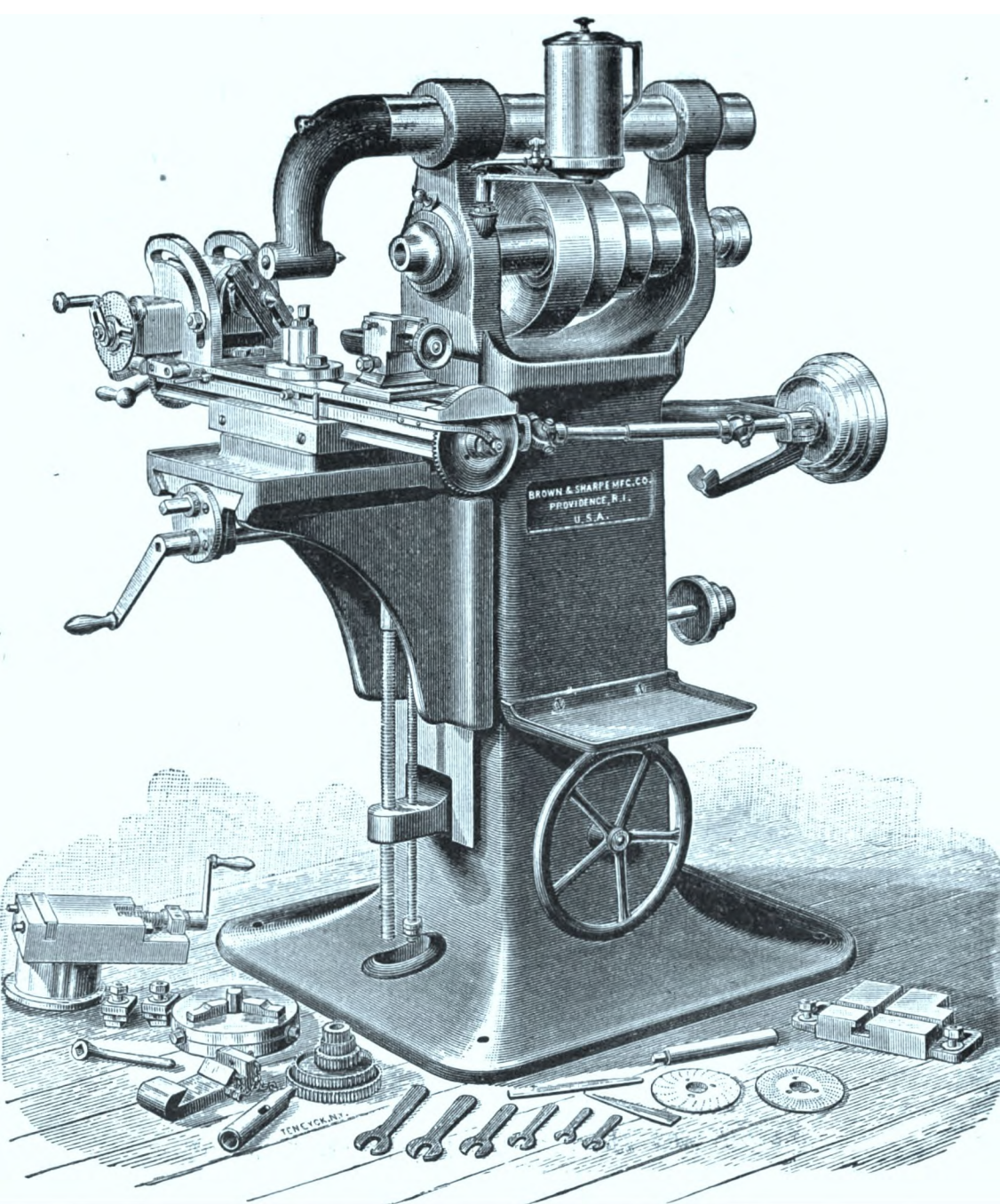
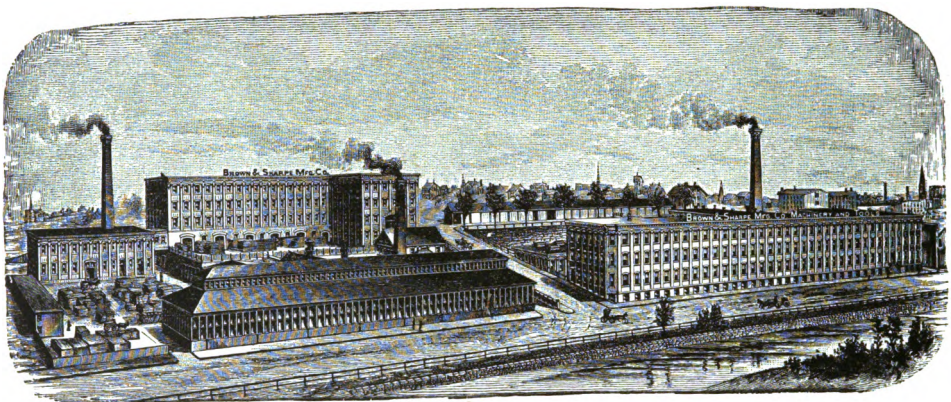




*A treatise on the construction
and use of milling machines ...*

Brown & Sharpe Manufacturing
Company (Providence, R.I.)

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A TREATISE
ON THE
CONSTRUCTION AND USE
OF
MILLING MACHINES

MADE BY
BROWN & SHARPE MFG. CO.,
PROVIDENCE, R. I., U. S. A.,
MANUFACTURERS OF
MACHINERY AND TOOLS.

PROVIDENCE, R. I.
BROWN & SHARPE MANUFACTURING COMPANY.
1894.

Entered according to Act of Congress, in the year 1891, by
BROWN & SHARPE MFG. CO.,
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PREFACE.

Our chief object in writing this book is to assist those who are not familiar with the construction or use of Universal or Plain Milling Machines. We desire to aid in having the machines well understood, properly cared for and profitably operated. Beyond this, we hope we have written somewhat of interest to those well versed in the theory and practice of milling.

CONTENTS.

UNIVERSAL MILLING MACHINES.....	11
---------------------------------	----

DESCRIPTION OF NO. 1 UNIVERSAL MILLING MACHINE.

Overhanging Arm, Stand, Knee, Clamp Bed, Saddle.....	15
Index Dials, Feed, Spindle Boxes, Spiral Head.,.....	17
Index Plates, Vise, Overhead Works, Capacity of Machine.....	23
Accessories.....	25

DESCRIPTION OF NO. 2 UNIVERSAL MILLING MACHINE.....	27
---	----

DESCRIPTION OF NO. 3 UNIVERSAL MILLING MACHINE.....	31
---	----

DESCRIPTION OF NO. 4 UNIVERSAL MILLING MACHINE.....	35
---	----

PLAIN MILLING MACHINES.....	38
-----------------------------	----

DESCRIPTION OF NO. 0 PLAIN MILLING MACHINE.....	41
---	----

DESCRIPTION OF NO. 1 PLAIN MILLING MACHINE.....	42
---	----

DESCRIPTION OF NO. 2 PLAIN MILLING MACHINE.....	45
---	----

DESCRIPTION OF NO. 3 PLAIN MILLING MACHINE.....	47
---	----

DESCRIPTION OF NO. 4 PLAIN MILLING MACHINE.....	49
---	----

DESCRIPTION OF NO. 5 PLAIN MILLING MACHINE.....	51
---	----

DESCRIPTION OF NO. 11 PLAIN MILLING MACHINE.....	53
--	----

DESCRIPTION OF NO. 12 PLAIN MILLING MACHINE.....	55
--	----

DESCRIPTION OF NO. 13 PLAIN MILLING MACHINE.....	57
--	----

DESCRIPTION OF NO. 23 PLAIN MILLING MACHINE.....	57c
--	-----

DESCRIPTION OF NO. 24 PLAIN MILLING MACHINE.....	57d
--	-----

DESCRIPTION OF NO. 2 VERTICAL SPINDLE MILLING MACHINE.....	59
---	----

ATTACHMENTS, ETC.

Gear Cutting Attachment, Circular Milling Attachment.....	62
Vertical Spindle Milling Attachments.....	63
High Speed Milling Attachments.....	65
Index Centres.....	66

MATERIALS, WORKMANSHIP, ETC.....68

CARE AND USE OF MILLING MACHINES.

Facing Machines and Counter-shafts, Diameter of Main Line Pulley, Speed of Counter-shafts, Oiling.....	69
Placing Tools in Closets of Machines, Oil Pans, Adjusting Spindle....	70

MILLING MACHINES AND SKILL.....71

CUTTERS USED ON MILLING MACHINES.

Axial Mills, Radial Mills.....	75
Angular Mills, Form Mills.....	78
Diameter of Mills, length or width of Mills.....	81
Temper of Mills, Number of Teeth of Mills.....	83
Cutting Angle of Teeth of Mills, Clearance of Mills.....	84
Sketches of Mills, Templets, Sharpening Mills.....	85

USE OF MILLING MACHINES—CONTINUED.

Oil on Mills or Work, Direction in which Work is moved.....	89
Speed of Mills.....	90
Limits in Milling.....	92
Table of Speeds and Feeds.....	93
Pickling Castings and Forgings, Washers, Collars and Lead Hammer..	94
Work for Novice, Setting Vise, Cutting off Stock.....	95
Squaring Ends of Small Pieces, Use of two or more Mills.....	96
Fixture for Small Work, Cutting Slots.....	100
Table of Decimal Equivalents.....	104
Milling Lathe Carriage, Bed of Grinder, Rack, etc.....	106
Milling Cuts in manufacturing No. 1 Universal Milling Machine.....	113

USE OF MILLING MACHINES—CONTINUED.

INDEXING.

Index Head and Plates.....	120
Sector, Effect of Change in Angle of Elevation of Spindle..	122

Index Tables.....	123
Dividing Cutters, etc., Fluting Reamers.....	126
Table for Setting when Cutting with Tap or Tap and Reamer Cutters.....	127
Cutting Gears.....	128
Worm Wheels.....	130
Bevel Gears.....	132

USE OF MILLING MACHINES—CONTINUED.

COMPOUND INDEXING.

Authorities, Explanation of Compound Indexing, Table of Compound Index Movements.....	134
Manner of Using the Machines, Proof of Correctness of the Moves.....	135
Approximate Indexings by Compound Method.....	136
Table of Index Movements, No. 1 Universal Milling Machine, for all Divisions (absolute or approximate) from 50 to 250.....	137
Schneider's Method, Table of Compound Index Movements, No. 1 Universal Milling Machine.....	142
Table of Compound Index Movements, No. 3 Universal Milling Machine.....	143
Adjustable Back Pin on Indexing Head Stock, Table of Compound Index Movements, No. 1 Universal Milling Machine with Adjustable Back Pin.....	144

USE OF MILLING MACHINES—CONTINUED.

CUTTING SPIRALS WITH UNIVERSAL MILLING MACHINES.

Selection of Change Gears.....	145
Rules for obtaining Ratio and Number of Teeth of Gears.....	147
Rules for ascertaining Spirals Cut by any Change Gears, Position of Spiral Bed.....	148
Use of Machines Cutting Spirals.....	150
Table of Change Gears, Spirals and Angles.....	151
Table of Natural Tangents.....	155
Cutting Worms, Milling Cutters, Twist Drills.....	157
Table of Cutters, Pitches, Gears and Angles for Twist Drills.....	158
Cutters for Making Twist Drills.....	161
Cutting Spirals with an End Mill.....	162



REAR VIEW OF NO. 1 BUILDING.

UNIVERSAL MILLING MACHINES.

A Universal has all the movements of a Plain Machine and in addition, the table is fed automatically at various angles to the axis of the spindle, and the spiral head is so made and connected with the feed screw that a positive rotary movement may be given to the work.

Besides doing the work of a Plain Milling Machine it can thus be used for an almost unlimited variety of other operations in the manufacture of machinery and tools.

"Peculiarly American in its design and construction*", this machine has done more for the introduction and demand for American machinery in Europe than any other.

"As exhibited by J. R. Brown & Sharpe in 1867 at the Paris Exhibition, it attracted the attention of engineers, machine tool builders, gun and sewing machine makers, and the directors of government arsenals and other large engineering works. It was one of those special tools by the aid of which Americans have been enabled to so far improve the construction of their machinery, that they were at once successful competitors for large orders of special and other machinery for governments and other large industries. Europe from that time forward could not afford to be without the Universal Milling Machine. Those sent for exhibition were sold, soon after the opening, to Continental machine tool builders, ostensibly for the purpose of using them as copies from which to build others.

"The workmanship on these machines was of such a quality that the purchasers found difficulty in producing others of equal character, except certain parts which were reproduced on these same tools; thus showing the imperative necessity of parent tools containing within their own structure the inherent qualities of truth and the highest excellence.

"One of the minor virtues in a good machine tool is general convenience, easy access to the various parts, the arrangement

*American Machinist, April, 1879, referring to No. 1 Universal Milling Machine.

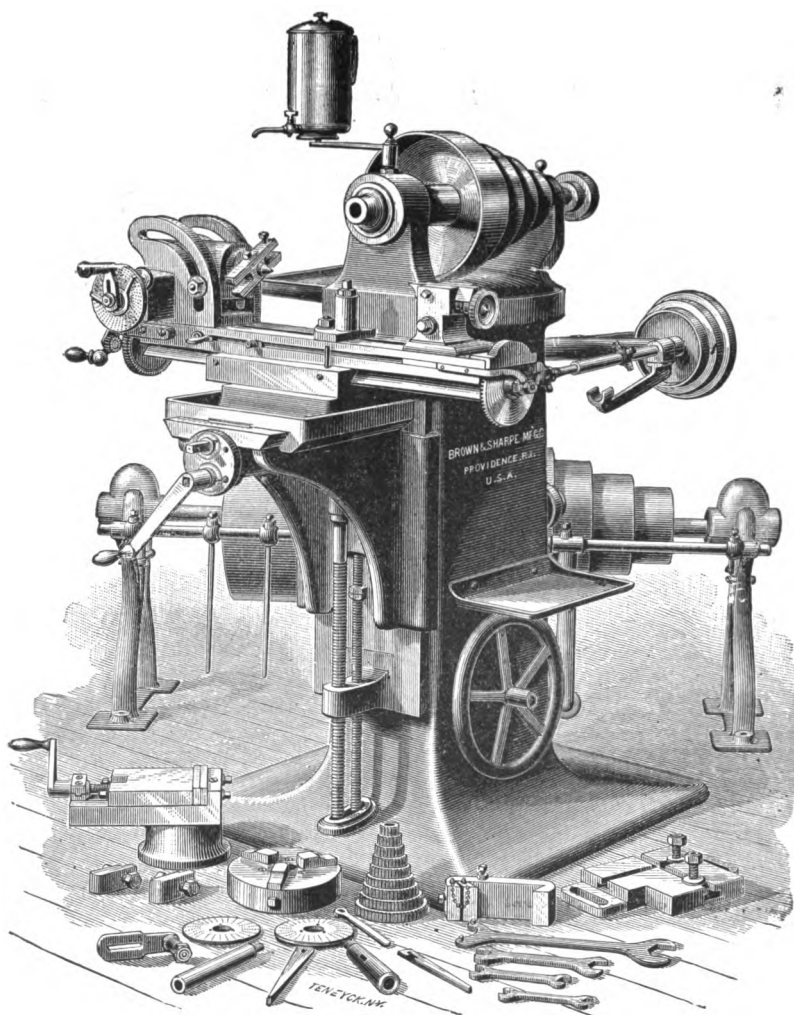


FIG. 1.
No. 1 Universal Milling Machine.
WITHOUT OVERHANGING ARM.

of handles for manipulation, and their being so combined that the attendant has not to waste his time in moving from the point of action in order to reach them. Another highly important point is that every tool should not only be sufficiently well made, but that the means of adjustment and compensation for wear should be such that the general soundness of the fitting can be maintained, and that the work produced by the machine during its life time should be perfect, and require no fitting afterwards. This is the true condition to be reached with tools, and a high standard is not secured unless the tool has a combination of all the virtues which should characterize a machine tool in this age of special machinery.

"At the Vienna Exhibition of 1873, Continental tool builders exhibited their copies of American Universal Milling Machines and Revolving Head Screw Machines, "System Brown & Sharpe," (so noted in the illustrated catalogue of one firm). Decidedly the best copies of these machines were those exhibited by the Alsatian firm of Ducommun & Steinlen of Mulhouse.

"At this exhibition, however, preference was given to the tools exhibited by Brown & Sharpe, and the consequence was that their tools were sold earlier and at a better price than the copies, some of which were very creditable.

"The late Paris Exhibition was especially rich in creditable productions of machinery of American design, very notable among which were copies of the Brown & Sharpe Universal Milling Machine.

"These were exhibited by several tool builders in the French, as also by a prominent English firm in the British section, who were considerably chagrined at the reply of the International Judges, who, in answer to their appeal for an award higher than the silver medal (of which they had received notice), informed them that with machinery as with the fine arts, 'copies were not entitled to so high an award as were the originals.'

"No gold medal awarded was more deserved than that given the Brown & Sharpe Manufacturing Co., for their fine exhibit of special machine tools, from which Continental and other firms are now constructing their copies."

In 1889 at the Paris Exposition our exhibit was again honored. It received the "Grand Prix," the highest possible distinction.

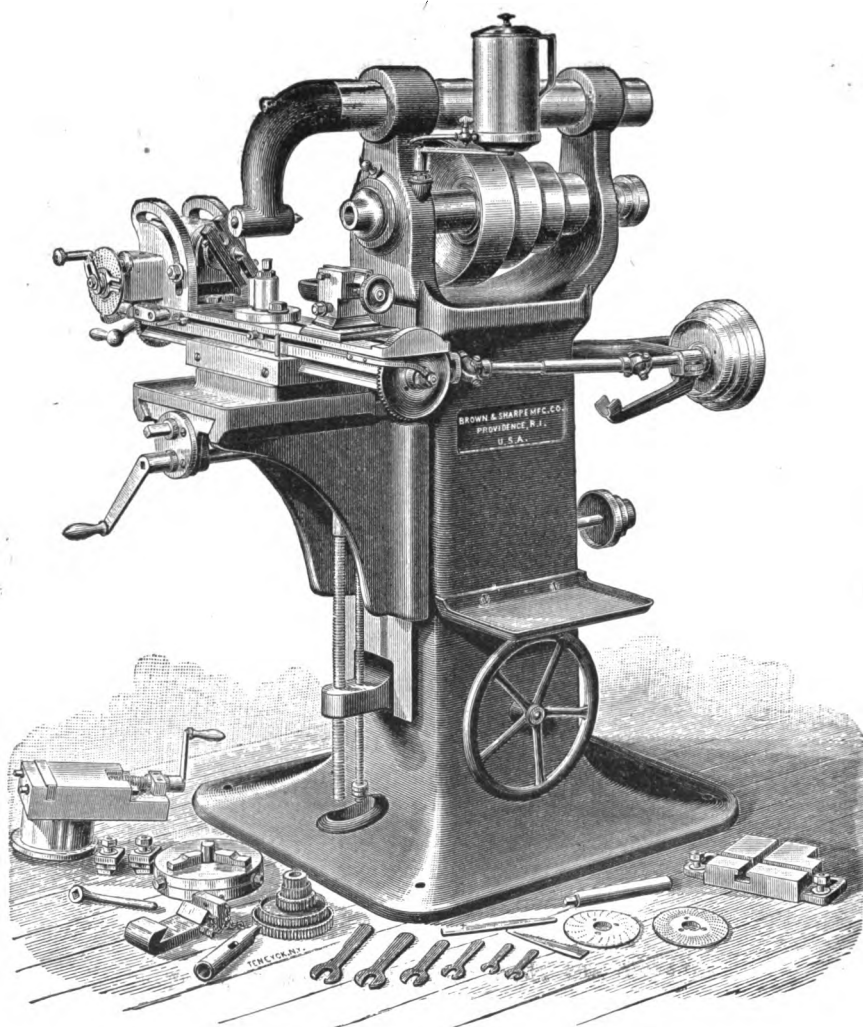


FIG. 2.

No. 1 Universal Milling Machine.
WITH OVERHANGING ARM.

No. 1 UNIVERSAL MILLING MACHINE.

The size and capacity of the No. 1 Universal Milling Machine adapt it for use in the ordinary shop.

General
Character
of the
Machine

It is pre-eminently a tool making machine, as is indicated by the fact that in the department where we make our jigs and fixtures, there are nearly as many No. 1 Universal Milling Machines as engine lathes. In all we have more than forty of these machines in operation in our shops.

A perspective view is given in Fig. 1.

The machine is also made with an overhanging arm, Fig. 2, which serves as a support for the outer end of the cutter arbor, and is of advantage when heavy cuts are desired. The arm can be turned up from the work or removed from the machine.

Machine
with
Overhang-
ing Arm.

The stand is fitted as a closet for the tools and attachments and one compartment contains a wooden case especially arranged to hold the change gears and index plates.

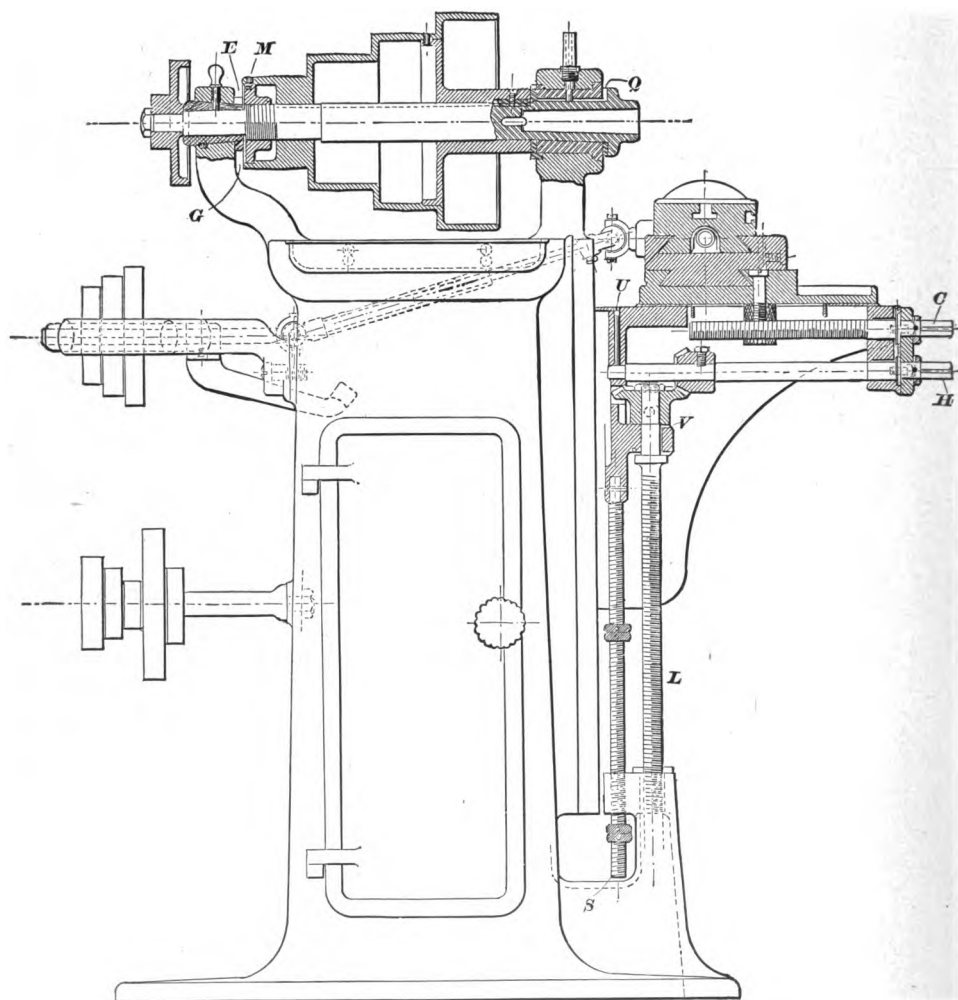
Stand.

The knee slides upon the ways on the frame and is raised or lowered by the screw L, Fig. 3, which is operated through bevel gears by the shaft H. One turn of this shaft moves the knee one-tenth of an inch, and the movement of the knee may be limited by adjustable nuts on the stop screw.

Knee.

The clamp bed shown in Fig. 4, slides upon the top of the knee in line with the main spindle of the machine. The saddle, which carries the spiral bed, swivels upon the clamp bed, and thus the spiral bed may be set at any desired angle. The saddle is clamped by the screw at the side of the clamp bed and a series of graduations on the clamp bed shows the position of the saddle, or

Clamp Bed
and
Saddle.

**Fig. 3.**

the angle to the axis of the spindle at which the work is to be fed. The clamp bed is moved by the cross feed screw shaft C, Fig. 3, and one turn of this shaft moves the clamp bed and spiral table two-tenths of an inch. This shaft and the shaft which raises and lowers the knee may be turned by the crank shown in place Fig. 1, or by the hand wheel shown on the side of the stand. The index dials on these shafts show the vertical and horizontal movements in thousandths of an inch. These dials are free to turn on the shafts and can be slipped around to commence reading from zero. They are held in place by the set screws in the ends of the shafts.

Index
Dials.

Motion is transmitted from the feed cone to the feed screw of the spiral bed through the universal joints and telescopic connections shown by the dotted lines in Fig. 3. The feed cone is driven from the cone A, by a cross belt, and the cone A is driven from the feed cone on the main spindle Fig. 5. The feed is equally effective in all positions of the spiral bed, and can be thrown out automatically at any point. It is engaged by moving the small lever on the front of the spiral bed towards the left, and may be operated by hand by turning the handle shown at the end of the table.

Feed.

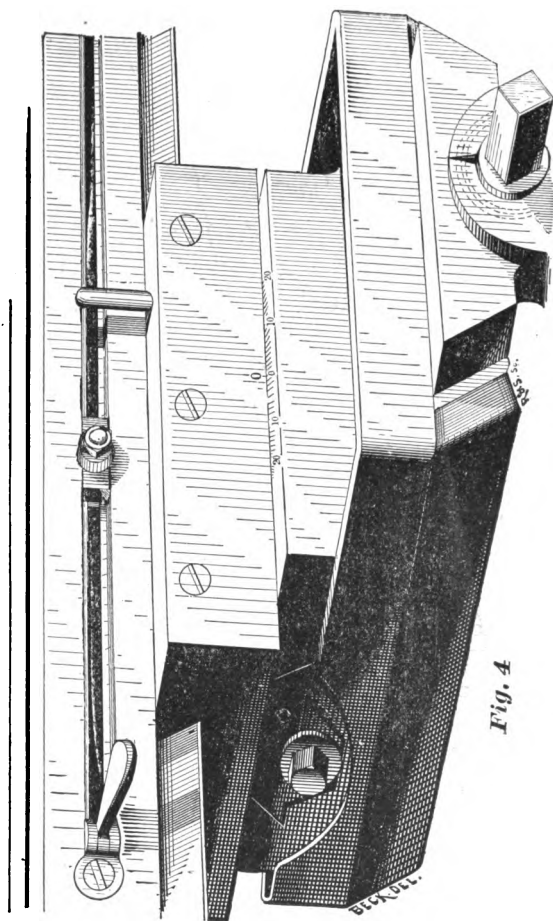
Means are provided to compensate for wear of the spindle boxes. The screw M is loosened, and by turning the nut G, Fig. 3, the spindle is drawn back in the front box. The rear box is then closed upon the spindle by the nut E.

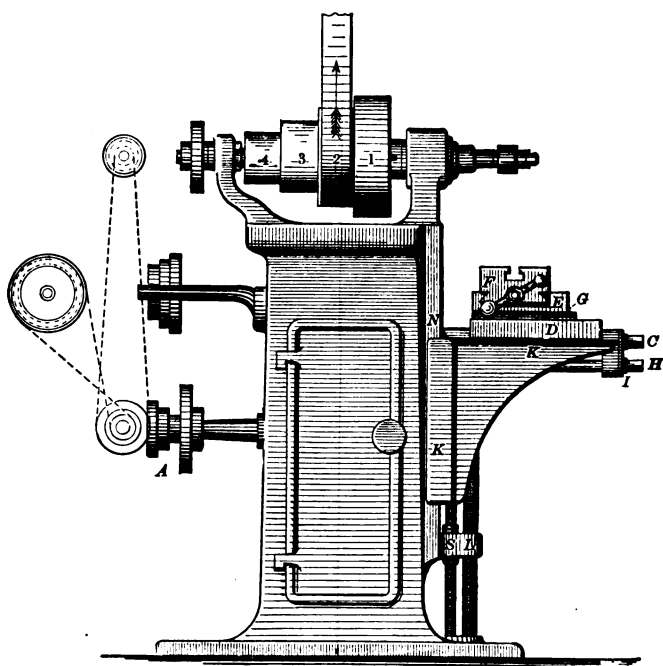
Wear of
Spindle
Boxes.

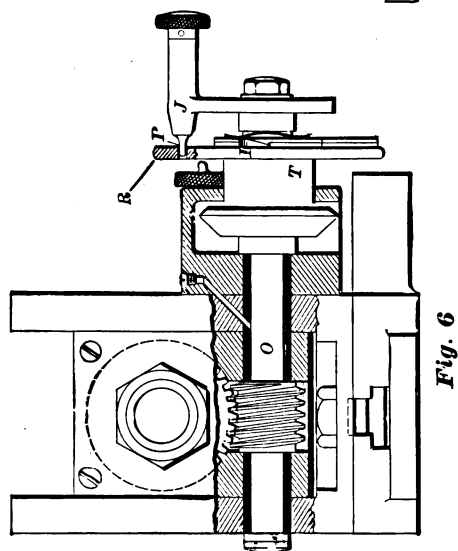
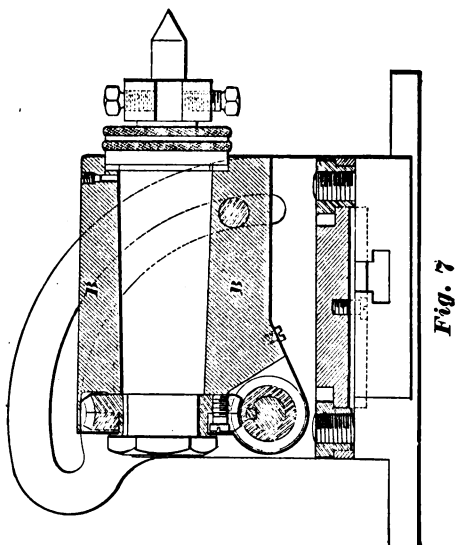
The end thrust of the spindle is taken by the collar Q. As the bearing is taper, the thickness of this collar determines the space between the spindle and box. This is sufficient to give room for the necessary oil.

The office of the indexing head stock, or the spiral head, is to divide the periphery of a piece of work into a number of equal parts. Besides this, it is so made that while the table is being moved by the feed screw a positive rotary movement may be given to the work. The velocity ratios of these movements are regulated by

Indexing
Head Stock
or Spiral
Head.



*Fig. 5.*



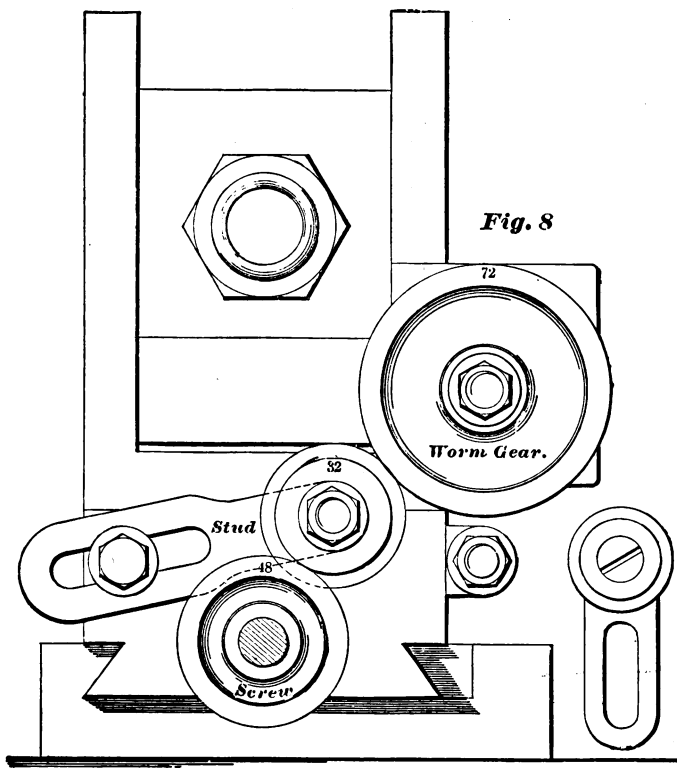
change gears and any spiral provided for may be cut without interfering with the divisions of the work obtainable from the index plate.

Figs. 6 and 7, show the construction of the spiral head. The spiral spindle or spiral shell is revolved by the index crank J, through a worm and worm wheel. The worm wheel has forty teeth and consequently one turn of the index crank or worm shaft O, makes one-fortieth of a revolution of the spiral spindle, and by the use of an index plate I, a turn of the worm shaft may be divided into various definite parts and the fortieth of the revolution of the spiral spindle correspondingly sub-divided.

In connection with the index plate there is a sector which is used to obviate the necessity of counting the number of holes in the plate when dividing the work. The index crank pin P, in the crank J, may be used in any circle of holes in the index plate by adjusting the crank. The index plate can be kept from turning by the stop pin R.

The steel bushings shown in black in the cuts afford not only an extended bearing for the worm shaft, but also serve as a pivot for the spindle box B. The front end of the spindle can thus be raised and the spindle set to any angle from five degrees below the horizontal to a perpendicular. The angle is shown by the graduations on one side of the spiral head. The spindle receives the same arbors as the main spindle, and is threaded for a chuck. When the chuck is not in use the thread is protected by a guard nut.

The arrangement of the change gears is shown in Fig. 8. Motion is transmitted from the change gears to the worm shaft by two mitre gears, one of which is shown near T, Fig. 6, and the other has upon its hub the gear marked "worm gear" Fig. 8. By this arrangement the spindle can be automatically rotated at whatever angle it may be set. With each machine there are sent tables giving the change gears for cutting 68 spirals. Spirals not given in the table may be cut by



using special gears or by determining by calculation many combinations of the regular gears not given in the table.

The three index plates sent with the machine have 15, 16, 17, 18, 19, 20; 21, 23, 27, 29, 31, 33, and 37, 39, 41, 43, 47, 49 holes respectively.

By means of the raising block shown in Fig. 1, the spiral head may be set at any angle on the bed. Raising Block.

The vise shown at the base of the machine, Fig. 1, has a graduated base and swivels so that it may be set at any angle on the bed. The jaws are made of steel and left soft unless otherwise ordered. Being held by screws they may be taken off and others designed for special work put in their places. Vise.

The overhead works, Figs. 9 and 10, include a shipper rod, stops and studs for attaching the lever, also hangers with adjustable self-oiling boxes. Overhead Works.

The cone has four steps for a three inch belt.

The spindle will carry a cutter arbor projecting about 12 inches; and cutters as large as 11 inches in diameter may be used with the overhanging arm. Capacity of the Machine, etc.

The spiral bed is 28 inches long and .5 inches wide, and can be fed 17 inches. It can be lowered 16 inches from the centre of spindle and set at any angle each way up to 45 degrees. The spiral bed has six changes of feed.

The saddle has a movement of six inches in line with the spindle, and the greatest distance from the middle of the spiral bed to the face of the stand, or knee slide, is $9\frac{1}{4}$ inches.

The spiral head and foot stock will take 14 inches between centres and swing 8 inches. These centres can be lowered to a distance of 12 inches below the main spindle.

The hole through the spiral spindle is $1\frac{1}{8}$ inches in diameter.

The vise has jaws $5\frac{1}{8}$ inches wide, $1\frac{1}{8}$ inches deep, and will open $2\frac{3}{4}$ inches.

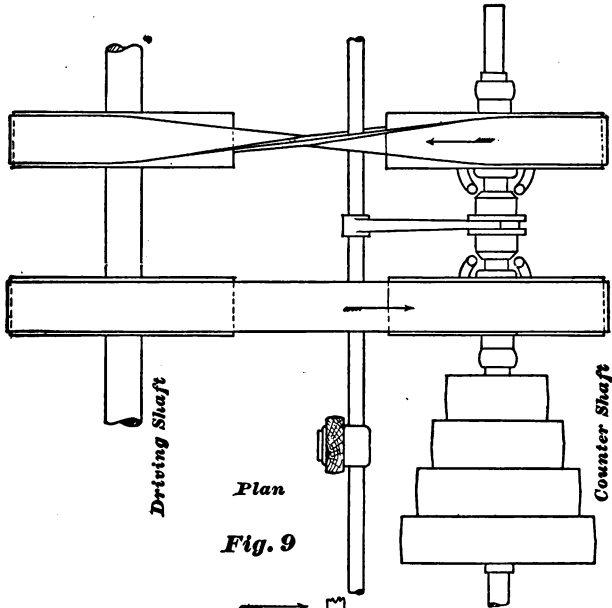


Fig. 9

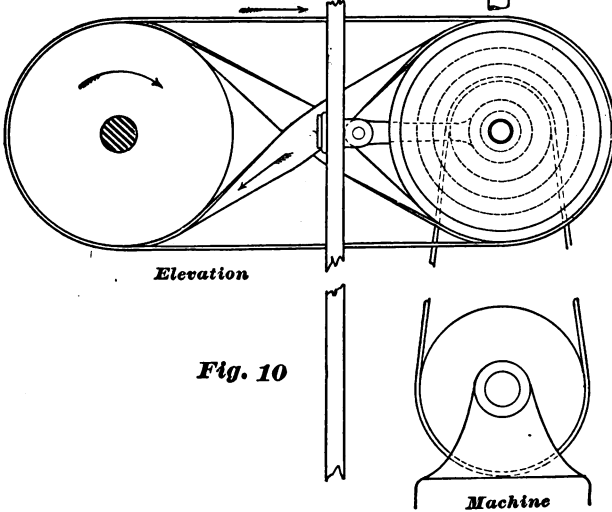


Fig. 10

The counter shaft has two 14 inch friction pulleys for $3\frac{1}{2}$ inch belts, and is usually run at about 110 turns a minute.

Floor space measured over the extreme projections and points of travel of the various parts, 55x42 inches.

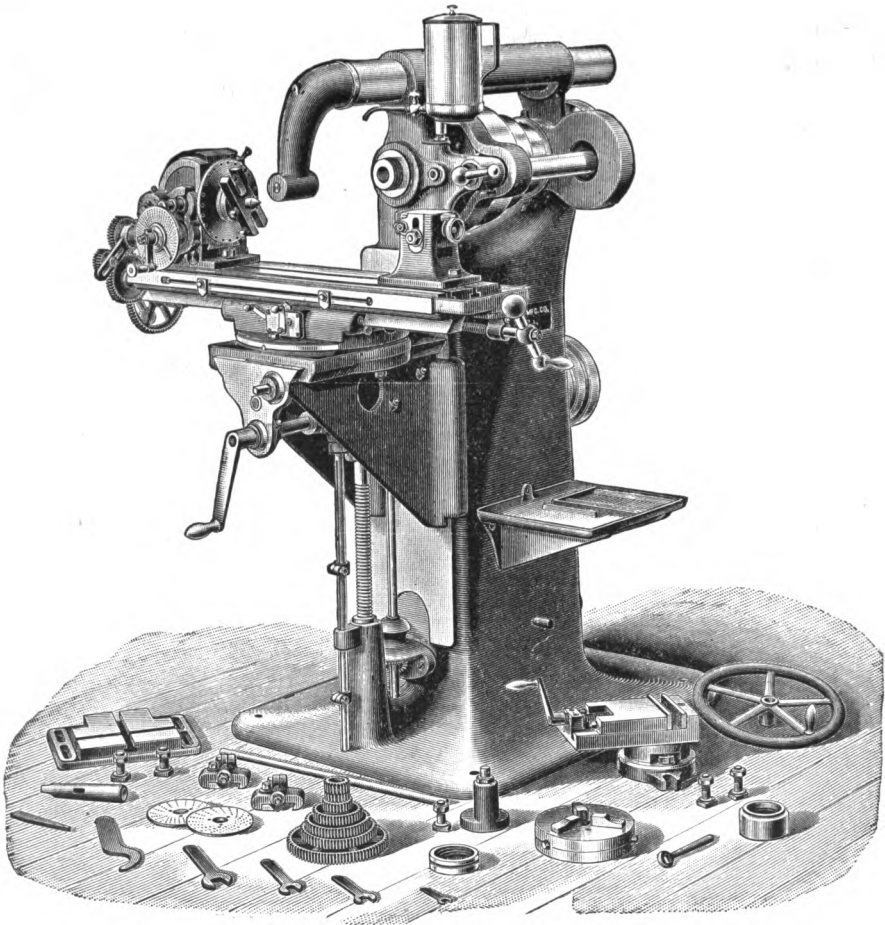
Weight of the machine ready for shipment is about 1,800 pounds.

