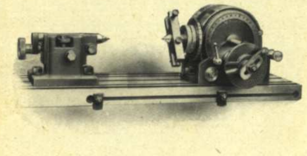
MILLING MACHINES AND MILLING PRACTICE

1914

THE R. K. LE BLOND
MACHINE TOOL CO.
CINCINNATI, O. U. S. A.

Milling Machines
and
Milling Practice



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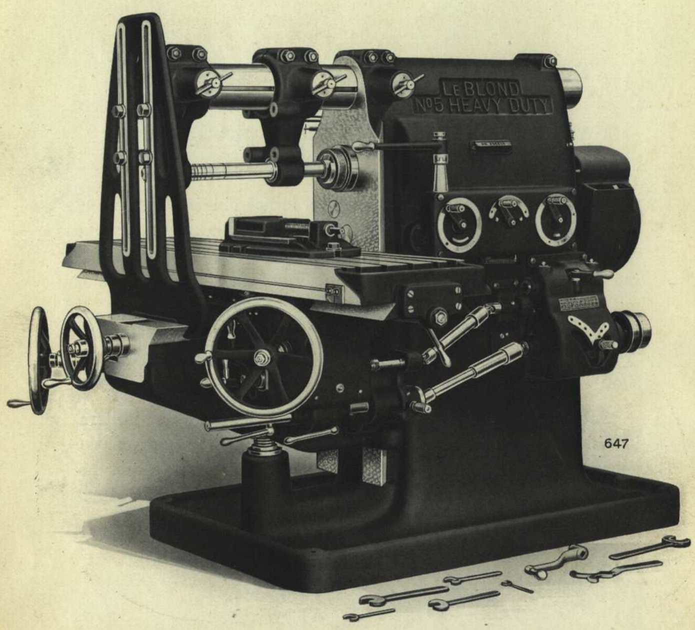
A TREATISE ON MILLING MACHINES AND MILLING PRACTICE.

THE fullest degree of usefulness is not obtained from any machine tool unless the operator possesses a comprehensive knowledge of both its construction and operation. Realizing the general lack of practical working data on the subject of milling and milling machines, we have issued this treatise. It is an analysis of the essentials of a "modern knee-type miller" from the standpoint of the practical mechanic and belongs in the shop with the machine.

Although formulated to cover the construction of our millers, it will be none the less valuable as an educational work on the general subject of milling. It contains instructive data on a typical class of commercial milling operations as well as several examples of tool-room practice.

APRIL, 1914.



LeBLOND No. 5 PLAIN HEAVY DUTY MILLING MACHINE

JIGS AND FIXTURES

The efficiency of any milling machine is nothing more or less than its ability to earn profits on the investment it represents. From no other machine tool is there the possibility for as large a return on the investment as from a modern milling machine with intelligently designed tool equipment.

Carefully designed jigs and fixtures not only provide for more rapid milling, but insure a degree of accuracy not obtainable by other means. Interchangeability of the work is assured, and the chucking or handling time is greatly reduced.

All of the standard machine parts in our shops are milled in large quantities in fixtures especially designed for the purpose. These fixtures were developed in our Engineering Department and represent the most advanced methods of chucking or holding work to be milled, the non-productive or idle machine time being reduced to an absolute minimum.

We offer the services of our Engineering Department to investigate conditions and recommend economical milling methods to interested parties. Our long experience along this line enables us to offer suggestions of value.

KINDS OF MILLING

Surface Milling

The most generally used form. The cutters are mounted on an arbor and the work clamped to the table using the longitudinal table feed. Solid cutters are made preferably with spiral teeth. On sizes 6″ and larger they are usually made by inserting high-speed steel blades in mild steel blanks. The most economical relations of the feeds and speeds are best determined by experiment. The hardness of material, the degree of finish required and the design of the cutters are big factors in determining production.

Single Chucking or Gang Milling

This type of milling is done either on a single or multiple chucking of the work. It may be taken as a general rule that where the total chucking time equals or exceeds the actual cutting time, there is no economy in gang milling. To remove finished pieces and replace them with rough work while other pieces in the fixtures are still under cut necessitates dropping the knee, in order to return the table, after which it is readjusted to the work, the finished pieces nearest the cutter removed and rough parts rechucked. In some cases of this kind the non-productive or idle machine time becomes excessive, and a careful consideration of these conditions would be of value in designing jigs or milling fixtures.

Face Milling

This type of milling, like surface milling, may be done with either single or multiple chucking fixtures. The face mill — generally an inserted blade cutter — is screwed on to the threaded nose of the spindle and is used in finishing surfaces at right angles to the spindle center. With our millers it is possible to make heavy reduction with very coarse feeds. The high belt velocity provided for by large gear reductions, the rigid knee, saddle and table construction, and the positioning of same, which provides for obtaining the greatest strength of these sections, are all factors. See example, page 123.

End Milling

End milling operations include surfacing bosses at right angles to the spindle center, key ways, T-slot and dovetail milling. Many inaccessible surfaces that can not be reached otherwise, can often be handled profitably as an end milling job. See examples. The general practice in the design of end mills tends toward the coarse pitch spiral cutter. A table of leads, angles and change gears for the modern design end mills is shown on page 166.

Form Milling

The formed milling cutter has come into more general use in manufacturing milling practice. They can be sharpened repeatedly without changing their form, and, while as a general rule they are not as substantial as an ordinary surface mill, satisfactory results are usually obtained as to speeds and feeds. These form cutters can be used in gangs or in combination with ordinary surface mills. In the shops of sewing machine and small arms manufacturers, these cutters are often of intricate form, and pieces that would otherwise be generated or profiled are finished much more rapidly by milling.

Alternate or Reciprocal Milling

This type of milling is done either with a vertical spindle attachment, or the horizontal spindle.

Two independent fixtures or chucks for holding the work are mounted on the table and the cutters fed alternately over each. The operator reversing the feeds at the end of the cut, removing the finished work and rechucking while the machine is at work on the piece in the other fixture. When provided with our quick power table traverse this becomes practically continuous milling, the table traveling from one fixture to the other at the rapid rate of twenty-five (25) feet per minute.

Circular Milling

Milling circular grooves, T-slots, etc., is accomplished with a rotary milling table on which the work is chucked and the cutter mounted in a vertical spindle attachment. This circular table is equipped with either power or hand feed, and a worm indexing arrangement provided for precision indexing. A jig, circular in form, is often bolted to the rotary table, a number of pieces chucked therein and fed continuously under the cutter, the operator removing the finished work while other pieces are still under cut. This production is continuous, as there is no rest period for the machine. The degree of handiness and the facility with which the finished work is removed and other pieces rechucked largely govern the production obtainable.

FEEDS AND SPEEDS

No fast and fixed rule can be given as to the practical relations of the feeds and speeds. Many elements enter into this problem, chief among them, the degree of finish necessary, the design of the cutters, and the support afforded them, while the stability of the work itself is an important factor. If the work is of a frail nature a coarse feed is apt to cause distortion.

The degree of finish required more generally limits the rate of feed, while the hardness of material or its tensile value determines the practicability of the cutting speed. On work where a high degree of finish is essential, experiment only will determine the fastest practical combinations of feeds and speeds. Where a large amount of stock is to be removed, greater economy is effected by the use of slower speeds and the coarsest possible feeds. Naturally the possibilities for coarse feeds are greater on some machines than others. The rigidity of the knee section, the support provided the cutter and arbor, as well as the efficiency of the feed transmission are factors. In selecting a miller for heavy service particular attention should be paid to the feed transmission, toward the elimination of friction generating devices, chains or other complications. Machines of complicated design, owing to the increased number of moving parts, must of necessity consume more power, be shorter lived and require more skill and attention to obtain a given result. We have paid particular attention to simplicity in our design.

As a general application to ordinary shop practice we suggest the following cutting speeds:

Cutting Speeds

Material.	Peripheral speed of cutter, feet per minute.
Soft Gray Iron	70
Machine Casting — Cast Iron	50-60
Cast Steel	40
Wrought Iron	45
Malleable Iron	40-45
Soft Machine Steel	45
Hard Machine Steel	30
Tool Steel Annealed	30-35
Tool Steel Unannealed	20-25
Soft Brass	125
Hard Brass (Copper)	90-100
Bronze	80
Aluminum	400-600

These speeds are approximate and must be adjusted to the nature of the material and the feed. Obviously the physical analysis, the hardness and grain, of practically all of the metals will vary.

Sometimes the SPEED of the cutter may be profitably increased, leaving the rate of FEED as it is. Again the *speed* could be decreased without changing the *feed*. In another case the SPEED may remain constant while the FEED may be increased or decreased to suit the nature of the work. It is excessive cutting speed that causes heating of a cutter when it is of design suitable for the work in hand.

CUTTER DESIGN

Correctly designed cutters greatly reduce the stresses in the the arbor and its supports as well as the strains in machine frame, because they consume less power.

The coarse pitch cutters with their increased chip room, that we designed and have used successfully for the past eight (8) years, have done much toward increasing the possibilities for heavy milling with a much smaller consumption of power for a given result. The general practice now tends towards cutters of this design. Although opinions of various authorities vary in regard to the spiral angles and depth of teeth, the average trend of practice is the same. The coarser pitch cutters provide for freer cutting action, more chip space and a decidedly more substantial tooth, consequently coarser feeds may be used. Larger chips are removed than with cutters of earlier design, and it becomes evident that the excessive power formerly consumed in forcing the chip through the restricted tooth space of the old cutters is now utilized in the actual removal of the metal. The apparent hardness of material with the use of the old cutters largely disappears when our millers with their unusually large arbors, are equipped with the more modern high-speed cutters. These cutters not only provide for an economic use of power, but are a great deal more durable and more easily sharpened.

For finishing operations a fine pitch cutter may be used to advantage, which will lessen the feed marks and provide a highly accurate surface. This is quite readily permissible, since on finishing cuts there is no great amount of metal to remove, and the space between the teeth is ample for the escape of the chips.

When these cutters are used in gangs for milling large surfaces it is advisable that they be split and the hand of the spirals be reversed to absorb the end thrusts.

A list of Angle Leads and Change Gears for milling these cutters is shown on page 163.

Cutter Gangs

In quantity manufacturing it is generally profitable to leave the cutters assembled in gangs. That is, keep them mounted on a single arbor, using the cutters as a unit, and not removing them for other jobs. This greatly simplifies their sharpening, and assures duplication of work.

Cutting Compounds

Much more dependable results will be obtained from any cutters when they are kept cool and cleared of chips. Steel, Malleable Iron, Cast Steel and other metals of high tensile strength require the use of a cutting or cooling compound for the cutters. This compound is best distributed under considerable pressure to effectively clear the cutters of all chips. Any of our millers can be equipped with a geared rotary pump for the distribution of the lubricant and flexible tubing for its return to the supply tank.

Paraffine and lard oil in equal parts is sometimes used, and, although very expensive, the results are satisfactory, and many manufacturers prefer it to the commercial "soda oils" or cutting compounds. Both, however, are used in large volumes, with but a small waste, and kept in constant circulation.

Care should be taken in the selection of the manufactured soda compounds to prevent the use of those which cause rusting of the finished parts of the machine.

On such Cast Iron work where the chips have small chance to escape, the cutters are best cleared of them with an air blast or jet. This is especially important on T-slot or undercutting operations. No lubricant is necessary and really would do more harm than good.

KNEE AND COLUMN TYPE MILLERS

The many marked improvements in the material and designs of cutters have necessitated radical changes in the construction of the milling machine to utilize these new cutters to the limit of their usefulness.

Some manufacturers have found it commercially profitable to strengthen their machines only at the weak points which developed. Others, after a more thorough analysis, found a radical re-design necessary, each size being laid out to accomplish a predetermined result.

We belong to the latter class and how well we have succeeded is evidenced by the successful performance of our machines in the shops of our customers.

They embody certain desirable features of construction not found in competing machines. In every case the quality and quantity of the work they are performing have justified the investment, and verified the intelligence used in their selection.

Plain and Universal Machines

Knee and Column Type Millers may be PLAIN or UNIVERSAL. The essential difference being the swivel table construction which characterizes the Universal Machine. The table of the Plain Machine is free to travel only at right angles to the spindle center, while the table of the Universal Miller may be swiveled fifty (50) degrees either side of its center.

The Plain Machine, on account of its greater simplicity and more rugged construction, is more used in manufacturing shop service.

The Universal Miller, on account of its greater flexibility, is more generally conceded to be a tool-room machine. The swivel table adds one more joint and the bevel gear table feed drive somewhat restricts the design; consequently, they can not be made quite as simple as the plain machine. However, these are faults of the type and the LeBlond Company has reduced them to minimum in the design of their higher powered Universal Miller. It has long been an exploded idea that there was any more necessity for precision work on a universal miller than on a plain machine. The plain machine, equipped with our precision Driving Head and with a Universal Spiral Cutting Attachment, becomes a fully efficient tool-room miller, capable of cutting spirals, etc.

Where the shop is only large enough to require one machine, we recommend that it be a Universal, due to its greater flexibility without attachments.

"Interchangeable Unit" Manufacturing

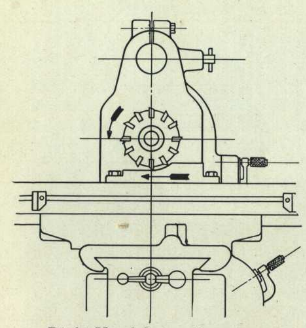
In any manufacturing scheme, interchangeability is a vitally necessary feature which is only obtainable by a carefully devised system of jigs, fixtures and templates. In highly specialized shops, such as our own, not only is each piece interchangeable but each complete unit also — as the knee, feed gear box and the back gear assemblages. These units are built and assembled in large quantities to the ultimate advantage of the consumer. The natural result of manufacturing on this large scale is a reduced sale price consistent with quality and an assurance that any repair furnished will fit without any corrective work.

Control Schemes

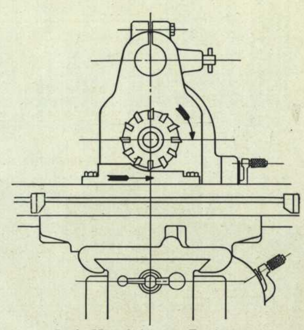
Much has been said on the subject of control schemes for all milling machines. This diversity of opinion resulting, probably, from a lack of practical knowledge of the operating conditions. However, it has been universally agreed that the degree of operating convenience provided has much to do with the production obtainable from any miller. For this reason we believe that a short analysis of the conditions governing the natural position of the operator would be of interest.

"Why A Milling Machine Should Run Right Handed"

In order to secure interchangeability of tools with the lathe, drill press and other machine tools, it is necessary that a milling machine spindle be run in the same direction. In face milling operations the mill is received on to the nose of the spindle and this thread is best made R. H., so that ordinary lathe chucks may be affixed to it and not work off with right-hand cutter rotation. Cutters which are mounted on arbors may, of course, be reversed on the arbor and the machine run left handed. This condition, however, is undesirable from a standpoint of a location of the controlling levers. LeBlond Millers are designed to run as nearly as possible with equal efficiency in both directions; however, it is recommended that they run right handed for the above reasons.

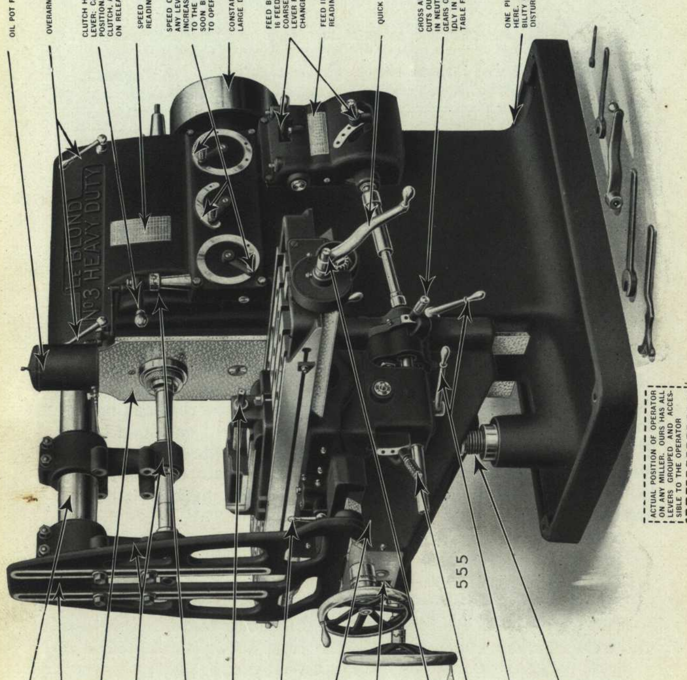


Right Hand Cutter Rotation.
Lathe Chucks, Drills, Counterbores, etc., are Interchangeable



Left Hand Cutter Rotation.
Lathe and Drill Press Tools will not Interchange

Adjustable gibs must be provided on all millers for adjustment for wear on the sliding members, the knee, saddle and table. Much more dependable work, both as regards accuracy and productions, is obtained when the cutter thrusts are absorbed against the solid side of these members. Only one side of each can be gibbed, consequently on any milling machine, regardless of its manufacture, the fullest efficiency can only be obtained when the spindle is running in the direction for which the machine is designed.



Efficiency Diagram and Control Scheme of "A RIGHT HANDED MILLING MACHINE"

Central Location of the Controlling Levers

Having established the proper direction of rotation for the cutter spindle, we next determine the correct location of the controlling levers to accompany this condition. In this discussion we are neglecting the left-handed operator, safely assuming that ninety-nine per cent of the machine operators are right handed.

The descriptive plate opposite shows the logical position of the operator on any milling machine in which the *cutter rotates right handed.* From this point he has an unobstructed view of the cutter at work, and every lever necessary to a full working control is within easy grasp; the quick traverse, start, stop, feed reverse and engaging levers. This is true on both plain and universal millers. The practice of placing the quick traverse lever on one side of the machine and the start, stop and feed control on the opposite side is obviously an error in principle. The quick traverse and start and stop lever, as well as the feed engaging levers, are used with every return stroke of the table; consequently, the greatest convenience is effected by grouping them on the same side of the machine; otherwise, the operator would be forced to walk around the extended table to return it after starting and stopping the machine. The feed and speed control mechanisms are also properly placed on this side of the machine in order that they may be adjusted to suit the work, while the machine is in operation.

The levers used in the preparatory, or setting-up operations, are conveniently placed on the opposite side of the knee, so as not to complicate the control scheme.

These levers are for the cross and vertical micrometer adjustment and fine feed to table, neither used in the actual operation but in setting up only. All of the feed engaging levers are reached from the operating position. The start and stop lever and the quick return for the table are grasped in the operator's right hand, certainly more convenient than any other system of control in which the operator uses his left hand.

Several milling machines may be of the same pulling capacity, the ability to remove metal, etc., although the actual production of one may exceed the others, due to its greater operating con-

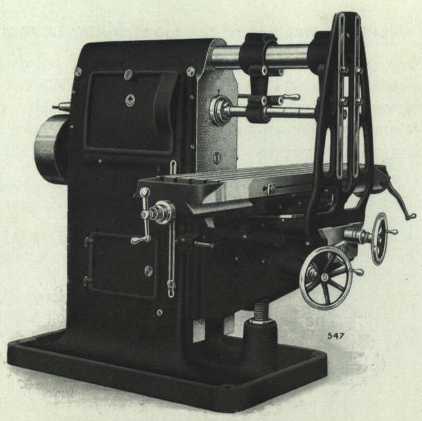


Fig. 1
Rear or oiling side of the machine. The operator has no occasion to be on this side of the machine except in oiling. All of the control levers are conveniently grouped on the right hand or operating side.

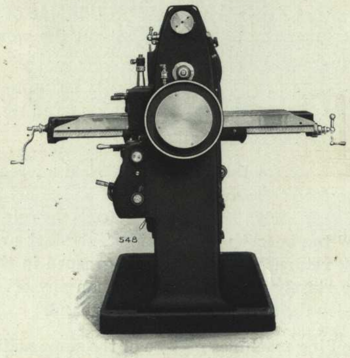
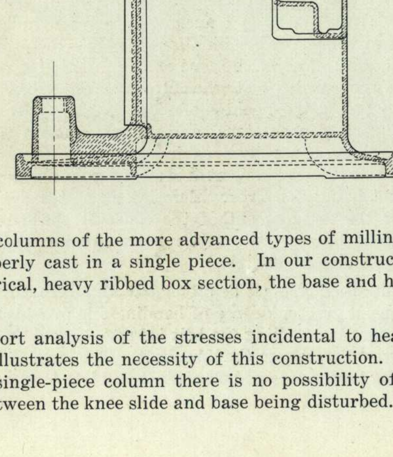


Fig. 2
End elevation showing general symmetry and ruggedness

venience. The operator's energy must be conserved in order to obtain the greatest possible production from any machine tool.

An operator and his machine form a production unit, the efficiency of which is largely determined by the facility with which the machine may be handled.

Unit Column Construction



The columns of the more advanced types of milling machines are properly cast in a single piece. In our construction it is a symmetrical, heavy ribbed box section, the base and housing cast integral.

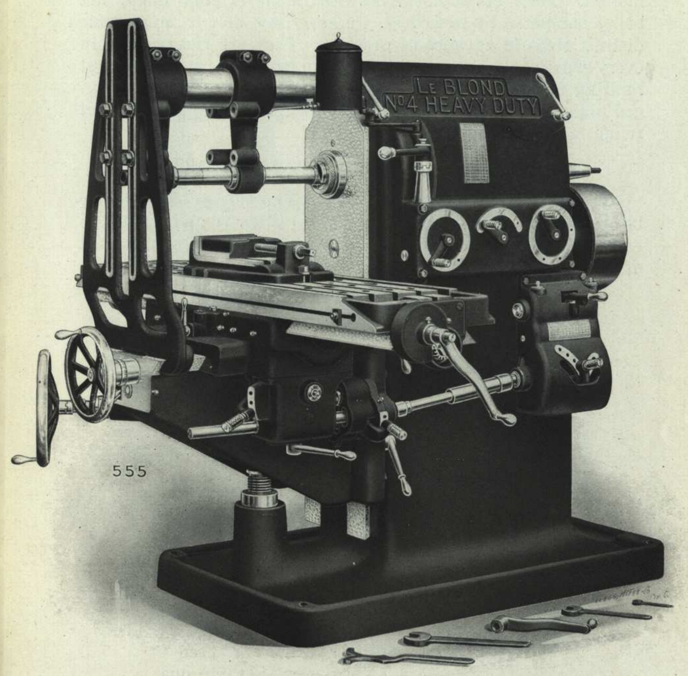
A short analysis of the stresses incidental to heavy milling clearly illustrates the necessity of this construction. Primarily, with a single-piece column there is no possibility of the alignment between the knee slide and base being disturbed. With our unit column construction all of the collapsing strains are resisted by internal ribbing and the strains set up by the thrust of the cut and the weight of the sliding members, the knee, saddle and table, are transmitted through the vertical walls to the base of the machine. This can not take place where there is a complete separation of the column and base, providing an extra joint subject to chatter and vibration. It is unquestionably a manufacturing economy to cast the column and base separately, as a number of them can then be strung out on the planer instead of planing them singly; however, the advantage is purely commercial in building the machine and its actual rigidity suffers in consequence.

CONSTANT SPEED DRIVE MILLERS

The advantages of the Single Pulley Drive All-Geared Milling Machine are now fully established. The tendencies of modern shop practice are toward heavier milling, and work of increased weight is rapidly being put on the milling machine. The constant speed drive miller has been developed as the result of this practice, and its field of operation is entirely distinct from that of the Heavy Duty Cone-Type Miller.

Notable among its advantages is the constant torque driving belt which travels at a high speed, productive of great power. This high powered drive is transmitted to the spindle through gear trains with selective combinations to obtain the proper series of spindle speeds. Unlike the cone drive construction practically the same power is delivered to the cutter regardless of the spindle speed. The cone drive machine employs different belt velocities, due to the various cone steps or diameters and on the slower speeds, and when, generally speaking, the greatest power is required, the belt velocity is decreased; consequently, the greatest power is not being delivered. This is one of the fundamental reasons for the development of the constant speed drive: its ability to take heavier cuts and remove greater quantities of metal in a given length of time.

All of the speed changes being made with levers through gear combinations, a greater degree of handiness is provided, the element of danger in handling the belt is removed and the machine may be driven direct from the line shaft. The large driving pulley providing larger area of belt contact and less tendency to belt slippage.



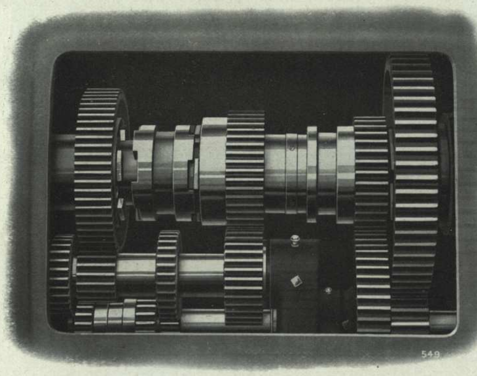
No. 4 PLAIN HEAVY DUTY LeBLOND CONSTANT SPEED DRIVE MILLING MACHINE

Range 42″ longitudinal, 12″ Cross and 20″ Vertical

Our particular design lends itself admirably to the application of the motor drive, equally well for variable or constant speed motors. Their development has been along original lines; not being hampered by precedent, we have been able to make some distinct steps in advance of practice. They are Heavy Duty in every sense of the word and designed to make the cutters the first limiting factor in their production. Notwithstanding their rugged high-power design, they embody a degree of convenience not found in other high-powered millers.

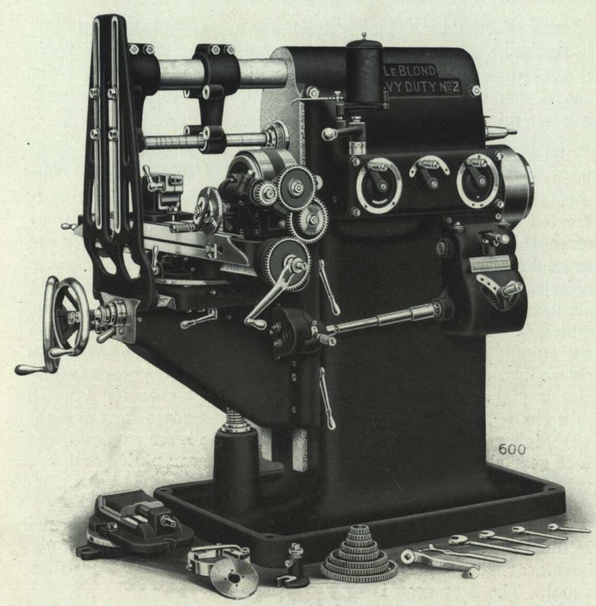
Design of Gearing

The combinations of gearing for the spindle drive that may be obtained are practically endless. In justification of the design embodied in our construction, which differs radically from that of other machines, we offer the following explanation:



Like other designs, the initial drive is from a constant speed pulley running at a high rate of speed, though the gear reductions are generally higher than found in competing designs, productive of a more powerful drive.

