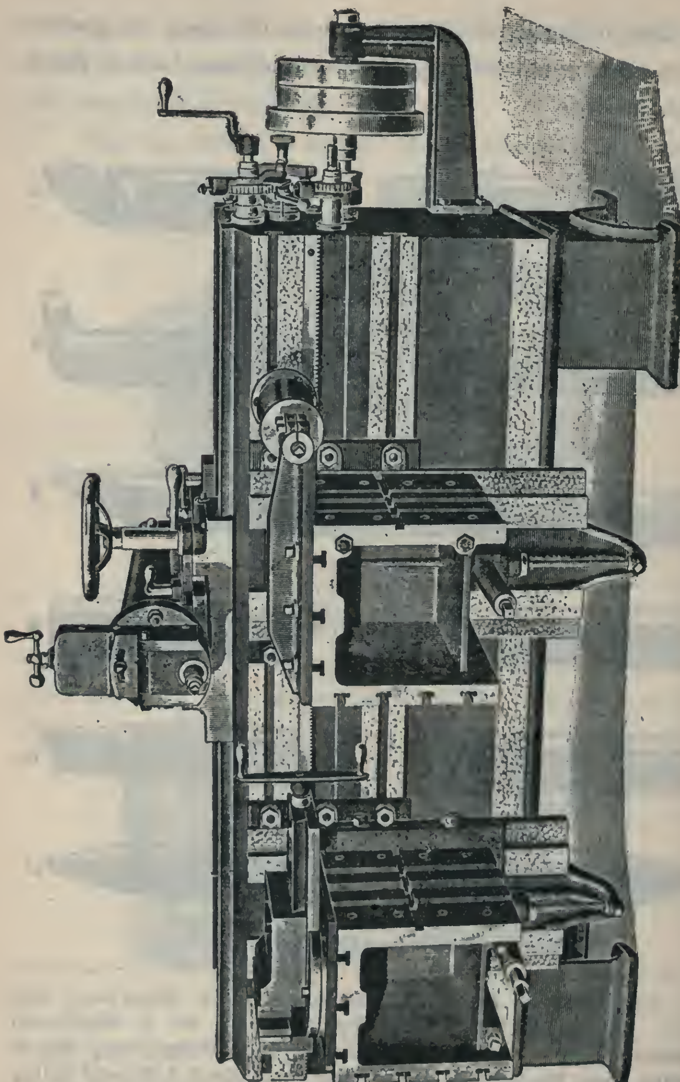


Fig. 157.

SHAPING MACHINES.

The shaper, or shaping machine, is a straight-line cutter of the planer class; they perform a large variety of operations formerly executed by hand-chipping and filing.

In this machine the work is held stationary, the tool being given a reciprocating cutting motion.

The feed-motion of shaping machines may be communicated either to the cutting-tool or to the work; when the feed is given to the cutting-tool the machine is described as *a traveling-head* shaper; such an arrangement is shown in fig. 157.

More generally—and in all small shapers—the feed is communicated to the work-table, as shown in fig. 158, the ram or tool-head having no side travel, the feed motion being given to the table carrying the work.

The shaper is a useful and handy tool, and is made in a variety of forms for special purposes, the work ranging from key grooves in shafting to planing valves and steam ports in engine cylinders.

Fig. 157 shows a usual type of traveling-head shaper; the tool-head is carried in a saddle having variable self-acting feed in either direction; it has also a rapid movement along the bed by hand through a rack and pinion, or in some cases it is operated by a powerful square-cut screw; the tool has ratchet down-feed motion; it can be swiveled and will act at an angle; two tables are provided,

NOTE—Shaping machines are generally run at a tool speed of 12 to 20 feet per minute.

PLANING OPERATIONS.

each having a hand movement along the bed, and also a vertical adjustment by screws; one table has, generally, a horizontal surface for clamping work, the other being provided with horizontal and vertical slotted surfaces for clamping the work in any desired position.

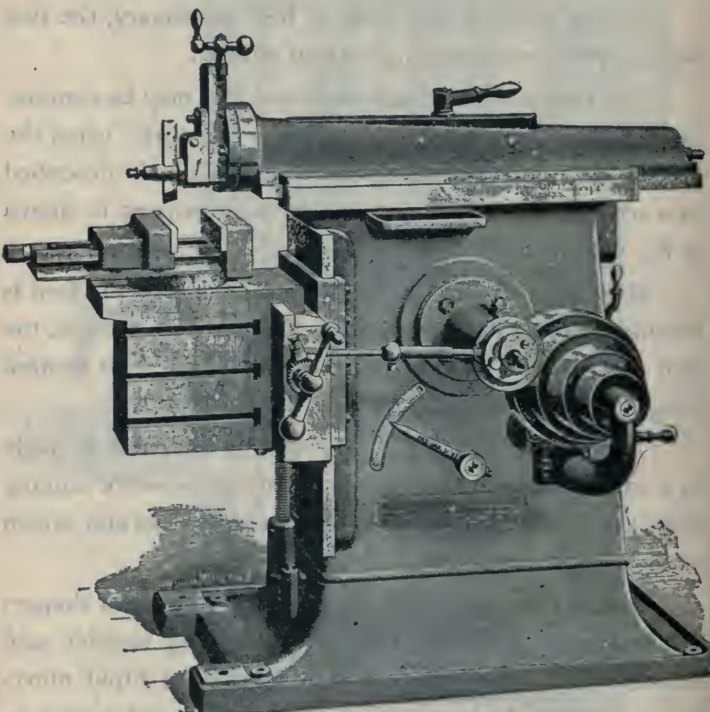


Fig. 158.

For forming teeth in spur-wheels cut out of solid blanks, shapers of special design are made, of which an example is given in fig. 159—it is the "Fellows' Gear Shaper."

SHAPING MACHINES.

A, *B*, *C*, are change gears; *D*, the "module" or pitch gear, the number of teeth of which must have a fixed ratio with the teeth of the cutter; *E*, feed trip; *F*, lower index; *G*, apron; *H*, chip pan; *I*, work arbor; *J*, cutter; *K*, cutter

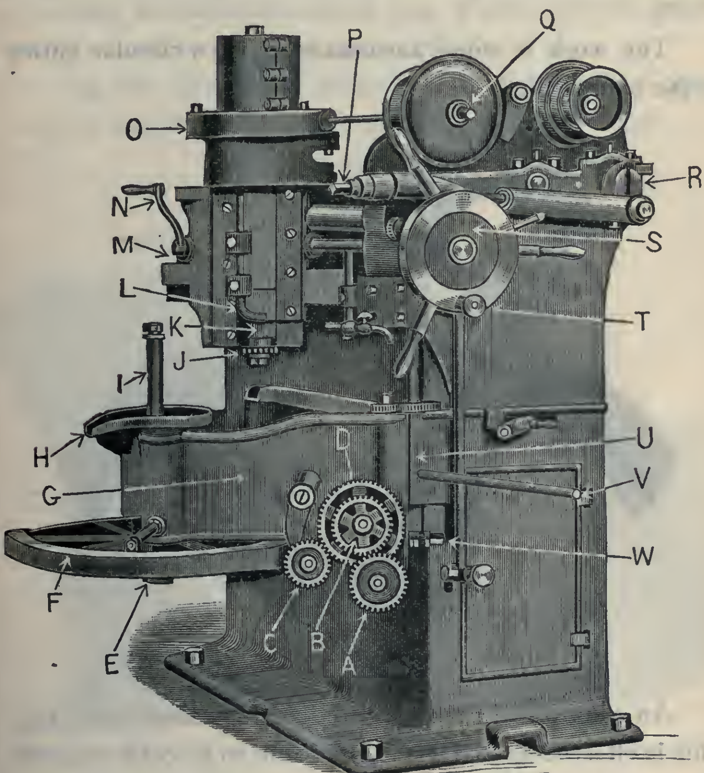


Fig. 159.

slide; *L*, work support; *M*, saddle binder; *N*, saddle adjustment; *O*, upper index; *P*, adjustment for the position of cutter; *Q*, to rotate cutter; *R*, driving crank; *S*, pilot wheel; *T*, locking pin; *U*, apron lever: *V*, detachable lever; *W*, worm adjustment.

PLANING OPERATIONS.

The Fellows Gear Shaper goes back to first principles and generates its tooth form from flat and circular surfaces which can be made absolutely true and can be proven to be so.

The work is done automatically, by a circular cutter of the correct pitch.

Fig. 160.

An example of the work produced is shown in fig. 160. This is effected as follows: The blank to be cut is securely fixed on the work arbor and the machine being started, the cutter reciprocating vertically on its center line is fed towards the blank, and cuts its way to the proper depth; at this point both cutter and blank begin to revolve, the cutter maintaining its reciprocating motion; this revolution of the cutter and blank is obtained by external mechanism, which insures that the movement

SHAPING MACHINES.

shall be as though the cutter and blank were two complete gears in correct mesh; fig. 161 shows a section through the centers of blank and cutter which will explain the process of cutting an external-toothed gear wheel; internal gears can be cut with equal ease and regularity.

Fig. 161 shows the action of the gear cutter, also each cut and the wedge form of the gear shaper chips.

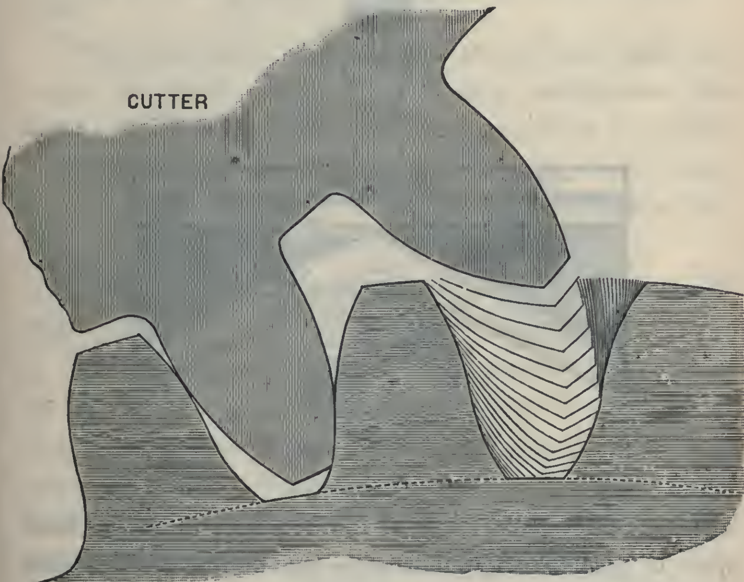


Fig. 161.

The combined result of rotary and reciprocatory motions is that the cutter teeth generate conjugate teeth in the blanks which mesh correctly with the cutter teeth and with each other.

Fig. 162 illustrates a device for setting planing or shaper tools; it consists of a body containing a spirit level, the bubble of which appears through an elongated opening

DEVICE FOR SETTING TOOLS.

formed in the top plate, attached to the body and provided at its side with linear graduations having their zero points coinciding with the zero point of the bubble. The body is provided with a downwardly extending web terminating in

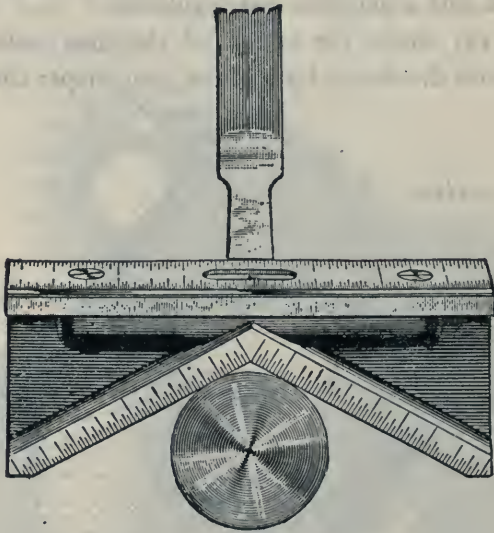


Fig. 162.

legs, extending at an angle of 150 degrees and having their apex in vertical alignment with the bubble of the spirit level. The outer faces of the legs are provided with linear graduations, reading from the apex outwardly.

NOTE.—The figure shows the instrument on the shaft and the tool in position in the tool post ready to cut a keyseat. For setting a square-nose tool in the shaper or planer, to cut a keyseat or groove, the operator places the instrument upon the shaft with the legs touching the sides of the shaft and turns the instrument until the bubble of the spirit level is at zero. The planer tool is then brought to the correct position by aid of the graduations and is set with its edge parallel with the top surface of the instrument.

THE SLOTTING MACHINE.

The slotting machine may be classed as a *vertical shaper*, or planing machine; it performs straight line cutting; the tool, as in the shaper, receives the motion, the bed or table being stationary, except for feed adjustment.

There are many varieties of slotters, both light and heavy; the small machines are usually crank-driven, the larger ones have steel racks and pinions driven by a train of spur gears, with shifting belts; for slotting heavy forge work, especially cutting propeller shaft cranks out of the solid, they are built of great cutting power.

The principal features aimed at in all, are smooth running and convenient handling of the work.

The advantageous features of the slotter are, first, that the lay-out of the work is always visible, the line to be worked to being on top where the tool begins to cut, instead of where it finishes the cut as in the case of the shaper; and second'y, that there are three feeds—longitudinal, cross and circular—all with a wide range.

For the slotting of interior surfaces, and the planing of such exterior surfaces as for one reason or another cannot be done advantageously on the planer or turned in the lathe, and where the pieces are of medium or large size, the slotter is a necessity.

For cutting keyways in wheels, etc., the slotting machine has no equal and in addition nearly all descriptions of broaching work can be accomplished with it.

PLANING OPERATIONS.

Fig. 163 shows a well known form of the tool in common use for machine-shop purposes; the tool-bar can be adjusted to suit the height of the work, or any length

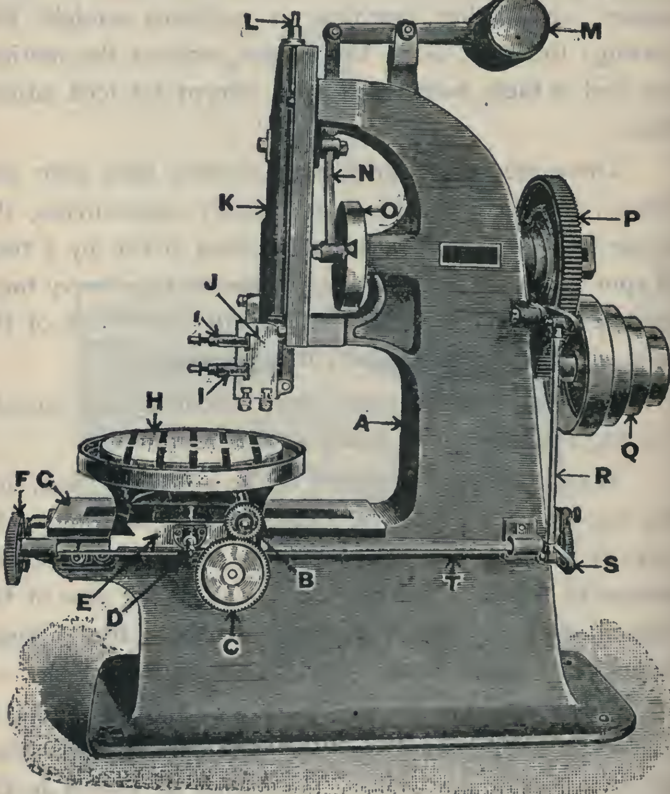


Fig. 163.

of tool used; the work-table has power feed for the longitudinal, cross and circular movement; all the feeds are moved at the top of the stroke, when the tool is clear of the work.

THE SLOTTING MACHINE.

The ram, or tool-bar, as shown in the illustration, is counter-weighted and easily regulated; the hand cranks and levers for all adjustments are placed within easy reach of the operator.

The cutting tools in slotting machines are gripped in a relief tool block, *J*, carried by the ram, *K*, moving vertically in the slides of the upright frame, *A;* the work being operated on is fixed on the work table, *H*, which lies horizontal beneath the ram; the work table is carried on a compound slide, having two horizontal motions: the lower slide or carriageway, *G*, is operated by the rod or feed-shaft, *T*, and the end main feed gear, *F;* the upper slide or saddle-way, *E*, is operated in a similar manner by the main intermediate gear, *C*. *D* is the transverse adjusting screw; the small wheel, *B*, operates a worm, which engages with a worm wheel on the periphery of the circular table, *H*, to rotate it; the tool-posts, *I*, *I*, are carried in the relief tool-block or apron, *J;* the ram, *K*, may be varied according to the thickness of the work on the table by the adjusting screw, *L*, on the ram; *M* is the counterweight which balances the ram and prevents "jump" when the tool is entering or leaving the work; *N* is the connecting rod attached to the crank-plate, *O*, which gives motion to the ram; the gear, *P*, on the crank-plate shaft is driven by a pinion on the driving-cone pulley, *Q;* the feed-rod, *R*, gives motion to the feed-shaft, *T*, by means of the bell-crank, *S*.

The cutting-bar slide is made adjustable on the outside of frame, and by making the slide very heavy, no matter at what point the cutting-bar is set, it will be very rigid. To adjust the cutting-bar slide, it is only necessary

PLANING OPERATIONS.

to tighten up one of the gib screws and loosen the clamping bolts, and by revolving the driving cone the slide can be adjusted in any desired position to bring it down close to the work.

The accompanying drawings (fig. 174 being a side view and fig. 175 a front view) will show the detail of the relief tool-block on all these machines.

A is the adjustable slide attached to the main frame by the bolts *C*; *B* is the ram having slides *H*, *H*; *D* is the

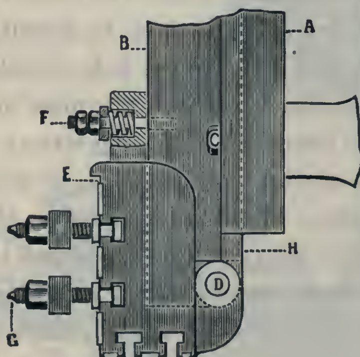


Fig. 174.

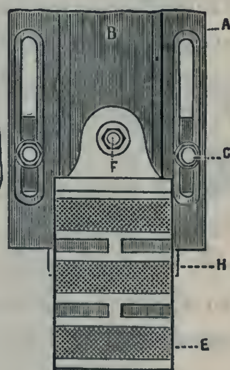


Fig. 175.

pivot or pin on which the apron or tool-box *E* hinges; *F* is the relief spring which presses the apron *E* against the ram *B* on the downward or cutting stroke of the tool, as illustrated in fig. 176; on the return or idle stroke, the relief spring yields and takes the pressure off the cutting point of the tool, which is carried in the tool posts *G*.

Fig. 177 shows a form of machine used largely in machine shops for cutting keyways up to one inch wide; it is constructed on the principle of a broacher or drift cutter,

THE SLOTTING MACHINE.

the work being fixed to the adjustable table, *A*, by the heavy clamping, *D*. The cutter-bar, *G*, which has coarse teeth, as shown, is drawn through the work: there is a provision for automatic relief on the return stroke, which prevents the breaking of the cutter-teeth; *B* is the supporting bracket used when cutting sleeves or hubs; it has an adjusting screw, *C*, for holding the work; the clamp, *D*, is used for holding all large work such as pulleys, spur and

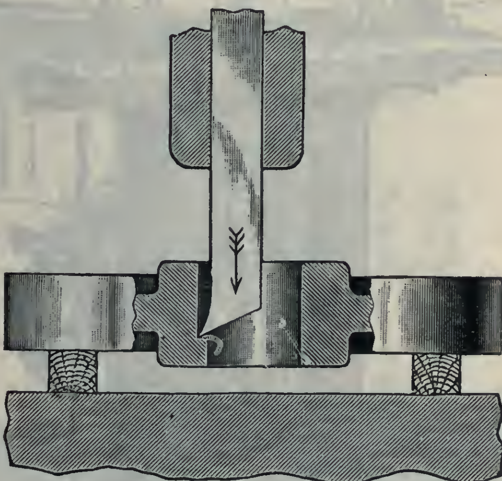


Fig. 176.

bevel gears, etc., being fixed by the screwed studs, *E*, which compress springs *Q*.

An adjustable chuck, *F*, is used for centering small work; the vertical cutter bar, *G*, is connected to the cross-head, *V*, which reciprocates in vertical guides under the table; a scale, *H*, is provided for graduating the depth of the key seat; collars or packing, *I*, regulate the height of

PLANING OPERATIONS.

the clamp, *D;* an adjustable clamp arm, *J*, is used for holding small work; it has hand feed screw; an adjusting post, *N*, and clamp screw, *M*, for attachment to the table.

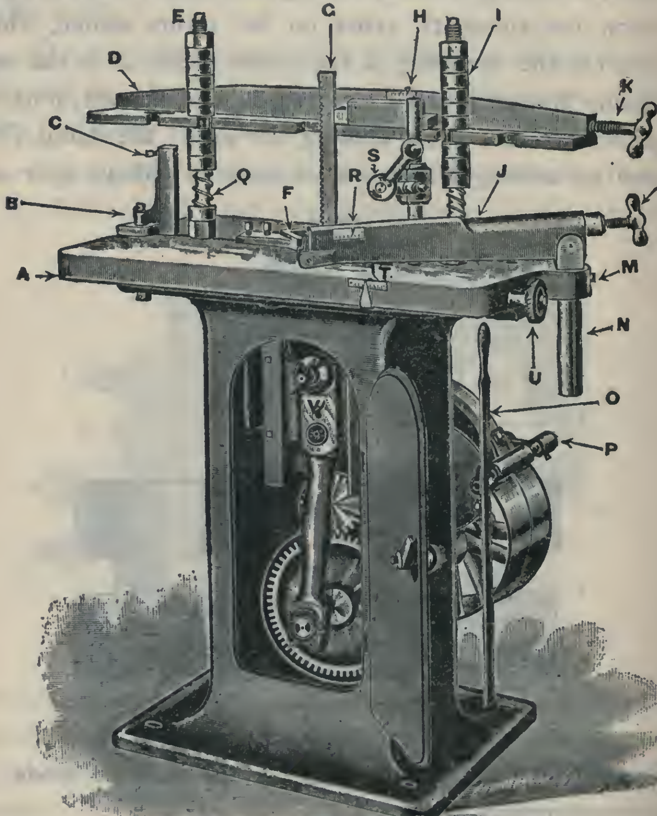


Fig. 177.

The spur gear enclosed in case, *O*, are driven by the tight and loose pulleys revolving at 175 revolutions per minute; in this machine the work is chucked by the hole or bore.

MILLING MACHINES

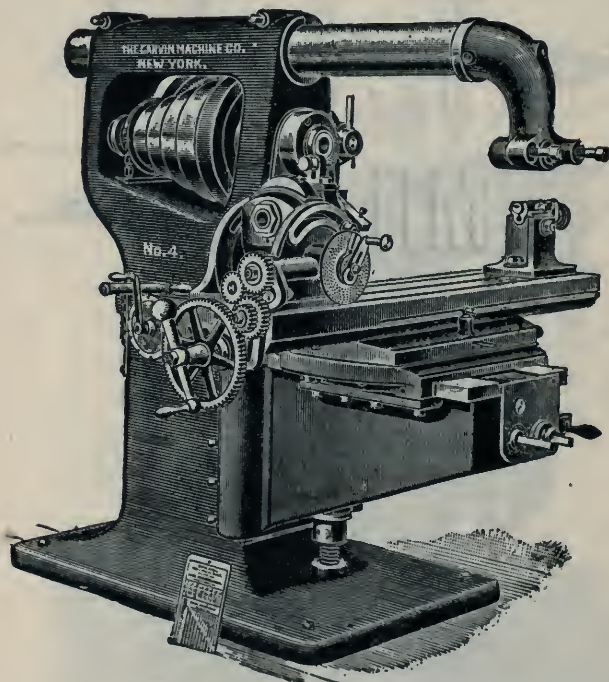


Fig. 178.

MILLING MACHINES.

A milling machine is a power machine-tool for shaping metal by means of a cylindrical cutter or serrated spindle.

No special tool has come more rapidly to the front in recent years than the milling machine; by its use a large variety of work which was formerly done by the planer, shaper, and by hand, is now performed on various types of these tools.

A milling machine has been defined as "a whole machine shop in itself"; it has a movable table, to which the work is fixed and on which it is brought to the cutter; it is fitted with index-plates and other appliances for securing accuracy in the work executed.

Milling is nearly identical with grinding; the former is a cutting and the latter an abrading process; the milling machine resembles in its action a high type of emery-grinder; the rotating cutter in the grinder being, however, of emery, while in the milling machine it is a steel cutter, the latter producing plain, curved or special formed surfaces on the material operated upon.

Metal may be cut away by a rotary milling cutter at from four to ten times the speed at which it can be cut in a shaping or planing machine

A "universal milling machine" is shown in fig. 178; this is capable of cutting spirals on either taper or parallel work, being provided with an index head arranged with suitable gearing or feed motion to rotate the work while it

MILLING MACHINES.

is travelling beneath the cutter; hence, when these two feed motions act simultaneously, the path of the work beneath the cutter is a spiral, and the action of the revolving cutter in the work is therefore similarly spiral; grooves may be cut or spiral projections left on the work according to the shape of the cutter employed.

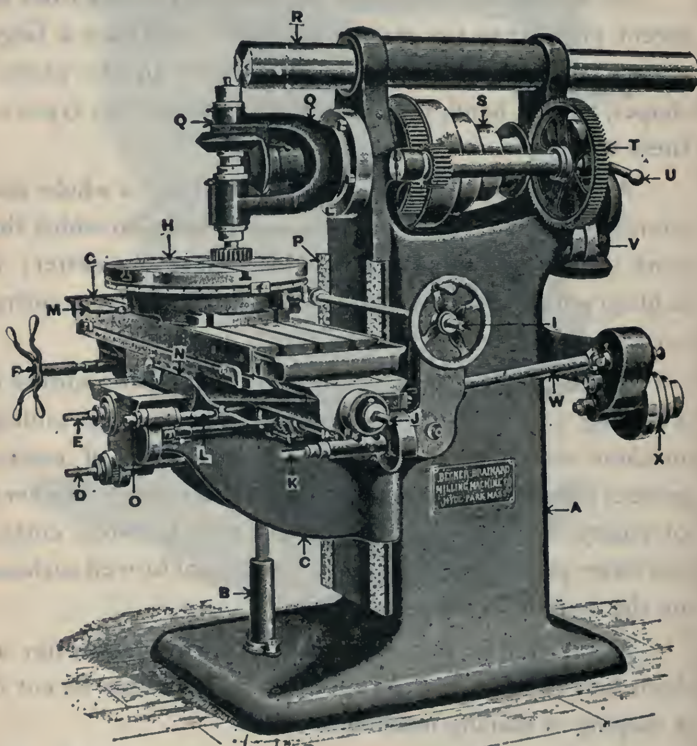


Fig. 179.

Fig. 179 shows a plain horizontal milling machine, fitted with a vertical head and rotary cutter.

PARTS OF MILLING MACHINE.

Following is a description of the principal parts of this machine tool and their use:

A is the standard on which is attached all the main parts of the machine.

B is called the horn, and contains the elevating screw for raising the knee, *C*, which is adjustable vertically on the slide, *P*.

D is the spindle with micrometer attachment for operating the elevating screw of the knee, *C*. This is also connected with the power feed spindle, *W*, through connecting spindle *O*.

E is the horizontal adjustment for the saddle, which, in turn, supports the table, *G*. This is also connected in the same manner as *D*.

F is the hand-wheel shown connected with the quick-return longitudinal movement of the table. This handle can also be used on the spindle, *K*, which also operates a quick-return movement connected with the table.

G is the table, which is shown with oil grooves on each side and oil pockets on each end. On each end of the table on the side, and shown connected by the T-slot running longitudinally with the table, is a dog, which, by engaging with the locking lever, *R*, in the center of the saddle, this, in turn, being connected by the rod, *N*, with the lever, *L*, throws the power feed off when the machine is in motion. This power feed is connected to the longitudinal and transverse motions of the table.

H is the rotary table which is shown bolted to the regular platen of the machine and connected with the power feed by the spindle, *I*. This, in turn, is connected by gearing, which is shown encased, with the spindle, *J*, which, in turn, is connected with power-feed spindle, *W*.

M is the lever connected with the interior mechanism of the rotary table for tightening the same when the table is to remain in a fixed position.

O is a spindle on which is the pull gear for connecting the cross or vertical feed with the power-feed spindle, *W*.

Q is the vertical attachment.

R is the overhanging arm, on which is used, at times, the out-board bearing for supporting the end of horizontal spindle. *S* is the driving cone on main spindle of machine.

T is the back-geared sleeve, and gears which are thrown in connection with the spindle by the lever, *U*.