Weight of the machine with overhanging arm, about 1,900 pounds.

Dimensions of box in which the machine is packed are 47x32x55 inches.

Dimensions of box in which the machine with overhanging arm is packed are 47x32x62 inches.

Each machine is furnished with 11 change gears, 1 Accessories reversing gear for left hand spirals, 3 index plates, 1 table of pitches and angles of spirals, 1 copy of this "Treatise on Milling Machines," 1 six inch three jawed chuck, 1 vise, 1 vise crank, 1 spiral bed stop, 1 hand wheel, 1 centre rest, 1 collet for holding shank mills, twist drills and similar tools, 1 raising block, 1 knee crank, 2 centre keys, 1 oil can and stand, 6 wrenches, and complete overhead works.

**No. 2.**

20 1-2 in. x 6 1-2 in. x 17 1-2 in.

Universal Milling Machine.

The table has an automatic longitudinal feed of $20\frac{1}{2}$ " , a transverse movement of $6\frac{1}{2}$ " , and can be lowered $17\frac{1}{2}$ " from centre of spindle. The centres swing 10" in diameter and take 15" in length.

No. 2

20 1-2 in. x 6 1-2 in. x 17 1-2 in.

UNIVERSAL MILLING MACHINE.

This machine, like the No 1, is termed Universal, as it may be used for performing an almost unlimited variety of operations. It has all the movements of a Plain Machine, and, in addition, the table is fed automatically at an angle to the axis of the spindle and the spiral head is so made and connected with the feed screw that a positive rotary movement may be given to the work.

It has just been placed upon the market and presents a number of new features, chiefly in connection with the feed, the spiral head and the foot stock.

THE SPINDLE has a hole its entire length and runs in bronze boxes provided with means of compensation for wear. It is ground and lapped. The front end is threaded and has a hole fitted for arbors with taper $\frac{1}{2}$ " per foot and 1.05" diameter at the small end.

THE CONE has 3 steps, the largest 10" diameter, for 3" belt, and is back geared, giving 6 changes of speed. The gears are covered.

THE OVERHANGING ARM has an adjustable centre, and can be easily reversed to receive an attachment, turned out of the way, or removed. The distance from the centre of the spindle to the arm is $5\frac{1}{2}$ "; greatest distance from end of spindle to centre in arm, 14".

THE TABLE, including oil pans and channels, is $35\frac{1}{2}$ " long, 8" wide, has a working surface $32" \times 6\frac{3}{4}"$, 2 T slots $\frac{5}{8}"$ wide, a transverse movement of $6\frac{1}{2}"$ and can be lowered $17\frac{1}{2}"$ from centre of spindle.

THE SADDLE, which carries the table, pivots in the clamp bed, and is rigidly clamped to it by three bolts which slide in circular slots and allow the table to be set at any angle up to 45 degrees, each way from zero. The saddle and knee are clamped by fixed handles, thus dispensing with wrenches.

THE KNEE can be moved vertically $17\frac{1}{2}$ ", and has a stop rod with sliding collars which may be quickly set at any desired point.

THE FEED of table, $20\frac{1}{2}$ ", is automatic in either direction and can be changed by a simple movement of a lever on the front of the saddle, and as it is driven from the centre it can be used with table clamped at an angle to the axis of the spindle. There are 12 changes of feed varying from .005" to .147" to one revolution of spindle. The table may be moved by hand from either end, as at each end a handle is provided for this purpose.

ADJUSTABLE DIALS, graduated to read to thousandths of an inch, indicate the longitudinal, transverse and vertical movements of table, and a series of graduations show in degrees the angle to the axis of the spindle at which the table is set. The dials may be adjusted without the aid of wrench or screw driver.

THE SPIRAL HEAD has indexing mechanism by which the periphery of a piece of work may be divided into equal parts, and the velocity of the rotary motion of its spindle, or of the work, relative to the speed of the feed screw, is regulated by change gears at the end of the table. Any spiral of the 68 provided for may be cut without interfering with the divisions obtainable from the index plates sent with the machine. A plate for rapid indexing of work into 24 or less divisions is placed directly on the spindle, and the worm which turns the spindle may be thrown quickly out of gear by a knurled knob on the back of the spiral head to allow for this direct or plain indexing. The spindle of the spiral head may be moved continuously, or through any required portion of a revolution; and by use of the raising block, the spiral head may be set at any angle on the table. A taper hole 1.05" diameter at the small end extends through the spindle, and is fitted to receive the same collets and arbors that are used in the main spindle. The front end of this spindle is

also threaded, and this end of the spindle may be elevated to any desired degree between 10 degrees below the horizontal and 10 degrees beyond the perpendicular, and rigidly clamped, if desired, at any point. The side of the spiral head is graduated in degrees to show the angle of the elevation of the spindle. The Spiral Head and Foot-Stock Centres swing 10" in diameter and take 15" in length.

THE FOOT-STOCK spindle may be raised vertically and set at an angle in a vertical plane. By this arrangement the spiral head and foot-stock spindles may, in ordinary use, be kept in line when the front of the spiral head spindle has been elevated or depressed.

THE FRAME is hollow and fitted as a closet to hold the small parts that accompany the machine. On the left side of the frame there is a pan for holding small tools, etc., and on the front of this there is a rack for wrenches. On the other side of the frame is a shelf for holding the spiral head and vise when they are not in use.

THE VISE swivels and has a graduated base. The jaws are 5 $\frac{1}{8}$ " wide, 1 $\frac{1}{8}$ " deep and will open 2 $\frac{3}{4}$ ".

THE COUNTER-SHAFT has 2 friction pulleys 14" in diameter for 3 $\frac{1}{2}$ " belts, and should run about 180 revolutions per minute.

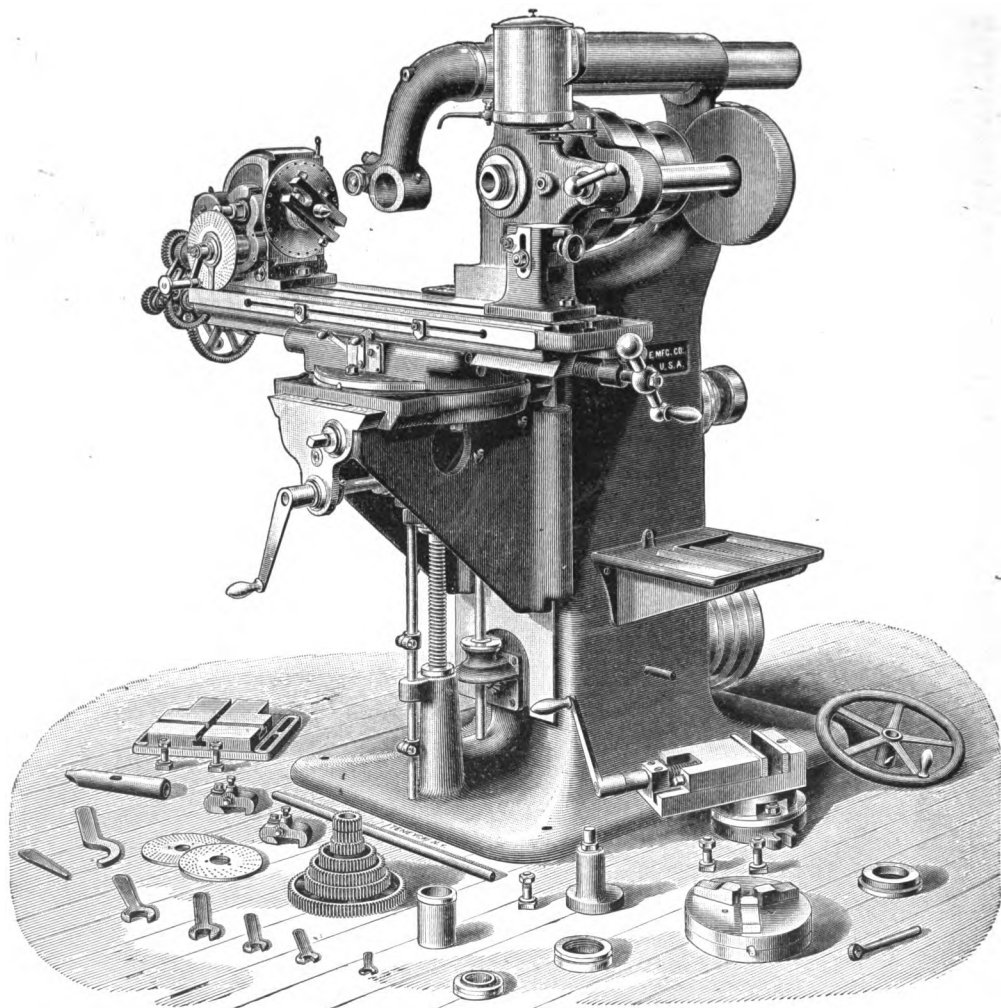
WEIGHT of machine ready for shipment, about 2185 lbs.

NET WEIGHT, about 1750 lbs.

FLOOR SPACE, 70" x 66".

DIMENSIONS of box in which machine is shipped, 49" x 35" x 62".

PRICE INCLUDES change gears, index plates and tables explaining the use of same, 6" 3-jawed chuck, vise, "E" collet, centre rest, raising block, wrenches, and everything else shown in cut, together with overhead works, boxed and delivered f. o. b. at Providence, R. I.

**No. 3.**

25 in. x 71-2 in. x 18 1-2 in.

Universal Milling Machine.

The table has an automatic longitudinal feed of 25", a transverse movement of 7½", and can be lowered 18½" from centre of spindle.

The centres swing 12" in diameter and take 21" in length.

No. 3.

25 in. x 7 1-2 in. x 18 1-2 in.

UNIVERSAL MILLING MACHINE.

With Hand or Power Transverse and Vertical Feeds.

This machine, like the Nos. 1 and 2, is termed Universal, as it may be used for performing an almost unlimited variety of operations. It has all the movements of a Plain Machine, and, in addition, the table is fed automatically at an angle to the axis of the spindle, and the spiral head is so made and connected with the feed screw that a positive rotary movement may be given to the work.

It has just been placed upon the market and presents a number of new features, chiefly in connection with the feed, the spiral head and the foot stock.

THE SPINDLE has a hole its entire length and runs in bronze boxes provided with means of compensation for wear. It is ground and lapped. The front end is threaded and has a hole fitted for arbors with taper $\frac{1}{2}$ " per foot and 1.25" diameter at the small end.

THE CONE has 3 steps, the largest 11" diameter, for $3\frac{1}{2}$ " belt and is back geared, giving 6 changes of speed. The gears are covered.

THE OVERHANGING ARM has a bearing for outer end of arbor, etc., as well as an adjustable centre. It can be easily reversed to receive an attachment, turned out of the way, or removed. The distance from the centre of the spindle to the arm is $6\frac{3}{8}$ "; greatest distance from end of spindle to centre in arm, $17\frac{1}{2}$ ".

THE TABLE, including oil pans and channels, is $44\frac{1}{2}$ " long, $9\frac{1}{2}$ " wide, has a working surface 40" x 8", 2 T slots $\frac{5}{8}$ " wide, a

transverse movement of $7\frac{1}{2}$ ", and can be lowered $18\frac{1}{2}$ " from centre of spindle.

THE SADDLE, which carries the table, pivots in the clamp bed, and is rigidly clamped to it by three bolts which slide in circular slots and allow the table to be set at any angle up to 45 degrees, each way from zero. The saddle and knee are clamped by fixed handles, thus dispensing with wrenches.

THE KNEE can be moved vertically $18\frac{1}{2}$ ", and has a stop rod with sliding collars which may be quickly set at any desired point.

THE FEED of table, 25", is automatic in either direction, and can be changed by a simple movement of a lever on the front of the saddle, and as it is driven from the centre it can be used with table clamped at any angle to the axis of the spindle. There are 16 changes of feed, varying from .003" to .22" to one revolution of spindle. The table may be moved by hand from either end, as at each end a handle is provided for this purpose.

ADJUSTABLE DIALS, graduated to read to thousandths of an inch, indicate the longitudinal, transverse and vertical movements of table, and a series of graduations show in degrees the angle to the axis of the spindle at which the table is set. The dials may be adjusted without the aid of wrench or screw-driver.

THE SPIRAL HEAD has indexing mechanism by which the periphery of a piece of work may be divided into equal parts, and the velocity of the rotary motion of its spindle, or of the work, relative to the speed of the feed screw, is regulated by change gears at the end of the table. Any spiral of the 68 provided for may be cut without interfering with the divisions obtainable from the index plates sent with the machine. A plate for rapid indexing of work into 24 or less divisions is placed directly on the spindle, and the worm which turns the spindle may be thrown quickly out of gear by a knurled knob on the back of the spiral head to allow for this direct or plain indexing. The spindle of the spiral head may be moved continuously, or through any required portion of a revolution; and by use of the raising block, the spiral head may be set at any angle on the table. A taper hole, 1.25" diameter at the small end, extends through the spindle,

and is fitted to receive the same collets and arbors that are used in the main spindle. The front end of this spindle is also threaded, and this end of the spindle may be elevated to any desired degree between 10 degrees below the horizontal and 10 degrees beyond the perpendicular, and rigidly clamped, if desired, at any point. The side of the spiral head is graduated in degrees to show the angle of the elevation of the spindle. The Spiral Head and Foot-Stock Centres swing 12" in diameter, and take 21" in length.

THE FOOT STOCK spindle may be raised vertically, and set at an angle in a vertical plane. By this arrangement the spiral head and foot-stock spindles may, in ordinary use, be kept in line when the front of the spiral head spindle has been elevated or depressed.

THE FRAME is hollow, and fitted as a closet to hold the small parts that accompany the machine. On the left side of the frame there is a pan for holding small tools, etc., and on the front of this there is a rack for wrenches. On the other side of the frame is a shelf for holding the spiral head and vise when they are not in use.

THE VISE swivels and has a graduated base. The jaws are $6\frac{1}{8}$ " wide, 17-16" deep, and will open $3\frac{5}{8}$ ".

THE COUNTER-SHAFT has 2 friction pulleys 16" in diameter for 4" belts, and should run about 175 revolutions per minute.

WEIGHT of machine ready for shipment, about 3,470 lbs.

NET WEIGHT, about 2,860 lbs.

FLOOR SPACE, 84" x 75".

DIMENSIONS of box in which machine is shipped, 59" x 40" x 67".

PRICE INCLUDES change gears, index plates, and tables explaining the use of same, 8" 3-jawed chuck, vise, "G" collet, centre rest, raising block, wrenches, and everything else shown in cut, together with overhead works, boxed and delivered f. o. b. at Providence, R. I.

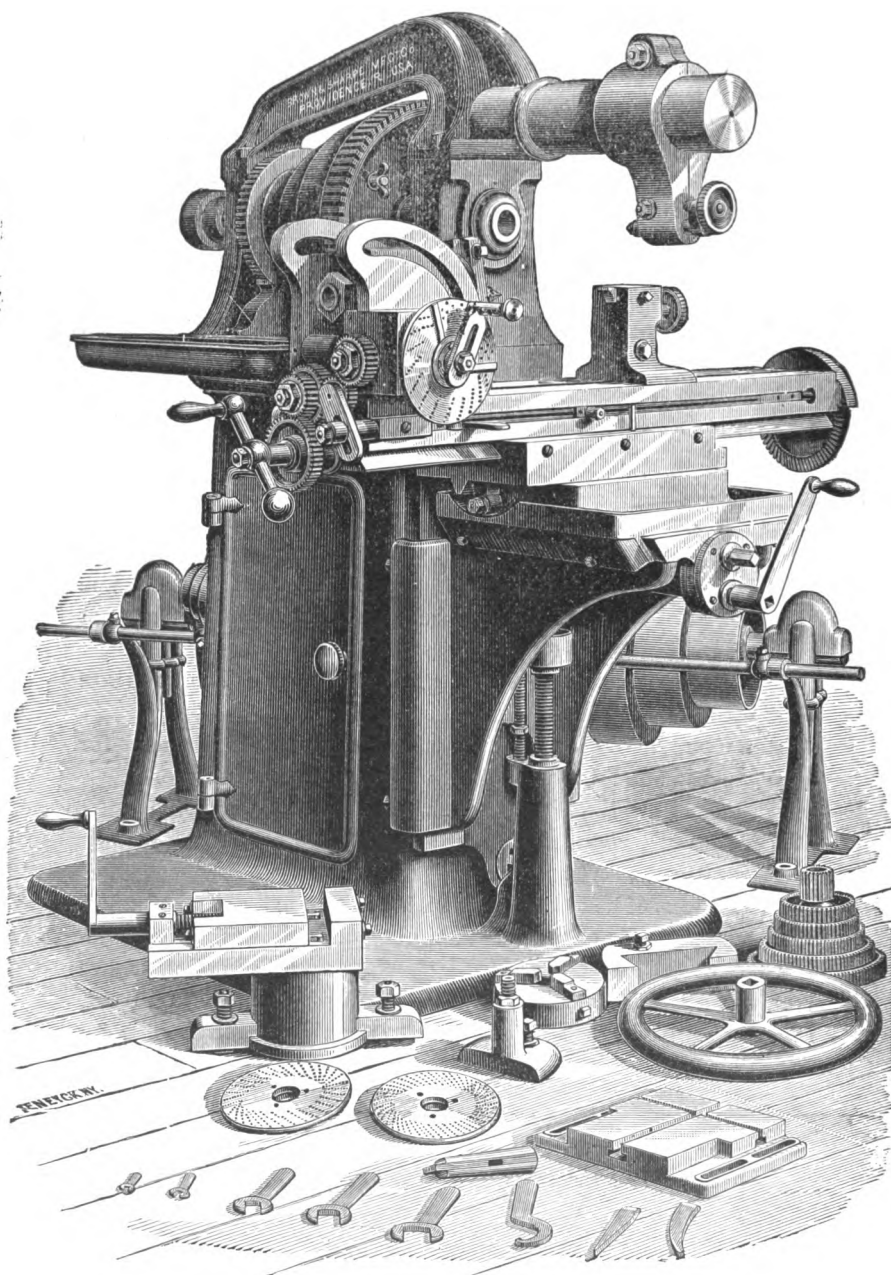


FIG. 11.
No. 4 Universal Milling Machine.

No. 4 UNIVERSAL MILLING MACHINE.

The No. 3 Universal Milling Machine is back geared, and is heavier and larger than the No. 1. In other respects it is like that machine, and the description of the construction of the No. 1 is applicable to the No. 3.

General
Character
of the
Machine.

Fig. 11 gives a perspective view of the machine with the various accessories furnished with it. Fig. 12 shows the spindle and back gears.

The spindle is adjusted to compensate for wear by tightening the nuts C and V, and the end thrust of the spindle is taken by a washer as shown at N.

Spindle.

The back gears, so called, are placed beneath the cone. They may be taken out by unscrewing the screw G, taking off the lever and taking out the screw M; the lever is then put back and the eccentric shaft with the bushing pulled out.

Back Gears

The cone has three steps for a $3\frac{1}{2}$ inch belt, and as the machine is back geared there are six changes of speed of spindle, and an intermediate cone between the cone on end of spindle and the feed cone provides for a corresponding number of changes of feed of spiral bed for each speed of spindle. The spindle will carry a cutter arbor projecting 15 inches and cutters as large as 8 inches in diameter may be used. The knee has a vertical movement of 21 inches.

Capacity
of the
Machine,
etc.

The spiral bed which is 40 inches long and 7 inches wide, can be fed 22 inches and lowered 21 inches from the centre of the spindle. It can be set at any angle each way up to 45 degrees, and has a movement of $6\frac{3}{8}$ inches in line with the spindle. The greatest attainable distance from the middle of the spiral bed to the face of the stand and knee slide is $10\frac{3}{4}$ inches.

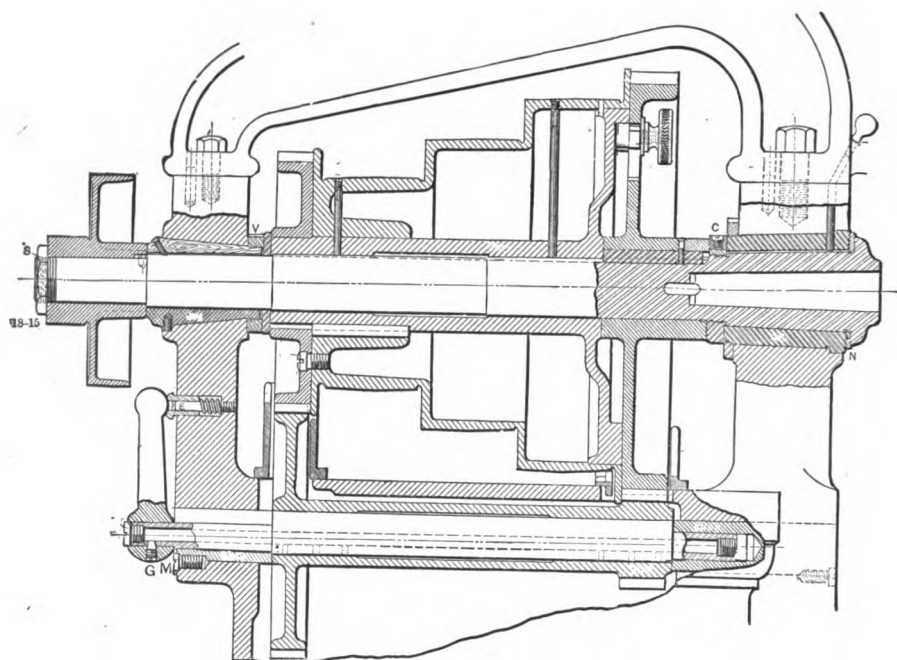


FIG. 12.

The spiral head and foot stock will take $22\frac{3}{4}$ inches between centres and swing $11\frac{1}{4}$ inches. These centres can be lowered a distance of 15 inches from the main spindle. The hole in the spiral spindle is $1\frac{1}{4}$ inches in diameter.

The vise has jaws $6\frac{1}{8}$ inches wide, $1\frac{7}{8}$ inches deep, and will open $3\frac{3}{8}$ inches.

The counter shaft has two 16 inch friction pulleys for 4 inch belts, and is usually run at about 105 turns per minute.

Weight of the machine ready for shipment is about 3,800 pounds.

Floor space measured over the extreme projections and parts of travel of various parts, is 74x57 inches.

Dimensions of box in which the machine is packed for shipment are 60x41x67 inches.

Each machine is furnished with 11 change gears, 1 reversing gear for left hand spirals, 3 index plates, 1 table of pitches and angles of spirals, 1 copy of this "Treatise on Milling Machines," 1 9-inch three jawed chuck, 1 swivel vise with graduated base, 1 vise crank, 1 spiral bed stop, 1 hand wheel, 1 centre rest, 1 collet for holding shank mill, twist drills and similar tools, 1 raising block, 1 knee crank, 2 centre keys, 1 oil can and stand, 6 wrenches and complete overhead works.

Accessories

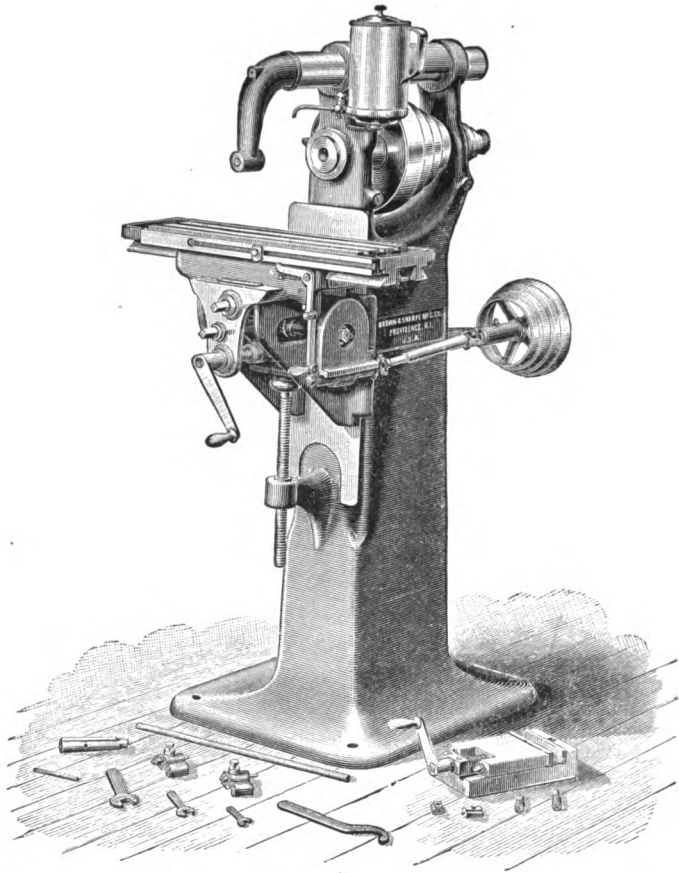
PLAIN MILLING MACHINES.

The majority of milling is plain milling. Cutting spirals, work requiring the use of indexing mechanism or work that is milled when the platen is at an angle, other than a right angle, with the spindle, form a comparatively small part of the work done even on Universal Milling Machines. Where a shop can have but one machine without doubt it should be a Universal, for then the workman is prepared for any operation that may be required. When a second machine, however, is to be purchased the advantages of obtaining a plain miller should be considered. The plain machines are more simple and consequently comparatively low priced, and as the platen is not swiveled it can rest directly upon the knee or other support, rendering the machine stiffer and enabling a heavier cut to be taken or more work produced in any given time.

To operate a Plain Machine requires so little attention comparatively that frequently the man who runs it can also run a Universal Machine. On many classes of work boys can be employed, and in a number of cases one boy can operate as many as four machines. As the advantage of plain milling is more adequately appreciated the number of machines in use is rapidly increasing. At one time it was thought that only irregular shaped or small pieces could be advantageously milled, but it is now quite well known that very many plain surfaces and large pieces can be milled more profitably than they can be planed. The cutter moving constantly through the work will accomplish more than the planing tool with its intermittent action. It is also now

more fully appreciated than formerly, that usually cutters can be made quite cheaply, and with care will last a long time, also that in manufacturing, even though the special cutters and fixtures are comparatively expensive, the saving in time and the superior accuracy of the work make their use profitable.

For a number of years we have used and built Plain Milling Machines, and they have formed parts of the exhibits which have been honored by the juries of award in the various world expositions during the past twenty-five years.



No. O.

16 in. x 4 1-4 in. x 12 in.

Plain Milling Machine.

The table has an automatic longitudinal feed of 16", a transverse movement of 4 1/4", and can be lowered 12" from centre of spindle.

No. O.
16 in. x 4 1-4 in. x 12 in.
PLAIN MILLING MACHINE.
With Rack or Screw Feed.

THE SPINDLE has a hole its entire length, and runs in bronze boxes provided with means of compensation for wear. The front end is threaded and has a hole fitted for arbors with taper $\frac{1}{2}$ " per foot and .90" diameter at the small end.

THE CONE has 4 steps, the largest 10" diameter, for $2\frac{1}{4}$ " belt.

THE OVERHANGING ARM can be easily reversed to receive an attachment, turned out of the way, or removed. The distance from the centre of the spindle to the arm is $5\frac{1}{8}$ "; greatest distance from end of spindle to centre in arm, $10\frac{1}{2}$ ".

THE TABLE, including oil pans and channels is 25" long, 8" wide, and has a working surface 20" x 6". It also has 3 T slots $\frac{1}{2}$ " wide, a transverse movement of $4\frac{1}{4}$ ", and can be lowered 12" from centre of spindle.

THE FEED of table, 16", is automatic in either direction, and there are 8 changes of feed, varying from .005" to .100" to one revolution of spindle.

ADJUSTABLE DIALS, graduated to read to thousandths of an inch, indicate the transverse and vertical movements of table, and these dials may be adjusted without the aid of wrench or screw-driver.

THE FRAME is hollow and fitted as a closet to hold the small parts that accompany the machine.

THE VISE has jaws $5\frac{1}{8}$ " wide, $1\frac{1}{8}$ " deep, and will open $2\frac{3}{4}$ ".

THE COUNTER-SHAFT has tight and loose pulleys, 12" in diameter, for $2\frac{1}{2}$ " belts, and should run about 180 revolutions per minute.

WEIGHT of machine ready for shipment, about 1085 lbs.

NET WEIGHT, about 770 lbs. FLOOR SPACE, 49" x 35".

DIMENSIONS of box in which machine is shipped, 39" x 30" x 59".

PRICE INCLUDES vise, oil can, "D" collet, wrenches, and everything else shown in cut, together with overhead works, boxed and delivered f. o. b. at Providence, R. I.

No. 1.

24 in. x 6 1-2 in. x 18 1-2 in.

Formerly No. 4,

PLAIN MILLING MACHINE,

With Rack or Screw Feed.

This machine has just been placed upon the market, and presents a number of new features, chiefly in connection with the feed.

THE SPINDLE has a hole its entire length, and runs in bronze boxes provided with means of compensation for wear. The front end is threaded, and has a hole fitted for arbors with taper $\frac{1}{2}$ " per foot and 1.05" in diameter at the small end.

THE CONE has 4 steps, the largest $10\frac{1}{2}$ " diameter, for 3" belt.

THE OVERHANGING ARM has a hole for a centre or for a bearing for outer end of arbor, etc. It can be easily reversed to receive an attachment, turned out of the way, or removed. The distance from the centre of the spindle to the arm is $5\frac{1}{2}$ "; greatest distance from end of spindle to centre in arm, 16". An arm brace is furnished, and, with this in position, milling can be done to $13\frac{1}{2}$ " from face of column.

THE TABLE, including oil pans and channels, is 38" long, 10" wide, and has a working surface $32" \times 7\frac{1}{2}"$. It also has 3 T slots $\frac{5}{8}"$ wide, a transverse movement of $6\frac{1}{2}"$, and can be lowered $18\frac{1}{2}"$ from centre of spindle.

THE FEED of table, 24", is automatic in either direction, and there are 8 changes of feed, varying from .005" to .09" to one revolution of spindle.

ADJUSTABLE DIALS, graduated to read to thousandths of an inch, indicate the transverse and vertical movements of table,

and these dials may be adjusted without the aid of wrench or screw-driver.

THE FRAME is hollow and fitted as a closet to hold the small parts that accompany the machine. On the left side there is a pan for holding small tools, etc., and on the front of this there is a rack for wrenches.

THE VISE swivels and has a graduated base. The jaws are $5\frac{1}{8}$ " wide, $1\frac{1}{8}$ " deep, and will open $2\frac{3}{4}$ ".

THE COUNTER-SHAFT has tight and loose pulleys, 14" in diameter, for $3\frac{1}{2}$ " belts, and should run about 110 revolutions per minute.

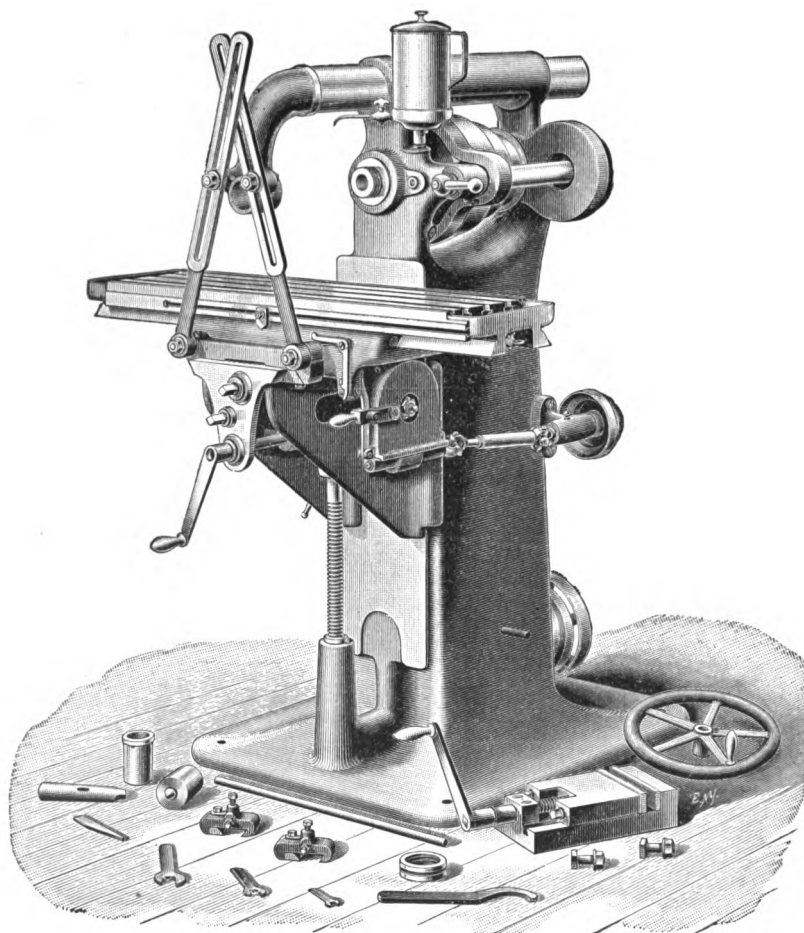
WEIGHT of machine ready for shipment, about 1850 lbs.

NET WEIGHT, about 1485 lbs.

FLOOR SPACE, 69" x 45".

DIMENSIONS of box in which machine is shipped, 46" x 59" x 33".

PRICE INCLUDES vise, oil can, "E" collet, wrenches, and everything else shown in cut, together with overhead works, boxed and delivered f. o. b. at Providence, R. I.

**No. 2.**

28 In. x 6 1-2 In. x 18 1-2 In.

Plain Milling Machine.

The table has an automatic longitudinal feed of $28''$, a transverse movement of $6\frac{1}{2}''$, and can be lowered $18\frac{1}{2}''$ from centre of spindle.

No. 2.

28 in. x 6 1-2 in. x 18 1-2 in.

PLAIN MILLING MACHINE.

THE SPINDLE has a hole its entire length, and runs in bronze boxes provided with means of compensation for wear. The front end is threaded, and has a hole fitted for arbors with taper $\frac{1}{2}$ " per foot, and 1.05" diameter at the small end.

THE CONE has 3 steps, the largest 10" diameter, for 3" belt, and is back geared, giving six changes of speed. The gears are covered.

THE OVERHANGING ARM has a hole for a centre, or for a bearing for outer end of arbor, etc. It can be easily reversed to receive an attachment, turned out of the way, or removed. The distance from the centre of the spindle to the arm is $5\frac{1}{2}$ "; greatest distance from end of spindle to centre in arm, is 16". An arm brace is furnished, and, with this in position, milling can be done to $13\frac{1}{2}$ " from face of column.

THE TABLE, including oil pans and channels, is 40" long, 10" wide, and has a working surface 34" x 10". It also has 3 T slots, $\frac{5}{8}$ " wide, a transverse movement of $6\frac{1}{2}$ ", and can be lowered $18\frac{1}{2}$ " from centre of spindle.

THE FEED of table, 28", is automatic in either direction, and there are 12 changes of feed, varying from .005" to .13" to one revolution of spindle.

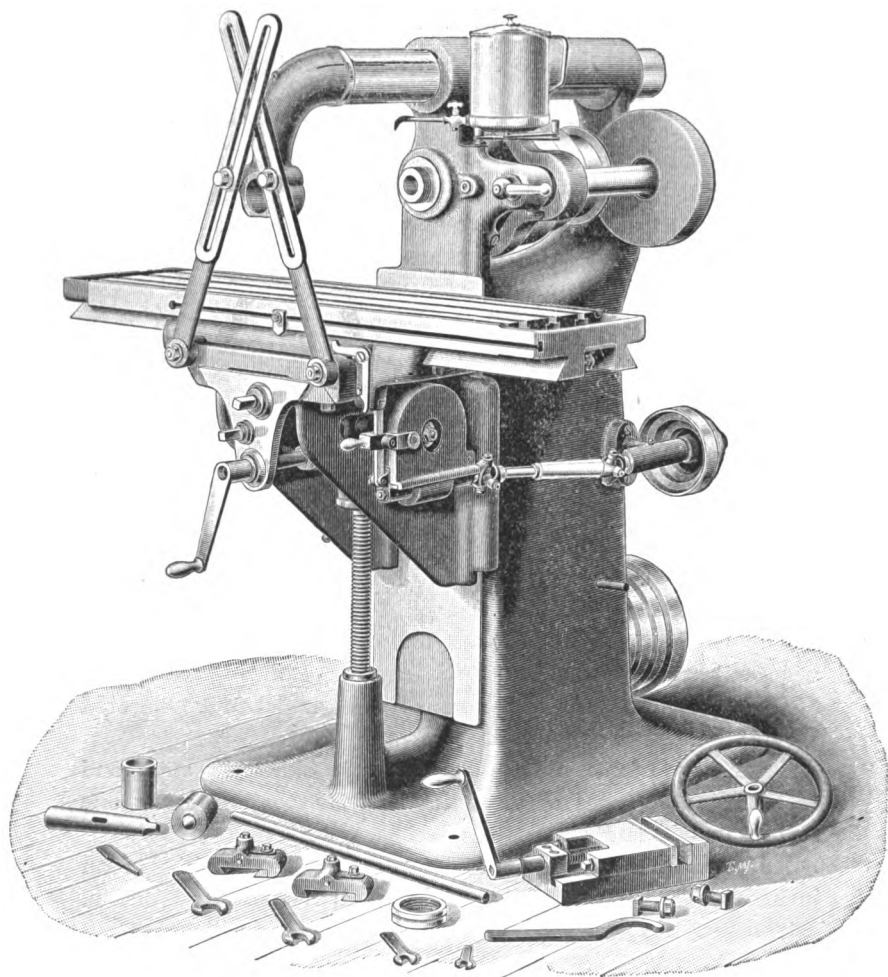
ADJUSTABLE DIALS, graduated to read to thousandths of an inch, indicate the transverse and vertical movements of table.

The VISE has jaws $6\frac{1}{8}$ " wide, 17-16" deep, and will open $3\frac{5}{8}$ ".

THE COUNTER-SHAFT has tight and loose pulleys, 14" in diameter, for $3\frac{1}{2}$ " belts, and should run about 180 revolutions per minute. WEIGHT of machine ready for shipment, about 2100 lbs. NET WEIGHT, about 1645 lbs. FLOOR SPACE, 68" x 45".

DIMENSIONS of box in which machine is shipped, 50" x 34" x 62".

PRICE INCLUDES vise, oil can, "E" collet, wrenches, and everything else shown in cut, together with overhead works, boxed and delivered f. o. b. at Providence, R. I.

**No. 3.****34 in. x 7 in. x 19 3/4 in.****Plain Milling Machine.**

The table has an automatic longitudinal feed of $\frac{3}{4}$ " , a transverse movement of $\frac{7}{8}$ " , and can be lowered $19\frac{3}{4}$ " from centre of spindle.

No. 3.

34 in. x 7 in. x 19 3-4 in.

PLAIN MILLING MACHINE.

THE SPINDLE has a hole its entire length, and runs in bronze boxes provided with means of compensation for wear. The front end is threaded, and has a hole fitted for arbors with taper $\frac{1}{2}$ " per foot, and 1.25" in diameter at the small end.

THE CONE has 3 steps, the largest 11" diameter, for $3\frac{1}{2}$ " belt, and is back geared, giving, with two speeds of counter-shaft, 12 changes of speed. The gears are covered.

THE OVERHANGING ARM has a hole for a centre, or for a bearing for outer end of arbor, etc. It can be easily reversed to receive an attachment, turned out of the way, or removed. The distance from the centre of the spindle to the arm is $6\frac{3}{8}$ "; greatest distance from end of spindle to centre in arm, 21". An arm brace is furnished, and, with this in position, milling can be done to $15\frac{1}{2}$ " from face of column.

THE TABLE, including oil pans and channels, is 50" long, 12" wide, and has a working surface 42" x 12". It also has 3 T slots, $\frac{5}{8}$ " wide, a transverse movement of 7", and can be lowered $19\frac{3}{4}$ " from centre of spindle.

THE FEED of table, 34", is automatic in either direction, and there are 16 changes of feed, varying from .004" to .33" to one revolution of spindle.

ADJUSTABLE DIALS, graduated to read to thousandths of an inch, indicate the transverse and vertical movements of table.

THE VISE has jaws $6\frac{1}{8}$ " wide, 17-16" deep, and will open $3\frac{5}{8}$ ".