It will be noted that the gear layout is simply that of a successful automobile transmission, carried out several stages, and back geared, to provide 16 changes of speed in a geometric pro-



No. 2 UNIVERSAL HEAVY DUTY CONSTANT SPEED DRIVE MILLER

Power Longitudinal and Cross Feeds Range 25″ x 8″ x 18″

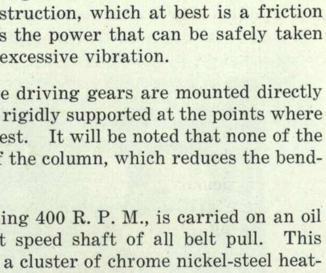
gression. In developing this gear drive we have entirely eliminated the tumbler gear construction, which at best is a friction generating device and limits the power that can be safely taken through the machine by its excessive vibration.

The shafts that carry the driving gears are mounted directly in the column, are short and rigidly supported at the points where the gear pressures are greatest. It will be noted that none of the shafts span the full width of the column, which reduces the bending to a minimum.

The driving pulley, running 400 R. P. M., is carried on an oil bush, relieving the constant speed shaft of all belt pull. This constant speed shaft carries a cluster of chrome nickel-steel heat-treated sliding gears, with stub form teeth to increase their strength and eliminate all clash in meshing them. The bores are ground concentric with the pitch circle, after hardening, to insure noiseless operation. These gears slide into mesh with four (4) similar gears on an intermediate shaft, giving it four (4) speeds, which are transmitted in two ratios to gears running loosely on the spindle sleeve. These gears are alternately clutched to the sleeve by a sliding nickel-steel, heat-treated, double-end, jaw clutch. The drive is then direct into the face gear for a series of eight (8) fast speeds or through the back gears for the eight (8) higher powered, slow speeds. A single lever engaging the face gear clutch and withdrawing the back gear pinion and *vice versa.*

The Large Face Gear

The face gear is probably the largest ever used on a geared Milling Machine. This, in connection with the mounting of the back gear shafts, permits of heavier cuts and coarser feeds than usual. The face gear is as large as the largest cutter the machine will swing on each respective size. All of the speeds must come through the big face gear, as it is the only member fixed on the spindle, effectually relieving it of all torsional vibration, as well as insuring smoother cutter rotation. The back gears, contrary to the practice of other builders, are not mounted on a shaft spanning the full width of the column, but on a short, stocky shaft not over eight inches long, and supported directly in the column.



This method of mounting the back gears and the elimination of the tumbler gear construction in our design has overcome a popular objection to the gear drive, as work equally as good in finish can be obtained as with a cone belt machine.

A particularly valuable feature in this type of construction is that there are no loose speed boxes necessary, all of the gear shafts being mounted directly in the column.

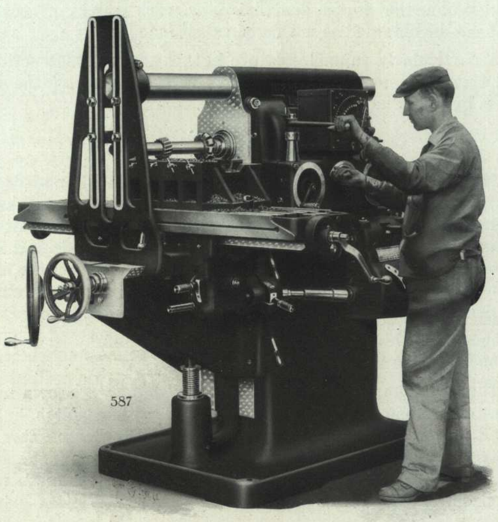
Speed Changing

The operation of speed changing is especially simplified; the gearing being so laid out that moving any one of the speed change levers to the right will increase the spindle speed, to the left will decrease it. This same condition is true of the feeds. It soon becomes mechanical to the operator, and he may neglect the index plate entirely except to determine the surface speed of the cutter.

The fine speed changes can all be made while running. The changes in the high runs are made more successfully by reducing the speed of the gears.

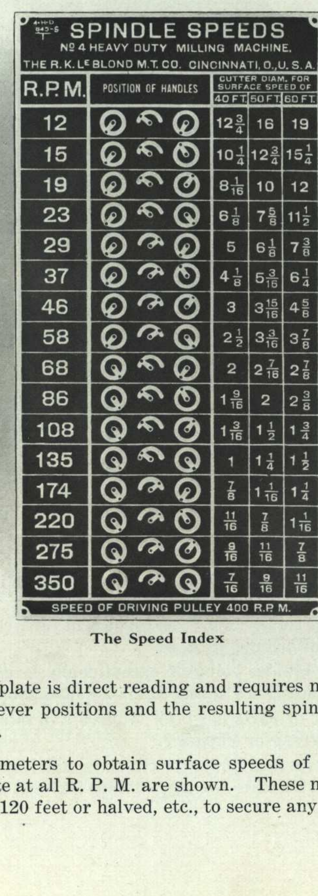
This is accomplished by the start and stop lever shown in the operator's grasp. The lever is provided with a clutch hub so that it may be set in any position convenient to the operator and with it any degree of driving tension can be obtained, just enough to turn the gears over, permitting them to slide into mesh without clash, or the full capacity of the powerful friction driving clutch.

On releasing this clutch the same lever applies a friction brake, bringing the spindle to an instant stop.



Operator changing speeds.
No ratchet or treadle devices required.

The Speed Index Plate



4-H-D 845-S SPINDLE SPEEDS
No 4 HEAVY DUTY MILLING MACHINE.
THE R. K. LE BLOND M.T. CO. CINCINNATI, O., U. S. A.

R.P.M.	POSITION OF HANDLES	CUTTER DIAM. FOR SURFACE SPEED OF		
		40 FT.	50 FT.	60 FT.
12		$12\frac{3}{4}$	16	19
15		$10\frac{1}{4}$	$12\frac{3}{4}$	$15\frac{1}{4}$
19		$8\frac{1}{16}$	10	12
23		$6\frac{1}{8}$	$7\frac{5}{8}$	$11\frac{1}{2}$
29		5	$6\frac{1}{8}$	$7\frac{3}{8}$
37		$4\frac{1}{8}$	$5\frac{3}{16}$	$6\frac{1}{4}$
46		3	$3\frac{15}{16}$	$4\frac{5}{8}$
58		$2\frac{1}{2}$	$3\frac{3}{16}$	$3\frac{7}{8}$
68		2	$2\frac{7}{16}$	$2\frac{7}{8}$
86		$1\frac{9}{16}$	2	$2\frac{3}{8}$
108		$1\frac{3}{16}$	$1\frac{1}{2}$	$1\frac{3}{4}$
135		1	$1\frac{1}{4}$	$1\frac{1}{2}$
174		$\frac{7}{8}$	$1\frac{1}{16}$	$1\frac{1}{4}$
220		$\frac{11}{16}$	$\frac{7}{8}$	$1\frac{1}{16}$
275		$\frac{9}{16}$	$\frac{11}{16}$	$\frac{7}{8}$
350		$\frac{7}{16}$	$\frac{9}{16}$	$\frac{11}{16}$

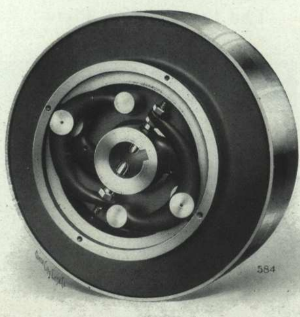
SPEED OF DRIVING PULLEY 400 R.P.M.

The Speed Index

The speed plate is direct reading and requires no explanation. The relative lever positions and the resulting spindle speeds are clearly shown.

Cutter diameters to obtain surface speeds of 40, 50 and 60 feet per minute at all R. P. M. are shown. These may be doubled for 80, 100 or 120 feet or halved, etc., to secure any diameters.

The Driving Clutch



Detail of Driving Clutch

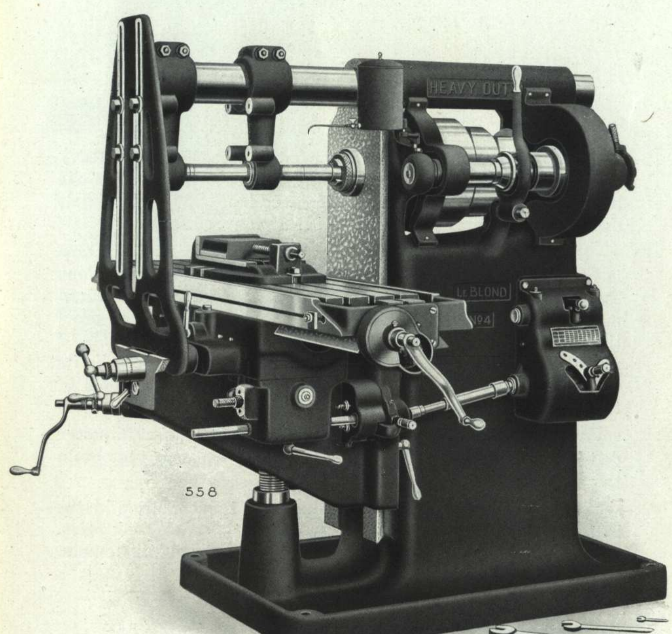
The friction driving clutch is the result of considerable experiment, and the final development we believe will be of interest from a mechanical standpoint. Besides being powerful enough to transmit the full H. P. rating of the motor, it must be sufficiently sensitive to slowly turn the gearing over to facilitate its meshing. We have accomplished this in the clutch shown above. The friction surfaces are of unusually large diameters; the ring is expanded at two points, diametrically opposite, by two powerful spreader fingers with hardened steel tips. These fingers act with a powerful wedge action on the friction ring and exactly balance each other.

In addition to the running balance, each finger is balanced independently to prevent them drawing away from the expansion plugs, due to the rotative force. Adjustment for wear and tension is provided at all points.

The clutch, besides being of exceptionally large diameter, is on the highest speed shaft, and naturally under low stress.

The number of parts has been reduced to a minimum, with a consequent increase in efficiency.

Within all practical limits the clutch is positive and eliminates the racking and shock to the gears trains incident to the use of a jaw clutch.



THE ORIGINAL HEAVY DUTY CONE TYPE MILLER DESIGNED BY THE R. K. LEBLOND MACHINE TOOL CO., 1912

Range 42″ x 12″ x 20″. Power feeds in all directions.

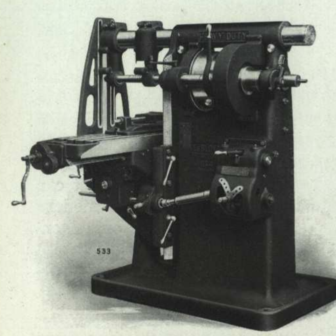
CONE TYPE MILLERS

In 1912 we completed developments on the original Heavy Duty Cone Drive Miller, placing on the market at that time our line, which we designated as the Straight Line Heavy Duty Miller, due to their general symmetry and high-powered design.

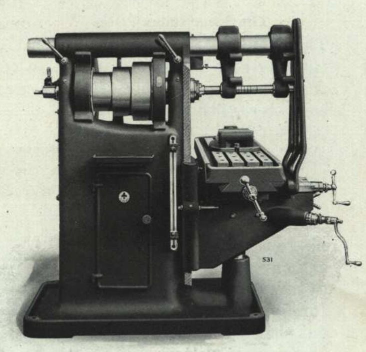
Unquestionably the light-pattern Cone Type Milling Machine is rapidly falling into disuse. However, the Heavy Duty Cone Type Miller continues to be an important factor in the modern manufacturing shop. Much of the work in ordinary shop practice does not call for the removal of the tremendous amounts of metal. They are cast or drop forged within fairly close limits of finish. This class of work furnishes the legitimate field of the Heavy Duty Cone Type Machine.

A characteristic of the cone belt drive is a variation in power delivered, due to the different belt velocities necessary to obtain the proper cutting speeds.

In the new design we largely eliminated this condition by the better proportion of the cone and the high-ratio double back gears. However, the characteristics of the cone belt drive still remain, to which we have added the Heavy Duty features.

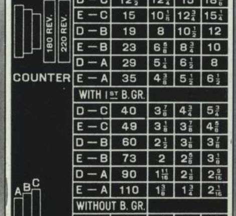


Three Quarter End View of Operating Side showing absence of overhanging parts.



Rear View. Illustrating general rigidity.

Double Friction Back Gears



SPINDLE SPEEDS.
THE R. K. LE BLOND M.T. CO. CINCINNATI, O., U. S. A.

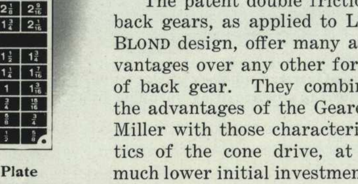
DRIVE	SPINDLE SPEED	CUTTER DIA. FOR SURFACE SPEED OF 40 FT.	50 FT.	60 FT.
WITH 2ND B. GR.				
D — C	$12\frac{1}{2}$	$12\frac{1}{4}$	15	$18\frac{3}{8}$
E — C	15	$10\frac{1}{8}$	$12\frac{3}{4}$	$15\frac{1}{4}$
D — B	19	8	$10\frac{1}{2}$	12
E — B	23	$6\frac{5}{8}$	$8\frac{3}{4}$	10
D — A	29	$5\frac{1}{4}$	$6\frac{1}{2}$	8
E — A	35	$4\frac{3}{8}$	$5\frac{1}{2}$	$6\frac{1}{2}$
WITH 1ST B. GR.				
D — C	40	$3\frac{7}{8}$	$4\frac{3}{4}$	$5\frac{3}{4}$
E — C	49	$3\frac{1}{8}$	$3\frac{7}{8}$	$4\frac{5}{8}$
D — B	60	$2\frac{1}{2}$	$3\frac{1}{8}$	$3\frac{7}{8}$
E — B	73	2	$2\frac{5}{8}$	$3\frac{1}{8}$
D — A	90	$1\frac{11}{16}$	$2\frac{1}{8}$	$2\frac{9}{16}$
E — A	110	$1\frac{3}{8}$	$1\frac{3}{4}$	$2\frac{1}{16}$
WITHOUT B. GR.				
D — C	131	$1\frac{1}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$
E — C	161	1	$1\frac{1}{4}$	$1\frac{7}{16}$
D — B	196	$\frac{13}{16}$	1	$1\frac{3}{16}$
E — B	240	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{15}{16}$
D — A	296	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$
E — A	362	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$

The Speed Index Plate

The cone and its back gearing are laid out to give a series of speeds in a geometric progression. The belts are sufficiently wide in connection with the high back gear reductions to transmit all of the power to the spindle that can be utilized with the modern high speed cutters on a general manufacturing service.

The patent double friction back gears, as applied to LeBlond design, offer many advantages over any other form of back gear. They combine the advantages of the Geared Miller with those characteristics of the cone drive, at a much lower initial investment. The changes from high to low back gear ratios are made while running and under cut, which, in connection with the countershaft speeds, give four (4) back geared speed changes, on each cone step, without a belt shift.

This is a valuable feature on roughing or finishing work, as the operator may select his roughing speed and have the option of three (3) speeds for finishing without shifting a belt. Their construction provides a drive equally as powerful as the old form of sliding back gears

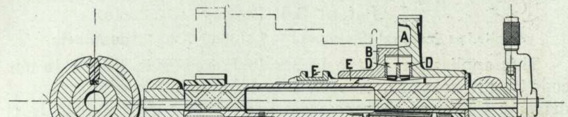


The Patent Double Friction Back Gears.

in addition to their greater convenience as to speed changes. It will be noted that the back gears are properly placed on the right hand, or operating, side of the machine, with the feed gear box and the entire control scheme.

An Operating Convenience

The ratios can then be changed under cut without the necessity of the operator walking completely around the machine. With this location of the back gearing the operator may shift the belt with greatly reduced danger, as the cone is unobstructed and he is not forced to reach over the revolving back gear shaft. The back gears being entirely on the outside of the column, the dimensions of the machine frame in no way restrict the gear ratios.



Section Drawing Through Back Gears

The friction, detail above, is exceedingly powerful and capable of transmitting the full horsepower of the driving belt with a liberal safety factor. All of the steel parts are hardened, the rings being made of cast iron to secure the proper frictional surfaces. They also have the highly desirable feature of being automatic in adjustment. The frictions are mounted on a sleeve, where they have only light duty to perform, the power being multiplied several times before reaching the cutter.

The cast iron friction rings (C-C) are expanded alternately in the rims of the gears (A and B) by means of the double taper key (E) and the taper plugs (D-D), rendering either ratio effective. The wedge and key are hardened and ground, which practically eliminates wear at these points, and the rings are snapped over the hubs to prevent them dragging when the clutch is disengaged.

Any degree of driving tension can be obtained, just enough to turn the gears over or the full capacity of the powerful frictions.

Their advantages over any single back gear construction are sufficiently well understood to require practically no explanation.

They increase the available spindle speeds fifty (50) per cent; the speed increment is very much smaller, and the operator can secure the proper cutting speed for practically any size cutter within the range of the machine.

It will also be noted that with the single back gear construction the speeds most frequently used are taken with the open belt, while with the double back gear machine the same speeds would be taken with the low gear ratio engaged, which is, of course, a much more powerful drive.

Patent Belt Shifter

Applied as Standard Equipment to LeBlond Cone Type Millers

This application of the LEBLOND Patent Belt Shifter to our cone type millers has removed a popular objection to this type of drive, as the speed changes are now made as safely and easily as with the gear type miller.

This patent belt shifter provides for all the good features of the geared countershaft without the objectionable ones.

The importance of the device from a standpoint of accident prevention can not be overestimated.

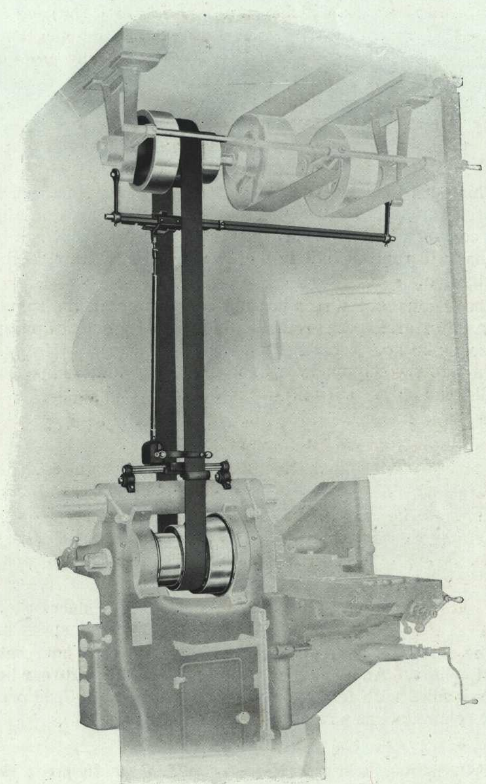
It marks a distinct epoch in the development of the cone driven machine tool, and opens up new fields to its usefulness.

The speed changes are accomplished without appreciable effort on the part of the operator. A single revolution of the crank makes the speed changes as rapidly as the gear shift of an automobile transmission.

From a standpoint of operating efficiency it places the cone driven machine on the same plane as the constant speed drive; and where the added pulling power of the latter is not required, the Heavy Duty Cone Driven Miller will often prove a better investment.

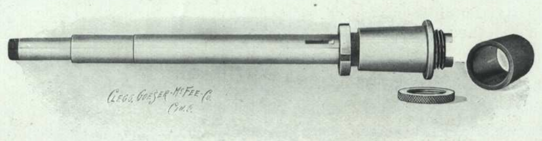
The Spindle and Bearings

The spindles are made from a forging of 60 point carbon crucible steel. They are of unusually liberal proportions. This will be seen on comparison of any specific size with millers in competition.



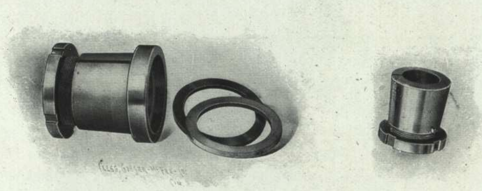
No. 4 HEAVY DUTY LEBLOND CONE TYPE MILLER, WITH PATENT BELT SHIFTER

The front journal is formed by pressing a hardened tool steel bush over the spindle, and afterwards ground in position.



This bush journals in a taper box of genuine Northern iron, of special analysis for bearings. The box soon takes on a glaze from contact with the hardened spindle, and the result is a bearing that will run indefinitely without wear and with a minimum of attention.

The strains on the rear box not being so great, the spindle is left in its natural state, ground and journals in a box of phosphor bronze. The box is tapered on the outside, split laterally and drawn into the column by a fine adjustment nut, compensating for all wear in the bearing.



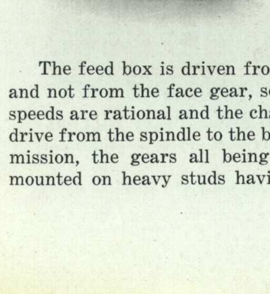
The thrust is absorbed against hardened steel and babbitt thrust collars. An oil slot is milled in both front and rear boxes, which is filled with felt wick which filters the oil. Core pockets in the column act as a reservoir.

Arbor Drive

The arbors are driven by a clutch jaw, milled in the spindle nose. The spindle nose is threaded, a U. S. Standard thread, to receive face mills, chucks, etc. A nose guard is furnished to protect the thread when not in use. The end of the arbor is tapped out to receive a draw-in bolt, operated from the clear end of the column, which also serves as a means of forcing the arbor out of the taper when required. The draw-in bolt has a square milled on the end to receive the vise crank.

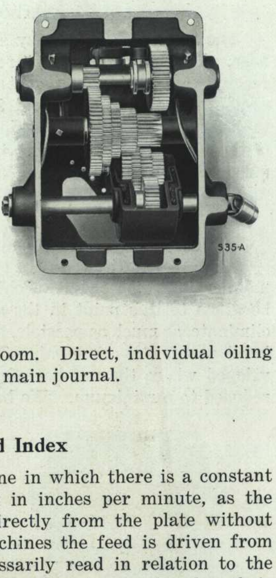
The Feed Mechanism

Next in importance to the spindle drive are the feeds and the manner in which they are obtained. Careful attention should be given to this point in the selection of a Milling Machine to eliminate, as much as possible, friction generating devices, chains, bevel gears, etc. A highly efficient feed drive can only be developed where the number of gears and revolving journals are reduced to a minimum. We have obtained the condition.



Sixteen feed changes are contained within the box, two levers controlling the set-up, the bottom tumbler lever making the fine changes and the top one compounding the range about 6 to 1, which gives the coarse changes. There are no pins to pull or any other factors to consider. The box is entirely self-contained, the entire feed range being obtained within it. All changes can be made under cut, except those impractical conditions resulting from a combination of the fastest speeds and fastest feeds.

The feed box is driven from a gear at the end of the spindle and not from the face gear, so that at all rates of feed the gear speeds are rational and the changes can be made under cut. The drive from the spindle to the box is by a straight spur gear transmission, the gears all being entirely within the column and mounted on heavy studs having a support at both ends in the



column walls. The gears are all cut from steel bar with a special tooth section to increase their strength and permit of easy running engagement. The gear speeds being comparatively low throughout the entire box, there is no harmful clash when the different ratios are slipped into engagement. The knuckle shaft is on the same side of the machine as the feed box, so the feed drive is not carried by extra gears through the column, creating excessive friction and absorbing the cabinet room. Direct, individual oiling arrangement is provided for each main journal.

The Feed Index

On the Geared Milling Machine in which there is a constant speed shaft, the feeds best read in inches per minute, as the production may then be read directly from the plate without calculation. On cone driven machines the feed is driven from the spindle and the speeds necessarily read in relation to the R. P. M. of the spindle. Both plates have been reduced to their simplest forms and require a minimum of effort on the part of the operator to determine the rate of feed obtaining.

FEED IN INCHES PER MINUTE.
THE R. K. LE BLOND M. T. CO. CINCINNATI, O. U.S.A.

LEVER								
→→	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{15}{16}$	$1\frac{3}{16}$	$1\frac{1}{2}$	$1\frac{15}{16}$	$2\frac{1}{2}$	$3\frac{7}{16}$
←←	$4\frac{1}{16}$	$5\frac{3}{16}$	$6\frac{5}{8}$	$8\frac{1}{2}$	11	14	18	25

OIL TUMBLER THRU HOLE AT END OF FEED BOX.

INDEX PLATE FOR CONSTANT SPEED DRIVE MILLERS

The output of the machine is determined at a glance without any computation

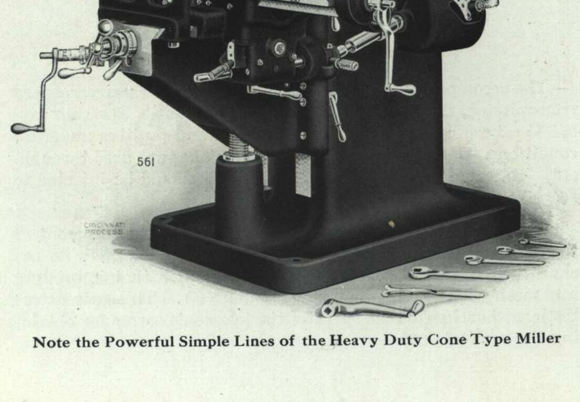
FEED PER REV. OF SPINDLE.
THE R. K. LE BLOND M.T. CO. CINCINNATI, O., U.S.A.

LEVER								
→→	.006	.009	.012	.016	.020	.025	.030	.036
←←	.043	.062	.086	.116	.148	180	.218	.255

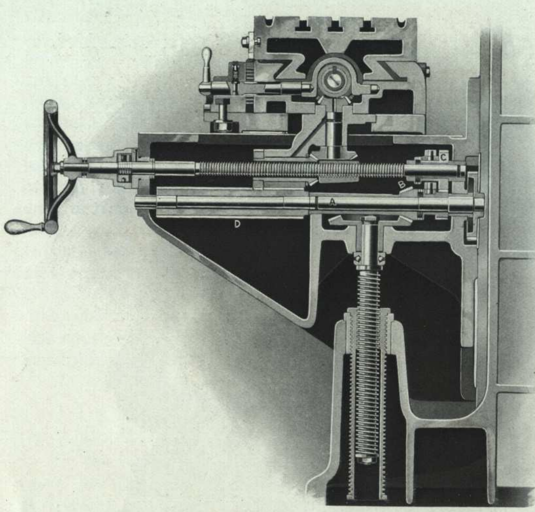
INDEX PLATE FOR CONE DRIVEN MACHINE

Reduced to its simplest form

To increase the feed, move the change lever to the right; to decrease, to the left. This condition also obtains on the cone driven machine.