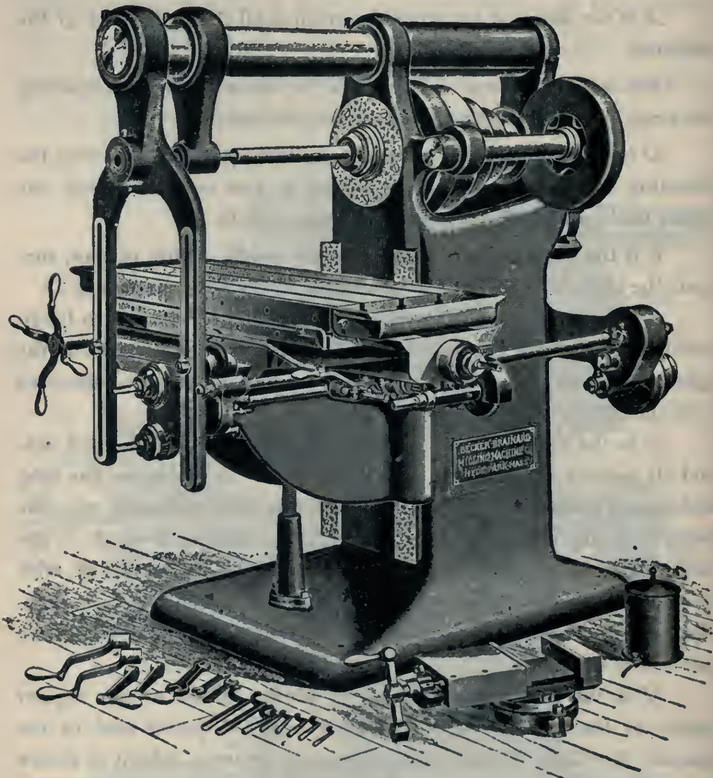


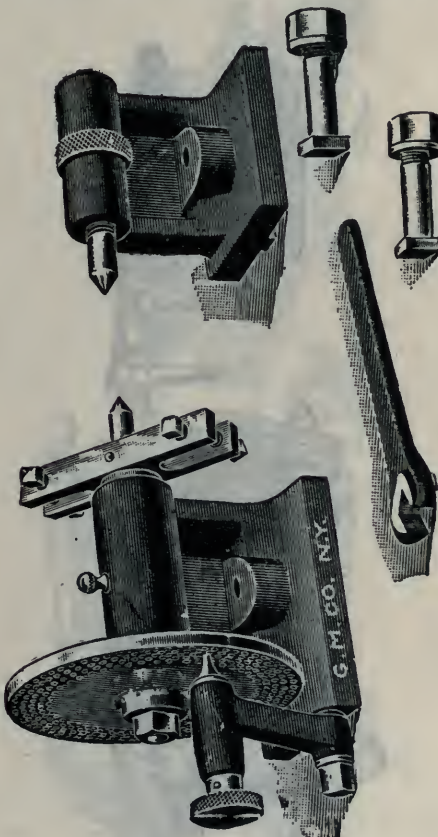
Fig. 180.

V is the feed cone connected by gearing with the end of the main spindle.

X is the feed-driving cone, which is connected by a belt with cone *V*. This cone drives the complete feed mechanism of the machine.

Fig. 180 shows a milling machine of the simplest design, with horizontal cutter; it is a similar machine to the one illustrated in fig. 179, without the vertical head.

Fig. 181 shows a dividing head and tail stock for a milling machine; the index plate has five rows of



Fig, 181.

holes drilled in circles of 48, 56, 60, 66 and 72; the spindle can be solidly bound for taking heavy cuts, thus relieving the index pin from strain.

Fig. 182 shows a dividing head and tail stock. In this example the dial is moved by a worm and gear which turns and at the same time holds the head-stock spindle, thus relieving the index pin and the dial of strain, and

Fig. 182.

also the attendant wear and loss of accuracy; the worm can be dropped out of gear when it is desirable to turn the dial by hand; the tail-stock spindle has a vertical adjustment for taper work, as shown in the illustration.

Fig. 183 shows a regular vise, mounted on a graduated base, and held by a beveled friction disk and bound at any angle.

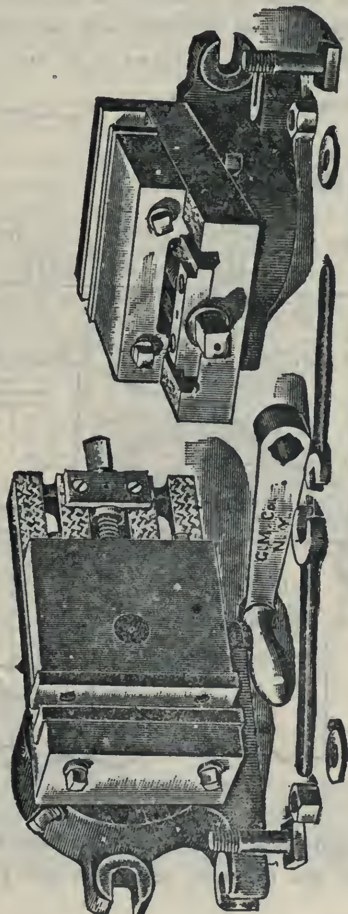


Fig. 183.

The base is provided with two clamping surfaces, so that the vise can be mounted horizontally or vertically, and clamped at any angle in either position.

The Feed Mechanism is a special feature of the Garvin Milling Machine

As shown by the illustration, fig. 184, the Change-Gear Box is set into the column and driven by a chain from the spindle. The Feed-Box is movable vertically and provided with an adjusting-screw, so that any slack in the chain can be taken up at once. A slip-friction

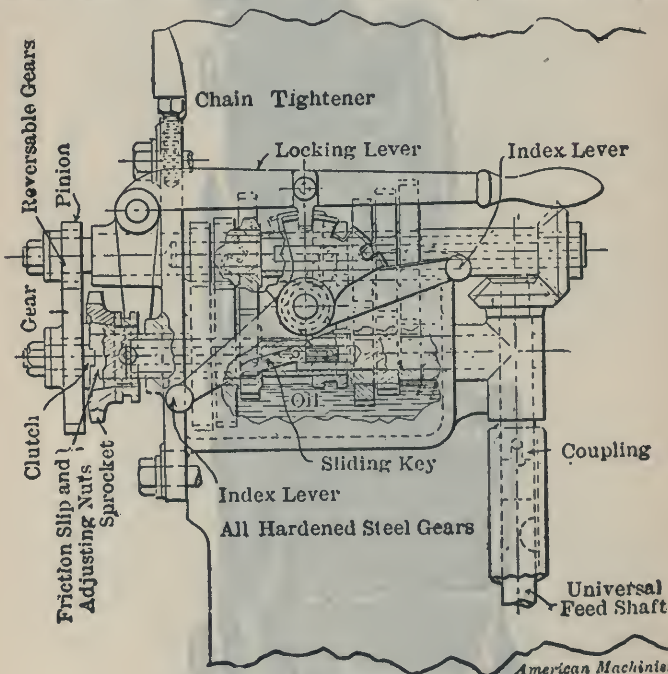


Fig. 184.

device is set in the feed-box sprocket, so that if any unusual strain is put on the machine, the frictional resistance will be overcome and prevent breakage.

Two double cones of gears are employed, which arrangement gives a larger number, and greater range, of feeds than is possible with a single cone. Nine direct changes are obtained, and by reversing the two outside gears, eighteen changes are obtained, ranging from $\frac{1}{210}''$ to $\frac{1}{4}''$ per revolution of spindle.

The change-gears in the box are all hardened steel and run in a bath of oil. Gears are connected to the shaft by means of two sliding spring-keys, as shown, which require no waiting for keyways to come in line. Each index lever is connected to a sliding key, and when each lever is moved the key is changed from one set of gears to another.

The numbers on the index table represent numbers of revolutions of spindle per inch travel of table. Feeds marked "pinion" mean that the outside pinion must be attached to the upper shaft, and feeds marked "gear" mean that the large outside gear should be attached to the upper shaft to obtain the indicated feed-speed. Supposing that a feed of $\frac{1}{100}''$ is required; examine table and see that combination 2——5 gives this feed; first lift the locking lever, and then bring No. 2 on the outside lever around to the setting point; then No. 5 on the inside lever is brought to the setting point. The locking-lever is now pushed down into place, thereby locking the index levers in place, when the connection will be made for this feed. These feeds are all positive.

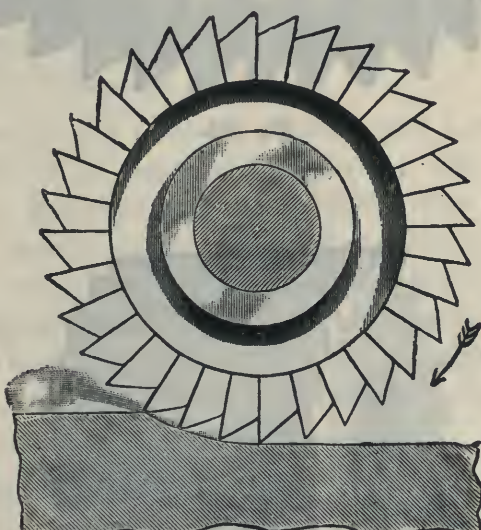


Fig. 185.

Fig. 185 represents a side view of a face or straddle mill in operation; the direction of the motion of the tool is shown by the arrow—the movement of the work being from the left hand to the tool.

MILLING OPERATIONS.

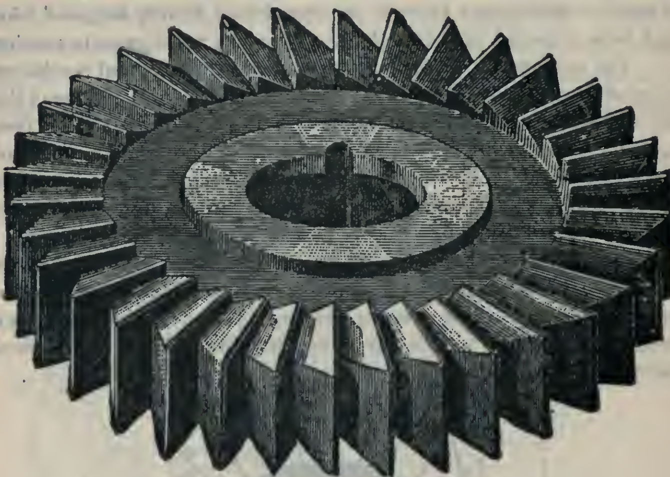


Fig. 186.

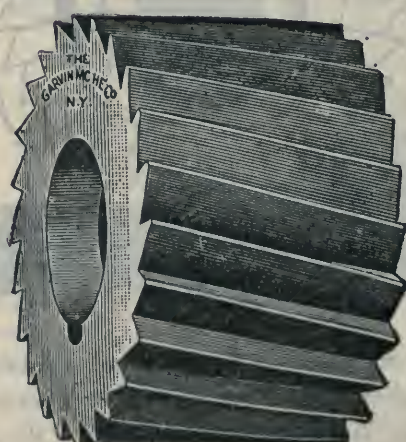


Fig. 187.

SPEED FOR MILLING CUTTERS.

The face mill shown in fig. 185 is a form in general use; it has straight teeth arranged at equal distances on its "face," parallel to its axis, and radial teeth on one side, as shown in fig. 186. When two of these mills are arranged in pairs, or when a single mill has teeth on its face and on two sides, it is called a "straddle" mill.

Should a mill have a wide "face," the teeth are cut spirally, as shown in fig. 187; wide, straight teeth would not maintain a uniform cut on entering or leaving the work; with spiral teeth the cut begins at one end of the tooth; the cut being started, the cutting is uniform, producing smooth work, also avoiding a sudden shock when entering or leaving the cut.

The face-mill cutter is provided with a center hole, which fits on an arbor, and is provided with a keyway, shown in the illustration; the end of the arbor fitting into a conical seat, is securely held in the machine spindle, permitting the arbor to revolve in either direction, without becoming released; the mill can be reversed on the arbor, and the feed of the work can be changed, which, it is plain, could not be done if the mill was on an arbor that screwed upon the driving spindle of the machine.

The proper rotating speed of the cutters is essential to the economical production of work done by milling machines. The following rules and table will be found of value.

RULE.—*Divide the required speed per minute in inches, by the circumference of the cutter in inches, and the result is the number of revolutions per minute of the cutter.*

MILLING OPERATIONS.

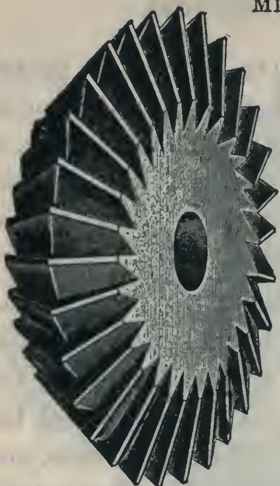


Fig. 188.
Angle or Spiral Cutter.

Fig. 189.
Angle or Spiral Cutter.

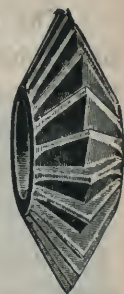


Fig. 190.
Double Angle Cutter.

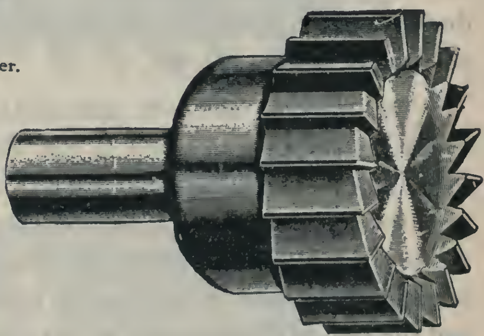


Fig. 191.
Face Milling Cutter.

Fig. 192.
Angle or Spiral Cutter.

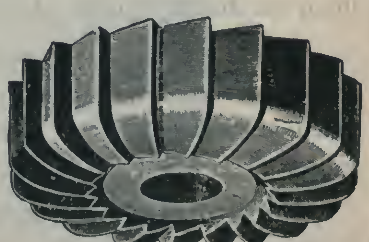


Fig. 193.
Face Milling Cutter.

SPEEDS FOR MILLING CUTTERS.

EXAMPLE FOR FIGURING CUTTER SPEEDS.—If a milling cutter is 3 inches in diameter, and it is required to cut wrought iron at a peripheral speed of 40 feet per minute, how many revolutions per minute must the cutter make? Now,

$$\frac{40 \times 12''}{3'' \times 3.1416} = \frac{480 \text{ inches}}{9.4248'' \text{ circum.}} = 51 \text{ revols., nearly. Ans.}$$

RULE.—*Multiply the circumference of the cutter in inches by the number of revolutions of the cutter per minute, divide by 12, the result is the cutting speed per minute in feet.*

If a milling cutter of 4 inches diameter makes 60 revolutions per minute, what is its peripheral cutting speed in feet per minute?

$$\frac{4 \times 3.1416 \times 60}{12} = 63 \text{ feet per minute, nearly. Ans.}$$

SPEEDS FOR MILLING CUTTERS

	Brass	Cast Iron	Machine Steel	Tool Steel Annealed
Ft. per min...	80 to 120	40 to 60	35 to 45	25 to 35

The speed of the cutters varies considerably with the kind of material to be operated upon, and is another case where the workman will be called upon to use his own judgment. The table shown above may be taken as a guide.

MILLING OPERATIONS.

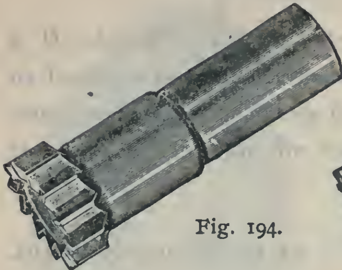


Fig. 194.

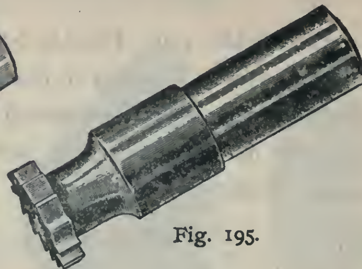


Fig. 195.

Fig. 196.

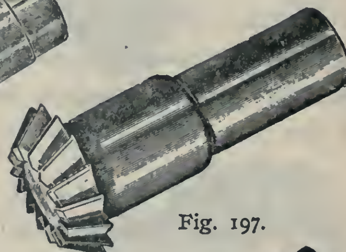


Fig. 197.

Fig. 198.

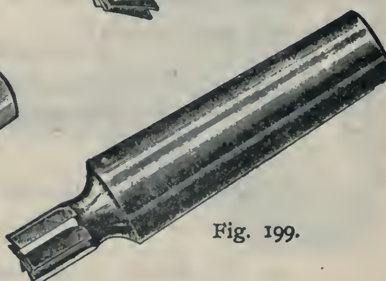


Fig. 199.

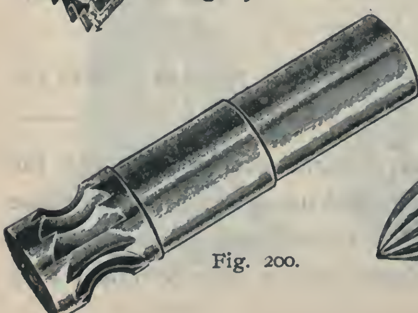


Fig. 200.

Fig. 201.

SPEEDS FOR MILLING CUTTERS.

It is more satisfactory to run milling cutters up to nearly the maximum speed, with comparatively light feed, than to reduce the speed of cutter, and overfeed the work.

A second table is added to the one printed on page 189; this gives the speeds for roughing and finishing, and also the traverse feed.

TABLE SHOWING AVERAGE MILLING SPEEDS, VIZ., THE PERIPHERY SPEED OF CUTTER (IN FEET) PER MINUTE.

	Steel	Wrought Iron	Cast Iron	Gun Metal	Brass
Roughing cut......	30	40	60	80	120
Finishing Cut......	40	55	75	100	140
Feed per min., ins..	¼″ to ½″	¾″ to 2″	½″ to 1½″	1¼ to 2″	2½

Where there is no great depth of material to cut away, these feeds may be taken as the maximum figures.

On page 188 are illustrated a variety of milling cutters or "mills."

Figs. 188 and 189 are angle mills used in cutting spiral grooves.

Fig. 190 is a double angle cutter.

Figs. 191 and 193 are face milling cutters.

Fig. 192 is an angle or spiral cutter.

On page 190: figs. 194–196 are T-slot cutters, figs. 197 and 198 are bevel mills, fig. 199 is an end mill or shank cutter, figs. 200 and 201 are surface mills or form cutters.

MILLING OPERATIONS.

Fig. 202.

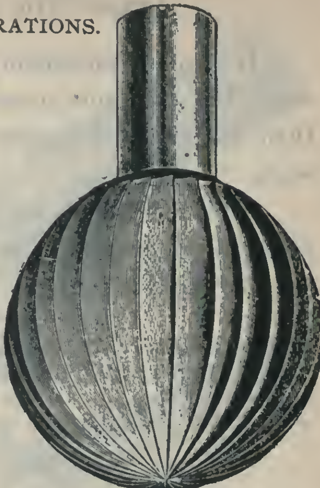


Fig. 203.

Fig. 204.

Rose or Groove Cutters.

Fig. 205

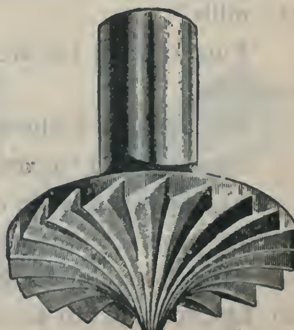


Fig. 206.

Counter Bore Mills.

MILLS AND CUTTERS.

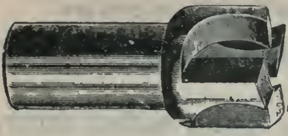


Fig. 207.

Fig. 208.

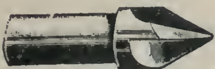


Fig. 209

Fig. 210.

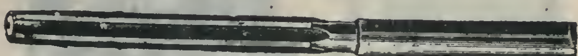


Fig. 211.

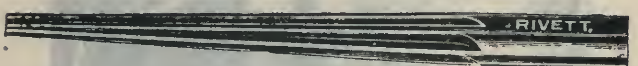


Fig. 212.

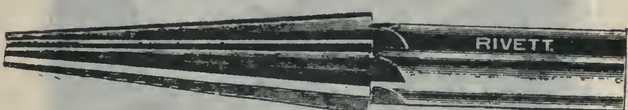


Fig. 213.

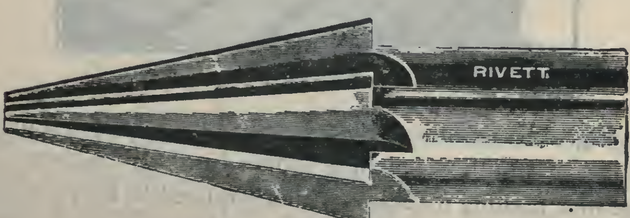


Fig. 214.

MILLING OPERATIONS.

Figs. 202–204 are rose mills or groove cutters.

Figs. 205 and 206 are counter-bore mills, or irregular cutters.

On page 193: fig. 207 is a special surface cutter, fig. 208 is a hollow end mill.

Fig. 209 is a center reamer.

Fig. 210 is a counter-bore mill.

Fig. 211 is a parallel reamer.

Figs. 212–214 are taper reamers.

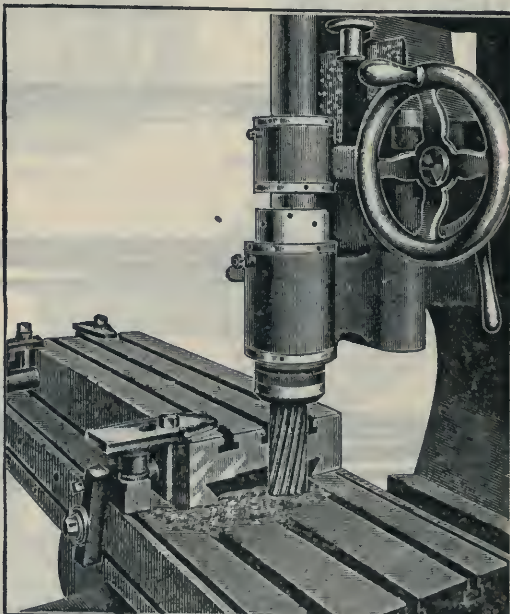


Fig. 215.

Fig. 215 exhibits a side cutter in operation, finishing the end of a milling machine table; formerly this work was done in a planing machine, which required to be very large, in order to permit the casting to pass between the housings.

MILLING OPERATIONS.

Fig. 216 illustrates a rose mill (see fig. 203) operating on the periphery of a circular casting, cutting a groove; this class of work can be done very much faster on a mill-

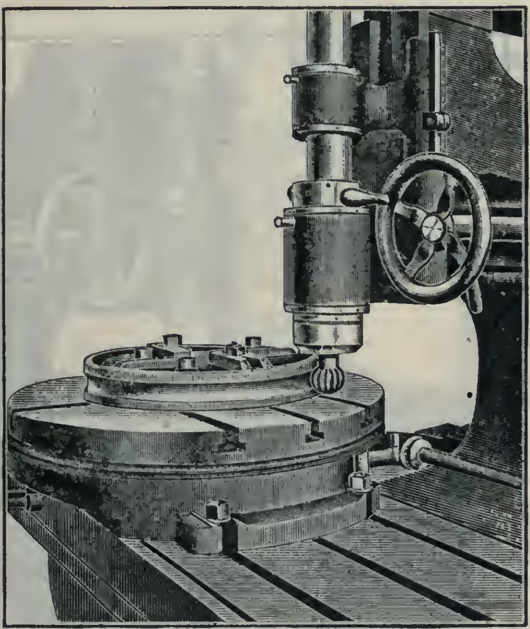


Fig. 216.

ing machine than it could be accomplished in a lathe; in addition, the shape of the recess is secured without a possibility of an error on the part of the operator, by the use of the rose mill.

MILLING OPERATIONS.

Fig. 217 illustrates a bevel or angle mill in operation, finishing a cone or bevel surface on a circular casting; this cutter bevels the internal face of a corresponding ring, in-

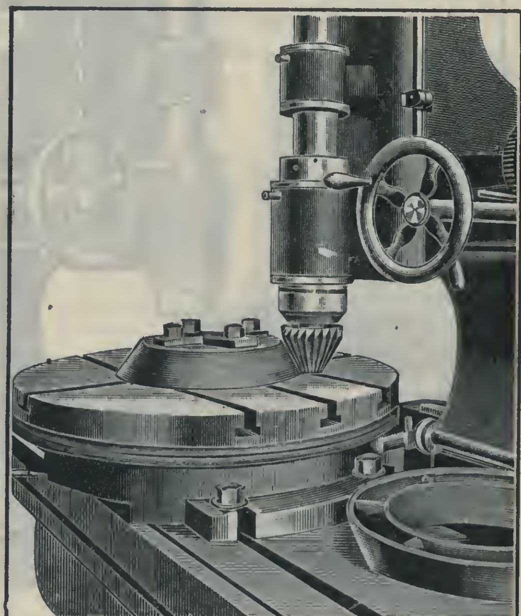


Fig. 217.

suring accuracy of fit between the two faces; this mill is largely used for economically finishing valves and many forms of similar work.

MILLING OPERATIONS.

Fig. 218 shows an angle mill in operation, finishing the parallel vees on the inside of a sliding-head casting; both the vees can be finished at one setting; the slides can

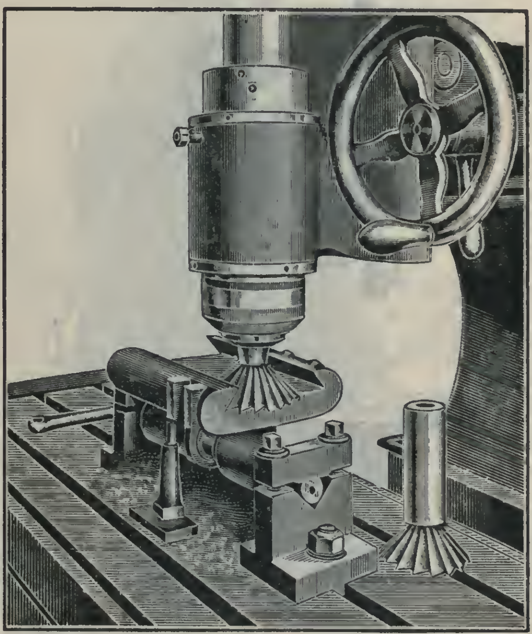


Fig. 218.

be made to match in duplication, or duplicate work, in less time in the milling machine than the same work could be done in a planer. For the four last illustrations credit is due to the Becker-Brainard Milling Machine Co.

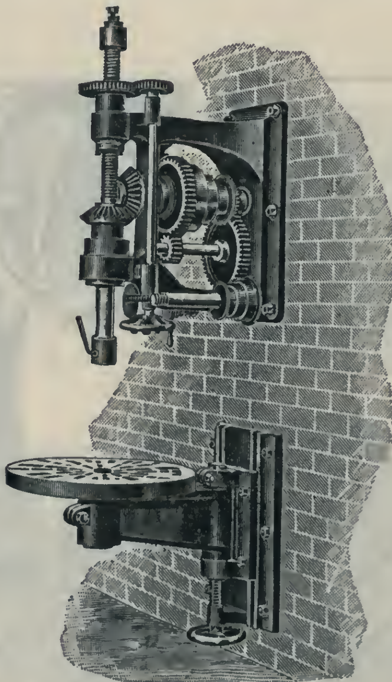
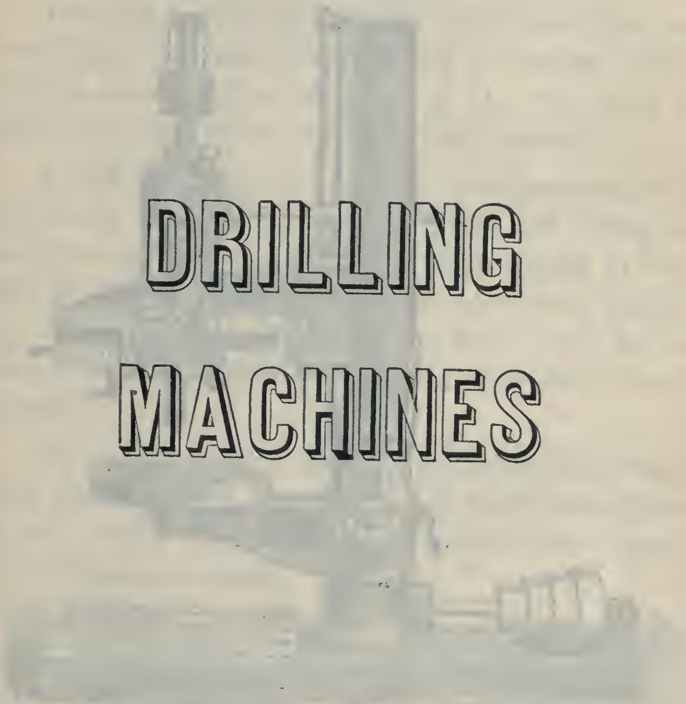


Fig. 219.

DRILLING MACHINES



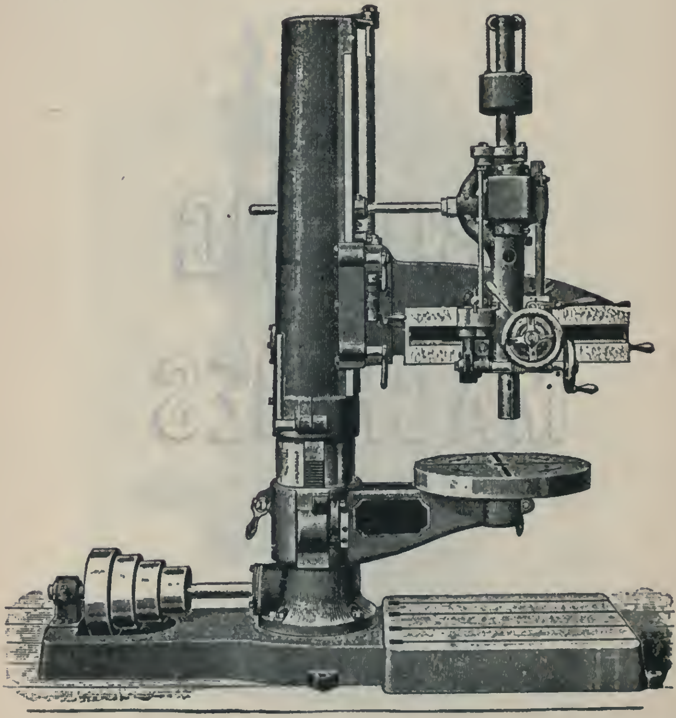


Fig. 220.