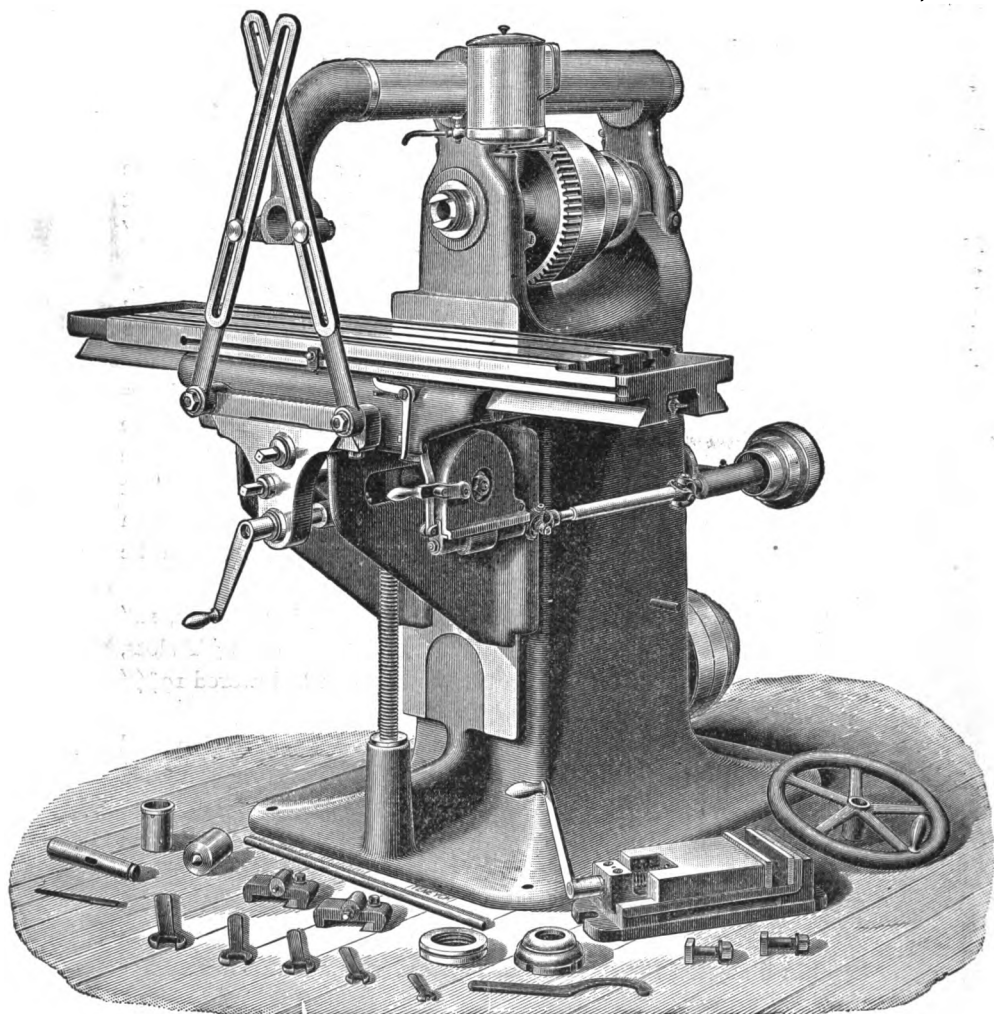
THE COUNTER-SHAFT has two tight and loose pulleys, 14" and 18" in diameter, for 4" belts, and should run about 200 and 155 revolutions per minute.

WEIGHT of machine ready for shipment, about 3375 lbs.

NET WEIGHT, about 2800 lbs. FLOOR SPACE, 84" x 51".

DIMENSIONS of box in which machine is shipped, 56" x 32" x 66".

PRICE INCLUDES vise, oil can, "G" collet, wrenches, and everything else shown in cut, together with overhead works, boxed and delivered f. o. b. at Providence, R. I.

**No. 4.****42 in. x 81-4 in. x 22 in.****Plain Milling Machine.****(Formerly No. 6.)**

The table has an automatic longitudinal feed of 42", a transverse movement $8\frac{1}{4}$ ", and can be lowered 22" from centre of spindle.

No. 4.

42 in. x 8 1-4 in. x 22 in.

PLAIN MILLING MACHINE.

(Formerly No. 6.)

THE SPINDLE has a hole its entire length, and runs in bronze boxes provided with means of compensation for wear. The front end is threaded, and has a hole fitted for arbors with taper $\frac{1}{2}$ " per foot, and 1.25" diameter at the small end.

THE CONE has 3 steps, the largest 13" diameter, for $3\frac{1}{2}$ " belt, and is back geared, giving, with two speeds of counter-shaft, 12 changes of speed. The gears are inside the column.

THE OVERHANGING ARM has a hole for a centre, or for a bearing for outer end of arbor, etc. It can be easily reversed to receive an attachment, turned out of the way, or removed. The distance from the centre of the spindle to the arm is $7\frac{1}{4}$ "; greatest distance from end of spindle to centre in arm, $26\frac{1}{2}$ ". An arm brace is furnished, and, with this in position, milling can be done to $18\frac{1}{2}$ " from face of column.

THE TABLE, including oil pans and channels, is 60" long, 14" wide, and has a working surface 48" x 14". It also has 3 T slots, $\frac{3}{4}$ " wide, a transverse movement of $8\frac{1}{4}$ ", and can be lowered 22" from centre of spindle.

THE FEED of table, 42", is automatic in either direction, and there are 12 changes of feed, varying from .005" to .23" to one revolution of spindle.

ADJUSTABLE DIALS, graduated to read to thousandths of an inch, indicate the transverse and vertical movements of table.

THE VISE has jaws $7\frac{1}{8}$ " wide, $1\frac{7}{8}$ " deep, and will open $4\frac{1}{2}$ ".

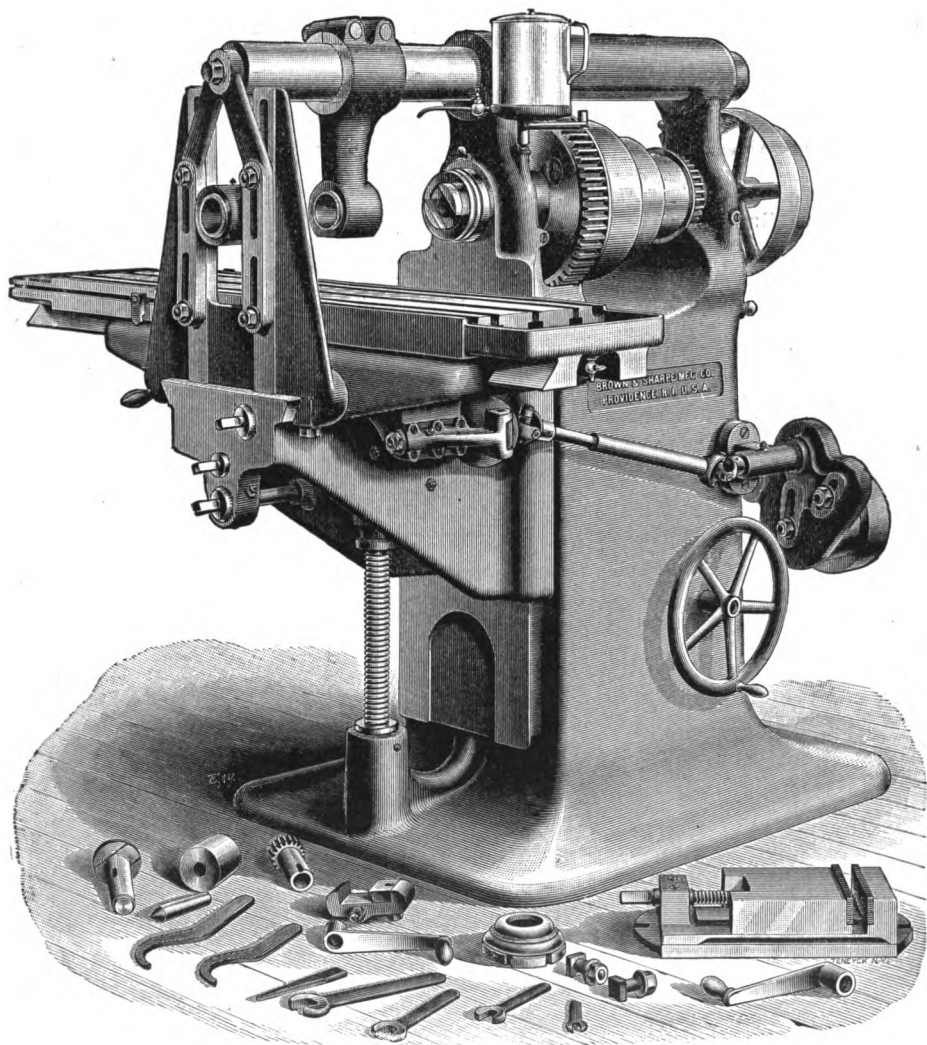
THE COUNTER-SHAFT has two tight and loose pulleys, 14" and 18" in diameter, for 4" belts, and should run about 200 and 155 revolutions per minute.

WEIGHT of machine ready for shipment, about 4100 lbs.

NET WEIGHT, about 3435 lbs. FLOOR SPACE, 102" x 59".

DIMENSIONS of box in which machine is shipped, 62" x 39" x 67".

PRICE INCLUDES vise, oil can, "G" collet, wrenches, and everything else shown in cut, together with overhead works, boxed and delivered f. o. b. at Providence, R. I.



No. 5.

48 In. x 9 3-4 In. x 19 1-2 In.

Plain Milling Machine.

(Formerly No. 8.)

The table has an automatic longitudinal feed of 48", a transverse movement of $9\frac{3}{4}$ ", and can be lowered $19\frac{1}{2}$ " from centre of spindle.

No. 5.

48 in. x 9 3-4 in. x 19 1-2 in.

PLAIN MILLING MACHINE.

(Formerly No. 8.)

Patented Oct. 18, 1892.

THE SPINDLE has a hole its entire length, and runs in bronze boxes provided with means of compensation for wear. The front end has a hole fitted for arbors with taper $\frac{1}{2}$ " per foot and 1.50" diameter at the small end.

THE CONE has 3 steps, the largest $13\frac{3}{4}$ " diameter, for $4\frac{1}{2}$ " belt, and is back geared, giving, with two speeds of counter-shaft, 12 changes of speed. The gears are inside the column.

THE OVERHANGING ARM has a hole for a centre, or for a bearing for outer end of arbor, etc. It can be easily pushed back from the table. The distance from the centre of the spindle to the arm is 8"; greatest distance from end of spindle to centre in arm, 24". An arm brace is furnished, and with this in position, milling can be done to 26" from face of column.

THE TABLE, including oil pans and channels, is 66" long, 16" wide, and has a working surface 54" x 16". It also has 3 T slots, $\frac{3}{4}$ " wide, a transverse movement of $9\frac{3}{4}$ ", and can be lowered $19\frac{1}{2}$ " from centre of spindle.

THE FEED of table, 48", is automatic in either direction, and there are 8 changes of feed, varying from .02" to .25" to one revolution of spindle.

ADJUSTABLE DIALS, graduated to read to thousandths of an inch, indicate the transverse and vertical movements of table.

THE VISE has jaws $7\frac{1}{8}$ " wide, $1\frac{1}{8}$ " deep, and will open $4\frac{1}{2}$ ".

THE COUNTER-SHAFT has two tight and loose pulleys, 16" and 20" in diameter, for 5" belts, and should run about 140 and 112 revolutions per minute. WEIGHT ready for shipment, 6,000 lbs.

NET WEIGHT, about 5,545 lbs. FLOOR SPACE, 115" x 69".

DIMENSIONS of boxes in which machine is shipped, 67" x 42" x 67" and 66" x 21" x 21".

PRICE INCLUDES vise, oil can, "T" collet, wrenches, and everything else shown in cut, together with overhead works, boxed and delivered f. o. b. at Providence, R. I.

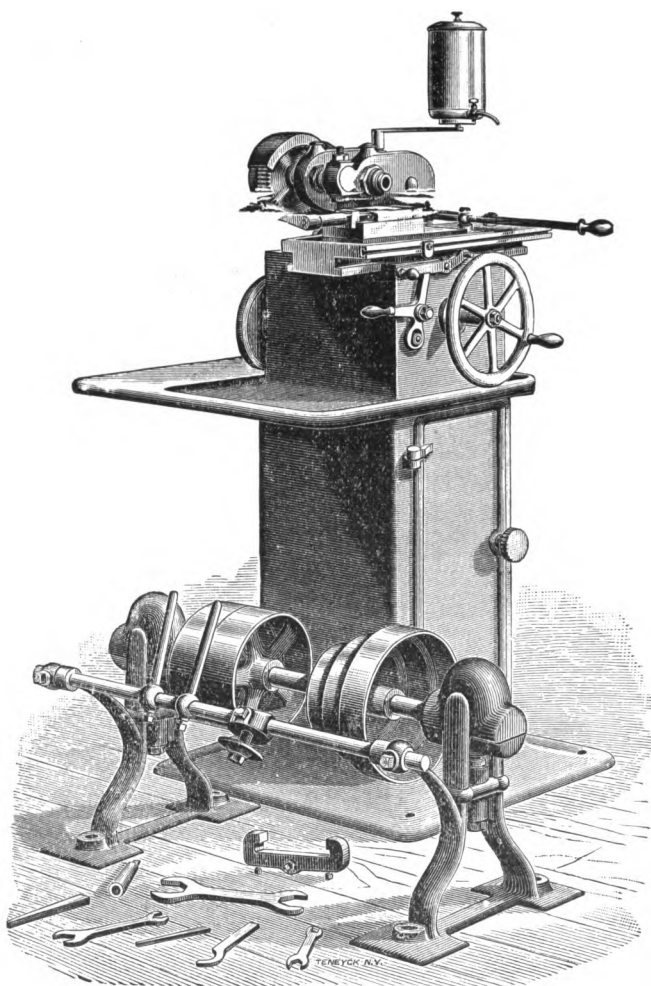


FIG. 16.
No. 11 Plain Milling Machine.

No. 11 PLAIN MILLING MACHINE.

This machine, Fig. 16, is designed for milling small work.

The table is fed automatically or by the hand lever, as may be desired. Attached to the stand and bed is a shelf, which forms a convenient place for tools and work.

The cone has three steps for a $1\frac{3}{4}$ inch belt. Length of the table is 20 inches; width $7\frac{3}{4}$ inches; the length of feed is 12 inches; the platen or finished portion of the table, is 11 inches long, $3\frac{1}{2}$ inches wide. Capacity

The spindle has bronze bearings with means for compensation for wear. It has a horizontal adjustment of $\frac{1}{2}$ inch, and the greatest distance from its centre to top of table is $3\frac{1}{4}$ inches; the least attainable distance is $1\frac{1}{2}$ inches.

The vise has jaws $3\frac{5}{8}$ inches wide, $1\frac{3}{8}$ inches deep, and will open $1\frac{1}{2}$ inches. The overhead works have tight and loose pulleys 8 inches in diameter for $2\frac{1}{4}$ inch belts, and should be run about 300 turns per minute. The hangers are self-oiling.

The weight of the machine ready for shipment is about 850 lbs. Floor space, 43x32 inches.

Dimensions of box in which the machine is packed for shipment are 32x32x53 inches.

Each machine is furnished with 1 vise, 1 hand lever, 1 platen stop, 1 collet, 2 centre keys, 6 wrenches, 1 oil can and stand, complete overhead works, and 1 copy of this "Treatise on Milling Machines." Accessories.

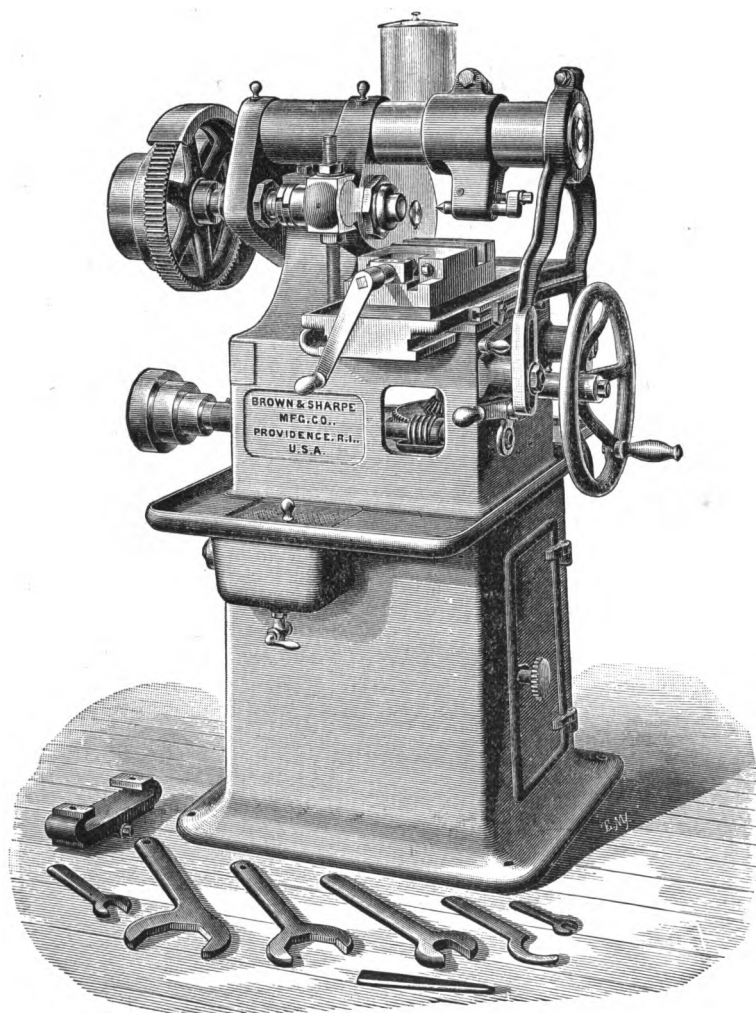


FIG. 17.

No. 12 Plain Milling Machine.

No. 12 PLAIN MILLING MACHINE.

This machine is designed for manufacturing purposes, and is well adapted for the rapid and economical production of many parts of machine tools, sewing machines, guns, instruments, etc.

General
Character
of the
Machine.

The spindle is raised and lowered by nuts upon the vertical screw shown in cut, and moved horizontally by nuts on the front box. The table is fed automatically, and the feed is automatically disconnected by an adjustable stop on the edge of platen. The spindle of the machine is provided with bronze bearings arranged for adjustment to compensate for wear. Attached to the stand is a table for holding work, tools, etc.

The arm carrying the centre support for the cutter arbor may be firmly secured to the bed of the machine by an arm brace, and in all parts the machine is unusually stiff and rigid.

The cone has three steps for a $2\frac{1}{2}$ inch belt. The greatest distance from the centre of spindle to top of table is 8 inches; the least attainable distance $2\frac{3}{4}$ inches. The spindle has a horizontal adjustment of $\frac{1}{2}$ inch.

Capacity.

The table is 28 inches long, $9\frac{1}{2}$ inches wide. The platen, to which the work is secured, is 19 inches long and 6 inches wide. The total length of feed, $17\frac{1}{2}$ inches.

The vise has jaws $6\frac{1}{8}$ inches wide, $1\frac{7}{8}$ inch deep, and will open $3\frac{3}{8}$ inches.

The counter-shaft pulleys are 10 inches diameter, for 3 inch belt and should run about 280 turns per minute.

Weight, 1,950 lbs. Floor space, 45x45 inches.

Dimensions of box in which the machine is packed for shipment are 43x33x36 inches.

Each machine is furnished with 1 vise, 1 platen stop, 1 centre key, 5 wrenches, 1 oil can and stand, complete overhead works, and 1 copy of this "Treatise on Milling Machines."

Accesso-
ries.

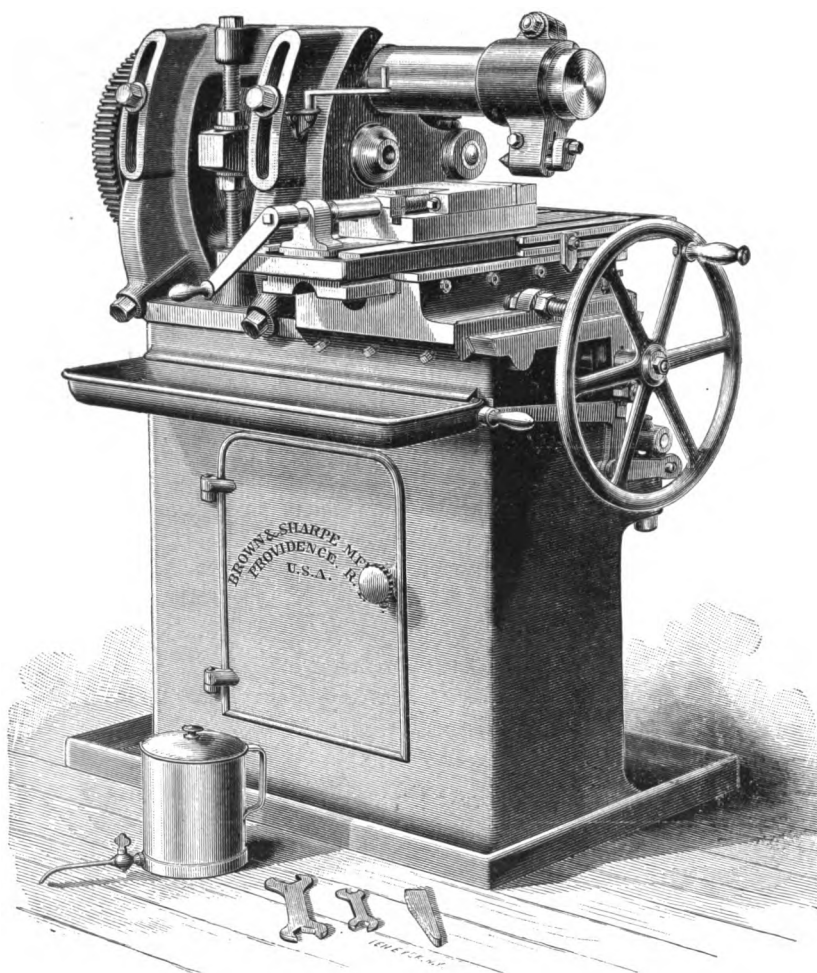


FIG. 18.

No. 13 Plain Milling Machine.

No. 13 PLAIN MILLING MACHINE.

This machine is compact and rigid, and so arranged that the work can be quickly placed in position, and quickly removed after the cut is taken.

The spindle is driven by a gear and pinion from a Capacity. three-step cone with a 3 inch belt. It has a vertical adjustment of $4\frac{1}{8}$ inches.

The table is 9 inches wide, 27 inches long, and has 15 inches longitudinal, and 3 inches transverse movement, and is moved longitudinally $1\frac{1}{4}$ inches by each turn of the hand wheel.

The feed is automatic with three changes, stopping automatically at any required point.

The vise has jaws $6\frac{1}{8}$ inches long, $1\frac{7}{8}$ inches deep, and will open $3\frac{3}{8}$ inches.

The counter-shaft has pulleys 10 inches diameter, for 3 inch belt, and should be run about 375 turns per minute.

Weight 2,650 lbs.

Floor space measured over the extreme projections and points of travel of the various parts, 47x47 inches.

Dimensions of box in which the machine is packed for shipment are 50x38x59 inches.

Each machine is furnished with 1 vise, 1 center key, 1 oil can and stand, 5 wrenches, 1 arm brace, complete overhead works, and copy of this "Treatise on Milling Machines." Accessories.

No. 23 PLAIN MILLING MACHINE.

This machine, like Figure 19, is especially adapted for work requiring large table capacity and long cuts. The table has three T slots running its entire length and as there is no saddle or cross-slide it rests directly on the knee thus bringing the work upon a firm support.

General
Character
of the
Machine.

Long and short arm braces are provided for securing the outer end of the arm to the knee and are of advantage when heavy cuts are taken or a cutter is used at the outer end of the arbor.

An index head and foot stock are not furnished with this machine but those shown by Fig. 15 may be used upon it.

The cone has three steps for a $2\frac{1}{2}$ inch belt and makes $13\frac{1}{3}$ turns to one turn of the spindle, which in connection with the two pulleys on the counter shaft gives the spindle six different speeds, graded from twenty-four to two hundred and seven turns a minute.

The spindle will carry a cutter arbor projecting 15 inches and cutters 10 inches in diameter. The spindle has a hole $1\frac{1}{4}$ inches in diameter through its entire length. The head has a horizontal movement of 9 inches, and the knee has a vertical movement of $18\frac{1}{2}$ inches. The table is $50\frac{5}{8}$ inches long, 10 inches wide, and can be fed its entire length in either direction. Its bearings are 30 inches in length.

The feed can be varied from 0 to $\frac{1}{16}$ of an inch per revolution of the spindle.

The vise has jaws $7\frac{1}{8}$ inches wide, $1\frac{7}{8}$ inches deep and will open $4\frac{1}{2}$ inches.

The counter-shaft has friction pulleys 10 inches and 14 inches in diameter, for 3 inch and $4\frac{1}{2}$ inch belts, and are usually run at about 420 and 300 turns per minute respectively.

The weight of the machine boxed ready for shipment is about 3,050 lbs.

Floor space measured from the extreme projections and points of travel of the various parts is 45x110 inches.

Dimensions of box in which the machine is packed for shipment are 50x37x65 inches.

Each machine is furnished with 1 vise, 1 knee crank, 1 collet, 1 centre key, 1 oil can and stand, 5 wrenches, 2 arm braces, 1 spindle bolt, complete overhead works, 1 copy of this "Treatise on Milling Machines."

Accesso-
ries.

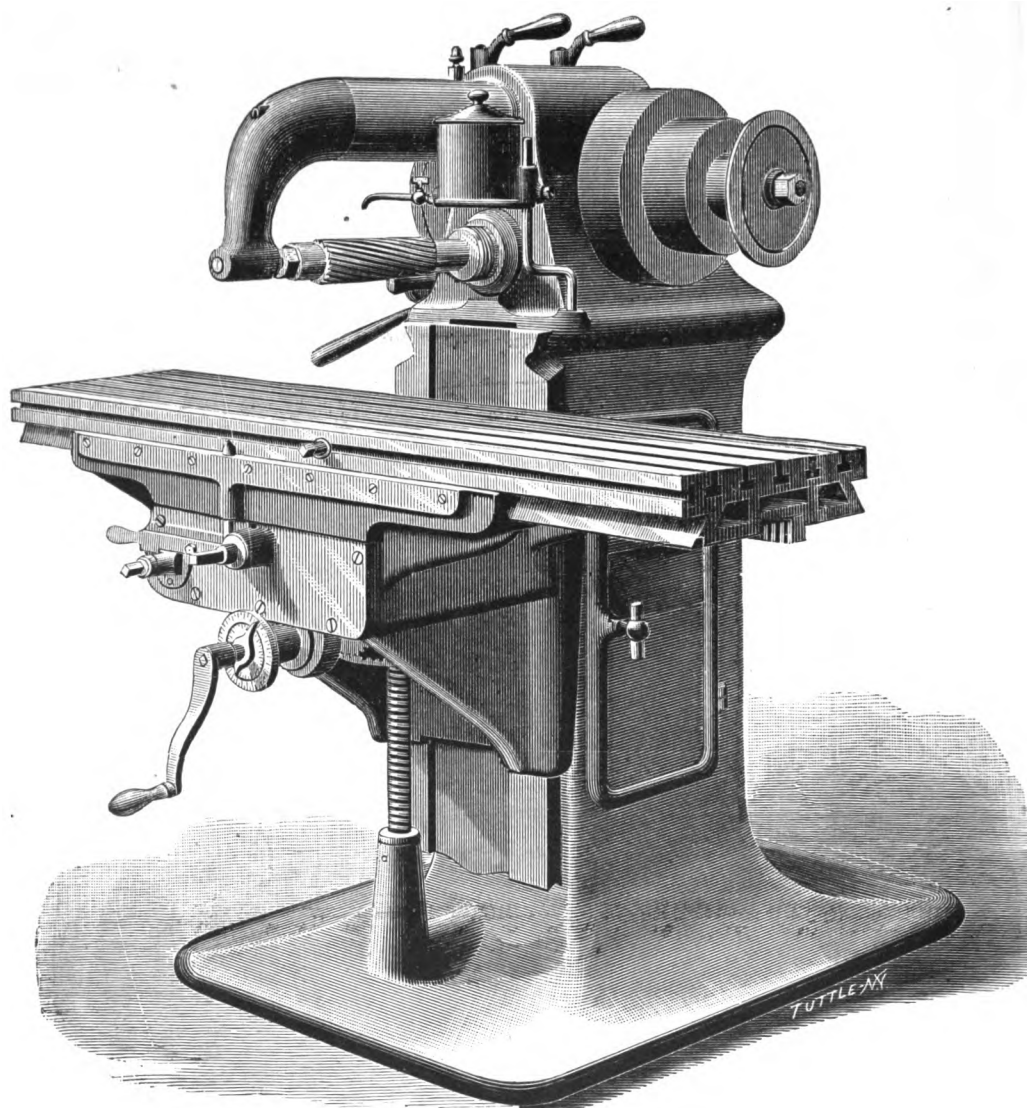


FIG. 19.
No. 24 Plain Milling Machine.

No. 24 PLAIN MILLING MACHINE.

The No. 24 Plain Milling Machine is similar in general design and construction to the No. 23 Plain Milling Machine. All the parts are larger and heavier, however, and thus greater capacity and efficiency is obtained.

General
Character
of the
Machine.

The outer end of the overhanging arm on this machine, is always so arranged that the arbor can be run on a centre or in a bushing. The latter method affords a firmer support for the arbor and relieves the spindle of end thrust caused by expansion of the arbor. It is particularly useful in heavy work.

The cone has three steps for 3 inch belts and makes $13\frac{1}{3}$ turns to 1 turn of the spindle, and in connection with the two pulleys on the counter shaft gives the spindle six changes of speed, graded from 16 to 110 turns per minute.

The spindle will carry a cutter arbor projecting 18 inches and cutters 11 inches in diameter may be used. The spindle has a hole $1\frac{1}{2}$ inches in diameter through its entire length. The head has a horizontal movement of 12 inches, and the knee has a vertical movement of $17\frac{5}{8}$ inches.

Capacity.

The table is 60 inches long, $14\frac{1}{2}$ inches wide, and has an automatic feed its entire length in either direction. The feed can be varied from the finest up to $\frac{1}{10}$ inch per revolution of the spindle. The table has 5 T slots its entire length, and can be lowered $18\frac{3}{4}$ inches below the centre of the spindle. The bearings of the table are 36 inches long.

The vise has jaws $7\frac{1}{8}$ inches wide, $1\frac{7}{8}$ inches deep and will open $4\frac{1}{2}$ inches.

The counter-shafts have friction pulleys 12 inches and 18 inches in diameter for $3\frac{1}{2}$ inch and $4\frac{1}{2}$ inch belts, and are usually run at about 300 and 200 turns per minute respectively.

The weight of the machine boxed ready for shipment is about 4,350 pounds.

Floor space measured from the extreme projections and points of travel of the various parts is 52x133 inches.

Dimensions of box in which the machine is packed for shipment are 59x39x69 inches.

This machine is also furnished with a table 72 inches long, and bearings on the knee 48 inches long.

Weight of machine with long table, is about 4,750 pounds.

Floor space, 52x153 inches.

**Accesso-
ries.**

Each No. 24 Plain Milling Machine is furnished with 1 vise, 1 table stop, 1 knee crank, 1 collet, 1 centre key, 1 oil can and stand, 5 wrenches, 2 arm braces, 1 spindle bolt, 1 centre arm bushing, 1 centre, complete over-head works, 1 copy of this "Treatise on Milling Machines."

NO. 2 VERTICAL SPINDLE MILLING MACHINE.

This machine, Fig. 22, for many kinds of work, is preferable to a machine with a horizontal spindle. The operator can more clearly and easily see the work and more readily follow any irregularity in the outline of the surface to be milled.

General
Character
of the
Machine.

The platen is gibbed solidly to a broad substantial base and rests upon flat and ample bearings. It is fed in either direction its entire length and width, automatically or by hand, and its movements are controlled from the front of the machine.

Vertical adjustments are obtained by raising or lowering the column and very fine variations in the height of the spindle are made by means of a collar nut. This is graduated and reads to thousandths of an inch. The bearings of the spindle are long and large and are provided with means to compensate for wear. The arbors may be held by a bolt which passes through the hole in the spindle.

The platen is 41 inches long, $13\frac{3}{4}$ inches wide, and has eight changes of speed for each speed of the spindle. The spindle has three belt and three gear speeds, which, with two speeds of counter, make twelve speeds in all. At its lowest position, the spindle is $1\frac{1}{2}$ inches and at its highest 15 inches above the platen. Cutters up to 8 inches diameter may be used. The overhead works have hangers with self-oiling and adjustable boxes.

Capacity.

The counter-shaft has friction pulleys 12 and 16 inches diameter for $3\frac{1}{2}$ and 4 inch belts, and should run 220 and 165 revolutions per minute.

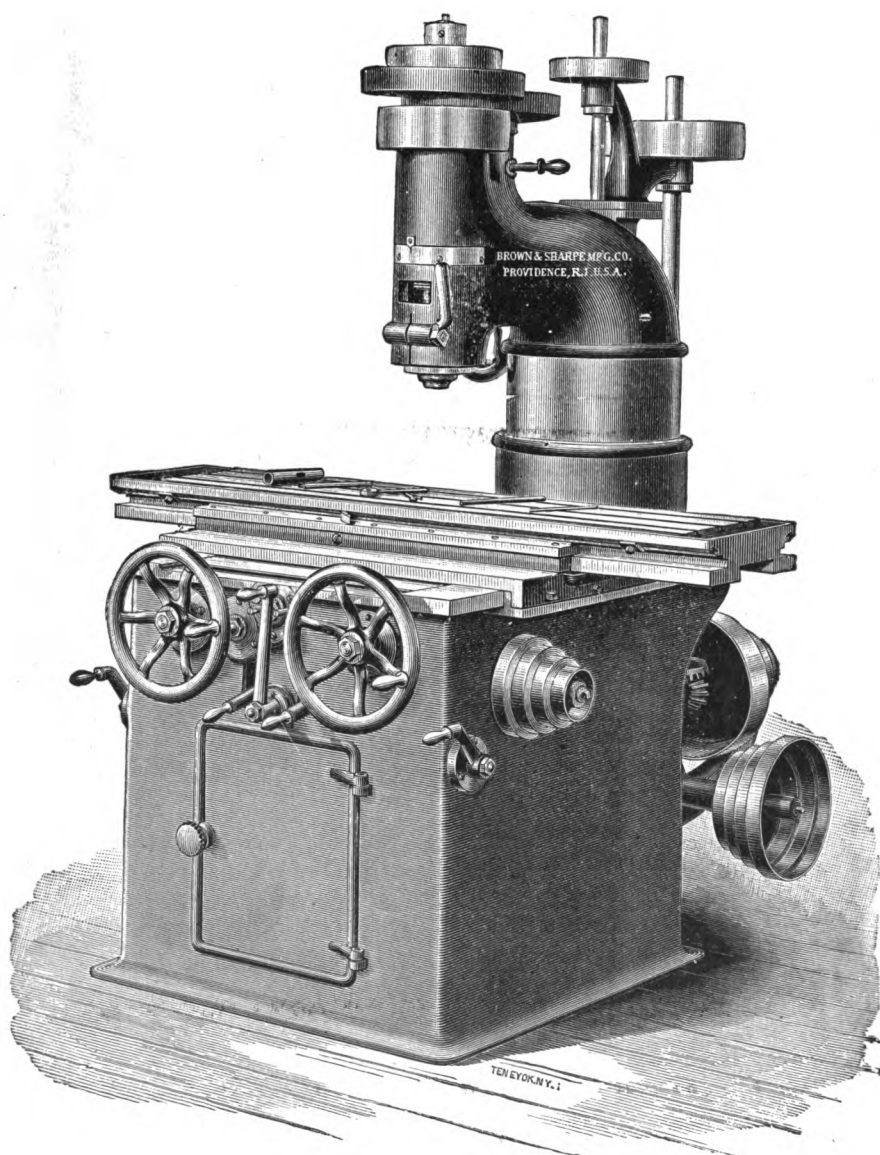


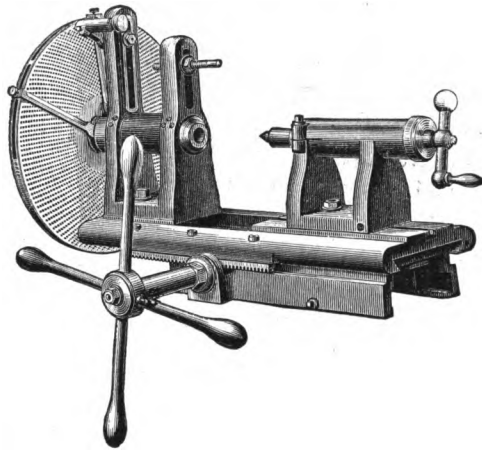
FIG. 22.
No. 2. Vertical Spindle Milling Machine.

Weight of machine, boxed ready for shipment, about 5,100 pounds.

Floor space, 82x78 inches.

Dimensions of box in which the machine is packed for shipment are 69x45x33 inches.

Each No. 2 Vertical Spindle Milling Machine is furnished with 1 collet, 1 centre key, 3 wrenches, 1 oil can and stand, complete overhead works, one copy of this "Treatise on Milling Machines." ^{Accessories.}

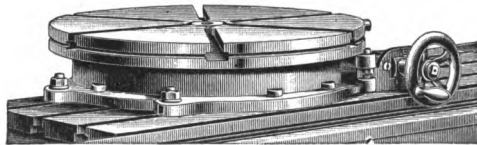


GEAR CUTTING ATTACHMENT FOR NO. 1 UNIVERSAL MILLING MACHINE.

This Attachment is for use in cutting gear wheels, and wheels larger and heavier than can be cut with the ordinary apparatus belonging to the No. 1 Universal Milling Machine. It swings 14 inches, and is furnished with a 20-inch index plate containing 4294 holes. It will divide all numbers to 75, and all even numbers to 150. Arbors fitted to the No. 1 Universal Milling Machine can be used in this device. The screw with set nuts over the spindle is designed as a support for the wheel while being cut. Weight, boxed, 440 lbs.

THE HEAD AND FOOT-STOCK of this attachment can be fitted for use upon the Nos. 2, 3 and 4 Universal, and the Nos. 1, 2, 3, 4, 5, 23 and 24 Plain Milling Machines.

CIRCULAR MILLING ATTACHMENT.



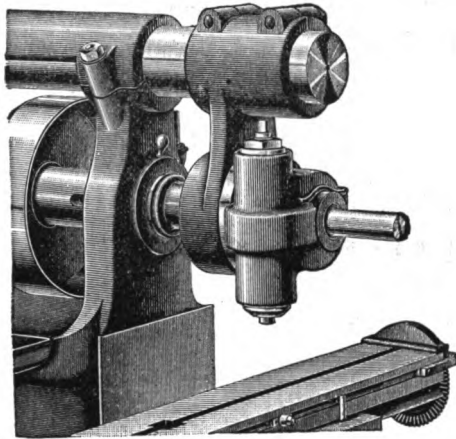
This Attachment for the No. 2 Vertical Spindle Milling Machine is of service in milling circles, segments of circles, circular slots, etc., on plain and irregularly shaped pieces. It is bolted to the table of the machine, and when so placed can be adjusted to any desired position.

THE TABLE is 20 inches in diameter, and has 6 T slots $\frac{3}{4}$ inch wide.

THE FEED of table is automatic and can be automatically released at any point. There are 8 changes of feed.

THE ATTACHMENT is $4\frac{1}{4}$ inches high.

PRICE INCLUDES everything shown in cut, together with bracket and pulleys for attaching it to the Machine.



VERTICAL SPINDLE MILLING ATTACHMENTS

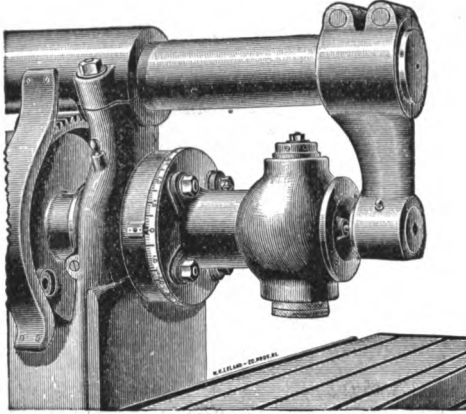
FOR NOS. 1, 2, 3 AND 4 UNIVERSAL, AND NOS. 1, 2, AND 3
PLAIN MILLING MACHINE.

These attachments are used for a large range of light milling, and are of special advantage for key-seating, die-sinking, cutting T slots, etc.

The holder or frame is secured to the overhanging arm, and the horizontal shaft is inserted in the cone spindle of the machine. The vertical spindle is driven by the horizontal shaft through spiral gears.

The spindle can be set at any angle from a vertical to a horizontal position. The position is indicated on the base of spindle head which is graduated.