Note the Powerful Simple Lines of the Heavy Duty Cone Type Miller



Transverse Section of Knee, Table and Saddle

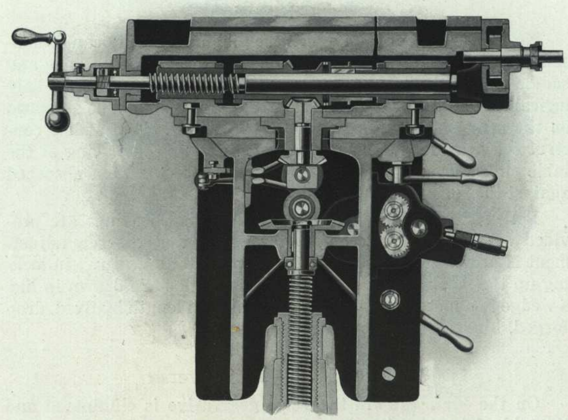
The Universal Knee Mechanism

The accompanying sectional views illustrate the universal feed transmission, through the knee, saddle and table. The gear lay-out is exceedingly powerful; it is geared and positive under all conditions. Hardened steel gears and clutches are used through-out. External oil plugs indicate where oil should be injected to reach each journal.

Feed Reverse

The Vertical Feed

The feeds are reversed by a tumbler gear from the front of the knee and carried through a large intermediate gear to the shaft (A). This shaft carries a sliding clutch that is brought into mesh with the clutch on bevel pinion (B). This gear drives the large bevel gear that operates the telescopic screw for obtain-ing the vertical feed.



Longitudinal Section of Knee, Table and Saddle

The Cross Feed

The cross feed is obtained by sliding the clutch gear (C) into mesh with the jaw clutch on the cross feed screw. The levers that engage the cross and vertical feeds are brought out conven-iently at the front of the knee in a neutral section.

The Table Feed

The table feed is driven through the sleeve gear (D); through the gear revolving in the cross feed bearing. The cross feed screw passes through this gear, but does not touch it. The drive is then through a pair of hardened generated miter gears into the vertical bevel shaft, to the gear that drives the table screw clutch. This clutch is engaged and disengaged at will from the front of the saddle.

The mechanism is so arranged as to allow of a series of lateral and transverse ribs throughout the knee, so placed as to effectu-ally resist all the stresses resulting from the heaviest milling. This construction permits the cross feed screw to be placed in the center of the knee, eliminating all twisting strains. The power being applied at a neutral axis, gives absolutely a free and un-restricted movement to the slide and does away with the "binding effect," common to other designs with the screw set off center. The vertical screw is telescopic, and has ball thrust bearings.

Gib Design

No Milling Machine on which the gibbing is faulty can do consistent work for any extended time. One side of the knee and saddle must be gibbed to compensate for wear, and it is only logical that on the heaviest milling the thrusts should be absorbed on the solid side of these members. Our knee and saddle construction provide for this condition as well as the placing of the table slide gib. The thrust of the cross feed is then absorbed against the solid side of the saddle as well.

Double Angle Gibs. No Set Screws

Both saddle to knee, and knee to column, bearings are provided with heavy double angle gibs. Fine thread screw adjustment is provided on these gibs to compensate for wear. In locking up the machine for severe cuts, these gibs are drawn in like a wedge to a metal to metal contact their full length by fixed, drop forged, binder handles.

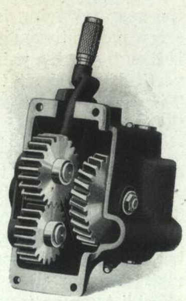
The Feed Trip and Reverse

On the Plain Millers the bevel gear drive is eliminated and the table driven by direct spur gearing on the end of the saddle. All feeds are engaged, reversed and tripped independently, so that the feed relation is governed entirely by the operator's will. When using the longitudinal feed all other feed gear trains can be cut out. This is the feed used ninety per cent of the time in ordinary shop practice.

All of the feeds are controlled from the operating position, so that there is no danger to either the operator or machine when operating at high speeds and fast speeds.

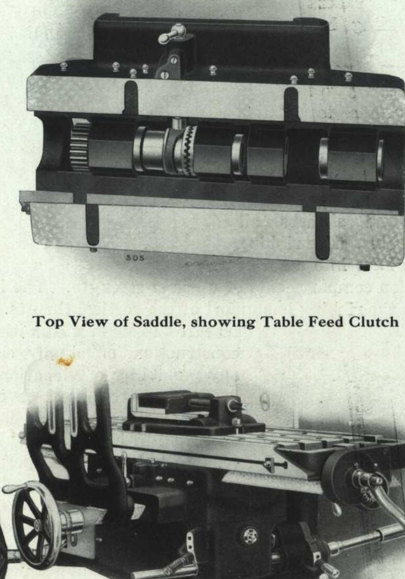
The table feed is driven by a pair of accurately cut spiral gears, to insure noiseless operation. The thrust is taken against ball thrust bearings.

The feed trip is the most sensitive applied to any machine tool. The trip dogs act directly on the feed clutches, the motion not being carried through any gear trains, in which some lost motion is bound to exist. The trip is equally sensitive, when feeding to the *right* or *left*, and will trip within decimal limits under any cut.

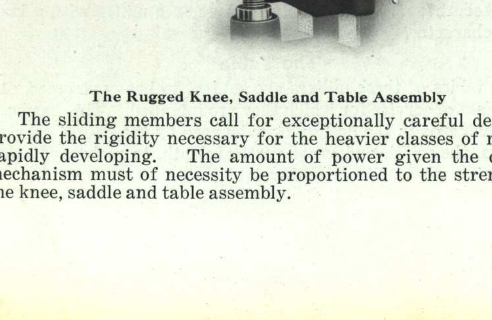


Feed Reverse Box, showing Spiral Gear Drive

THE KNEE, SADDLE AND TABLE



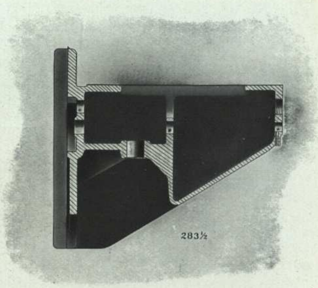
Top View of Saddle, showing Table Feed Clutch



The Rugged Knee, Saddle and Table Assembly

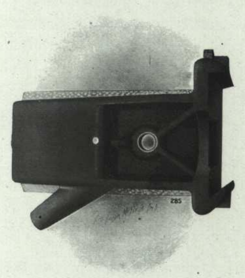
The sliding members call for exceptionally careful design to provide the rigidity necessary for the heavier classes of milling, rapidly developing. The amount of power given the driving mechanism must of necessity be proportioned to the strength of the knee, saddle and table assembly.

The Knee



The knee is an exceptionally rigid box section casting, every stress incident to the heaviest milling being provided for.

The column bearing is extended practically to the table working surface to furnish support where it is most needed to resist deflection. The heavy internal ribbing provides against collapsing pressures and absorbs all twisting strains. The ribbing divides the knee into a series of box section compartments of unusual strength. The inverted view shows the ribbing in support of the vertical thrusts. These features, in connection with the gib construction, effectually eliminate any possibility of vibration.

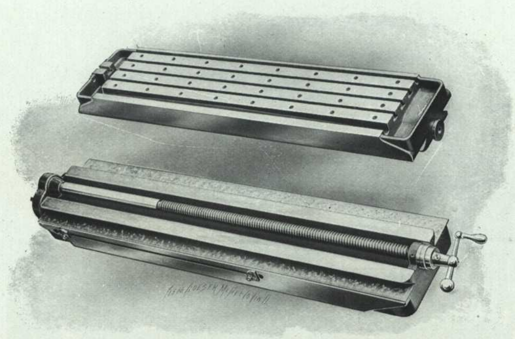


Sliding sheet steel covers protect the mechanism from chips and dirt at all times. The openings are reduced to the smallest permissible area and are placed in neutral sections so that they in no way impair the strength of the member.

The generous bearing surfaces and massive high power design furnish a striking example of the rigidity that characterizes the entire line. Accurate milling can only be done on a miller with a knee of this character.

The Table

The tables of these millers are subject to heavy stresses, due to the class of service for which they are intended. This has been well considered in the design, as evidenced by the liberal bearing surfaces, the width and great vertical depth, to resist deflection in carrying work of increased weight.



They are made of a steel mixture to increase the tensile value of the metal around the T-slots and secure a tough, close-grained metal. The slides are wiped by felt oil pads in the saddle. The slide bearing is taken at the top of the dovetail and is the full width of the table.

A valuable provision is the holes for stop plugs similar to the practice of planer builders. They provide a degree of convenience in clamping not to be overlooked in the selection of a heavy manufacturing miller, as in many cases locating fixtures can be dispensed with.

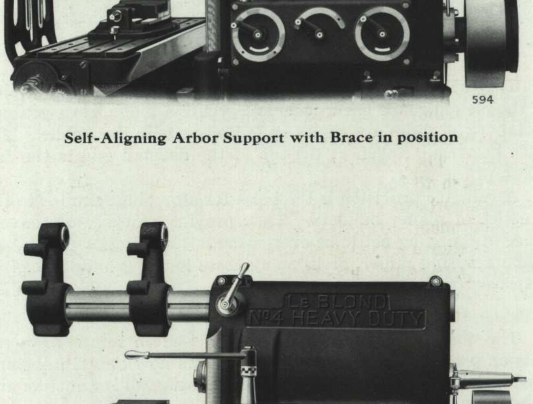
The Saddle

The massive proportions are easily seen on reference to the cuts on preceding pages. This also shows how the trip dog and feed clutch are directly connected, eliminating all lost motion and insuring accurate tripping. Heavy arch ribs at frequent intervals in the length, brace it against twisting strains.

The saddle occupies as little vertical space as is consistent with the necessary rigidity. Adjustment for wear between saddle and table is provided for by a long taper gib. This gib is made with a tongue to resist any tendency to lift.

The two parts of the swivel saddle on the Universal machine are effectively clamped by three large T-slot bolts in a circular T-slot near the outside of the swivel, rendering them practically a unit. The large diameter of swivel base is graduated to half degrees for angular settings.

Self-Aligning Arbor Support with Brace in position



The Arbor Supports thrown up out of the way

SELF-ALIGNING ARBOR SUPPORTS

The question of strength of the overhanging arm has never been a serious difficulty in the design of the better type millers. It is readily made large enough, as evidenced in our design, to resist the severe strains resulting from the heavier milling practice. The matter of arbor alignment and its permanency under heavy cut, however, has been the subject of considerable study. Our design always called for the introduction of heavier arbors and overhanging arms, and by far the most radical step in advance of practice towards their better support, is the development of the aligning device illustrated, by means of which the Arbor, Spindle and Overarm are automatically brought into correct alignment. They provide a rigid key relation between these parts that were formerly secured by friction clamping only.

Cuts that were formerly taken with a brace in place are now accomplished without it, and with the brace in position it opens up new possibilities for heavier milling.

The column and both arbor supports are provided with aligning plugs. The plug in the column fixes the relation of the slot in the overarm to the spindle center. The aligning plugs in the arbor supports then fix the arbor center in relation to the machine alignment. After the arbor is centered by the taper aligning plugs they are then drawn to a firm seat, keying the mechanism rigidly to resist the thrusts. The effect is that of a triangle frame with a wide base; when the brace is in position this frame is double trussed.

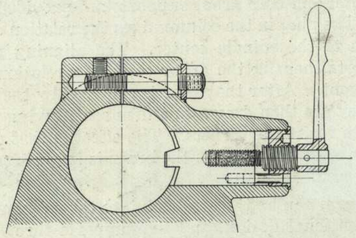
The overarm can be thrown back into the column as easily as on the conventional design, and the supports thrown up out of the way, as shown in the illustration opposite.

The lugs, as will be seen on reference to the sectional view, are bored to permit of extra large plugs. These plugs are hardened and ground.

The slot in the overarm is made with a straight and a taper side, the taper drawing the overarm down to a seat on the flat side of the plug. This insures accurate indexing, as the straight side of the slot is lined up with the spindle center and the arbor supports bored and reamed in position. The screws for setting these plugs are made with two threads of coarse leads and opposite hands. One thread being stationary and the other movable, gives the advantage of the leads of both threads acting in the same direction, providing means of quick removal and insertion of the aligning plugs. The smaller diameter screw forces the plunger in, the large screw feeds itself into the nut with the same motion, giving a double screw action with a very small movement of the handle.

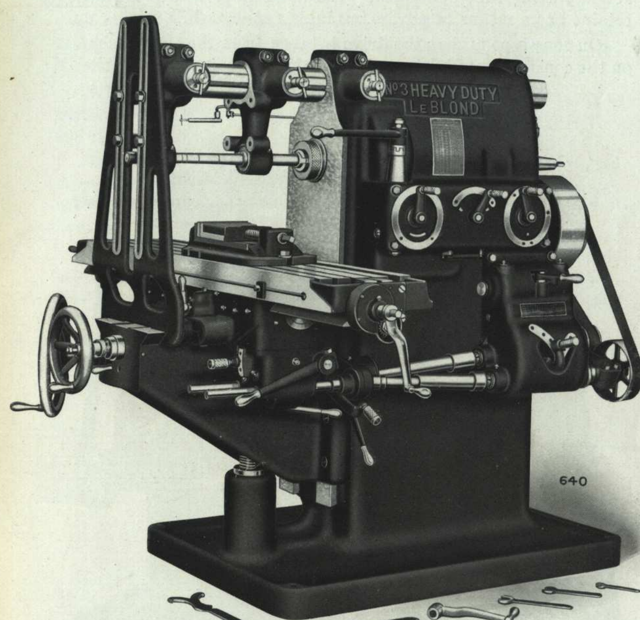
The column is split in front and rear, and provided with binder studs for clamping the overarm. These studs are made with a shoulder and set up to maintain an easy sliding contact between the column bore and overarm. The overarm can then be clamped and released at will without disturbing the tension of this stud.

The importance of this device on a milling machine for heavy service can hardly be overestimated. The arbor can not possibly run out of line and is supported in such a manner as to render the overarm, arbor, column and knee practically a unit for the support of the cutter, greatly prolonging the productive life of the machine.



Sectional View Through Aligning Plug

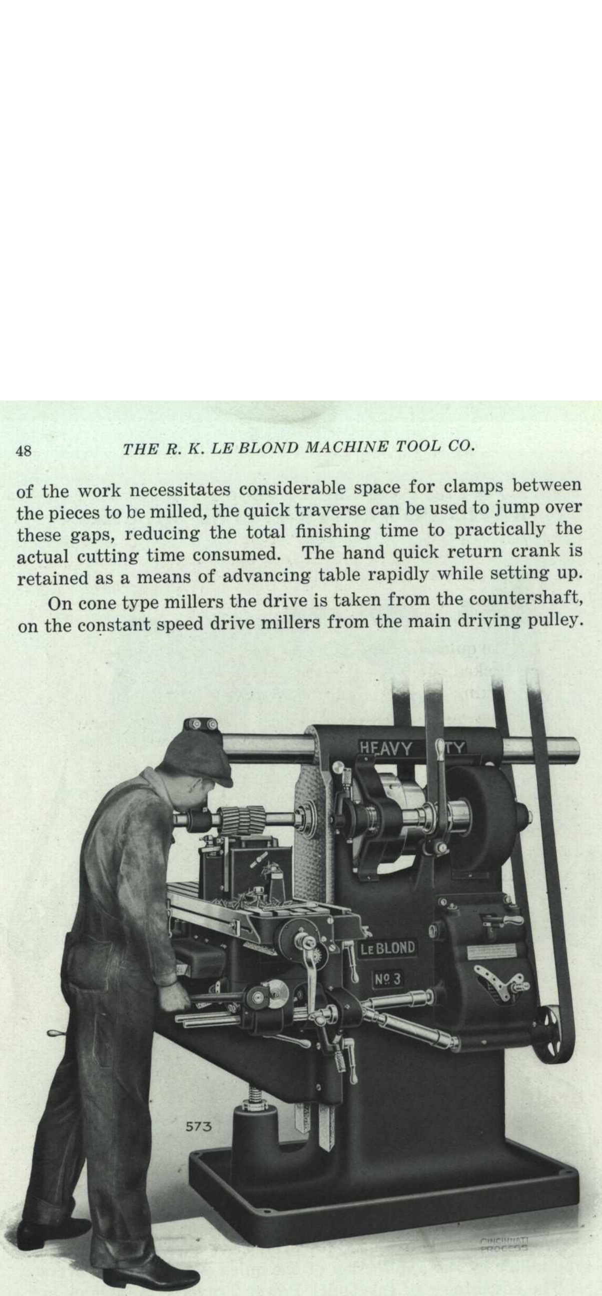
RAPID POWER TRAVERSE MILLERS



We have greatly extended the productive capacity on the knee type miller by the application of the quick power table traverse.

The advantages of this Quick Power Traverse to table on any class of milling is apparent at a glance. After long cuts the table can be returned at the rate of 25 feet per minute without exertion on the part of the operator. In string milling, where the nature of the work necessitates considerable space for clamps between the pieces to be milled, the quick traverse can be used to jump over these gaps, reducing the total finishing time to practically the actual cutting time consumed. The hand quick return crank is retained as a means of advancing table rapidly while setting up.

On cone type millers the drive is taken from the countershaft, on the constant speed drive millers from the main driving pulley.



The Quick Traverse Lever is Shown in the Operator's Grasp

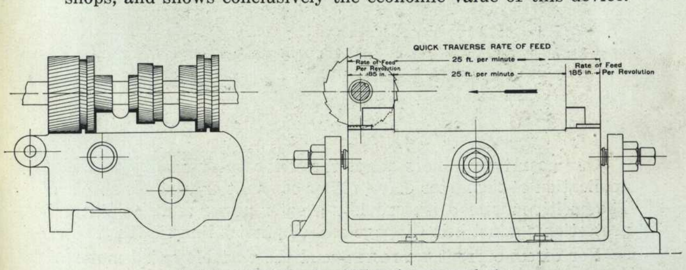
The Quick Traverse is built into the feed mechanism and becomes an integral part of the machine. It is driven independently of the regular feeds from a separate pulley on the countershaft calculated to give a speed of 25 feet per minute. The regular feeds in no way affect the rate of the quick traverse, which is always constant, after the design of the Rapid Traverse on the Turret Lathe.

When the quick traverse is thrown in the regular feed is automatically kicked out. A hardened point spring plunger prevents the feed picking up accidentally, safeguarding the machine.

When the quick traverse lever is released it automatically comes into neutral position, with all gears out of mesh, the operator simply engaging the feed clutch to start the working feed again.

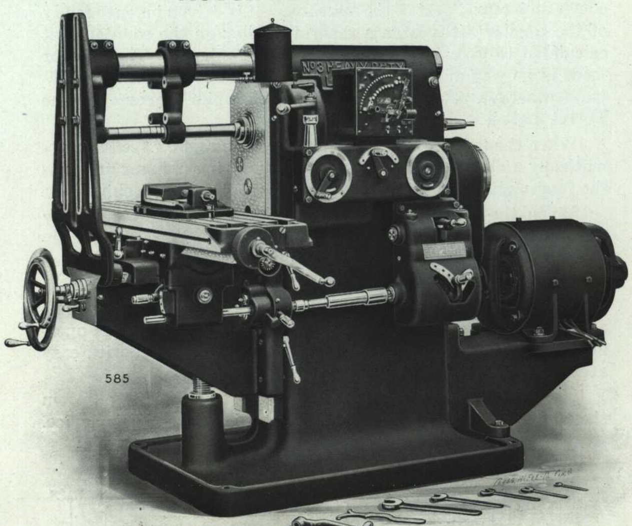
It will be noted that the quick traverse is on the right or operating side of the machine and located conveniently for the operator, who is shown in his natural operating position, with easy access to the entire mechanical control.

The line cut below is drawn from actual practice in our own shops, and shows conclusively the economic value of this device.



Actual cutting feeds, .185 inch per revolution
Between cuts, rate of feed, 25 feet per minute
Return table, 25 feet per minute

MOTOR DRIVEN MILLERS



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Our gear type millers adapt themselves very readily to the application of the motor drive, either constant or variable speed. The positive motor drive provides greater power and flexibility, protection against belt slippage and eliminates line shafting.

For direct current we recommend the variable speed motor, as it somewhat simplifies the gear trains, as we omit the first run of sliding gears securing the base speeds electrically. The constant speed D. C. Motor, however, is applied at the customer's option.

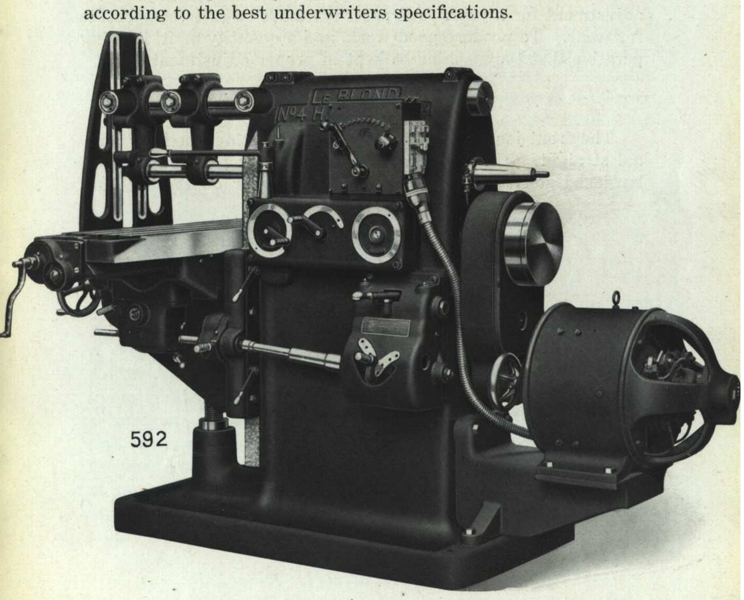
For the alternating current motor drive we maintain the full range of mechanical gear changes.

The electrical equipment on the D. C. variable speed drive consists of a non-reverse dial type controller. For D. C. constant

speed drive, a slate front starting panel is furnished. For Alternating Current drive a starting compensator is provided. The motors are attached as shown in the illustration on the preceding page, the motor becoming practically an integral part of the machine.

The space occupied by the motor is available for no other purpose, as it must be kept open to throw the overarm back. Our method of mounting eliminates the chain drive found in other designs. The driving pulley is replaced by a large driving gear, with a friction clutch in its periphery. The drive is through large spur gears, and a rawhide intermediate gear. The intermediate gear is mounted on a heavy stud pressed directly into the column. Provision for the stud is made on all machines so that the motor can be attached at any time, at a very slight cost.

Whenever possible, they are wired complete in metal conduit, according to the best underwriters specifications.



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CARE AND ADJUSTMENTS OF MILLING MACHINES

It is assumed that the proper care and judgment has been exercised in the selection of type of machine best adapted to the class of work to be done.

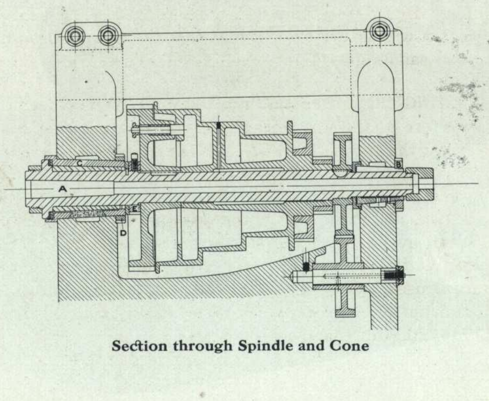
The following facts should be firmly impressed upon the operator: The life of any machine, as well as the efficiency and the ease with which it is manipulated, will depend in a large degree on the care bestowed upon it. Each part should be kept clean, well lubricated and every movable part kept in proper adjustment for accurate work.

The possibilities of neglecting these parts are largely minimized in our design by the ease with which the adjustments are made and the efficient lubricating facilities provided.

Our Milling Machines are properly adjusted and carefully inspected before leaving the shop, and should not require re-adjustment for a year. All parts are made so as to compensate for wear. To produce good work, and a quantity of it, it is imperative that the machine be kept in proper adjustment.

Cone Type Millers

The front journal of spindle is made tapering, the back journal straight. The thrust is taken at front end of spindle by a hardened steel and babbitt collar. The wear on these collars



Section through Spindle and Cone

will be in proportion to the wear on the spindle, and when adjusted back to fit the box, will come to a proper bearing on the end thrust.

TO ADJUST THE FRONT JOURNAL — Draw the spindle back into box by tightening nut E. This nut is directly on the spindle and draws the spindle back into the box. There should be a small space between the nut and face gear.

TO ADJUST THE REAR JOURNAL — Tighten the nut B; this draws the taper bronze bush back into the column, compressing it on the spindle. The adjustment of spindle will not interfere with the alignment of the machine.

TO ADJUST THE END MOTION OF TABLE AND CROSS FEED SCREW — These screws run in a bush screwed into the table and saddle; by removing the graduated collar on the screw, a nut is exposed to view; tightening this nut will take up the end motion of the screw between its bearings. Care should be taken that the nut is securely fastened after adjustment. The table gib is made tapering and is supplied with a tongue at the lower edge, to keep it from lifting; it is adjusted longitudinally by screws, which securely lock it for end movement. With this style of gib we secure a metal to metal bearing. The gib being securely fastened, can not raise or move when the table is at the extreme position. By this method we secure freer table movement, avoiding cramp occasioned by movement of the gib. To adjust the knee and saddle gibs, tighten the large fillister head screws.

LOCKING THE DIFFERENT MOVEMENTS of the machine does not interfere in any way with the gib adjustment, and is accomplished by the locking handles. In accurate work, see that all movements not in use are securely locked; this greatly stiffens the machine. Place the cutter as close to the body of the machine as possible. Use the braces and supports on the overhanging arm for heavy work. Two supports are furnished. If cutters are used at the extreme end of a long arbor, see that both supports are used. The knee brace can be reversed, giving maximum amount of cross movement when brace is used. It can be bolted to either of the arbor supports.