DRILLING OPERATIONS.

The word "drill" has a history; it is formed from the word "rille," now called *rill*, meaning "a channel," hence the root signification of the word is "to turn, wind, or *twist*," a trickling stream wearing its own channel.

A drill is a tool to pierce holes; a drilling machine is adapted for drilling holes in metal; boring and drilling are nearly the same, the former term being applied to very large and the latter word to smaller operations; drilling, too, differs from boring in that the latter term applies specially to the enlarging and "truing" of a hole already formed.

The operation called drilling is the perforation of solid metal with revolving tools; these are made pointed and adapted to suit the work. The tool receives the "feed," the work being stationary.

Two classes of stress are imposed upon drilling machines; this is owing to the fact, never to be forgotten, that a revolving drill does not cut at its central point, while its outermost circumference may have excellent cutting effect; hence, the two strains, one of direct pressure and the other of twisting or torsion, are to be always reckoned with in designing a drilling machine.

The torsion is easily met by a spindle of high carbon steel, accurately cut gearing, and stiff driving shafts; to reach large work the drill must overhang. and therefore needs a very strong frame to stand the end pressure.

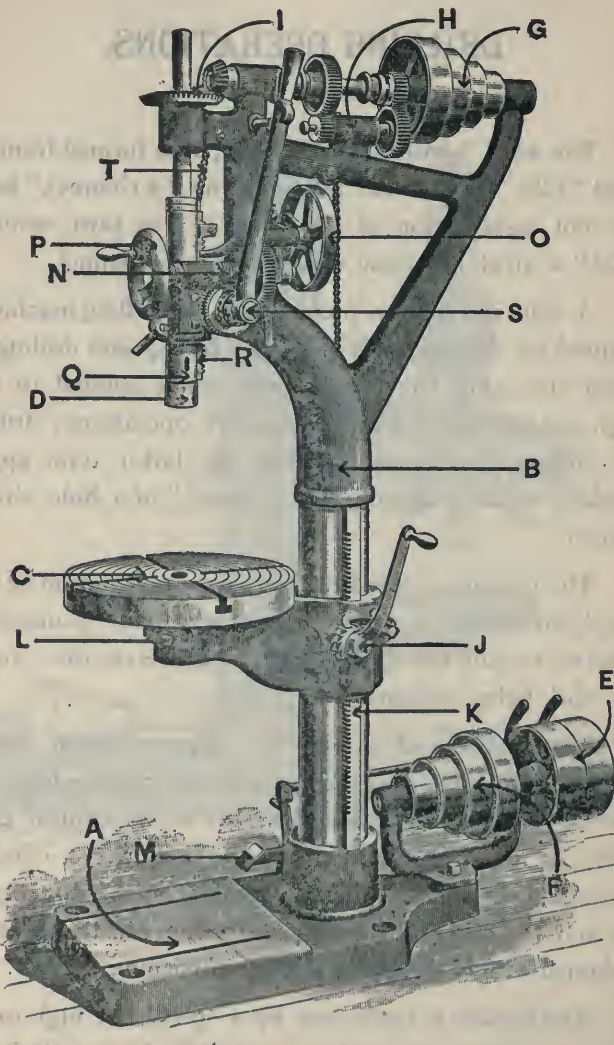


Fig. 221.

DRILLING OPERATIONS.

Drilling machines are made in many forms and sizes, suitable for fixing to the floor, the bench or the wall, according to requirements.

Drilling machines are described by some special feature which they possess, as a "single cutting," "multiple drilling," "direct," "double-geared," "rigid," "radial," "self-acting," "friction feed," etc.

Fig. 221 shows a vertical drilling machine, double-geared, with hand and self-acting feed, and adjustable table, with the parts lettered, to aid in the description following:

A is a substantial base plate, having planed upper face having bolt-holes for fixing to foundations, and also provided with T-slots for bolts used to fix large or special work, which, on account of size or shape, cannot be operated on the ordinary table, *C*.

B is the upright pillar frame, or standard, which carries the drill spindle and its driving and feed motion.

C is a circular table, or face-plate, provided with slot-grooves for sliding clamping bolts; it has a cylindrical box on the under side which fits into a recess in its supporting bracket.

D is the vertical drill spindle or arbor which has recess and provision for fixing drills and boring tools.

E shows the power—fast and loose—pulleys for shifting belt.

F is the speed cone fixed on pulley spindle.

G is the speed cone which receives motion from Cone *F*.

H is the spur gear, to reduce speed of cone and thereby increase the power of cutter.

I shows a pair of bevel wheels which transmit the motion and power from the horizontal spindle to the vertical drill spindle, *D*; the bevel wheel slides on spindle *D*, and rotates it by means of a key or feather sliding in a groove running the length of spindle.

J exhibits the hand-ratchet motion for raising and lowering table by a spur pinion, or ratchet spindle, geared into rack *K*.

DRILLING OPERATIONS.

K is the rack fitted into a groove in the bracket ; this rack slides loose with bracket round the pillar, and is used to raise and lower the table, the rack being confined between the collars of the pillar.

L is the bracket supporting the table ; this slides every way on pillar according to adjustment.

M shows a foot-lever actuating belt fork or guide on fast and loose pulleys for starting or stopping the drill.

N is a self-acting feed for vertical spindle *D;* it receives its motion from horizontal shaft through pulley *O*, which communicates it through a pair of spur wheels and a pair of worm wheels to a spur pinion gearing into rack *R* on sleeve *Q*.

O is a pulley for self-acting feed motion.

P is a hand wheel for hand-feed attachment fixed on worm spindle ; when using the hand feed the self-acting feed can be disconnected by cam attachment.

Q is a sleeve for raising or lowering drill spindle *D*, which revolves in it.

R is a rack on sleeve.

S is a hand lever for quickly adjusting spindle *D*, used for hand feed.

T is a balance weight and chain to counterbalance weight of spindle *D*, drill, etc.

On page 198 is shown a wall drilling-machine ; it is double geared, with self-acting feed motion, as shown in the upper portion of the illustration ; the lower part shown is the table, with an elevating screw beneath to regulate the height ; these portions shown are bolted to a wall, hence the name.

The advantage of the machine consists in its portability, allowing its use in rough and temporary situations, aside from its extreme lightness.

DRILLING MACHINES.

Fig. 220 shows one form of the approved "radial" drill; the name is derived from "radius"—from a center.

The base of this machine has traverse slots for facilitating the clamping of the work; the column extends to the top of the sleeve, which is a feature affording stiffness to the machine, which is so essential to true work; the radial arm is raised and lowered by power under the control of a lever located within convenient reach of the operator; the arm describes a free circle about the column, which is desirable for many classes of work; the back gears are fitted with friction clutches; the feed is automatic.

Drills used in machines vary in size according to the nature of the work; in ordinary shop practice $\frac{3}{8}$-inch to 3-inch diameter is the range of holes drilled. Therefore, tools are made in sets; with each set is a steel socket which fits the drill spindle at one end, and at the other end the recess fits all the drills in the set; they are, therefore, interchangeable.

Fig. 222.

A socket or collet is shown in above illustration.

To enable the drill to be easily extracted from the socket, the latter is provided with a slot, as shown in the figure; this slot passes through it; the drill end protrudes

NOTE.—Usually the sockets are in sizes from $\frac{1}{4}$ to $\frac{19}{32}$ inch; $\frac{5}{8}$ to $\frac{29}{32}$ inch; $\frac{15}{16}$ to $1\frac{1}{4}$ inches; $1\frac{9}{32}$ to 2 inches, and $2\frac{1}{16}$ to 3 inches diameter.

DRILL CHUCKS.

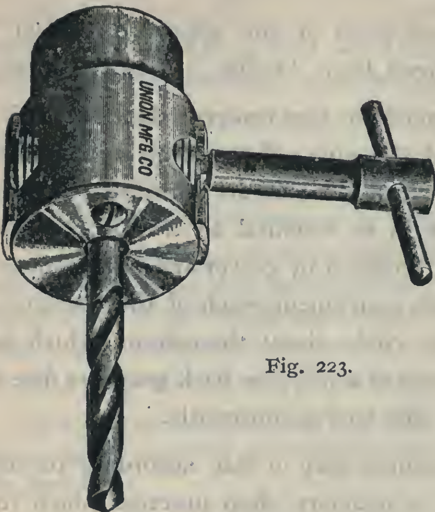


Fig. 223.

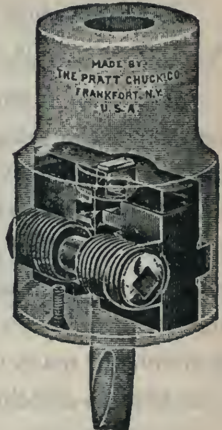


Fig. 224.

into the stop, so that a key driven into the aperture will force the drill out.

Fig. 223 shows one of many forms of drill chucks ; it

Fig. 225.

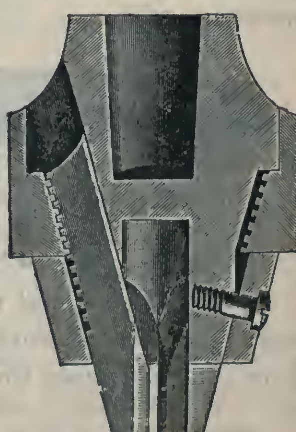


Fig. 226.

DRILLING OPERATIONS.

consists of two movable jaws operated by a spindle, on which are formed a right-hand and a left-hand thread; the spindle is operated by a key, as shown; the jaws which grip the drill move simultaneously towards or recede from one another, closing or opening as required.

Fig. 224 shows a similar chuck in section.

Fig. 225 is a patent drill chuck; the jaws are operated by the action of a nut or collar as shown in section in fig. 226.

Twist drills are illustrated in figs. 228 and 229. These are fast superseding all other forms of drills used in machine work.

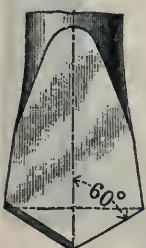


Fig. 227.

Care must be exercised in grinding and sharpening both the ordinary "flat drill" and the "twist drill," to get a proper cutting angle. Authorities differ on the question of the angle, but one found excellent in actual practice is to grind each cutting lip to an angle of 60°, with a line taken through the central axis of the drill, as shown in fig. 227.

NOTE.—The flat drill must be forged in order to keep it up to the required size and to keep its point thin enough for cutting; on account of this forging it is difficult to get a flat drill to run true; the sides of the drill form a very indifferent guide in the hole; the diameter of the hole made by the drill depends on the accuracy of the grinding of the cutting edge; should one edge be longer than the other, as soon as the end pressure is applied, the flat drill will endeavor to revolve on its point, and the tendency of the drill will be to cut eccentric, the greatest cutting radius making a larger hole than the diameter of the drill.

TWIST DRILLS.

Fig. 228.

Fig. 229.

Fig. 230.

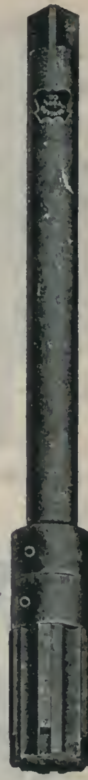


Fig. 231.

Fig. 228 is a roughing drill, having two cutting edges; fig. 229 is an enlarging drill, having three cutting edges, and fig. 230 is a finishing reamer; fig. 231 is an adjustable reamer; fig. 232 is an adjustable shell reamer; fig. 233 and fig. 234 are fluted shell reamers.

DRILLING OPERATIONS.

Fig. 232.

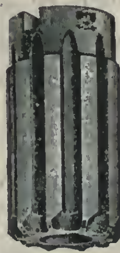


Fig. 233.

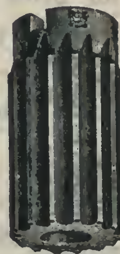


Fig. 234.

Fig. 235 shows a device designed for use on a twist drill. To grind twist drills to the proper angle, place the drill parallel and against the left-hand leg, to bring the cutting edge parallel with the other leg. Note the length of one cutting edge by the graduations, then turn the drill half

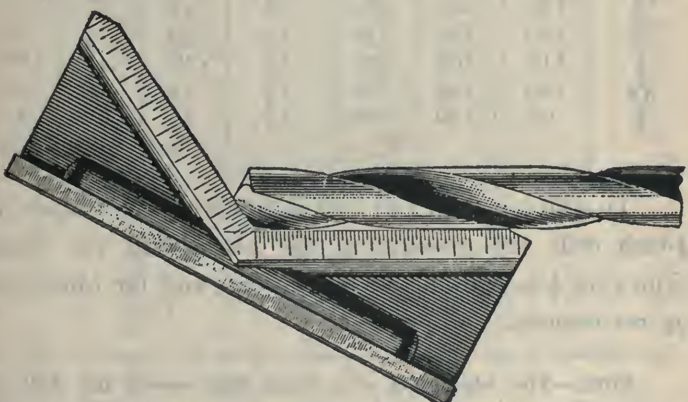


Fig. 235.

way round to get the length of the other cutting edge, and continue turning the drill and grinding the edges until they are the same length.

TABLE OF SPEEDS

The table below gives the revolutions per minute for drills from $\frac{1}{16}$ inch to 2 inch diameter, as usually applied; the table shows the drill speeds recommended by the Morse Twist Drill and Machine Co. for cutting steel, iron and brass.

TABLE OF SPEEDS FOR TWIST DRILLS.

Diameter of Drill in inches.	Revolutions per Minute.			Diameter of Drill in inches.	Revolutions per Minute.		
	For Steel.	For Iron.	For Brass.		For Steel.	For Iron.	For Brass.
$\frac{1}{16}$	940	1280	1560	$\frac{3}{4}$	75	105	130
$\frac{1}{8}$	460	660	785	$\frac{7}{8}$	65	90	115
$\frac{3}{16}$	310	420	540	1	58	80	100
$\frac{1}{4}$	230	320	400	$1\frac{1}{8}$	52	70	90
$\frac{5}{16}$	190	260	320	$1\frac{1}{4}$	46	62	80
$\frac{3}{8}$	150	220	260	$1\frac{3}{8}$	42	58	72
$\frac{7}{16}$	130	185	230	$1\frac{1}{2}$	39	54	66
$\frac{1}{2}$	115	160	200	$1\frac{5}{8}$	36	49	60
$\frac{9}{16}$	100	140	180	$1\frac{3}{4}$	33	45	56
$\frac{5}{8}$	95	130	160	$1\frac{7}{8}$	31	41	52
				2	29	39	49

To drill 1 inch in soft cast iron will usually require for $\frac{1}{4}$-inch drill, 125 revolutions; for $\frac{1}{2}$-inch drill, 120 revolutions; for $\frac{3}{4}$-inch drill, 100 revolutions, and for 1-inch drill, 95 revolutions.

NOTE.—The advantages of a twist drill over a flat drill are chiefly:—The cuttings can find free egress in the twist drill; in the flat drill the cuttings jamb between the hole and the wedge-shape sides of the drill, causing frequent removal of the drill to extract the cuttings. In deep holes more time is occupied in this manner than in the actual cutting operation. The twist drill always runs true, and requires no reforging or tempering, and, by reason of its shape, fits closely and produces a straight, parallel hole, provided the point is ground true.

SPEED OF DRILLS.

The following is a table given by the Standard Tool Co. and recommended by them.

SPEED OF DRILLS.

Diameter of Drill.	Revolutions per Minute.			Diameter of Drill.	Revolutions per Minute.		
	Steel.	Iron.	Brass.		Steel.	Iron.	Brass.
$\frac{1}{16}$	890	1220	1550	$1\frac{1}{2}$	37	52	63
$\frac{1}{8}$	445	630	775	$1\frac{9}{16}$	35	50	60
$\frac{3}{16}$	291	405	525	$1\frac{5}{8}$	34	48	58
$\frac{1}{4}$	223	305	395	$1\frac{11}{16}$	33	46	55
$\frac{5}{16}$	178	245	315	$1\frac{3}{4}$	32	44	53
$\frac{3}{8}$	148	205	260	$1\frac{13}{16}$	31	42	50
$\frac{7}{16}$	122	175	225	$1\frac{7}{8}$	30	40	49
$\frac{1}{2}$	111	150	195	$1\frac{15}{16}$	29	39	46
$\frac{9}{16}$	98	135	175	2	28	38	45
$\frac{5}{8}$	89	125	155	$2\frac{1}{16}$	28	37	44
$\frac{11}{16}$	81	110	140	$2\frac{1}{8}$	27	35	43
$\frac{3}{4}$	74	100	125	$2\frac{3}{16}$	27	34	42
$\frac{13}{16}$	69	95	115	$2\frac{1}{4}$	26	33	41
$\frac{7}{8}$	63	85	110	$2\frac{5}{16}$	25	33	40
$\frac{15}{16}$	59	80	105	$2\frac{3}{8}$	25	32	39
1	55	75	100	$2\frac{7}{16}$	24	31	38
$1\frac{1}{16}$	52	70	95	$2\frac{1}{2}$	23	30	37
$1\frac{1}{8}$	49	68	90	$2\frac{9}{16}$	22	30	36
$1\frac{3}{16}$	46	65	80	$2\frac{5}{8}$	22	29	35
$1\frac{1}{4}$	44	60	75	$2\frac{3}{4}$	21	28	34
$1\frac{5}{16}$	42	58	70	$2\frac{7}{8}$	20	27	33
$1\frac{3}{8}$	40	56	68	3	19	26	32
$1\frac{7}{16}$	38	54	65				

The above table gives a suitable speed for drills, for general use, but it can be increased from 50 to 75 per cent. to suit special conditions.

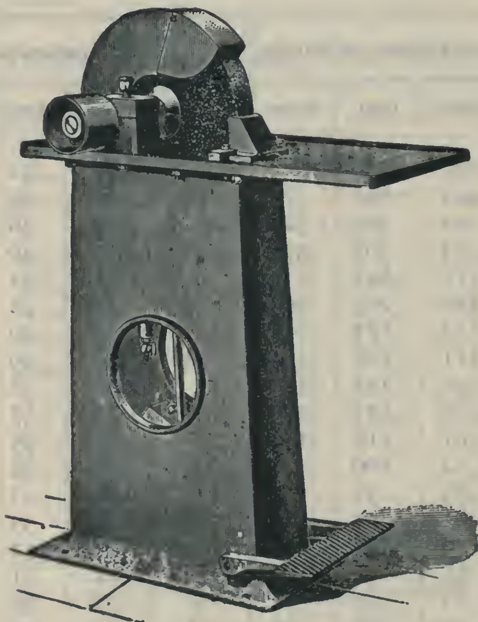


Fig. 236.

GRINDING OPERATIONS

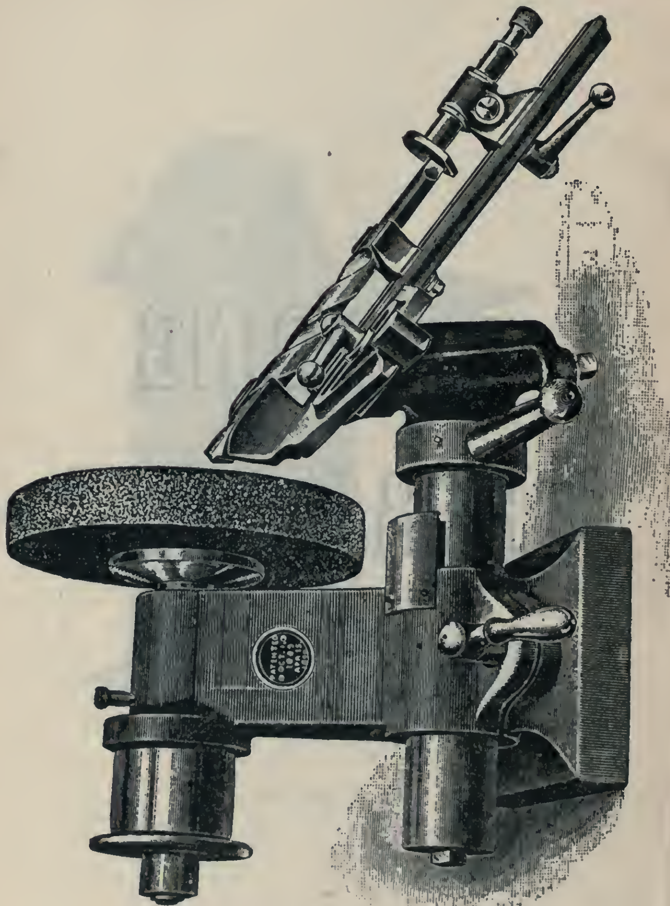


Fig. 237.

GRINDING OPERATIONS.

To grind is to wear down, smooth or sharpen by friction, as by friction of a wheel or revolving stone to give a smooth surface, edge or point to an object.

To abrade is the act of wearing or rubbing off or away by friction or attrition. *An abrasive* is a material used for grinding, such as emery, sand, powdered glass, etc. The

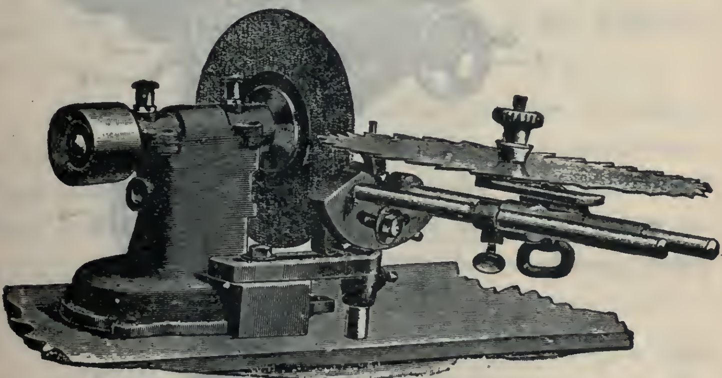


Fig. 238.

operation of grinding is an abrasive process, the material being ground away rather than cut; grinding makes possible the accurate finish of the hardest metals.

In modern machine-shop practice the grinding machine has become recognized as an indispensable tool, and no shop equipment is considered complete without it. The use of hardened spindles in lathes, milling machines, drilling machines, etc., also hardened crank pins and cross-head pins in steam engines, is made possible by its use; with it can be ground milling cutters of all shapes, taps, reamers,

GRINDING OPERATIONS.

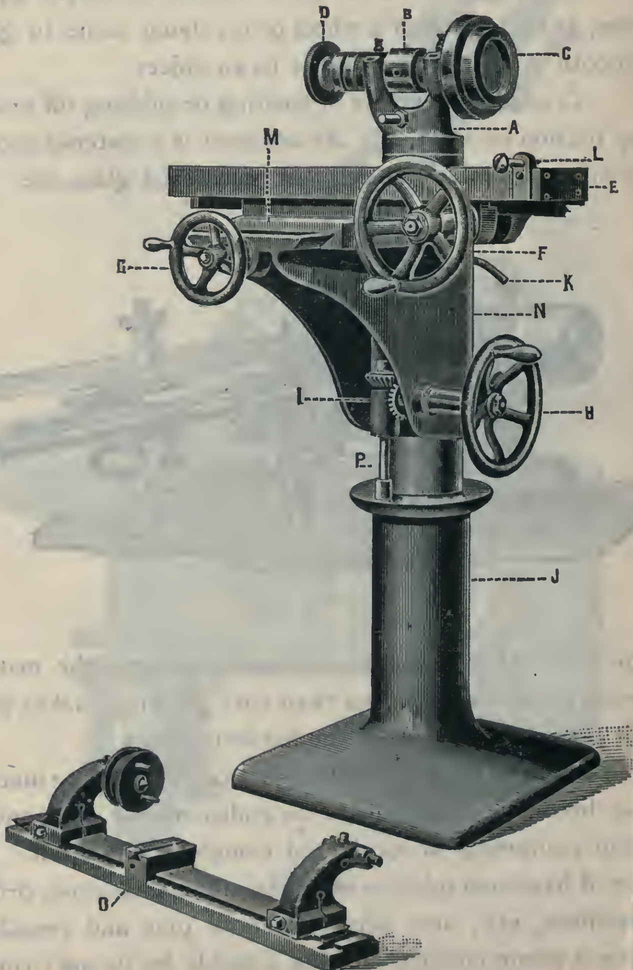


Fig. 239.

arbors, keys, gauges, holes in cutters or other articles, edges, sides and ends of flat, square, hexagon or octagon objects, leaving the ends square with the sides or edges, and also many other kinds of work.

Grinding machines are of various designs, and range from the simple rotating emery or corundum wheel to a perfectly automatic, self-acting universal and surface-grinding machine. One of the former is shown in fig. 236. On page 218, fig. 240, is shown a machine of the latter description.

Fig. 236 shows a simple Wet Tool Grinder; the emery wheel being mounted on a spindle, running in broad bearings, is driven by the pulley; the emery wheel is covered with a shield, to prevent the water splashing; it has no pump; the water trough is raised to the wheel by pressing on the footpedal shown in front of the machine.

Fig. 237 shows an emery grinder sharpening a twist drill; a rest is provided for the shank of the drill, also an adjustable end stop, for any length of drill.

Fig. 238 shows an emery grinder sharpening a circular saw; a self-centering device holds the saw in position; the attachment can be "tilted" to give any desired bevel to the saw.

Fig. 239 is a Grinder, on which a variety of work can be done; the arbor is arranged for two wheels, one on each end; *A* is the "head" of the machine, mounted upon the "standard" *J*; the head contains a spindle driven by the "pulley" *B*, and having emery wheel *D* on left-hand end.

GRINDING OPERATIONS.

and cup emery wheel *C* on right-hand end; *H* is the hand-wheel which operates the bevel gears *I*, and gives the vertical adjustment to the knee *N*, by the screw *P*; *G* is the hand-wheel fastened to the cross-feed screw, which moves the cross-carriage *M* forward or back; *K* is the binder-screw, which clamps the knee *N* when in the required position; *F* is the hand-wheel fixed on pinion, which operates the long slide *E*; *L* is the adjusting screw, which swivels the pair of centers, *O*, which can be fixed on long slide *E*, when grinding reamers, taps, etc.

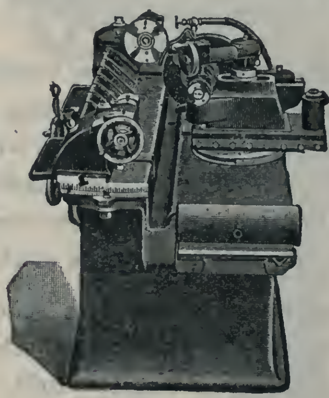


Fig. 240.

Fig. 240 exhibits a front view of a grinding machine, for straight and taper work, that revolves on two dead centers. To obtain the best results, a great variety of table work and wheel speeds are necessary; all speed changes are adaptation of the belt and cone, easily understood by operators.

Provision is made for the amount of power and water demanded by the rapid rate at which the machine is designed to work.

GRINDING OPERATIONS.

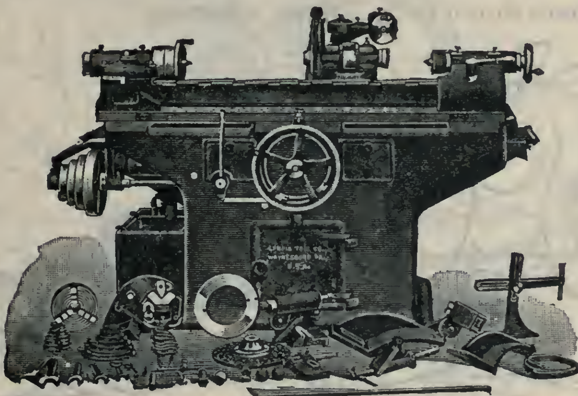


Fig. 241.

Fig. 241 is a front view and fig. 242 is a back view of the machine shown in fig. 240. From these views the arrangement of the machine can be easily understood.

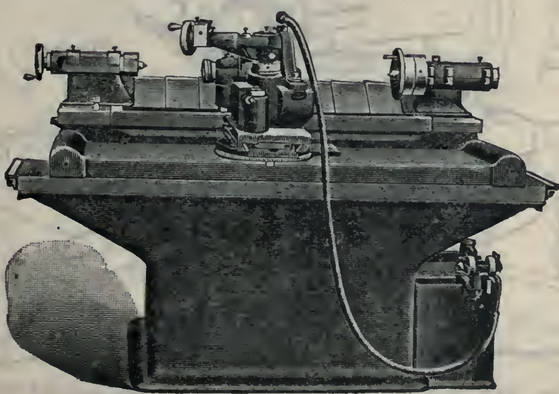


Fig. 242.

GRINDING OPERATIONS.

The following illustrations show several of the many kinds of accurate work, for which the universal grinding machines shown in fig. 178 are adapted.