Machine on which attachment is used, }	Nos. 1 & 2 Univ.	Nos. 3 & 4 Univ.
	Nos. 1 & 2 Plain.	No. 3 Plain.
Taper Hole in Spindle,	7	9
Collet furnished,	"J"	"K"



VERTICAL SPINDLE MILLING ATTACHMENTS

FOR NOS. 4 AND 5 PLAIN MILLING MACHINES.

The holder or frame is secured to the frame of the machine, and the horizontal shaft is inserted in the spindle of the machine.

The vertical spindle is driven by the horizontal shaft through bevel gears.

The spindle can be set at any angle from a vertical to a horizontal position. The position is indicated on the base of spindle head, which is graduated.

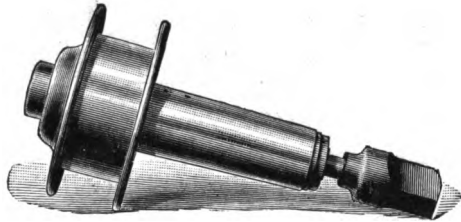
Machine on which Attachment is used,	No. 4 Plain.	No. 5 Plain.
Taper Hole in Spindle,	9	11
Collet,	"K"	"O"
Distance from Centre of Spindle to Column,	9½ in.	11 in.

VERTICAL SPINDLE MILLING ATTACHMENTS

FOR NO. 24 PLAIN MILLING MACHINE.

The holder or frame is secured to the overhanging arm, and the vertical spindle is driven by a worm and worm wheel by a belt from cone of the machine

On certain classes of work two cuts can be made simultaneously, one by a cutter on the arbor in the spindle of the machine, the other by a mill in the vertical spindle of the attachment.



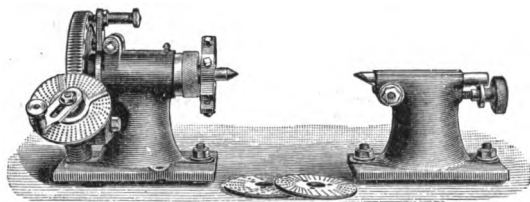
HIGH SPEED MILLING ATTACHMENT

FOR NOS. 1 AND 2 UNIVERSAL AND 1 AND 2 PLAIN
MILLING MACHINES.

This attachment is of service for light or finishing cuts with end mills, and consists of a small collet or spindle running in a hardened shell that fits the hole in the cone spindle of the machine. It is driven directly from an extra pulley on the counter-shaft, and thus small mills may be run much faster than the usual speed of the cone spindle. When the attachment is used the cone pulley is stationary.

PRICE INCLUDES an extra pulley and a holder to which the belt can be shifted when not in use.

10-INCH INDEX CENTRES.



THE CENTRES SWING $10\frac{1}{4}$ " in diameter.

THE SPINDLE is threaded on front and has a taper hole. The straight hole at end of taper $1\frac{1}{8}$ " in diameter.

THE WORM WHEEL is $6\frac{1}{2}$ " in diameter, and one revolution is made by 40 revolutions of index crank. It has 24 holes and when the worm is disengaged direct indexing can be done and the wheel held by means of an index pin.

THE INDEX PLATES are the same that are used on the No. 1 Universal Milling Machine.

THE HEAD-STOCK can be clamped at any angle on table.

THE TONGUES AND BOLTS furnished fit a T slot $\frac{5}{8}$ " wide. The tongues are inserted.

COMBINED LENGTH of head and foot stocks, $13\frac{3}{4}$ ".

PRICE INCLUDES index plates and tables explaining the use of the same, wrenches and everything else shown in cut.

12-INCH INDEX CENTRES.

These Centres are of the same general design as the 10" Index Centres described above.

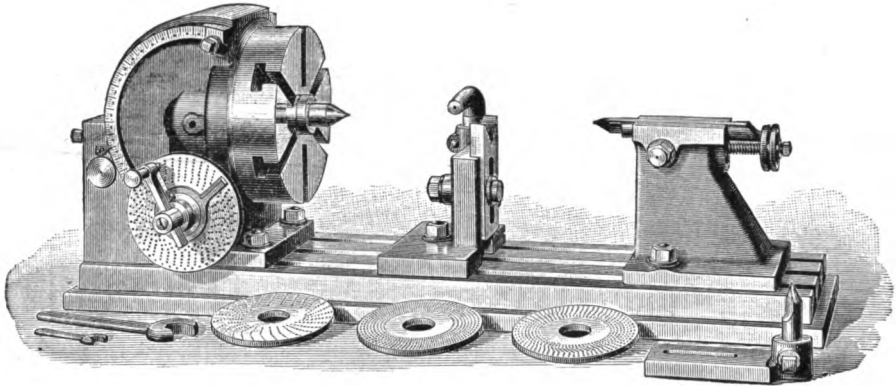
THE CENTRES SWING $12\frac{1}{4}$ " in diameter.

THE WORM WHEEL is $7\frac{3}{4}$ " in diameter.

THE TONGUES AND BOLTS furnished fit a T slot $\frac{3}{4}$ " wide.

COMBINED LENGTH of head and foot-stocks, $16\frac{3}{4}$ ".

PRICE INCLUDES index plates and tables explaining the use of the same, wrenches and everything else shown in cut of 10" Index Centres.



INDEX HEAD AND CENTRES WITH CENTRE REST.

PATENTED FEBRUARY 5, 1884.

These Centres are designed for use on Milling Machines, but the strength, stiffness and stability of the Index head in all positions enable it also to be advantageously used on Planers, Upright Drills and Slotting Machines.

THE CENTRES SWING $12\frac{1}{2}$ " in diameter.

THE HEAD can be set at any angle from 10 degrees below the horizontal to 10 degrees beyond the perpendicular.

THE SPINDLE is provided with a face plate and adjustable dog carrier. The front end has a taper hole. The straight hole at end of taper is $1\frac{1}{2}$ " in diameter.

THE WORM WHEEL is 6" in diameter, and one revolution is made by 60 revolutions of index crank.

THE INDEX PLATES divide all numbers to 100, all even numbers to 134, and all divisible by 4 to 200.

THE TABLE is provided with flanges, is 32" long, 8" wide, and has 3 T slots $\frac{3}{4}$ " wide.

COMBINED LENGTH of head and foot-stocks, 18".

CENTRE REST will take work to $3\frac{1}{8}$ " in diameter.

WEIGHT about 350 lbs.

PRICE INCLUDES table, index plates and tables explaining the use of the same, wrenches and everything else shown in cut.

MATERIAL, WORKMANSHIP, DESIGN, ETC.

Our machines are made with the intention that they shall be the best of their respective classes. Materials are used which experience has shown are the most suitable for the various parts, and careful attention is constantly given to insure good workmanship.

Our buildings are modern and specially arranged for the business. The machinery and appliances are the best attainable. Our machines are manufactured in large quantities with expensive special tools, and much greater accuracy has been obtained than can be reached by the usual methods of manufacturing. All plane bearings are scraped to surface plates; all cylindrical bearings are ground and fitted to standards. The alignments are correct. The machines are subjected to thorough inspection and, when deemed necessary, to actual operation before being packed.

The general design of our Universal Milling Machines has, for thirty years, been appreciated by mechanical experts, and faithfully imitated by almost every one who has desired to enter upon the manufacture of Milling Machines. The design of the large plain machines, in the main features, is similar to that of the Universal or Semi-Universal Machines. The distinguishing features of the smaller plain milling machines are the rapidity with which they can be operated; and their convenience for setting and removing the work. The Nos. 2 and 3 are also unusually stiff for their size and weight.

We are constantly endeavoring to improve the machines, and from time to time modify the details, and for this reason we suggest that our catalogue be frequently consulted, as all changes are there most speedily brought to the attention of the public.

CARE AND USE OF MILLING MACHINES.

The Machines should be placed upon a level, and if possible, a solid floor or foundation. The Universal and several of the Plain Machines should not be set where the screw which raises and lowers the knee will come directly over a beam; for there must be room for this screw below the base of the machine in order that the knee may reach its lowest position.

Placing
Machines.

The counter-shafts are generally placed over the machines, but if necessary the position of the cone and other pulleys may be changed.

Placing
Counter-
shafts.

The shippers are most convenient when on the left side of the machines.

To find the diameter of pulley required to run the counter-shaft at a given speed: multiply the speed of counter-shaft by the diameter of pulley on the same, and divide the product by the speed of main, or driving shaft.

Diameter
Pulley on
Main Line.

It is sometimes best to vary the speeds of counter-shafts from those given in our catalogue. In our own works some counter-shafts belonging to No. 1 Universal Milling Machines are run at only 90 turns per minute, while others are run at 150 turns per minute.

Speed of
Counter-
shafts.

As the life and efficiency of machines depend largely upon the amount of care bestowed upon them, it is important that they should be kept clean and well oiled, and that all repairs should be promptly made.

A coal or mineral oil called No. 2 cosmoline, we have found to be excellent for lubricating. In oiling the No. 1 Universal Milling Machine, the oil hole U, Fig. 4, and the knee screw bearing V, should not be overlooked. Several oil holes are marked and have threaded stoppers.

Oiling.

The back gear of the No. 4 Universal Milling Machine is oiled through the screw hole W, Fig. 12, and enough oil is held in the quill to last for several months. There are two other oil holes in the cone of this machine.

The greatest care should be taken that chips do not get into the holes in the spindles or between the arbor collars. Chips should also be kept from between the knee and frame.

Placing
Tools in the
Closets of
Machines.

In placing the tools belonging to the Nos. 1 and 3 Universal Milling Machines in the closets the following method is convenient: Put the wrenches, centre keys, collet and spanner upon the top shelf; the chuck, centre rest and rising block upon the second shelf from the top; the change gears and index plates in the wooden compartment, and the vise and its clamps upon the bottom shelf. When the hand wheel is not in use it should hang on the stud at the side of the machine, and when the machine is not in use it is well to have the spiral head and foot stocks on the table.

Oil Pans. For catching oil from the work it is convenient to have two pans, one about $5\frac{1}{4}$ inches square, and the other $5\frac{1}{4}$ inches wide and 8 inches long. The pans can be about $1\frac{1}{4}$ inches deep and should have a strainer near the top. Cleats on the bottom of the pans will keep them from slipping off the table. These pans are not sent with the machines but may be ordered from us if desired.

Adjusting
Spindle.

The construction of the machine should be examined carefully before any part is removed or adjusted. The proper adjustment will allow the spindle to be easily revolved by hand. The adjustment of the spindles will not need to be changed for a long time after the machines have left our works.

The question is often asked, How much skill is required to properly use or operate milling machines? A conservative answer is given in the following editorial from the *American Machinist*:

MILLING MACHINES AND SKILL.

"No one who has had sufficient experience with the milling machine in its various forms to acquire a reasonably clear idea of its capabilities, and who has an opportunity to see the machine in use in the various shops, can fail to see that in many of them it is very imperfectly understood, and that, as a consequence, comparatively poor results are obtained from its use—results, we mean, which are very poor compared with those which should be obtained, and are obtained in every case where the legitimate functions of the machine are clearly recognized, and the conditions necessary to its successful operation secured.

The milling machine intelligently selected or constructed, with reference to the work it is expected to do, provided with well-designed and well-made special fixtures, where the nature of the work calls for them, and then skillfully handled, is a surprisingly efficient tool, but used as it is being used in many shops to-day, it is a delusion, a failure, and an injury alike to the users, to the builders, and to the good name of milling machines generally.

While it is true that there is scarcely a machine tool in use which will yield more satisfactory returns for a given outlay, when pains are taken to use it in the best possible manner, it is also true, we think, that there is no tool in common use, the efficiency of which is so much reduced by careless or ignorant handling and abuse. Considerable intelligence and skill, as well as constant attention, must be bestowed upon the milling

machines in order to secure anything like a satisfactory performance from them, either in the quality of the work done or in its quantity.

In some cases this skill and intelligence must be possessed and exercised by the man who actually handles the machine, in other cases by some one who, though he does not actually operate it, supervises its operation, and is responsible for the work done by it. But in any case, the skill, the intelligence and the careful attention must be exercised, or the results will be anything but satisfactory.

We hear a great deal about the comparatively cheap labor required to do milling machine work, and it is evident that too many shop proprietors have concluded from this that about all that is necessary to do such work is to buy the machine, hire a boy to run it, have him "shown how" for an hour or so by one of the lathe hands, and then let the boy and the machine work out their own salvation.

No greater mistake could possibly be made, and it is in such a shop that a milling machine man finds the machine working often at less than half its capacity, with an apology for a cutter, ground by hand in every shape but the right one, two or three only of its superabundant teeth touching the work, and they, with a distinct thump and knock, indicating anything but a real cutting action, while the boy stands by and occasionally—when it occurs to him to do so—squirting a few drops of black lubricating oil onto the chips with which the spaces between the teeth are tightly jammed. The proprietors of such shops are not usually very enthusiastic regarding the use of milling machines, and it would be a wonder if they were.

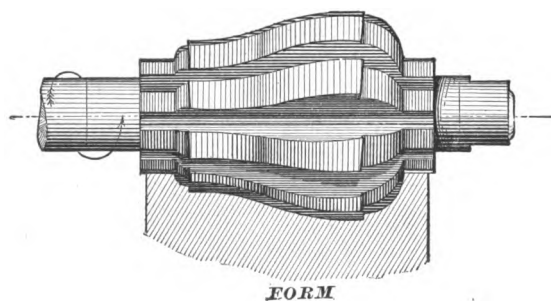
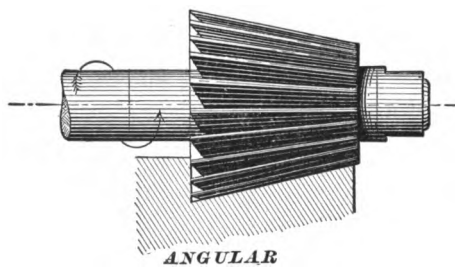
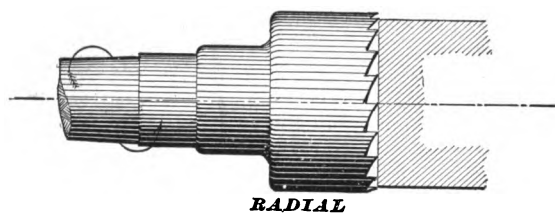
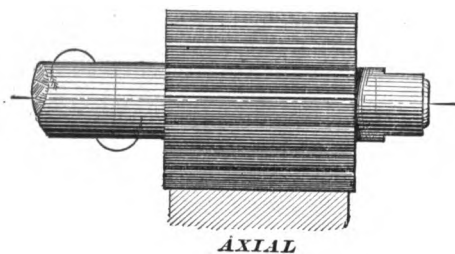
Where a universal milling machine is used upon tool work, or for other purposes requiring a constant change from one job to another, it is a mistake to suppose that there is economy in the employment of a boy or cheap man to operate it. And many of those who think they are saving money in that way would be greatly sur-

prised to see the work turned out from such machines by good mechanics who thoroughly understand them, and are capable of earning good wages upon them.

Experience has proved that it pays as well to put first-class mechanics upon such machines as upon any other machine tools.

Where milling machines are used for regular manufacturing operations, and the same cycle of movements is to be repeated for a large number of pieces, boys, or men who are not skilled mechanics, answer every purpose; but the skilled supervision must be there, and it must be seen to that the machine is as well taken care of, the cutters as well made and ground, and in fact, everything as well done as though a good mechanic actually operated the machines. In fact, in the shops in which the best results are obtained from the use of milling machines in regular manufacturing operations all changes of the machines from one job to another, all adjustments, and the grinding and replacing of cutters are done by, or at least under the direct supervision of a skilled mechanic, responsible for the work of the machines and who thoroughly understands and appreciates them. In this way only can the full benefits of the machine be realized.

It is far too common to go into the tool-room and find a splendid universal milling machine standing idle, while perhaps two or three men are doing at the shaper, planer or vise, jobs which could be done by an expert milling machine hand in one-fourth down to one-tenth of the time, and a great deal better. One fault, which is far more common than would readily be believed in some quarters, is a failure to recognize the fact that a milling machine necessarily calls for some sort of a machine for grinding cutters, and that a machine upon which cutters are used, that are ground by holding the edges one after the other against an emery wheel by hand, is at a decided disadvantage, and will do no work which either in quality or cost will make a favorable showing when compared with that which is done by properly ground cutters.

**Fig. 27.**

It should be much more generally recognized that in milling machine practice, as in other things, there is a right way and a wrong way, and that skilled, intelligent labor pays best. When these facts are more generally recognized, it will be better for both the builders and for the users of the machines.

CUTTERS USED ON MILLING MACHINES.

A common class of milling is that in which the surface milled is parallel to the axis of the spindle, and a kind of cutter very frequently used for this work is the milling cutter shown at the head of the page, Fig. 27 and in Fig. 28. When the diameter of this cutter is large, compared with the length, and teeth are cut on the side, as in Fig. 29, it is called a side mill or side milling cutter. When used in pairs, as in Fig. 45, they are called twin or straddle mills. When the diameter is small, compared with the length, and the cutter has a solid shank, as in Fig. 30, it is generally called an end mill.

**Axial
Mills.**

The screw slotting cutter is shown in Fig. 31. It has no clearance except that given by the burr on the teeth, and should be used only for cutting shallow slots. For deep slots the metal slitting saw, Fig. 32, should be used. On this saw the clearance is ground.

When milling cutters, saws, or similar mills are used, the surface milled is parallel to the axis of the mill as well as the axis of the spindle of the machine, and the work is done by axial teeth, that is by teeth on the face or convex surface of the mill, these teeth being directly parallel to the axis, or having the same general direction as the axis of the mill.

Another class of milling is when the surface milled is in a plane perpendicular to the axis of the spindle, and such work is milled by the end mill Figs. 27 and 30, by

**Radial
Mills.**

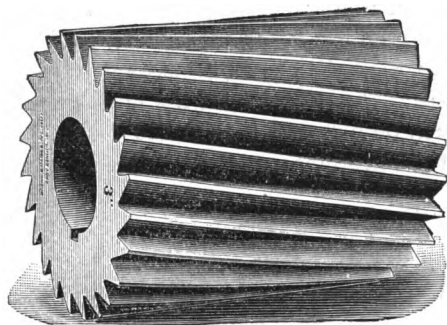


FIG. 28.

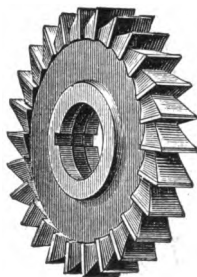


FIG. 29.

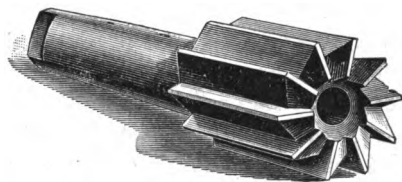


FIG. 30.



FIG. 31.

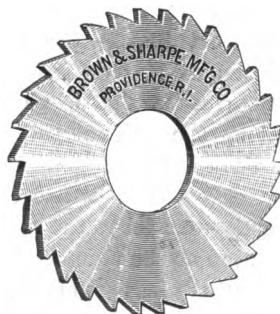


FIG. 32.

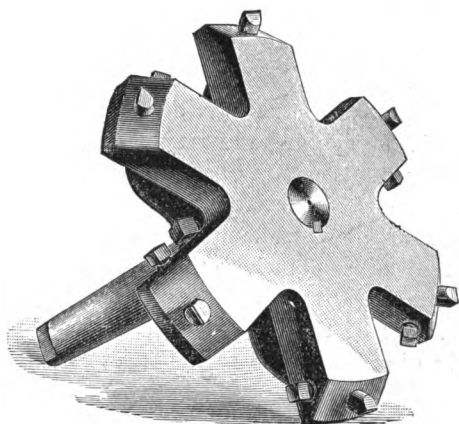


FIG. 33.

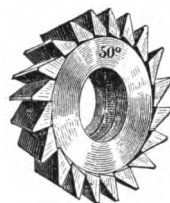


FIG. 34.

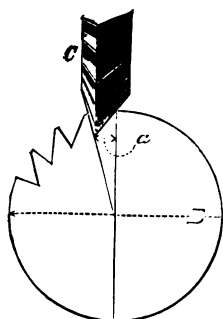


FIG. 35.

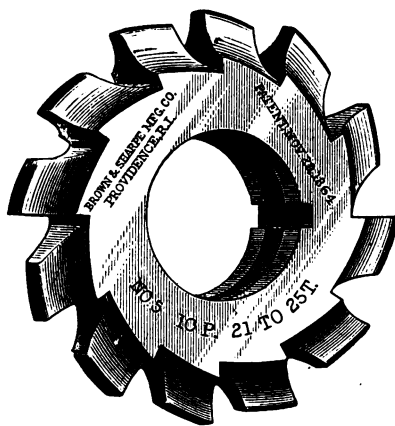


FIG. 36.

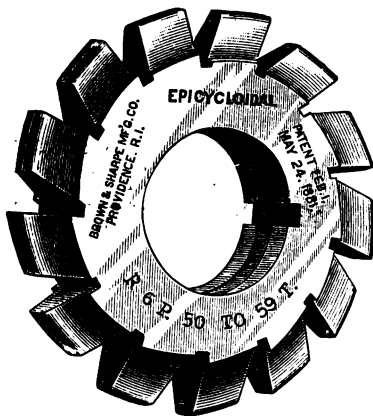


FIG. 37.

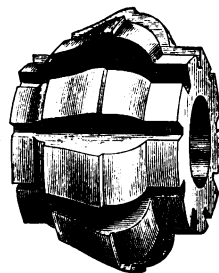


FIG 38

the teeth on the sides of the side milling cutter Fig. 29, or, if large, by the inserted tooth mill Fig. 33. Such surfaces are perpendicular to the axis of the mills, as well as to the axis of the spindle, and may be said to lie in a plane parallel with the radii of the mills, or to be cut by the radial teeth of mills, that is, the teeth on the ends or radial faces of the mills.

**Angular
Mills.**

The third class of milling is where the surface to be milled is at an angle other than a right angle with the axis of the spindle or of the cutter. Cutters for this work are shown in Figs. 27, 34 and 35, and most of these have teeth both on the face and on the side. When one or both cutting edges of the tooth make an angle with the radial planes or sides of the cutter the angle of the cutter may be given as the angle between the sides of the groove cut. When the two cutting edges of a tooth make different angles it is convenient to name the angle that each makes with the side of the mill. Thus, one side of the tooth of a cutter for spiral mills, Fig. 35, makes an angle of 40 degrees with the side of the cutter, while the other makes an angle of 12 degrees. Hence, the sides of the groove form an angle of 52 degrees.

The teeth of our angular mills are brought almost to a sharp point, as for some work this is necessary. For most work, however, the points should be rounded when ground, since it is better not to have a sharp corner at the bottom of a groove, and it is difficult to prevent the sharp points from soon becoming dull.

**Form
Mills.**

The fourth class of milling is where the surface to be milled is curved or irregular in form. Mills for this work are made in a great variety of forms, Fig. 27 and Fig. 38, and are usually termed form mills or cutters. They include a number of special cutters named principally from the work which they perform. As for example: gear cutters Fig. 36 and Fig. 37, twist drill cutters, tap cutters and tap and reamer cutters.

The most simple of the form cutters is the fly cutter shown with its holder in Fig. 39, the cutting face as shown by the end view being held about in line with the

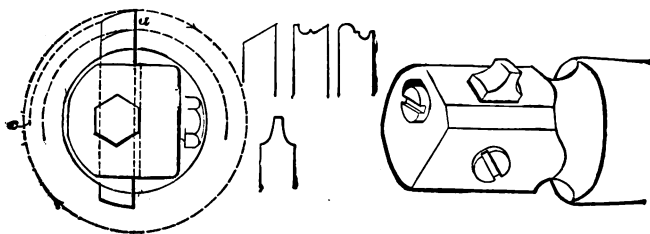


FIG. 39.

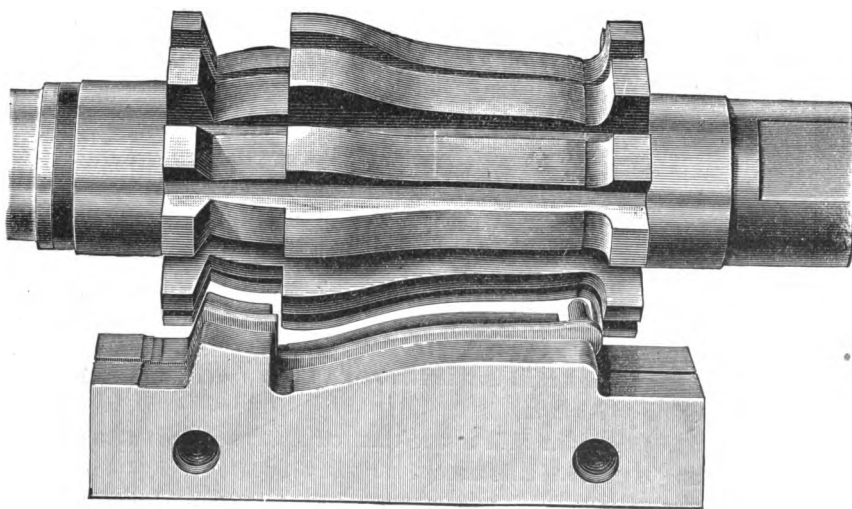


FIG. 40.

centre of the holder. As these cutters have but one cutting edge they mill accurately to their own shape, but of course do not mill so fast, or wear as long as cutters with a number of teeth. They can be formed very exactly to any desired shape at comparatively small expense, and thus may be used for many operations that otherwise will not bear the cost of special cutters;—for example: when one or two small gears are wanted in experimental work. Fly cutters are also of special advantage in making and duplicating screw machine and other tools of an irregular cutting contour. The clearance in tools thus made may be obtained by holding the tool blank in the vise so that the front end will be elevated several degrees.

Our form cutters can be sharpened without changing their outline, and are called formed mills.

Single formed mills, as shown in Fig. 38, are not uncommonly made in one piece 7 inches diameter or 6 inches long. When the width of the cut is greater than can be easily made by one cutter several cutters are combined in a gang as in Fig. 40. A gang is limited in length only by the capacity and power of the milling machine.

Summary
and Definition
of
different
classes of
Mills.

From what has been said it appears that mills naturally fall into four classes, and may be designated by the four varieties of work performed, that is, they may be termed Axial, Radial, Angular and Form Mills. To define them:

An Axial mill is one that cuts flat surfaces parallel to its axis.

A Radial Mill is one that cuts flat surfaces perpendicular to its axis.

An Angular Mill is one that cuts flat surfaces at any angle with its axis except a right angle.

A Form Mill is one that cuts curved or irregular surfaces. An example of each class is seen in Fig. 27.

Distributing the various kinds of cutters under the several heads of this classification, milling cutters, screw slotting cutters and saws are axial mills. Inserted tooth mills, end mills and side milling cutters are radial mills.

The two last, however, are also axial, and should be termed such when the axial teeth are to be used in dressing the work. Angular and form mills naturally appear under the proposed classification.

This classification has several features which make it advantageous for general use. The different parts of a mill can be designated with no reasonable chance of a misunderstanding, while with the usual method of referring to mills this is not the case for the terms "side," "face" or "end" are applied indiscriminately and there is no common agreement on these terms among mechanics. The same term under the proposed classification is never applied to two different parts, and the mills are arranged in four definite classes according to the work which they perform.

It is well to have mills or cutters as **small in diameter** Diameter of Mills. as the work or their strength will admit. The reason is shown by Fig. 41. Suppose the piece I D C J E is to be cut from I J to D E. If the large mill A is used, it will strike the piece first at I when its centre is at K, and will finish its cut when its centre is at M. The line G shows how far the mill must travel to cut off the stock I J D E. If the small mill B is used, however, it travels only the length of the line H. It can also be seen that a tooth of B travels through a shorter distance between the lines D E and I J than a tooth of A. This is true of all ordinary work, or where the depth of cut I D is not more than half the diameter of the small mill.

The advantage of small mills has been illustrated in our own works, where a difference of $\frac{1}{2}$ an inch in the mills has made a difference of 10% in the cost of the work.

In short, small mills do more and better work, cut more easily, keep sharp longer and cost less than large mills.

When it is possible the mill should be wider than the Length of Mills. work, and the hole in a mill should be as small as the Diameter of Hole in Mills. strength of the arbor will admit. The stock around the hole, however, should not be less than $\frac{3}{8}$ of an inch thick.

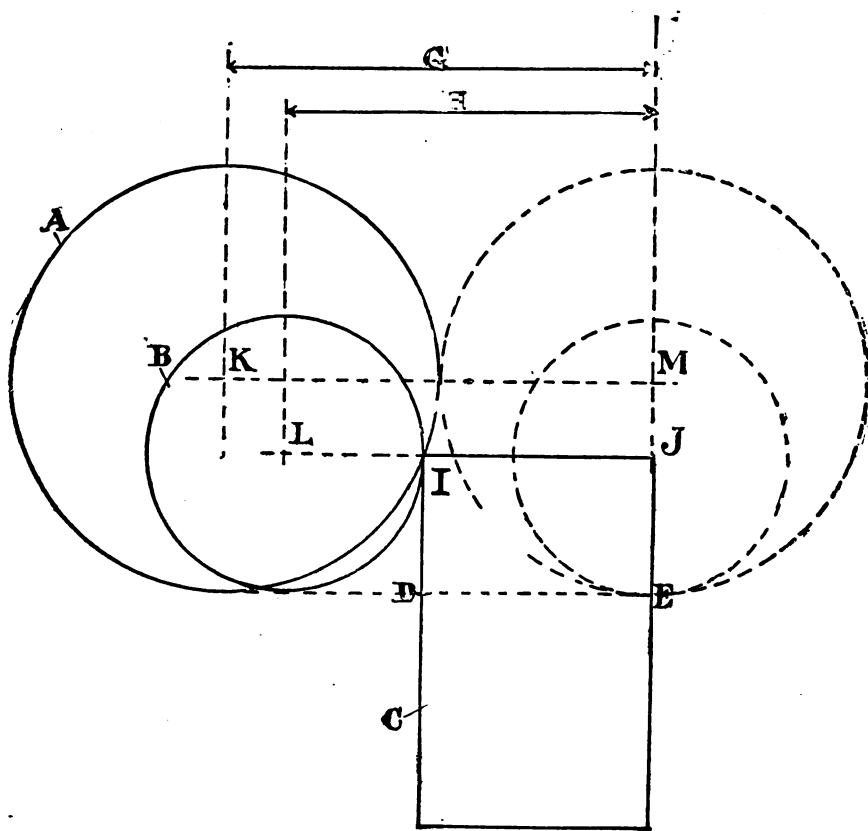


FIG. 41.

A mill is not necessarily too soft because it can be scratched with a file, for sometimes when cutters are too hard or brittle and trouble is caused by pieces breaking out of the teeth they can be made to stand well and do good work by starting the temper.

Of late years mills have been made with coarser teeth than formerly, the advantages being more room for the chips and less friction between the teeth and the work. When the teeth are so fine that the mill drags, or the stock is powdered the mill heats quickly and does not cut freely.

Our practice in making cutters for general use, is to give a cutter such a number of teeth that there will always be one tooth, and about one-half the time, two teeth cutting. For Example: we give stock cutters 2 inches, 3 inches, 6 inches and 8 inches in diameter, 18, 24, 32 and 36 teeth respectively.

Knowing the conditions under which a mill is to be used, we modify the number of teeth as seems expedient, usually making the special mills coarser in pitch than the stock mills, for our observation indicates there are more mills with too many teeth than with too few. But sometimes we relatively increase the number of teeth, as for instance, large mills, in some cases, can advantageously be designed to have more than one tooth cutting all the time on broad surfaces and in deep cuts.

In England cutters generally have finer teeth than in America, the pitch being about two thirds as much as ours, as shown by the rules given at a meeting of the Institution of Mechanical Engineers in London, October 30, 1890. These rules we are permitted to print by the courtesy of the gentlemen who presented them at the meeting.

Mr. Geo. Addy, of Sheffield, estimates the pitch of teeth of cutters from 4 inches to 15 inches diameter by the following rule:

Pitch in inches = $\sqrt{(\text{diameter in inches} \times 8)} \times 0.0625$.
Mr. J. Macfarlane Gray pointed out that this rule might be put into a somewhat simpler form for more convenient

use as a plain workshop rule, by saying that the product of the pitch in inches multiplied by the pitch in thirty-seconds of an inch was equal to the diameter in inches, and that a still more simple way of stating what was substantially the same rule was to say that the number of teeth in a milling cutter ought to be one hundred times the pitch in inches; that is, if there were 27 teeth, the pitch ought to be 0.27 inch.

Cutting
Angle of
Teeth
of Mills.

In regard to the cutting angle of the teeth we in theory agree with what Mr. Addy stated in the paper before referred to, viz: "The adoption of the most suitable cutting angle should receive the same close attention that is now universally bestowed upon the ordinary tools for turning and planing." But in practice while in many instances adopting the angle according to the material to be used, yet taking into consideration all the conditions of using and caring for the cutters, we have generally found it satisfactory to have the cutting edges of the teeth radial. As a result of considerable research and experience Mr. Addy gives as his opinion that the front of the teeth instead of being truly radial should have a backward inclination of 10 degrees from the radius, the cutting angle in this way being 70 degrees and the clearance angle 10 degrees.

Clearance
of Mills.

The relief or clearness of mills we think should usually be about three degrees and the land at the top of the teeth from .02 inches to .04 inches wide before the clearness is cut or ground.

On cotter mill's, Fig. 42, the clearance should be at the outside of the two teeth, as the cutting is not done directly upon the end; but this clearance should usually be only about one-quarter of that on other mills.

Mills to cut grooves should be hollowing about five one-hundredths in one inch for clearance, that is, a grooving mill should be about one one-hundredth of an inch thinner at one inch from its edge or circumference than it is at the edge. Our grooving mills are given a limit of two one-thousandths in thickness. Mills made to exact thickness are very expensive. In cutting grooves

that are to have some parts of their sides nearly or quite parallel, it is well to leave considerable stock, for the finishing cut, as mills like taps do better work when they can get well into the stock.

For the same reason if the sides have to be left slanting before the finishing cut is taken, no part of either side should slant less than three degrees, or about one $\frac{1}{10}$ of an inch in each inch.

Clearance in a fly cutter is obtained by moving the cutter towards A, Fig. 39.

A sketch of a mill with a solid shank, or of one that has half of its outline unlike the other half, should clearly show which way the mill is to turn. This can be done by an arrow as in Fig. 43, or by writing the word "coming" either at the top or bottom of the sketch, as the case may be. Fig. 43 also shows how the terms right and left are applied to angular cutters and end mills. It is well to show the work in red lines in the position that it will occupy when cut by the mill. Sketches
of Mills.

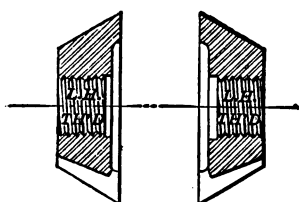
In ordering formed cutters it is well to send Templets. templets of the desired shapes, and to state how nearly exact the cutters must be. If any part of the outline is to be a straight line the sketch should clearly show this, and if any part is to be circular the radius should be given. Unless instructions have been given to the contrary, mills are generally made and hardened to cut steel or iron.

A dull mill wears away rapidly and does poor work. Accordingly care must be taken to keep mills sharp. In sharpening them it is necessary to be very careful that the temper should not be drawn, and to avoid this danger the emery wheel should be run true and not too fast. Sharpen-
ing
Mills.

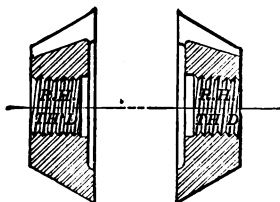
A wheel is not necessarily too soft when it can be cut with a pocket knife. If it is not hard it can be $\frac{1}{4}$ inch thick, but if it is hard it should be turned just at the edge to less than $\frac{1}{4}$ inch, and sometimes it is better to have the wheel as thin as $\frac{1}{8}$ inch, or even thinner. It should not be finer than No. 90 emery, and often No.



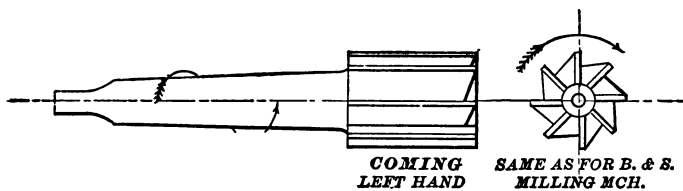
FIG. 42.



COMING
LEFT HAND RIGHT HAND

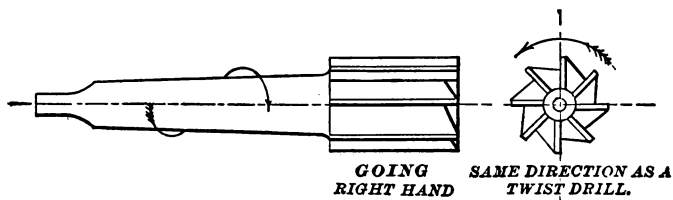


GOING
LEFT HAND RIGHT HAND



COMING
LEFT HAND

SAME AS FOR B. & S.
MILLING MCH.



GOING
RIGHT HAND

SAME DIRECTION AS A
TWIST DRILL.

FIG. 43.

60 is not too coarse. In one of our circulars is published a list of wheels and speeds suitable for tool grinding machines.

Mills that have their teeth ground for clearance are particularly apt to have their temper drawn in sharpening, especially at the edge of the teeth, and often when the temper has been drawn and the teeth are polished, they will look as usual after being ground.

In sharpening angular cutters it is best to leave the side of the teeth crowning or a little higher towards the centre or hole of the cutter than towards the point of the teeth.

Form mills are sharpened by central or radial grinding upon the front of the teeth, square across the mill or in line with the axis, for if the teeth are not ground radially the work done by them will not be of the correct shape. The tendency, however, in grinding these mills is to take away too much from the outer part of the front of the teeth. An attachment for grinding form cutters is made for our No. 3 Universal Cutter and Reamer Grinder.

The best plan is to have all mills sharpened immediately after they have been used, before they are put away.

The advantage of properly sharpening cutters is indicated by the amount of work done by the gear cutter shown in Fig. 44. This cutter was, when new, the same in appearance as that shown in Fig. 36, and it has cut 467, 4 pitch, 64 teeth, 3-inch face cast iron gears,—making a total length of cut of 7472 feet. The teeth of the gears were cut from solid blanks and finished in one cut. This record while good is not exceptional.

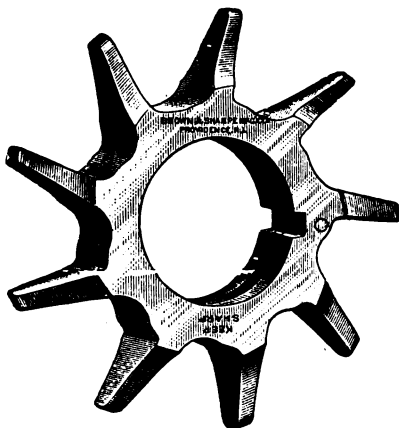


FIG. 44.

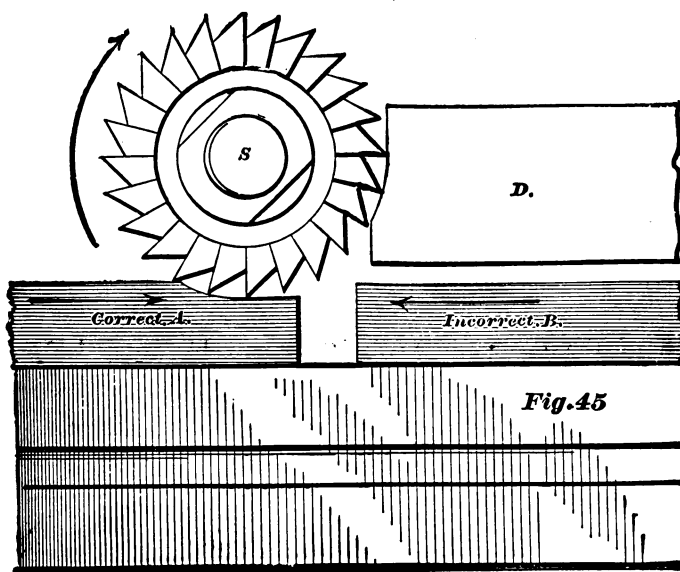


Fig. 45

USE OF MILLING MACHINES—CONTINUED,

EXAMPLES OF OPERATIONS.