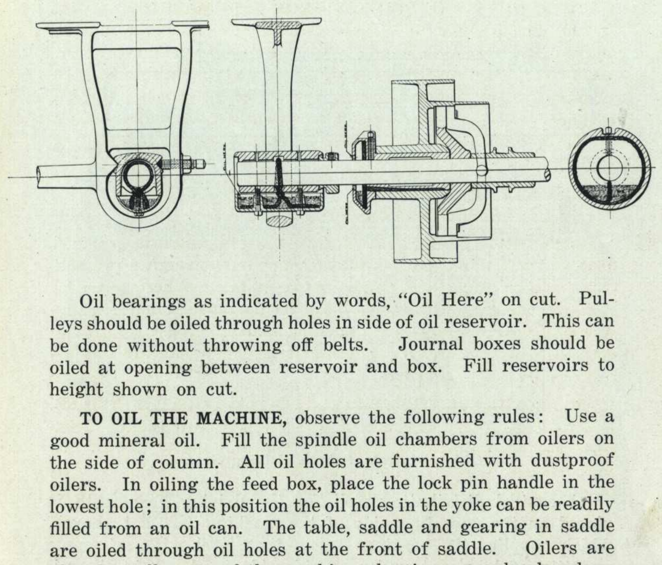
TO REMOVE THE SPINDLE FROM THE MACHINE — Take off the nut carrying the arbor extracting rod, unscrew nut E, and this will force the spindle out. Care should be taken of the last two or three threads by tapping the end of the spindle with a piece of babbitt or soft metal, so that the nut can be removed without forcing. When this nut is clear, the spindle can be drawn from the machine. The nut must be raised to clear the spindle key.

Instructions for Setting Up

ERECT MILLER ON A GOOD FLOOR — It is essential that the floor should be free from vibration and stiff enough so that it will not give under the weight of the miller. Where possible, stone or concrete foundation will answer the purpose much better. When leveling, use only solid packing under the base. Level in both directions, using an accurate level. See that the column rests securely on all corners.

PLACE THE COUNTERSHAFT DIRECTLY OVER THE MILLER — This is necessary in order to have the belt clear the overarm. Have the countershaft in line with the line shaft. When the hangers are securely tightened, countershaft should revolve freely. Place the thrust collars so that the shaft has one-eighth inch end play. The pulleys also should have one-sixteenth inch end play on the bush — this end play helps distribute the oil. Place pulley for slow speeds next to driving cone. Both pulleys should run in the same direction — this will double the spindle speeds, also give a quick change without shifting the belt.

COUNTERSHAFT PULLEYS CAN BE OILED without throwing off the belt, and should be oiled once a week. The journal boxes are self-oiling and the reservoir should be filled to oil hole. If the shaft has been removed, care should be taken to have wicking properly replaced in the boxes and threaded around the shaft.

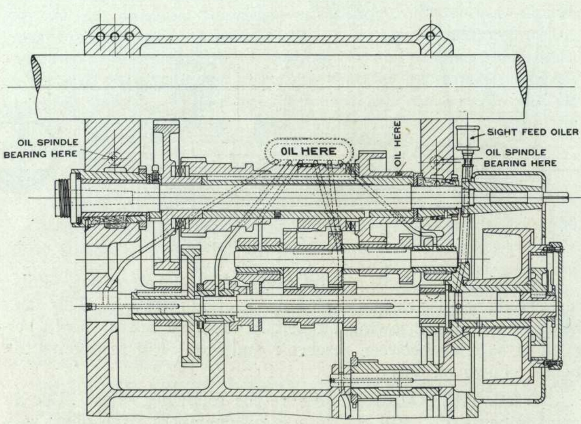


Oil bearings as indicated by words, "Oil Here" on cut. Pulleys should be oiled through holes in side of oil reservoir. This can be done without throwing off belts. Journal boxes should be oiled at opening between reservoir and box. Fill reservoirs to height shown on cut.

TO OIL THE MACHINE, observe the following rules: Use a good mineral oil. Fill the spindle oil chambers from oilers on the side of column. All oil holes are furnished with dustproof oilers. In oiling the feed box, place the lock pin handle in the lowest hole; in this position the oil holes in the yoke can be readily filled from an oil can. The table, saddle and gearing in saddle are oiled through oil holes at the front of saddle. Oilers are placed in all parts of the machine, showing very clearly where oil is required. The machine and countershaft should be thoroughly cleaned and oiled and let run thirty minutes under careful inspection to see that all parts run properly.

Constant Speed Drive Geared Millers

While the general characteristics of both types of our millers are the same, the oiling arrangement of the gear trains may require some slight explanation. The erection instructions, page 53, holds good on both types. The constant speed belt driven millers are generally driven direct from the line shaft; however, when this arrangement is not feasible, a jack shaft can be furnished that the machine may be located independent of the main line shaft drive.



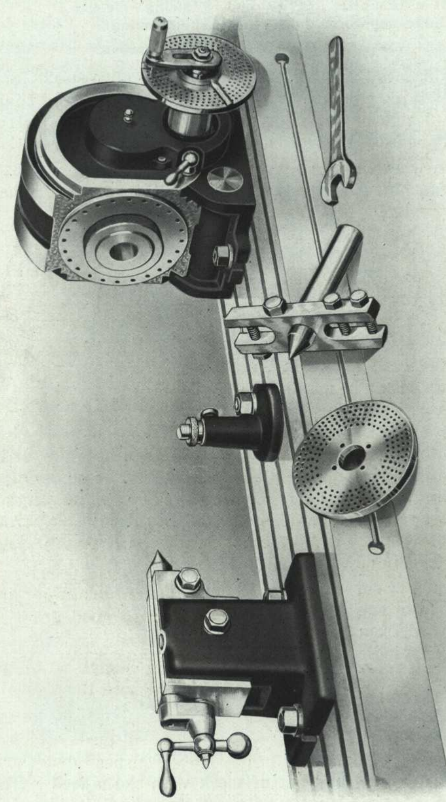
Oiling Diagram, Spindle Driving Gears

A central distributing well for the driving gear train is placed on the operating side of the machine (see cut above), which supplies the bearings below that level with an ample quantity of lubricant under considerable head. This oil well should be supplied daily.

The oil chambers for the spindle bearings are dustproof and should be filled every two or three days with a good grade of mineral oil.

The spindle sleeve is chambered and holds enough oil to last several days. An oil plug clearly indicates where the sleeve is to be filled.

The main driving pulley is carried on an oil bush, which is supplied from a sight feed oiler, that also furnishes lubricant to friction driving clutch. This oiler is constantly in view of the operator and there is little chance of it being neglected.



LeBLOND 15" "UNIVERSAL DIVIDING HEAD"
With Plain Equipment

THE LeBLOND UNIVERSAL DIVIDING HEAD

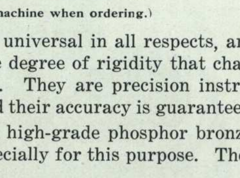
(Built in three sizes, 11″, 13″ and 15″ swing—the size indicating the diameters the head will swing.)

(Give construction number of machine when ordering.)

The dividing head is absolutely universal in all respects, and furnishes a striking example of the degree of rigidity that characterizes the design of our millers. They are precision instruments in every sense of the word and their accuracy is guaranteed.

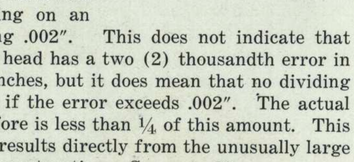
The Dividing Worm Wheel

The worm wheels are cut from high-grade phosphor bronze, hobbed on a machine developed especially for this purpose. They are mounted centrally between the front and rear journals, pressed on the spindle and keyed, to insure positive indexing. Each wheel is hobbed on its own spindle, from which it is never removed. The degree of accuracy resulting from the practice is clearly shown in the test sheet, page 112. The maximum allowable error indicating on an eighteen-inch circle being .002″. This does not indicate that every LeBlond dividing head has a two (2) thousandth error in a diameter of eighteen inches, but it does mean that no dividing head can leave our shop if the error exceeds .002″. The actual error in the worm therefore is less than 1/4 of this amount. This high degree of accuracy results directly from the unusually large worm wheel used in our construction. See page 66.



The Worm and Shaft

The worm and worm shaft are made in one piece and turned from a high carbon spindle steel bar. The shaft is carried in an eccentric sleeve, with a bearing at both ends, which furnishes means for throwing the worm in and out of mesh with the wheel. The sleeve carries a sector on its rear end in which is placed a stop screw to govern the meshing of the worm and wheel, and enables the operator, after once setting the worm, to throw it



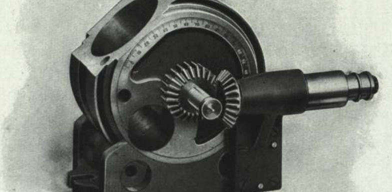
out of mesh for direct indexing and bring it back to the correct point of engagement without further adjustment, or possibility of error. The stop screw is adjusted to make the point of engagement exactly perpendicular to the axis of the wheel. The movement of the eccentric is laid out so that it acts practically in a true vertical direction and co-relative with the thrust adjustment of the spindle, insuring the correct meshing of the worm and wheel even after long and continuous service. The end thrust is absorbed against hardened and ground thrust collars with oil grooves to provide for lubrication.

The Spindle

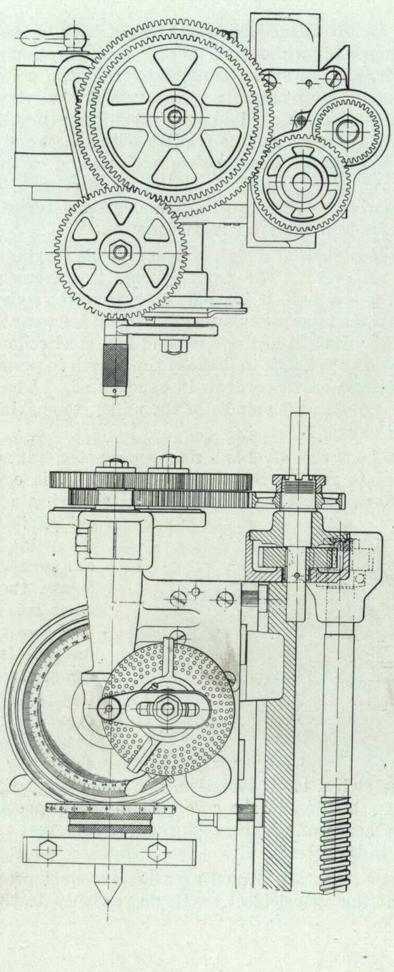
The spindle is made of a high carbon crucible forging finished and ground all over. The front journal is extremely large, minimizing the strains. It journals directly in the swivel block and is made with a taper, providing adjustment for wear. Thrust is provided for by hardened and ground tool steel collars. The spindle is made with a hole in it the entire length to permit work to be passed through it, or draw-in chuck used. The nose is threaded the same as the spindle of the miller, to enable chucks, etc., to interchange.

The Swivel Base

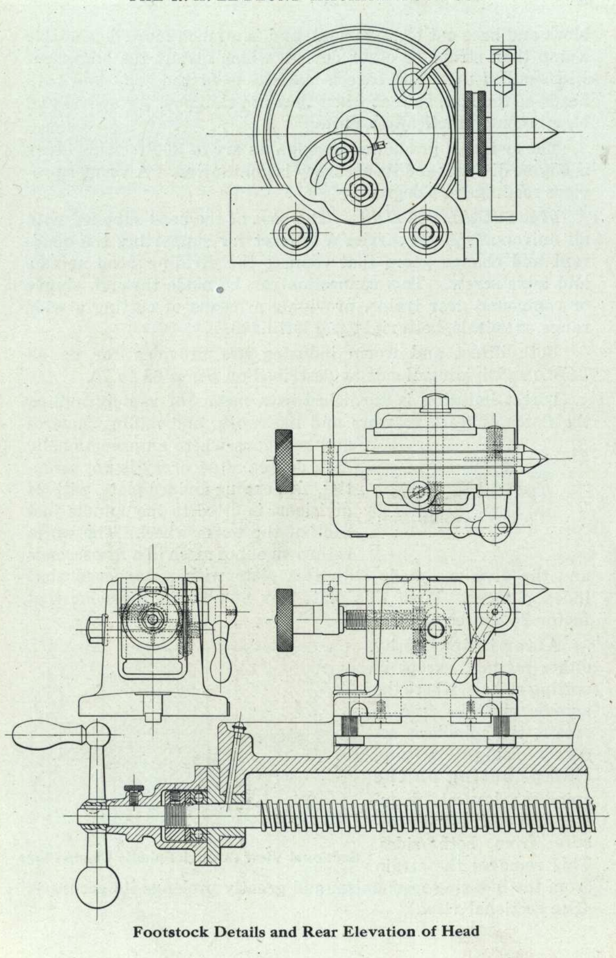
The main body or swivel is a single-piece steel-mixture casting, jig-bored to receive the various parts. It is completely circular in form, except on the front side, which has a segment cut off to increase the swing between centers and decrease the height when set in a vertical position. A dovetail is turned completely around the swivel for clamping to the base. The base is accurately bored to jig to fit the swivel block trunnion, and the main body of the swivel takes a bearing in the case. Clamping is accomplished by bolts, the heads of which are turned to the exact radius of the dovetail in the swivel.



The clamp plugs are drawn up with an equal pressure on both sides of the swivel block, with no tendency to throw the



Side and End Elevations Universal Spiral Cutting Head



Footstock Details and Rear Elevation of Head

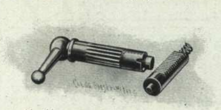
block and base out of alignment, and is a much more dependable clamp than straps or other devices which distort the alignment when pulled up. The base is reamed to fit the body and both heads of the bolt, so that when they are clamped, the swivel and base become practically a unit.

The swivel is graduated through an arc of 200°. This index is engine divided, and its accuracy is guaranteed. A vernier provides readings to 5 degrees.

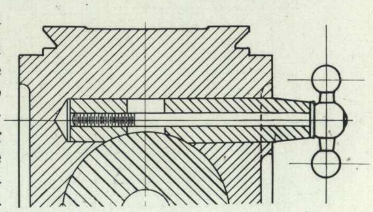
FOR SPIRAL CUTTING — The base of the head supplied with all universal millers carries a bracket for supporting the quadrant and change gears that connect the dividing head spindle and table screw. This connection can be made through simple or compound gear trains, providing a means of cutting a wide range of spirals, both right and left hand.

Both direct and worm indexing are provided for on all LeBlond Dividing Heads as described on pages 68 to 70.

Direct indexing is furnished as a means of rapidly milling the flutes of taps, reamers and like work, and milling squares and hexagons where an exceptionally high degree of accuracy is not essential. An engine divided plate, with 24 divisions, is fitted to the spindle just back of the worm wheel. The worm is thrown out of mesh in a few seconds and the divisions made with this plate with a hardened steel index plunger. With this plate any number of divisions that factor 24 can be cut.



After indexing by either method, except in cutting spirals, where the spindle must be free to rotate, the spindle is securely clamped by plug clamps acting on the spindles' largest diameter and with equal pressure from both sides. This removes the strain from the indexing mechanism and greatly prolongs its accuracy. (See sectional view.)



Sectional View through Spindle Clamp Plugs

The Footstock

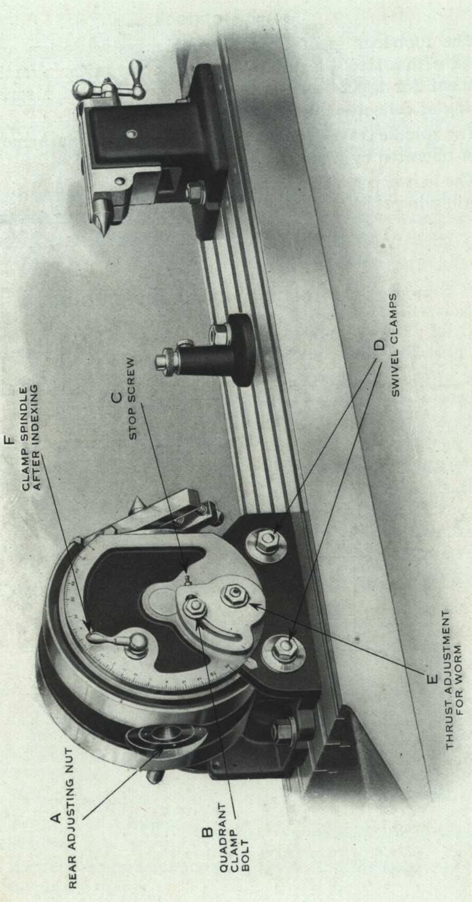
The footstock is of proportionate massive design and furnished with a steel tongue to locate it on the table. Vertical adjustment for taper work is provided by means of a screw permitting of delicate adjustment.

The spindle travels longitudinally by means of an Acme thread screw operated by a knurled knob at the rear end.

The barrel is split and provided with a clamp bolt which locks it rigidly in position to resist the thrust of the cutter.

SPECIFICATIONS UNIVERSAL DIVIDING HEAD

Size of Head	Universal Machine where Regularly Furnished	Swing	Taper in Spindle B. & S.	Spindle Nose Diameter	Length of Head and Foot Stock Combined	Diam of Worm Wheel	WEIGHT With Quadrant and Change Gear	WEIGHT Without Quadrant and Change Gear
11″	No. 1	11⅛″	No. 10	3″x 5Thd.	20⅞″	4½″	205	160
11″	No. 1½	11⅛″	No. 10	3″x 5Thd.	20⅞″	4½″	205	160
11″	No. 2	11⅛″	No. 10	3″x 5Thd.	20⅞″	4½″	205	160
11″	No. 2½	11⅛″	No. 10	3″x 5Thd.	20⅞″	4½″	205	160
13″	No. 3	13⅛″	No. 11	3¼″x 5Thd.	22½″	5 15/16″	285	230
15″	No. 4	15¼″	No. 12	3¾″x 4Thd.	26½″	7⅝″	410	330



THE CARE OF THE DIVIDING HEAD

Though our dividing heads are built for rugged service, they are precision instruments and should be treated as such. The more intelligent attention they receive the more dependable will be the results obtained.

None of the parts upon which the accuracy of the dividing mechanism depends are exposed to the action of dirt or chips.

The swivel can be turned through an arc of 200 degrees, 10 degrees below the horizontal center line on either side. NO PART OF THE HEAD IS TO BE REMOVED TO SECURE THIS RANGE.

Simplicity gives the LeBlond head a great advantage over other designs. All of the adjustments are made from the outside and with standard wrenches. The main parts can be removed and replaced in a very few minutes.

The swivel block is graduated to degrees and provided with a vernier providing for readings to one-twelfth degree.

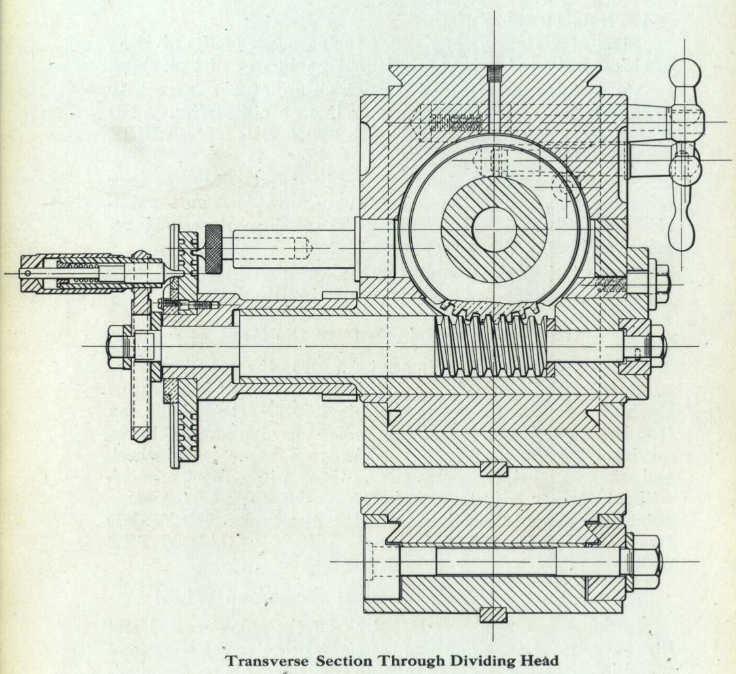
To Remove Spindle from the Head

Take off the rear adjusting nut A. Drop the worm from engagement with the wheel. To do this, loosen the nut B at rear of the head and turn the worm shaft to LEFT. The spindle can then be removed from the swivel block. The stop screw C in the quadrant, governs the point of mesh between the worm and wheel, and when once set, the worm can be thrown in and out of mesh without further adjustment, always coming back to the same point of engagement on the axis of the wheel. BE SURE AND BRING THE SHAFT BACK TO A FULL STOP AGAINST THE SCREW.

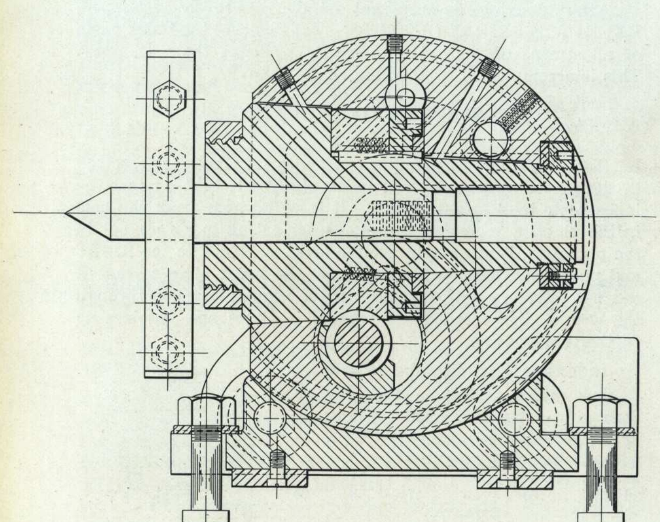
To Adjust for Wear Between Worm and Wheel

Unclamp quadrant bolt B. Back off the stop screw C and turn eccentric sleeve slightly to the *right*, bringing the worm and wheel into closer relation to take up the lash. Clamp the quadrant and reset screw C. Care should be taken not to jam the worm into the wheel too tight. There should be a smooth sliding action between the worm and wheel.

Take up wear in the spindle by the adjusting nut A at the rear. DO NOT PULL THIS NUT UP TOO TIGHT.



Transverse Section Through Dividing Head



"Longitudinal Section" Through Head

Take up thrust in the worm shaft by tightening nut E. This pulls the shaft up to a fit between two hardened and ground thrust collars.

The head should be oiled regularly with a good grade of mineral oil. Oil plugs indicate clearly where lubricant should be injected to reach each journal. The worm and wheel are enclosed in a chamber holding a quantity of oil.

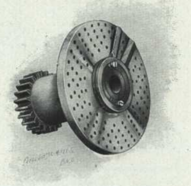
After indexing, be sure that spindle is securely reclamped, EXCEPT IN SPIRAL CUTTING. This relieves the index parts of all strains of the cut and greatly prolongs their accuracy. This is accomplished by the plug clamp lever F.

SYSTEMS OF INDEXING

Direct

First throw the worm out of mesh with the wheel, as described in the preceding pages. The index plunger is kept against the index plate by a spiral spring. It is withdrawn from the hole in the plate by means of a pinion lever acting in a rack cut in the plunger. When not in use the lever is turned to the **RIGHT** and pulled out, locking it away from the index plate so that it can not interfere with indexing in the regular manner through the worm. The method of indexing is direct and requires no further explanation.

Indexing Through the Worm



Two index plates, each drilled on both sides, are furnished. They are drilled as follows:

	A Plate.				
1st side......34	39	46	51	58	
2d side......36	41	47	53	60	
	B Plate.				
1st side......37	42	48	54	62	
2d side......38	43	49	56	66	

With these plates all numbers to and including 58 can be divided. Even numbers to 100, and many numbers to 360.

Page 71 shows a facsimile of the chart that accompanies each dividing head.

The relation between the worm and wheel is as 1 to 40; the worm has a single thread and the wheel has 40 teeth. In other words, 40 turns of the worm crank will rotate the spindle one revolution; 20 turns, one-half revolution, and 80 turns, 2 revolutions.

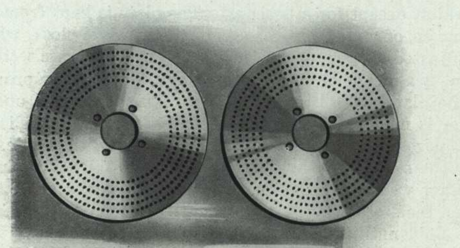
When the work is to be divided into four divisions, the crank will rotate $\frac{1}{4} \times 40$ or 10 revolutions, and any circle of holes can be used, as 40 is exactly divisible by four, making 10 complete turns.

If three divisions are to be made, a circle of holes exactly divisible by 3 is selected, e. g., 66 holes. The number of turns given the worm crank is then 40 divided by 3, or $13\frac{1}{3}$ turns, or, in other words, 13 turns and 22 holes on the plate having 66 divisions. This explanation of the principles involved, and the charts accompanying the head, greatly simplify the operation of the head, and the charts render calculation unnecessary to the operator, except for a "check." The plate is kept from rotating by means of a stud projecting from the swivel block, which may be adjusted to engage any circle of holes. The brass sector blades serve as a means of quickly directing the eye to the proper holes in the plate after they have once been determined upon. The sector is made with two independent arms, one to indicate complete revolutions, the other fractional parts of the circle. In setting the sector, do not count the hole in which the plunger is; in other words, for 15-hole spacing there should be 16 holes between the sector blades. The length of the crank arm is adjustable for length to engage any of the circles of holes. ALL OF THE DIVISIONS CAN BE MADE WITH THE HEAD SET AT ANY ANGLE. **Using the Sector**

The range of divisions by these two plates covers all practical commercial requirements, and very few shops have need for any other method of obtaining divisions. However, by means of differential indexing and high number index plates, many other divisions are obtainable. On all spiral cutting Universal Heads, differential indexing is provided for, *regularly* embracing all divisions to 360.

There is one point in connection with all systems of indexing involving gears between index plate and spindle, that requires attention. Owing to worn gears, inaccuracy of setting or some other cause, there is often likely to be some backlash in the gears, which can not always be avoided. Now, if in indexing, the index handle be always revolved in the same direction, this backlash is taken up before starting and thereafter makes no difference, but if, at any time, the motion of the handle be reversed, this backlash at once enters into the effectual movement **Back-Lash** of spindle. For this reason, in moving the index pin from one hole to another, let it approach its hole slowly, and as soon as it reaches it, drop it in. DO NOT LET IT PASS THE HOLE AND THEN COME BACK TO POSITION. If it should accidentally pass the hole, turn it backward some distance and then come up to the hole again, THEREBY ALWAYS APPROACHING THE HOLE IN THE SAME DIRECTION.