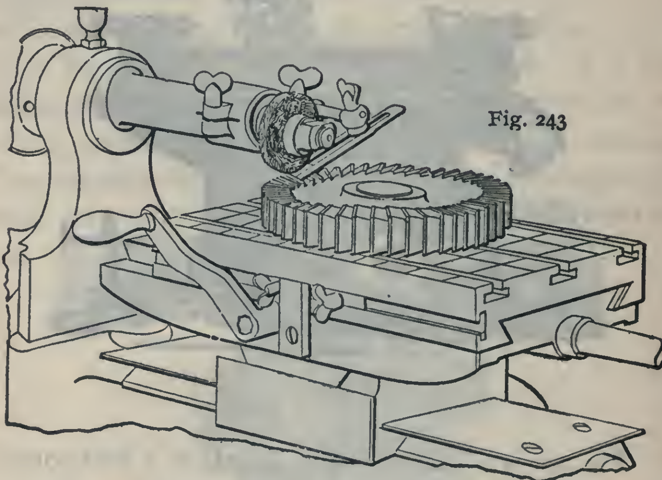


Fig. 243

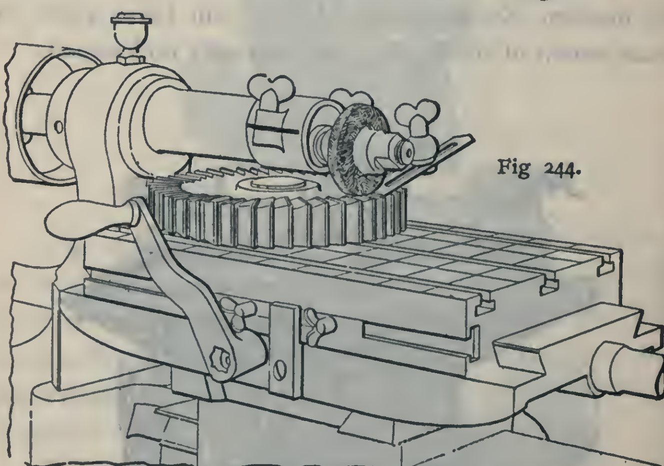


Fig 244.

Fig. 243 and fig. 244 exhibit the method of grinding the sides of a face, or straddle mill, by means of the

GRINDING OPERATIONS.

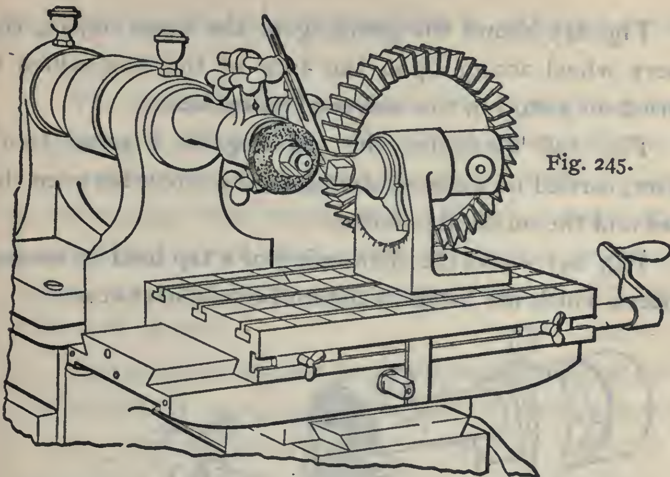


Fig. 245.

emery wheel. The straddle mill is placed upon the table of the grinding machine, and is revolved on a stud, so as to bring each tooth in turn under the action of the revolving emery wheel.

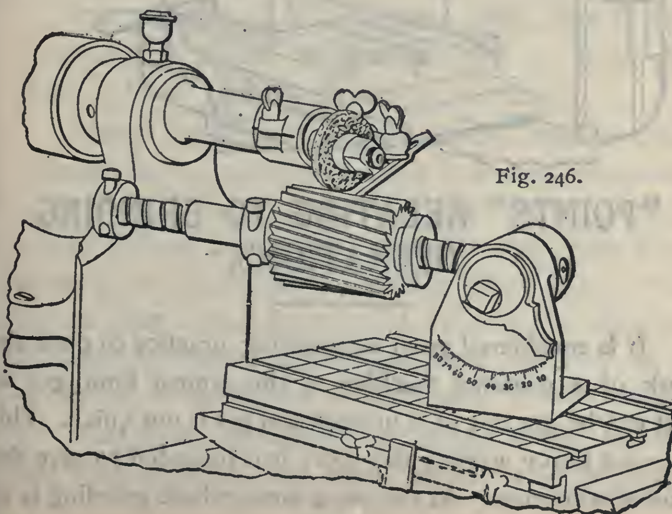


Fig. 246.

GRINDING OPERATIONS.

Fig. 245 shows the grinding of the same object, the emery wheel acting upon the face of the mill, which is carried on a stud in the universal cutter-head.

Fig. 246 illustrates the grinding of a spiral tooth cutter, carried on a sleeve, sliding on the arbor, between the head and the adjustable collar.

Fig. 247 shows the sharpening of a tap held in reamer centers, which are fitted in the universal cutter-head.

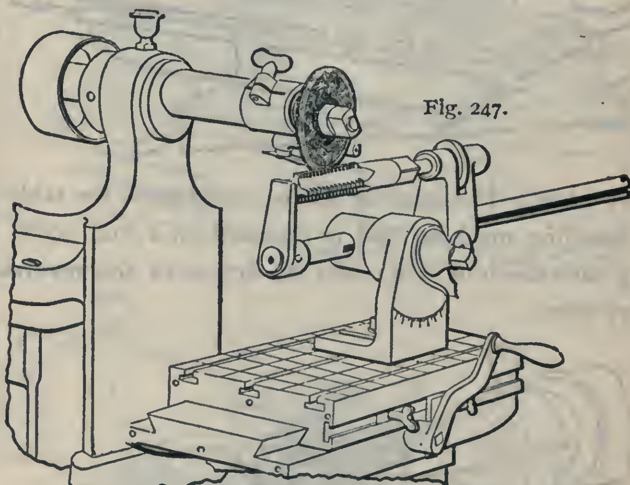


Fig. 247.

"POINTS" RELATING TO GRINDING OPERATIONS.

It is considered good engineering practice to push the work of a grinding machine to the utmost limit, get all that can be got out of it in work and get it out quick. This does not imply wasting the tool; it is intended to save the time of workmen. At the same time, where grinding is to

GRINDING OPERATIONS.

be done rapidly and well, a machine to do it must be heavy and powerful.

The durability and usefulness of all machines depend largely upon proper care, which if not given will in a short time cause them to become unreliable, even though the machines are well constructed. The grinding machine being a tool upon which great accuracy is required, becomes, therefore, most susceptible to bad results through such lack of care.

The machine should be kept clean and the bearings well lubricated, using the best oil only, to prevent gumming.

In order to produce correct work it is important that the spindle boxes be kept in proper adjustment, so that there may be no lost motion. This is true of the head-stock, foot-stock and emery wheel spindles and also the wheel spindle boxes, which, to do accurate work, should be adjusted closely, even though they warm up slightly.

The adjustment of the emery wheel slide is equally important; it should be close and yet not tight enough to move hard; the slide should be well oiled.

Wheels for internal grinding should be softer than for external, as the surface in contact is greater; therefore the wheel will not let go the dulled particles so readily. It should be very keen cutting and of coarser grade than for external grinding. As the surface speed of the wheel is not as great as that for external grinding, the work cannot therefore be done as rapidly, and more time must be given to remove the stock, and the work must be revolved slower.

Too great a variety of work should not be expected of one grade of wheel, and when the amount of grinding will

GRINDING OPERATIONS.

warrant it, several grades of wheels can be profitably employed, each carefully selected for its particular purpose.

All machines should be securely fastened to a solid floor or foundation where there is no vibration.

To grind tools without drawing the temper requires a soft grade of wheel, which would not be suitable for rough work; moreover, much depends upon the nature of the material to be ground as to whether a hard or soft, coarse or fine wheel should be used.

A wheel should be kept perfectly true and in balance to obtain the best results, both as regards rapidity and accuracy in grinding. For the sake of economy it is necessary that a dresser be kept constantly at hand to dress up the wheels a little and not allow them to become out of true.

It should be remembered, the contact between an emery wheel and the work is entirely different from that of the lathe or planer tool in operation. In the latter case some extra pressure is always required to counteract spring between work and tool; but in the former condition, some material is removed at the slightest contact.

The speed of work should be in proportion to the amount of stock removed at each revolution, as the wheel must always have sufficient time to do its work; if the

NOTE.—There can be no hard and fast rules for the speed of emery and polishing wheels, since there is so great a variety in the nature of the work to be done, but a peripheral speed of a mile—5,280 feet—a minute for ordinary emery wheels is commonly regarded as good practice. For water tool-grinders the speed is usually about two-thirds that of dry grinders, while on the other hand, polishing wheels are generally run at about one and one-half, and buff wheels at twice the speed of dry grinders. Emery wheels are classed as water grinders and dry grinders; the former run at about one-third less than the dry grinders, that is, about two-thirds of a mile per minute on the surface.

GRINDING OPERATIONS.

work is revolved too rapidly the wheel is liable to crowd, chatter and waste, and make an unsatisfactory job. There is no fixed rule as to speed, but by a little experience the operator will soon learn what is best.

These numbers represent the grades of emery, and the degree of smoothness of surface may be compared to that left by files as follows:

8 and 10	represent	the	cut	of	a wood rasp.
16 " 20	"	"	"	"	a coarse rough file.
24 " 30	"	"	"	"	an ordinary rough file.
36 " 40	"	"	"	"	a bastard file.
46 " 60	"	"	"	"	a second-cut file.
70 " 80	"	"	"	"	a smooth file.
90 " 100	"	"	"	"	a superfine file.
120 F and FF	"	"	"	"	a dead-smooth file.

Nearly all emery wheel makers use a letter to designate the grade of hardness of wheels, grade M being the medium between the hardest and the softest. All letters before M are softer, as L, K, J, I, in the order given; while all letters after M are harder, as N, O, P, in their order.

Wheels are numbered from coarse to fine; that is, a wheel made of No. 60 emery is coarser than one made of No. 100. Within certain limits, and other things being equal, a coarse wheel is less liable to change the temperature of the work and less liable to glaze than a fine wheel. As a rule, the harder the stock the coarser the wheel required to produce a given finish. For example, coarser wheels are required to produce a given surface upon hardened steel than upon soft steel. while finer wheels are required to produce this surface upon brass or copper than upon either hardened or soft steel.

Wheels are graded from soft to hard, and the grade is denoted by the letters of the alphabet, A denoting the softest grade. A wheel is soft or hard chiefly on account of the amount and character of the material combined in its manufacture with emery or corundum. But

GRINDING OPERATIONS.

other characteristics being equal, a wheel that is composed of fine emery is more compact and harder than one made of coarser emery. For instance, a wheel of No. 100 emery, grade B, will be harder than one of No. 60 emery, same grade.

The softness of a wheel is generally its most important characteristic. A soft wheel is less apt to cause a change of temperature in the work, or to become glazed, than a harder one. It is best for grinding hardened steel, cast-iron, brass, copper and rubber, while a harder or more compact wheel is better for grinding soft steel and wrought iron. As a rule, other things being equal, the harder the stock the softer the wheel required to produce a given finish.

Generally speaking, a wheel should be softer as the surface in contact with the work is increased. For example, a wheel 1/16-inch face should be harder than one ½-inch face. If a wheel is hard and heats or chatters, it can often be made somewhat more effective by turning off a part of its cutting surface; but it should be clearly understood that while this will sometimes prevent a hard wheel from heating or chattering the work, such a wheel will not prove as economical as one of the full width and proper grade, for it should be borne in mind that the grade should always bear the proper relation to the width.

Pieces intended to be ground can frequently be profitably turned in the lathe to near the finished size before being tempered. *After hardening*, the pieces can then be accurately finished in the grinding machine, thus securing the utmost accuracy united with great durability. Many pieces of work require but one cut to prepare them for the grinding machine; if the tool has dulled or the work has sprung in hardening or in turning, it causes no trouble when being ground.

NOTE.—Emery is a granular mineral substance and belongs to the species corundum, but is not pure, being mixed with magnetic or hematite ores. Corundum is a mineral substance found in a crystalline form. Its hardness is next to the diamond. Emery is granular corundum more or less impure. As an abrasive, corundum cannot be excelled, its diamond-like hardness, brittleness and sharpness giving it lasting qualities.

PUNCHING

AND

SHEARING

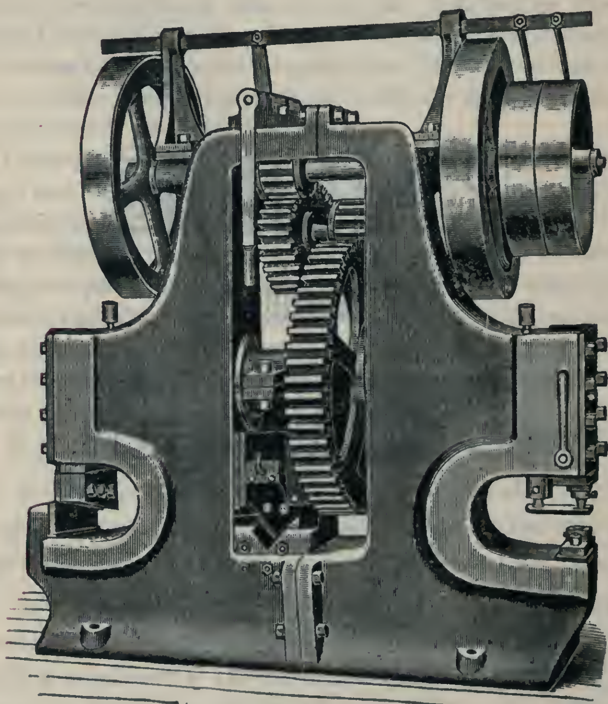


Fig. 248.

PUNCHING AND SHEARING.

To punch is to pierce, to perforate or indent a solid material.

To shear is to clip or cut with a sharp instrument; the act or operation of cutting by means of two edges of sharpened steel, as on the principle upon which shears are operated.

A punch is a tool, the working end of which is pointed or blunt, and which acts either by pressure or percussion—applied in the direction of its length—to drive out or in, or to make a hole or holes, as in sheet or plate iron and steel.

Shears consist of two blades with beveled edges facing each other and used for cutting. There are innumerable forms of these two implements—punches and shears—but this volume has to do only with those actuated by power, hence called "power-punching machines" or "power-cutting machines," etc.

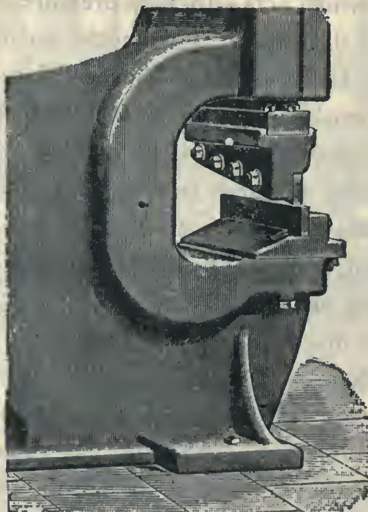
Punching machines are very commonly combined with shearing machines, the work of both being essentially the same. In some cases the construction is such as to allow of the removal of the shear-blades and substitution of the punch, and *vice versa*, as desired. More usually, however, the two contrivances are separate, though arranged in the same supporting frame. Fig. 248 represents a punching and shearing machine. The reason the two are combined in one machine is that it is very usual for both shearing and punching to be needed on the same plate.

Presses used for stamping or forming purposes are properly punches; the term punch includes two very dif ferent kinds of instruments; 1, tools whose duty is to indent

PUNCHING AND SHEARING.

the material without absolutely separating or dividing it, 2, tools which, in conjunction with a bolster placed underneath the work, cut or divide it similarly to the action of a pair of shear blades.

Punching machines, as is evident from the flat or obtuse angle of the edge of the punch, do not effect the division of the material by cutting, but by a tearing apart



View of throat, showing tools in position.

Fig. 249.

of the fibre of the material; this is equally true of the upper and lower blades of a shearing machine, as shown in fig. 249; the blades are not cutting edges, but are flat or nearly so.

The operations of both punching and shearing may be regarded as similar, one being done with circular or curved and the other with straight tools. The blades of a shearing machine will pass through a plate an inch and a half in thickness with a rapidity and appearance of ease which give little idea of the power actually used.

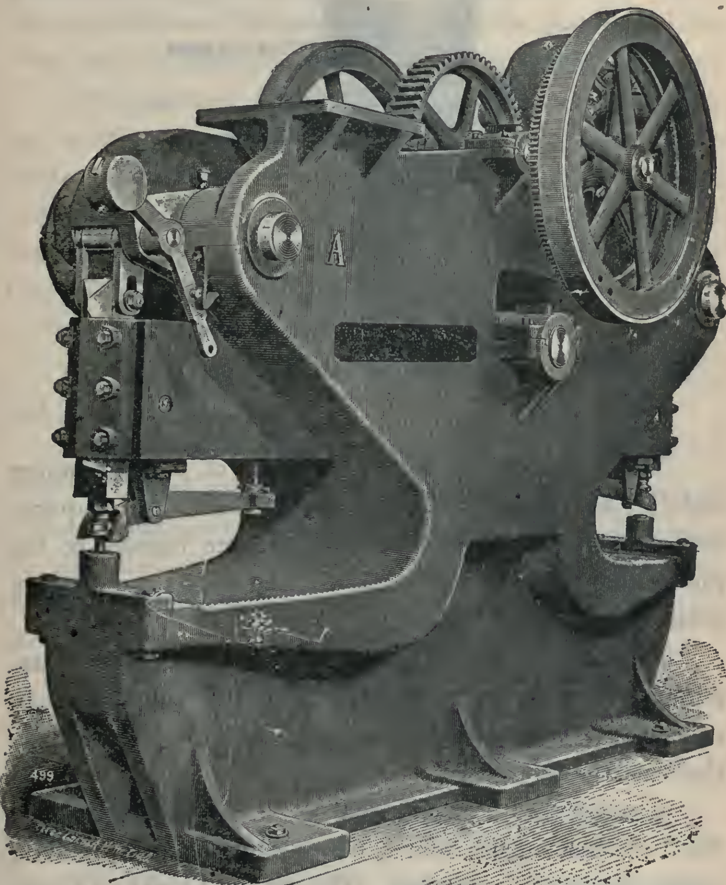


Fig. 250.

Fig. 251 shows an enlarged view of the arrangement of the punch end of the machine illustrated in fig. 248; the operation is that of perforating a hole in a heavy plate;

PUNCHING AND SHEARING.

each portion is named, to more readily convey the idea of the work and the several parts of the machine.

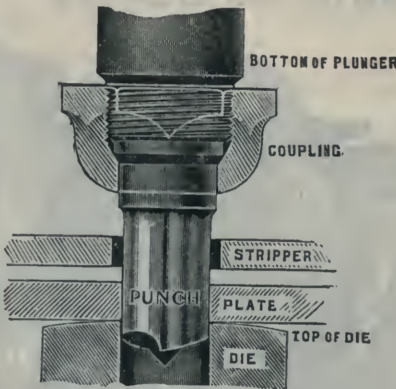


Fig. 251.

The above cut shows the positions of punch, plunger and die; also the positions of the stock, punch and coupling, and the correct position of the stripper relative to the punch and plate, in use, to prevent the plate from binding when the punch is drawn.

In punching and shearing machines the power is applied in many ways: 1, by screw pressure; 2, by hydraulic pressure; 3, by a lever: or, 4, by eccentrics—the latter is the usual method.

A complete set of punching tools includes 1 punch, 1 die, 1 die block, 1 die holder, 1 socket, 1 stripper or pull-off, 1 edge gauge and wrenches. The die block bolts on to the lower jaw to receive the die holder or the die, and the die holder is made to fit in the die block and is bored to receive the various sizes of small dies. The edge-gauge bolts to the frame of the machine, and its edges serve as a gauge

PUNCHING AND SHEARING.

for the edge of the piece being punched. The stripper or pull-off is a pivoted lever whose forward end straddles the punch and strips the sheet as the punch rises; it is adjustable up and down by means of a pin at the rear end of the lever, so as to accommodate different thicknesses of metal.

The capacities of the different machines vary according to the size, and the throats in the same size vary in depth. The distance from the edge of the sheet at which punching or shearing can be done, is governed by the depth of the throat; by the depth of the throat is meant the distance from the center of the punch to the back wall of the throat.

Fig. 248 shows a double-ended eccentric, punching and shearing machine.

This machine is double-geared, the frame cast in halves securely bolted and dowelled together. The driving and eccentric shafts are of steel, and the latter drives the slides through short connecting rods. The slides have large rectangular bearing surfaces, those for the punch and the shears being fitted with stop motions.

Fig. 250 shows a double-ended lever punch of approved design.

This machine is double-geared, and the punch and shear slides are worked by levers which allow the slides to remain at the top of the stroke during half a revolution of the main shaft, thus affording time for adjustment of the plate.

In single-ended machines the punching and shearing are both operated from one slide, the shears being placed at the top.

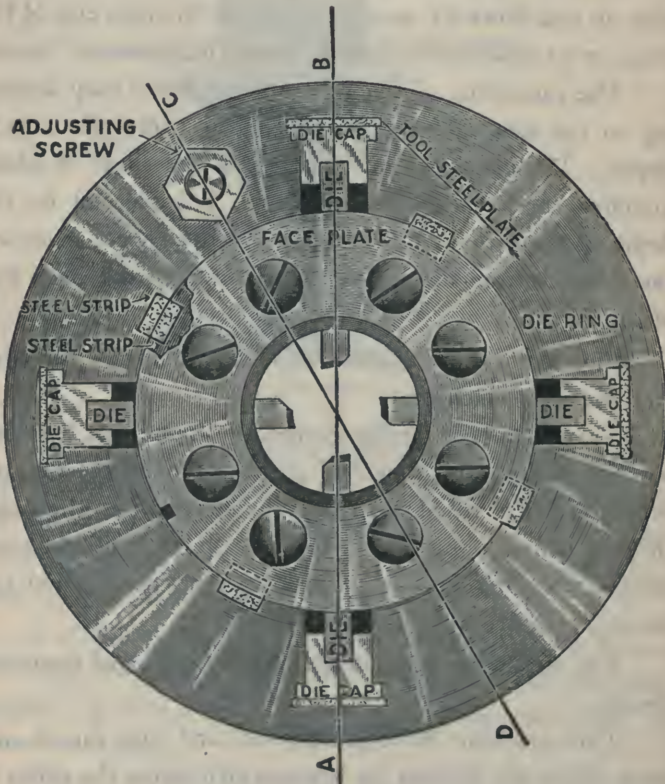

B
C
ADJUSTING
SCREW
DIE CAP
TOOL STEELPLATE
DIE
FACE PLATE
STEEL STRIP
STEEL STRIP
DIE RING
DIE CAP
DIE
DIE
DIE CAP
DIE
DIE CAP
D
A

Fig. 252.

MACHINE BOLT CUTTING.

This subject also properly includes nut tapping and bolt-heading. Bolt-cutters, like most other machines, require additional tools and devices, according to their complication and general construction; an example of this is the special cutting-off tool designed to reduce round rolled iron to the exact length necessary for heading in the heading machine, which is in itself an accessory of the bolt-cutter; another example is the power feed-attachment, designed to be applied to the main machine, to produce coarse bastard threads true to the pitch.

Fig. 254 shows an improved bolt-thread cutter, arranged with gear for screwing large diameters of bolts.

The cutters, four in number, are arranged in a revolving die head; fig. 252 is a front view of same; the carriage is moved to and from the die head by a rack and pinion operated by hand wheel; the lubrication for the dies is supplied by an oil pump of plain plunger type, placed within the column of the machine, and is driven from the cone pulley—the throw of the crank pin can be adjusted to and from the center, thereby decreasing and increasing the stroke of the plunger, and regulating the supply of oil to the cutters.

A substantial metal box frame *A*, provides an oil tank in the base, the top forms the bed and the slides for the carriage; the headstock *B* carries the live spindle *C*, to which is bolted the die head *D*; the hand wheel *F* opens and closes the vise *E*, which slides with carriage *G*, and is operated by hand wheel *H* and the rack and pinion shown;

MACHINE BOLT CUTTING.

the hand lever *I* operates the clutch ring, opening and closing the dies, which is also automatically accomplished

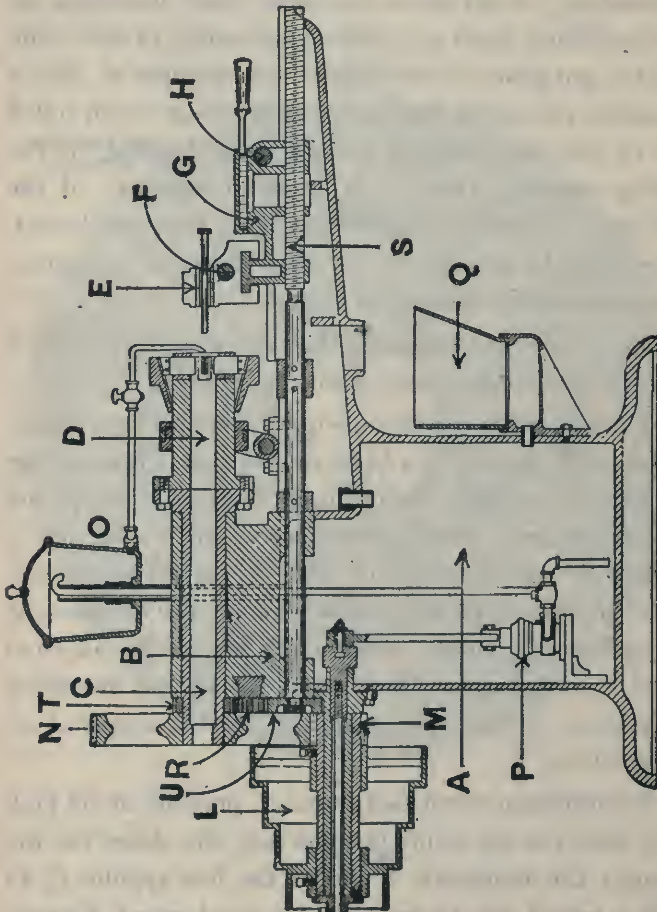


Fig. 253.

by the stop rod *J*, which slides through the vise block, and the stops *K K*, being set to the length of the screw to be cut, are operated by contact with the vise.

MACHINE BOLT CUTTING.

The driving cone *L*, with pinion *M*, gear into wheel *N* on the live spindle; the oil supply *O* is fed by the pump *P*, in the metal box frame, through the center of the overflow pipe; the discharge end is curved downwards slightly below the top of the overflow pipe, which prevents splashing of the oil.

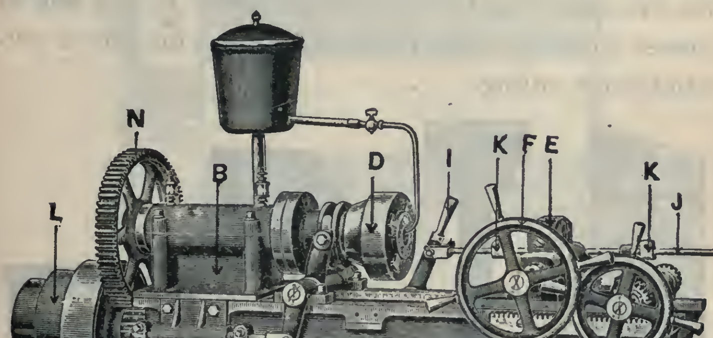


Fig. 254.

The pump is of ample size, so that when running on the slow speed a sufficient supply of oil is discharged into the oil-pot to keep a constant stream on the dies when cutting threads; the removable chip-pan will hold the chips of a day's work.

MACHINE BOLT CUTTING.

Fig. 253 is a section side view of the machine, showing the interior arrangment of the parts and the plunger pump *P;* it also shows a device, a substitute for the rack and pinion motion for travelling carriage, which is not shown in fig. 254, viz., a self-acting lead screw *S*, which is driven from the live spindle by two spur gears, *T* and *U*, and idle or carrier wheels *R*, which reverse the motion for right or left-hand screw cutting.

Fig. 255.

Fig. 256.

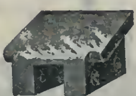


Fig. 257.

Fig. 258.

The die ring is made of cast iron; this ring controls the movement of the dies radially to and from the center, by means of recesses at an angle to its face; the clutch ring has a phosphor-bronze ring working in a groove and attached to the automatic spring and closing device; the movement of the clutch ring is transmitted to the die ring through the rocking lever and toggle.

The cutters are four in number; fig. 255 is a side view, fig 256 an end view, of the cutter with cast-steel head attached; figs. 257 and 258 show the tool-steel caps; the upper one is for a full-size die. When recut several times, it is needful to use the deeper steel cap, to make up for the shortening of the cutter by recutting.

MACHINE BOLT CUTTING.

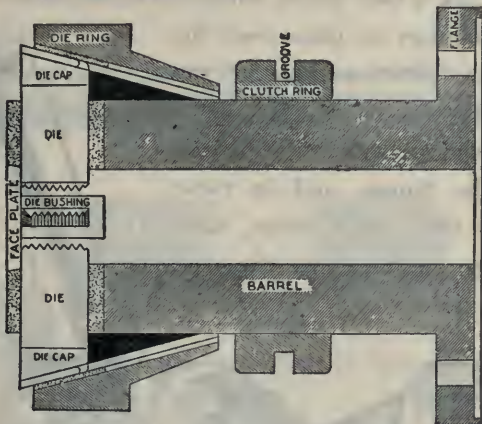


Fig. 259.