Oil is used in milling to obtain smoother work, to make the mills last longer, and, where the nature of the work requires, to wash the chips from the work or from the teeth of the cutters. It is generally used in milling a large number of pieces of steel, wrought iron, malleable iron or tough bronze. When only a few pieces are to be milled it frequently is not used, and some steel castings are milled without oil; also in cutting cast iron it is not used. For light, flat cuts it is put on the cutter with a brush, giving the work a thin covering like a varnish; for heavy cuts it should be led to the mill from the drip can sent with each machine, or it should be pumped upon or across the mill in cutting deep grooves, in milling several grooves at one time, or indeed, in milling any work where, if the chips should stick, they might catch between the teeth and sides of the groove and scratch or bend the work.

Use of Oil
on the
Mills or
Work.

Generally we use lard oil in milling, but any animal or fish oils may be used. The oil may be separated from the chips by a centrifugal separator, or by the wet process, so that a large amount may be used with but little waste.

Some manufacturers prefer to mix mineral oil with lard or fish oil, and state the mixture is less expensive and works well. Prof. J. E. Denton has made experiments with mixtures and thinks that mineral or coal oil can be advantageously used.

In most cases the work moves against the mill as shown at A, Fig. 45. When it moves in this way the teeth of the cutter, in commencing their work, as soon

Direction
in which
Work is
Moved un-
der a Mill.

as the hard surface or scale is once broken, are immediately brought in contact with the softer metal, and when the scale is reached it is pried or broken off. Also when a piece moves in this way the cutter cannot dig into the work as it is liable to do when the bed is moved in the direction indicated at B. When a piece is on the side of a cutter that is moving downwards, the piece should, as a rule, have a rigid support and be fed by raising the knee of the machine.

Some work, however, is better milled by moving with the cutter. For example: To dress both sides of a thick piece D with a pair of large straddle mills, it might be well to move the piece towards the left, as the mills then tend to keep it down in place instead of lifting it.

Again, in milling deep slots with a thin mill or saw, it may be better to move the work with the mill, as the mill is then less likely to crowd side-wise and make a crooked slot.

When the work is moving with the mill, the table gib screws must be set up rather hard, for if the work moves too easily the mill may catch and the cutter or work be injured. A counter weight to hold back the table is excellent in such milling.

Speed
of Mills.

It is impossible to give definite rules for the speed and feed of mills, and what is here said is only in the way of suggestions. The judgment of the foreman or man in charge of the machine should determine what is best in each instance.

As usually the highest possible speed and feed are desirable, it pays to increase the speed and feed until it is seen that something will break or burn and then reduce to a speed and feed of safety. Sometimes the speed must be reduced, and yet the feed need not be changed.

The average speed on wrought iron and annealed steel is perhaps forty feet a minute, which gives about sixty turns a minute for mills $2\frac{1}{2}$ inches diameter. The feed of the work for this surface speed of the mill can be about $1\frac{1}{2}$ inches a minute, and the depth of cut say $\frac{1}{16}$ of an

inch. In cast iron a mill can have a surface speed of about fifty feet a minute while the feed is $1\frac{1}{2}$ inches a minute and the cut $\frac{3}{16}$ of an inch deep, and in tough brass the speed may be eighty feet, the feed as before and the chip $\frac{3}{8}$ of an inch.

As a small mill cuts faster than a large one, an end mill, for example, $\frac{1}{2}$ inch diameter can be run about 400 revolutions with a feed of 4 inches a minute.

For examples of what may regularly be done under suitable conditions, we may mention that mills $2\frac{1}{2}$ inches in diameter used in cutting annealed cast iron in our works are run at more than 200 turns, or at a surface speed of more than 125 feet, while the work is fed more than 8 inches a minute. The cuts are light, not more than $\frac{1}{8}$ of an inch deep, and the work is short, from $\frac{1}{2}$ inch to 1 inch long. Two side mills 5 inches in diameter running 50 turns a minute, dress both edges of cast iron bars $\frac{3}{4}$ of an inch thick, with a feed of more than 4 inches a minute.

An English authority, Mr. Geo. Addy, gives as safe speeds for cutters of 6 inches diameter and upwards:

Steel,	36 ft. per minute with a feed of $\frac{1}{2}$ " per minute.
Wrought Iron, 48 "	" " " 1" "
Cast Iron 60 "	" " " $1\frac{2}{3}$ "
Brass, 120 "	" " " $2\frac{2}{3}$ "

And he gives as a simple rule for obtaining the speed:—Number of revolutions which the cutter spindle should make when working on cast iron = 240 divided by the diameter of the cutter in inches.

Mr. John H. Briggs, another English authority, states, "for cutting wrought iron with a milling cutter taking a cut of one inch depth—which was a different thing from mere surface cutting—a circumferential speed of from 36 to 40 feet per minute was the highest that could be attained with due consideration to economy, and to the time occupied in grinding and changing cutters; the feed would be at the rate of $\frac{5}{8}$ inch per minute. Upon soft mild steel, about 30 feet per minute was the highest

speed, with $\frac{1}{4}$ inch depth of cut and $\frac{3}{4}$ inch feed per minute. Upon tough gun-metal, 80 feet per minute, with $\frac{1}{2}$ inch depth of cut and $\frac{3}{4}$ inch feed. For cutting cast iron geared wheels from blanks previously turned, and using in this case comparatively small milling cutters of only $3\frac{1}{2}$ inches diameter, the speed was $26\frac{1}{2}$ feet per minute, with $\frac{1}{2}$ inch depth of cut and $\frac{3}{4}$ inch feed per minute."

Slotting cutters may often be run at a higher speed than other cutters of the same diameter, but with a wider face. Angular cutters must in some instances be used with a fine feed to prevent breaking the points of the teeth.

The following table may be of service as suggesting speeds that may be tried with our machines on ordinary work, but it is not published as an absolute guide, and as before stated, the judgment of the foreman must determine what is best in each instance. In considering the table it must be borne in mind that rapid progress is being made in milling, and that all figures are submitted with the certainty that improvements in machines, cutters and fixtures will soon render them obsolete. As these figures are better than formerly obtained, so we soon shall be able to do much better.

**Limits in
milling.**

An ordinary limit is four one thousandths of an inch. This is allowable for bolt heads, nuts, and the squares at the ends of shafts where cranks or hand wheels are used, also for some kinds of gibs and many parts that are milled for a finish.

In most sewing machine pieces, electrical and scientific instruments, type writers and fine machinery, the limit is two one thousandths. Thus a slot that is called half an inch wide may be any size between half an inch and five hundred and two one thousandths of an inch (.500 to .502") while the tongue or piece that goes into the half inch slot may be any size between two one-thousandths less than one-half inch and one-half inch

SPEEDS AND FEEDS OF No. 3 PLAIN MILLING MACHINE.

BROWN & SHARPE MFG. CO.

93

CAST IRON.

Diam. of Mill.	Rev. per Minute.	Speed of Cutter pr. Minute.	Depth of Cut.	Width of Cut.	FEED PER MINUTE.	
					In Scale of Cast Iron.	Under Scale of Cast Iron
1" $\frac{1}{2}$	305	40	1-32"	1-2"	21"	88"
	305	40	3-32	1-2	3	8
$\frac{7}{8}$	174	40	3-32	7-8	7	10 1-4
	174	40	9-16	7-8	7-8	1 1-8
1 $\frac{1}{4}$	130	60	1-8	1 3-4	3	4 1-2
	65	30	13-16	1 3-4	7-8	1 1-2

SURFACE MILLING CAST IRON.

3	46	37	1-8	1	5 1-2	7
	46	37	1-8	2	3 1-8	5
	46	37	1-8	3	2	3 1-2
	46	37	1-2	1	1 3-4	2
	46	37	1-2	2	1 1-4	1 1-2
	46	37	1-2	3	3-4	1
4 $\frac{1}{2}$	36	42	1-16	3	6 1-2	11
	36	42	7-16	3	1-2	5-8
	36	42	1-16	4	3 1-2	5
	36	42	7-16	4	2	3
	36	42	1-16	6	3	4
	36	42	13-16	6	1-8	3-16
5	26	35	1-16	5	10	12
	26	35	1-4	5	2	3

SOFT MACHINERY STEEL.

Diam. of Mill.	Rev. per Minute.	Speed of Cutter pr. Minute.	Depth of Cut.	Width of Cut.	FEED PER MINUTE.	
					In Scale of Steel.	Under Scale of Steel.
1" $\frac{1}{2}$	240	32	1-16"	1-2"	3 3-4"	4"
	240	32	9-32	1-2	3-4	1
1	130	34	3-32	1	2 1-4	3
	130	34	3-8	1	1-2	3-4
1 $\frac{1}{4}$	54	25	1-16	1 3-4	2 3-4	3
	54	25	5-8	1 3-4	3-8	1-2

SURFACE MILLING SOFT MACHINERY STEEL.

3	46	37	1-16	1	4	6
	46	37	9-16	1	1-4	3-8
	46	37	1-16	2	1 1-2	2
	46	37	9-16	2	3-16	1-4
	46	37	1-16	3	1	1 1-2
	46	37	7-16	3	1-4	5-16
4 $\frac{1}{2}$	36	42	1-16	3	1 1-4	1 1-2
	36	42	7-16	3	1-4	5-16
	36	42	1-16	6	3-4	1
	36	42	7-16	6	1-8	3-16

SPEEDS AND FEEDS OF NO. 4 PLAIN MILLING MACHINE.

END OR FACE MILLING CAST IRON.										END OR FACE MILLING SOFT MACHINERY STEEL.																			
Diam. of Mill.	Rev. per Minute.	Speed of Cutter pr. Minute.	Depth of Cut.	Width of Cut.	FEED PER MINUTE.		Diam. of Mill.	Rev. per Minute.	Speed of Cutter pr. Minute.	Depth of Cut.	Width of Cut.	FEED PER MINUTE.																	
					In Scale of Cast Iron.	Under Scale of Cast Iron						In Scale of S. M. S.	Under Scale of S. M. S.																
3	310	40'	1-64"	1-2"	30	3 8"	72"	200	26'	1-16"	1-2"	2 1-4"	3 1-2"																
	310	40	3-16	1-2	3	3 3-8	8 1-4	200	26	3-16	1-2	7 8	1 1-4																
	260	60	1-16	7-8	25	1-2	63	120	27	1-16	1	3 1-4	4 5-8																
	260	60	5-8	7-8	7	10 3-4		120	27	3-8	1	9-16	7-8																
	170	80	1-16	1 3-4	25	40		31	25	1-16	1 3-4	2 1-4	3 3-8																
4 1/2	170	80	3-4	1 3-4	1 1-8	1 7-8		31	25	10-32	1 3-4	1-4	3-8																
	24	30	13-32	5	2 3-8	3 3-4																							
SURFACE MILLING CAST IRON.															SURFACE MILLING SOFT MACHINERY STEEL.														
3	51	40	1-16	1	8	12	40	31	1-16	1	6 3-8	9																	
	51	40	1-2	1	3 1-4	4 3-4	40	31	1-2	1	1 1-2	1 5-8																	
	51	40	1-16	2	5	8	40	31	1-16	2	1 5-8	2 1-2																	
	51	40	1-2	2	2	3 1-4	40	31	1-2	2	5-8	1																	
	51	40	1-16	3	3 1-4	5	40	31	1-16	3	1 1-8	1 5-8																	
4 1/2	51	40	1-2	3	7-8	1 3-8	40	31	1-2	3	3-8	5-8																	
	32	38	1-16	4	3 1-8	5	32	38	1-16	4	3	5																	
	32	38	1-4	4	2	3 1-8	32	38	1-4	4	1 5-16	2																	
	32	38	1-16	6	2	3 1-8	32	38	1-16	6	1 5-16	2																	
	32	38	1-4	6	1 1-4	1 3-8	32	38	1-4	6	1-2	7-8																	
	32	38	1-16	8	2	3 1-8	32	38	1-16	8	1	1 5-16																	
	32	38	1-4	8	1 3-8	2	32	38	1-4	8	11-32	1-2	7-8																
	32	38	1-16	10	1 3-8	2	32	38	1-16	10	1-2	7-8																	
	32	38	1-4	10	7-8	1 1-4	32	38	1-4	10	7-32	11-32																	
	32	38	1-16	12	1 3-8	2	32	38	1-16	12	7-8	1																	
	32	38	1-4	12	1-2	7-8	32	38	1-4	12	9-64	7-32																	

SPEEDS AND FEEDS OF No. 5 PLAIN MILLING MACHINE.

FACE MILLING SOFT MACHINERY STEEL.													
Diam. of Mill.	Rev. per Minute.	Speed of Cutter pr. Minute.	Depth of Cut.	Width of Cut.	FEED PER MINUTE.		Diam. of Mill.	Rev. per Minute.	Speed of Cutter pr. Minute.	Depth of Cut.	Width of Cut.	FEED PER MINUTE.	
					In Scale of S. M. S.	Under Scale of S. M. S.						In Scale of S. M. S.	Under Scale of S. M. S.
1"	382	50'	1-16"	1-2"	23"	35"	1"	267	35'	1-16"	1-2"		
1	382	50	1-8	1-2	7	11		267	35	1-4	1-2		
	191	50	1-16	1	30	40		152	40	1-16	1	3	4 3-4
	191	50	1-2	1	3	5 1-2		152	40	1-2	1		
1 3/4	109	50	1-8	1 3-4	17	23		87	40	1-16	1 3-4	2 3-4	4 1-2
	109	50	3-4	1 3-4	3 5-8	4 1-8		87	40	3-4	1 3-4		1 3-4
5	42	55	1-4	5	2 5-8	4 1-8							
16	10	45	1-4	16	7-8	1							
SURFACE MILLING SOFT MACHINERY STEEL.													
Diam. of Mill.	Rev. per Minute.	Speed of Cutter pr. Minute.	Depth of Cut.	Width of Cut.	FEED PER MINUTE.		Diam. of Mill.	Rev. per Minute.	Speed of Cutter pr. Minute.	Depth of Cut.	Width of Cut.	FEED PER MINUTE.	
					In Scale of S. M. S.	Under Scale of S. M. S.						In Scale of S. M. S.	Under Scale of S. M. S.
3	42	34	1-16	1	6 5-8	8 7-8	3	38	30	1-16	1	6	8
	42	34	1-2	1	4 1-8	6 1-2		38	30	1-2	1	1 1-8	1 7-8
	42	34	1-16	2	6 5-8	8 7-8		38	30	1-16	2	2 3-8	3 1-2
	42	34	1-2	2	2 1-2	4 1-8		38	30	1-2	2	3-4	1 1-8
	42	34	1-16	3	6 5-8	8 7-8		38	30	1-16	3	1 1-8	1 7-8
	42	34	7-16	3	1 3-8	2 3-16		38	30	3-8	3	3-4	1 1-8
3 1/2	42	40	5-32	8	4 1-8	6 1-4	3 1/2	38	35	1-16	8	1 7-8	3
	42	40	1-2	3 1-2	2 1-2	3 1-2		38	35	1-8	8	3-4	1 1-8
	42	50	1	2	4 1-8	6 1-2		25	30	1-16	3	4	5
	42	50	1	4	3 1-2	4 1-8		25	30	1-16	5	2 1-2	4 1-2
4 1/2	42	50	1	6	2	2 1-4		25	30	3-8	5		1-2
	42	50	1-8	6	4 1-8	6 1-2		25	30	1-16	10	1 3-4	2 1-2
	42	50	11-32	12	1 3-8	2		25	30	3-16	10	1-2	7-8
6 = KEYSEATING OR GANG MILLS.													
4	42	45	1-16	7-8 each.	6 1-8	8 7-8	4	28	30	1-16	7-8 each.	4 3-8	5 7-8
	42	45	1-2	7-8 each.	1 3-8	1 1-2		28	30	1-2	7-8 each.	1-2	7-8

END OR FACE MILLING CAST IRON.													
Diam. of Mill.	Rev. per Minute.	Speed of Cutter pr. Minute.	Depth of Cut.	Width of Cut.	FEED PER MINUTE.		Diam. of Mill.	Rev. per Minute.	Speed of Cutter pr. Minute.	Depth of Cut.	Width of Cut.	FEED PER MINUTE.	
					In Scale of Cast Iron.	Under Scale of Cast Iron						In Scale of S. M. S.	Under Scale of S. M. S.
1"	382	50'	1-16"	1-2"	23"	35"	1"	267	35'	1-16"	1-2"		
1	382	50	1-8	1-2	7	11		267	35	1-4	1-2		
	191	50	1-16	1	30	40		152	40	1-16	1	3	4 3-4
	191	50	1-2	1	3	5 1-2		152	40	1-2	1		
1 3/4	109	50	1-8	1 3-4	17	23		87	40	1-16	1 3-4	2 3-4	4 1-2
	109	50	3-4	1 3-4	3 5-8	4 1-8		87	40	3-4	1 3-4		1 3-4
5	42	55	1-4	5	2 5-8	4 1-8							
16	10	45	1-4	16	7-8	1							
SURFACE MILLING CAST IRON.													
Diam. of Mill.	Rev. per Minute.	Speed of Cutter pr. Minute.	Depth of Cut.	Width of Cut.	FEED PER MINUTE.		Diam. of Mill.	Rev. per Minute.	Speed of Cutter pr. Minute.	Depth of Cut.	Width of Cut.	FEED PER MINUTE.	
					In Scale of Cast Iron.	Under Scale of Cast Iron						In Scale of S. M. S.	Under Scale of S. M. S.
3	42	34	1-16	1	6 5-8	8 7-8	3	38	30	1-16	1	6	8
	42	34	1-2	1	4 1-8	6 1-2		38	30	1-2	1	1 1-8	1 7-8
	42	34	1-16	2	6 5-8	8 7-8		38	30	1-16	2	2 3-8	3 1-2
	42	34	1-2	2	2 1-2	4 1-8		38	30	1-2	2	3-4	1 1-8
	42	34	1-16	3	6 5-8	8 7-8		38	30	1-16	3	1 1-8	1 7-8
	42	34	7-16	3	1 3-8	2 3-16		38	30	3-8	3	3-4	1 1-8
3 1/2	42	40	5-32	8	4 1-8	6 1-4	3 1/2	38	35	1-16	8	1 7-8	3
	42	40	1-2	3 1-2	2 1-2	3 1-2		38	35	1-8	8	3-4	1 1-8
	42	50	1	2	4 1-8	6 1-2		25	30	1-16	3	4	5
	42	50	1	4	3 1-2	4 1-8		25	30	1-16	5	2 1-2	4 1-2
4 1/2	42	50	1	6	2	2 1-4		25	30	3-8	5		1-2
	42	50	1-8	6	4 1-8	6 1-2		25	30	1-16	10	1 3-4	2 1-2
	42	50	11-32	12	1 3-8	2		25	30	3-16	10	1-2	7-8
6 = KEYSEATING OR GANG MILLS.													
4	42	45	1-16	7-8 each.	6 1-8	8 7-8	4	28	30	1-16	7-8 each.	4 3-8	5 7-8
	42	45	1-2	7-8 each.	1 3-8	1 1-2		28	30	1-2	7-8 each.	1-2	7-8

(.498 to .500"). On many pieces, for instance usually on those milled for a finish, the limit may of course be either above or below the standard size.

Some work should be milled as close as possible to exact size; and when close fits are required it is often cheaper and better to do the fitting by the milling machine than by filing or other hand work.

The most accurate results in milling to a given thickness or size are ordinarily obtained by straddle mills; for when only one side is milled at a time and the piece has to be changed from side to side it is hardly practicable to work to a smaller limit than two one-thousandths of an inch. Side or radial milling frequently requires more attention to keep the work smooth than ordinary surface or axial milling. But very accurate milling may be done and excellent surfaces obtained by small end mills running at high speeds.

Pickling
Castings
and
Forgings.

Castings that are to be milled should be free from sand. They should be well pickled, and in some cases it is an advantage to have them rattled after being pickled. Where they are small and are to be finished rapidly it is also well to have them annealed.

Forgings should be free from scale. They can be pickled in ten minutes in one part sulphuric acid and twenty-five parts boiling water, and if then rinsed in boiling water they will dry before becoming rusty.

Washers
and
Collars
for Arbors.

When the collars sent with our milling arbors are not the right thickness to bring the cutters into the desired position washers are employed. The following thicknesses are convenient—.001", .002", .004", .008", .016", and .032"—as these give all steps from .001 to .032". The collars usually sent are cast iron but for hard usage steel collars are preferable.

Lead
Hammer.

A lead hammer is frequently used to drive arbors or collets into the spindle or bottom or seat work in the vise.

A bar of brass or copper, $\frac{3}{4}$ inch diameter by 5 or 6 inches long, will also be found useful to place against end mills, or the end of small collets after

the mills are in place. In this way the driving is often more conveniently done and any hammer may be used.

The construction of the machine having been carefully examined, and the novice having made himself familiar with the various classes of cutters, it is well if he is using a Universal Machine, to choose some work at the outset that does not require the use of the spiral head. Such work is generally held in the vise when milled.

The vise can be set with its jaws parallel to the spindle by placing one of the milling arbors in the spindle and then bringing the jaws up to the arbor. It can be set at right angles with the spindle by a square placed against the arbor and the jaws.

The front of the table of the machine can also be used in setting the vise.

The vise can be set at any angle with the spindle in the Universal Milling Machines, by first setting the saddle at the given angle, then setting the vise parallel to the spindle and lastly bringing the saddle back to o.

To illustrate the various ways in which the machines are used, we have given in the following pages descriptions and cuts of a number of operations. These for the most part are performed on the No. 1 Universal Milling Machine, but it is obvious that the other machines may generally be adapted to similar work, and the directions given in connection with the No. 1 Universal Milling Machine can, in most instances, be applied when doing work on the other machines.

Small stock may be conveniently and advantageously cut into short lengths, especially when it is of a section not easily handled in a cutting off machine. The cutter commonly used is that shown in Fig. 32. It is held on an arbor as in Fig. 45, and the work is fed as indicated by the arrow on the piece A. The table may be fed by hand or automatically, the stop being used to determine the length of feed, and the work may be placed exactly in the required position by noting the readings on the

Selection
of Work
for Novice.

Setting
Vise.
with Plain
Base.

Examples
of Work
Done on
Milling
Machines.

Cutting
off Stock.

graduations around the end of the cross feed shaft. When cut in a milling machine the pieces are square at both ends and uniform in length.

**Squaring
the Ends
of Small
Pieces.**

If it is desirable only to square the ends of small pieces and make them uniform in length, it may be done by first squaring one end of all the pieces, and then by bringing the finished end against a piece clamped to the immovable vise jaw to serve as a stop, while the other end is brought against the mill by the cross feed and run past it automatically or by hand, the vise jaws being parallel with the spindle. In squaring up the ends, at first, a radial mill may be used, preferably an end mill, Fig. 30, or possibly a side milling cutter, Fig. 45, screwed on the end of an arbor.

**Simultane-
ous Use
of two or
more Mills.**

Fig. 46 shows two side mills or twin mills upon an arbor. They ordinarily revolve in the direction indicated by the arrow, and are used in milling tongues or ribs.

As shown they are held apart by a collar or washer, but a milling cutter may be put between them and used to dress the top of the tongue and five surfaces then be milled at once.

The two sides and bottom of our Milling Machine Vises, Fig. 47, are milled on the No. 4 Plain Milling Machine, with cutters arranged in this way. The length of cut on the No. 2 Vise is $9\frac{1}{2}$ inches, width on the top $5\frac{1}{2}$ inches, and the height of the sides $2\frac{1}{4}$ inches, making the total width of cut 10 inches. The side mills have 38 teeth and are 8 inches in diameter, the milling cutter has 14 teeth and is $2\frac{3}{4}$ inches in diameter. The number of revolutions of the spindle is 20 per minute; the feed is $1\frac{5}{8}$ inches per minute. The time required to set and remove the work and make the cut is eleven minutes. The figures are not given as showing remarkable speed, but as indicating what may be easily attained in ordinary work.

By a similar arrangement of cutters small rectangular pieces can be milled with two cuts, the first across the top and sides, the second across the bottom and ends.

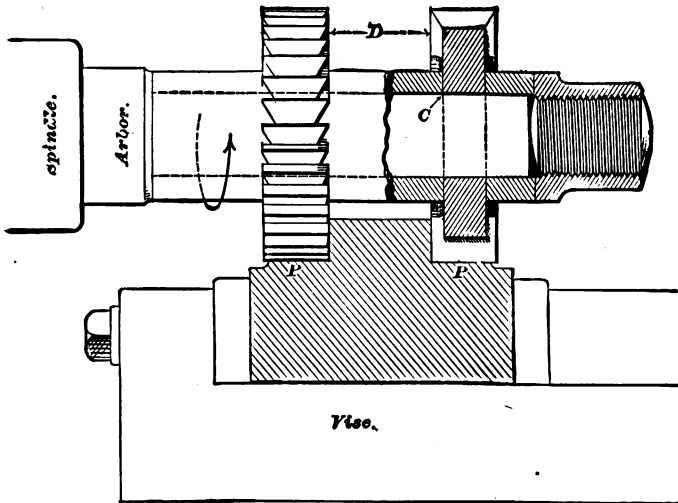


FIG. 46.

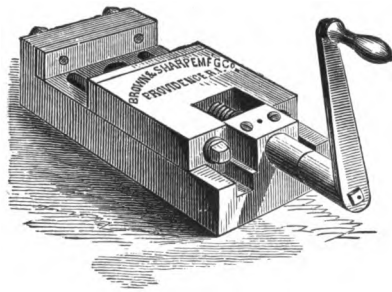


FIG. 47.

Cast iron pieces 6 inches wide and about 8 inches long are milled on the sides and bottom on the No. 24 Plain Milling Machine, by cutters making 24 revolutions per minute, with a feed of 2 inches per minute. The side milling cutters are $5\frac{5}{8}$ inches diameter, and the milling cutters 3 inches diameter. The total width of cut is about 8 inches and the depth $\frac{3}{16}$ inch. The top is milled by an inserted tooth mill $6\frac{3}{4}$ inches diameter, making 22 revolutions per minute, with a feed of $2\frac{1}{8}$ inches. Another cut is made on the inside with an inserted tooth mill 4 inches diameter, making 36 revolutions per minute, with a feed of $2\frac{3}{4}$ inches.

A guaranteed cut in tool steel on the No. 4 Plain Machine, which was surpassed in daily practice was 8 inches wide, $\frac{1}{8}$ inch deep, with $\frac{3}{4}$ inch feed a minute. And one of the cuts most commonly seen on a No. 23 Plain in our shops is in cast iron 9 inches wide, $\frac{1}{8}$ inch deep, with 3 inch feed and 30 feet surface speed a minute.

When the radial or side cutting teeth are dull, straddle mills may be interchanged thus bringing sharp teeth into use and if it is necessary that the distance D, Fig. 46, must be kept uniform, the distance between the cutters should be capable of reduction to compensate for wear and for the loss caused by grinding. This reduction in the distance D, is often accomplished by removing the washers between the cutter and steel washer as at C.

Combinations or gangs of form cutters work somewhat similar to that indicated by Fig. 46, are shown in Figs. 40 and 48. These figures represent the milling of opposite sides of small steel rods, 3 inches long and $\frac{1}{2}$ inch wide. The vise jaws as shown are made to fit the piece. This is a class of work which is usually done on the small Plain Milling Machines and on which one boy can run several machines. A similar class of work, made by a combination of two form and one ordinary milling cutter, is shown by Fig. 49.

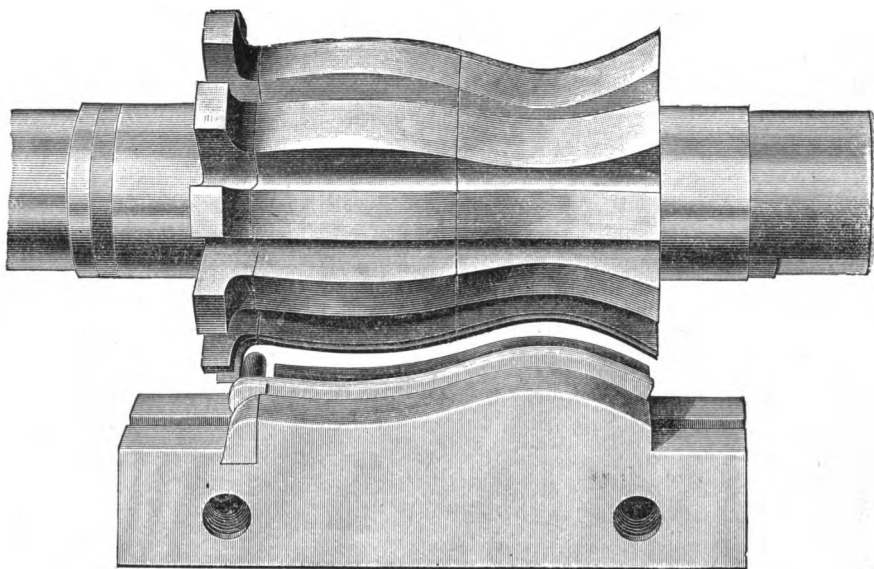


FIG. 48.

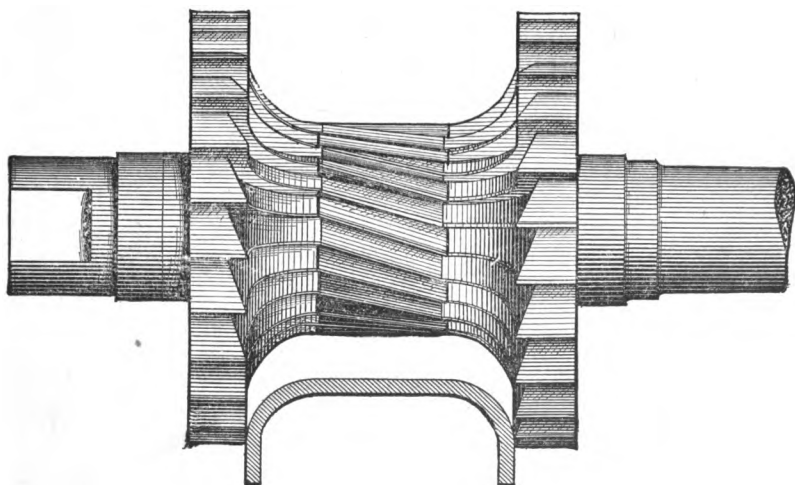


FIG. 49.

Fig. 50 shows twin mills cutting a bolt head or nut. When these mills are not at hand the work can be milled by a milling or axial cutter as in Fig. 51, or by an end or radial mill as in Fig. 52. Or if desired the axial teeth of the end mill could be used instead of the milling cutter, Fig. 51. In either case when nuts are milled they are usually strung on a mandrel.

**Fixtures
for Small
Work.**

For many kinds of work the fixture shown in Fig. 53 is convenient. It consists of a square piece of cast iron several inches in length, bored to receive a shaft or spindle to be split at one end or both ends as shown; or to have a series of holes or flat places made at right angles with, or directly opposite each other. The slot runs the entire length of the fixture and a small screw is inserted at S to hold the work and prevent from turning while in the shell.

The fixture is held in the vise as in Fig. 53, and the work does not have to be changed in the fixture, but after each cut is taken, the fixture is given one-quarter of a turn, and each of the four sides of the bolt head or other work, brought to the mill.

If the work to be milled is three or six sided, the fixture must be six sided. With two mills as in Fig. 50, the fixture would have to be changed in the vise only three times to mill a six sided piece. A fixture can be made without the slot and with a tapering hole for holding the shanks of end mills, twist drills and milling arbors while the tenons are milled.

**Cutting
Slots.**

Two mills can be put together with the teeth interlocked as in Fig. 54, and used in cutting slots. The advantage of this arrangement is that the mills can be blocked apart to keep the width of the cut always the same.

The end mill can also be used in cutting slots, as in Fig. 55, the width of the slot being the same as the diameter of the mill. Shafts that are to be slotted may be held in the chuck on the spiral head, as shown in Fig. 55, one end of the shaft being supported by the foot stock centre. In this case it is better to feed the

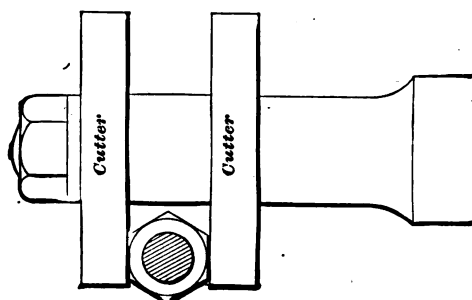


FIG. 50.

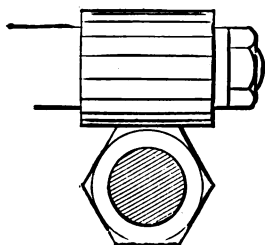


FIG. 51.

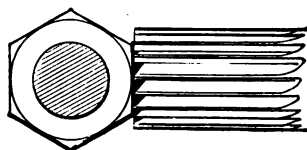


FIG. 52.

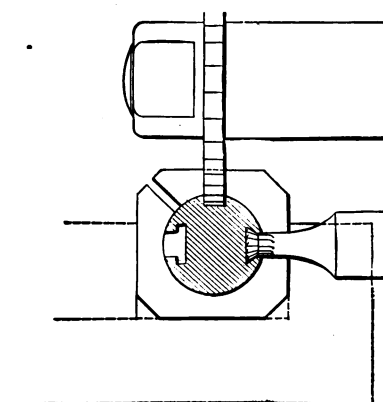
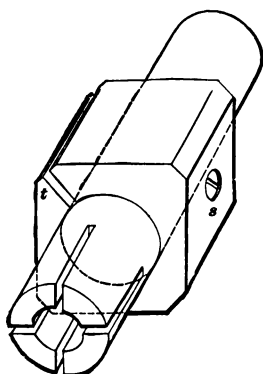


FIG. 53.

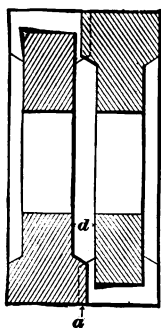


FIG. 54.

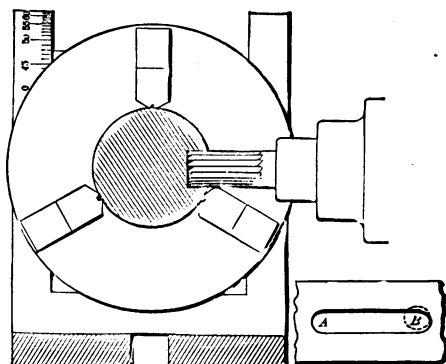
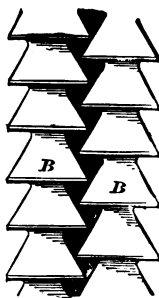


FIG. (55)

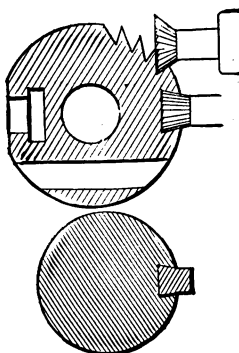


FIG. 56.

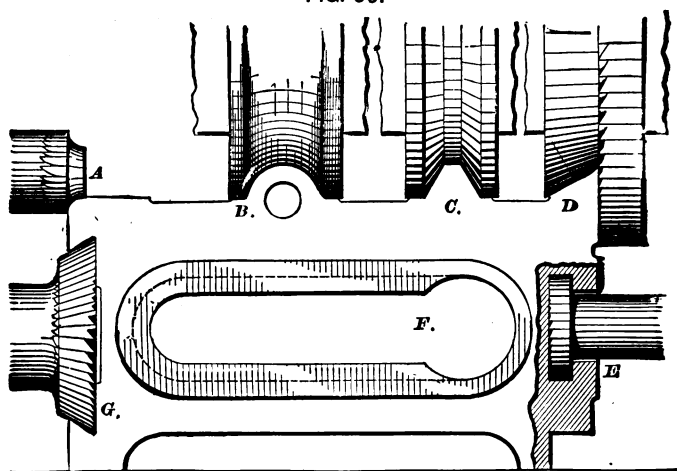


FIG. 57.

work back and forth the full length, then to drill holes at A and B ; for, unless unusual care is taken in drilling, they are likely to be out of line. By use of the cross feed the work may be moved in until the seat is cut to the desired depth. For cutting slots some prefer the Cotter mill, Fig. 42. Each of these mills when dropped directly into the work, leaves a teat in the centre, but when the work is fed along to make the slot, the Cotter will cut its teat off more easily than the end mill. Neither a Cotter mill nor an end mill should be used to make slots when they can be made with an axial cutter, Fig. 28, for milling cutters cut faster and produce slots more uniform in size than either end or Cotter mills.

When, as in Fig. 55, the centre of the index spindle must be at the same height as the cone spindle, the top of the knee is brought to the line on the frame marked *centre*.

Should it be desirable to go either above or below the centre of the spindle a given distance, the graduated collar on the lower screw shafts may be turned and set at zero ; then by use of the following table of decimal equivalents the distance may be readily determined in eighths, sixteenths, etc., as every turn of the screw shaft will raise or lower the knee one tenth or one hundred one thousandths of an inch.

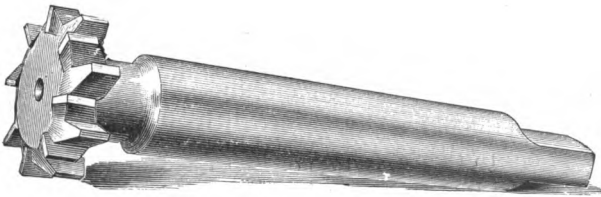


FIG. 58.

TABLE OF DECIMAL EQUIVALENTS.

8ths.	$\frac{7}{8} = .21875$	$\frac{11}{8} = .265625$
$\frac{1}{8} = .125$	$\frac{9}{8} = .28125$	$\frac{12}{8} = .296875$
$\frac{2}{8} = .25$	$\frac{11}{8} = .34375$	$\frac{13}{8} = .328125$
$\frac{3}{8} = .375$	$\frac{13}{8} = .40625$	$\frac{14}{8} = .359375$
$\frac{4}{8} = .50$	$\frac{15}{8} = .46875$	$\frac{15}{8} = .390625$
$\frac{5}{8} = .625$	$\frac{17}{8} = .53125$	$\frac{16}{8} = .421875$
$\frac{6}{8} = .75$	$\frac{19}{8} = .59375$	$\frac{17}{8} = .453125$
$\frac{7}{8} = .875$	$\frac{21}{8} = .65625$	$\frac{18}{8} = .484375$
	$\frac{23}{8} = .71875$	$\frac{19}{8} = .515625$
16ths.	$\frac{25}{8} = .78125$	$\frac{20}{8} = .546875$
$\frac{1}{16} = .0625$	$\frac{27}{8} = .84375$	$\frac{21}{8} = .578125$
$\frac{2}{16} = .1875$	$\frac{29}{8} = .90625$	$\frac{22}{8} = .609375$
$\frac{3}{16} = .3125$	$\frac{31}{8} = .96875$	$\frac{23}{8} = .640625$
$\frac{4}{16} = .4375$		$\frac{24}{8} = .671875$
$\frac{5}{16} = .5625$	64ths.	$\frac{25}{8} = .703125$
$\frac{6}{16} = .6875$	$\frac{1}{64} = .015625$	$\frac{26}{8} = .734375$
$\frac{7}{16} = .8125$	$\frac{3}{64} = .046875$	$\frac{27}{8} = .765625$
$\frac{8}{16} = .9375$	$\frac{5}{64} = .078125$	$\frac{28}{8} = .796875$
32nds.	$\frac{7}{64} = .109375$	$\frac{29}{8} = .828125$
$\frac{1}{32} = .03125$	$\frac{9}{64} = .140625$	$\frac{30}{8} = .859375$
$\frac{3}{32} = .09375$	$\frac{11}{64} = .171875$	$\frac{31}{8} = .890625$
$\frac{5}{32} = .15625$	$\frac{13}{64} = .203125$	$\frac{32}{8} = .921875$
	$\frac{15}{64} = .234375$	$\frac{33}{8} = .953125$
		$\frac{34}{8} = .984375$

Fig. 56 shows a key-way, widest at the bottom, that is cut by an angular shank mill similar to an end mill. Such key-ways are used in a number of places, for instance; where change gears are to be kept from slipping by a key. If made in a single cut, and the mill be a delicate one, it is preferable to feed by hand, as the resistance and progress can be easily felt, and the liability of breaking the tool obviated.