Special Index Plates



These plates provide for special divisions by the simple indexing method, not obtainable with the plates regularly furnished. The divisions tabulated on the next page are obtained with these plates.

C Plate.					
1st side	61	71	81	91	127
2d side	57	67	77	87	97

D Plate.					
1st side	63	73	83	93	103
2d side	59	69	79	89	99

These plates, in connection with those regularly furnished, give all divisions to and including 100 and many others. A special index handle and pin are furnished to fit smaller diameter of holes with which plate is drilled. Plates drilled with any special number of holes are furnished on order.

TABLE OF SPACING ON PLAIN DIVIDING HEAD

No. Teeth	Circle	Turns	Holes	No. Teeth	Circle	Holes	No. Teeth	Circle	Holes	No. Teeth	Circle	Holes
2	any	20	.....	41	41	40	94	47	20	185	37	8
3	66	13	22	42	42	40	95	38	16	188	47	10
4	any	10	.....	43	43	40	96	48	20	190	38	8
5	any	8	.....	44	66	60	98	49	20	192	48	10
6	66	6	44	45	54	48	100	60	24	195	39	8
7	56	5	40	46	46	40	102	51	20	196	49	10
8	any	5	.....	47	47	40	104	39	15	200	60	12
9	54	4	24	48	48	40	105	42	16	204	51	10
10	any	4	.....	49	49	40	106	53	20	205	41	8
11	66	3	42	50	60	48	108	54	20	210	42	8
12	48	3	16	51	51	40	110	66	24	212	53	10
13	39	3	3	52	39	30	112	56	20	215	43	8
14	49	2	42	53	53	40	115	46	16	216	54	10
15	66	2	44	54	54	40	116	58	20	220	66	12
16	48	2	24	55	66	48	120	66	22	224	56	10
17	34	2	12	56	56	40	124	62	20	230	46	8
18	54	2	12	58	58	40	130	39	12	232	58	10
19	38	2	4	60	42	28	132	66	20	235	47	8
20	any	2	.....	62	62	40	135	54	16	240	66	11
21	42	1	38	64	48	30	136	34	10	245	49	8
22	66	1	54	65	39	24	140	56	16	248	62	10
23	46	1	34	66	66	40	144	54	15	260	39	6
24	48	1	32	68	34	20	145	58	16	264	66	10
25	60	1	36	70	56	32	148	37	10	270	54	8
26	39	1	21	72	54	30	150	60	16	272	34	5
27	54	1	26	74	37	20	152	38	10	280	56	8
28	42	1	18	75	60	32	155	62	16	290	58	8
29	58	1	22	76	38	20	156	39	10	296	37	5
30	48	1	16	78	39	20	160	56	14	300	60	8
31	62	1	18	80	34	17	164	41	10	310	62	8
32	56	1	14	82	41	20	165	66	16	312	39	5
33	66	1	14	84	42	20	168	42	10	320	48	6
34	34	1	6	85	34	16	170	34	8	328	41	5
35	56	1	8	86	43	20	172	43	10	330	66	8
36	54	1	6	88	66	30	176	66	15	340	51	6
37	37	1	3	90	54	24	180	54	12	344	43	5
38	38	1	2	92	46	20	184	46	10	360	54	6
39	39	1	1									
40	any	1	.....									

SPECIAL DIVISIONS

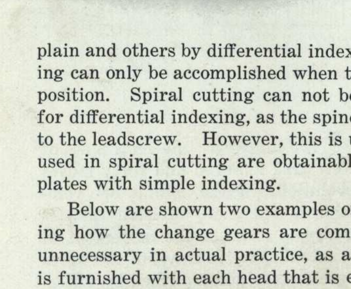
Not Obtainable with the Plates Regularly Furnished with the Indexing and Dividing Head

Number of Divisions	Circle	Holes	Number of Divisions	Circle	Holes
57	57	40	244	61	10
59	59	40	252	63	10
61	61	40	254	127	20
63	63	40	268	67	10
67	67	40	276	69	10
69	69	40	284	71	10
71	71	40	285	57	8
73	73	40	292	73	10
77	77	40	295	59	8
79	79	40	305	61	8
81	81	40	308	77	10
83	83	40	315	63	8
87	87	40	316	79	10
89	89	40	324	81	10
91	91	40	332	83	10
93	93	40	335	67	8
97	97	40	345	69	8
99	99	40	348	87	10
103	103	40	355	71	8
114	57	20	356	89	10
118	59	20	364	91	10
122	61	20	365	70	8
126	63	20	372	93	10
127	127	40	385	77	8
134	67	20	388	97	10
138	69	20	395	79	8
142	71	20	396	99	10
146	73	20	405	81	8
154	77	20	412	103	10
158	79	20	415	83	8
162	81	20	435	87	8
166	83	20	445	89	8
174	87	20	456	57	5
178	89	20	465	93	8
182	91	20	472	59	5
186	93	20	485	97	8
194	97	20	488	61	5
198	99	20	495	99	8
206	103	20	504	63	5
228	57	10	508	127	10
236	59	10	515	103	8

DIFFERENTIAL INDEXING

Furnished on all Spiral Cutting Heads

The differential indexing device consists of an arrangement whereby the spindle and index plate are connected together through change gear trains. The index plate is advanced in relation to the worm crank through the spindle, which divides the movement of the worm, giving all divisions to 360 with the standard index plates furnished. The head is furnished with quadrant and change gears, and the spindle is taper bored on the rear end to receive the driving gear stud. A chart, the fac simile of which is shown following, is furnished, which shows the means of indexing all divisions up to and including 360, obtainable, some by plain and others by differential indexing. The differential indexing can only be accomplished when the head is set in a horizontal position. Spiral cutting can not be accomplished when geared for differential indexing, as the spindle can not then be connected to the leadscrew. However, this is unimportant, as the divisions used in spiral cutting are obtainable through the regular index plates with simple indexing.



Below are shown two examples of differential indexing, showing how the change gears are computed. This computation is unnecessary in actual practice, as a chart giving these divisions is furnished with each head that is equipped with this device.

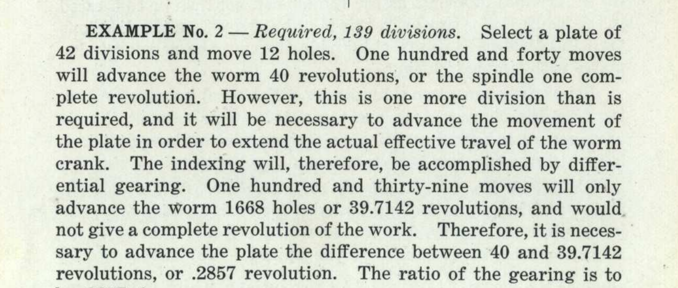
EXAMPLE No. 1 — *Required, 107 divisions.* When using a plate of 60 holes and moving 24 holes for each division with the index plate stationary, 100 moves would advance the worm 40 revolutions or 1 revolution of the spindle. 107 moves would advance the worm $\frac{107 \times 24}{60} = 42.8$ revolutions, which is 2.8 revolutions more than required. Therefore, the gearing must be arranged to retard the plate 2.8 revolutions, while the worm crank makes 107 moves of 24 holes each. Therefore, the total gear ratio will be 2.8 : 1.

$$\frac{2.8}{1} = \frac{2.8}{2} \times \frac{2}{1}$$

$$\frac{2.8}{2} \times \frac{20}{20} = \frac{56}{40}$$ — 1st gear on quadrant (driver). / gear on worm (driven).

$$\frac{2}{1} \times \frac{32}{32} = \frac{64}{32}$$ — gear on spindle (driver). / 2d gear on quadrant (driven).

As the gears used are a compound train, an idler is required to move the plate in the opposite direction to the crank, and the gear train is as shown below:

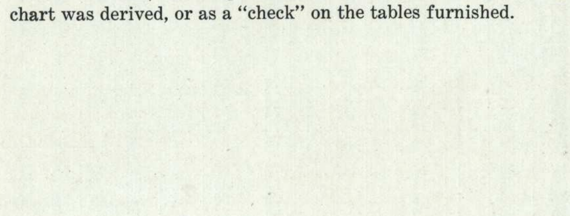


EXAMPLE No. 2 — *Required, 139 divisions.* Select a plate of 42 divisions and move 12 holes. One hundred and forty moves will advance the worm 40 revolutions, or the spindle one complete revolution. However, this is one more division than is required, and it will be necessary to advance the movement of the plate in order to extend the actual effective travel of the worm crank. The indexing will, therefore, be accomplished by differential gearing. One hundred and thirty-nine moves will only advance the worm 1668 holes or 39.7142 revolutions, and would not give a complete revolution of the work. Therefore, it is necessary to advance the plate the difference between 40 and 39.7142 revolutions, or .2857 revolution. The ratio of the gearing is to be .2857 : 1.

$$\frac{2857}{10000} = \frac{2857}{5000} \times \frac{1}{2}$$

A ratio of .5714 : 1 must exist in one pair of gears. Selecting the largest gear, 72 teeth, we find that a mate of between 41 and 42 teeth would be used. This gear is not furnished, so we use a gear of 56 T with a mating gear in the ratio of .5714 : 1 or 32 T. The other gears are as 1 : 2, and we select 24 and 48 T gears.

No idler is used as we wish to advance the plate the *opposite condition* to 1st example, and the gears are arranged as in the train shown.



The calculations are really not necessary, as the chart gives full information, but are given as a means of illustrating how this chart was derived, or as a "check" on the tables furnished.

Table for Spacing on LeBlond Dividing Head

All Numbers—2 to 360

No. of Spaces	Circle	Turns	Holes	Gear on Worm	Gear on Spindle	Idlers	No. of Spaces	Circle	Turns	Holes	Gear on Worm	Gear on Spindle	Idlers
2	Any	20	....	....	....	....	47	47	....	40	....	....	....
3	66	13	22	....	....	....	48	48	....	40	....	....	....
4	Any	10	....	....	....	....	49	49	....	40	....	....	....
5	Any	8	....	....	....	....	50	60	....	48	....	....	....
6	66	6	44	....	....	....	51	51	....	40	....	....	....
7	56	5	40	....	....	....	52	39	....	30	....	....	....
8	Any	5	....	....	....	....	53	53	....	40	....	....	....
9	54	4	24	....	....	....	54	54	....	40	....	....	....
10	Any	4	....	....	....	....	55	66	....	48	....	....	....
11	66	3	42	....	....	....	56	56	....	40	....	....	....
12	48	3	16	....	....	....	57	42	....	30	56	40	2
13	39	3	3	....	....	....	58	58	....	40	....	....	....
14	49	2	42	....	....	....	59	39	....	26	48	32	1
15	66	2	44	....	....	....	60	42	....	28	....	....	....
16	48	2	24	....	....	....	61	39	....	26	48	32	2
17	34	2	12	....	....	....	62	62	....	40	....	....	....
18	54	2	12	....	....	....	63	39	....	26	24	48	2
19	38	2	4	....	....	....	64	48	....	30	....	....	....
20	Any	2	....	....	....	....	65	39	....	24	....	....	....
21	42	1	38	....	....	....	66	66	....	40	....	....	....
22	66	1	54	....	....	....	67	42	....	24	28	48	1
23	46	1	34	....	....	....	68	34	....	20	....	....	....
24	48	1	32	....	....	....	69	60	....	36	40	56	2
25	60	1	36	....	....	....	70	56	....	32	....	....	....
26	39	1	21	....	....	....	71	54	....	30	72	40	1
27	54	1	26	....	....	....	72	54	....	30	....	....	....
28	42	1	18	....	....	....	73	42	....	24	28	48	2
29	58	1	22	....	....	....	74	37	....	20	....	....	....
30	48	1	16	....	....	....	75	60	....	32	....	....	....
31	62	1	18	....	....	....	76	38	....	20	....	....	....
32	56	1	14	....	....	....	77	60	....	30	32	48	1
33	66	1	14	....	....	....	78	39	....	20	....	....	....
34	34	1	6	....	....	....	79	60	....	30	48	24	1
35	56	1	8	....	....	....	80	34	....	17	....	....	....
36	54	1	6	....	....	....	81	60	....	30	48	24	2
37	37	1	3	....	....	....	82	41	....	20	....	....	....
38	38	1	2	....	....	....	83	60	....	30	32	48	2
39	39	1	1	....	....	....	84	42	....	20	....	....	....
40	Any	1	....	....	....	....	85	34	....	16	....	....	....
41	41	....	40	....	....	....	86	43	....	20	....	....	....
42	42	....	40	....	....	....	87	60	....	28	40	24	2
43	43	....	40	....	....	....	88	66	....	30	....	....	....
44	66	....	60	....	....	....	89	54	....	24	72	32	1
45	54	....	48	....	....	....	90	54	....	24	....	....	....
46	46	....	40	....	....	....	91	39	....	18	24	48	2

No. of Spaces	Circle	Holes	Gear on Worm	1st Gear on Quad	2d Gear on Quad	Gear on Spindle	Idlers	No. of Spaces	Circle	Holes	Gear on Worm	1st Gear on Quad	2n Gear on Quad	Gear on Spindle	Idlers
92	46	20	....	....	....	....	....	137	42	12	28	....	....	24	1
93	54	24	24	....	....	32	2	138	42	12	56	....	....	32	1
94	47	20	....	....	....	....	....	139	42	12	56	32	48	24	....
95	38	16	....	....	....	....	....	140	56	16	....	....	....	....	....
96	42	18	28	....	....	32	2	141	54	15	....	48	....	40	1
97	60	24	40	....	....	48	1	142	42	12	56	....	....	32	2
98	49	20	....	....	....	....	....	143	42	12	28	....	....	24	2
99	60	24	50	....	....	20	1	144	54	15	....	....	....	....	....
100	60	24	....	....	....	....	....	145	58	16	....	....	....	....	....
101	60	24	72	24	40	48	1	146	42	12	28	....	....	48	2
102	60	24	40	....	....	32	2	147	42	12	24	....	....	48	2
103	60	24	40	....	....	48	2	148	37	10	....	....	....	....	....
104	39	15	....	....	....	....	....	149	42	12	28	....	....	72	2
105	42	16	....	....	....	....	....	150	60	16	....	....	....	....	....
106	43	16	86	....	....	48	1	151	60	15	32	....	....	72	1
107	60	24	40	56	32	64	1	152	38	10	....	....	....	....	....
108	54	20	....	....	....	....	....	153	60	15	32	....	....	56	1
109	48	18	32	....	....	28	2	154	60	15	32	....	....	48	1
110	66	24	....	....	....	....	....	155	62	16	....	....	....	....	....
111	39	13	24	....	....	72	1	156	39	10	....	....	....	....	....
112	39	13	24	....	....	64	1	157	60	15	32	....	....	24	1
113	39	13	24	....	....	56	1	158	60	15	48	....	....	24	1
114	39	13	24	....	....	48	1	159	60	15	64	32	56	28	....
115	46	16	....	....	....	....	....	160	56	14	....	....	....	....	....
116	58	20	....	....	....	....	....	161	60	15	64	32	48	24	1
117	39	13	24	....	....	24	1	162	60	15	48	....	....	24	2
118	39	13	48	....	....	32	1	163	60	15	32	....	....	24	2
119	39	13	72	....	....	24	1	164	41	10	....	....	....	....	....
120	66	22	....	....	....	....	....	165	66	16	....	....	....	....	....
121	39	13	72	....	....	24	2	166	60	15	32	....	....	48	2
122	39	13	48	....	....	32	2	167	60	15	32	....	....	56	2
123	39	13	24	....	....	24	2	168	42	10	....	....	....	....	....
124	62	20	....	....	....	....	....	169	60	15	32	....	....	72	2
125	39	13	24	....	....	40	2	170	34	8	....	....	....	....	....
126	39	13	24	....	....	48	2	171	42	10	56	....	....	40	2
127	39	13	24	....	....	56	2	172	43	10	....	....	....	....	....
128	48	15	....	....	....	....	....	173	54	12	72	56	32	64	....
129	39	13	24	....	....	72	2	174	54	12	24	....	....	32	1
130	39	12	....	....	....	....	....	175	54	12	72	40	32	64	....
131	60	18	40	....	....	28	1	176	54	12	72	....	....	64	1
132	66	20	....	....	....	....	....	177	54	12	72	....	....	48	1
133	42	12	24	....	....	48	1	178	54	12	72	....	....	32	1
134	42	12	28	....	....	48	1	179	54	12	72	24	48	32	....
135	54	16	....	....	....	....	....	180	54	12	....	....	....	....	....
136	34	10	....	....	....	....	....	181	54	12	72	24	48	32	1

No. of Spaces	Circle	Holes	Gear on Worm	1st Gear on Quad	2d Gear on Quad	Gear on Spindle	Idlers	No. of Spaces	Circle	Holes	Gear on Worm	1st Gear on Quad	2d Gear on Quad	Gear on Spindle	Idlers
182	54	12	72	....	....	32	2	227	49	8	28	64	56	72	....
183	54	12	48	....	....	32	2	228	54	9	24	....	....	48	1
184	46	10	....	....	....	....	....	229	54	9	24	....	....	44	1
185	37	8	....	....	....	....	....	230	46	8	....	....	....	....	....
186	54	12	48	....	....	64	2	231	54	9	32	....	....	48	1
187	54	12	72	48	24	56	1	232	58	10	....	....	....	....	....
188	47	10	....	....	....	....	....	233	54	9	48	....	....	56	1
189	54	12	32	....	....	64	2	234	54	9	24	....	....	24	1
190	38	8	....	....	....	....	....	235	47	8	....	....	....	....	....
191	60	12	40	....	....	72	1	236	54	9	48	....	....	32	1
192	60	12	40	....	....	64	1	237	54	9	48	....	....	24	1
193	60	12	40	....	....	56	1	238	54	9	72	....	....	24	1
194	60	12	40	....	....	48	1	239	54	9	72	24	64	32	....
195	39	8	....	....	....	....	....	240	66	11	....	....	....	....	....
196	49	10	....	....	....	....	....	241	54	9	72	20	40	24	1
197	60	12	40	....	....	24	1	242	54	9	72	....	....	24	2
198	60	12	50	....	....	20	1	243	54	9	64	....	....	32	2
199	60	12	50	20	48	24	....	244	54	9	48	....	....	32	2
200	60	12	....	....	....	....	....	245	49	8	....	....	....	....	....
201	60	12	72	24	40	24	1	246	54	9	24	....	....	24	2
202	60	12	72	24	40	48	1	247	54	9	48	....	....	56	2
203	60	12	40	....	....	24	2	248	62	10	....	....	....	....	....
204	60	12	40	....	....	32	2	249	54	9	32	....	....	48	2
205	41	8	....	....	....	....	....	250	54	9	24	....	....	40	2
206	60	12	40	....	....	48	2	251	54	9	32	44	48	64	1
207	60	12	40	....	....	56	2	252	54	9	24	....	....	48	2
208	60	12	40	....	....	64	2	253	66	10	24	....	....	40	1
209	60	12	40	....	....	72	2	254	54	9	24	....	....	56	2
210	42	8	....	....	....	....	....	255	54	9	24	40	48	72	1
211	48	9	64	....	....	28	1	256	54	9	24	....	....	64	2
212	43	8	86	....	....	48	1	257	49	8	28	64	56	48	1
213	54	10	72	....	....	40	1	258	43	7	32	....	....	64	2
214	60	12	32	64	40	56	1	259	42	6	24	....	....	72	1
215	43	8	....	....	....	....	....	260	39	6	....	....	....	....	....
216	54	10	....	....	....	....	....	261	58	8	48	64	24	72	....
217	42	8	48	....	....	64	2	262	60	9	40	....	....	28	1
218	48	9	64	....	....	56	2	263	49	8	56	64	28	72	1
219	42	8	28	....	....	48	2	264	66	10	....	....	....	....	....
220	66	12	....	....	....	....	....	265	42	6	56	40	24	72	....
221	51	9	24	....	....	24	1	266	42	6	32	....	....	64	1
222	54	9	24	....	....	72	1	267	54	8	72	....	....	32	1
223	43	8	86	40	20	64	1	268	42	6	28	....	....	48	1
224	54	9	24	....	....	64	1	269	60	9	64	32	40	28	1
225	54	10	24	....	....	40	2	270	54	8	....	....	....	....	....
226	54	9	24	....	....	56	1	271	42	6	56	....	....	72	1

No. of Spaces	Circle	Holes	Gear on Worm	1st Gear on Quad	2d Gear on Quad	Gear on Spindle	Idlers	No. of Spaces	Circle	Holes	Gear on Worm	1st Gear on Quad	2d Gear on Quad	Gear on Spindle	Idlers
272	42	6	56	....	....	64	1	317	48	6	64	....	....	24	1
273	42	6	24	....	....	24	1	318	48	6	56	....	....	24	2
274	42	6	56	....	....	48	1	319	58	8	32	56	28	64	1
275	42	6	56	....	....	40	1	320	48	6	....	....	....	....	....
276	42	6	56	....	....	32	1	321	48	6	72	24	64	24	1
277	42	6	56	....	....	24	1	322	46	6	32	....	....	64	2
278	42	6	56	32	48	24	....	323	48	6	64	....	....	24	2
279	54	8	24	....	....	32	2	324	48	6	64	....	....	32	2
280	56	8	....	....	....	....	....	325	48	6	64	....	....	40	2
281	42	6	72	24	56	24	1	326	48	6	32	....	....	24	2
282	43	6	86	....	....	56	1	327	48	6	32	....	....	28	2
283	42	6	56	....	....	24	2	328	41	5	....	....	....	....	....
284	42	6	56	....	....	32	2	329	48	6	64	....	....	72	2
285	42	6	56	....	....	40	2	330	66	8	....	....	....	....	....
286	42	6	56	....	....	48	2	331	48	6	24	48	64	44	1
287	42	6	24	....	....	24	2	332	48	6	32	....	....	48	2
288	42	6	28	....	....	32	2	333	54	6	24	....	....	72	1
289	42	6	56	....	....	72	2	334	48	6	32	....	....	56	2
290	58	8	....	....	....	....	....	335	60	8	24	56	32	64	1
291	60	8	40	....	....	48	1	336	48	6	32	....	....	64	2
292	42	6	28	....	....	48	2	337	43	5	86	40	32	56	....
293	60	8	48	32	40	56	....	338	48	6	32	....	....	72	2
294	42	6	24	....	....	48	2	339	54	6	24	....	....	56	1
295	60	8	48	....	....	32	1	340	51	6	....	....	....	....	....
296	37	5	....	....	....	....	....	341	43	5	86	24	32	40	....
297	60	8	56	....	....	20	1	342	54	6	32	....	....	64	1
298	42	6	28	....	....	72	2	343	60	8	24	86	40	64	1
299	46	6	24	....	....	24	1	344	43	5	....	....	....	....	....
300	60	8	....	....	....	....	....	345	54	6	24	....	....	40	1
301	43	6	24	....	....	48	2	346	54	6	72	56	32	64	....
302	48	6	32	....	....	72	1	347	43	5	86	24	32	40	1
303	60	8	72	24	40	48	1	348	54	6	24	....	....	32	1
304	48	6	24	....	....	48	1	349	43	5	86	....	....	50	1
305	60	8	48	....	....	32	2	350	54	6	72	40	32	64	....
306	60	8	40	....	....	32	2	351	54	6	24	....	....	24	1
307	42	6	32	48	28	72	1	352	54	6	72	....	....	64	1
308	48	6	32	....	....	48	1	353	54	6	72	....	....	56	1
309	60	8	40	....	....	48	2	354	54	6	72	....	....	48	1
310	62	8	....	....	....	....	....	355	54	6	72	....	....	40	1
311	48	6	64	....	....	72	1	356	54	6	72	....	....	32	1
312	39	5	....	....	....	....	....	357	54	6	72	....	....	24	1
313	48	6	32	....	....	28	1	358	54	6	72	32	48	24	....
314	48	6	32	....	....	24	1	359	43	5	86	50	24	72	1
315	48	6	64	....	....	40	1	360	54	6	....	....	....	....	....
316	48	6	64	....	....	32	1								

Change Gears Regularly Furnished

The following Change Gears are regularly furnished with our Spiral Cutting Head and provide practically an unlimited range of spirals covering all commercial requirements:

20, 24, 24, 28, 32, 40, 44, 48, 56, 64, 72 and 86 teeth.

The charts on page 85 show a selected number of leads, the change gear combinations for obtaining them and the set over angles.

Pages 169 to 198 show the full list of leads obtainable on LEBLOND Dividing Head with the change gears regularly furnished.

SPIRAL CUTTING

IMPORTANT NOTE — LEBLOND MILLERS are provided with a table screw having 2½ threads per inch or a lead of .4". This provides practically twice as great a thread bearing as usually found, and gives a much more powerful driving angle to the thread. Ball thrust bearings are provided at both ends of the screw to maintain a constant tension in the screw regardless of the direction of travel.

The dividing heads on all LEBLOND MILLERS are properly placed on the same end of the table as the quick return and the entire working control. This is a very important feature in spiral cutting, as the operator does not walk back and forth the length of the table to index and use the quick return lever. The graduated dial on table screw is only used in the original set-up and is placed on the opposite end of the table.

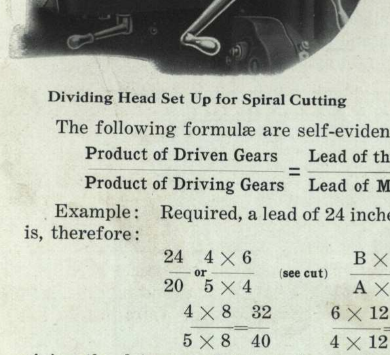
By means of gears connecting the table screw and dividing head the work center is rotated in a mathematical relation to the angle through various gear combinations, and by setting the table over to the proper angle, practically any spiral can be generated.

The normal spiral lead of our miller is 20 inches; that is, with even gears on the head and screw the table advances 20 inches to one revolution of the dividing head spindle or will cut a spiral with a 20-inch lead.

NOTE—It is highly important that the index plate stop pin be withdrawn before starting to cut a spiral. This plate must be free to revolve.

The lead of a milling machine is computed as follows:

The screw has 2½ threads per inch; for each inch of travel of the table the quick return stud, from which the head is driven, revolves twice, since the ratio of the gear on the screw to the gear on the quick return stud is as 24:30.