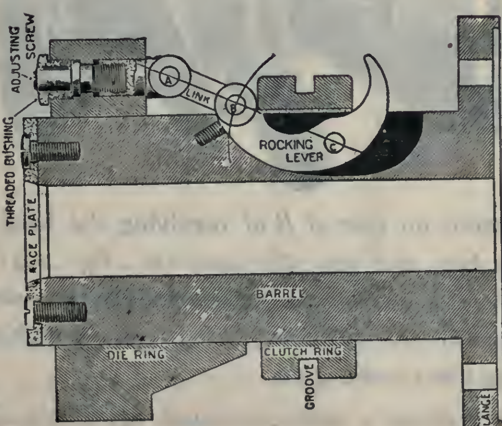


Fig. 260.

MACHINE BOLT CUTTING.

Fig. 261 shows the side view of the die head, which is made of cast iron, turned, milled and bored. To the post end is fastened a face plate, which serves to hold the dies and die bushings in place—see fig. 252; in the outer surface of the barrel, there are four longitudinal grooves milled to within a short distance of the flange, and in these grooves are fitted steel strips, hardened and ground to resist the wear of the sliding die ring.

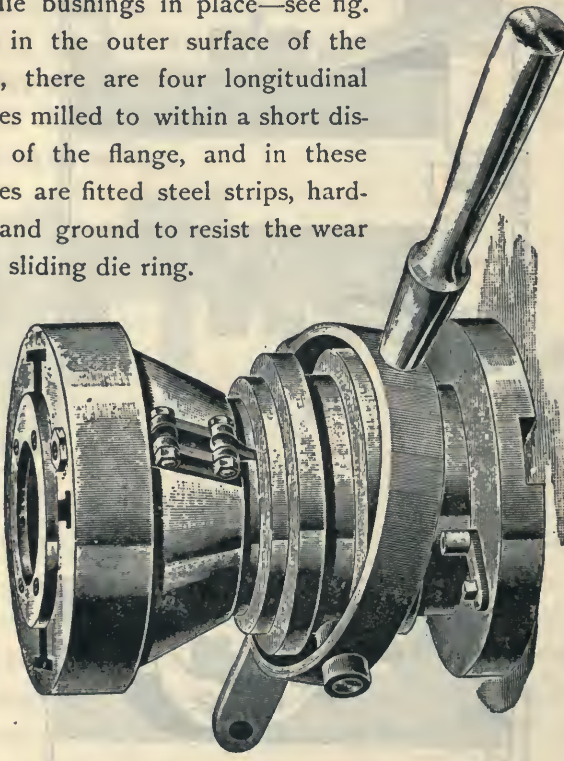


Fig. 261.

A section on line *A B* of revolving die head; figure 252 shows the dies and die caps, etc., fig. 259; a section on line *C D* of the die head—see fig. 260—shows the opening and closing device operated by the clutch ring and the rocking lever and toggle.

Fig. 262 shows a lead screw, and fig. 263 a split-nut; these are required for each pitch cut; the lead screws

MACHINE BOLT CUTTING.

are made short and they can be changed from one pitch to another; the bronze split-nut fits in the carriage and is opened and closed by means of a cam disc and lever operated by hand.

Fig. 262.

Fig. 263.

The cutting speeds for dies in bolt cutting are as follows:

TABLE.

Diameter of Bolt.	Revolution of Dies.	Diameter of Bolt.	Revolution of Dies.
$\frac{1}{8}$	460	$1\frac{1}{8}$	50
$\frac{1}{4}$	230	$1\frac{1}{4}$	45
$\frac{5}{16}$	188	$1\frac{3}{8}$	40
$\frac{3}{8}$	153	$1\frac{1}{2}$	38
$\frac{7}{16}$	131	$1\frac{5}{8}$	35
$\frac{1}{2}$	115	$1\frac{3}{4}$	32
$\frac{9}{16}$	102	$1\frac{7}{8}$	30
$\frac{5}{8}$	93	2	28
$\frac{3}{4}$	75	$2\frac{1}{4}$	25
$\frac{7}{8}$	65	$2\frac{1}{2}$	22
1	55	$2\frac{3}{4}$	20
		3	18

The usual cutting speed for bolts in machine-shop practice is fifteen lineal feet per minute; the above table is based upon that capacity of work. In tapping nuts, the same number of revolutions of the taps are required.

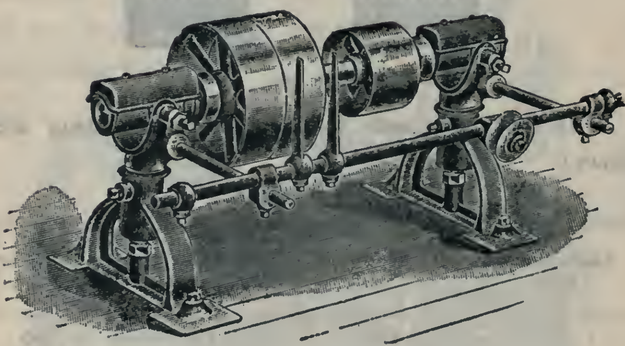
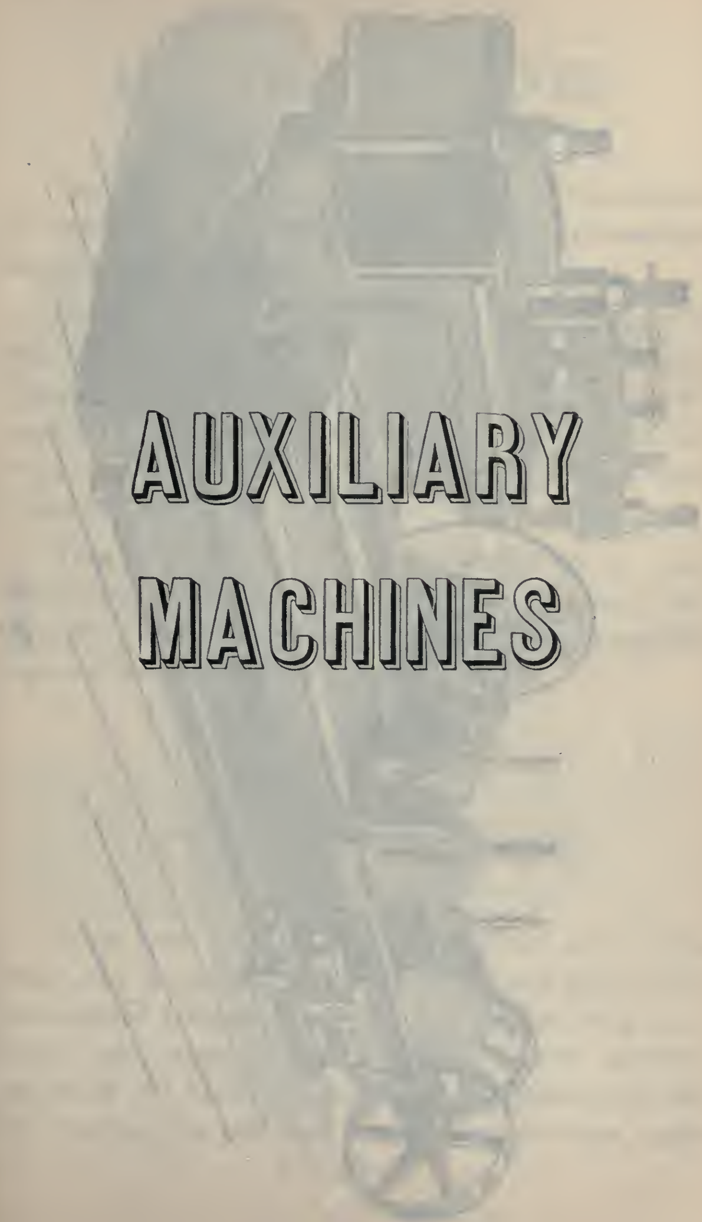


Fig. 204.

AUXILIARY MACHINES



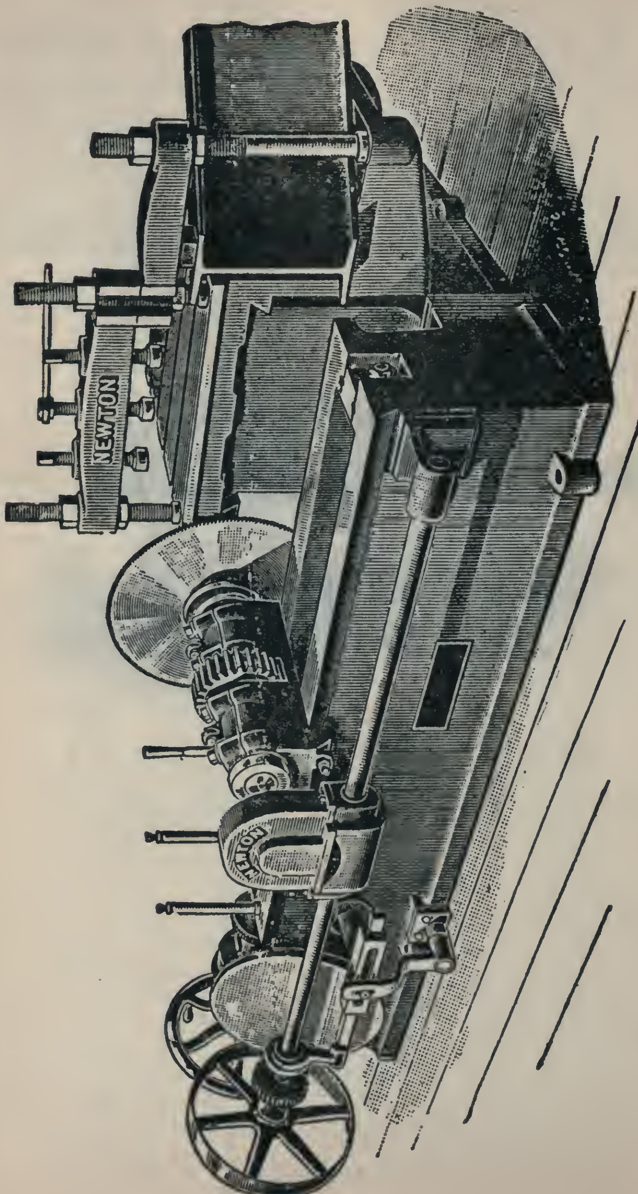


Fig. 265.

AUXILIARY MACHINES.

The introduction of a new machine or device implies the immediate employment of a whole series of auxiliary and dependent appliances.

Some of these are seemingly of more importance than the parent machine, and frequently are much more complicated and expensive to build; they are named, frequently, by their use, and largely aid in the practical success of the new machine which they are designed especially to operate with.

Thus a "cutting-off" machine is used to cut off stock to the required length before it can be operated on by the lathe, etc.; one of these machines is shown on the opposite page and described below.

CUTTING-OFF MACHINES.

When rods, etc., are required to be cut to a certain length, the operation is performed in several ways; 1, either by a special lathe designed for the purpose, or, 2, by a power saw; when executed in a lathe, the revolving spindle in the headstock is constructed hollow, the rods pass through the hole and are then cut to exact length by an ordinary "parting" or cutting-off tool fixed in the rest or carriage of the lathe.

A special cutting-off tool for the purpose is shown in fig. 266; it consists of a substantial drop-forged steel

Fig. 266.

holder; the under edge is extended, giving a firm support to the blade directly under the cut; the blades are six inches long, seven-eighths inch wide, milled and ground on both sides to give proper clearance. The top, or cut-

Fig. 267.

ting edge, and bottom are ground square, to gauge of slot in holder. Hence the blades used in this style of holder require grinding on the end only. In use, the blade should be set to project beyond the supporting lip of holder, or under side, a sufficient distance to cut to center of stock; on heavy stock the blade can be advanced after making a cut of one inch or so on the outside. The blade is held in position by a substantial strap, bolts and case-hardened nuts.

Fig. 267 is a similar cutting-off tool, but fitted with an offset holder for particular work which could not be executed by the straight tool holder shown in fig. 266.

A "cutting-off" saw is a machine designed for "cropping" the ends of work and cutting it to length; in the ordinary machine shop practice, a power-driven hack-saw is used, but when cutting large work, a circular, revolving saw is used to cut the work cold; this is commonly styled a cold saw cutting-off machine; the latter is shown in fig. 265.

The power hack-saw illustrated in fig. 268 is especially designed to meet all the requirements of a machine for sawing metal. The upper arm of the frame can be extended so that large work can be cut; the jaws holding the work are planed and can be set so that work on any required angle, as well as straight sawing, can be done. The machine has an 8-inch stroke with quick return; by loosening the set screw in the stud holding the connecting rod, the frame can be swung to either side; by this adjustment the saw can be made to cut perfectly straight; the lower arm of the frame passes through a hole in the sliding thimble with a projecting stud, to which the connecting rod is attached, and on which friction nuts are placed; a set screw runs through this stud and holds the frame in

---

NOTE.—It has been the custom, when cutting a piece of iron or steel, especially hard tool-steel, to send it to the blacksmith to heat the metal in the forge and cut it to the required length; this method has the disadvantage of deteriorating the steel in quality consequent on the heating, and the rod is returned in a rough shape.

AUXILIARY MACHINES.

any set position; a piece of steel with concaved end is placed under the set screw to prevent the point from coming in contact with the arm. The slide in which the thimble runs is split so that any wear can readily be taken up by tightening the screws at each end. There is no drag on the saw during the backward movement.

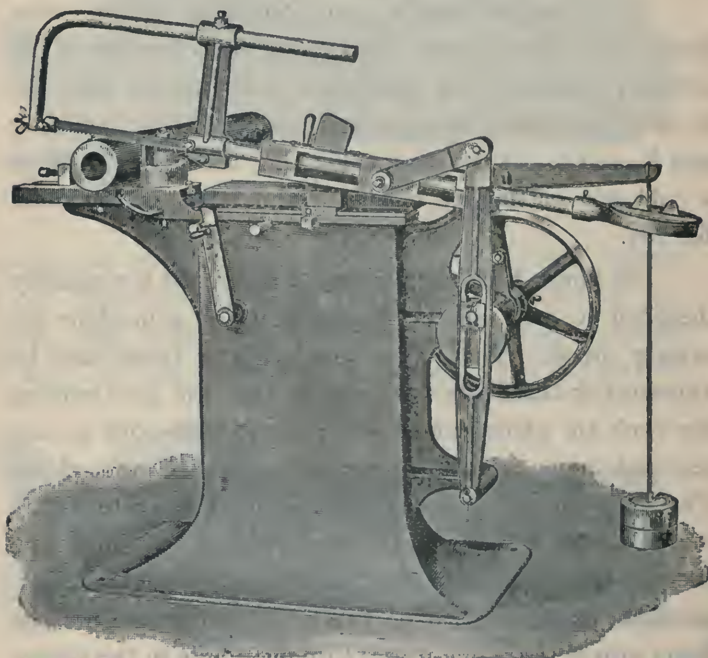


Fig. 268.

By adjusting the friction on the connecting rod the saw can be made to lift gently from the work when going backward, and the pressure on the forward stroke can be increased or diminished by the same means. A coil containing twenty-five feet of saws is placed in the magazine on the rear end of the arm, and can be drawn through the proper distance for the work being sawed. By using the magazine coil principle the saws can be used their entire length. This feature alone reduces the cost of saws fully one-half, and as the saw is firmly clamped at both ends instead of being held by pins, the danger of the holes being pulled out of the ends of blades is entirely obviated. The usual speed of the blade is 40 strokes per minute. After a cut is finished, the clutch is automatically thrown out and the machine is stopped.

With flexible hack-saw blades the teeth only are hardened, the back remaining untempered; thus the blade will

Fig. 269

Fig. 270.

neither snap nor break, assuring full efficiency until the teeth are worn dull. Fig. 270 shows the construction of the flexible back blade; fig. 269 shows the set of the teeth. These blades for cutting iron, steel, brass, etc., are made from 23-gauge stock, and have 15 teeth to the inch; for cutting tubing and sheet metals the teeth are finer, being made 24 teeth to the inch.

Fig. 264 shows the countershaft used with the power hack-saw shown in fig. 268; the motion is stopped by shifting the driving belt from the fast on to the loose pulley; these are the pair shown in the cut, the small pulley being the driving pulley connected to the pulley on the machine.

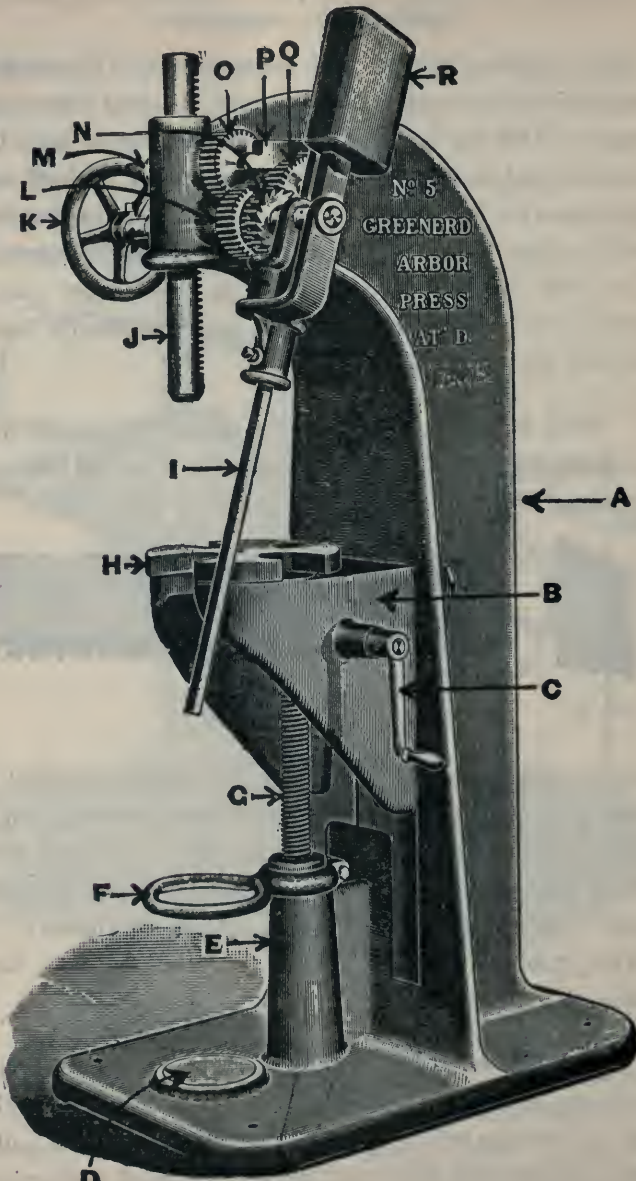


Fig. 271.

THE ARBOR PRESS.

The arbor press is a machine devised for accomplishing the work described in the note, which is ordinarily done by hand, by means of a hammer, etc. The arbor or mandrel is a spindle which is forced or driven into a bored hole in the work, such as a pulley or wheel, to enable it to revolve between the centers of a lathe, milling cutter, etc.

Fig. 271 shows such a machine, which is a very useful device, being quick in action, and which can be bolted on the end of the lathe-bed or on a separate bench, and which is always ready for use. Operated by a hand lever, a pressure of seven and a-half tons can be obtained by an ordinary man by means of the gear-wheels shown in the engraving; it is exceedingly simple in action, and consists of a massive standard *A*, which carries a sliding or adjustable knee *B*, which can be regulated to the height of the work by a square-thread screw *G*, which acts in a nut in the top of standard *E*; the handle *C* operates the screw *G*; the plate *H* is free to revolve on the knee *B*, and is provided with lateral openings of graduated sizes for various-dimensioned mandrels; when released from the work, the arbor or mandrel drops on the soft babbitted cushion *D*, and is caught or retained in the large steel ring *F*; the plunger or ram *J* has a rack cut on one side; this rack is engaged with two pinions, one on spindle *M* and one on

NOTE.—Very generally the mandrel is driven into the work with a lead-headed hammer, or an ordinary sledge is used; as a precaution, a piece of sheet-brass, copper or hard-wood is placed against the end of the mandrel to receive the force of the blow of the sledge and thus prevent the "center" in the mandrel being damaged or destroyed, as the brass strips will spread and become thin from repeated use, soon rendering it unfit for the purpose.

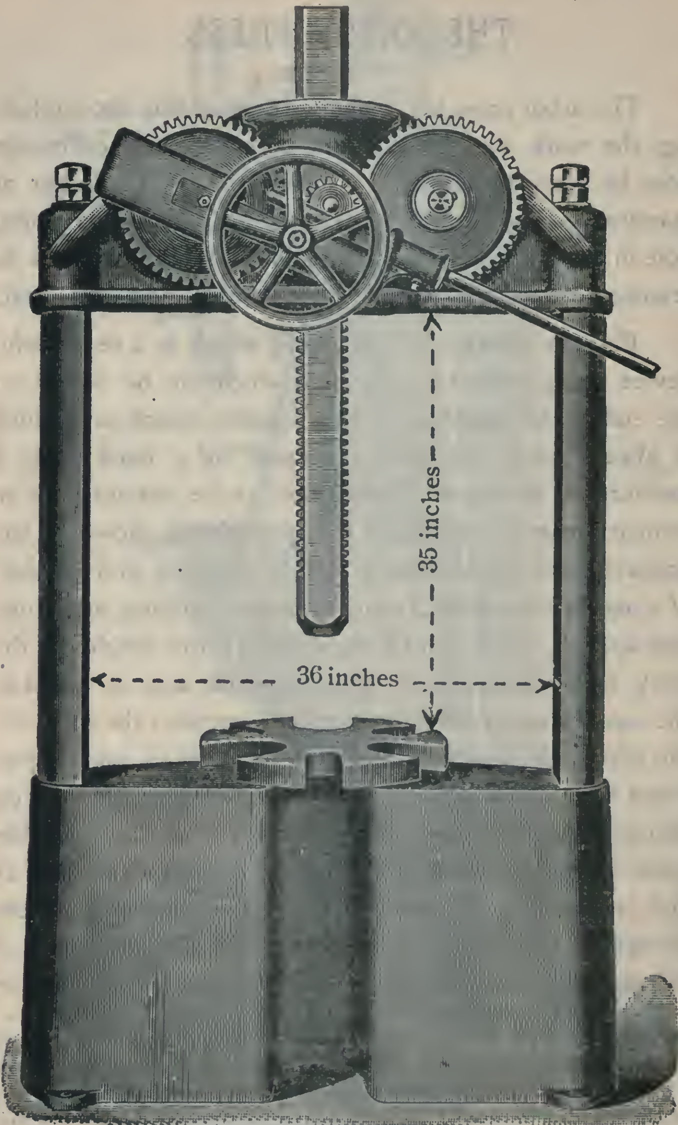


Fig. 272.

the lever spindle, and they are geared together by the spur wheels *L* and *O*; the leverage is obtained by means of wheel *Q* and a pinion hidden in the drawing by the ratchet *N*; a pawl fits into the casting, into which the lever *I* is fixed; a leverage of 135 to 1 is thus obtained. The counterweight *R* balances the lever and keeps it in an upright position when not in use; a pin projects from one side of the pawl, so that when the lever casting is upright,

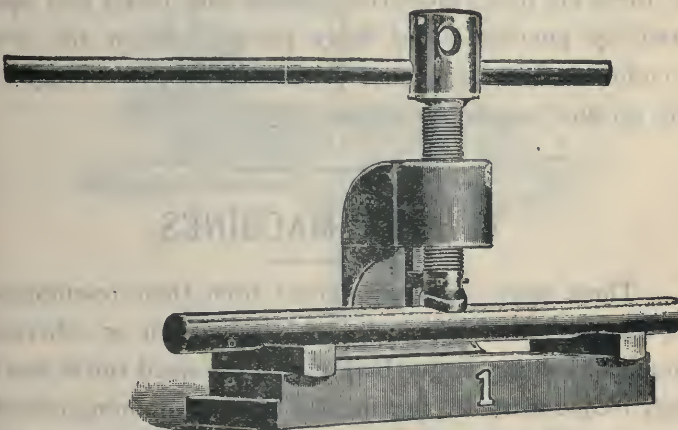


Fig. 273.

the pawl rides the "shedder" *P*, disengaging the pawl from the ratchet, thus leaving the ram *J* free to be moved up or brought down to the work by means of the hand-wheel *K*.

Fig. 272 shows a very powerful press, designed for mandrels up to 7 inches diameter; the ram is made of four-inch steel and has a rack cut on two opposite sides; the gears are steel, have a leverage of 250 to 1 and exert a pressure of about sixteen tons at the end of the ram, with a man of ordinary strength at the lever.

SHAFT-STRAIGHTENING MACHINES.

Fig. 271 shows a hand-power shaft-straightening machine intended for bench use; it has a powerful screw made of steel; the bed is planed true and has two steel blocks or vees fitted to slide upon it; these can be adjusted to suit the bend or twist in the shaft, and will accommodate work of any length.

This is but one of many devices of this nature; some of these are much more complicated and costly and operated by pneumatic and other powers; one of the most common is a machine used in railroad shops in straightening car and locomotive engine axles.

TURRET MACHINES.

These were originally named from their resemblance to the *turrets* or "little towers rising from or otherwise connected with a larger building;" the word turret was in very frequent use in the middle ages as defining *movable towers* used in military operations; at the present date turrets, in engineering practice, are always understood to mean a revolving mechanism, as the turret-gun, designed for use in "a revolving turret," and the turret lathe, which has a revolving tool-holder.

NOTE.—*The monitor, or turret lathe*, derives its name from the Ericsson's Monitor, designed and built in 1862; this carrries on its deck one or more *revolving turrets*, each containing one or more great guns, which can be successively brought into range by revolving the steel-clad turret, thus combining the maximum of gun power with the minimum of exposure. Ericsson named his newly-invented ship *The Monitor*, from its use as a caution or warning to the enemies of his adopted country.

AUXILIARY MACHINES.

In modern machine shops a turret is known as a revolving tool holder; that is, a tool holder which contains a number of cutting tools, any one of which may be used by revolving the holder, which brings the cutting tool successively into position to operate on the work; while the turret is principally used on lathes, screwing and drilling machines, it is applied to many other machines, such as the planer, and shaper, and also in wood-working machines.

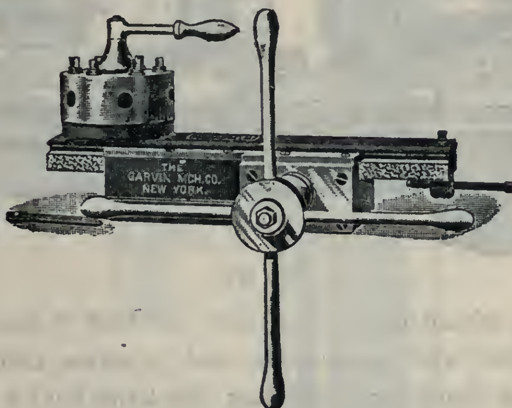


Fig. 272.

Fig. 272 shows a turret fitted on the shears or bed of a lathe; the turret is bored with holes for the reception of six tools; it has hand longitudinal and cross feeds, the turret being revolved by hand; it has at its base, a steel index ring of large diameter, hardened and ground; the locking bolts are hardened and ground, and provided with a taper gib for taking up the wear; a spiral spring forces the locking bolts into the slots, and is adjusted by a screw at the back end of the turret slide. The turret slides move in flat bearings with adjustable taper gibs to maintain correct alignment.

THE TURRET LATHE.

Fig. 273 exhibits a turret fitted on the carriage of an engine lathe, similar to that illustrated in fig. 61; it shows the hexagonal turret mounted on the carriage, being interchangeable with the compound rest shown in fig. 61, enabling the lathe to be used either as an engine lathe or a turret lathe.

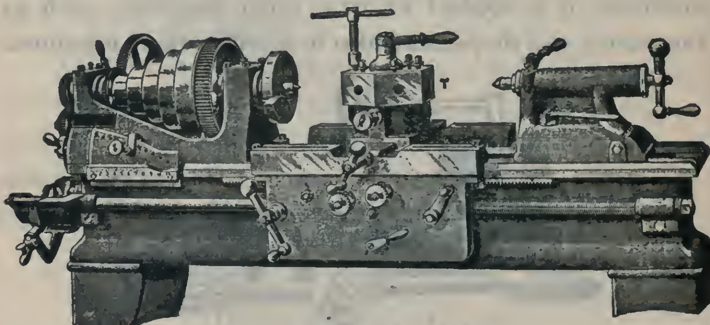
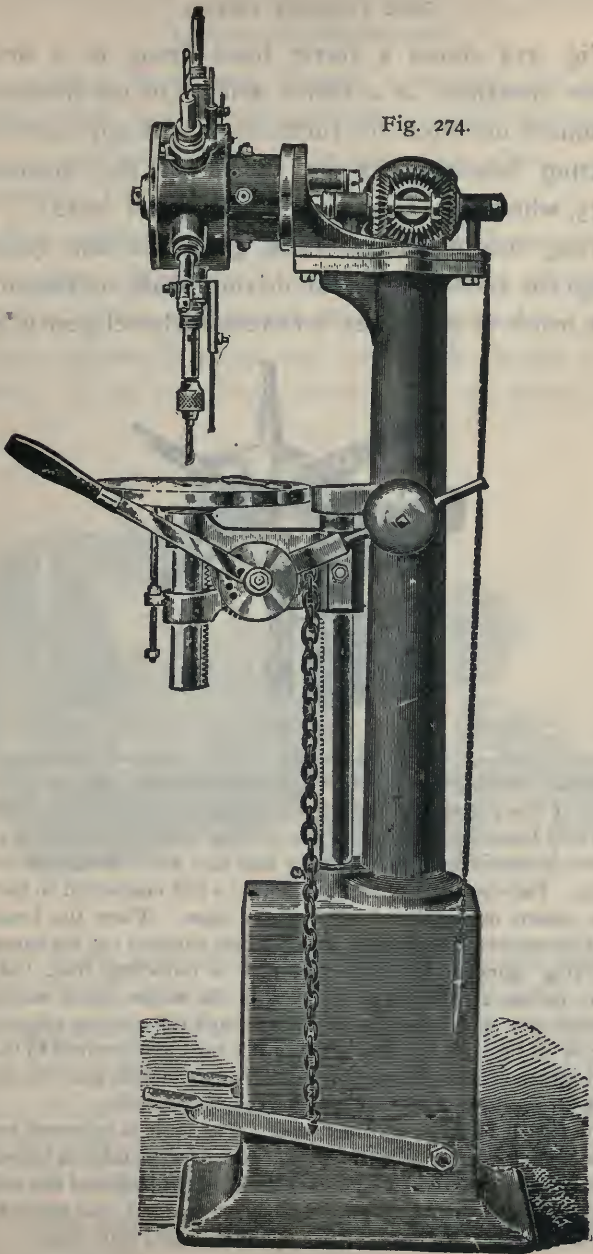


Fig. 273.