In Fig. 57, at G, is seen the milling of an angular slot for a slide. At D is shown the milling of a slide. At E is the milling of a T slot. In this case a slot is first cut to the full depth of the T slot and then finished by a mill like that shown at E. A mill shown in Fig. 58, with every other tooth shortened at one end, lasts longer and cuts faster in milling T slots than an ordinary end mill. Some T slots are enclosed like F,

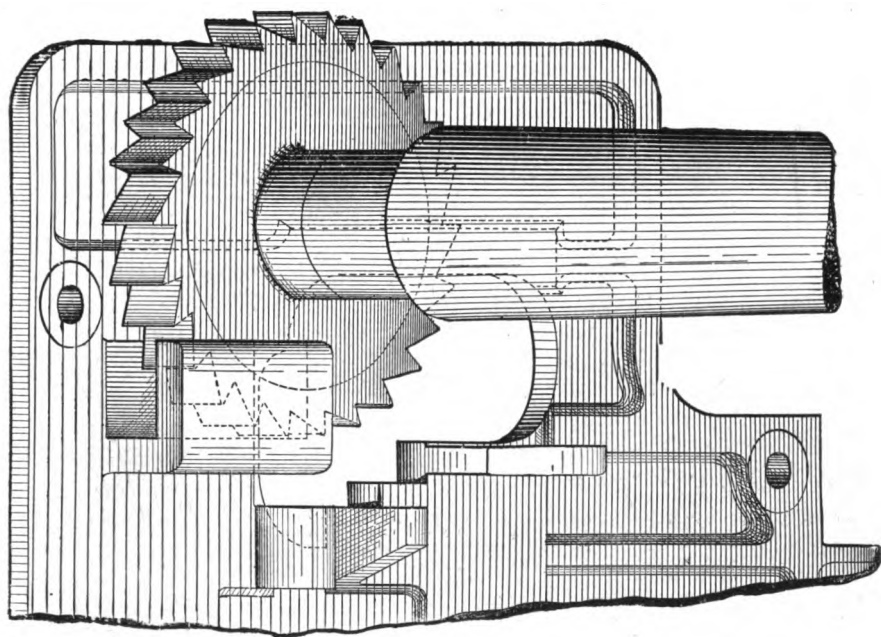


FIG. 59.

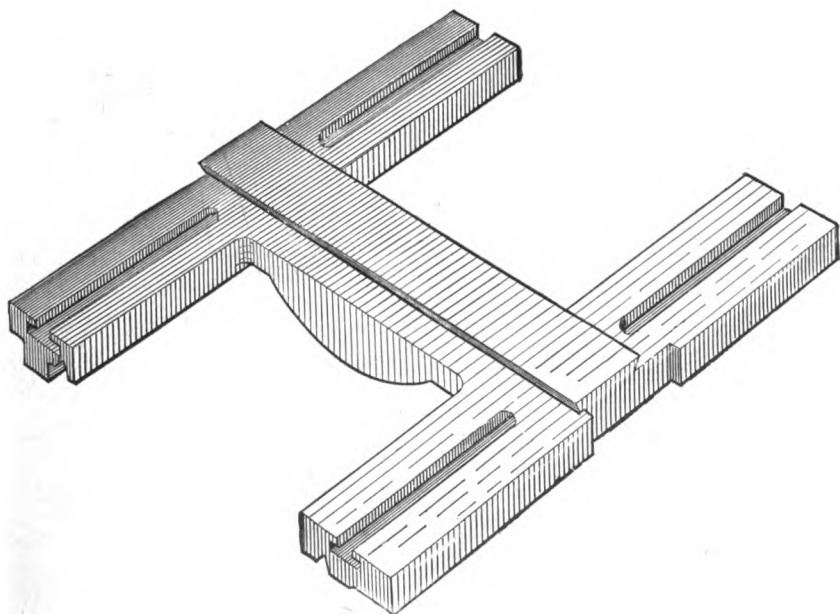


FIG. 60.

Fig. 57, and to enter this a hole is sometimes made at the back through the body of the piece.

In milling cored T slots in cast iron, it is better to have the mill small enough to cut only one side of the slot at a time, and the side of the slot that is being milled should move against the mill. If the mill is large enough to cut both sides at once, then the teeth strike the scale first in the side of the slot that runs with the mill and are soon dulled. A full size mill is also likely to be broken by catching upon high places in the side of the slot. It is doubtful whether anything is gained by coring T slots that are to be milled.

It is usually economical to do work like C with a formed cutter, and anything like B, should certainly be done with such a cutter. A very simple example of form milling is seen at A, where a corner is rounded for a finish. This method costs less and is more perfect than finishing corners with a file, and for such work a mill of large diameter used on an arbor is better than a shank mill, unless the shank mill is run very fast.

Fig. 59 shows a method of cutting a slot or groove with an axial cutter. The piece shown is cast iron and the cuts are to a close limit.

Special
Operations

A lathe carriage in which T slots have been milled is shown in Fig. 60. The bearings of this carriage and the ways of the lathe bed are also milled, and the method of doing this work is indicated by Fig. 61, which represents the bed of a No. 2 Universal Grinding Machine.

The teeth of hair clippers shown in Fig. 62, are examples of work done on the No. 12 Plain Milling Machine.

In Fig. 63 is shown a method of milling a surface and squaring one side of a projection on the surface. The vise jaws are special to hold the work in the best manner and to save time in setting it in position.

In Fig. 64 is seen the use of formed cutters in milling rack teeth. The cutter shown is made in three parts and each part cuts six teeth in the rack.

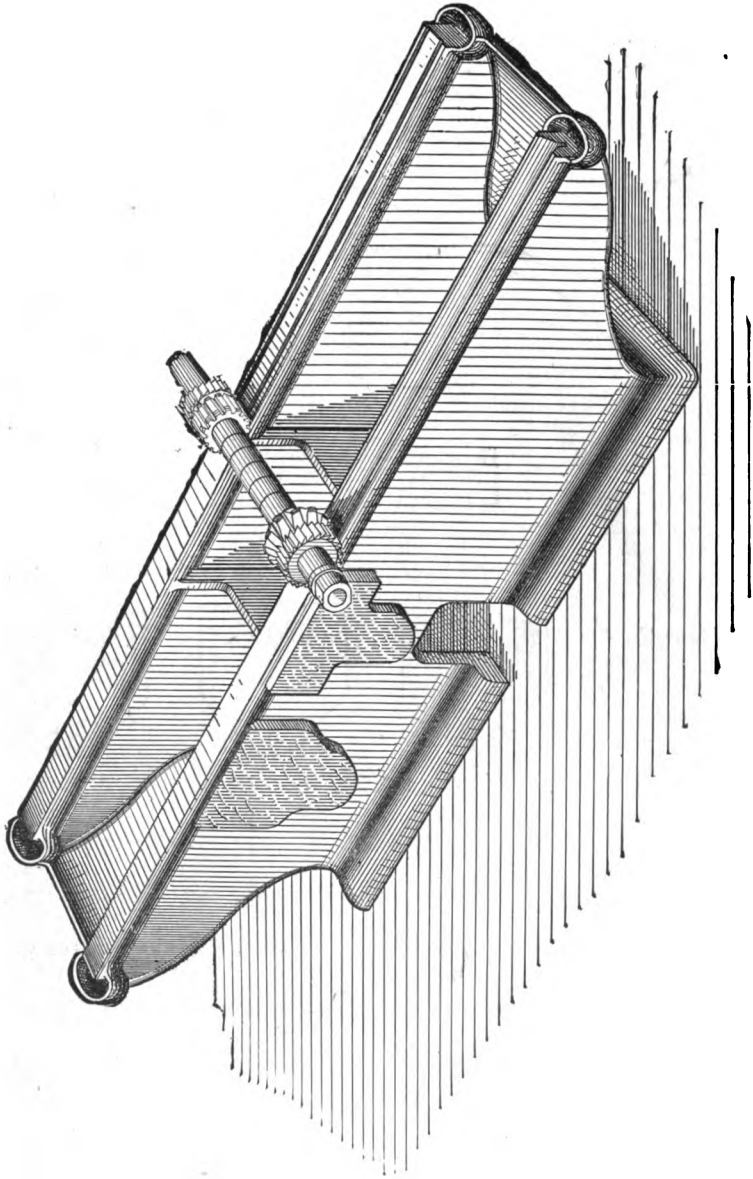


FIG. 61.

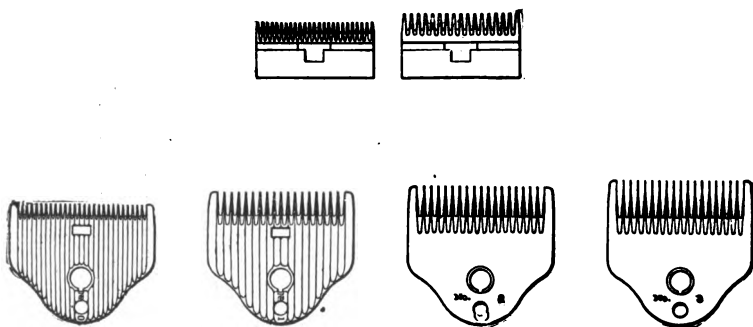


FIG. 62.

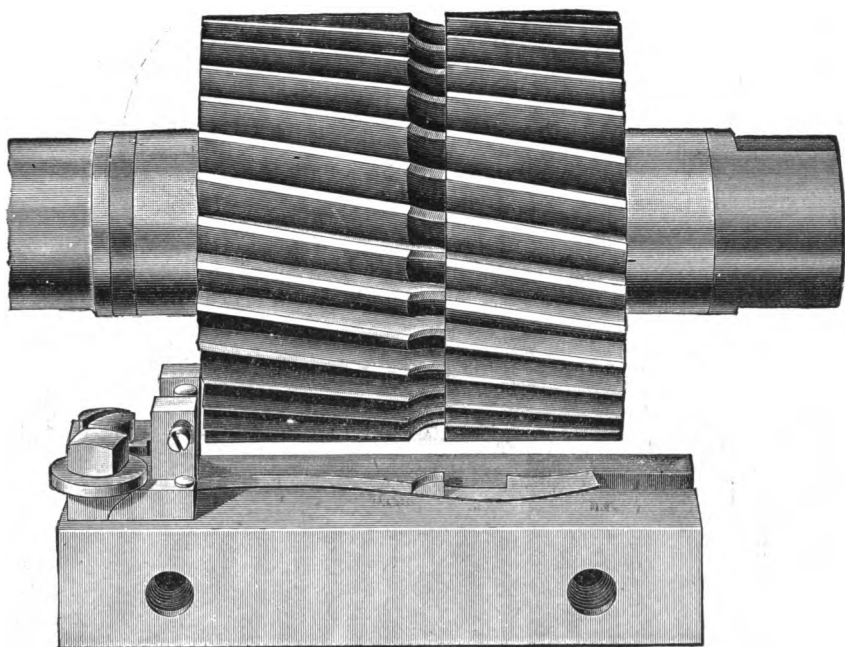


FIG. 63.

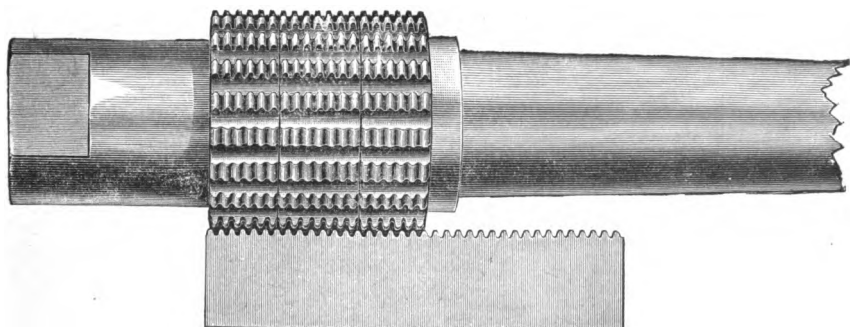


FIG. 64.

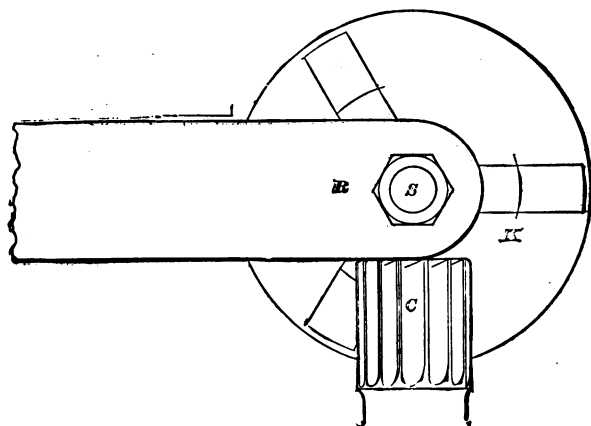


FIG. 65.

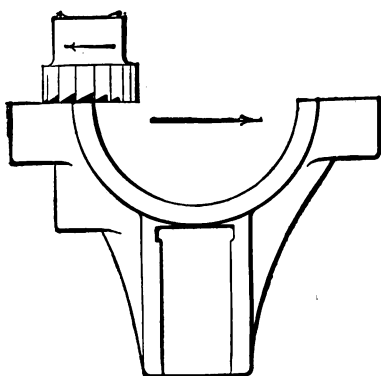


FIG. 66.

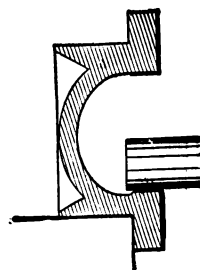


FIG. 67.

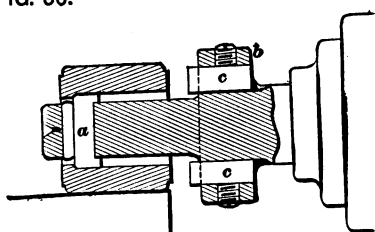


FIG. 68.



FIG. 69.

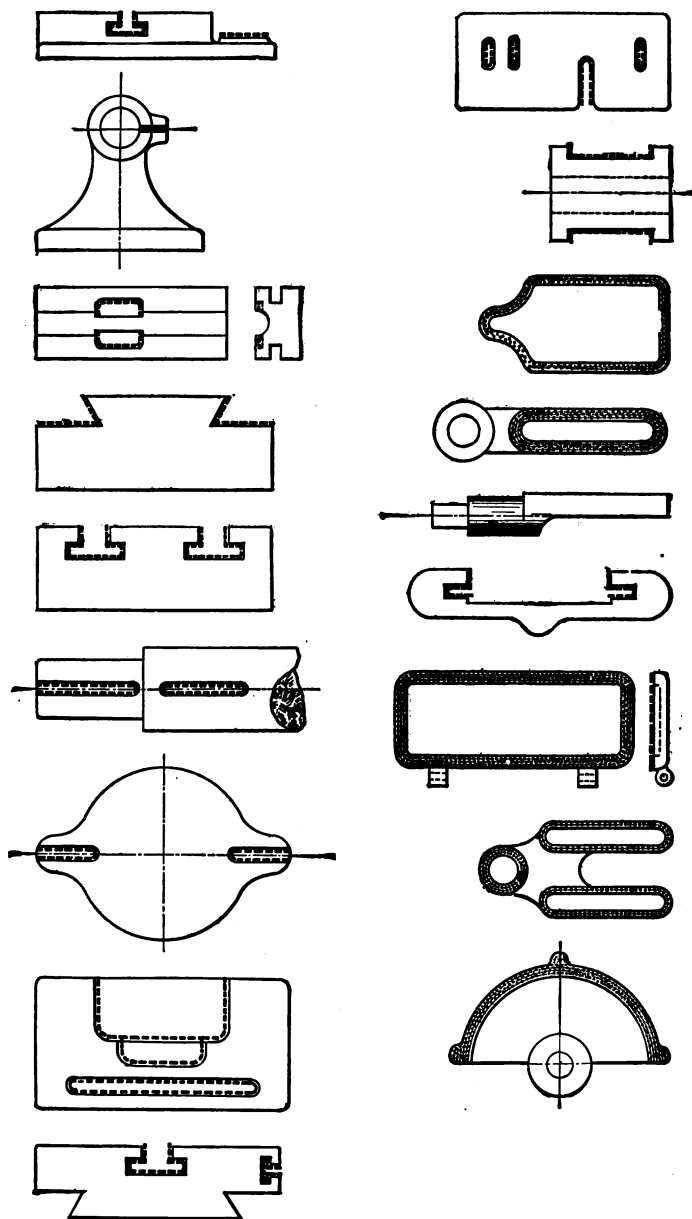


FIG 70.

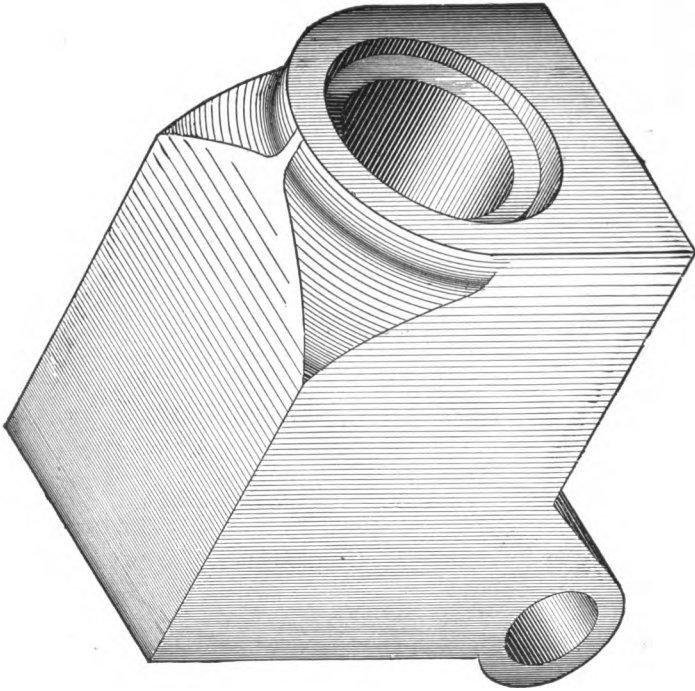


FIG. 71.

When a few pieces are to have round ends they may be milled as in Fig. 65, the piece R being rotated about S against the mill C.

Figs. 66 and 67 are representative operations that need no description.

Fig. 68 shows how a cylinder may be bored and one end squared in a milling machine, the action of the parts of a Plain Milling Machine being quite similar to that of a boring machine.

Fig. 69 shows a method of milling between the arms of hand wheels.

Fig. 70 shows samples of work done on the Vertical Spindle Milling Machine. Many of these cuts may also be made, though less conveniently, on machines with horizontal spindles, and all may be made on a horizontal machine with a Vertical Spindle Milling Attachment.

As an illustration of the number of operations and the variety of work which can profitably be done on the milling machine in the manufacture of machine tools, we give an approximate list of the milling operations performed in our works in the manufacture of the No. 1 Universal Milling Machine. Those marked with a star require the use of an Index Head, but by far the larger part of the work can be done without an Index Head upon our various Universal or Plain Milling Machines, and are examples of what may be practically termed plain milling.

Milling
Cuts made
in Manu-
facturing
the No. 1
Universal
Milling
Machine.

LIST OF THE MILLING OPERATIONS IN THE MANUFACTURE OF THE No. 1 UNIVERSAL MILLING MACHINE.

SPIRAL HEAD, FIG. 71.

	NO. OF CUTS.
*Roughing both sides and finishing top.....	3
Milling bottom and angle as shown in Fig. 72.....	1
Milling back end.....	1
Milling around lug for worm.....	1
*Milling front end.....	1
*Bevel cut clearance for mitre gears.....	1

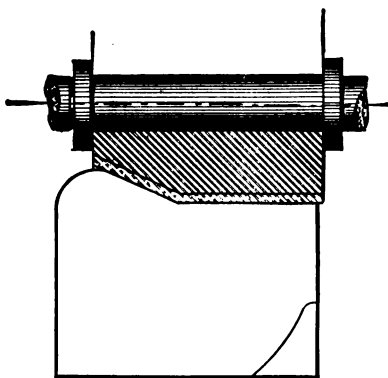


FIG. 72.

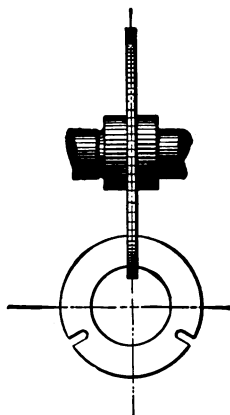


FIG. 75.

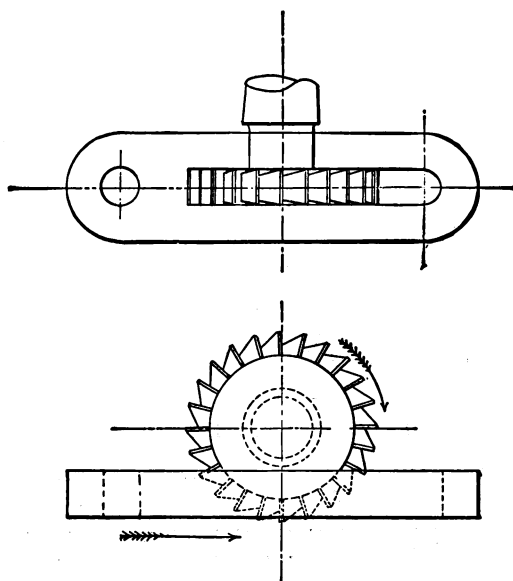


FIG. 74.

SPIRAL BOX, FIG. 73.

Milling inside bottom.....	1
Milling recess for nuts on bottom.....	2
Milling back side.....	1
*Milling around circle.....	1
*Milling around circle on top.....	2
Milling circular bolt slots.....	2
Milling for tongue in bottom.....	1
Milling complete sector.....	3

INDEX CRANK J, FIG. 6.

Milling both sides.....	2
Milling both edges with a form cutter.....	2
Milling slot as shown in Fig. 74.....	1

WORM SHAFT O, FIG. 6.

*Straddle cut for index crank similar to Fig. 20.....	1
*Cut for worm key, Fig. 75.....	1

SPIRAL SHELL.

*Milling dovetail key-way similar to Fig. 56	1
--	---

FACE PLATE.

Gang cut ends and slot like Fig. 76.....	2
--	---

CENTRE.

Milling spot for set screw.....	1
---------------------------------	---

MITER GEAR COVER.

Milling complete.....	6
-----------------------	---

MITRE GEAR BLOCK.

Milling two gang cuts, like Fig. 77, all over.....	2
--	---

SHEET STEELS.

Milling around the edges of worm wheel cover and miter gear cover, shown in black lines in Figs. 6 and 7.....	11
--	----

BACK CENTRE, SEE FIG. 1.

Milling bottom.....	1
Milling sides.....	2

BACK CENTRE STAND, SEE FIG. 1.

Milling face.....	1
Milling top.....	1
Milling back side.....	1
Milling bottom similar to Fig. 46.....	1

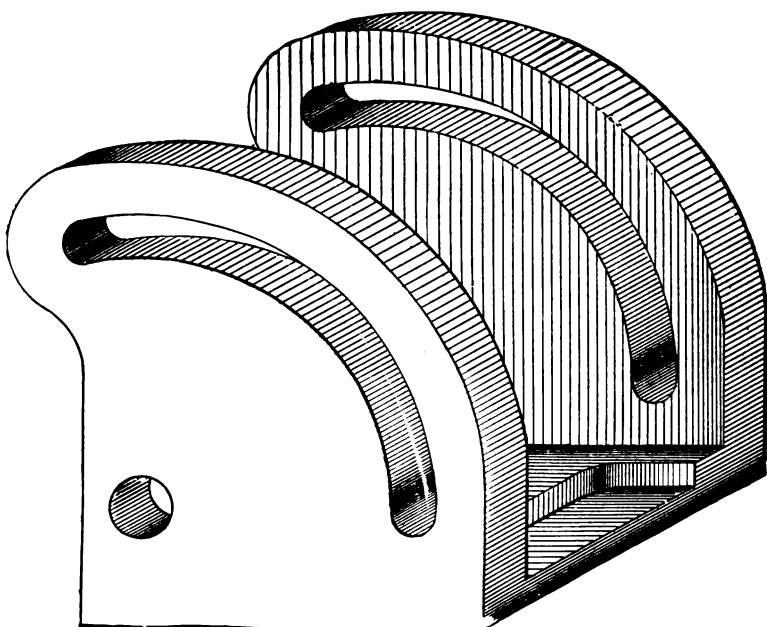


FIG. 73.

CENTRE REST.

Sawing off part of base similar to Fig. 57.....	1
Milling bottom for tongue, similar to Fig. 46	1

CENTRE REST SHELL.

Milling key-way for point of screw, similar to Fig. 75.....	1
---	---

SPIRAL BED, F, FIG. 5.

Milling top similar to A, Fig. 45,.....	1
Milling edges, similar to A, Fig. 45.....	2
Milling bevels with an angular cutter.....	2
Milling T slots, similar to E, Fig. 57	2
Milling clutch end.....	2
Milling clutches at end of bed.....	2
Milling crown gear cover shown at right end of bed, Fig. 1.....	8
Milling goose-neck shown at right end of bed, Fig. 1.....	10
Milling gear pocket.....	5
Milling feed slide, similar to Fig. 74.....	3
Milling feed lever stand.....	4
Milling spiral bed stop.....	2
Milling screw and clutch block....	5
Milling raising block R, Figs. 6 and 7.....	6
*Milling reverse gear stud R, Fig. 8.....	6
Milling reverse gear stud plate, Fig. 8 and Fig. 74.....	3
Milling intermediate gear stud, plate V, Fig. 8.....	3
*Milling Universal joints, Fig. 3	19
Milling Universal joint support, similar to A, Fig. 45.....	1
Milling feed pulley bracket, Fig. 3.....	2

CLAMP BED, FIG. 5.

Roughing bottom, gang cut like Fig. 78.....	1
Milling around edges	3
Roughing top similar to A, Fig. 45.....	1
Roughing bevel on bottom like G, Fig. 57.....	2
Roughing for shoe.....	1
Finishing for shoe.....	2
Milling circular cut for saddle bearing G, Fig. 57.....	1
Milling oil groove on back side.....	1
Finishing for knee bearing	1
Milling shoe complete	4
Milling shoe screw	1
Milling clamp bed nut.....	1

SADDLE E, FIG. 5.

Milling bevel with angular cutter.....	1
Milling ends of gibs.....	2
Milling saddle nut.....	5

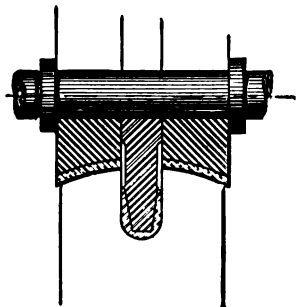


FIG. 76.

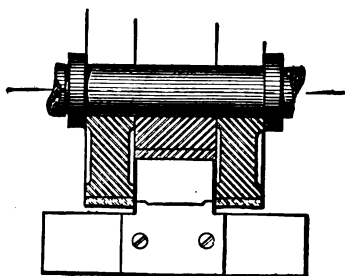


FIG. 77.

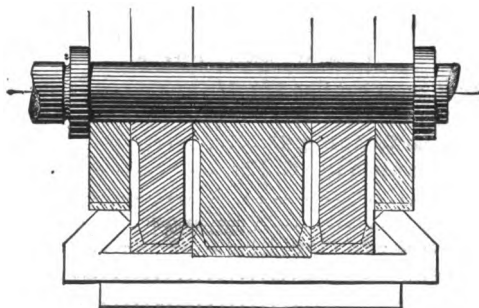


FIG. 78.

KNEE K, FIG. 5.

Milling top.....	1
Milling back	2
Milling front end.....	1
Cut for steel guard.....	1
Milling knee dial plate.....	2

KNEE CRANK.

Milling outside.....	1
Milling inside	1
Milling edges.....	2
*Milling around ends	2

KNEE SCREW.

Milling spot for set screw.....	1
---------------------------------	---

CLAMP BED SCREW AND KNEE SHAFT.

*Milling ends for crank and spot for set screw.....	3
---	---

SPINDLE.

*Milling long key-way.....	1
*Milling short key-way	1

SPINDLE FRONT BOX.

Milling oil grooves on ends.....	2
----------------------------------	---

SPINDLE REAR BOX.

*Milling and splitting box, Fig. 75.....	3
--	---

COLLET.

*Milling sides of tongue	2
Milling end of tongue, similar to d, Fig. 45	1
*Milling around edge of key-way, similar to A, Fig. 57.....	1

OIL CAN LINK, ETC.

Milling sides.....	2
Milling ends.....	2
Milling oil stop for spiral bed.....	5
Milling dove-tail splines, similar to Fig. 56	3
*Milling 14 hexagonal nuts like Fig. 50.....	24
*Milling 11 bolt heads like Fig. 50.....	9
Milling Vise.	34
Milling wrenches.....	6

Total number of milling operations..... 289

USE OF MILLING MACHINES—CONTINUED.

INDEXING.

Use of
Indexing
Head to
Divide
Periphery
of Work
into Equal
Parts.

The first office of the indexing head stock or spiral head, as mentioned in the description of the machines is to divide the periphery of a piece of work into a number of equal parts, and in connection with the foot stock, it also enables the milling machine to be used for work sometimes done on planer centres and on gear cutting machines.

As the index spindle may be revolved by the crank, and as forty turns of the crank make one revolution of the spindle, to find how many turns of the crank are necessary for a certain division of the work, or what is the same thing, for a certain division of a revolution of the spindle, forty is divided by the number of the divisions which are desired. The rule then, may be said to be, divide forty by the number of divisions to be made and the quotient will be the number of turns, or the part of a turn, of the crank, which will give each desired division. Applying this rule—to make forty divisions the crank would be turned completely around once to obtain each division, or to obtain twenty divisions it would be turned twice. When, to obtain the necessary divisions, the crank has to be turned only a part of the way around, an index plate is used. For example: If the work is to be divided into eighty divisions the crank must be turned one-half way around, and an index plate with an even number of holes in one of the circles would be selected, it being necessary only to have two holes opposite to each other in the plate. If the work is to be divided into three divisions an index plate should be selected

Index
Plate.

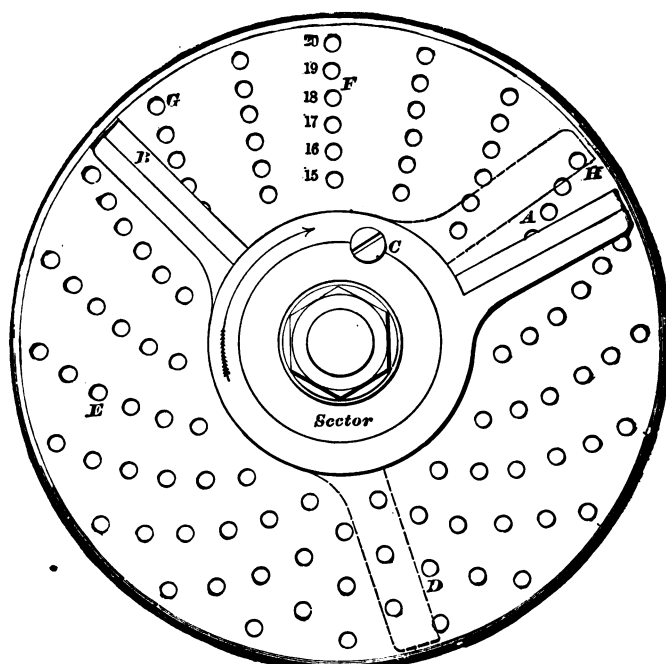


FIG. 79.

which has a circle with a number of holes that can be divided by three, as fifteen or eighteen in Fig. 79, the numbers on the index plates indicating the number of holes in the various circles.

Sector. The sector is of service in obviating the necessity of counting the holes at each partial rotation or turn of the crank, and to illustrate its use it may be supposed that it is desired to divide the work into 144 divisions. Dividing 40 by 144 the result, $\frac{5}{18}$, shows that the index crank must be moved $\frac{5}{18}$ of a turn to obtain each of the 144 divisions. An index plate with a circle containing eighteen holes or a multiple of eighteen, is selected, and the sector is set to measure off five spaces or the corresponding multiple, ten spaces for example, in a circle with thirty-six holes. When the sector is set it is held in place by the screw C, Fig. 79. In setting the sector it should be remembered that there must always be one more hole between the arms than there are spaces to be counted or measured off. Starting with the crank pin in the hole B, for example, a cut would be made in the work and then the crank would be turned and the pin brought into the hole at A and a second cut made in the work. The sector would then be moved to the position shown at dotted line, that is the arm would be brought against the pin in the crank. When the third cut is to be made the crank would be turned and the pin brought to the hole D. The next step would bring the pin to the hole E, and so on. When the operation has been repeated 144 times one revolution of the spindle will have been made. The required number of turns of the crank for a large number of divisions may be readily ascertained from the accompanying index tables.

Effect of Change in Angle of Elevation of Spindle If the angle of elevation of the spiral head spindle is changed during the progress of the work, the work must be rotated slightly to bring it back to the proper position, as when the spindle is elevated or depressed the worm wheel is rotated about the worm, and the effect is the same as if the worm were turned in the opposite direction.

INDEX TABLE.

Number of Divisions.	Number of Holes in the Index Circle.	Number of Turns of the Crank.	Number of Divisions.	Number of Holes in the Index Circle.	Number of Turns of the Crank.
2	ANY	20	35	49	1 $\frac{1}{2}$
3	39	13 $\frac{1}{3}$	36	27	1 $\frac{2}{3}$
4	ANY	10	37	37	1 $\frac{3}{4}$
5	"	8	38	19	1 $\frac{3}{4}$
6	39	6 $\frac{2}{3}$	39	39	1 $\frac{1}{2}$
7	49	5 $\frac{2}{7}$	40	ANY	1
8	ANY	5	41	41	4 $\frac{1}{4}$
9	27	4 $\frac{1}{3}$	42	21	2 $\frac{1}{2}$
10	ANY	4	43	43	4 $\frac{1}{2}$
11	33	3 $\frac{1}{3}$	44	33	3 $\frac{1}{3}$
12	39	3 $\frac{1}{3}$	45	27	2 $\frac{1}{2}$
13	39	3 $\frac{1}{3}$	46	23	2 $\frac{1}{2}$
14	49	2 $\frac{4}{7}$	47	47	4 $\frac{1}{2}$
15	39	2 $\frac{4}{5}$	48	18	1 $\frac{1}{2}$
16	20	2 $\frac{1}{2}$	49	49	4 $\frac{1}{2}$
17	17	2 $\frac{1}{7}$	50	20	1 $\frac{1}{2}$
18	27	2 $\frac{1}{3}$	52	39	3 $\frac{1}{2}$
19	19	2 $\frac{1}{5}$	54	27	2 $\frac{1}{2}$
20	ANY	2	55	33	3 $\frac{1}{3}$
21	21	1 $\frac{1}{2}$	56	49	4 $\frac{1}{2}$
22	33	1 $\frac{2}{3}$	58	29	2 $\frac{1}{2}$
23	23	1 $\frac{1}{3}$	60	39	3 $\frac{1}{2}$
24	39	1 $\frac{2}{3}$	62	31	3 $\frac{1}{2}$
25	20	1 $\frac{1}{2}$	64	16	1 $\frac{1}{2}$
26	39	1 $\frac{2}{3}$	65	39	3 $\frac{1}{2}$
27	27	1 $\frac{1}{3}$	66	33	3 $\frac{1}{3}$
28	49	1 $\frac{2}{7}$	68	17	1 $\frac{1}{2}$
29	29	1 $\frac{1}{2}$	70	49	4 $\frac{1}{2}$
30	39	1 $\frac{1}{3}$	72	27	2 $\frac{1}{2}$
31	31	1 $\frac{1}{3}$	74	37	3 $\frac{1}{2}$
32	20	1 $\frac{1}{2}$	75	15	1 $\frac{1}{2}$
33	33	1 $\frac{1}{3}$	76	19	1 $\frac{1}{2}$
34	17	1 $\frac{1}{4}$	78	39	3 $\frac{1}{2}$

INDEX TABLE.

Number of Divisions.	Number of Holes in the Index Circle.	Number of Turns of the Crank.	Number of Divisions.	Number of Holes in the Index Circle.	Number of Turns of the Crank.
80	20	$\frac{1}{2}0$	164	41	$\frac{1}{2}1$
82	41	$\frac{2}{2}1$	165	33	$\frac{3}{2}3$
84	21	$\frac{1}{2}1$	168	21	$\frac{5}{2}1$
85	17	$\frac{1}{2}7$	170	17	$\frac{1}{2}7$
86	43	$\frac{2}{2}3$	172	43	$\frac{1}{2}3$
88	33	$\frac{1}{2}3$	180	27	$\frac{5}{2}7$
90	27	$\frac{1}{2}7$	184	23	$\frac{5}{2}3$
92	23	$\frac{1}{2}3$	185	37	$\frac{3}{2}7$
94	47	$\frac{2}{2}7$	188	47	$\frac{1}{2}7$
95	19	$\frac{1}{2}9$	190	19	$\frac{1}{2}9$
98	49	$\frac{2}{2}9$	195	39	$\frac{3}{2}9$
100	20	$\frac{1}{2}0$	196	49	$\frac{1}{2}9$
104	39	$\frac{1}{2}9$	200	20	$\frac{1}{2}0$
105	21	$\frac{2}{2}1$	205	41	$\frac{1}{2}1$
108	27	$\frac{1}{2}0$	210	21	$\frac{1}{2}1$
110	33	$\frac{1}{2}3$	215	43	$\frac{1}{2}3$
115	23	$\frac{5}{2}3$	216	27	$\frac{5}{2}7$
116	29	$\frac{1}{2}9$	220	33	$\frac{5}{2}3$
120	39	$\frac{1}{2}9$	230	23	$\frac{5}{2}3$
124	31	$\frac{1}{2}1$	232	29	$\frac{5}{2}9$
128	16	$\frac{1}{2}6$	235	47	$\frac{1}{2}7$
130	39	$\frac{1}{2}9$	240	18	$\frac{1}{2}8$
132	33	$\frac{1}{2}3$	245	49	$\frac{1}{2}9$
135	27	$\frac{2}{2}7$	248	31	$\frac{1}{2}1$
136	17	$\frac{1}{2}7$	260	39	$\frac{3}{2}9$
140	49	$\frac{1}{2}9$	264	33	$\frac{1}{2}3$
144	18	$\frac{1}{2}8$	270	27	$\frac{1}{2}7$
145	29	$\frac{2}{2}9$	280	49	$\frac{1}{2}9$
148	37	$\frac{1}{2}7$	290	20	$\frac{1}{2}0$
150	15	$\frac{1}{2}5$	296	37	$\frac{5}{2}7$
152	19	$\frac{1}{2}9$	300	15	$\frac{1}{2}5$
155	31	$\frac{2}{2}1$	310	31	$\frac{1}{2}1$
156	39	$\frac{1}{2}9$	312	39	$\frac{3}{2}9$
160	20	$\frac{1}{2}0$	360	18	$\frac{1}{2}8$

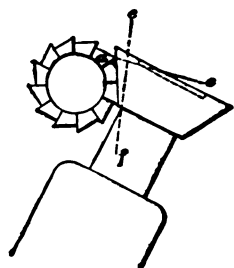


FIG. 80.

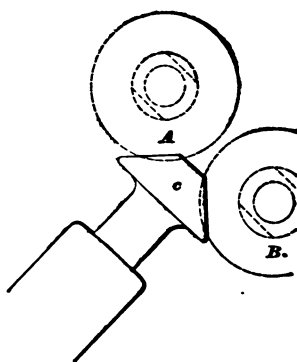


FIG. 81.

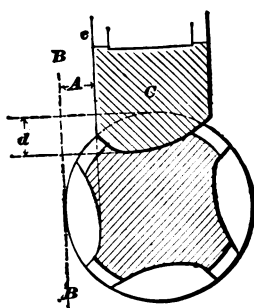


FIG. 82.

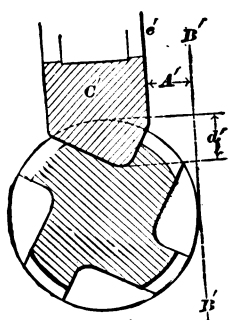
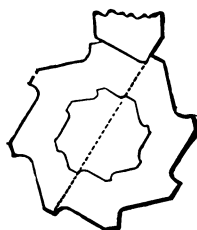


FIG. 83.



Examples of Work. A simple use of the index centers is that of milling bolt heads, nuts, etc. Those shown in Figs. 50, 51 and 52, for instance, could be milled by being held on the spiral head instead of the fixture previously described.

Milling Bolt Heads. Among work commonly divided on the index centres are saws, Fig. 32; screw slotting cutters, Fig. 31; and a large variety of straight tooth mills, for example, Figs. 29, 30, 36 and 38. Cutting the teeth of ratchets represents a similar use of the centres. In milling teeth of angular cutters the index spindle can be set as shown in Fig. 80, and when the spindle and cutter are in this position the knee of the machine is raised by the vertical feed. Fig. 81 shows that the same cutter may be used for making a right or left hand mill, in one case the feed being vertical and the other horizontal.

Dividing Cutters, etc. The fluting or grooving of taps and reamers is another kind of work in which index centres are used. A table showing the tap and reamer cutters to be used in grooving reamers is given in our catalogue, different cutters being used for a certain size reamer than for the same size tap. The accompanying table gives the figures for setting taps sidewise and also for the depths of groove. These figures will be found convenient, but are not given to be followed absolutely, for mechanics have different opinions as to the best shape and the proper depth of groove in taps.