Dividing Head Set Up for Spiral Cutting

$\frac{24}{30} \times 2\frac{1}{2}$ turns $= 2$ revolutions of the worm per inch of table travel.

Therefore, in one complete revolution of the spindle or forty turns of the worm, the table will travel 20 inches.

Computing the change gears for different leads is a simple operation and accomplished in the same manner as the change gears of a screw cutting lathe.

The following formulæ are self-evident:

$$\frac{\text{Product of Driven Gears}}{\text{Product of Driving Gears}} = \frac{\text{Lead of the Required Spiral.}}{\text{Lead of Machine.}}$$

Example: Required, a lead of 24 inches, the ratio of the leads is, therefore:

$$\frac{24}{20} \text{ or } \frac{4 \times 6}{5 \times 4} \quad \text{(see cut)} \quad \frac{B \times D}{A \times C} = \frac{24}{20}$$

$$\frac{4 \times 8}{5 \times 8} = \frac{32}{40} \qquad \frac{6 \times 12}{4 \times 12} = \frac{72}{48}$$

giving the drivers and driven for the compound train. In factoring and selecting the multiples, the operator should be governed by the necessity for keeping the resulting gears among those furnished with the machine.

This is the basis on which the table (page 85) furnished with the machine was calculated. The gears in each case are the proper combinations to consume the least power. This table shows a number of selected leads that can be cut with standard change gears, and the angular set-over for different diameter blanks. The change gears for any other leads is computed by the foregoing formulæ. In case the proper leads are not obtainable with the regular change gears, special gears can also be computed in this manner.

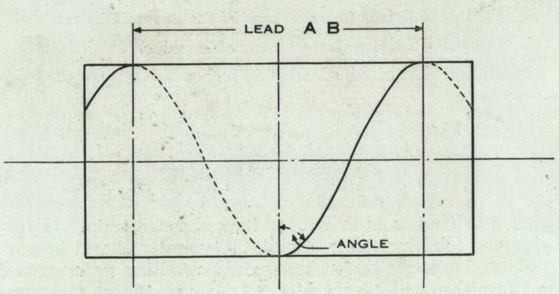
INVERSELY — To determine the lead obtained with a given train of gears:

$$\text{Formula: } \frac{B \times D}{A \times C} \times \frac{20}{1} = \text{lead.}$$

Determining the Angle

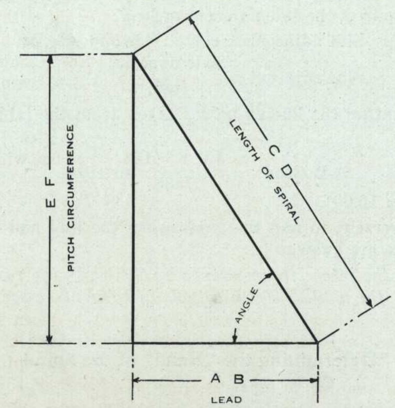
There is a fixed mathematical relation between the spiral angle, the lead and the pitch circumference of the blank. The pitch diameter is, of course, predetermined. If the spiral is short enough the lead can be measured as well; however, this case seldom occurs, as in spiral gears of narrow faces, etc., there is seldom a complete spiral, and it is necessary to compute the lead. To do so, however, the spiral angle must be known.

Example: Assume a blank 4-inch pitch diameter, with a spiral angle of 37 degrees. Required, the lead.

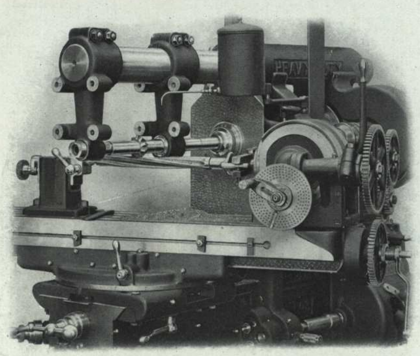


NOTE—Care should be taken to have the center line of the cutter directly on the center line of the dividing head before swiveling the table.

From this we construct the right angle triangle below:



In which A-B corresponds to the lead and E-F to the pitch circumference, and from the relation of the trigonometric functions we derive the following:



Cutting a Long Lead Spiral Three Lip Drill. Milled from the Solid at one Cut. Table Swiveled to Spiral Angle. Geared for Lead through the Worm.

Known, the angle and side opposite or the pitch circumference. Required, the side adjacent or lead:

$$\text{Side adjacent} = \text{cot.} \times \text{side opposite, or}$$

$$\text{Side adjacent} = \frac{\text{side opposite}}{\text{tan.}}$$

Substituting the known values taken from the table of tangents:

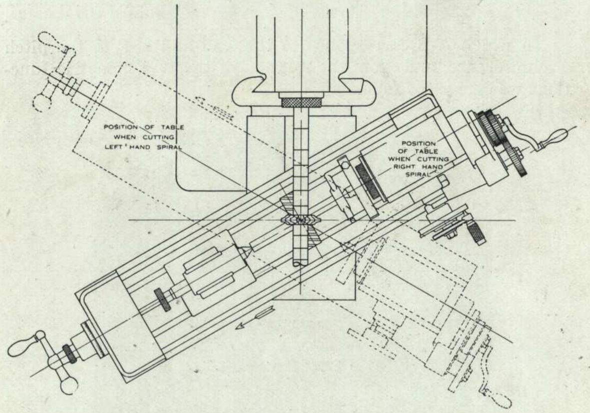
$$\text{A-B (lead)} = \frac{4 \times 3.1416}{.7535} \text{ or } 16.66.$$

Lead = 16.66″.

Or, inversely, to find the angle when the lead and pitch circumference are known:

Divide the pitch circumference by the lead; the result is the tangent of the angle. From a table of tangents, page 208, find the angle.

Determining the "Hand" of the Spiral



It is well to remember that a single idler gear will reverse the direction of rotation of the dividing head spindle. For a left hand spiral *no idler* or *an even number of idlers* are used, for a right hand spiral use a single idler.

Table for Cutting Spirals on LeBlond Milling Machines

FORMULA $\left\{ \frac{B \times D \times 20}{A \times C} = \text{LEAD} \right.$

NOTE—With equal Gears on Head and Screw, Table advances 20 inches to one revolution of the Spindle.

Divide the circumference by the Lead to find the Tangent of the Angle and from a Table of Tangents find the Angle.

A SCREW	B COMPOUND	C COMPOUND	D HEAD	LEAD	DIAMETER OF BLANK TO BE CUT ⅛″	¼″	⅜″	½″	⅝″	¾″	⅞″	1″	1¼″	1½″	1¾″	2″	2¼″	2½″	2¾″	3″	3¼″	3½″	3¾″	4″	4¼″	4½″	4¾″	5″
86	20	72	24	1.55	14	26¾	37¼	45½																				
86	20	72	28	1.81	12¼	23½	33	41																				
86	20	72	32	2.07	10¾	20¾	29¾	37½	43½																			
86	24	72	28	2.17	10	20	28½	36	42¼																			
86	24	72	32	2.48	9	17½	25½	32¼	38¼	43½																		
86	20	72	40	2.58	8¾	17	24½	31¼	37¼	42½																		
86	28	72	32	2.89	7¾	15¼	22¼	28½	34¼	39¼	43¼																	
86	24	72	40	3.10	7¼	14¼	20¾	26¾	32¼	37¼	41½	45																
72	32	64	24	3.34	6¾	13¼	19½	25¼	30½	35¼	39½	43¼																
72	28	64	32	3.88	5¾	11½	17	22	26¾	31¼	35¼	39	45															
72	40	64	24	4.16	5¼	10¾	15¾	20¾	25¼	29½	33½	37	43¼															
72	28	56	32	4.44	5	10	14¾	19½	24	28	31¾	35	41¼															
72	48	64	24	5.00	4½	9	13¼	17½	21½	25¼	28¾	32	38	43¼														
72	28	56	40	5.56	4	8	11¾	15¾	19½	23	26¼	29½	35¼	40½	44¾													
72	56	64	24	5.84	3¾	7¾	11½	15	18½	22	25¼	28¼	34	39	43¼													
72	28	48	40	6.48	3½	7	10¼	13½	16¾	20	23	25¾	31¼	36	40½	44¼												
72	32	48	40	7.40	3	6	9	12	14¾	17¾	20¼	23	28	32½	36½	40½	44½											
72	24	48	56	7.78	3	5¾	8½	11½	14¼	16¾	19¼	22	26¾	31¼	35¼	39	42¼											
64	48	72	40	8.34	2¾	5½	8	10¾	13¼	15¾	18¼	20½	25¼	29½	33½	37	40½	43¼										
86	32	40	48	8.92	2½	5	7½	10	12½	14¾	17¼	19¼	23¾	27¾	31½	35	38½	41½	44									
72	56	64	40	9.72	2¼	4½	7	9¼	11½	13½	15¾	17¾	22	25¾	29½	33	36	39	41¾	44¼								
72	32	40	48	10.66	2	4¼	6¼	8½	10½	12½	14½	16½	20¼	23¾	27¼	30½	33½	36½	38¾	41½	44							
72	28	40	56	10.88	2	4	6¼	8¼	10¼	12¼	14	16	20	23½	26¾	30	32¾	36	38½	41	43¼	45						
64	28	40	56	12.24	1¾	3¾	5½	7¼	9	11	12¾	14½	17¾	21	24¼	27	30	33	35¼	37¾	40	42						

Table for Cutting Spirals—Continued

FORMULA $\left\{\frac{B \times D \times 20}{A \times C} = \text{LEAD}\right.$

NOTE—With equal Gears on Head and Screw, Table advances 20 inches to one revolution of the Spindle.

Divide the circumference by the Lead to find the Tangent of the Angle and from a Table of Tangents find the Angle.

A SCREW	B COMPOUND	C COMPOUND	D HEAD	LEAD	DIAMETER OF BLANK TO BE CUT ⅛"	¼"	⅜"	½"	⅝"	¾"	⅞"	1"	1¼"	1½"	1¾"	2"	2¼"	2½"	2¾"	3"	3¼"	3½"	3¾"	4"	4¼"	4½"	4¾"	5"
72	32	40	56	12.44	1¾	3½	5½	7¼	9	10¾	12½	14¼	17½	20¾	23¾	26¾	29½	32½	34¾	37¼	39¼	41½	43½					
72	40	48	56	12.96	1¾	3½	5¼	7	8½	10¼	12	13½	16¾	20	23	25¾	28½	31½	33¾	36¼	38¼	40¼	42¼	44¼				
56	28	48	64	13.34	1¾	3½	5	6¼	8	10	11½	13¼	16½	19½	22½	25¼	26¾	30¾	33	35¼	37½	39½	41½	43½	45			
64	40	48	56	14.58	1½	3	4¾	6¼	7¾	9¼	10¾	12¼	15	18	20½	23½	26	28½	30¾	33	35	37	39	41	42½	44¼		
72	40	48	64	14.82	1½	3	4½	6	7¼	9	10½	12	14¾	17¾	20¼	22¾	25½	28¼	30¼	32½	34½	36½	38½	40¼	42	43¾		
56	32	48	64	15.24	1½	3	4½	6	7¼	8¾	10¼	11½	14½	17¼	19¾	22¼	25	27½	29½	32	33¾	36	37¾	39½	41¼	43	44¼	
72	40	32	48	16.66	1½	2¾	4	5½	6¾	8	9½	10½	13¼	15¾	18¼	20½	23	25½	27½	29½	31½	33½	35¼	37	38¾	40¼	41¾	43½
56	28	48	86	17.90	1¼	2½	3¾	5	6¼	7½	8¾	10	12½	14¾	17	19¼	21½	24	26	28	29¾	31¾	33½	35¼	36¾	38½	39¾	41¼
72	48	40	56	18.66	1¼	2½	3½	4¾	6	7¼	8½	9½	11¾	14	16¼	18½	20¾	23	24¾	27	28¾	30½	32¼	34	35½	37¼	38¾	40¼
56	40	48	64	19.04	1¼	2¼	3½	4¾	6	7	8¼	9¼	11½	13¾	16	18¼	20¼	22½	24½	26½	28¼	30	31½	33½	35	36½	38¼	39½
56	32	40	72	20.58	1	2¼	3¼	4½	5½	6½	7¾	8¾	10¾	12¾	15	17¼	19	21	22¾	24¾	26½	28¼	29¾	31½	33	34½	36	37½
72	56	48	64	20.74	1	2¼	3¼	4¼	5½	6½	7½	8½	10½	12¾	14¾	17	18¾	20¾	22½	24½	26¼	28	29½	31¼	32¾	34¼	35¾	37¼
64	56	40	48	21.00	1	2¼	3¼	4¼	5¼	6¼	7½	8½	10½	12½	14½	16¾	18½	20½	22¼	24¼	26	27¾	29¼	31	32½	34	35½	36¾
72	48	40	64	21.34	1	2	3¼	4¼	5¼	6¼	7¼	8¼	10¼	12¼	14¼	16½	18¼	20¼	22	24	25½	27¼	29	30½	32	33½	35	36½
64	40	32	56	21.88	1	2	3	4	5	6	7¼	8¼	10¼	12	14	16¼	18	20	21½	23½	25	26¾	28¼	30	31½	33	34½	35¾
72	40	32	64	22.22	1	2	3	4	5	6	7	8	10	11¾	13¾	16	17¾	19¾	21¼	23	24¾	26½	28	29½	31	32½	34	35¼
72	48	32	56	23.32	1	2	3	3¾	4¾	5¾	6¾	7½	9½	11¼	13¼	15¼	17	18¾	20¼	22	23¾	25¼	26¾	28½	29¾	31¼	32½	34
48	32	40	72	24.00	1	2	2¾	3¾	4¾	5¾	6½	7¼	9¼	11	12¾	15	16½	18¼	19¾	21½	23	24¾	26¼	27¾	29	30½	31¾	33¼
64	48	32	56	26.24	¾	1¾	2½	3½	4¼	5¼	6	6¾	8½	10¼	11¾	13½	15	16¾	18¼	20	21¼	22¾	24¼	25¾	27	28¼	29¾	31
72	48	28	56	26.66	¾	1¾	2½	3½	4¼	5	6	6½	8¼	10	11½	13¼	14¾	16½	18	19½	21	22½	23¾	25½	26½	28	29¼	30½
56	48	40	64	27.42	¾	1¾	2½	3½	4	4¾	5¾	6½	8	9¾	11¼	13	14½	16	17½	19	20½	22	23¼	24¾	26	27¼	28½	30
72	48	28	64	30.48	¾	1½	2¼	3	3¾	4½	5¼	5¾	7¼	8¾	10¼	11¾	13	14½	15¾	17¼	18½	20	21	22½	23¾	25	26	27¼
72	56	32	64	31.12	¾	1½	2¼	3	3½	4¼	5	5¾	7¼	8¾	10	11½	12¾	14¼	15½	17	18¼	19½	20¾	22	23¼	24½	25½	27
40	72	64	56	31.50	¾	1½	2¼	2¾	3½	4¼	5	5½	7	8½	9¾	11¼	12½	14	15¼	16¾	18	19¼	20½	21¾	23	24¼	25¼	26½
64	48	32	72	33.74	¾	1¼	2	2¾	3¼	4	4½	5¼	6¾	7¾	9¼	10½	11¾	13¼	14½	15¾	17	18¼	19¼	20½	21¾	22¾	23¾	25

Table for Cutting Spirals—Continued

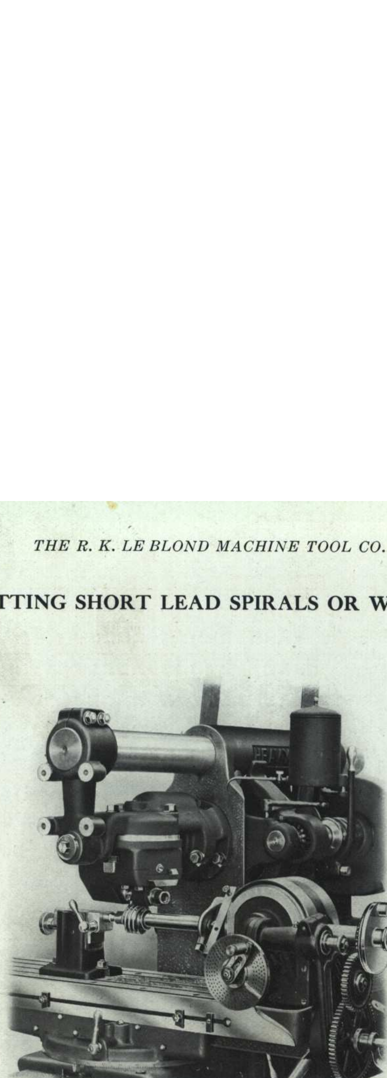
FORMULA $\left\{\frac{B \times D \times 20}{A \times C} = \text{LEAD}\right.$

NOTE—With equal Gears on Head and Screw, Table advances 20 inches to one revolution of the Spindle.

Divide the circumference by the Lead to find the Tangent of the Angle and from a Table of Tangents find the Angle.

A SCREW	B COMPOUND	C COMPOUND	D HEAD	LEAD	DIAMETER OF BLANK TO BE CUT ⅛"	¼"	⅜"	½"	⅝"	¾"	⅞"	1"	1¼"	1½"	1¾"	2"	2¼"	2½"	2¾"	3"	3¼"	3½"	3¾"	4"	4¼"	4½"	4¾"	5"
56	48	32	64	34.28	¾	1¼	2	2½	3¼	4	4½	5¼	6½	7¾	9	10¼	11½	13	14¼	15½	16½	17¾	19	20¼	21¼	22¼	23¼	24¾
48	40	32	72	37.50	¾	1¼	1¾	2½	3	3¾	4¼	4¾	6	7¼	8¼	9½	10¾	12	13	14¼	15¼	16¼	17½	18½	19¼	20¾	21¾	22¾
56	48	32	72	38.58	½	1¼	1¾	2¼	3	3½	4	4½	5¾	7	8	9¼	10½	11½	12¾	13¾	15	16	17	18¼	19	20¼	21¼	22¼
56	48	28	64	39.18	½	1¼	1¾	2¼	2¾	3½	4	4½	5¾	6¾	8	9¼	10¼	11½	12½	13½	14½	15¾	16¾	18	18¾	20	20¾	22
64	56	32	72	39.38	½	1¼	1¾	2¼	2¾	3½	4	4½	5¾	6¾	8	9	10	11½	12½	13½	14½	15¾	16¾	17¾	18¾	20	20¾	21¾
56	40	24	72	42.86	½	1¼	1½	2	2½	3	3¾	4¼	5¼	6¼	7½	8½	9½	10½	11½	12½	13½	14½	15¼	16½	17¼	18½	19¼	20¼
64	56	28	72	45.00	½	1¼	1½	2	2½	3	3½	4	5	6	7	8	9	10	11	12	12¾	13¾	14¾	15¾	16½	17½	18¼	19¼
48	56	32	64	46.66	½	1¼	1½	2	2½	3	3½	4	5	5¾	6¾	7¾	8½	9¾	10½	11½	12¼	13¼	14¼	15¼	16	17	17¾	18¾
64	56	24	72	52.50	½	¾	1¼	1¾	2¼	2½	3	3½	4¼	5	6	7	7¾	8½	9½	10¼	11	12	12¾	13½	14¼	15	16	16¾
48	56	28	64	53.34	½	¾	1¼	1¾	2	2½	3	3½	4¼	5	6	6¾	7½	8½	9¼	10	10¾	11¾	12½	13¼	14	14¾	15½	16½
40	56	32	64	56.00	½	¾	1¼	1½	2	2½	2¾	3¼	4	4¾	5¾	6½	7¼	8	8¾	9½	10¼	11¼	12	12¾	13½	14¼	15	15¾
40	48	28	72	61.72	½	¾	1	1½	1¾	2¼	2½	3	3¾	4½	5	5¾	6½	7¼	8	8¾	9½	10	10¾	11½	12¼	13	13½	14¼
40	56	32	72	63.00	¼	¾	1	1½	1¾	2¼	2½	3	3½	4¼	5	5¾	6½	7¼	7¾	8½	9¼	10	10½	11¼	12	12¾	13¼	14
40	64	32	72	72.00	¼	½	1	1¼	1½	1¾	2¼	2½	3¼	3¾	4½	5	5½	6¼	7	7½	8	8¾	9¼	10	10½	11	11¾	12¼
40	64	28	72	82.28	¼	½	¾	1	1½	1½	2	2¼	2¾	3¼	4	4½	5	5½	6	6½	7	7¾	8¼	8¾	9¼	9¾	10¼	10¾
32	56	28	72	90.00	¼	½	¾	1	1¼	1½	1¾	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10
40	64	24	72	96.00	¼	¼	¾	1	1¼	1¼	1½	2	2½	3	3¼	3¾	4¼	4¾	5¼	5½	6	6½	7	7½	8	8½	8¾	9¼
32	64	28	72	102.86	¼	¼	¾	¾	1	1¼	1½	1¾	2¼	2¾	3	3½	4	4½	4¾	5¼	5¾	6	6½	7	7½	7¾	8¼	8¾
32	64	24	72	120.00	¼	¼	½	¾	1	1	1¼	1½	2	2¼	2½	3	3½	3¾	4½	4½	5	5½	5½	6	6¼	6¾	7	7½
28	64	24	72	137.14	¼	¼	½	¾	¾	1	1¼	1¼	1¾	2	2¼	2½	3	3¼	3½	4	4¼	4¼	4¾	5¼	5½	5¾	6¼	6½

CUTTING SHORT LEAD SPIRALS OR WORMS



When short worm leads are to be cut, owing to the high reduction necessary in the gear trains, the frictional losses often become excessive, too much power being consumed in the transmission before it reaches the work. This condition exists on all milling machines regardless of its manufacture.

In order to overcome these frictional losses we have devised an attachment by which the drive is directly from the table to the dividing head spindle dropping out the 40 to 1 ratio between the worm and wheel.

Leads up to 6 inches are cut in this manner through the usual change gear combinations, dividing the leads listed in the table by 40 to obtain the lead resulting from the use of the device. The gear trains may be either simple or compound.

The worm is dropped out of mesh with the wheel and the work indexed through a dividing plate and index plunger on the rear of the head. The work is driven from a clutch milled in the end of the dividing spindle and the entire mechanism pulled up to a firm seat by a draw-in bolt in the head center operated from the clear end of the spindle.

The index plate has twelve divisions providing for indexing 2-3-4-6 and 12 threads.

Special plates with any reasonable number of divisions are provided at a nominal charge.

In cutting these short leads the spiral angle will exceed the swivel capacity of the Universal Miller, viz.: 50 degrees, and it becomes necessary to swivel the cutter. The Universal Spiral Cutting Attachment illustrated, provides for this condition. The cutter may be swiveled through the entire angle or taken partly through the attachment and the compliment of the angle by swiveling the table.

Cutting Spirals on the Plain Miller

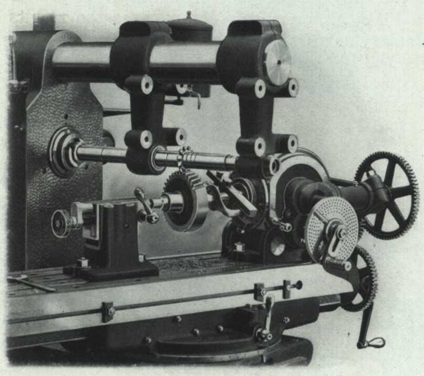
With the Universal Spiral Cutting Attachment spirals can be cut on a Plain Miller, and in many cases the results are fully as satisfactory as a Universal Miller. The attachment has practically the full strength of the machine.

CUTTING SPIRAL GEARS ON THE MILLING MACHINE

Spiral gears can be readily cut on the milling machine, and when carefully handled, their efficiency compares very favorably with a hobbed gear.

As a general rule, complete information for cutting a spiral gear is given the operator from the draughting room, and the actual cutting of the gear is practically the same as an ordinary spiral. For this reason we will not enter into the discussion of the efficiency or power ratios, but will quote a few fundamental formulæ for calculating spiral gears, in such form as may be readily understood by the operator.

For this data we are indebted to Messrs. Colvin and Stanley, in their "American Machinist's Handbook." This gives full cutting data, including the selection of the cutter.



CUTTING SPIRAL GEAR

Table swivel to spiral angle. Cutter set central with dividing head centers before swiveling. Geared for lead. Use longitudinal feed.

SPIRAL GEARS

The term spiral gear is usually applied to gears having angular teeth, and which do not have their shafts or axes in parallel lines, and usually at right angles. Spiral gears take the place of bevel gears and give a smoother action, as well as allowing greater speed ratios in a given space. When gears with angular or skew teeth run on parallel shafts, they are usually called helical gears.

In considering speed ratios for spiral gears the driving gear can be taken as a worm having as many threads as there are teeth and the driven as the worm wheel with its number of teeth, so that one revolution of the driver will turn a point on the pitch circle of the driven gear as many inches as the lead of the teeth of the driver. Divide this by the circumference of the pitch circle of the driven gear to get the revolutions of the driven.

When the spiral angles are 45 degrees, the speed ratio depends entirely on the number of teeth as in bevel gears, but for other angles of spiral the following formula will be useful:

Let R_1 = Revs. of Driver.
R_2 = Revs. of Driven.
D_1 = Pitch Diameter of Driver.
D_2 = Pitch Diameter of Driven.
N_1 = Number of Teeth in Driver.
N_2 = Number of Teeth in Driven.

Then with shafts at 90 degrees we have

$$\frac{R_2}{R_1} = \frac{D_1}{D_2} \times \text{cotangent of helix angle of driver with its axis.}$$

$$R_2 = \frac{D_1 \times R_1}{D_2} \times \text{cotangent of helix angle of driver with its axis.}$$

$$D_1 = \frac{\frac{R_2 \times D_2}{R_1}}{\text{Cotangent of Helix.}} \qquad D_2 = \frac{R_1 \times D_1}{R_2} \times \text{Cot. of helix.}$$

Or in the form of rules we have:

Having	To Find	Rule
Both gears same diameter ...... Speed of driving gear ...... Cotangent of tooth angle of driver	Speed of Driven Gear	Multiply speed of driver by cotangent of tooth angle of driver with axis.
Driven gear the largest .... Speed of driving gear.......... Cotangent of driver angle...... Diameter of driving gear....... Diameter of driven gear	Speed of Driven Gear	Divide diameter of driver by diameter of driven. Multiply by speed of driver and by cotangent of driver tooth angle with axis.
Speed ratio of gears or revolutions of driver and driven... Cotangent of tooth angle of driver Diameter of driven gear........	Diameter of Driver	Divide speed of driven gear by speed of driver and multiply by diameter of driven. Divide by cotangent of tooth angle of driver with axis.
Speed ratio or revolution of driver and driven........... Cotangent of tooth angle of driver.................... Diameter of driver............	Diameter of Driven	Divide speed of driver by speed of driven and multiply by diameter and by cotangent of tooth angle of driver with axis.