The advantages of this turret are that it has power, longitudinal and cross feeds, and is screw cutting; it has all the changes of feed that the lathe has; it may be used in connection with the half-nuts, and therefore chase a thread; it permits running in such taps as conform with the threads cut by the lathe at their proper pitch and bringing them out without danger of stripping any of the threads; it may be "set over" either way from the center and is provided with centre stops.

NOTE.—In practice, all pieces made from the continuous bar are machined as follows: A long bar of the rough iron or steel is pushed through the spindle, until the piece projects beyond the chuck long enough to make the piece desired. The various tools on the turret are set for the different diameters and cuts, and after each performs its operation, it is turned out of the way to admit the next tool. Since a number of tools are set for the various diameters, it gives this machine a great advantage over the lathe where there is but one tool.

Fig. 274.



THE TURRET DRILL.

Fig. 274 shows a turret head fitted to a drilling machine described as a turret drill. On the trunnion of the frame is mounted the turret head with any number of projecting bearings; six are shown in the illustration fig. 275, which is a front view of the turret head. These projecting bearings support and guide the drill spindles; through the frame passes the driving shaft, on the end of which, inside of the turret, is fastened a bevel gear in mesh

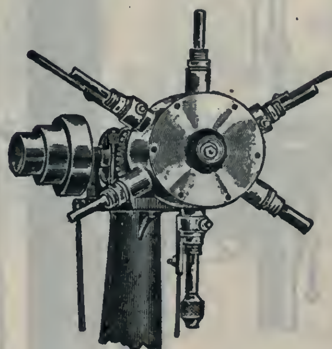


Fig. 275.

NOTE.—Pivoted on the front of the gear-case, fig. 275, in the interior of the turret head is a bell crank lever, one end of which is forked and loosely connected to the driving spindle; the other arm of this lever is connected to the locking bolt that holds the turret head in position. Fastened to the locking bolt is a rod connected to the foot-treadle shown on left-hand side of the base. When the treadle is pressed downward it moves the locking bolt outward; at the same time the driving spindle moves upward and is unlocked from the drill spindle before the locking bolt leaves its socket, thus making it impossible for the turret to be moved while the driving spindle is in contact with the drill spindle. When the turret is revolved to the tool wanted, the bolt will automatically drop in its socket, and the driving spindle moves downward and engages the drill spindle.

The feed is by hand and foot lever. The table is balanced and has a vertical feed motion. The knee that supports the table is fastened to the face of the column and balanced by a weight inside of the column. The drill spindles are of steel, hardened and ground, and reamed to fit the Morse taper; the spindles have an independent drill stop.

AUXILIARY MACHINES.

with another bevel gear, loosely splined to the driving spindle, which has on its lower end a clutch that engages, when in operation, with a corresponding clutch on the inner end of the drill spindle.

Fig. 276 shows a screw-cutting die-head which is self-opening and adjustable; it is designed for use on screwing machines, lathes and in turrets, being provided with an internal adjustable gauge for varying the length of the threads. It has few parts, yet admits of the finest adjust-

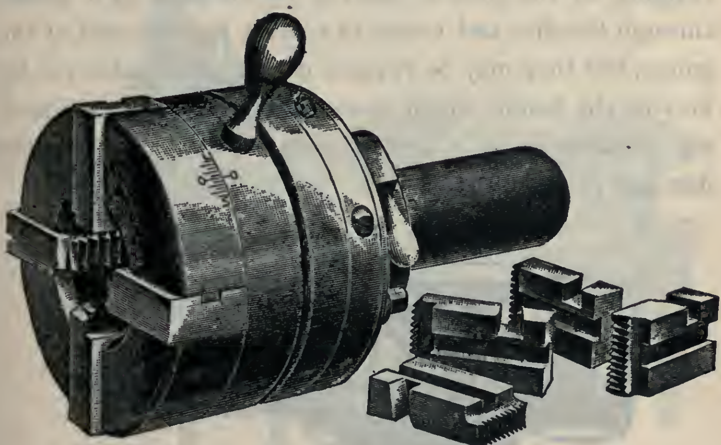


Fig. 276.

ments; being graduated upon one side of the shell and provided with an index by which quick and accurate variations in the diameter of threads may be made, and as the index is controlled by one screw, both dies are adjusted simultaneously. It is provided with four single-point dies, and also with a roughing and finishing attachment, by means of which two cuts may be taken in making a thread, and insures a more perfect quality of work than is possible to produce with one passage of dies.

SCREW-CUTTING DIE HEAD.

The roughing and finishing attachment is operated by a small handle located at one side and back of the head proper, and as shown in the illustration, so arranged that by moving it to a forward position the dies are opened slightly for the roughing cut, and when the handle is returned to its original or backward position, the dies are closed and locked at a predetermined point for the finishing cut; this handle is easily and quickly manipulated by the left hand of the operator. In regular practice the tripping of the dies is effected by the stock as it passes through the dies and comes in contact with the end of the gauge, but they may be tripped at any point on the cut by moving the handle which operates the roughing and finishing attachment to a central position, which unlocks the dies and causes them to open.

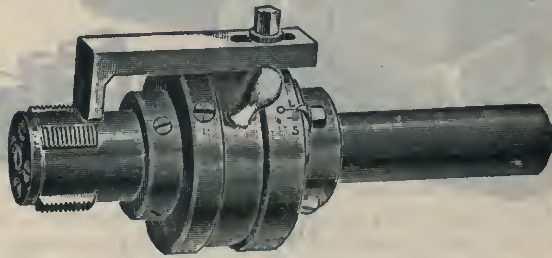


Fig. 277.

Adjustable collapsing taps, as shown in fig. 277, are designed for use in screwing machines and lathes and are held either in the turret, or in the rotary or live spindle. By reason of not requiring to be reversed, these taps retain their cutting edges longer and will cut smoother and cleaner than a solid tap; the standard size of thread can be maintained by adjusting the chasers or cutters in a similar manner to the adjustable dies described on page 259.

KEYSEATING MACHINE.

Fig. 278 shows a machine which will cut keyseats on any portion of a shaft, without removing it from its bearings; the machine being firmly fastened to the shaft by two clamps, the cutter-head is fed along the shaft and will mill a keyseat 12 inches long without resetting, and as it has a sliding support under the cutter at all times, it cuts without jar and produces keyseats with straight sides and

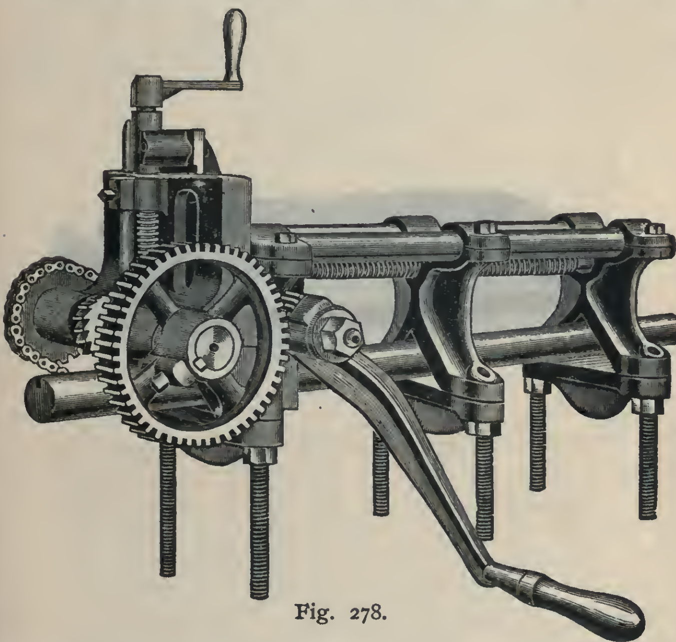


Fig. 278.

smooth bottoms. The machine is provided with an automatic feed while cutting, but this feed may be disengaged if desired, and the cutter-head fed by hand.

Five milling cutters are used with each machine; by employing one or more of which on spindle, keyseats of any of the following sizes may be milled full width at one operation: $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{16}$, $\frac{1}{2}$, $\frac{9}{16}$, $\frac{5}{8}$, $\frac{11}{16}$, $\frac{3}{4}$, $\frac{13}{16}$, $\frac{7}{8}$, $\frac{15}{16}$, 1, $1\frac{1}{16}$, $1\frac{1}{8}$ in.

Fig. 279.

UTILITIES

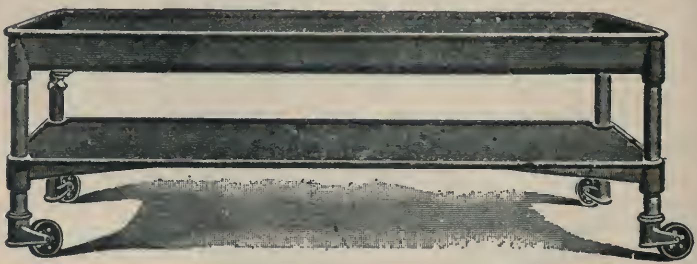


Fig. 280.

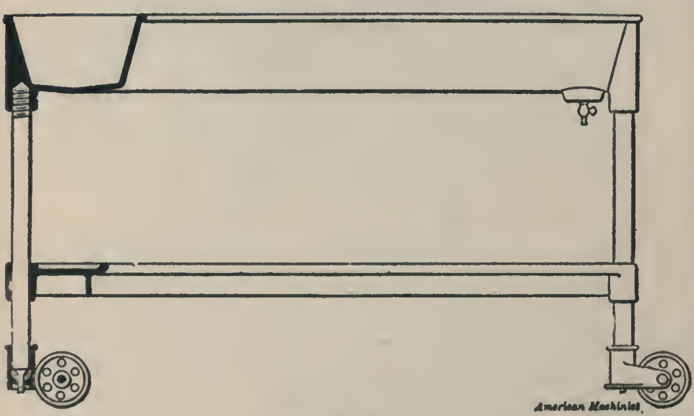


Fig. 281.

UTILITIES AND ACCESSORIES.

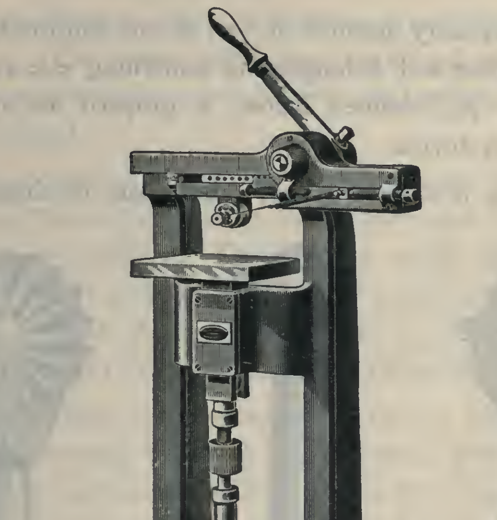


Fig. 282.

A utility is defined as a useful thing; a machine shop utility is a tool or device adapted for use among machines of larger and more pretentious reputation; each shop has

JIGS, SHOP KINKS AND WRINKLES.

its own utilities, and upon their proper application depends largely the success of the whole organization.

An accessory machine or tool is one contributing to a general effect and belonging to something else as a principal; a "jig," defined below, is properly an accessory machine or device.

A jig is defined as any subordinate mechanical contrivance or convenience to which no definite name is attached; a jig is a small special tool or otherwise a "wrinkle" or shop "kink."


Fig. 283.

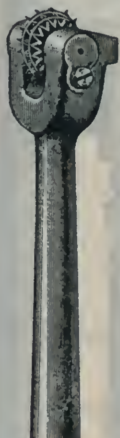


Fig. 284.

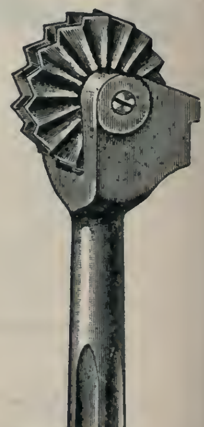


Fig. 285.

NOTE —In repetition work, where hundreds, thousands or even millions of similar pieces are to be worked upon, the profitableness of these special devices is most apparent. Jigs to the number of many thousands have been devised and used, although not always to advantage; they have often "cost more than they come to" in economical results.

The few examples shown on the following pages are rather as suggestions than an attempt to fully explain all the useful contrivances known under the names of utilities, jigs, etc.

UTILITIES AND ACCESSORIES.

Fig. 279 shows a pressed-steel shop pan used for handling bolts, rivets, nails, screws, nuts, washers, castings and other substances; they are also used under lathes and drilling machines, to catch the turnings, trimmings, oil drippings, etc. The pressed steel pans are found, in practice, more durable than riveted ones, and are lighter and more easily cleansed.

Fig. 280 shows a lathe pan; the lower pan or "shelf" is intended for the usual lathe extras, the upper pan is for the chips or cuttings. The top tray, which catches the chips and oil, is sometimes provided with a strainer and draw-off cock, as shown in section in fig. 281; by using this, the lubricant can be separated and used again.

When emery wheels wear out of true or glaze on the surface, it becomes necessary to true them. For this purpose a hand tool is used, which consists of a pure carbon or black diamond set firmly in the end of a steel rod provided with a suitable wooden handle; with this tool any desired shape, round or bevel, can be given to face of the wheel; the diamond produces true and smooth work, but the cutting qualities of the emery are slightly impaired by its action.

The above device is designed to be operated by hand; it is not illustrated; a similar tool is used, which can be fixed in the tool-post, the diamond being set in a solid steel shank.

Emery wheel dressing tools usually held in a sliding holder are shown in three figures on the opposite page.

NOTE.—The chips are made at or near the headstock end and, of course, drop in one end of the pan; when brass and iron work alternate, to keep the chips separate, simply turn the pan end for end—for this purpose the wheels of the casters are large and swivel readily.

EMERY-WHEEL DRESSING TOOLS.

For the purpose of removing the smoothness from emery wheels which have become glazed, emery-wheel dressers, as shown, are used; they are serrated or grooved discs which are pressed against the wheel and traversed back and forth across the face; the tool shown in fig. 283 is specially intended for large, thick wheels, say from 8 inches diameter and 2 inches thick or

Fig. 286.

more, but are not practical for use on small, thin wheels; while the dressers shown in fig. 284 and fig. 285 are generally used on smaller and thin wheels, but can likewise be used on the large wheels.

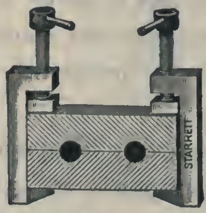


Fig. 287.

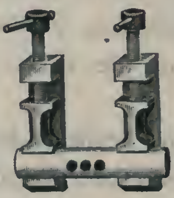


Fig. 288.

Figs. 286 to 288 are steel clamps made from drop forgings, case-hardened, and have take-up blocks to slip on and off the end of the screw. They will hold work square and parallel for laying out on surface plates, drilling, etc. A round piece may be rigidly held in two of the clamps and drilled, as shown in the illustration, fig. 288.

UTILITIES AND ACCESSORIES.

Various devices are used for stamping on metal surfaces impressions of trademarks, etc.; the machine shown in fig. 282 is designed for this purpose ; it will mark, by means of steel dies, letters, numbers, etc., on either flat or round metal surfaces, such as twist drills, taps, dies, reamers, etc.

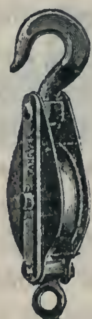
The piece of work to be marked is held on the table by a suitable fixture. For marking flat surfaces a cylindrical die is used, carried in a yoke or holder, which is attached to the slide bar or rack, and which is moved by the lever and pinion shown. By using a round die only a single point on its circumference is in contact with the work at one time. Many kinds of material that would be distorted by the use of a punch press can readily be stamped by this machine. When marking round surfaces, as the shanks of drills and reamers, a flat die is attached to the rack or slide, and the work allowed to roll on the table as the die comes in contact with it. Adjustments are provided when using flat or round dies, so that the proper character on the die shall come in contact with the work at a stated point ; the amount of travel, after contact is made, is governed by screw stops ; the round die, after use, is relieved of pressure and returned by spring tension to its original position.

Fig. 289.

Fig. 289 shows a screw jack, which is useful for lifting heavy castings into position on the planer, etc. The illustration explains itself, the cap being self-adjusting

MACHINE SHOP UTILITIES.

Fig. 290 exhibits a pair of "two and two" sheave rope blocks, fitted with an "automatic lock" or self-sustaining brake, which holds the load in any desired position; this lock can be released only by a pull on the rope, hence it is a safety block; for many purposes, rope blocks are superior to chain blocks.



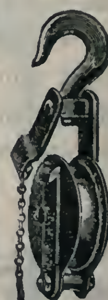


Fig. 291. Fig. 292. Fig. 293. Fig. 294.

Fig. 291 is a snatch block; fig. 292 a double, or two-sheave block; fig. 293 is a three-sheave block; fig. 294 is a snatch block with disconnecting side strap.

Fig. 295 illustrates a wall crane, designed for use with a lathe, slotting planer or, in fact, any tool in which heavy articles are machined; the construction enables this crane to be used without occupying any of the floor, nor does it interfere with the movements of the workman; with this description of crane, pulley

Fig. 290.

SNATCH AND SHEAVE BLOCKS.

blocks are generally used to raise the work, to a trolley which slides on the top of the crane arm, as shown in fig. 295.

Fig. 296 shows a simple and convenient method of supplying a grindstone with water, an essential feature being to provide a supply of water for the wheel while in operation, and to keep the wheel dry when not in use. The wheel, as illustrated, is mounted on a wooden frame, and the trough for the water is made of galvanized iron, the

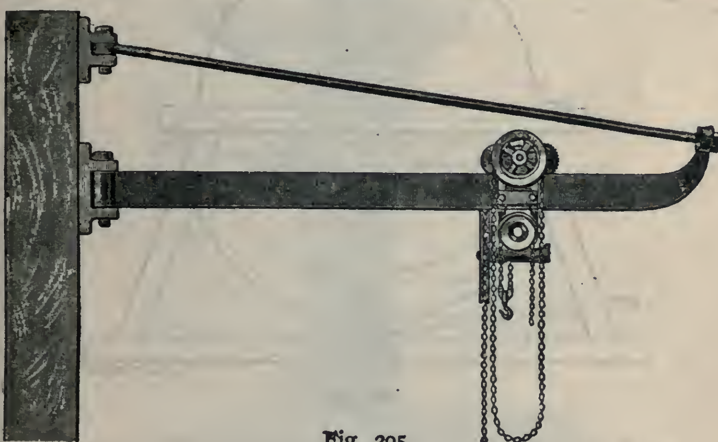


Fig. 295.

trough being high enough to enter the top of the frame, which serves as a guide, thus returning all the water to the trough again. When down, the water is below the bottom of the stone; the treadle, made of a piece of pine 1×5 inches, is connected to the trough by a couple of kettle ears and fulcrumed about the center of its length to the floor. The weight of the water keeps the trough down, and a presssure of the foot quickly brings the water in contact with the stone.

MACHINE SHOP UTILITIES.

Fig. 297 shows a "buff" or polishing machine. The stand or pedestal is hollow, and the wheel guard is of such shape that the draught, caused by the rapid movement of the wheel, carries the larger part of the dust produced by polishing, from the operator to the bottom of the stand; this may be connected with a blower, and the dust almost completely removed.

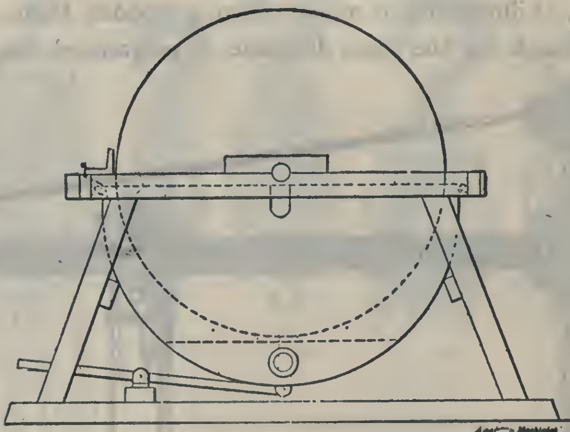


Fig. 296.

Polishing wheels are made of different materials, such as wood covered with leather, canvas clamped between iron plates, felt, unbleached muslin, etc.; the best wheels are

NOTE.—While most shops are provided with special tool grinders and sharpeners, the old grindstone still seems to have a place of its own among them, and most machinists prefer the grindstone when it is kept in good shape and well supplied with water. The chief objections to grindstones are that they do not hold their form any great length of time, and that the means usually employed to keep them well supplied with water are unsatisfactory. If the stone is kept submerged in water when not running, soft spots will result, and these will wear much faster than the rest of the stone.

solid leather and are made in three grades: soft, medium and hard; and they are well adapted to all kinds of polishing. These wheels are made of discs of oak-tanned leather, held together with elastic water-proof cement, and compressed under a hydraulic pressure of from 75 to 100 tons. They have advantages over other wheels, being more pliable and elastic, can be turned to any shape face, saving the

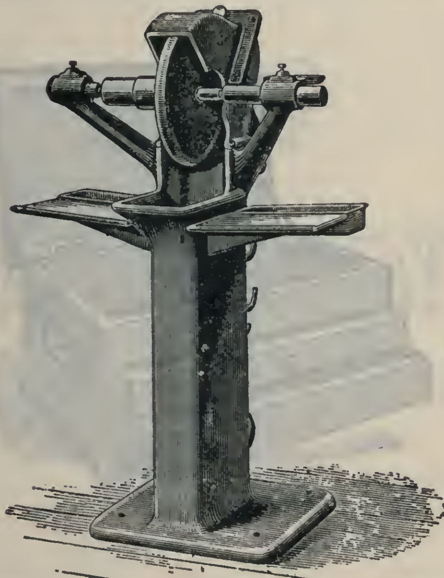


Fig. 297.

expense of re-covering, as a coat of emery is all that is needed to make them ready for service. Being water-proof, they can be washed like a leather-covered wood wheel when a new coat of emery is needed, and they can be run at any speed with perfect safety.

A tool chest is shown in fig. 298. This is preferably made of hardwood and furnished with locks and handles

"The user of the machine tool, wiser in his generation than the agitator, refuses to make sudden and radical changes in methods which have proved successful. To him machines are but a means to an end. He does not purchase them because they make watches, or engines, or ships. For these things he does not care. He wants them to make money, and

Fig. 298.

if he finds that a new machine can turn out more of it in an hour than an old machine, he tries the new. But it is labor lost, explaining the beauties of its construction, the excellence of its work, and the rapidity of its output, if it cannot be shown that it makes more money than a tool his grandfathers found good."

SHOP

MANAGEMENT

"The most successful managers are those who manage men, not things. By selecting the right heads of departments, encouraging them to do their best, by showing in a substantial manner their work is appreciated, the manager or superintendent can suggest improvements to the various departments that far out-weigh the whole cost of some of the details. It is well to know the details, so as to be able to examine them occasionally, but to attempt to follow them continually prevents attention to features of more importance."

"The shop manager must educate his foremen; must train them to his methods; must teach them concentration along the line of their particular work. Imbued with this spirit the shop foreman will train the gang boss, and he in turn the workmen under him. All must understand, that the greatest output of perfect, finished product, with the least delay and waste, is the sole object in view."

SHOP MANAGEMENT.

The advanced machinist, in common with other trades and professions, has, in very recent times, learned the value of co-operation between man and man, and between man and machines; at last he is working on the principles he has found to underlie good results in any trade—division of labor and organization.

When the modern machinist undertakes a problem of construction, or a special line of manufacture, he looks it squarely in the face, and if the equipment is not equal to the demands of the situation, supplies the need with the most approved machines or he invents new and improved devices and tools, and guarantees successful and definite results even before the work is begun. He does this by what is broadly named shop management.

The subject suggests two things—a shop and a manager; or, to enlarge a little, shops with machinery in operation and a foreman; again, to widen the view still further, shop management may properly include as its field of operations, a vast establishment with thousands of skilled and unskilled workmen, with their gang-bosses, foremen, and superintendents of departments, the whole animated and directed as a single whole by a general manager, who in turn is responsible to a board of directors, representing the capital employed.

For its most effective use, the shop may be considered a machine, sometimes large and sometimes small, of which the equipment and men are the moving parts. These are so placed as to work one with another, so that the product,

SHOP MANAGEMENT.

passing through the shop, reaches the finished condition with the least expense, in the desired state of finish and accuracy, thus effecting the combination of superiority and low price.

Be the "plant" large or small, the first thing that enters into its successful management is a "system" adapted to its size, condition and location. The word system explains the idea: A plan or scheme according to which ideas or things are connected together as a whole; a union of parts forming a whole; whatever savors of system, savors of accuracy, speed, ease and comfort.

Let it not be forgotten, that of thousands of machine-shops now in existence, the exceptions are few in number but what they had their beginnings in the days of small things, as to men and equipment; they have simply grown with passing years, but with all, the fact has been, that success and continuance has depended upon a proper system, which has been classified as

1. Organization;

2. Management;

3. Equipment.

NOTE.—"System is not work, but is simply a law of action for reducing work; it does not require special executors, but permits few to accomplish much. It loads no man with labor but lightens the labor of each by rigidly defining it. Hard work begins when system relaxes.

System never under any circumstances, interferes with variations in human action, but includes them; elasticity is not a quality of system, but comprehensiveness is. System is the result of two rigid laws: 1, a place for everything and everything in its place, and, 2, specific lines of duty for every man. The laws being written, understood and executed, lighten the responsibility of every man."—*Chordal's Letters.*

ORGANIZATION.

The term organization refers to the arrangement of departments and the positions they occupy, but in this book, the term does not include the commercial organization, of account keeping, financing or business management.

EQUIPMENT.

The term equipment may be said to include all machinery, tools, gauges, auxiliary plant, means of transportation and shop fittings; this is nearly a definition of a power-plant.

MANAGEMENT.

The above enter into the operation of every shop and "plant," and so the problems of to-day in shop and factory management, *are not so much problems of machinery as of men;* the question of men is, and always will be a difficult one; men are, as a rule, willing to do a good, fair day's work for a fair day's pay. They do not have to be driven to this. It is only necessary that the foreman let them know, in manly, inoffensive ways, what is expected of them.

Many schemes of co-operation have been attempted in the various trades and factories, with varying success. Many schemes have been too complicated, and many have a serious drawback in the length of time necessary before the workman knows to what extent he has participated in the profits. Many schemes are too visionary, and some good ones may have been failures on account of the methods taken to introduce them. Any plan, to succeed, must be practical and simple enough to introduce without

NOTE.—The Century Dictionary defines a "plant" as "the fixtures, machinery, tools, apparatus, etc., necessary to carry on any trade or mechanical business, or any mechanical process or operation."

displacing entirely the old. The most practical schemes seem to be those in which the workman is able to participate in the profit on a given piece. That is, he is given opportunity to reduce cost of production and is allowed an increase of wage for so doing.

PIECE-WORK PLAN.

The piece-work is the most widely introduced of any system in which the machinist shares in his increased productiveness. It consists in paying a fixed price for a certain piece of work. Although it was originally intended to benefit the manufacturer, in its first result it most directly benefited the workman, as he received an increase of wage, while the price per piece remained constant to the manufacturer, who, however, gains something by the greater output of his plant.

THE DIFFERENTIAL PLAN.

The differential plan consists of paying a man a high price per piece in consideration of his reaching a certain high-water mark of production per day, and a lower price per piece provided he falls below this rate of production. This plan congregates the ablest of workmen, but leaves the medium men considerably in the shade. It necessi-

---

NOTE.—"A tour of the machine shops of the United States and the newer works of Europe gives few impressions more striking than the one created by the widespread evidence of growing thought for the comfort of the workman. Humanitarian considerations aside, *it pays*—pays in quality and lower cost of output—when the worker is kept well nourished and in good hygienic surroundings. It is not, of course, possible for all works to go so far as some others, but the general principles are everywhere applicable."—*The Editors of the Engineering Magazine.*

tates a radical change from the method of paying by the hour, but perhaps conforms more closely than any other plan to the true theory of having the wage proportionate to the production.

THE PREMIUM PLAN.