Fluting Taps and Reamers. The columns in the table as marked refer to the special tap cutters the shape of which are shown in Fig. 82, and tap and reamer cutters Fig. 83. One class of our twist drill cutters have a round edge, and can also be used in grooving taps.

The top of the table of the machine when doing this work is moved sidewise along the distance A, between B B and e, which is .125 of an inch, as given in the column under A. The work is next set for the depth of the cut d, which is given in the table under the column d, and is .2 of an inch. This depth is read off by the graduated collar on the vertical feed shaft.

Table for Setting when Cutting with Special Tap Cutters, or with Tap and Reamer Cutters.

Diameter of Tap.	No. of Cutter.	Value of A, d and A', d'				Diameter of Cutter.
		A=	d =	A'=	d' =	
$\frac{1}{8}$	1	.025	.025	.000	.028	$1\frac{1}{8}$
$\frac{5}{32}$	2	.003	.031	*	.035	"
$\frac{3}{16}$	"	.018	.037	.000	.043	"
$\frac{1}{2}$	"	.034	.043	.015	.050	"
$\frac{3}{4}$	"	.050	.050	.031	.057	"
$\frac{7}{8}$	3	.028	.056	.015	.065	$1\frac{1}{2}$
$\frac{1}{16}$	"	.043	.062	.031	.072	"
$\frac{3}{32}$	"	.075	.075	.062	.086	"
$\frac{1}{8}$	4	.031	.087	.031	.100	2
$\frac{3}{16}$	"	.062	.100	.062	.115	"
$\frac{1}{4}$	"	.093	.112	.093	.129	"
$\frac{5}{16}$	"	.125	.125	.125	.144	"
$\frac{3}{8}$	5	.081	.137	.093	.158	$2\frac{1}{2}$
$\frac{1}{2}$	"	.112	.150	.125	.172	"
$\frac{5}{8}$	"	.143	.162	.156	.187	"
$\frac{3}{4}$	"	.175	.175	.187	.200	"
$\frac{7}{8}$	6	.093	.187	.125	.215	$2\frac{1}{4}$
1	"	.125	.200	.156	.230	"
$1\frac{1}{16}$	"	.156	.212	.187	.245	"
$1\frac{1}{8}$	"	.187	.225	.218	.258	"
$1\frac{3}{16}$	"	.218	.237	.250	.273	"
$1\frac{1}{2}$	"	.250	.250	.281	.287	"
$1\frac{5}{8}$	7	.168	.262	.218	.300	$2\frac{3}{8}$
$1\frac{3}{4}$	"	.200	.275	.250	.316	"
$1\frac{7}{8}$	"	.231	.287	.281	.330	"
$1\frac{9}{8}$	"	.262	.300	.312	.345	"
$1\frac{11}{8}$	"	.293	.312	.344	.359	"
$1\frac{13}{8}$	"	.325	.325	.375	.373	"
$1\frac{15}{8}$	8	.243	.337	.312	.388	$2\frac{5}{8}$
$1\frac{17}{8}$	"	.275	.350	.344	.400	"
$1\frac{19}{8}$	"	.337	.375	.406	.430	"
2	"	.400	.400	.468	.460	"

* No. 2 Regular Cutter, $\frac{1}{16}$ " thick.

The depth of groove cut in a tap by a special tap cutter is .2 of the diameter of the tap. The depth of groove cut by a tap and reamer cutter is .23 of the diameter of the tap.

The machine, as a rule, is fed automatically while cutting, and after each cut is taken the index crank is turned as previously described.

Screw
Machine
Tool.

Fig. 84 shows a tool used in a screw machine or turret lathe.

Cutting
Gears.

In cutting gears care must be taken to have the cutter central with the index centres, and to have the cut the exact depth required. A good way of testing the setting is to cut a groove in a piece on the centres, then shift the piece end for end and try the groove upon the cutter. A good method of holding the gear blanks is on an arbor with a taper shank which fits in the index spindle, the outer end of the arbor being supported by the foot stock centre. Frequently in cutting gears we use a shank arbor with expanding bushing and a nut on the arbor at each end of the bushing, one nut forcing the bushing up on the arbor and holding the gear blank, while the other pushes the bushing off the taper and releases the gear when finished. If the common arbor and dog are used, care should be taken that the dog does not spring the arbor. The screws, Fig. 7, may be used to hold the dog so that there shall be no back lash between the index spindle and the work. The depth of the cut can be gauged from the outside of the blank or, if desired, marked on the side by a gear tooth depth gauge. In cutting gears, when the blank has been placed in position it is raised by the elevating screw until it just touches the cutter. The graduated collar on the vertical feed shaft is placed on zero and the blank moved horizontally from the cutter. Then the work is raised the number of thousandths of an inch required for the depth of tooth.

In our catalogue we give the depth of gear teeth of a number of pitches, directions regarding sizing and

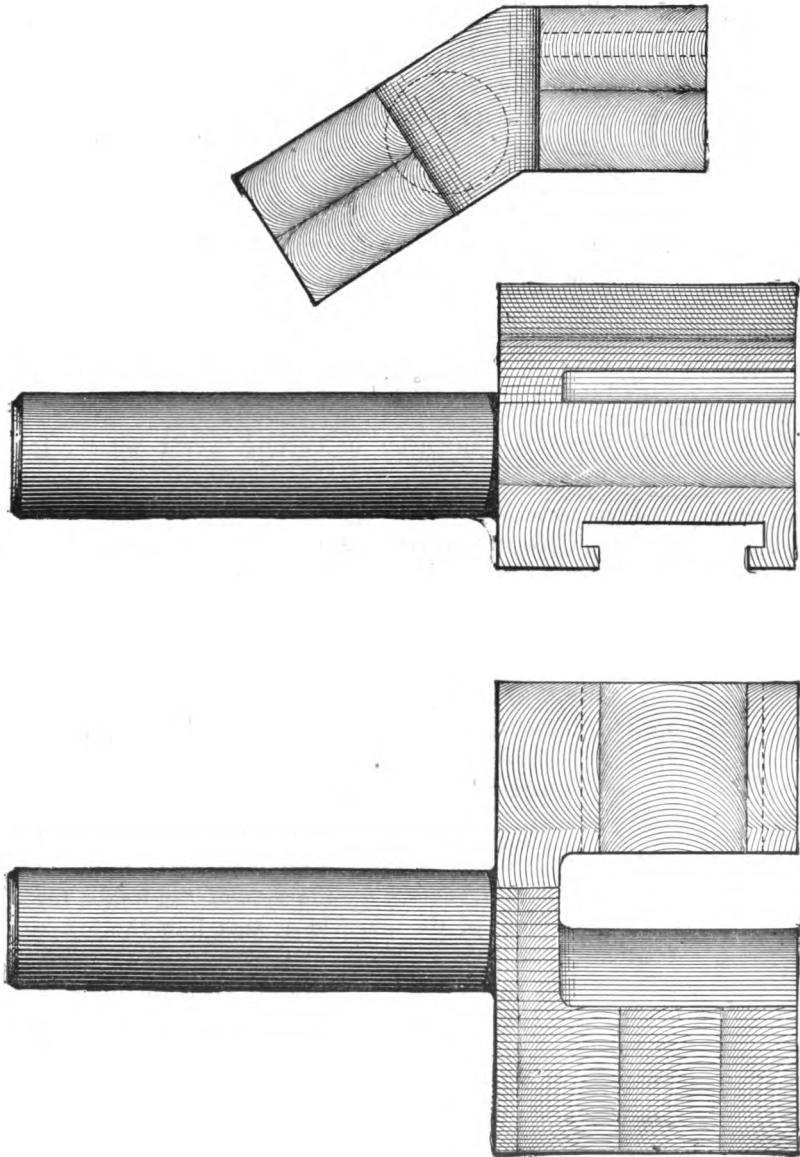


FIG. 84.

cutting of gear wheels, formulae for determining the dimensions of small gears by diametral pitch, also directions for selecting involute and epicycloidal gear cutters for any given pitch. The catalogue contains as well a number of plain rules for determining various dimensions of gears. More complete information on this subject is given in our "Practical Treatise on Gearing."

**Worm
Wheels.**

For several years we have milled the faces of worm wheels in our Universal Milling Machines, as this costs less and is better than turning them in an engine lathe. The operation will be understood from Fig. 85, one part of which shows a segment of a spur wheel, and the other part S, a segment of a worm wheel blank.

The practice involved in cutting worm wheels is seen in Fig. 86.

The index centers are set central with the cutter on the line C D, as in cutting spur gears. The arbor holding the worm wheel blank is put on the centres, and by moving the table lengthwise the centre of the face of the worm wheel is set under the centre of the cutter spindle A B. The table stop is put on so that the table will not move, then the saddle is set to the angle of the teeth as seen by the lines E and C D, and the vertical feed is used in cutting the work. Worm wheels can be hobbled in the Universal Milling Machine.

The wheel can be hobbled to the right depth by setting a rule on the top of the knee and measuring up to the line marked centre on the side of the frame, for when the back of the knee is at this line the index centres are at the same height as the centre of the cone spindle, the measurement from the knee to this line being, in other words, the distance between the centres of the worm and wheel. When hobbing a worm wheel, the shaft of which is at right angles with the axis of the worm, the spiral bed should be set at zero.

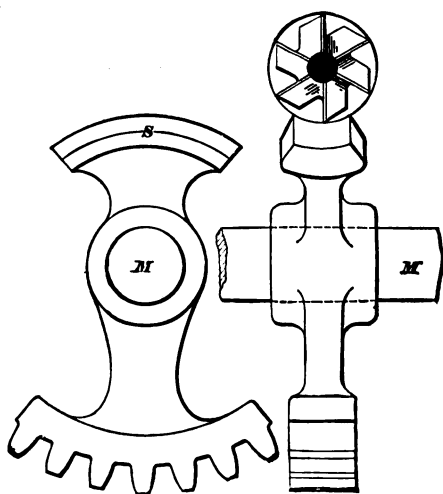


FIG. 85.

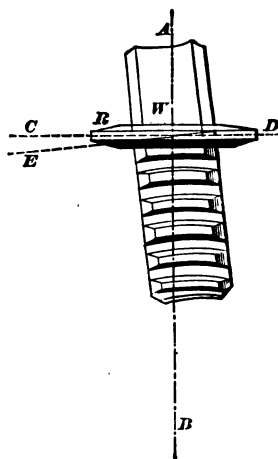


FIG. 86.

**Bevel
Gears.**

The teeth of a bevel gear, Figs. 87 and 88, may be considered as formed upon the surface of a cone (instead of a cylinder as is the case with a spur gear) and converge toward the apex and it is obvious then that they cannot be produced by the single passage of any rotary cutter. By taking two cuts to each tooth, however, each cut to make one side of each tooth central at the pitch line, approximately correct results are obtained. The two cuts give the necessary variation in width to the teeth, but they do not give the corresponding changes in the curves. For example, in Fig. 87, the line *a a* represents the outline of the tooth of a bevel gear at the large end and the line *b b* represents the same tooth at the small end. As each side of the tooth from the large end to the small end is cut by a single passage of the cutter, if the cutter is of the form to give the correct outline of the tooth at the large end, the tooth at the small end will be too thick at the point as indicated by the dotted line *b b'*, and if the cutter is of the form to give the correct outline at the small end of the tooth, the large end of the tooth will be too thin at the point, as indicated by the dotted line *a a'*. This variation in the curves of the teeth will depend upon the number of teeth in the gear, and the length of face as compared with the diameter of the gear. To make the required change in the shape of the teeth, they are often filed at the small ends.

As the sides of the teeth must be central, it follows that that side of the cutter which is to form the corresponding side of a tooth must also be central and the cutter must be set to one side of the centre enough to make it so. This distance is approximately the half thickness of the cutter measured at the pitch line at the large end of the tooth and in practice is determined by trial.

For gears of less than thirty teeth, cutters of suitable form for the large end of the tooth are used, and for gears of over thirty teeth, cutters suited to the form midway between the two ends, the cutters in all cases being somewhat thinner than the space at the small end. It is perhaps needless to observe that conditions so difficult to state and so constantly varying as are presented in cutting the teeth of bevel gears require experience and judgment on the part of the workman.

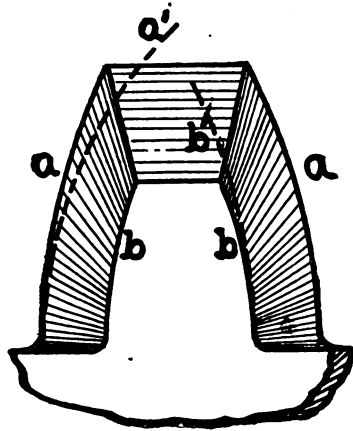


FIG. 87.

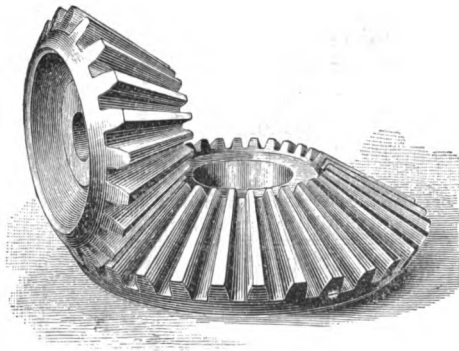


FIG. 88.

USE OF MILLING MACHINES,—CONTINUED.

COMPOUND INDEXING.

Compound
Indexing
Defined.

It is sometimes desired to divide the work into a number of parts, which cannot be obtained by a single indexing because the index plates have not a circle with the requisite number of holes. Frequently, however, the desired divisions can be readily obtained by using two circles of holes, according to the method termed compound indexing ;—a method which has been considered quite fully by Mess. Fred J. Miller, Walter Gribben, G. Schneider and J. V. Hamilton, and explained by them in contributions to the "American Machinist," October 31st and December 12, 1889, and January 16th, May 22d, July 17th, August 14th and October 16th, 1890.

In the following tables, and for these we are chiefly indebted to the kindness of Mr. Walter Gribben, the method of combining the two index settings is indicated by the signs plus and minus ; the plus sign showing that the two indexings are added together, or that the movement of the work in both indexings is in the same direction, while the minus sign shows that we take the difference between the two indexings, or that we move one indexing in one direction and the second indexing in the opposite direction, the principle in making the calculations being simply the addition or subtraction of fractions. The denominators of the fractions indicate which circles of holes are used in the index plates.

Compound Index Movements of the No. 1 Universal Milling Machine.

Number of Divisions.	Movements.	Number of Divisions.	Movements.	Number of Divisions.	Movements.
69	$\frac{21}{3} - \frac{11}{3}$	154	$\frac{8}{21} - \frac{4}{3}$	273	$\frac{21}{4} - \frac{11}{3}$
77	$\frac{21}{3} + \frac{5}{3}$	174	$\frac{34}{3} - \frac{1}{9}$	276	$\frac{41}{3} - \frac{34}{3}$
87	$\frac{21}{3} - \frac{11}{3}$	182	$\frac{34}{3} + \frac{2}{9}$	287	$\frac{14}{3} - \frac{21}{3}$
91	$\frac{21}{3} + \frac{11}{3}$	186	$\frac{34}{3} - \frac{11}{3}$	288	$\frac{21}{3} - \frac{11}{3}$
93	$\frac{36}{8} + \frac{11}{3}$	198	$\frac{34}{3} + \frac{5}{3}$	294	$\frac{23}{3} - \frac{34}{3}$
96	$\frac{36}{8} + \frac{5}{3}$	225	$\frac{27}{5} - \frac{2}{10}$	297	$\frac{34}{3} + \frac{21}{3}$
99	$\frac{36}{8} - \frac{3}{3}$	231	$\frac{34}{3} + \frac{1}{3}$	301	$\frac{41}{3} - \frac{41}{3}$
138	$\frac{17}{3} - \frac{2}{3}$	253	$\frac{34}{3} - \frac{12}{3}$	304	$\frac{10}{2} - \frac{17}{3}$
147	$\frac{17}{3} - \frac{2}{3}$	259	$\frac{44}{3} - \frac{7}{3}$	308	$\frac{21}{3} - \frac{34}{3}$
		272	$\frac{10}{3} - \frac{17}{3}$		

To illustrate the manner of using the machine in compound indexing, it may be supposed that we desire to divide the work into 69 parts. Reference to the table shows that the work is moved through 21 spaces, or "holes," in the 23 hole circle and then turned in the opposite direction 11 "holes" in the 33 hole circle of one of the index plates. The first movement is made in the ordinary manner. The stop or back pin is placed in the 33 hole circle, the index crank pin is pulled out of the 23 hole circle, and the index crank is turned through 21 "holes" in the desired direction, the "holes" being measured by the sector. For the second movement, the index crank pin is left in the 23 hole circle, the back pin is pulled back from the plate and, as the minus sign is given in the table, the crank is turned 11 "holes" in the direction opposite to that of the former movement. In this part of the indexing the index plate and crank turn together and, as there is no sector on the back of the plate, the "holes" or spaces have to be counted directly in the plate. Had the plus sign been given, as in the indexing to obtain 77 divisions of the work, both movements of the crank would have been in the same direction. Ordinarily the order of the movements is not material and if more convenient for any reason, the back pin could usually be withdrawn first, and the movement described as the second could be made first. In some instances indeed, for example, in dividing the work into 174, 272 or 273 parts, the outer circle is naturally used first.

The correctness of the operations indicated by the table is easily appreciated when the fractions are added or subtracted. For example: to divide the work into 69 parts the figures are $\frac{21}{23} - \frac{11}{33} = \frac{21}{23} - \frac{1}{3} = \frac{63}{69} - \frac{23}{69} = \frac{40}{69}$; and this equals one division of the work or the desired result, as there are 40 teeth in the worm wheel and to obtain 1-69 of a complete revolution it is desired that 40 should be divided by 69.

To obtain 77 divisions the figures are $\frac{9}{21} + \frac{3}{33} = \frac{3}{7} + \frac{1}{11} = \frac{33}{77} + \frac{7}{77} = \frac{40}{77} =$ one division.

Manner of
Using the
Machines.

Proof of
Correct-
ness of the
Moves.

This method of calculation (although fractions are involved) is essentially the same as that described on page 120.

Approximate
Indexings
by
Compound
Method.

The next table gives the movements for divisions of the work (absolutely, or within close limits) from 50 to 250. Where only one indexing is indicated the figures are taken from the tables on pages 123 and 124, and where absolutely correct results are shown by the compound indexing, the figures are taken from the last table. In regard to this table, Mr. Gribben writes us as follows :

"The figures in the first column give the desired number of teeth, or the nearest approximations to the desired number of teeth, which approximations are so near in the instance of 51, 53, 57, 61, 67, 71, 73, 79, 81, etc., that the error may be safely neglected.

The figures in the second column give the moves for the index shaft, in opposite directions when connected by a — sign, and in the same direction when connected by a + sign.

The figures in the third column show the error in position of the last space cut if the cross-slide be not moved, and we are cutting a gear of 1 diametral pitch. If a gear of finer pitch is to be cut, the figures in the third column will have to be divided by the diametral pitch of the gear under consideration, and the result (if of sufficient magnitude to be taken into account) distributed up around the circumference as best it may.

For instance, if we wish to cut 112 teeth of 6 pitch, the error in the last cut would be about .001 inch, which might be corrected by moving the cross-slide .0001 inch after every 11 cuts.

If the index head is set for a lower number than the desired one, then the larger of the two moves must carry the top of blank in the opposite direction from that in which the cross-slide is moved, while if the index head is set for a higher number than the desired one, then the larger of the two moves must carry the top of blank in the same direction as that in which the cross-slide is moved."

Compound Index Movements on the No. 1 Universal Milling Machine. (Absolute and Approximate.)

NO. OF TEETH.	MOVES.	ERROR ON DIAMETRAL FITCH.	TIMES AROUND.
50.	$\frac{18}{20}$		
51.0001	$8\frac{1}{17} - \frac{12}{19}$	.0002	11
52.	$\frac{20}{21}$		
53.0001	$6\frac{1}{19} - \frac{6}{20}$	.0002	9
54.	$\frac{20}{27}$		
55.	$\frac{24}{25}$		
56.	$\frac{24}{26}$		
56.9999	$5\frac{2}{19} - \frac{7}{17}$	.0003	7
58.	$\frac{20}{29}$		
58.9997	$7\frac{1}{13} + \frac{10}{19}$	.0009	11
60.	$\frac{28}{30}$		
60.9999	$4\frac{2}{19} - \frac{5}{17}$	.0003	6
62.	$\frac{20}{31}$		
62.9994	$5\frac{1}{11} - \frac{10}{19}$	.0019	8
64.	$\frac{10}{18}$		
65.	$\frac{24}{24}$		
66.	$\frac{20}{33}$		
67.0002	$3\frac{1}{19} - \frac{11}{11}$	.0005	5
68.	$\frac{10}{19}$		
69.	$\frac{21}{31} - \frac{11}{33}$		
70.	$\frac{24}{24}$		
70.9999	$3\frac{1}{11} - \frac{2}{19}$	.0005	6
72.	$\frac{15}{27}$		
73.0001	$6\frac{2}{17} - \frac{1}{19}$	.0002	12
74.	$\frac{20}{29}$		
75.	$\frac{8}{18}$		
76.	$\frac{10}{19}$		
77.	$\frac{2}{11} + \frac{3}{33}$		
78.	$\frac{20}{39}$		
79.0002	$3\frac{2}{19} - \frac{1}{13}$	.0005	6
80.	$\frac{10}{18}$		
80.9999	$5\frac{5}{11} - \frac{9}{19}$	.0003	10
82.	$\frac{21}{21}$		
83.0003	$3\frac{1}{17} - \frac{5}{19}$	.0011	8
84.	$\frac{10}{21}$		
85.	$\frac{8}{17}$		
86.	$\frac{20}{23}$		
87.	$\frac{23}{29} - \frac{11}{33}$		
88.	$\frac{13}{33}$		
89.0001	$3\frac{2}{39} - \frac{6}{19}$	.0005	8
90.	$\frac{12}{27}$		

$$\frac{2}{20} - \frac{2}{15} = \frac{1}{60}$$

Compound Index Movements on the No. 1 Universal Milling Machine. (Absolute and Approximate.)

NO. OF TEETH.	MOVES.	ERROR ON DIAMETRAL PITCH.	TIMES AROUND.
91.	$\frac{6}{39} + \frac{14}{49}$		
92.	$\frac{10}{23}$		
93.	$\frac{5}{31} + \frac{11}{33}$		
94.	$\frac{20}{47}$		
95.	$\frac{8}{19}$		
96.	$\frac{5}{18} + \frac{5}{20}$		
96.9999	$\frac{427}{41} - \frac{6}{49}$	.0004	11
98.	$\frac{20}{49}$		
99.	$\frac{15}{27} - \frac{5}{33}$		
100.	$\frac{8}{20}$		
101.0001	$\frac{433}{43} - \frac{13}{49}$	.0003	11
102.0002	$\frac{417}{43} - \frac{13}{49}$	.0007	11
103.0003	$\frac{113}{49} + \frac{3}{43}$	.0010	4
104.	$\frac{13}{39}$		
105.	$\frac{1}{21}$		
106.0003	$\frac{323}{49} - \frac{3}{41}$	.0009	9
107.0004	$\frac{231}{31} - \frac{2}{33}$	.0012	7
108.	$\frac{10}{27}$		
108.9998	$\frac{219}{39} + \frac{4}{49}$	.0006	7
110.	$\frac{13}{33}$		
111.0001	$\frac{417}{49} - \frac{13}{47}$	.0003	11
111.9980	$\frac{410}{31} - \frac{13}{33}$	.0063	11
112.9999	$\frac{329}{49} - \frac{13}{43}$	.0004	9
113.9996	$\frac{225}{49} - \frac{2}{37}$	.0014	7
115.	$\frac{8}{23}$		
116.	$\frac{10}{29}$		
117.0001	$\frac{71}{47} - \frac{9}{49}$	.0002	20
117.9994	$\frac{138}{39} + \frac{24}{49}$	.0019	5
119.0005	$\frac{34}{23} - \frac{16}{33}$	.0015	8
120.	$\frac{13}{39}$		
120.9982	$\frac{114}{47} - \frac{15}{49}$	.0055	3
122.0003	$\frac{341}{43} - \frac{17}{49}$	.0008	11
123.0006	$\frac{117}{49} + \frac{12}{43}$	.0018	5
124.	$\frac{10}{31}$		
125.0010	$\frac{234}{41} - \frac{14}{49}$	.0031	8
125.9985	$\frac{316}{19} - \frac{7}{20}$	.0047	11
127.0002	$\frac{312}{49} - \frac{16}{39}$	.0006	9
128.	$\frac{5}{19}$		
128.9997	$\frac{615}{49} - \frac{17}{41}$	.0011	19
130.	$\frac{12}{39}$		
130.9990	$\frac{341}{49} - \frac{3}{43}$	.0031	11
132.	$\frac{10}{33}$		

Compound Index Movements on the No. 1 Universal Milling Machine. (Absolute and Approximate.)

NO. OF TEETH.	MOVES.	ERROR ON DIAMETRAL PITCH.	TIMES AROUND.
133.0006	$3\frac{1}{3} - \frac{1}{3}$	.0020	11
134.0002	$4\frac{1}{3} - \frac{2}{3}$	.0007	13
135.	$\frac{5}{27}$		
136.	$\frac{5}{17}$		
137.0001	$3\frac{1}{3} - \frac{2}{3}$	.0005	11
138.	$\frac{1}{3} - \frac{1}{3}$		
138.9998	$3\frac{1}{3} - \frac{1}{3}$	.0005	11
140.	$\frac{1}{3}$		
141.0007	$2\frac{1}{3} - \frac{7}{3}$	.0022	8
141.9998	$4\frac{1}{3} + \frac{1}{3}$	.0006	15
142.9991	$1\frac{2}{3} - \frac{1}{3}$	.0029	5
144.	$\frac{5}{13}$		
145.	$\frac{5}{29}$		
145.9994	$2\frac{1}{3} - \frac{1}{3}$	.0018	7
147.	$\frac{1}{3} - \frac{1}{3}$		
148.	$\frac{1}{3}$		
149.0003	$3\frac{1}{3} - \frac{1}{3}$	.0010	11
150.	$\frac{1}{3}$		
151.0008	$1\frac{1}{3} - \frac{1}{3}$	.0024	7
152.	$\frac{5}{13}$		
153.0002	$2\frac{1}{3} - \frac{1}{3}$	.0005	11
154.	$\frac{1}{3} - \frac{1}{3}$		
155.	$\frac{1}{3}$		
156.	$\frac{1}{3}$		
157.9990	$5\frac{1}{3} - \frac{1}{3}$	.0031	19
158.0003	$3\frac{1}{3} - \frac{1}{3}$	.0010	12
159.0002	$2\frac{1}{3} + \frac{1}{3}$	.0007	10
160.	$\frac{5}{25}$		
161.0016	$2\frac{1}{3} - \frac{1}{3}$	.0051	9
161.9982	$1\frac{1}{3} - \frac{2}{3}$	.0057	7
162.9996	$3\frac{1}{3} - \frac{2}{3}$	.0013	11
164.	$\frac{1}{3}$		
165.	$\frac{1}{3}$		
165.9989	$1\frac{1}{3} + \frac{1}{3}$	.0035	7
166.9995	$2\frac{1}{3} + \frac{1}{3}$	.0015	9
168.	$\frac{5}{21}$		
169.0005	$2\frac{1}{3} - \frac{1}{3}$	.0016	9
170.	$\frac{1}{3}$		
170.9997	$2\frac{1}{3} - \frac{1}{3}$	.0008	7
172.	$\frac{1}{3}$		
173.0003	$1\frac{1}{3} + \frac{1}{3}$	.0011	6

Compound Index Movements on the No. 1 Universal Milling Machine. (Absolute and Approximate.)

NO. OF TEETH.	MOVES	ERROR ON DIAMETRAL PITCH.	TIMES AROUND.
174.	$\frac{11}{33} - \frac{2}{29}$		
174.9964	$\frac{1^8}{33} + \frac{4}{31}$	.0112	6
176.0024	$\frac{1^8}{49} + \frac{14}{43}$	.0075	7
176.9991	$\frac{2^4}{49} + \frac{19}{47}$	.0027	11
177.9995	$\frac{4^{11}}{49} - \frac{19}{47}$	.0014	17
179.0002	$\frac{2^4}{47} - \frac{13}{49}$	.0006	11
180.	$\frac{6}{27}$		
180.9996	$\frac{2^{12}}{49} + \frac{8}{43}$	.0012	11
182.	$\frac{3}{39} + \frac{7}{49}$		
183.0003	$\frac{2^8}{49} - \frac{4}{41}$	.0009	8
184.	$\frac{5}{23}$		
185.	$\frac{8}{37}$		
186.	$\frac{17}{31} - \frac{11}{33}$		
186.9982	$\frac{1^4}{49} + \frac{29}{47}$	.0056	8
188.	$\frac{10}{47}$		
189.0015	$\frac{2^6}{41} - \frac{15}{49}$	.0046	11
190.	$\frac{4}{19}$		
191.0015	$\frac{2^4}{49} - \frac{9}{47}$	.0046	10
191.9983	$\frac{2^4}{41} - \frac{4}{49}$	.0055	11
193.0007	$\frac{1^5}{37} - \frac{15}{49}$	.0021	4
193.9981	$\frac{2^{22}}{37} - \frac{16}{49}$	.0061	11
195.	$\frac{8}{39}$		
196.	$\frac{10}{49}$		
196.9996	$\frac{2^{16}}{49} - \frac{4}{43}$	.0013	11
198.	$\frac{3}{27} + \frac{3}{33}$		
199.0005	$\frac{2^{12}}{41} - \frac{4}{49}$	.0014	11
200.	$\frac{4}{26}$		
201.0003	$\frac{3^{10}}{49} - \frac{29}{47}$	.0011	13
201.9991	$\frac{4^6}{49} - \frac{31}{41}$	.0028	17
202.9979	$\frac{1^3}{39} + \frac{9}{49}$	.0065	9
203.9992	$\frac{2^3}{49} + \frac{20}{41}$	.0025	13
205.	$\frac{8}{41}$		
206.0007	$\frac{2^4}{39} + \frac{2}{49}$	.0023	15
206.9991	$\frac{3^8}{41} - \frac{24}{49}$	.0029	14
207.9980	$\frac{2^{16}}{49} - \frac{28}{47}$	.0063	9
208.9987	$\frac{8}{49} + \frac{9}{41}$	.0041	2
210.	$\frac{2}{21}$		
211.0013	$\frac{1^8}{39} + \frac{18}{49}$	.0039	1
211.9995	$\frac{3^8}{49} + \frac{4}{47}$	.0017	17
212.9990	$\frac{1^8}{39} + \frac{2}{49}$	.0033	8
214.0003	$\frac{3^9}{47} - \frac{19}{49}$	.0010	15

Compound Index Movements on the No. 1 Universal Milling Machine. (Absolute and Approximate.)

NO. OF TEETH.	MOVES.	ERROR ON DIAMETRAL PITCH.	TIMES AROUND.
215.	$\frac{8}{43}$		
216.	$\frac{5}{27}$		
217.0014	$2\frac{16}{49} + \frac{3}{43}$	.0044	13
217.9986	$1\frac{2}{49} - \frac{2}{49}$	.0042	7
218.9989	$3\frac{2}{43} - \frac{10}{49}$	.0034	19
220.	$\frac{6}{33}$		
220.9996	$1\frac{5}{47} - \frac{1}{49}$	.0013	6
222.0019	$2\frac{4}{43} - \frac{10}{49}$	.0060	11
222.9998	$3\frac{13}{49} - \frac{17}{43}$	.0005	16
223.9955	$2\frac{6}{23} + \frac{2}{33}$	.0143	13
225.	$\frac{5}{13} - \frac{2}{20}$		
225.9995	$2\frac{16}{49} - \frac{1}{39}$	.0014	13
226.9999	$3\frac{3}{43} + \frac{5}{49}$	.0005	18
228.0010	$2\frac{8}{41} - \frac{13}{49}$	.0032	11
229.0002	$2\frac{10}{41} - \frac{18}{49}$	.0007	12
230.	$\frac{4}{23}$		
231.	$2\frac{3}{11} + \frac{1}{33}$		
232.	$\frac{5}{29}$		
233.0007	$2\frac{6}{49} - \frac{11}{47}$	.0022	11
234.0022	$3\frac{6}{33} - \frac{8}{29}$	.0068	17
235.	$\frac{8}{47}$		
236.0007	$3\frac{9}{49} - \frac{13}{43}$	.0021	17
236.9998	$2\frac{12}{47} - \frac{3}{49}$	.0006	13
237.9992	$2\frac{14}{33} + \frac{3}{31}$	.0024	15
238.9997	$2\frac{15}{49} - \frac{20}{43}$	.0008	11
240.	$\frac{3}{13}$		
240.9997	$1\frac{23}{49} + \frac{1}{41}$	.0010	9
241.9996	$2\frac{23}{41} - \frac{4}{49}$	.0013	15
242.9997	$1\frac{29}{41} - \frac{3}{49}$	.0009	10
243.9986	$2\frac{10}{33} + \frac{15}{31}$	.0044	17
245.	$\frac{8}{49}$		
246.0012	$1\frac{6}{43} - \frac{16}{49}$	.0037	5
247.0002	$2\frac{15}{43} - \frac{4}{49}$	.0007	14
248.	$\frac{5}{31}$		
249.0002	$3\frac{4}{43} - \frac{2}{49}$	.0005	19
250.0027	$2\frac{9}{37} - \frac{8}{49}$	.0083	13

The following table is the result of Mr. Schneider's ingenious suggestion, that sometimes it is not necessary to use the compound indexing for obtaining each division of the work, but that it is often sufficient to use the method once in going around the work twice or twice in going around three times, etc. For example: 96 divisions may be obtained by indexing for 48 and going completely around the work in the ordinary way, then dividing one of the spaces in equal parts, or obtaining one of the desired 96 divisions by the compound method ($\frac{3}{18} + \frac{5}{20}$), and finally by again going around the work, indexing as at first for 48 divisions.

Compound Index Movements for No. 1 Universal Milling Machine. (Schneider's Method.)

NUMBER OF TEETH.	SET FOR	TIMES AROUND.	ORDINARY MOVES.	COMPOUND MOVES.	NUMBER OF COMPOUND MOVES.
69	23	3	$1\frac{17}{23}$	$2\frac{1}{23} - \frac{11}{33}$	2
87	29	3	$1\frac{11}{29}$	$2\frac{3}{29} - \frac{11}{33}$	2
91	13	7	$3\frac{3}{39}$	$3\frac{6}{39} + \frac{14}{49}$	6
93	31	3	$1\frac{9}{31}$	$3\frac{1}{31} + \frac{11}{33}$	2
96	48	2	$1\frac{5}{48}$	$1\frac{3}{48} + \frac{5}{20}$	2
138	46	3	$2\frac{3}{46}$	$3\frac{11}{46} - \frac{1}{23}$	2
174	58	3	$2\frac{20}{58}$	$3\frac{11}{58} - \frac{3}{29}$	2
182	26	7	$1\frac{13}{26}$	$3\frac{3}{26} + \frac{7}{49}$	6
186	62	3	$2\frac{20}{62}$	$3\frac{17}{62} - \frac{11}{33}$	2
225	45	5	$2\frac{4}{45}$	$5\frac{18}{45} - \frac{2}{20}$	4
231	21	11	$1\frac{19}{21}$	$2\frac{1}{21} + \frac{1}{33}$	10
233	23	11	$1\frac{17}{23}$	$2\frac{12}{23} - \frac{12}{33}$	10
259	37	7	$1\frac{3}{37}$	$1\frac{11}{37} - \frac{7}{49}$	6
272	136	2	$1\frac{5}{136}$	$1\frac{10}{136} - \frac{6}{17}$	2
273	39	7	$1\frac{1}{39}$	$4\frac{21}{39} - \frac{11}{39}$	6
276	92	3	$1\frac{0}{92}$	$2\frac{11}{23} - \frac{11}{33}$	2
287	41	7	$4\frac{0}{41}$	$1\frac{14}{41} - \frac{6}{41}$	6
288	144	2	$1\frac{5}{144}$	$2\frac{0}{20} - \frac{2}{18}$	2
301	43	7	$1\frac{40}{43}$	$4\frac{18}{43} - \frac{14}{49}$	6
304	152	2	$1\frac{5}{152}$	$1\frac{10}{20} - \frac{1}{19}$	2

The foregoing tables were prepared with reference to the No. 1 Universal Milling Machine, as this machine is most frequently used for the operations requiring indexing mechanism. When however, the movements involve the use of the two outer circles of holes of the index plate, the figures given can be applied to the No. 3 Universal Milling Machine, the crank pin of this machine being used, at such times, in the outer circle of holes, and the back pin in the second circle.

The following table gives a number of movements of the No. 3 machine by the compound method.

Compound Index Movements on the No. 4 Universal Milling Machine.

NO. OF DIVISIONS.	MOVES.	NO. OF DIVISIONS.	MOVES.
57	$\frac{6}{18} + \frac{7}{18}$	217	$\frac{12}{21} - \frac{11}{11}$
93	$\frac{11}{33} + \frac{3}{31}$	228	$\frac{6}{18} - \frac{3}{18}$
114	$\frac{12}{18} - \frac{6}{18}$	282	$\frac{13}{18} - \frac{9}{17}$
141	$\frac{26}{39} - \frac{13}{47}$	285	$\frac{12}{18} - \frac{10}{18}$
171	$\frac{8}{18} - \frac{4}{19}$	304	$\frac{9}{18} - \frac{7}{18}$
186	$\frac{22}{38} - \frac{11}{31}$		

Adjustable
Back Pin.

In his articles upon compound indexing, Mr. Fred. J. Miller has shown how much the usefulness of an index plate is increased if the back pin of the mechanism is made adjustable, the same as the front pin, and Mr. Miller holds a patent on Index Centres, which is important in this connection. Applying this principle to our machines, if the back pin of the No. 3 were made so that it would engage in the outer circle of holes of the index plates, all the figures in the tables would apply to the No. 3, as well as the No. 1 Universal, and if the No. 1 had an adjustable back pin, the number of the attainable movements would be correspondingly increased. The following table is indicative of this.

COMPOUND INDEX MOVEMENTS.

Extra Divisions Obtained by Making the Back Pin Adjustable on No. 1 Universal Milling Machine.

NO. OF DIVISIONS.	MOVES.	NO. OF DIVISIONS.	MOVES.
51	$\frac{2}{17} + \frac{1}{18}$	204	$\frac{9}{17} - \frac{6}{18}$
57	$\frac{7}{18} + \frac{1}{19}$	207	$\frac{7}{23} - \frac{3}{27}$
63	$\frac{11}{21} + \frac{3}{27}$	217	$\frac{12}{21} - \frac{1}{31}$
102	$\frac{1}{17} + \frac{6}{18}$	222	$\frac{19}{37} - \frac{1}{39}$
111	$\frac{1}{37} + \frac{1}{38}$	228	$\frac{18}{38} - \frac{1}{39}$
114	$\frac{1}{18} - \frac{6}{19}$	246	$\frac{13}{38} - \frac{7}{41}$
123	$\frac{2}{39} - \frac{1}{41}$	252	$\frac{1}{21} + \frac{3}{27}$
126	$\frac{2}{21} + \frac{6}{27}$	255	$\frac{6}{18} - \frac{1}{17}$
129	$\frac{1}{39} - \frac{1}{43}$	258	$\frac{21}{43} - \frac{1}{39}$
141	$\frac{2}{39} - \frac{1}{47}$	261	$\frac{6}{27} - \frac{2}{29}$
153	$\frac{1}{17} - \frac{8}{18}$	279	$\frac{2}{27} + \frac{1}{31}$
161	$\frac{9}{23} - \frac{3}{21}$	282	$\frac{13}{38} - \frac{9}{47}$
171	$\frac{8}{18} - \frac{4}{19}$	285	$\frac{9}{19} - \frac{6}{18}$
189	$\frac{6}{21} - \frac{2}{27}$	306	$\frac{6}{17} - \frac{4}{18}$
192	$\frac{6}{18} - \frac{3}{18}$	...	

Mr. Miller has given a great deal of attention to the results obtained by the use of two adjustable pins in connection with an index plate, and his tables are interesting and, in many instances, would be of great value. We do not reproduce them, however, as none happen to be applicable to the index plates regularly furnished with the machines.

USE OF MILLING MACHINES—CONTINUED.

CUTTING SPIRALS WITH UNIVERSAL MILLING MACHINES.