Other formulas for spiral gears are:

Lead = Distance the spiral advances in one turn.

Angle = The angle formed on the pitch surface by sides of teeth and a line parallel with the axis of the gear.

45° Angle Spiral = Two spirals are cut 45° when the pitch diameters and teeth are in the same ratio.

Formulæ for 45° Spirals

Diametral Pitch = Number of teeth ÷ pitch diameter.

" " = (Number of teeth + 1.414) ÷ outside diameter.

Normal Pitch = Diametral pitch ÷ .707.

Number Teeth = Pitch diameter × diametral pitch.

" " = Outside diameter × diametral pitch — 1.414.

Lead = Pitch diameter × 3.1416.

Cutter = Select spur gear cutter to nearest standard normal pitch for *three* times as many teeth as in spiral. Cut to get the tooth parts figured from the correct normal pitch.

Figure normal tooth parts the same as for a spur gear.

Formulæ for any Angle—Axis at Right Angles

Diametral Pitch = Number of teeth ÷ pitch diameter.

" " = Number of teeth + 2 × cosine angle ÷ outside diameter.

" " = Number of teeth ÷ (pitch diameter × cosine of angle).

" " = Diametral pitch ÷ cosine of angle.

Number of Teeth = Pitch diameter × diametral pitch.

" " = Outside diameter × diametral pitch — 2 × cosine spiral angle.

Lead = Pitch Diameter × 3.1416 ÷ tangent of angle.

Cutter = Divide the number of teeth in the spiral gear by the cube of the cosine of the angle. Select a spur gear cutter for the standard normal pitch which is nearest to this. Then cut as before.

Normal Pitch of Driver = Its circular pitch × cosine of spiral angle.

Normal Pitch of Follower = Circular pitch × cosine of spiral angle.

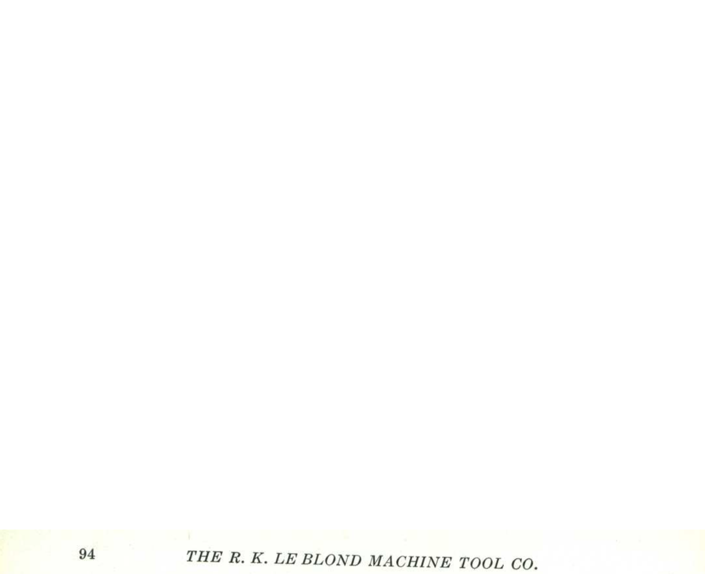
NOTE — In determining the outside diameter of the blank the addendum should be based on the normal pitch and not the axial pitch, as this prevents a narrow, pointed addendum and gives the correct tooth with an involute spur gear cutter.

The change gears are determined from the spiral cutting chart as described in the foregoing pages. The table is swiveled to the right or left, as the case may be, and set to the spiral angle. In case the angle exceeds 50 degrees, it is necessary to use a Spiral Cutting Attachment, which swivels the cutter, or the angle can be divided between the swivel table and the attachment.

*For a complete and thorough treatise on spiral gears, we refer the reader to "The American Machinist Gear Book," by the Hill Publishing Co., New York.

GRAPHIC METHOD

Below is shown a graphic method of laying out a pair of spiral gears. This method is in use in our own shops.



Determine gear ratio and pitch desired.

Lay off AB to pitch diameter wanted for pinion.

With radius BH equal to number of diametral pitches in pinion draw arc DE.

Tangent to DE and through A draw AJ.

Angle X equals spiral angle of pinion.

Angle Y equals spiral angle of gear = (90° — Angle X).

With radius equal to number of diameter pitches in gear draw arc FG tangent to AJ (Center Line on AM).

AC = Pitch diameter of gear.

AB × 3.1416 = AK = Pitch circumference of pinion.

Erect perpendicular at K extending until it intersects AJ at L. KL = lead of pinion.

AC × 3.1416 = AM = Pitch circumference of gear.

Draw horizontal at M extending until it intersects AJ at N. MN = lead of gear.

From B let fall perpendicular.

Draw line through A at right angles to AJ and prolong until it intersects perpendicular at O.

Number of pitches in AO will give cutter required for pinion.

Draw horizontal at C and extend AO until it intersects horizontal at P.

Number of diametral pitches in AP will give cutter required for gear.

Pitch selected should be for some regular stock cutter.

Add two pitches to get outside diameter of gears.

WORM GEARS

Worm gears can be cut in three ways on the milling machine.

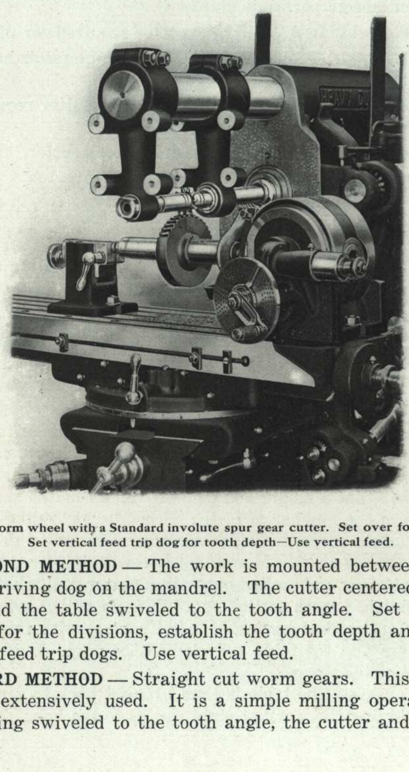
FIRST — By the Hobbing process — first gashing the teeth.

SECOND — Mounting the work on dividing head centers and dropping in with the vertical feed using a standard involute spur gear cutter.

THIRD — Cutting straight through with a spur gear cutter using longitudinal feed.

The first method is by far the most satisfactory as to results. The continuous efficiency is greater, the area of tooth contact is larger, and, when judging from a standpoint of expense, it is well to remember that a single hob cuts all wheels of the same pitch regardless of the number of teeth; of course, providing they are large enough to cover the width of face. The worm gear blank is first accurately sized. Mounted between dividing head centers, with a dog driver and gashed out with a cutter somewhat smaller than the finished tooth section space, bringing it to approximate depth, the cutter first having been set central with the dividing head centers and the table swiveled to the angle corresponding to the lead of the worm.

After gashing, the table is then brought back to zero on the swivel, bringing the work at right angles to the hob. The driving dog removed from the work, as it must be free to revolve between centers — the hob driving the work around. The table should be run up in the face of the hob using the vertical feed until the full depth of the tooth is obtained. This should be done slowly so that the hob teeth do not jam in the metal left by the gashing operation. This method gives a perfect tooth form and a contact the full width of the gear.



Cutting a worm wheel with a Standard involute spur gear cutter. Set over for tooth angle. Set vertical feed trip dog for tooth depth—Use vertical feed.

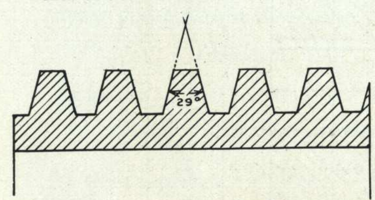
SECOND METHOD — The work is mounted between centers with a driving dog on the mandrel. The cutter centered over the work and the table swiveled to the tooth angle. Set the index sectors for the divisions, establish the tooth depth and set the vertical feed trip dogs. Use vertical feed.

THIRD METHOD — Straight cut worm gears. This is a type of gear extensively used. It is a simple milling operation, the table being swiveled to the tooth angle, the cutter and depth of

tooth established and the gear cut after the same principle as our ordinary spur gear.

It is highly important that the cutter be centered with the dividing head before swiveling the table.

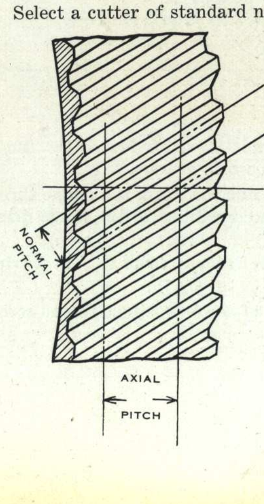
Gears cut in this manner show a high degree of efficiency when new, though the life does not compare favorably with the hobbed gear. This is due to the smaller tooth contact, the bearing being practically at one point and not distributed the full width of the tooth.



SELECTING THE CUTTER—A worm has a normal section identical with a rack tooth to mesh with an involute tooth pinion. In selecting a cutter for a wheel to mesh with a worm, it is evident that some standard involute cutter would be correct. To determine upon the cutter, the same method prescribed on page 93 for spiral gears is used, viz.:

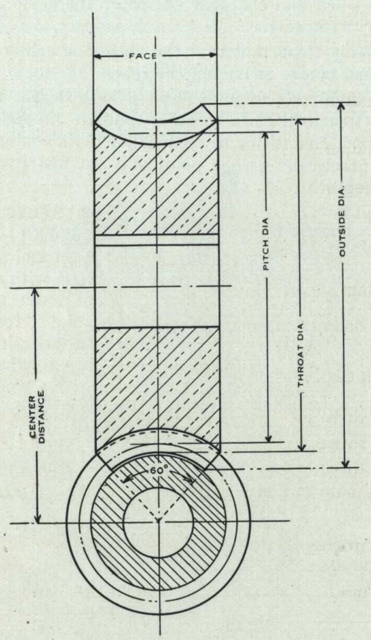
$$\frac{\text{No. of teeth.}}{(\text{Cosine tooth angle})^3}$$

Select a cutter of standard normal pitch most nearly coinciding with it.



The tooth parts are determined from the normal or true pitch. A table of these parts is shown on page 108. A list of standard involute cutters and teeth they will cut, shown on page 107.

The diagram opposite illustrates the difference between the axial tooth section and the normal or actual section, the normal section being taken at 90 degrees to helix angle.



For the benefit of the mechanic we list a few of the fundamental principles for calculating worm gears.

When a worm wheel has 40T and the worm is a single thread screw, the ratio is 40 to 1, or one revolution of the worm drives the wheel around 1 tooth.

On a double thread worm the ratio is 40 to 2. On a triple thread 40 to 3, etc.

Linear pitch of wheel = lead of worm on single thread screw.

$$\text{Diametral P} = \frac{3.1416}{\text{Linear Pitch}}$$

Pitch diameter of worm gear =

$$\frac{\text{No. of teeth} \times \text{L. P.}}{3.1416} \quad \text{or} \quad \frac{\text{No. of teeth}}{\text{Diametral pitch.}}$$

$$\text{Throat diameter of gear} = \text{pitch diameter} + \frac{2}{\text{D. P.}}$$

$$\text{Outside diameter of gear} = \text{pitch diameter} + \frac{4}{\text{D. P.}}$$

Whole depth of tooth — worm or wheel = linear pitch × .6866.

Width at bottom of tooth = linear pitch × .310.

$$\text{Addendum} = \frac{1}{\text{Diametral Pitch}}$$

Dedendum = Tooth Clearance + Addendum.

$$\text{Thickness of tooth on pitch line} = \frac{\text{Linear Pitch}}{2}$$

$$\text{Tooth Clearance} = \frac{\text{thickness of tooth on pitch line}}{10}$$

Single thread worm, outside diameter = linear pitch × 4.

Double thread worm, outside diameter = linear pitch × 5.

Triple thread worm, outside diameter = linear pitch × 6.

The diameter of hob = diameter of worm + (clearance × 2).

Cutting Depth of Tooth for Worm Gears

Threads per Inch Worm	Depth of Tooth	Threads per Inch	Depth of Tooth
1	.6866″	7	.0981″
1½	.4575″	8	.0857″
2	.3432″	9	.0762″
2¼	.3048″	10	.0685″
2½	.2747″	11	.0623″
3	.2289″	12	.0571″
4	.1716″	14	.0490″
5	.1372″	16	.0429″
6	.1144″	18	.0377″

BEVEL GEARS

Finish cutting bevel gears on a milling machine is not a commercial means of producing this type of gear and does not compete successfully with the generating process. However, when time is not a consideration, a fairly efficient bevel or mitre gear can be cut with a rotary cutter.

The teeth of a bevel gear constantly become thinner as they approach the apex of the cone. At the outside diameter both the pitch and the depth are correct and identical with a spur gear of the same size, but as the tooth nears the apex, the tooth section or pitch is constantly changing, while the number of teeth remains the same, so that a tooth made with a rotary cutter has the proper theoretical tooth section only at the large diameter.

The blanks should be accurately machined before cutting, with correct reading diameter, face and back angle. This is necessary, as it is most convenient to take the depth of tooth directly from the blank by gauge. The information necessary is, first, the diametral pitch, the number of teeth, the cutting angle, the depth of tooth, the thickness of tooth at pitch line.

Selecting the Cutter

Practically all of the manufacturers of small tools make these cutters up in sets, eight in number, of standard pitches. These cutters each cut a wide range of teeth of any given pitch.

The cutters as laid out will cut any bevel gear in which the tooth face is not longer than one-third the cone radius, that is, the distance from the outside end of the gear, to the apex of the cone where the shaft centers meet. This makes the tooth thickness at the thinner end of the gear two-thirds of the thickness at the outer end.

When the face of the gear is longer than one-third of the cone distance a special cutter must be used.

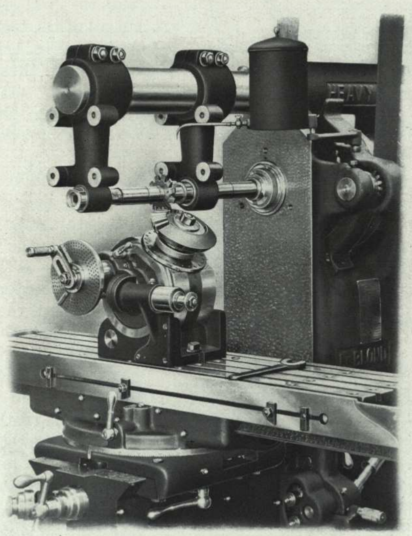
TO SELECT THE CUTTER, *divide the number of teeth in the gear by the cosine of the pitch or center angle of the gear. The quotient is the number of teeth in a spur gear with the same tooth section, and from the table choose the proper cutter.*

A list of these cutters and the teeth each will cut of a given pitch is shown on page 107.

This same calculation also applies to the pinion, i. e., *dividing the number of teeth in the pinion by the cosine of the pitch angle of the pinion, or by the sine of the pitch angle of the gear, which, of course, gives the same result.*

This applies to shafts at 90 degrees only.

Having selected the cutter, mount on the arbor of the miller. If the miller is a universal machine, set the swivel saddle to zero and clamp. Put a center in the dividing head, and set this center to the center line of the cutter. Next, set the cross feed dial to zero and clamp, as future readings are taken from the dial. Set the dividing head swivel to the cutting angle of the gear. Mount the gear on a rigid stub arbor in the dividing head (see illustration). Pass the blank under the cutter and elevate the knee until the cutter just touches the outside diameter of the gear.



Milling a Bevel Gear. Set Swivel Block to Cutting Angle. Establish Tooth Depth. Set Saddle Swivel to Zero. A Plain or Universal Miller can be used.

Set the elevating screw dial to zero, move the gear from below the cutter and raise the table to correct tooth depth, shown in the table of tooth parts, page 108. After setting the sectors on the index plate for the proper number of divisions, corresponding to the number of teeth, which is obtained from the index chart sent with the machine, the gear is ready to be cut.

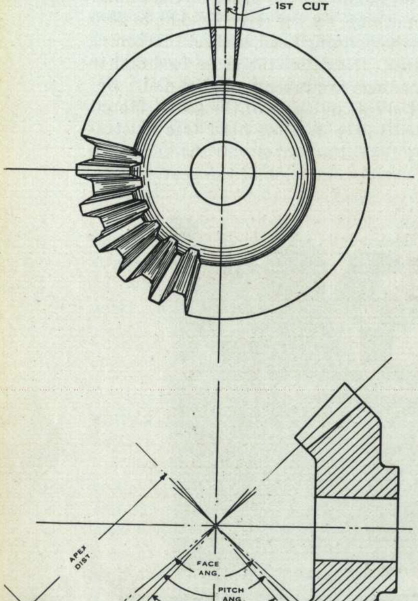


Figure 1

The usual way of cutting the first gear is to cut all of the teeth on the first cut, Fig. 1, then taking two cuts through each tooth after setting over and rolling the gear. After the first gear is cut and the proper set-over and roll noted, the next gear can be cut in two cuts if the pitch is not too heavy, dispensing with the center or first cut. After the center cut has been taken through all of the teeth, set the gear out of center by means of the cross feed screw, a distance equal to approximately one-tenth to one-eighth of the tooth thickness at the large end. This can be found by referring to the table of tooth parts, page 108.

Next, roll the gear around in the opposite direction from which it was set over, until the cutter just barely touches the side of the tooth on the inner or small end of same. This will take off considerable metal at the outside end, and, with the gear set over and rolled in this direction, cut three or four teeth.

Next, bring the table back to center by returning the cross feed dial to zero. Move the table out of center, the opposite way, the same amount as before. Roll the gear the opposite way with the index handle and mill the same three teeth on the opposite side. The object of setting the gear out of center is to trim off the thick end of the tooth, and if the gear is still too thick, the gear should be given more set-over. The thickness is best measured with the Brown & Sharpe Gear Tooth Caliper. After increasing the roll and set-over gradually till the tooth section conforms to gauge at the large end, the correct roll and set-over are noted, and other gears of the same kind are cut without experiment.

Formulæ for Calculating Bevel Gears with Axes at 90 Degrees

Required	Formula—Gear	Formula—Pinion
Center Angle	Tangent Center Angle = $\frac{\text{No. of teeth in gear}}{\text{No. of teeth in pinion}}$	90 degrees—less center angle of gear.
Face Angle	Center angle + angle increment	Center angle + angle increment
Cutting Angle	Center angle — angle decrement	Center angle — angle decrement
Back Angle	90 degrees to center angle......	90 degrees to center angle.
Apex Distance	$\frac{\text{Pitch Diameter}}{2 \times \text{Sine center angle}}$	$\frac{\text{Pitch Diameter}}{2 \times \text{Sine center angle}}$
Angle Increment	Tangent of Angle Increment = $\frac{2 \times \text{Sine center angle}}{\text{Number of teeth}}$	Tangent of Angle Increment = $\frac{2 \times \text{Sine center angle}}{\text{Number of teeth}}$
Angle Decrement	Tangent of Angle Decrement = $\frac{2.314 \times \text{Sine center angle}}{\text{Number of teeth}}$	Tangent of Angle Decrement = $\frac{2.314 \times \text{Sine center angle}}{\text{Number of teeth}}$
Pitch Diameter	Number of teeth ÷ diametral pitch	Number of teeth ÷ diametral pitch
Outside Diameter	Pitch diameter + (2 × diameter increment)	Pitch diameter + (2 × diameter increment)
Diameter Increment	2 × addendum × Cosine center angle	2 × addendum × Cosine center angle

SPUR GEARS

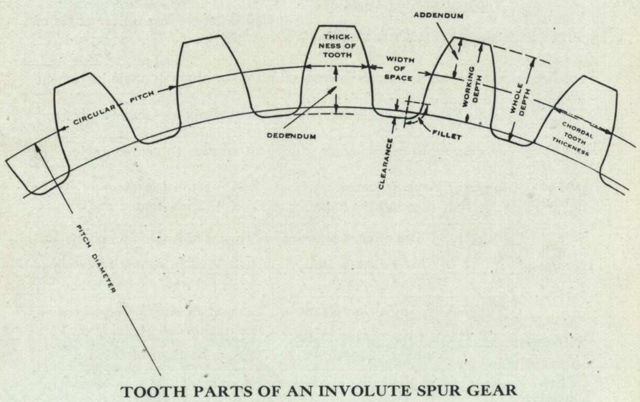
Spur gears are designated by their pitch diameter, the number of teeth and the pitch.

The DIAMETER is understood to mean "pitch diameter." The pitch may be expressed as diametral or circular.

The DIAMETRAL PITCH is the number of teeth divided into the pitch diameter in inches.

The CIRCULAR PITCH is the distance, center to center of the teeth, measured along the pitch circle.

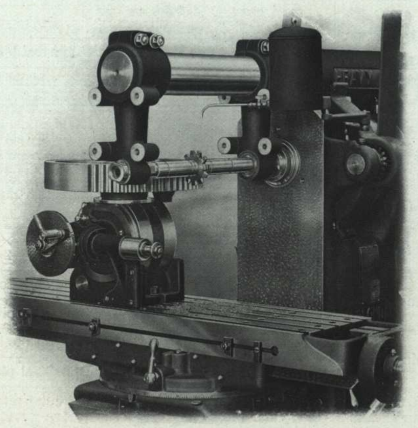
The CHORDAL PITCH (seldom used) is the distance, center to center of teeth, measured in a straight line.



TOOTH PARTS OF AN INVOLUTE SPUR GEAR

Formulæ for Spur Gears with Involute Teeth

Required	Having	Formulae
Circular pitch.......	Diametral pitch.....	$\frac{3.1416}{\text{Diametral pitch}}$
Diametral pitch......	Circular pitch	$\frac{3.1416}{\text{Circular pitch}}$
Diametral pitch......	Number of teeth and outside diameter...	$\frac{\text{Number of teeth} + 2}{\text{Outside diameter}}$
Number of teeth.....	Pitch diameter and diametral pitch...	Pitch diameter × diametral pitch
Number of teeth.....	Outside diameter and diametral pitch...	(Outside diameter × diametral pitch)—2
Pitch diameter.......	Number of teeth and diametral pitch ...	$\frac{\text{Number of teeth}}{\text{Diametral pitch}}$
Outside diameter.....	Number of teeth and diametral pitch...	$\frac{\text{Number of teeth} + 2}{\text{Diametral pitch}}$
Thickness of tooth at pitch line.........	Circular pitch......	$\frac{\text{Circular pitch}}{2}$
Thickness of tooth at pitch line..........	Diametral pitch.....	$\frac{1.57}{\text{Diametral pitch}}$
Whole depth of tooth.	Circular pitch.......	Circular pitch × .6866
Distance between centers..............	Number of teeth in each gear and the diametral pitch...	$\frac{\frac{\text{Total No. of teeth in both gears}}{2}}{\text{Diametral pitch}}$
Addendum.........	Diametral pitch.....	$\frac{1}{\text{Diametral pitch}}$
Addendum..........	Circular pitch	Circular pitch × .3183
Dedendum..........	Diametral pitch.....	$\frac{1.157}{\text{Diametral pitch}}$
Dedendum........	Circular pitch	Circular pitch × .3683



Cutting large spur Gear on a Milling Machine. Head set in upright position. Use vertical feed. Provide a suitable jack near cutter if gear is not sufficiently rigid.

Gears too large to be cut between centers can be cut as shown above. Gears up to 36″ in diameter can be cut in this manner, although we strongly advise against straining the dividing head by mounting too heavy gears in this manner.

The illustration shows a gear 16″ diameter, 4 diameter pitch. The teeth are taken from the solid in one cut.

Gears of smaller diameter, up to the full swing of the head, are cut by mounting them on an arbor between centers.

With either method the cutter should be accurately set to the center of the dividing head before starting the cut.

After centering the cutter the knee is elevated until the cutter just touches the work, the work backed off from the cutter and the knee elevated the amount of the depth of the tooth, the reading being taken from the graduated dial on the elevating shaft.

The selection of a cutter for a spur gear presents no difficulty, due to the very convenient manner in which these sets for involute tooth forms are arranged. Those listed below are made by all of the small tool manufacturers.

No. 1	cutter	cuts	all	teeth	from	135	to	a rack.	
No. 2	"	"	"	"	"	55	to	134	teeth.
No. 3	"	"	"	"	"	35	"	54	"
No. 4	"	"	"	"	"	26	"	34	"
No. 5	"	"	"	"	"	21	"	25	"
No. 6	"	"	"	"	"	17	"	20	"
No. 7	"	"	"	"	"	14	"	16	"
No. 8	"	"	"	"	"	12	"	13	"

Eight cutters are required for each pitch to cut from 12 teeth to a rack. The cutters are stamped with a number corresponding to the above table, as well as their pitch. If a 24 tooth, 8 pitch gear is to be cut, the cutter used will be No. 5, as it cuts all the teeth between 21 and 25 of a given pitch.

It is highly important that these cutters be kept sharp. This can be done without injuring their form, *as they are ground on the cutting face only.*

This can be most advantageously done on the LeBlond Universal Cutter and Reamer Grinder.