The premium plan consists of setting a "time limit" upon the piece, within which limit the piece is expected to be completed. The man is paid his hourly wage for every hour he works upon the piece, and a specified premium for every hour he saves or does not work upon the piece inside the "time limit" set. The "time limits" and premium rates are not changed or cut. The advantages of this plan are: First, adaptability to ordinary work fitting in alongside of regular day work; second, its self-regulating feature, whereby the cost per piece is reduced to the employer and the wage per hour increased to the workman every time any improvement is made in production; third, its flexibility, due to the opportunity at the start of fixing a premium rate adapted to the conditions or business in hand, and the opportunity thereafter of setting either a liberal or close "time limit" to regulate cost per piece. It does not crowd out the medium machinist, but gives him encouragement to become better.

It also serves the foreman as the best indicator possible for setting the rates of men per hour, by affording him an opportunity to note the amount of product turned out in a given time.

Of these three plans of co-operation, the piece work plan requires the least knowledge in fixing prices; the differential plan requires a most extensive, minute and complete knowledge of the exact maximum rate of production. The premium plan requires a fair knowledge and judgment of machine-shop operations, in order to set a reasonable "time limit," but with proper premium rates the "time limits" may vary considerably, without varying the actual cost to a dangerous extent.

AN EQUITABLE METHOD.

An equitable method of scaling the rates for machine labor would tend to clear the atmosphere for those who are in doubt. An even rate for all machinists greatly handicaps the most skilled labor and benefits most the incompetent.

PLANNING A SHOP.

In planning a shop, however small, the possibility of its steady growth for many years to come, should be kept constantly in mind. No building should be erected that does not conform with part of the whole scheme of what the plant might be in the remote future. Another consideration is to provide for the unity of the plant, even though it trebles or quadruples in size.

NOTE.—A notable example of forethought in guarding against this possibility is the new Allis-Chalmers shop at Milwaukee. Provision has been made not only for its doubling, but for its expansion indefinitely, without loss of its integrity. The foundry and pattern shop run parallel to each other. At right angles and abutting the foundry are three machine shop bays, and at the other end of these bays, running out at right angles to them, is the erecting shop, so that the castings from the foundry go through the varions machine shop bays and into the erecting shop by the most direct routes. But the finest feature of this whole plant is that more bays may be added and the foundry, pattern shop and erecting shop lengthened without damaging the correct proportions of these departments relatively to each other, and without their growing apart.

DEPARTMENTS.

As an army is divided into divisions, brigades and companies, so are the large shops of the present day divided into departments, each of which has its official head.

A description of one will be sufficient to indicate the management of many. It is that of a well ordered pattern shop, which constituted a department in an extensive establishment.

The closing paragraphs of the article are especially worthy of attention:

"The shop was on the second floor of a separate building, having windows on all sides. Benches were around the outer walls, each having a window over it. Windows had shades to roll from both top and bottom, thus getting all possible light without the glare of the sun. Each bench had a tool rack at back of same for tools most commonly used, and drawers built in the bench for workmen's supplies and such tools as were only occasionally used. A small clothes closet with towel, rack and mirror over each bench completed the individual equipment. Each workman was required to leave his bench clean and in order at night.

"The shop floor was swept every night, and the refuse taken out, thereby lessening fire dangers. The lumber was kept in racks on edge, one size above another, the heavier pieces near the floor. In this way any piece could be taken out without moving any other. There was but one scrap pile in the shop. Instead of being thrown on the floor in a heap, pieces of lumber were properly sorted in a rack next the band-saw, shelves being provided for the smaller pieces and cross-bars for longer ones. But little time was lost getting nearly the right piece. No scrap was allowed under the benches. All pieces left had to be put in the rack or thrown in the waste. The floor under the benches was kept as clean as the rest of the shop.

"The machines were in groups in the center of the shop at one end, leaving a large floor space at the other end. This made the machines accessible from all sides. All machines were belted from below, thus avoiding belts across the shops. All face-plates, centers, wrenches calipers, etc., were kept on shelves under the lathe, and back of same to be easily accessible. Each workman was required to leave machines clean and in order.

SHOP MANAGEMENT.

"A great deal of work was only sandpapered after sawing. Some was only sawed. Saws were kept in order by the foreman and hung alongside the machine. The buzz planer was kept in the best possible condition. The 30-inch grindstone ran 450 revolutions per minute, taking water on its side, centrifugal force carrying it out. The stone was properly hooded, had tight and loose pulleys and iron frame. This machine had the fast cutting qualities of an emery grinder without its heating disadvantages. There was a small bench drill taking small twist drills and the ordinary wood bits up to one inch. There was one large trimmer and two smaller ones conveniently arranged about the shop. Round, concave and convex sandpapering blocks of standard sizes and curves were kept in a rack for that purpose.

"Time slips and approximate amount of material used were turned in to the foreman every night. The aim in this shop seemed to be to waste nothing; to do work at as low cost as possible; to do good work; to be considerate of the comforts and conveniences of the men, and to have good order and cleanliness everywhere."

Mr. Sibley, in the same journal, tells of a new foreman who reformed a shop noted for its untidiness:

"Shortly after his appearance on the scene, he started a crusade against dirt and rubbish; he had the carpenter build a bin in one corner of the yard, which was roofed over and fitted with a door, made in sections which could be successively inserted as the bin filled, after which he sawed in two a half dozen empty oil barrels, which were painted a bright red and on which were inscribed in large white letters the legend "Refuse;" these were located in convenient places. A laborer was selected and given an outfit consisting of broom, rake, shovel and wheelbarrow, and to him was assigned the task of raking up and wheeling away all litter from the yard; also once a day cleaning out the chips and scraps from the various boxes around the machine tools and depositing them in the bin.

"It is an axiom that 'Like begets like,' and the result of such surroundings was to make the men more careful and painstaking in their work, reducing the loss from waste and spoiled jobs, and also having the effect of drawing and holding a much better and more intelligent class of workmen than could otherwise be obtained for the same wages."

THE FOREMAN.

The man upon whom the success, comfort, character, and continuance of a "works" depends in the ultimate is the model foreman; he has been described as follows:

THE FOREMAN.

"A foreman is a chief or leading man, with those whom he is appointed to manage and direct; a successful foreman must be two-sided. He must not only keep the machinery under his charge in proper order, but he must discipline, direct and control the animated human machine that operates the inanimate tools. He should be a good mechanic as well as a good leader of men.

"To be a leader of men, he should cultivate perfect patience, forbearance and self-control, remembering that no man has controlled others who did not start by controlling himself. He should be even-tempered, or, if not born so, should not let anyone discover it. He should be strictly just, granting cheerfully everything due his employees, while jealously guarding his employer's interests, curbing his generosity in spending funds intrusted to him. A man so qualified should make a successful master mechanic, but will not long remain one in the present day of keen competition in all branches, calling for competent men for advancement."

The shop manager should be keen to remove and keep removed from the foreman such tasks as do not bear directly upon the production. The foreman must turn out the maximum of good products. To do this he must have his materials supplied to him without effort on his part. He must be left time to pick and choose the men best suited to the various classes of work. He must train them into rapid and skillful workmen. He must keep the machine tools in good order and see that they are worked to their full capacity, and the organization of which he is a part must make it possible for him to do all this, and must not distract his attention with anything else.

GANG BOSSES.

Gang bosses are now common on the erecting floors of even small shops, and there is no reason why gang bosses should not be appointed to oversee work on tools also. For example, the best lathe hand in a group of three or four is paid a trifle more and put in authority over them. The foreman instructs this man in regard to the work laid out ahead for these lathes, while the man in turn sees that it is carried out in detail. He is still a producer, but at the same time he is relieving the foreman of a considerable burden. In this way the foreman is left freer to plan out the more important details of his work.

A quotation expresses a strongly-felt need for information: "There are a great many problems for the small shop to solve, and the methods of the big shops furnish no solution. I mean the small shop that is just big enough to have troubles, but not big enough to have a fine organization—where one man has to do many things—where the question of *commercial* expediency turns up daily. I mean the shop employing from twenty-five to fifty hands and doing a variety of small work—sometimes a quantity of pieces, sometimes a limited number of special machines. Something a little beyond the jobbing machinists, but away behind the great sewing machine companies and small arms companies and type-writer concerns. *I sometimes think the manager of such a shop has a tougher job than a man with one ten times as large.*"

USEFUL RECIPES

"A machinist must love the tools he uses. They are his work-day companions during life; he learns to handle them with skillful gentleness; he learns to regard them with that sort of warmth of feeling which, during the long years of association with them, unfolds itself into a genuine love for those that have stood by him—have remained 'good to the last.' They are his 'never fail me's,' and with certain ones he would not part for ten times their cost to him."

WORKSHOP RECIPES.

A recipe, in popular usage, is a receipt for making almost any mixture or preparation.

Shop recipes pertain to the shop, and embrace a thousand processes, receipts, kinks and formulas, in common report among mechanics; these are passed along from man to man and frequently are printed and thus pass into literature.

Each establishment has its own particular collection of recipes, and many of them are applicable only in their own home-land, where necessity has given them birth. In the same way, each machinist, engineer and artisan should possess, as a part of his private equipment, a good store of these useful and most helpful items of knowledge.

Each one is advised to keep a memorandum-book in which he may record, from time to time, such recipes as, in his line of activity, may be considered valuable, eliminating and omitting—like old lumber—all such as belong to outside affairs and hence of no service to the compiler of what may be properly called a "list of useful recipes."

A few only, of many of such in current use, are here presented, more as a guide for such collections which each one can make for himself, rather than as a complete exhibit of recipes and formulas.

BABBITT METAL.—Babbitt metal is an alloy, composed of tin 45.5, copper 1.5, antimony 13, lead 40 parts.

Formerly the alloy, originated by Isaac Babbitt, was used for all purposes, but there is no one composition that will bring equally good results in all kinds of machinery, hence are given the following:

WORKSHOP RECIPES.

Babbitt metal for light duty is composed of 89.3 parts of copper, 1.8 parts of antimony, 8.9 parts of lead.

Babbitt metal for heavy bearings is composed of 88.9 parts of copper, 3.7 parts of antimony, 7.4 parts of lead.

SOLDERS.—Alloys employed for joining metals together are termed "solders," and they are commonly divided into two classes: hard and soft solders. The former fuse only at a red heat, but soft solders fuse at comparatively low temperatures. Common solders are composed of equal parts of tin and lead; fine solder, two parts of tin to one of lead; cheap solder, one of tin and two of lead; common pewter contains four lead to one of tin; German silver solder is composed of copper 38, zinc 54, nickel 8 parts=100.

HOW TO SOLDER ALUMINIUM.—In soldering aluminium, it is necessary to bear in mind that upon exposure to the air a slight film of oxide forms over the surface of aluminium, and afterwards protects the metal. The oxide is the same color as the metal, so that it cannot easily be distinguished. The idea in soldering is to get underneath this oxide while the surface is covered with the molten solder. With the following procedure quick manipulation is necessary: 1, clean off all dirt and grease from the surface of the metal with a little benzine; 2, apply the solder with a copper bit, and when the molten solder is

NOTE.—The best treatment for wrought steel, which has a knack of growing gray and lustreless, is to first wash it very clean with a stiff brush and ammonia soapsuds, rinse well, dry by heat if possible, then oil plentifully with sweet oil, and dust thickly with powdered quick lime. Let the lime stay on two days, then brush it off with a clean very stiff brush. Polish with a softer brush, and rub with cloths until the lustre comes out. By leaving the lime on, iron and steel may be kept from rust almost indefinitely.

HOW TO SOLDER ALUMINIUM.

covering the surface of the metal, scratch through the solder with a little wire scratch-brush. By this means you break up the oxide on the surface of the metal underneath the soldering, and the solder, containing its own flux, takes up the oxide and enables you, so to speak, to tin the surface of the aluminium.

TO TIN A SOLDERING IRON.—File the bolt clean over the part to which the tinning is to be applied. Wet this part with soldering fluid. Heat the bolt till it is hot enough for use and rub it into solder placed upon a piece of tin. If this does not secure an even coating, heat the bolt again and attend to the bare spots in the same manner as before. If you use a soldering pot, you can keep sal-ammoniac on top of the solder, and dip the iron into the solder through the liquid.

BRAZING CAST IRON.—The reason that cast iron cannot be brazed with spelter as wrought iron can, is that the graphitic carbon in the former prevents the adhesion of the spelter, as a layer of dust prevents the adhesion of cement to stone or brick. A process to remove this graphite has been patented in Germany, consisting essentially in applying to the surfaces to be united an oxide of copper and protecting them against the influence of the air with borax or silicate of soda. When the joint is heated the oxide of copper gives up its oxygen to the graphite, converting it into carbonic oxide gas, which escapes in bubbles, while particles of metallic copper are deposited on the iron.

NOTE.—For removing rust from iron the following is given: Iron may be quickly and easily cleaned by dipping in or washing with nitric acid one part, muriatic acid one part and water twelve parts. After using wash with clean water.

Any oxide of iron which may be formed is dissolved by the borax, and the surfaces of the iron, thus freed from graphite, unite readily with the spelter which is run into the joint before it cools, the copper already deposited on the iron assisting the process. The inventor claims that cast iron can in this way be readily brazed in an ordinary blacksmith's forge.

A CHEAP LUBRICANT FOR MILLING AND DRILLING.—Dissolve separately in water, 10 pounds of whale-oil soap and 15 pounds of sal-soda. Mix this in 40 gallons of clean water. Add two gallons of best lard oil, stir thoroughly, and the solution is ready for use.

SODA WATER FOR DRILLING.—Dissolve three-fourths to one pound of sal-soda in one pailful of water.

FUSING POINTS OF TIN-LEAD ALLOYS.

Tin 1 to lead 10, . . .	558° F.	Tin 1½ to lead 1, . . .	334° F.
" 1 " " 5, . . .	511° F.	" 2 " " 1, . . .	340° F.
" 1 " " 3, . . .	482° F.	" 3 " " 1, . . .	356° F.
" 1 " " 2, . . .	441° F.	" 4 " " 1, . . .	365° F.
" 1 " " 1, . . .	370° F.	" 5 " " 1, . . .	378° F.

USE OF LIME TO KEEP SHOP FLOORS CLEAN.—In the Elevated Railroad shops of Chicago it has been found that the use of lime aids in cleaning up the shop floors and in keeping them in good condition. This lime is simply swept over the floor every day, in addition to the regular cleaning. Very little remains on the floor after the sweeping, but it is sufficient to counteract the effect of the oil

NOTE.—Among all the soft metals in use there are none that possess greater anti-friction properties than pure lead; but lead alone is impracticable, for it is so soft that it cannot be retained in the recess of a bearing. In most of the best and most popular anti-friction metals in use, sold under the name "Babbitt," the basis is lead.

and grease, and to make it easy at the beginning of each day to clean up what has fallen the previous day, as well as to improve the appearance of the floor.

NICKEL-PLATING SOLUTION.—To a solution of 5 to 10 per cent. of chloride of zinc (5 grains, drams or ounces, to 95 of water, or 10 parts to 90 of water) add enough sulphate of nickel to produce a strong green color, and bring to boiling boint in a porcelain or stoneware vessel. The piece, or article, to be plated must be free from grease (by dipping in dilute acid); it is introduced by hanging on wire by a stick across the vessel, so that it touches the sides as little as possible. Boiling is continued from 30 to 60 minutes, water being added to supply that lost by evaporation. During boiling, the nickel is deposited as a white and brilliant coating. Boiling for two or three hours does not increase the thickness of the coating. As soon as the object appears to be plated, wash in water having a little chalk in suspension, and then carefully dry. Polish the article with chalk. The chloride of zinc and nickel sulphate must be free from metals precipitable by iron. If, during the precipitation of the nickel on the articles, the solution becomes colorless, more nickel sulphate should be added. The liquid spent may be used again by exposing it to the air until the contained iron (from the articles) is precipitated, filtering and adding the salts as above.—W. B. BURROW in *Power*.

MARKING SOLUTION.—Dissolve one ounce of sulphate of copper (blue vitriol) in four ounces of water and half a teaspoonful of nitric acid. When this solution is applied on bright steel or iron, the surface immediately turns cop

WORKSHOP RECIPES.

per color, and marks made by a sharp scratch-awl will be seen very distinctly.

For Bluing Brass.—Dissolve one ounce (or any other unit in the same proportion will do) of antimony chloride in twenty ounces of water and add three ounces of pure hydrochloric acid. Place the warmed brass article into this solution until it has turned blue. Then wash it and dry in sawdust.

To Protect Bright Work from Rust.—Use: 1, a mixture of one pound of lard, one ounce of gum camphor, melted together, with a little lamp-black; or, 2, a mixture of lard oil and kerosene, in equal parts; or, 3, a mixture of tallow and white lead; or, 4, of tallow and lime.

Varnish for Copper.—To protect copper from oxidation a varnish may be employed which is composed of carbon disulphide 1 part, benzine 1 part, turpentine oil 1 part, methyl alcohol 2 parts and hard copal 1 part. The varnish is very resisting; it is well to apply several coats of it to the copper.—*Die Werkstatt.*

To Remove the Sand and Scale from Iron Castings.—Immerse the parts in a mixture composed of one part of oil of vitriol to three parts of water; in six to ten hours remove the objects, and wash them thoroughly with clean water; this is called "pickling." A weaker solution can be used by allowing a longer time for the action of the solution.

Note.—A common sewing needle held in a suitable handle makes an excellent scriber for accurate work. It is so cheap that grinding is unnecessary, as, when dull, it can be simply replaced by a new one. The point on a needle is ground by an expert, and is far superior to anything possible by the ordinary machinist.

EXTRACTING BROKEN TOOLS.

RUST JOINT COMPOSITION.—This is a cement made of sal-ammoniac 1 lb., sulphur ½ lb., cast-iron turnings 100 lbs.; the whole should be thoroughly mixed and moistened with a little water; if the joint is required to set very quick, add ¼ lb. more sal-ammoniac. Care should be taken not to use too much sal-ammoniac, or the mixture will become rotten.

RUST JOINT (slow setting)—Two parts sal-ammoniac, 1 flour of sulphur, 200 iron borings. This composition is the best, if joint is not required for immediate use.

CEMENT FOR FASTENING PAPER OR LEATHER TO IRON.—The following ingredients are required: 1 pound best flour, ¼ pound best glue, ½ pound granulated sugar, ½ ounce powdered borax, ½ ounce sal-ammoniac, ¼ ounce alum. Soak the glue in three pints of soft water for 12 hours, or if you have glue already melted, pour in the quantity. Mix the flour in one quart of soft water, mix all together, and boil over a slow fire, or cook with a steam jet. When cool it is ready for use. The face of the pulley or surface where the leather is to be applied must be thoroughly clean and free from grease.

EXTRACTING BROKEN TOOLS.—To extract the fragment of a drill, punch or steel tool, which has broken off while working any metal but iron or steel. The object containing the broken-off piece is immersed in a boiling solution composed of 1 part common alum to 4 or 5 parts of water. This solution may be held in a vessel of stoneware, porcelain, copper, etc., but not of iron. The object should be so placed that the gaseous bubbles that form as the alum attacks the metal are easily disengaged. At the end of a short time the fragment of the tool is entirely dissolved. A piece of steel spring, one-sixteenth of an inch thick, dissolved in a concentrated solution of alum in three-quarters of an hour.—*Herr Bornhauser, Prussia.*

LUBRICANTS FOR USE IN CUTTING BOLTS AND TAPPING NUTS.—Dissolve 1½ pounds of sal-soda in three gallons of warm water, then add one gallon of pure lard oil. This is called a soda solution. Pure lard oil is the best for fine, true work. Never use mineral oil.—*Acme Machinery Co.*

SOLDERING FLUIDS.—Add pieces of zinc to muriatic acid until the bubbles cease to rise, and the acid may be be used for soldering with soft solder.

Mix one pint of grain alcohol with two tablespoonfuls of chloride of zinc. Shake well. This solution does not rust the joint as acids are liable to do.

When soldering lead, use tallow or resin as a flux, and use a solder consisting of one part tin and 1½ parts lead.

PREVENTING RUST ON TOOLS.—To prevent rust on tools, use vaseline, to which a small amount of gum camphor has been added; heat together over a slow fire.

IN LAYING OUT WORK—on planed surfaces of steel or iron, use blue vitriol and water on the surface. This will copper-plate the surface nicely, so that all lines will show plainly. If on oily surfaces, add a little oil of vitriol; this will eat the oil off and leave a nicely coppered surface.

A METAL THAT WILL EXPAND IN COOLING—is made of 9 parts lead, 2 parts antimony, and 1 part bismuth. This metal will be found very valuable in filling holes in castings.

TO COPPER THE SURFACE OF IRON OR STEEL WIRE.—Have the wire perfectly clean, then wash with the following solution, when it will present at once a coppered surface: Rain water, three pounds; sulphate of copper, 1 pound.

TO KEEP WATER FROM FREEZING.—Common salt is the best material, and by using common (agricultural) salt the expense is the least.

AN OIL THAT WILL NOT GUM.—Take good Florence olive oil and put it in a bottle with some strips of zinc and shavings of lead, which should be clean. Expose the bottle to sunlight until the curdy matter ceases to be deposited; this will require considerable time, but the oil when decanted will be of very fine quality and will not gum.

AID TO THE INJURED IN ACCIDENTS.

A noted surgical writer has said that the fate of an injured person depends upon the acts of the one into whose hands he first falls. In the time of an accident, the presence of a person with a knowledge of what to do and the presence of mind to carry such knowledge into effect, is invaluable.

NOTE.—Few subjects can more usefully employ attention and study than the proper treatment and first remedies made necessary by the peculiar and distressing accidents to which persons are liable who are employed in or around machinery; under the title of "First Aid," etc., there are most helpful instructions printed and distributed, well worth the study of the advanced machinist; where enough in number of the trade are together, it would be worthy of praise, for owners to provide each year, a short course of lectures, illustrated, for the benefit of those unfortunately injured, as they are sure to be from time to time, and in a greater or less degree.

USEFUL RECIPES.

A clear head, a steady hand and some practical knowledge of what is to be done, are what are needed in the first moments of sudden disaster of any kind; an experienced machinist or engineer is nearly always found, in the confusion incident to such a time, to be the one most competent to advise and direct the efforts made to avert the danger to life, limb or property, and to remedy the worst after-effects.

To fulfill this responsibility is worth much previous preparation, so that the best things under the circumstances may be done quickly and efficiently. To this end the following advice is given relating to the most common accidents which are likely to happen, in spite of the utmost care and prudence.

1, Keep cool. 2, Summon a surgeon at once. 3, Send a written message, describing the accident and injury if possible, in order that the surgeon may know what instruments and remedies to bring. 4, Remove the patient to a quiet, airy place where the temperature is comfortable. 5, Keep bystanders at a distance. 6, Handle the patient gently and quietly.

IN CASE OF WOUNDS.

Arrange the injured person's body in a comfortable position; injuries to the head require that the head be raised higher than the level of the body; when practical

NOTE.—An entire chapter on "*Accidents and how to avoid them,*" would be useful; the first advice might be this: To resolve firmly *to be constantly careful*, and *determine*, with all the solemnity of an oath, neither to be injured oneself, nor to cause injury to another. This has been the author's rule and it has resulted well; again: *always to look in the direction in which one is moving.*

lay the patient on his back with the limbs straightened out in their usual natural position. Unless the head be injured, have the head on the same level as the body. Loosen the collar, waist-band and belts. If the patient should be faint, have his head rather lower than his feet. If the arm or leg be injured, it may be slightly raised and laid on a cushion or pillow.

Watch carefully if unconscious.

If vomiting occurs, turn the patient's body on one side, with the head low, so that the matters vomited may not go into the lungs.

If a wound be discovered in a part covered by the clothing, cut the clothing in the seam. Remove only sufficient clothing to uncover and inspect the wound.

All wounds should be covered and dressed as quickly as possible. If a severe bleeding should occur, see that this is stopped, if possible, before the wound is finally dressed.

Bleeding is of three kinds: 1, from the arteries which lead from the heart; 2, that which comes from the veins which take the blood back to the heart; 3, that from the small veins which carry the blood to the surface of the body. In the first, the blood is bright scarlet and escapes as though it were being pumped. In the second, the blood is dark red and flows away in an uninterrupted stream. In the third, the blood oozes out. In some wounds all three kinds of bleeding occur at the same time.

The simplest and best remedy to stop the bleeding is to apply direct pressure on the external wound by the fingers. Should the wound be long and gaping, a compress of some soft material large enough to fill the cavity may be pressed into it; but this should always be avoided, if possible, as it prevents the natural closing of the wound.

Pressure with the hands will not suffice to restrain bleeding in severe cases for a great length of time, and recourse must be had to a ligature, this can best be made with a pocket handkerchief or other article of apparel, long enough and strong enough to bind the limb. Fold the article neck-tie fashion, then place a smooth stone, or anything serving for a firm pad, on the artery, tie the handkerchief loosely, insert any available stick in the loop and proceed to twist it, as if wringing a towel, until just tight enough to stop the flow.

Examine the wound from time to time, lessen the compression if it becomes very cold or purple, or tighten up the handkerchief if it commences bleeding.

Some knowledge of anatomy is necessary to guide the operator where to press. Bleeding from the head and neck requires pressure to be placed on the large artery which passes up beside the windpipe and just above the collar bone. The artery supplying the arm and hand runs down the inside of the upper arm, almost in line with the coat seam, and should be pressed with the finger or thumb.

The artery feeding the leg and foot can be felt in the crease of the groin, just where the flesh of the thigh seems to meet the flesh of the abdomen, and this is the best place to apply the ligature. In arterial bleeding, the pressure must be put between the heart and the wound, while in *venous* bleeding it must be beyond the wound, to stop the flow as it goes toward the heart.

AID TO THE INJURED.

In any case of bleeding, the person may become weak and faint; unless the blood is flowing actively, this is not a serious sign, and the quiet condition of the faint often assists nature in staying the bleeding, by allowing the blood to clot and so block up any wound in a blood vessel.

Unless the faint is prolonged or the patient is losing much blood, it is better not to hasten to relieve the faint condition; when in this state anything like excitement should be avoided, external warmth should be applied, the person covered with blankets, and bottles of hot water or hot bricks to the feet and arm-pits.

In Case of Cuts.

The chief points to be attended to are: 1, arrest the bleeding; 2, remove from the wound all foreign bodies as soon as possible; 3, bring the wounded parts opposite to each other and keep them so; this is best done by means of strips of adhesive plaster, first applied to one side of the wound and then secured to the other; these strips should not be too broad, and space must be left between the strips to allow any matter to escape. Wounds too extensive to be held together by plaster must be stitched by a surgeon, who should always be sent for in severe cases.

For washing a wound, to every pint of water add 2½ teaspoonfuls of carbolic acid and 2 tablespoonfuls of glycerine—if these are not obtainable, add 4 tablespoonfuls of borax to the pint of water—wash the wound, close it, and

NOTE.—Severe bleeding is not usual after machinery and railroad accidents, as the wounds inflicted are such that the blood vessels are generally closed, because they are torn and twisted off. This is not the case with cuts.

apply a compress of a folded square of cotton or linen; wet it in the solution used for washing the wound and bandage down quickly and firmly.

If the bleeding is profuse, a sponge dipped in very hot water and wrung out in a cloth should be applied as quickly as possible—if this is not to be had, use ice, or cloth wrung out in ice water.

Wounds heal in two ways: 1, rapidly by primary union, without suppuration, and leaving only a very fine scar; 2, slowly by suppuration and the formation of granulations and leaving a large red scar.

Do not touch the wounds with the hands either during examination, or while applying dressings, unless they have been previously made clean.

After dressing a wound, do no more to the patient unless necessary to restore him to consciousness or relieve faintness.

If suffering from shock, place him in a comfortable position and await the arrival of the surgeon.

In Case of Broken Bones.

The treatment consists of: 1, carefully removing or cutting away, if more convenient, any of the clothes which

---

NOTE.—"Bones do not break directly across; they break zig-zag and one bone overlaps the other, sometimes with many sharp points, and if you pick up a patient and do not pay special attention to how you carry him, the first thing you know, one sharp end of the bone will be sticking out. This is a great element of danger to the case. If he is to be conveyed some distance, and no one is on hand to attend to him, the best thing to do is to apply a splint and bandage. Take a piece of board about four inches wide and two and one-half feet long and put it on the back side of the leg, then put two or three turns of the bandage around it. This will answer well enough to convey the patient some distance."—J. EMMON BRIGGS, M.D.

are compressing or hurting the injured parts; 2, very gently replacing the bones in the natural position and shape, as nearly as possible, and putting the part in a position which gives most ease to the patient; 3, applying some temporary splint or appliance, which will keep the broken bones from moving about and tearing the flesh; for this purpose, pieces of wood, pasteboard, straw, or firmly folded cloth may be used, taking care to pad the splints with some soft material and not to apply too tightly, while the splints may be tied by loops of rope, string or strips of cloth; 4, conveying the patient home or to an hospital.

To get at a broken limb or rib, the clothing must be removed, and it is essential that this be done without injury to the patient; the simplest plan is to rip up the seams of such garments as are in the way. Boots must be cut off. It is not imperatively necessary to do anything to a broken limb before the arrival of a doctor, except to keep it perfectly at rest.

How to Carry an Injured Person.

In case of an injury where walking is impossible, and lying down is not absolutely necessary, the injured person may be seated in a chair, and carried; or he may sit upon a board, the ends of which are carried by two men, around whose necks they should place his arms so as to steady himself.

Where an injured person can walk he will get much help by putting his arms over the shoulders and round the necks of two others.