The indexing head stock or spiral head, as indicated Selection of Change Gears. in connection with the descriptions of the Universal Milling Machines, is used for cutting spirals, the flutes of twist drills, for example, as well as for indexing or dividing. A positive rotary movement is given to the work while the spiral bed is being moved lengthways by the feed screw, and the velocity ratios of these movements are regulated by four change gears, shown in position in Fig. 8, and known as the gear on worm or worm gear, first gear on stud, second gear on stud and gear on screw or screw gear. The screw gear and first gear on stud are the drivers and the others the driven gears. Usually these gears are of such ratio that the work is advanced more than an inch while making one turn and thus the spirals, cut on Milling Machines, are designated in terms of inches to one turn, rather than turns, or threads per inch; for instance a spiral is said to be of 8 inches lead, not that its pitch is $\frac{1}{8}$ turn per inch.

The feed screw of the spiral bed has four threads to the inch, and forty turns of the worm make one turn of the spiral head spindle; accordingly, if change gears of equal diameter are used, the work will make a complete turn while it is moved lengthways 10 inches; that is, the spiral will have a lead of 10 inches. But this lead is practically the lead of the machine, as it is the resultant of the action of the parts of the machine that are always employed in this work, and it is so regarded in making the calculations used in cutting spirals.

Principle
same as for
Change
Gears of a
Lathe.

In principle, these calculations are the same as for change gears of a Screw Cutting Lathe. The compound ratio of the driven to the driving gears equals in all cases, the ratio of the lead of the required spiral to the lead of the machine. And this can be readily understood by changing the diameters of the gears.

Gears of the same diameter produce, as explained above, a spiral with a lead of 10 inches, which is the same lead as the lead of the machine. Three gears of equal diameter and a driven gear double this diameter produce a spiral with a lead of 20 inches, or twice the lead of the machine; and with both driven gears twice the diameters of the drivers, the ratio being compound, a spiral is produced with a lead of 40 inches or four times the machine's lead. Conversely, driving gears twice the diameter of the driven, produce a spiral with a lead equal to $\frac{1}{4}$ the lead of the machine or $2\frac{1}{2}$ inches.

Expressing the ratios as fractions, $\frac{\text{Driven Gears}}{\text{Driving Gears}} = \frac{\text{Lead of Required Spiral}}{\text{Lead of Machine}}$ or as the product of each class of gears determines the ratio, the head being double geared, and as the lead of the machine is ten inches $\frac{\text{Product of Driven Gears}}{\text{Product of Driving Gears}} = \frac{\text{Lead of Required Spiral}}{10}$. That is, the compound ratio of the Driven to the Driving Gears may always be represented by a fraction whose numerator is the lead to be cut and whose denominator is ten. Or, in other words, the ratio is as the required lead is to 10, that is, if the required lead is 20 the ratio is 20 : 10; or to express this in units instead of tens, the ratio is always the same as one tenth of the required lead is to one. And frequently this is a very convenient way to think of the ratio; for example, if the ratio of the lead is 40, the gears are 4 : 1. If the lead is 25, the gears are 2.5 : 1, etc.

To illustrate the usual calculations, assume as in Fig. 8 that a spiral of 12 inch lead is to be cut. The compound ratio of the driven to the driving gears equals the desired lead divided by 10, or it may be represented by the fraction $\frac{12}{10}$. Resolving this into two factors to

represent the two pairs of change gears, $1\frac{2}{3} = \frac{2}{3} \times \frac{4}{1}$. Both terms of the first factor are multiplied by such a number (24 in this instance) that the resulting numerator and denominator will correspond with the number of teeth of two of the change gears furnished with the machine, (such multiplications not affecting the value of a fraction) $\frac{2}{3} \times \frac{24}{1} = \frac{48}{1}$. The second factor is similarly treated $\frac{4}{1} \times \frac{3}{8} = \frac{12}{8}$, and the gears with 72 and 32 and 48 and 40 teeth are selected, $1\frac{2}{3} = (\frac{72 \times 82}{48 \times 40})$. The first two are the driven and the last two the drivers, the numerators of the fractions having represented the driven gears, and the 72 is placed as the worm gear, the 40 as the first on stud, 32 the second on stud and 48 as the screw gear. The two driving gears might be transposed and the two driven gears might also be transposed without changing the spiral. That is, the 72 could be used as the second on stud and the 32 as the worm gear, if such an arrangement was more convenient.

From what has been said, the rules are plain :

Note the ratio of the required lead to ten. This ratio is the compound ratio of the driven to the driving gears. Example: if the lead of required spiral is 12 inches, 12 to 10 will be the ratio of the gears.

Rules for
obtaining
Ratio of
the Gears
necessary
to Cut a
Given
Spiral

Or, divide the required lead by 10 and note the ratio between the quotient and 1. This ratio is usually the most simple form of the compound ratio of the driven to the driving gears. Example: if the required lead is 40 inches, the quotient $40 \div 10$ is 4 and the ratio 4 to 1.

Having obtained the ratio between the required lead and ten by one of the preceding rules, express the ratio in the form of a fraction; resolve this fraction into two factors, raise these factors to higher terms that correspond with the teeth of gears that can be conveniently used. The numerators will represent the driven and the denominators the driving gears that produce the required spiral. For example, what gears shall be used to cut a lead of 27 inches?

Rule for
Determin-
ing Num-
ber of
Teeth of
Gears re-
quired to
Cut a
Given
Spiral.

$$\frac{27}{10} = \frac{2}{3} \times \frac{3}{5} = (\frac{1}{3} \times \frac{16}{5}) \times (\frac{9 \times 8}{3 \times 8}) = \frac{48 \times 72}{32 \times 40}$$

From the fact that the product of the driven gears divided by the product of the drivers equals the lead divided by ten, or one-tenth of the lead, it is evident that ten times the product of the driven gears divided by the product of the drivers will equal the lead of the spiral. Hence the rule :

Rule for
Ascertain-
ing what
Spiral
may be
cut by any
given
Change
Gears.

Divide ten times the product of the driven gears by the product of the drivers and the quotient is the lead of the resulting spiral in inches to one turn. For example, what spiral will be cut by gears with 48, 72, 32 and 40 teeth, the first two being used as driven gears? Spiral to be cut equals $\frac{10 \times 48 \times 72}{32 \times 40} = 27$ inches to one turn.

This rule is often of service in determining what spirals may be cut with the gears the workman chances to have at hand.

The tables on pages 151 to 154 give the leads of spirals produced by the gears furnished with the machines.

The chapter on "Continued Fractions" in our Practical Treatise on Gearing is of assistance in selecting gears for fractional spirals.

Position of
the Spiral
Bed in
Cutting
Spirals.

The change gears having been selected, the next step in cutting spirals is to determine the position at which the spiral bed must be placed to bring the spiral in line with the cutter as the work is being milled, for, if the spiral is not in line with the cutter the groove will not be cut to the shape of the cutter.

The correct position of the spiral bed is indicated by the angle shown at "A," Fig. 89, and this angle, as may be noted from that figure, has the same number of degrees as the angle "B," which is termed the angle of the spiral, and is formed by the intersection of the spiral and a line parallel with the axis of the piece being milled. The reason the angles "A" and "B" are alike is that their corresponding sides are perpendicular to each other.

The size of the angle of the spiral depends upon the lead of the spiral and the diameter of the piece to be

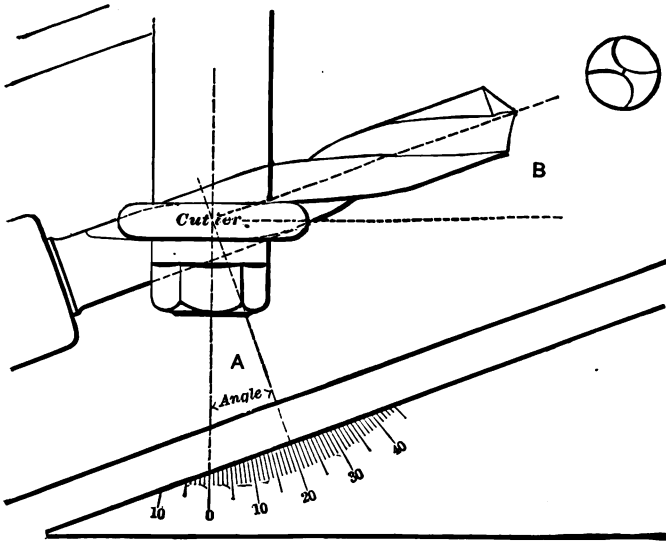


FIG. 89

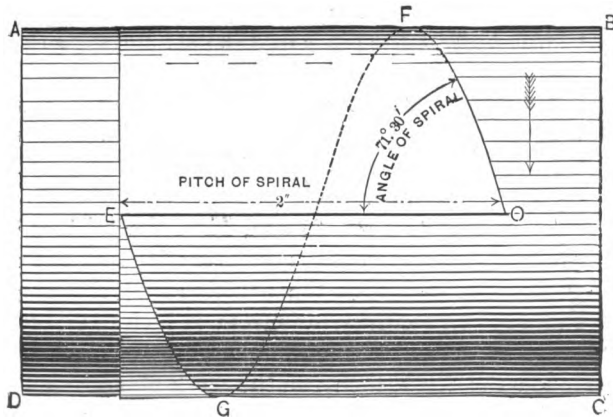


FIG. 90.

milled. The greater the lead of a spiral of any given diameter, the smaller the angle, and the greater the diameter of any spiral the greater the spiral angle.

The angle may be ascertained in two ways, graphically, or more conveniently by a simple calculation and reference to the accompanying tables. In determining it graphically, a right angle triangle is drawn to scale. One of the sides which forms the right angle represents the lead of the spiral in inches; the other side represents the circumference of the piece in inches, and the hypotenuse represents the line of the spiral. The angle between the lines representing the line of the spiral and the lead of the spiral is the angle of the spiral. This angle can be transferred from the drawing to the work by a bevel protractor, or even by cutting a paper templet and winding it about the work as shown in Fig. 90. The machine is then set so that the spiral or groove as it touches the cutter will be in line with the cutter. Or the angle may be measured and the spiral bed set to a corresponding number of degrees by the graduations on the clamp bed.

The natural tangent of the angle of the spiral is the quotient of the circumference of the piece divided by the lead of the spiral. Accordingly, the second method of obtaining the angle of the spiral is to divide the circumference of the piece by the lead and note the number of degrees opposite the figures that correspond with the quotient in the accompanying tables of natural tangents, pages 155 and 156. The angle having been thus obtained, the spiral bed is set by the graduations on the clamp bed.

Tables, pages 151 to 154, give the lead of spirals produced by the various combinations of the change gears furnished with the machine and the angles of these spirals for diameters from $\frac{3}{8}$ inch to 4 inches.

Use of
Machines
in Cutting
Spirals.

Before a spiral is cut, it is well to let the mill just touch the work, then run the work along by hand and make a slight spiral mark, and by this mark see whether the change gears give the right lead. The saddle can then be set to the proper angle.

TABLE OF CHANGE GEARS, SPIRALS AND ANGLES.

Pitch in Inches to one turn.				DIAMETER OF THE BLANK, OR SPIRAL, TO BE CUT.																	
Gear on Worm.	First Gear on Stud.	Second Gear on Stud.	Gear on Screw.	1/8"	1/4"	3/8"	1/2"	5/8"	3/4"	7/8"	1"	1 1/4"	1 1/2"	2"	2 1/4"	2 1/2"	3"	3 1/4"	3 1/2"	3 3/4"	4"
24 86 24 100				30 1/2																	
24 86 28 100				26	44 1/2																
24 86 32 100				23 1/2	41																
24 86 40 100				19	34 1/2																
24 86 48 100				16	30 1/2	41 1/2															
24 64 28 72				14 1/2	28	38 1/2															
24 86 56 100				13 1/2	26 1/2	37															
24 64 32 72				12 1/2	25	34 1/2	43 1/2														
32 64 28 72				11 1/2	21 3/4	31	39	45													
24 64 40 72				10 1/2	20 1/2	29 1/2	37	43 1/2													
32 56 28 72				9 1/2	19 1/2	27 1/2	35	41 1/2													
24 64 48 72				8 3/4	17	25	32	38	43 1/2												
40 56 28 72				8	15 1/2	23	29 1/2	35 1/2	40 1/2	44 1/2											
24 64 56 72				7 1/2	15	21 1/4	28 1/4	34	39	43 1/2											

ANGLE FOR SETTING THE SADDLE.

TO FIND THE ANGLE OF SPIRAL, DIVIDE THE CIRCUMFERENCE BY THE PITCH OR LEAD, AND THE QUOTIENT WILL BE THE TANGENT OF THE ANGLE. THEN FIND THE ANGLE IN A TABLE OF TANGENTS. FOR COMPLETE EXPLANATION SEE PRACTICAL TREATISE ON GEARING.

TABLE OF CHANGE GEARS, SPIRALS AND ANGLES.

DIAMETER OF THE BLANK, OR SPIRAL, TO BE CUT.					ANGLE FOR SETTING THE SADDLE.															
Gear on Worm.	First Gear on Stud.	Second Gear on Stud.	Gear on Screw.	Pitch in inches to one turn.	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"
					1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"
64	48	40	56	9.52	21°	41°	7°	91°	111°	133°	16°	181°	221°	261°	30°	331°	361°	391°	421°	45°
72	40	32	56	10.29	2	41°	61°	81°	101°	121°	15	171°	211°	241°	281°	311°	341°	371°	401°	421°
64	48	56	72	10.37	2	41°	61°	81°	101°	121°	141°	161°	201°	241°	28	311°	341°	371°	401°	421°
48	40	56	64	10.50	2	41°	61°	81°	101°	121°	141°	161°	201°	241°	271°	311°	341°	371°	401°	421°
64	40	48	72	10.67	2	41°	61°	81°	101°	121°	141°	161°	201°	241°	271°	301°	331°	361°	391°	421°
56	32	40	64	10.94	2	41°	61°	81°	101°	121°	141°	161°	201°	231°	261°	301°	331°	361°	391°	421°
64	32	40	72	11.11	2	41°	61°	81°	101°	121°	141°	161°	201°	231°	261°	301°	331°	361°	391°	421°
56	32	48	72	11.66	1	31°	51°	71°	91°	111°	131°	151°	181°	221°	251°	281°	311°	341°	371°	401°
72	40	32	48	12.00	1	31°	51°	71°	91°	111°	121°	151°	181°	211°	241°	271°	301°	331°	361°	391°
56	32	48	64	13.12	1	31°	51°	61°	81°	101°	111°	131°	161°	201°	221°	251°	281°	311°	341°	371°
56	28	48	72	13.33	1	31°	51°	61°	81°	101°	111°	131°	161°	191°	221°	251°	281°	311°	341°	371°
64	40	48	56	13.71	1	31°	41°	51°	61°	71°	81°	91°	101°	111°	121°	131°	141°	151°	161°	171°
64	28	48	56	15.24	1	31°	41°	51°	61°	71°	81°	91°	101°	111°	121°	131°	141°	151°	161°	171°
64	32	56	72	15.56	1	31°	41°	51°	61°	71°	81°	91°	101°	111°	121°	131°	141°	151°	161°	171°
56	64	72	40	15.75	1	21°	41°	51°	61°	71°	81°	91°	101°	111°	121°	131°	141°	151°	161°	171°
72	32	48	64	16.87	1	21°	41°	51°	61°	71°	81°	91°	101°	111°	121°	131°	141°	151°	161°	171°
64	32	48	56	17.14	1	21°	41°	51°	61°	71°	81°	91°	101°	111°	121°	131°	141°	151°	161°	171°
72	32	40	48	18.75	1	21°	31°	41°	51°	61°	71°	81°	91°	101°	111°	121°	131°	141°	151°	161°

TABLE OF CHANGE GEARS, SPIRALS AND ANGLES.

DIAMETER OF THE BLANK, OR SPIRAL, TO BE CUT.																									
Pitch in inches to one turn.				1"	1 1/2"	1"	1 1/4"	1 1/2"	1 3/4"	2"	2 1/4"	2 1/2"	2 3/4"	3"	3 1/4"	3 1/2"	3 3/4"	4"							
Gear on Worm.	First Gear on Stud.	Second Gear on Stud.	Gear on Screw.	1°	2 1/4	3 1/4	4 1/4	5 1/4	5 3/4	7°	8°	9 1/4	11 1/4	13 1/4	16°	18 1/4	20 1/4	22 1/4	24°	26°	28°	29 1/4	31 1/4	32 1/4	33°
72 32 48 56	64 28 48 56	72 32 48 56	19.29	1°	2 1/4	3 1/4	4 1/4	5 1/4	5 3/4	7°	8°	9 1/4	11 1/4	13 1/4	16°	18 1/4	20 1/4	22 1/4	24°	26°	28°	29 1/4	31 1/4	32 1/4	33°
64 28 48 56	72 32 48 56	64 28 48 56	19.59	1°	2 1/4	3 1/4	4 1/4	5 1/4	5 3/4	7°	8°	9 1/4	11 1/4	13 1/4	16°	18 1/4	20 1/4	22 1/4	24°	26°	28°	29 1/4	31 1/4	32 1/4	33°
72 32 56 64	72 32 56 64	72 32 56 64	19.69	1°	2 1/4	3 1/4	4 1/4	5 1/4	5 3/4	7°	8°	9 1/4	11 1/4	13 1/4	16°	18 1/4	20 1/4	22 1/4	24°	26°	28°	29 1/4	31 1/4	32 1/4	33°
72 24 40 56	72 24 40 56	72 24 40 56	21.43	1°	2	3 1/4	4 1/4	5	5 3/4	7 1/2	8 1/2	10 1/2	12 1/2	14 1/2	16 1/2	18 1/2	20 1/2	22 1/2	24 1/2	26 1/2	28 1/2	29 1/2	30 1/2	31 1/2	32 1/2
72 28 56 64	72 28 56 64	72 28 56 64	22.50	1°	2	3	4 1/4	5	5 3/4	7 1/2	8 1/2	10 1/2	12 1/2	14 1/2	16 1/2	18 1/2	20 1/2	22 1/2	24 1/2	26 1/2	28 1/2	29 1/2	30 1/2	31 1/2	32 1/2
64 32 56 48	64 32 56 48	64 32 56 48	23.33	1°	2	3	4	5	5 3/4	7 1/2	8 1/2	10 1/2	12 1/2	14 1/2	16 1/2	18 1/2	20 1/2	22 1/2	24 1/2	26 1/2	28 1/2	29 1/2	30 1/2	31 1/2	32 1/2
72 24 56 64	72 24 56 64	72 24 56 64	26.25	1°	1 3/4	2 1/4	3 1/4	4 1/4	5 1/4	6 1/4	7 1/4	8 3/4	10 1/4	12 1/4	14 1/4	16 1/4	18 1/4	20 1/4	22 1/4	24 1/4	26 1/4	28 1/4	29 3/4	31 1/4	32 1/4
64 28 56 48	64 28 56 48	64 28 56 48	26.67	1°	1 3/4	2 1/4	3 1/4	4 1/4	5 1/4	6 1/4	7 1/4	8 3/4	10 1/4	12 1/4	14 1/4	16 1/4	18 1/4	20 1/4	22 1/4	24 1/4	26 1/4	28 1/4	29 3/4	31 1/4	32 1/4
64 32 56 40	64 32 56 40	64 32 56 40	28.00	1°	1 3/4	2 1/4	3 1/4	4 1/4	5 1/4	6 1/4	7 1/4	8 3/4	10 1/4	12 1/4	14 1/4	16 1/4	18 1/4	20 1/4	22 1/4	24 1/4	26 1/4	28 1/4	29 3/4	31 1/4	32 1/4
72 28 48 40	72 28 48 40	72 28 48 40	30.86	1°	1 3/4	2 1/4	3 1/4	4 1/4	5 1/4	6 1/4	7 1/4	8 3/4	10 1/4	12 1/4	14 1/4	16 1/4	18 1/4	20 1/4	22 1/4	24 1/4	26 1/4	28 1/4	29 3/4	31 1/4	32 1/4
72 32 56 40	72 32 56 40	72 32 56 40	31.50	1°	1 3/4	2 1/4	3 1/4	4 1/4	5 1/4	6 1/4	7 1/4	8 3/4	10 1/4	12 1/4	14 1/4	16 1/4	18 1/4	20 1/4	22 1/4	24 1/4	26 1/4	28 1/4	29 3/4	31 1/4	32 1/4
72 32 64 40	72 32 64 40	72 32 64 40	36.00	1°	1 1/2	2 1/2	3 1/2	4 1/2	5 1/2	6 1/2	7 1/2	8 1/2	9 1/2	10 1/2	11 1/2	12 1/2	13 1/2	14 1/2	15 1/2	16 1/2	17 1/2	18 1/2	19 1/2	20 1/2	21 1/2
72 28 64 40	72 28 64 40	72 28 64 40	41.14	1°	1 1/2	2 1/2	3 1/2	4 1/2	5 1/2	6 1/2	7 1/2	8 1/2	9 1/2	10 1/2	11 1/2	12 1/2	13 1/2	14 1/2	15 1/2	16 1/2	17 1/2	18 1/2	19 1/2	20 1/2	21 1/2
72 28 56 32	72 28 56 32	72 28 56 32	45.00	1°	1 1/2	2 1/2	3 1/2	4 1/2	5 1/2	6 1/2	7 1/2	8 1/2	9 1/2	10 1/2	11 1/2	12 1/2	13 1/2	14 1/2	15 1/2	16 1/2	17 1/2	18 1/2	19 1/2	20 1/2	21 1/2
72 24 64 40	72 24 64 40	72 24 64 40	48.00	1°	1 1/2	2 1/2	3 1/2	4 1/2	5 1/2	6 1/2	7 1/2	8 1/2	9 1/2	10 1/2	11 1/2	12 1/2	13 1/2	14 1/2	15 1/2	16 1/2	17 1/2	18 1/2	19 1/2	20 1/2	21 1/2
72 28 64 32	72 28 64 32	72 28 64 32	51.43	1°	1 1/2	2 1/2	3 1/2	4 1/2	5 1/2	6 1/2	7 1/2	8 1/2	9 1/2	10 1/2	11 1/2	12 1/2	13 1/2	14 1/2	15 1/2	16 1/2	17 1/2	18 1/2	19 1/2	20 1/2	21 1/2
72 24 64 32	72 24 64 32	72 24 64 32	60.00	1°	1 1/2	2 1/2	3 1/2	4 1/2	5 1/2	6 1/2	7 1/2	8 1/2	9 1/2	10 1/2	11 1/2	12 1/2	13 1/2	14 1/2	15 1/2	16 1/2	17 1/2	18 1/2	19 1/2	20 1/2	21 1/2
72 24 64 28	72 24 64 28	72 24 64 28	68.57	1°	1 1/4	2 1/4	3 1/4	4 1/4	5 1/4	6 1/4	7 1/4	8 3/4	10 1/4	12 1/4	14 1/4	16 1/4	18 1/4	20 1/4	22 1/4	24 1/4	26 1/4	28 1/4	29 3/4	31 1/4	32 1/4

ANGLE FOR SETTING THE SADDLE.

NATURAL TANGENT.

Deg.	0'	10'	20'	30'	40'	50'	60'	
0	.00000	.00290	.00581	.00872	.01163	.01454	.01745	89
1	.01745	.02036	.02327	.02618	.02909	.03200	.03492	88
2	.03492	.03783	.04074	.04366	.04657	.04949	.05240	87
3	.05240	.05532	.05824	.06116	.06408	.06700	.06992	86
4	.06992	.07285	.07577	.07870	.08162	.08455	.08748	85
5	.08748	.09042	.09335	.09628	.09922	.10216	.10510	84
6	.10510	.10804	.11099	.11393	.11688	.11983	.12278	83
7	.12278	.12573	.12869	.13165	.13461	.13757	.14054	82
8	.14054	.14350	.14647	.14945	.15242	.15540	.15838	81
9	.15838	.16136	.16435	.16734	.17033	.17332	.17632	80
10	.17632	.17932	.18233	.18533	.18834	.19136	.19438	79
11	.19438	.19740	.20042	.20345	.20648	.20951	.21255	78
12	.21255	.21559	.21864	.22169	.22474	.22780	.23086	77
13	.23086	.23393	.23700	.24007	.24315	.24624	.24932	76
14	.24932	.25242	.25551	.25861	.26172	.26483	.26794	75
15	.26794	.27106	.27419	.27732	.28046	.28360	.28674	74
16	.28674	.28989	.29305	.29621	.29938	.30255	.30573	73
17	.30573	.30891	.31210	.31529	.31850	.32170	.32492	72
18	.32492	.32813	.33136	.33459	.33783	.34107	.34432	71
19	.34432	.34758	.35084	.35411	.35739	.36067	.36397	70
20	.36397	.36726	.37057	.37388	.37720	.38053	.38386	69
21	.38386	.38720	.39055	.39391	.39727	.40064	.40402	68
22	.40402	.40741	.41080	.41421	.41762	.42104	.42447	67
23	.42447	.42791	.43135	.43481	.43827	.44174	.44522	66
24	.44522	.44871	.45221	.45572	.45924	.46277	.46630	65
25	.46630	.46985	.47341	.47697	.48055	.48413	.48773	64
26	.48773	.49133	.49495	.49858	.50221	.50586	.50952	63
27	.50952	.51319	.51687	.52056	.52427	.52798	.53170	62
28	.53170	.53544	.53919	.54295	.54672	.55051	.55430	61
29	.55430	.55811	.56193	.56577	.56961	.57347	.57735	60
30	.57735	.58123	.58513	.58904	.59297	.59690	.60086	59
31	.60086	.60482	.60880	.61280	.61680	.62083	.62486	58
32	.62486	.62892	.63298	.63707	.64116	.64528	.64940	57
33	.64940	.65355	.65771	.66188	.66607	.67023	.67450	56
34	.67450	.67874	.68300	.68728	.69157	.69583	.70020	55
35	.70020	.70455	.70891	.71329	.71769	.72210	.72654	54
36	.72654	.73099	.73546	.73996	.74447	.74900	.75355	53
37	.75355	.75812	.76271	.76732	.77195	.77661	.78128	52
38	.78128	.78598	.79069	.79543	.80019	.80497	.80978	51
39	.80978	.81461	.81946	.82433	.82923	.83415	.83910	50
40	.83910	.84406	.84906	.85408	.85912	.86419	.86928	49
41	.86928	.87440	.87955	.88472	.88992	.89515	.90040	48
42	.90040	.90568	.91099	.91633	.92169	.92708	.93251	47
43	.93251	.93796	.94345	.94896	.95450	.96008	.96568	46
44	.96568	.97132	.97699	.98269	.98843	.99419	1.0000	45
	60'	50'	40'	30	20'	10'	0'	Deg.

NATURAL COTANGENT.

NATURAL TANGENT.

Deg.	0'	10'	20'	30'	40'	50'	60'	
45	1.0000	1.0053	1.0117	1.0176	1.0235	1.0295	1.0355	44
46	1.0355	1.0415	1.0476	1.0537	1.0599	1.0661	1.0723	43
47	1.0723	1.0786	1.0849	1.0913	1.0977	1.1041	1.1106	42
48	1.1106	1.1171	1.1236	1.1302	1.1369	1.1436	1.1508	41
49	1.1503	1.1571	1.1639	1.1708	1.1777	1.1847	1.1917	40
50	1.1917	1.1988	1.2059	1.2131	1.2203	1.2275	1.2349	39
51	1.2349	1.2423	1.2496	1.2571	1.2647	1.2723	1.2799	38
52	1.2799	1.2876	1.2954	1.3032	1.3111	1.3190	1.3270	37
53	1.3270	1.3351	1.3432	1.3514	1.3596	1.3680	1.3763	36
54	1.3763	1.3848	1.3933	1.4019	1.4106	1.4193	1.4281	35
55	1.4281	1.4370	1.4453	1.4550	1.4641	1.4733	1.4825	34
56	1.4825	1.4919	1.5013	1.5108	1.5204	1.5301	1.5398	33
57	1.5398	1.5497	1.5596	1.5696	1.5798	1.5900	1.6003	32
58	1.6003	1.6107	1.6212	1.6318	1.6425	1.6533	1.6642	31
59	1.6642	1.6753	1.6864	1.6976	1.7090	1.7204	1.7320	30
60	1.7320	1.7437	1.7553	1.7674	1.7793	1.7917	1.8040	29
61	1.8040	1.8164	1.8290	1.8417	1.8546	1.8676	1.8807	28
62	1.8807	1.8940	1.9074	1.9209	1.9347	1.9485	1.9626	27
63	1.9626	1.9768	1.9911	2.0056	2.0203	2.0352	2.0503	26
64	2.0503	2.0655	2.0809	2.0965	2.1123	2.1283	2.1445	25
65	2.1445	2.1609	2.1774	2.1943	2.2118	2.2285	2.2460	24
66	2.2460	2.2637	2.2816	2.2998	2.3183	2.3369	2.3558	23
67	2.3558	2.3750	2.3944	2.4142	2.4342	2.4545	2.4750	22
68	2.4750	2.4959	2.5171	2.5386	2.5604	2.5826	2.6050	21
69	2.6050	2.6279	2.6510	2.6746	2.6985	2.7228	2.7474	20
70	2.7474	2.7725	2.7980	2.8239	2.8502	2.8770	2.9042	19
71	2.9042	2.9318	2.9600	2.9886	3.0178	3.0474	3.0776	18
72	3.0776	3.1084	3.1397	3.1715	3.2040	3.2371	3.2708	17
73	3.2708	3.3052	3.3402	3.3759	3.4123	3.4495	3.4874	16
74	3.4874	3.5260	3.5655	3.6058	3.6470	3.6890	3.7320	15
75	3.7320	3.7759	3.8203	3.8667	3.9136	3.9616	4.0107	14
76	4.0107	4.0610	4.1125	4.1653	4.2193	4.2747	4.3314	13
77	4.3314	4.3896	4.4494	4.5107	4.5736	4.6382	4.7046	12
78	4.7046	4.7728	4.8430	4.9151	4.9894	5.0659	5.1445	11
79	5.1445	5.2256	5.3092	5.3955	5.4845	5.5763	5.6712	10
80	5.6712	5.7693	5.8708	5.9757	6.0844	6.1970	6.3137	9
81	6.3137	6.4348	6.5605	6.6911	6.8269	6.9682	7.1153	8
82	7.1153	7.2687	7.4287	7.5957	7.7708	7.9530	8.1443	7
83	8.1443	8.3449	8.5555	8.7768	9.0098	9.2553	9.5143	6
84	9.5143	9.7881	10.078	10.385	10.711	11.059	11.430	5
85	11.430	11.826	12.250	12.706	13.196	13.726	14.300	4
86	14.300	14.924	15.604	16.349	17.169	18.075	19.081	3
87	19.081	20.205	21.470	22.904	24.541	26.431	28.636	2
88	28.636	31.241	34.367	38.188	42.964	49.103	57.290	1
89	57.290	68.750	85.939	114.58	171.88	343.77	∞	0
	60'	50'	40'	30'	20'	10'	0'	Deg.

NATURAL COTANGENT.

Special care should be taken in cutting spirals that the work does not slip and when a cut is made, it is well to drop the work away from the mill while coming back for another cut, or the mill may be stopped and turned to such a position that the teeth will not touch the work while the spiral bed is brought back preparatory to another cut.

Among the spirals most commonly cut on Milling Machines are worms, spiral gears, spiral mills, counter-bores and twist drills.

In making such cuts as are alike on both sides, for instance, the threads of worms or the teeth of spiral gears, care must be taken to set the work centrally perpendicular with the centre line of the cutter before swinging the spiral bed to the angle of the spiral. Worms

Cuts that have one face radial are best made with an angular cutter, as shown in Fig. 34, for cutters of this form readily clear the radial face of the cut, and so keep sharp longer and produce a smoother surface than when the radial face is cut in a vertical plane with a cutter like Fig. 29, where the teeth can have no side clearance from the work. The setting for these cuts must also be made before swinging the spiral bed to the angle of the spiral. Milling
Cutters
etc.

By setting the cutter, Fig. 35, so that the distance "a" is one tenth the diameter B, the face cut by the 12 degree side of the cutter will be nearly radial for teeth of milling cutters of the usual proportions.

The operation of forming a twist drill is shown in Fig. 89. The drill is held in a collet or chuck, and, if very long, is allowed to pass through the spindle of the spiral head. The cutter is placed on the arbor so that it will be directly over the centre of the drill, and the bed is set at the angle of spiral, as given in the following table : Twist
Drills

TABLE OF CUTTERS, PITCHES, GEARS AND ANGLES FOR
TWIST DRILLS.

Diameter of Drill.	Thickness of Cutter.	Pitch in Inches.	Gear on Worm.	First Gear on Stud.	Second Gear on Stud.	Gear on Screw.	Angle of Spiral.
$\frac{1}{16}$	.06	.67	24	86	24	100	16° 20'
$\frac{1}{8}$	.08	1.12	24	86	40	100	19° 20'
$\frac{3}{16}$	.11	1.67	24	64	32	72	19° 25'
$\frac{1}{4}$	.15	1.94	32	64	28	72	21°
$\frac{5}{16}$	.19	2.92	24	64	56	72	20°
$\frac{3}{8}$	.23	3.24	40	48	28	72	21°
$\frac{7}{16}$	.27	3.89	56	48	24	72	20° 10'
$\frac{1}{2}$	.31	4.17	40	72	48	64	20° 30'
$\frac{9}{16}$	.35	4.86	40	64	56	72	20°
$\frac{5}{8}$	.39	5.33	48	40	32	72	20° 12'
$\frac{11}{16}$	.44	6.12	56	40	28	64	19° 30'
$\frac{3}{4}$	.50	6.48	56	48	40	72	20°
$\frac{7}{8}$	.56	7.29	56	48	40	64	19° 20'
$\frac{15}{16}$	.62	7.62	64	48	32	56	19° 50'
1	.70	8.33	48	32	40	72	19° 30'
$\frac{11}{8}$	.77	8.95	86	48	28	56	19° 20'
$\frac{13}{8}$	.85	9.33	56	40	48	72	20° 40'

The depth of groove in twist drill diminishes as it approaches the shank, in order to obtain increased strength at the place where the drill is otherwise generally broken. The variation in depth is conditional; depending mainly on the strength it is desirable to obtain, or the usage the drill is subject to, as in different classes of work. To secure variation in the depth of the groove, the spiral head spindle is elevated slightly; depending, in this case, on the length of flute, for which, when 2 inches or less in length, the angle may be $\frac{1}{2}$ degree; 2 to 5 inches, $\frac{3}{4}$ degree; 5 inches and over, 1 degree. This is generally satisfactory in this respect, in our own work, as the drills are seldom very long.

When large drills are held by the centres, the head should be depressed in order to diminish the depth of groove.

The outer end of the drill is supported by the centre rest, as shown in Fig. 91, and when quite small, should be pressed down firmly, as illustrated, until the cutter has passed over the end.

The elevating screw of this rest is hollow, and contains a small centre piece with a V groove cut therein to aid in holding the work central. This piece may be made otherwise, to adapt it to special work.

Another, and very important operation on the twist drill, is that of "backing off" the rear of the lip, so as to give it the necessary clearance, to prevent excessive frictional resistance. In the illustration, Fig. 92, the bed is turned about $\frac{1}{2}$ degree as for cutting a right hand spiral, but as the angle depends on several conditions, it will be necessary to determine what the effect will be under different circumstances. A slight study of the figure will be sufficient for this, by assuming the effect of different angles, mills and the pitches of spirals. The object of placing the bed at an angle is to cause the mill E to cut into the lip at c' and have it just touch the surface at c' . The line r being parallel with the face of the mill, the angular deviation of the bed is clearly shown at a , in comparison with the side of the drill.

From a little consideration it will be seen that while the drill has a positive traversing and rotative movement, the edge of the mill at c' must always touch the lip a given distance from the front edge; this being the vanishing point, if such we may call it. The other surface forming the real diameter of the drill, is beyond reach of the cutter, and is so left to guide and steady it while in use. Fig. 93 is an enlarged section, showing the point c , where the cutting commences, and its increase until it reaches a maximum depth at c , where it may be increased or diminished, according to the angle employed in the operation, the line of cutter action being represented by $i i$. Before backing off, the sur-

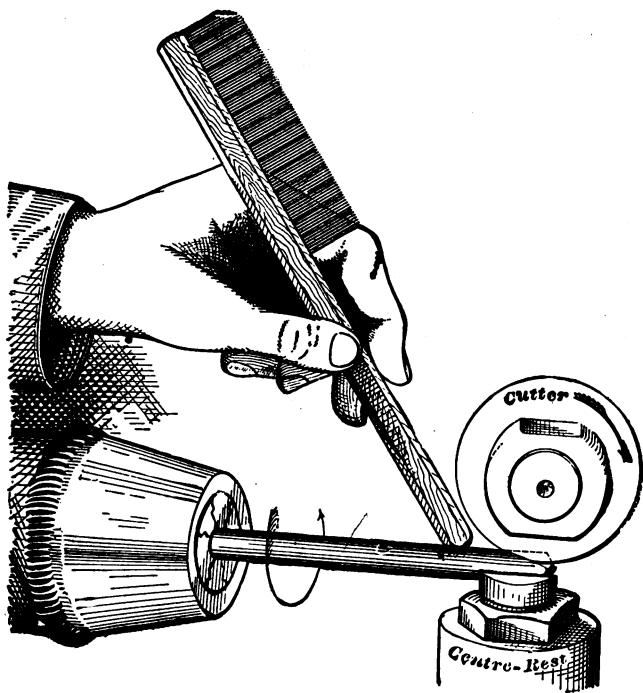


FIG. 91.

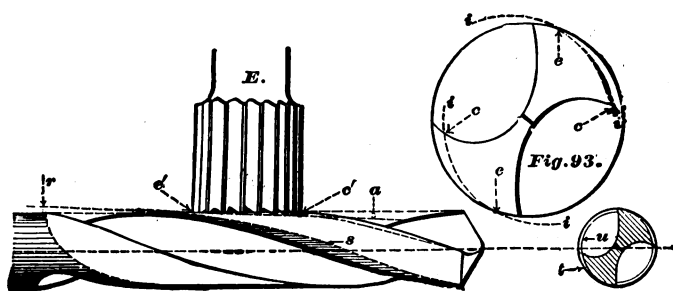


FIG. 92.

face of the smaller drills, in particular, should be oxidized by heating until it assumes some distinct color. The object of this is to clearly show the action of the mill on the lip of the drill, for, when satisfactory, a uniform streak of oxidized surface, from the front edge of the lip back, is left untouched by the mill, as represented in the cut at *e*.

LIST OF PATENT CUTTERS FOR MAKING TWIST DRILLS.

Number of Cutter.	Diameter of Drill.	Diameter of circle made by Cutter.	Hole in Cutter.	Diameter of Cutter.
1	1-16 in.	.06 in.	7-8 in.	1 3-4 in.
2	1-8 "	.08 "	"	"
3	3-16 "	.11 "	"	"
4	1-4 "	.15 "	"	"
5	5-16 "	.19 "	"	2 in.
6	3-8 "	.23 "	"	"
7	7-16 "	.27 "	"	"
8	1-2 "	.31 "	"	"
9	9-16 "	.35 "	"	2 1-8 in.
10	5-8 "	.39 "	"	"
11	11-16 "	.44 "	"	"
12	3-4 "	.50 "	"	2 1-4 in.
13	13-16 "	.56 "	"	"
14	7-8 "	.62 "	"	2 1-2 in.
15	15-16 "	.70 "	"	"
16	1 "	.77 "	"	2 3-4 in.
17	1 1-8 "	.85 "	"	"

The foregoing remarks refer to the production of right hand spirals. For the production of left hand spirals, evidently the only changes necessary are the swinging of the spiral bed to the opposite side of the centre line, the introduction of an intermediate gear upon the stud, Fig. 8, to engage with either pair of change gears for changing the direction of rotation of the spiral head spindle.

Cutting
Left Hand
Spirals.

Cutting
Spirals
with an
End Mill.

When spirals cannot be conveniently cut with axial mills, as previously described, it is sometimes convenient to use radial or end mills, as for example, when the diameter of the piece is very large, or the spiral is of such a lead that the spiral bed cannot be set at the requisite angle, the work is so held that its centre and that of the mill will be in the same plane and the bed is parallel with the ways of the machine. Fig. 94 is a suggestive specimen of work done in this way.

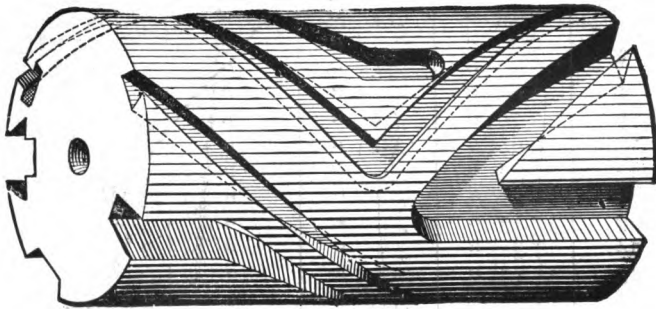


FIG. 94.

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