A seat may be made with four hands and the person

USEFUL RECIPES.

may be thus carried and steadied by clasping his arms around the necks of his bearers.

If only one person is available and the patient can stand up, let him place one arm round the neck of the bearer, bringing his hand on and in front of the opposite shoulder of the bearer. The bearer then places his arm behind the back of the patient and grasps his opposite hip, at the same time catching firmly hold of the hand of the patient resting on his shoulder, with his other hand; then by putting his hip behind near the hip of the patient, much support is given, and if necessary, the bearer can lift him off the ground and as it were, carry him along.

To carry an injured person by a stretcher (which can be made of a door, shutter or settee—with blankets or shawls or coats for pillows), three persons are necessary. In lifting the patient on the stretcher *it should be laid with its foot to his head*, so that both are in the same straight line; then one or two persons should stand on each side of him, raise him from the ground and slip him on the stretcher;

NOTE.—A broad board or shutter may be employed as a stretcher; but if either of them be used, some straw, hay, or clothing should be placed on it, and then a piece of stout cloth or sacking; the sacking is useful in taking the patient off the stretcher when he arrives at the bedside.

Always test a stretcher before placing the patient on it. Place an uninjured bystander upon it and let the bearers carry him a short distance, practicing placing him upon it, laying down, raising up, turning around, etc.

Never allow stretchers to be carried on the bearers' shoulders.

Always carry patient feet-foremost, except when going up a hill. In cases of fractured thigh or fractured leg, if the patient has to be carried down hill, carry the stretcher head-first.

In carrying a patient on a stretcher, care should be taken to avoid lifting the stretcher over walls or ditches.—*Johnson's First Aid Manual.*

AID TO THE INJURED.

this to avoid the necessity of any one stepping over the stretcher, and the liability of stumbling.

If a limb is crushed or broken, it may be laid upon a pillow with bandages tied around the whole (*i. e.*, pillow and limb) to keep it from slipping about. In carrying the stretcher the bearers should "break step" with short paces; hurrying and jolting should be avoided and the stretcher should be carried so that the patient may be in plain sight of the bearers.

IN CASE OF BURNS AND SCALDS.

Burns are produced by heated solids or by flames of some combustible substance; *scalds* are produced by steam or a heated liquid. The severity of the accident depends mainly, 1, on the intensity of the heat of the burning body, together with, 2, the extent of surface, and, 3, the vitality of the parts involved in the injury; thus, a person may have a finger burned off with less danger to life than an extensive scald of his back.

In severe cases of burns or scalds the clothes should be

NOTE.—The immediate effect of scalds is generally less violent than that of burns; fluids not being capable of acquiring so high a temperature as some solids, but flowing about with great facility, their effects become most serious by extending to a large surface of the body. A burn which instantly destroys the part which it touches may be free from dangerous complication, if the injured part is confined within a small compass; this is owing to the peculiar formation of the skin.

The skin is made up of two layers; the outer one has neither blood vessels nor nerves, and is called the scarf-skin or cuticle; the lower layer is called the true skin, or cutis. The latter is richly supplied with nerves and blood vessels, and is so highly sensitive we could not endure life unless protected by the cuticle. The skin, while soft and thin, is yet strong enough to enable us to come in contact with objects without pain or inconvenience.

removed *with the greatest care*—they should be carefully cut, at the seams, and not pulled off.

In scalding by burning water or steam, cold water should be plentifully poured over the person and clothes, and the patient then carried to a warm room and laid on the floor or a table, but not put to bed as there it becomes difficult to attend further to the injuries.

The secret of the treatment is to avoid chafing. *and to keep out the air.* Save the skin unbroken, if possible, taking care not to break the blisters; after removal of the clothing, an application to the injured surface, of a mixture of *soot and lard*, is, according to practical experience, an excellent and efficient remedy. The two or three following methods of treatment also are recommended according to convenience in obtaining the remedies.

Take ice well crushed or scraped, as dry as possible, then mix it with fresh lard until a broken paste is formed; the mass should be put in a thin cambric bag, laid upon the burn or scald and replaced as required. So long as the

---

NOTE.—A method in use in the New York City Hospital known as the "glue burn mixture," is composed as follows: "7½ Troy oz. white glue, 16 fluid oz. water, 1 fluid oz. glycerine, 2 fluid drachms carbolic acid. Soak the glue in the water until it is soft, then heat on a water bath until melted; add the glycerine and carbolic acid and continue heating until, in the intervals of stirring, a glossy, strong skin begins to form over the surface. Pour the mass into small jars, cover with paraffine papers and tin foil before the lid of the jar is put on and afterwards protect by paper pasted round the edge of the lid. In this manner the mixture may be preserved indefinitely. When wanted for use, heat in a water bath and apply with a flat brush over the burned part."

AID TO THE INJURED.

ice and lard are melting, there is no pain from the burn; return of pain calls for a repetition of the remedy.

In burns with lime, soap, lye or *any caustic alkali*, wash abundantly with water (do not rub), and then with weak vinegar or water containing a little sulphuric acid; finally apply oil, paste or mixture as in ordinary burns.

INSENSIBILITY FROM SMOKE.

To recover a person from this, dash cold water in the face, or cold and hot water alternately. Should this fail, turn the patient on his face with the arms folded under his forehead; apply pressure along the back and ribs and turn the body gradually on the side; then again slowly on the face, repeating the pressure on the back; continue the alternate rolling movements about sixteen times a minute until breathing is restored. A warm bath will complete the cure.

HEAT-STROKE OR SUN-STROKE.

The worst cases occur where the sun's rays never penetrate and are caused by the extreme heat of close and confined rooms, overheated workshops, boiler-rooms, etc. The symptoms are: 1, a sudden loss of consciousness; 2, heavy breathing; 3, great heat of the skin, and 4, a marked absence of sweat.

Treatment.—The main thing is to lower the temperature. To do this, strip off the clothing, apply chopped ice wrapped in flannel to the head; rub ice over the chest, and place pieces under the armpits and at the side. If no ice can be had use sheets or cloth wet with cold water, or the body can be stripped and sprinkled with cold water from a common watering pot.

USEFUL RECIPES.

FROST BITE.

No warm air, warm water, or fire should be allowed near the frozen parts until the natural temperature is nearly restored; rub the affected parts gently with snow or snow water in a cold room; the circulation should be restored very slowly; and great care must be taken in the after-treatment.

TO REMOVE FOREIGN BODIES IN THE EYE.

Take hold of the upper lid and turn it up so that you can look on the inside of the upper lid. Have the patient make several movements with the eye; first up, then down, to the right side and to the left. Then take a tooth-pick with a little piece of absorbent cotton wound around the end and moistened in cold water, and swab it out. The foreign body will adhere to the swab and you will get the object out of the eye without any trouble.

DEATH SIGNS.

The note following is added with some doubt as to its useful application, but this whole subject relates to very serious occurrences, and it may be well, considering all things, to print it.

NOTE.—Hold the hand of the person apparently dead before a candle or other light, the fingers stretched, one touching the other, and look through the space between the fingers toward the light. If the person is living, a scarlet red color will be seen where the fingers touch each other, due to the still circulating fluid blood as it stows itself between the transparent, but yet congested tissues. When life is extinct this phenomenon ceases. Another method is to take a cold piece of polished steel, for instance a a razor blade or table knife, hold this under the nose and before the mouth; if no moisture condenses upon it, it is safe to say that there is no breathing.

In cases of severe shock, etc., it is not sufficient to test the cessation of the heart-beat by feeling of the pulse at the wrist. An acute ear can generally detect the movement of the heart by the sound when the ear is applied to the chest or back. The electric battery may be used under the advice of a physician in doubtful cases.

AID TO THE INJURED.

THE D'ARSONVILLE METHOD OF RESUSCITATION FROM ELECTRIC SHOCK.

The proof of the efficacy of this method is now so complete that no one following pursuits in which there is danger from electric shocks, is justified in neglecting to make himself familiar with it.

First, it must be appreciated that accidental shocks seldom result in absolute death unless the victim is left unaided for too long a time, or efforts at resuscitation are suspended too early.

In the majority of instances the shock is only sufficient to suspend animation temporarily, owing to the momentary and imperfect contact of the conductors, and also on account of the indifferent parts of the body submitted to the influence of the current. It must be appreciated also that the body under the conditions of accidental shocks seldom receives the full force of the current in the circuit, but only a shunt current, which may represent a very insignificant part of it.

When an accident of this nature occurs, the following rules should be promptly adopted and executed with due care and deliberation:

1.—Remove the body at once from the circuit by breaking contact with the conductors. This may be

NOTE.—The introduction of electricity as an industrial and useful agent has been attended with many distressing accidents, causing great suffering and frequently loss of life; while happily these accidents are becoming less frequent, none the less it is important to both know and observe the rules for safety so constantly repeated.

Currents of electricity passed through the limbs affect the nerves with certain painful sensations, and cause the muscles to undergo involuntary contractions. The effect experienced by the discharge with high potential difference is that of a sharp and painful *shock*.

RESUSCITATION FROM ELECTRIC SHOCK.

accomplished by using a dry stick of wood, which is a non-conductor, to roll the body over to one side, or to brush aside a wire, if that is conveying the current. When a stick is not at hand, any dry piece of clothing may be util-

Fig. 299.

ized to protect the hand in seizing the body of the victim, unless rubber gloves are convenient. If the body is in contact with the earth, the coat-tails of the victim, or any loose or detached piece of clothing, may be seized with impunity to draw it away from the conductor. When this has been accomplished, observe Rule 2.

Fig. 300.

2.—Turn the body upon the back, loosen the collar and clothing about the neck, roll up a coat and place it under the shoulders, so as to throw the head back, and then make efforts to establish artificial respiration (in other words,

AID TO THE INJURED.

make him breathe), just as would be done in case of drowning. To accomplish this, kneel at the subject's head, facing him, and seizing both arms draw them forcibly to their full length over the head (as shown in fig. 299), so as to bring them almost together above it, and hold them there for two or three seconds only. (This is to expand the chest and favor the entrance of air into the lungs.)

Then carry the arms down to the sides and front of the chest, firmly compressing the chest walls, and expel the air from the lungs (as shown in fig. 300). Repeat this manœuvre at least sixteen times per minute. These efforts should be continued unremittingly for at least an hour, or until natural respiration is established.

3.—At the same time that this is being done, some one should grasp the tongue of the subject with a handkerchief or piece of cloth to prevent it slipping, and draw it forcibly out when the arms are extended above the head, and allow it to recede when the chest is compressed.

This manœuvre should be repeated at least sixteen times per minute. This serves the double purpose of freeing the throat so as to permit air to enter the lungs, and also, by exciting a reflex irritation from forcible contact of the under part of the tongue against the lower teeth, frequently stimulates an involuntary effort at respiration. If the teeth are clenched and the mouth cannot be opened

---

NOTE.—Linemen's rubber gloves are designed to prevent the frequent and often fatal accidents occurring to linemen from shock while handling electric light wires or other wires in contact with the same, and also the dangers of line work from lightning in stormy weather. The gloves are also useful in handling the strong acids of batteries, being impervious to the same.

readily to secure the tongue, force it open with a stick, a piece of wood, or the handle of a pocket-knife.

Commence always with pulling the tongue, but the method of artificial respiration should be applied at the same time if possible.

Concurrent efforts should be made to bring back the circulation by rubbing the surface of the body, smartly striking it with the hands or wet towels, throwing from time to time water on the face, and causing the victim to inhale ammonia and vinegar.

The dashing of cold water into the face will sometimes produce a gasp and start breathing, which should then be continued as directed above. If this is not successful the spine may be rubbed vigorously with a piece of ice. Alternate applications of heat and cold over the region of the heart will accomplish the same object in some instances. It is both useless and unwise to attempt to administer stimulants to the victim in the usual manner by pouring it down his throat.

While this is being done, a physician should be summoned.

COLIC.

Apply heat in the form of hot water bags, or bottles, hot plates, and mustard plaster over the seat of pain. Hot baths are sometimes useful.

VOMITING.

Give large amounts of hot water, as hot as can be taken. Patient should always lie down. Small bits of ice held in the mouth or swallowed, will relieve vomiting caused by indigestion. A lump of ice held against the pit of the stomach will sometimes bring relief. When other means fail, apply a mustard plaster to the pit of the stomach.

BANDAGES.

These are frequently made by cutting a piece of linen or calico forty inches square into two pieces crosswise, and may be used either as a "broad" or "narrow" bandage. The broad is made by spreading the bandage out, then bringing the point down to the lower border, and then folding into two folds. The narrow is made by drawing the point down to the lower border, and then folding into three; a bandage should always be fastened either by a pin or by being tied with a reef-knot.

When rolled into strips, the following sizes have been found advantageous; for hand, fingers, and toes, one inch wide, one to two yards in length; for arms, legs, and extremities, two and a half inches wide, seven yards in length; for thigh, groin, and trunk, three inches wide and eight to ten yards in length.

POULTICES.

These outward applications are useful to relieve sudden cramps and pains due to severe injuries, sprains and colds. The secret of applying a mustard poultice is to apply it hot and keep it so by frequent changes—if it gets cold and clammy it will do more harm than good. A poultice to be of any service and hold its heat should be from one-half to one inch thick. To make it, take flaxseed, oatmeal, rye meal, bread, or ground slippery elm; stir the meal slowly into a bowl of boiling water, until a thin and smooth dough is formed. To apply it take a piece of old linen of the right size, fold it in the middle, spread the dough evenly on one-half of the cloth and cover it with the other.

To make a "mustard paste" as it is called, mix one or two tablespoonfuls of mustard and the same of fine flour, with enough water to make the mixture an even paste; spread it neatly with a table knife on a piece of old linen, or even cotton cloth. Cover the face of the paste with a piece of thin muslin.

CARE OF SELF.

Want of care is the cause of more injuries than want of knowledge; hence care and knowledge should be well commingled. It is easier to form a habit than to break one off, therefore we should strive to form correct habits in relation to avoiding accidents.

PRINCIPLES INVOLVING THE RESPONSIBILITY OF EMPLOYERS FOR THE SAFETY OF THEIR WORKMEN.

The following are abstracts chiefly from recent decisions in the higher courts of various states. In general they are indicative of the law throughout the country:

The risks and dangers assumed by an employee are such as are incident to his employment, such as are known to him, and such as are obvious and patent. (*Pa. 9 Dist. Rep. 291.*)

To show that an employee assumed the risks connected with the operation of a machine it must appear, not only that a defect was patent, but that he knew the danger of operating it in its defective condition. (*Minn. 92 N. W. Rep. 981.*)

NOTE.—The portions of the above abstracts printed *in italics* are the Law References to cases which have established and confirmed verdicts in test cases. *The American Machinist* is entitled to the credit for this list of cases.

A minor cannot recover for an injury received while working a machine when the danger of the machine is such as can readily be seen, and he was duly instructed in its use, and the machine was in good condition. (*Pa. 17 L. L. Rep. 247.*)

Where an employee is injured while obeying the orders of his employer to perform work in a dangerous manner, the employer is liable, unless the danger is so imminent that a man of ordinary prudence would not incur it. (*88 Ill. App. Ct. Rep. 169.*)

In order to recover for defects in the appliances of the business, the employee must establish by proof three propositions: First, that the appliance was defective; second, that the employer had notice or knowledge of such defect, or should have had; third, that the employee did not know of the defect, and had not equal means of knowing with the employer. (*87 Ill. App. Ct. Rep. 551.*)

It is incumbent on an employer to exercise ordinary care to provide and maintain a reasonably safe place and reasonably safe machinery and appliances in which and by means whereof an employee is to perform his service. (*U. S. Ct. App. 163 Fed. Rep. 265.*)

It is not only the duty of an employer to warn his employee against the danger that lies in the unskillful or careless operation of machinery involved in his employment or task, but he should also give suitable instructions as to the manner of using the same so as to avoid danger. (*13 Pa. Sup. Ct. Rep. 219.*)

While it is settled law that an employee assumes the ordinary and apparent risks of his employment, he does not assume the risk from defects in the plant itself, which the employer is bound to make and keep in a reasonably safe condition. (*Me. 46 Atl. Rep. 804.*)

An experienced workman of mature years cannot continue to operate a machine, which he knows is dangerous, without assuming the risk, simply because the employer has assured him that it is safe, when the workman has just as much knowledge of the danger arising from its use as the employer. (*Mich. 82 N. W. Rep. 797.*)

The burden of proving that an accident arose out of and in the course of the workman's employment lies on the employee; but the burden of proving serious and willful misconduct lies on the employer. (*Eng. 80 L. T. 317.*)

If the negligence of the employer operates as a concurring and efficient cause of an injury to an employee, his liability will not be relieved by the negligence of fellow-employees also concurring. (*88 Ill. App. Ct. Rep. 162.*)

To constitute fellow-servants they must either directly co-operate in the particular business so that they may exercise an influence on one another promotive of proper caution, or their duties must be such as to bring them into habitual association so that they may exercise such influence on each other. (*88 Ill. App. Ct. Rep. 169.*)

TABLES

AND

INDEX

TABLES
USEFUL FOR MACHINISTS.

The speeds required for machining advantageously the different materials, according to the different diameters. may be termed "surface speeds." Roughly speaking, the surface speeds for the different materials vary in comparatively narrow limits. We may assume the following speeds for the following:

TABLE OF SURFACE SPEEDS.

Cast iron........30 to 45 feet per minute.
Steel............20 to 25 feet per minute.
Wrought iron....30 feet per minute.
Brass..... .....40 to 60 feet per minute.

For cast iron as found in Europe, we may assume 20 to 35 feet per minute. This is owing to the fact that European iron is considerably harder.

SPEED OF SAWS, ETC.

Band saws for hot iron and steel run at about 200 to 300 feet per minute. Plain soft iron discs run at a rim velocity of 12,000 feet per minute, and are sometimes used to cut off ends of steel rails, jets of water playing on the circumference of the saw.

Average Cutting Speed for Drills.

The following table represents the most approved practice in rate of cutting speed for drills ranging from $\frac{1}{16}$ inch to 2 inches in diameter.

Diameter of Drills	Speed on Steel	Speed on Cast Iron	Speed on Brass	Diameter of Drills	Speed on Steel	Speed on Cast Iron	Speed on Brass
$\frac{1}{16}$	1,712	2,383	3,544	$1\frac{1}{16}$	72	106	180
$\frac{1}{8}$	855	1,191	1,772	$1\frac{1}{8}$	68	102	170
$\frac{3}{16}$	571	794	1,181	$1\frac{3}{16}$	64	97	161
$\frac{1}{4}$	397	565	855	$1\frac{1}{4}$	58	89	150
$\frac{5}{16}$	318	452	684	$1\frac{5}{16}$	55	84	143
$\frac{3}{8}$	265	377	570	$1\frac{3}{8}$	53	81	136
$\frac{7}{16}$	227	323	489	$1\frac{7}{16}$	50	77	130
$\frac{1}{2}$	183	267	412	$1\frac{1}{2}$	46	74	122
$\frac{9}{16}$	163	238	367	$1\frac{9}{16}$	44	71	117
$\frac{5}{8}$	147	214	330	$1\frac{5}{8}$	40	66	113
$\frac{11}{16}$	133	194	300	$1\frac{11}{16}$	38	63	109
$\frac{3}{4}$	112	168	265	$1\frac{3}{4}$	37	61	105
$\frac{13}{16}$	103	155	244	$1\frac{13}{16}$	36	59	101
$\frac{7}{8}$	96	144	227	$1\frac{7}{8}$	33	55	98
$\frac{15}{16}$	89	134	212	$1\frac{15}{16}$	32	53	95
1	76	115	191	2	31	51	92

Size of Drills for U. S. Standard Taps.

Diam. of Tap	Threads per inch	Diam. of Drill	Diam. of Tap	Threads per inch	Diam. of Drill	Diam. of Tap	Threads per inch	Diam. of Drill
$\frac{1}{4}$	20	$\frac{3}{16}$	$\frac{7}{8}$	9	$\frac{3}{4}$	$1\frac{3}{4}$	5	$1\frac{1}{2}$
$\frac{5}{16}$	18	$\frac{1}{4}$	1	8	$\frac{27}{32}$	$1\frac{7}{8}$	5	$1\frac{5}{8}$
$\frac{3}{8}$	16	$\frac{5}{16}$	$1\frac{1}{8}$	7	$\frac{31}{32}$	2	$4\frac{1}{2}$	$1\frac{3}{4}$
$\frac{7}{16}$	14	$\frac{23}{64}$	$1\frac{1}{4}$	7	$1\frac{3}{32}$	$2\frac{1}{4}$	$4\frac{1}{2}$	$1\frac{31}{32}$
$\frac{1}{2}$	13	$\frac{13}{32}$	$1\frac{3}{8}$	6	$1\frac{3}{16}$	$2\frac{1}{2}$	4	$2\frac{3}{16}$
$\frac{5}{8}$	11	$\frac{17}{32}$	$1\frac{1}{2}$	6	$1\frac{9}{32}$	$2\frac{3}{4}$	4	$2\frac{7}{16}$
$\frac{3}{4}$	10	$\frac{5}{8}$	$1\frac{5}{8}$	$5\frac{1}{2}$	$1\frac{13}{32}$	3	$3\frac{1}{2}$	$2\frac{5}{8}$

Table of Emery Wheel Speeds.

Diam. Wheel.	Rev. per Minute for Surface Speed of 4,000 ft.	Rev. per Minute for Surface Speed of 5,000 ft.	Rev. per Minute for Surface Speed of 6,000 ft.
1 in.	15,279	19,090	22,918
2 "	7,639	9,549	11,459
3 "	5,093	6,366	7,639
4 "	3,820	4,775	5,370
5 "	3,056	3,820	4,584
6 "	2,546	3,183	3,820
7 "	2,183	2,728	3,274
8 "	1,910	2,387	2,865
10 "	1,528	1,910	2,292
12 "	1,273	1,592	1.910
14 "	1,091	1,364	1,637
16 "	955	1,194	1,432
18 "	849	1,061	1,273
20 "	764	955	1,146
22 "	694	868	1,042
24 "	637	796	955
30 "	509	637	764
36 "	424	531	637

The above table designates the number of revolutions per minute for specific diameters of emery wheels to cause them to run at the respective periphery rates of 4,000, 5,600 and 6,000 feet per minute.

The medium of 5,000 feet is usually employed in ordinary work, but in special cases it is sometimes desirable to run them at a lower or higher rate, according to requirements.

The stress on the wheel at 4,000 feet periphery speed per minute is 48 lbs. per square inch; at 5,000 feet, 75 lbs.; at 6,000 feet, 108 lbs.

U. S. Standard Screw Threads.

Nominal Diameter of Screw.		Number of Threads per inch.	Diameter of Tap at Root of Thread.		Size of Tap Drill, giving a Clearance of ⅓ the Height of the Original Thread Triangle.		Area at Root of Thread.	Safe Load on Threaded Bolt on basis of 6,000 lbs. Stress per sq. in. of Section at Root of Thread.
Inches	Inches		Inches	Nearest 64ths	Inches	Nearest 64ths	Sq. In.	Pounds
¼	.250	20	.185	3/16 −	.196	13/64 −	.027	162
5/16	.312	18	.240	15/64 +	.252	¼ +	.045	270
⅜	.375	16	.294	19/64 −	.307	5/16 −	.068	408
7/16	.437	14	.345	11/32 +	.360	23/64 +	.093	558
½	.500	13	.400	13/32 −	.417	27/64 −	.126	756
9/16	.562	12	.454	29/64 +	.472	15/32 +	.162	997
⅝	.625	11	.507	½ +	.527	17/32 −	.202	1210
11/16	.687	11	.569	9/16 +	.589	19/32 −	.254	1520
¾	.750	10	.620	⅝ −	.642	41/64 +	.302	1810
13/16	.812	10	.683	11/16 −	.704	45/64 +	.366	2190
⅞	.875	9	.731	47/64 −	.755	¾ +	.420	2520
15/16	.937	9	.793	51/64 −	.817	13/16 +	.494	2960
1	1.000	8	.838	27/32 −	.865	55/64 +	.551	3300
1 1/16	1.062	8	.900	29/32 −	.927	59/64 +	.636	3810
1⅛	1.125	7	.939	15/16 +	.970	31/32 +	.694	4160
1 3/16	1.187	7	1.002	1 +	1.032	1 1/32 +	.788	4720
1¼	1.250	7	1.064	1 1/16 +	1.095	1 3/32 +	.893	5350
1⅜	1.375	6	1.158	1 5/32 +	1.215	1 7/32 −	1.057	6340
1½	1.500	6	1.283	1 9/32 +	1.345	1 11/32 +	1.295	7770
1⅝	1.625	5½	1.389	1 25/64 −	1.428	1 27/64 +	1.515	9090
1¾	1.750	5	1.490	1 31/64 +	1.534	1 17/32 +	1.746	10470
1⅞	1.875	5	1.615	1 39/64 +	1.659	1 21/32 +	2.051	12300
2	2.000	4½	1.711	1 23/32 −	1.760	1 49/64 −	2.302	13800
2¼	2 250	4½	1.961	1 61/64 +	2.010	2 1/64 −	3.023	18100
2½	2.500	4	2.175	2 11/64 +	2.230	2 15/64 −	3.719	22300
2¾	2.750	4	2.425	2 27/64 +	2.480	2 31/64 −	4.620	27700
3	3.000	3½	2.629	2⅝ +	2.691	2 11/16 +	5.428	32500
3¼	3.250	3½	2.879	2⅞ +	2.941	2 15/16 +	6.510	39000
3½	3.500	3¼	3.100	3 3/32 +	3.167	3 11/64 −	7.548	45300
3¾	3.750	3	3.317	3 5/16 +	3.389	3 25/64 −	8.641	51800
4	4.000	3	3.567	3 9/16 +	3.639	3 41/64 −	9.063	59700

Machinery, New York.

Standard Sizes of Wrought Iron Welded Pipe.

Inside diameter, nom.	Actual outside Diameter.	Thickness.	Actual inside Diameter.	External circumference.	Internal circumference.	Length of pipe per square foot of outside surface.	Length of pipe per square foot of inside surface.	External area.	Actual internal area.	Length of pipe containing one cubic foot.	Weight per foot of length.	No. of threads per inch of screw.	Length perfect screw.
1/8	.405	.068	0.269	1.272	0.848	9.440	14.15	.129	.0572	2500.	.243	27	0.19
1/4	.54	.088	0.364	1.696	1.144	7.075	10.50	.229	.1041	1385.	.422	18	0.29
3/8	.675	.091	0.493	2.121	1 552	5.657	7.67	.358	.1916	751.5	.561	18	0.30
1/2	.840	.109	0.622	2.652	1.957	4.502	6.13	.554	.3048	472.4	.845	14	0.39
3/4	1.050	.113	0.824	3.299	2.589	3.637	4.635	.866	.5333	270.0	1.126	14	0.40
1	1.315	.134	1.047	4.134	3.292	2.903	3.679	1.357	.8627	166.9	1.670	11 1/2	0.51
1 1/4	1.660	.140	1.38	5.215	4.335	2.301	2.768	2.164	1.496	96.25	2.258	11 1/2	0.54
1 1/2	1.90	.145	1.61	5.969	5.061	2.010	2.371	2.835	2.038	70.65	2.694	11 1/2	0.55
2	2.375	.154	2.067	7.461	6.494	1.611	1.848	4.430	3.355	42.36	3.667	11 1/2	0.58
2 1/2	2.875	.204	2.467	9.032	7.754	1.328	1.547	6.491	4.783	30.11	5.773	8	0.89
3	3.50	.217	3.066	10.996	9.636	1.091	1.245	9.621	7.388	19.40	7.547	8	0.95
3 1/2	4.0	.226	3.548	12.566	11.146	.955	1.077	12.566	9.837	14.56	9.055	8	1.00
4	4.50	.237	4.026	14.137	12.648	.849	0.949	15.904	12.730	11.31	10.728	8	1.05
4 1/2	5.0	.247	4.506	15.708	14.153	.765	0.848	19.635	15.939	9.03	12.492	8	1.10
5	5.563	.259	5.045	17.475	15.849	.629	0.757	24.299	19.990	7.20	14.564	8	1.16
6	6.625	.280	6.065	20.813	19.054	.577	0.630	34.471	28.889	4.98	18.767	8	1.26
7	7.625	.301	7.023	23.954	22.063	.505	0.544	45.663	38.737	3.72	23.410	8	1.36
8	8.625	.322	7.981	27.096	25.076	.444	0.478	58.426	50.039	2.88	28.348	8	1.46
9	9.688	.344	9.00	30.433	28.277	.394	0.425	73.715	63.633	2.26	34.677	8	1.57
10	10.750	.366	10 018	33.772	31.475	.355	0.381	90.762	78.838	1.80	40.641	8	1.68


HERE IS YOUR LIST OF
HELPING HAND BOOKS FOR MECHANICS
WRITTEN SO ALL CAN UNDERSTAND

A GOOD BOOK IS A GOOD FRIEND

To Our Readers:

The good books, here described, deserve more than a passing notice, considering that the brief description under each title indicates only their wide scope, and is merely suggestive of the mine of useful information contained in each of the volumes.

Written so they can be easily understood, and covering the fundamental principles of engineering, presenting the latest developments and the accepted practice, giving a working knowledge of practical things, with reliable and helpful information for ready reference.

These books are self-educators, and "he who runs may read" and improve his present knowledge in the wide field of modern engineering practice.

Sincerely,

Theo. Audel & Co.
Publishers

72 5th Ave., N. Y.