TABLE OF TOOTH PARTS

Spur gears, standard involute tooth section. 14½° pressure angle

Diametral Pitch	Circular Pitch	Whole Tooth Depth	Thickness at Pitch Line	Addendum	Working Depth of Tooth
1¼	2.5133	1.726	1.257	.8000	1.600
1½	2.094	1.438	1.047	.6666	1.333
1¾	1.795	1.233	.898	.5714	1.1429
2	1.570	1.078	.785	.5000	1.000
2¼	1.396	.959	.698	.4444	.888
2½	1.256	.863	.628	.4000	.800
2¾	1.142	.784	.571	.3636	.727
3	1.047	.719	.524	.3333	.666
3½	.897	.616	.449	.2857	.571
4	.785	.539	.393	.2500	.500
5	.628	.431	.314	.2000	.400
6	.523	.360	.262	.1666	.333
7	.448	.308	.224	.1429	.285
8	.392	.270	.196	.1250	.250
9	.349	.240	.175	.1111	.222
10	.314	.216	.157	.1000	.200
11	.285	.196	.143	.0909	.181
12	.261	.180	.131	.0833	.166
14	.224	.154	.112	.0714	.142
16	.196	.135	.098	.0625	.125
18	.174	.120	.087	.0555	.111
20	.157	.108	.079	.0500	.100
22	.142	.098	.071	.0455	.090
24	.130	.090	.065	.0417	.083
26	.120	.083	.060	.0385	.076
28	.112	.077	.056	.0357	.071
30	.104	.072	.052	.0312	.066
32	.098	.067	.049	.0294	.062

COMPARATIVE TABLES—CIRCULAR AND DIAMETRAL PITCHES

TABLE No. 1		TABLE No. 2	
Diametral Pitch	Circular Pitch	Circular Pitch	Diametral Pitch
	Inches	Inches	
2	1.571	2	1.571
2¼	1.369	1⅞	1.676
2½	1.257	1¾	1.795
2¾	1.142	1⅝	1.933
3	1.047	1½	2.094
3½	.898	1 7/16	2.185
4	.785	1⅜	2.285
5	.628	1 5/16	2.394
6	.524	1¼	2.513
7	.449	1 3/16	2.646
8	.393	1⅛	2.793
9	.349	1 1/16	2.957
10	.314	1	3.142
11	.286	15/16	3.351
12	.262	⅞	3.590
14	.224	13/16	3.867
16	.196	¾	4.189
18	.175	11/16	4.570
20	.157	⅝	5.027
22	.143	9/16	5.585
24	.131	½	6.283
26	.121	7/16	7.181
28	.112	⅜	8.378
30	.105	5/16	10.053
32	.098	¼	12.566
36	.087	3/16	16.755
40	.079	⅛	25.133
48	.065	1/16	50.266

ACCURACY TESTS OF THE DIVIDING HEAD

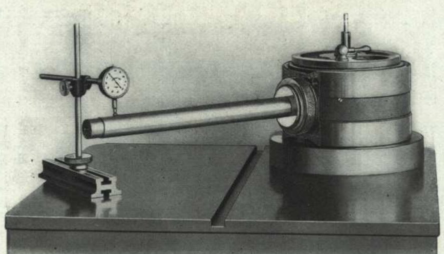
In building a precision device of this character in quantities, it is necessary to resort to exhaustive accuracy tests, to preclude any possibility of error, even though they are machined in jigs, ground and lapped, and each piece inspected with snap limit gauges.

There is very seldom any necessity for corrective work after assembling, so very carefully are they built.

A record of each test is kept on file, which shows the maximum allowable error and the actual alignment of the head. A copy of this record will be sent to any purchaser.

We are prepared to guarantee our dividing heads for the greatest accuracy obtainable by commercial methods.

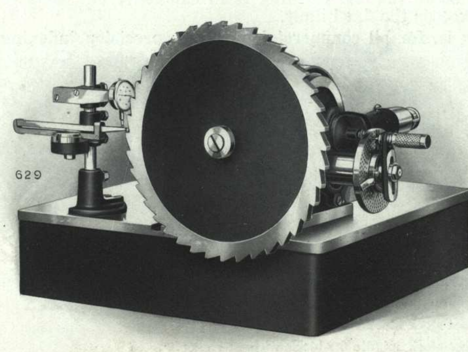
TESTING THE "TRUTH" OF THE SWIVEL BEARING



It is not sufficient that a perfect "side alignment" be maintained when the head is in a horizontal position. This same degree of accuracy must register with the head at any angle. To insure this condition the swivel bearings are tested as shown above, for parallel accuracy.

The heads are placed on a hardened and ground master disc on a surface plate, and indicator readings taken at several points on an 18″ bar.

THE MAXIMUM ALLOWABLE ERROR REGISTERED AT THE END OF AN 18″ BAR IS .001 PART OF AN INCH.



TESTING THE ACCURACY OF THE WORM WHEEL

A hardened and ground master plate 18″ in diameter is mounted in the dividing head spindle. This plate has 40 engine divided notches, as many as there are teeth in the dividing worm wheel. Readings are taken from each notch; indicating the relative error between each two teeth of the worm, shows just where the error is and whether or not it is accumulative. The maximum allowable relative error indicating on an 18″ circle is .002″ between any two teeth.

The errors indicating on the master plate are reduced to nearly $\frac{1}{4}$ of this amount in the wheel itself.

A record of these readings is kept for reference.

This is a facsimile of a "recent test card" on LEBLOND Dividing Head, selected at random from several hundred. It does not indicate that every LEBLOND Dividing Head has an error of .001″ in the worm wheel, indicating on an 18″ circle, but it does indicate that no dividing head can leave our shop if the error exceeds the fixed limit.

This is, for all commercial purposes, precision indexing.

TEST CARD

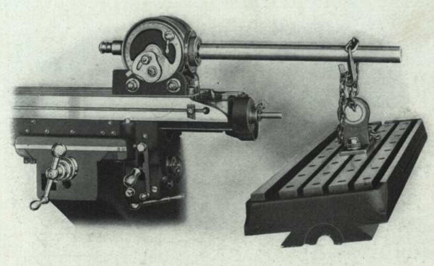
No. 134 DIVIDING HEAD 12″ Size

Date completed 9-16-13 Inspector Niebush

Order No. C-2956

Swivel bearing in bottom and sides of block	✓
Clamping bolts and plugs for hole	✓
Clamping plugs bearing in grooves	✓
Spindle scraped to bearing	✓
Spindle fitted properly in swivel	✓
Foot stock block scraped to housing	✓
Foot stock spindle fits block without shake	✓
Direct index pin fits hole in head and plate properly	✓
Worm index pin fits hole in handle and plate	✓
Spindle revolves freely in bearing without shake	✓
Worm and w'm wheel revolve freely when engaged	✓
No shake bet. worm and worm wheel when engaged	✓
Bevel gears fitted properly—no shake—no noise	✓
No marred screws or nuts	✓
Head swivels 5 deg. below horizontal on either side of center	✓
Center bears in head	✓

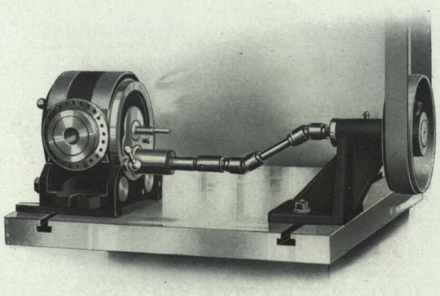
ALIGNMENTS—	Limit of Error	Test
Taper hole in spindle runs true—error at outer end with 18-inch test bar	.001	.0005
Error of worm wheel 18 inches diameter—test in four positions with 18-in. test bar	.002	.001
Spindle square with table in vertical position—test at outer end 18-in. test bar	.002	.001
Head spindle parallel with table and mark zero—test at extremes 16-in. test bar	.0005	.00025
Head spindle parallel with T-slots—test at extremes 16-in. test bar	.001	.00025
Alignment of foot stock with head spindle—test with 16-in. test bar	.0005	.0005



ILLUSTRATING THE EFFICIENCY OF THE PLUG CLAMPS

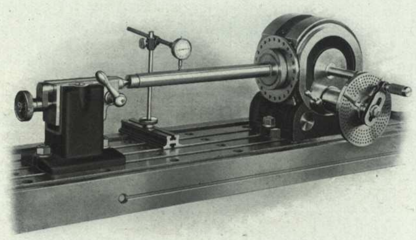
The swivel blocks of our dividing heads are efficiently clamped by plugs turned to the exact radius of the swivel dovetail. These plugs are brought up against both sides of the swivel blocks with equal pressure, so that there is never a tendency to throw the swivel block out of relation to the base.

The illustration shows a weight of 750 pounds supported at the end of a 22″ bar in the spindle of our 11″ dividing head. The swivel clamps were drawn up moderately tight with a 10″ wrench. The load was sustained without any evidence of failure.



RUNNING IN THE WORM AND WORM WHEEL

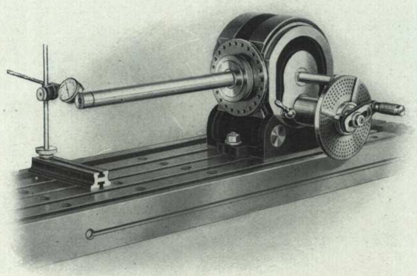
In order that the action between the worm and wheel may be absolutely free and unrestricted, all our dividing heads are run off under power. The worm is then adjusted to the wheel. No readjustment will be necessary for a considerable time, and then, only after hard and continuous usage. This is due to the large worm and wheel and the excellence of their material. The wheel is made of the best quality bronze and the worm of a high carbon crucible spindle steel.



TESTING THE ALIGNMENT OF HEAD AND TAIL CENTERS

These readings are taken both on vertical and horizontal centers and indicate the accuracy of the alignment between head and tail centers. LEBLOND Dividing Heads retain their original accuracy indefinitely. This is due to the excellence of design, the liberal bearing surfaces, and the rigid inspection of each single part in their construction.

The limit of error on this test is .001″. More than 90 per cent of our heads indicate less than ½ of this amount.

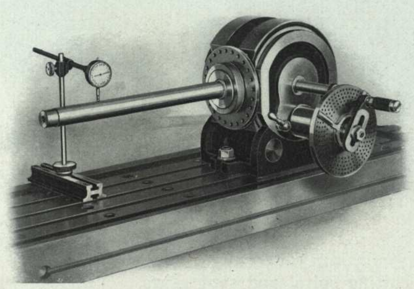


TESTING THE PARALLEL ACCURACY OF THE SPINDLE AND THE T SLOTS IN THE TABLE

In this case the indicator block is tongued to the table and guided from the T slots. Moving it the length of 18″ test bar shown in the spindle and taking the indicator reading (in ¼ thousandths) proves the parallelism of the T slots and the spindle.

This is a highly important test, as the T slots in the tables are of course correct in relation to the entire machine alignment.

The limit of error allowed is .001″ at the end of the bar.

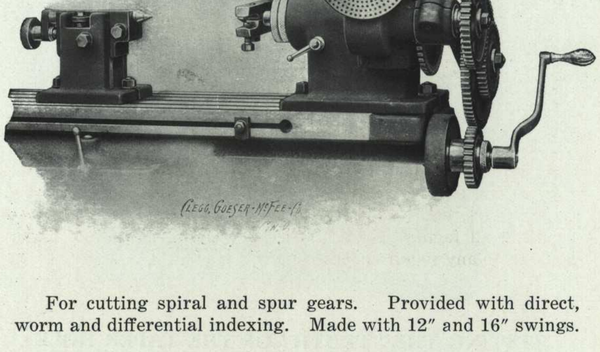


TESTING THE "TRUTH" OF THE TAPER HOLE

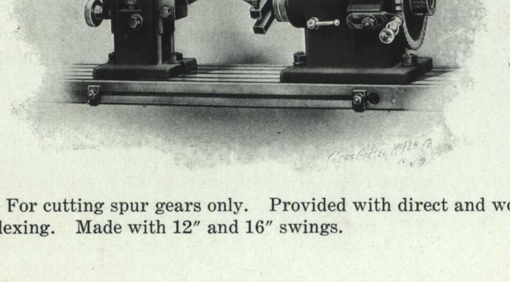
The spindle is revolved through the worm, and the indicator registers the amount that the spindle runs out. A true running center is highly essential, and every detail must be in perfect harmony to insure this condition. The indicator shows the variation each side of a true position. This test is taken at the mouth of the hole, and at the extremities of an 18″ test bar, both on horizontal and vertical centers.

If the indicator shows more than .001″ off at the end of the bar it will not pass inspection, and must be realigned.

LeBlond Gear Cutting Heads

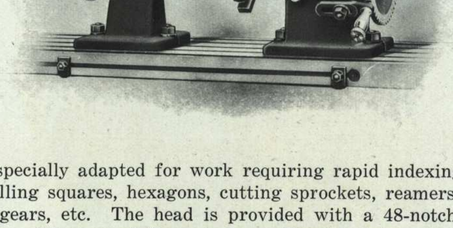


For cutting spiral and spur gears. Provided with direct, worm and differential indexing. Made with 12″ and 16″ swings.

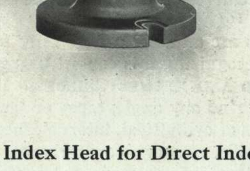


For cutting spur gears only. Provided with direct and worm indexing. Made with 12″ and 16″ swings.

Plain Index Centers for Direct Indexing Only

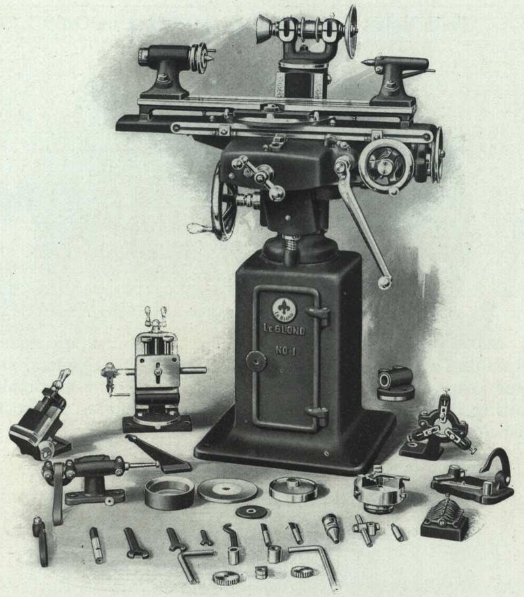


Especially adapted for work requiring rapid indexing, such as milling squares, hexagons, cutting sprockets, reamers, small spur gears, etc. The head is provided with a 48-notch plate, cutting all factors of that number. Special plates can be furnished to any requirements.



Vertical Index Head for Direct Indexing

This head provides an economical means of indexing for milling clutches, screw heads, etc. After the divisions are made, the spindle is locked by a spring plunger and effectively clamped to resist the thrust, by the clamp lever shown in the cut. The full height is 5¾″; the index plate, 5″ diameter with 24 divisions.



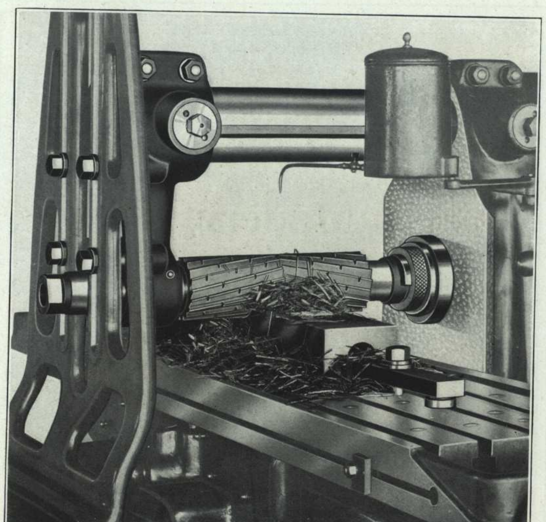
LeBlond Universal Cutter and Reamer Grinder
Range, 16″ table feed x 6¼″ cross, x 8¼″ vertical

Sharp cutters are an absolute necessity for continuous accurate milling. Recognizing this condition, we have developed the LeBlond Cutter and Reamer Grinder. It is absolutely universal, and will grind any angle, taper or face. It is adapted to grinding all kinds of cylindrical, internal, face and angular work, face mills, end mills, reamers, counterbores, circular saws, snap gauges, gear cutters, rose reamers, flat surfaces, and practically any job of tool-room grinding.

Capacity, work 8″ diameter and 17″ long between centers. With universal attachment, cutters up to 18″ diameter. Saws up to 36″ diameter that are ground on their radial faces.

We issue a separate treatise on grinding.

Modern Milling Practice



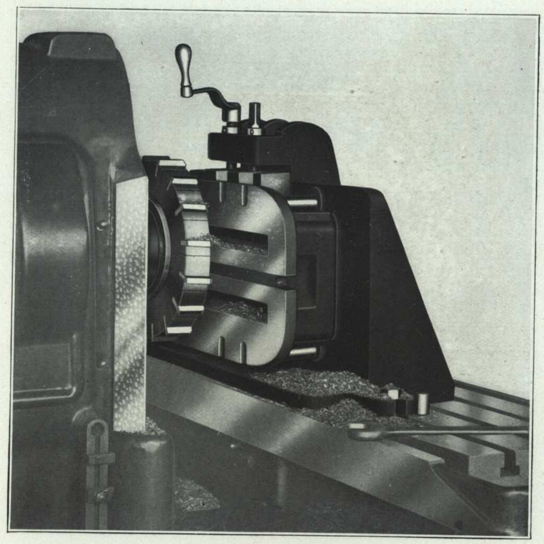
SLAB MILLING

This is a severe test of every element in support of the cut as well as the driving mechanism.

The material is machinery steel 65,000 pounds tensile strength, bar 5 inches wide. The depth of cut, ½ inch. Feed, 6⅝ inches per minute; cutting speed, 37 revolutions per minute. The cutter is 4 inches diameter.

This is equivalent to removing 16.5 cubic inches per minute. The machine is a No. 4 LeBlond All Geared Miller direct connected to a 15 horsepower motor. The net horsepower consumed by the cut is 16. Better than a cubic inch of metal per horsepower.

This production is only possible as the result of the powerful geared spindle drive, the absence of tumbler and bevel gearing and similar friction generating devices, a highly efficient feed drive and our rigid extended knee support. Details on page 62. It is suggestive of the possibilities for heavy milling on our machines when equipped with high speed cutters.



FACE MILLING

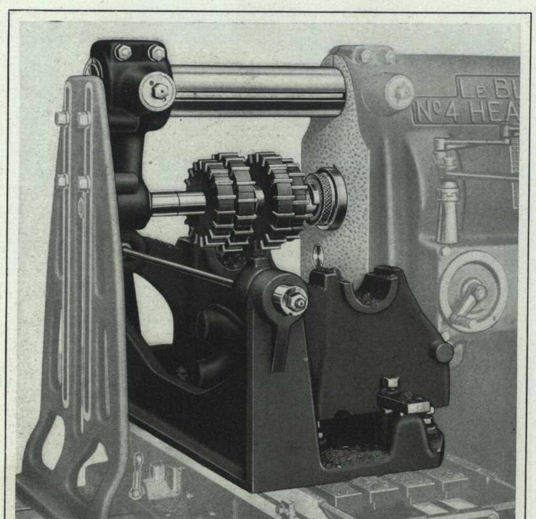
No. 4 LeBlond Single Pulley Drive Heavy Duty Miller.

Diameter of face mill, 12″. Feed, 6⅝″ per minute. Revolutions, 15. Amount of metal removed, ¼″.

The pieces are vise bottoms of semi-steel 22½″ long. A high degree of finish is not necessary, the finishing cut is taken after assembling. They are chucked in the quick clamping fixture illustrated and operation completed in six (6) minutes, including handling time.

The conditions under which these pieces are finished are most favorable. The knee, saddle and table are positioned to secure the greatest rigidity of their sections.

Our highly efficient feed drive, however, is an important factor to secure this production. We have determined that less than ¼ horsepower is required to drive the table traverse at 6⅝″ per minute. This is accomplished by the elimination of all chains, bevel gearing, or other power consuming devices.

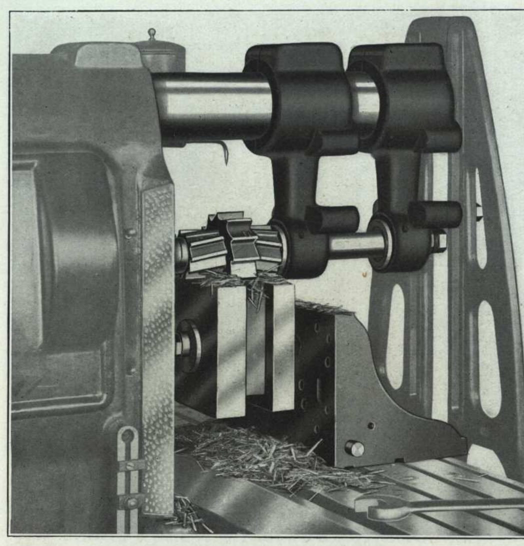


THESE PIECES WERE FORMERLY PLANED

These and many other similar pieces are more economically finished on the Heavy Duty Miller than on the planer. This is especially true on jobs of this character on which our rapid power traverse is used to jump over the spaces between the cuts at the rate of 25 feet per minute. Details, page 47. This reduces the total finishing time to practically actual cutting time. The pieces are interchangeable and absolutely to gauge. They are gray iron machine castings.

The large mills are $9\frac{5}{8}''$ diameter.
The small mills are $8\frac{7}{8}''$ diameter.
Rate of feed, $3\frac{7}{16}''$ per minute.
R. P. M., 23.
Rate quick traverse, 25′ per minute.
Total finishing time each, including handling, 12 minutes.
The castings are chucked in the rough and weigh 670 pounds.

The right handed system of control and the handiness of operation greatly facilitate the removal and replacing of the work.



AN EXAMPLE OF HEAVY SLAB MILLING

No. 4 LeBlond Plain Single Pulley Drive Miller.

The pieces are 30 point carbon steel, forged turret blocks, milled from the solid, in one cut. They are clamped on an indexing angle plate. The cutter gang consists of two slab mills $6\frac{3}{4}''$ diameter x $1\frac{3}{4}''$ wide and one $3\frac{3}{4}''$ diameter x $2\frac{1}{2}''$. All are of the coarse pitch design for the removal of large quantities of metal and provide ample chip space for the heaviest cuts.

Feed, $1\frac{1}{2}''$ per minute.

R. P. M., 43.

Total finishing time (4 cuts), 34 minutes, including handling time.

A milling machine in which the gibs for the sliding members are not correctly designed will of necessity chatter under this class of work. See page 41 for details of the double angle gibs, and the extended knee to column bearing providing support where it is most needed to resist the deflection.

LeBLOND No. 3 PLAIN SINGLE PULLEY DRIVE MILLER

Feed and speed are sacrificed on this job to secure a high degree of finish, and because the nature of the work will not permit of crowding. The finished surfaces must be to gauge and parallel.

The large mills are 4½″ diameter; high speed steel.

The smaller one for forming the tongue, 4″ diameter.

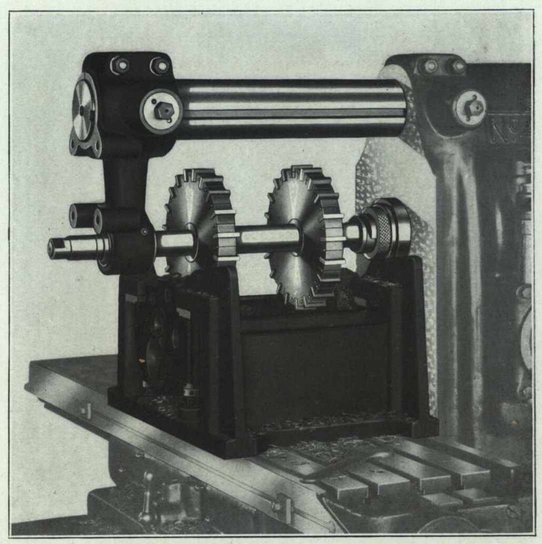
Feed, $5\frac{3}{16}$″ per minute. R. P. M., 46.

Length of cut, 18½″.

Total finishing time, including chucking, 6½ minutes.

The castings are chucked in the rough. All subsequent operations are worked from the milled surfaces. The accuracy of the finished piece is, therefore, dependent entirely upon the first milling operation.

Prominent among the features which enable our millers to excel on this class of work is the correctly designed arbor support, the liberal spindle bearings with hardened journals — both important factors.



THE VERTICAL FEED

No. 4 LeBlond Heavy Duty Single Pulley Drive Miller

This is the second milling operation on our quick change gear boxes. They are semi-steel machine castings, 35,000 pounds tensile strength.

The cutters are a pair of inserted blade side mills, 12½″ diameter.

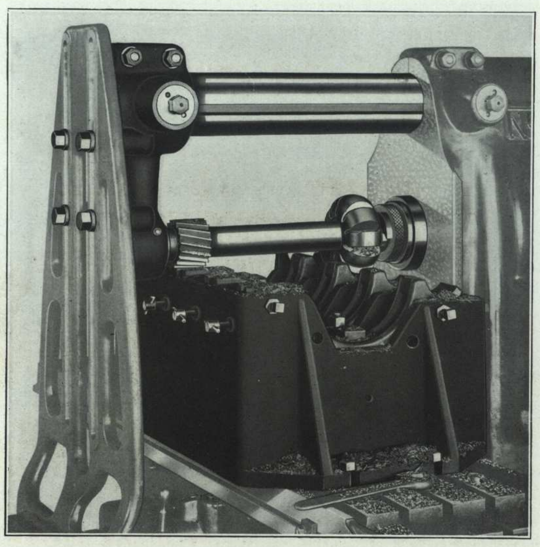
The work is fed vertically onto cutters.

Feed, .130 per revolution.

Cutting speed, 60′ per minute, or 19 R. P. M.

Work of this nature requires a rigid support for the cutter arbor, as no knee brace can be used to tie the supporting members together. This condition is obtained with our Patent Self-Aligning Arbor Supports, which provide a positive key alignment between the overarm and arbor, rendering them practically a unit for the resistance of the cutter thrusts.

Our box form knee, with its vertical ball thrust bearings, provides more than adequate support for the downward pressure resulting from the cut.



FORM MILLING

This job in no way taxes the pulling capacity of the machine, although the range of our No. 4 Miller is necessary to an economical jigging of the pieces.

The feed is limited by the design of the circular form cutter, as well as by the design of the work itself.

The pieces are steady rest tops, gray iron machine castings.

The cutters are $6\frac{3}{4}$″ and 4″ diameter.

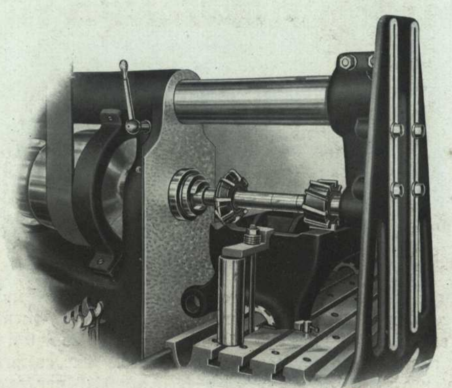
Feed, $1\frac{5}{16}$″ per minute.

R. P. M., 40.

Total finishing time each, 4 minutes, including chucking time.

The central location of the feed control, the handy positioning of the start, stop and quick return levers are big factors in determining the possibilities of rapid milling on this class of work.

The machine is a No. 4 Single Pulley Drive Geared Miller.



No. 4 PLAIN MILLING MACHINE, CONE DRIVEN

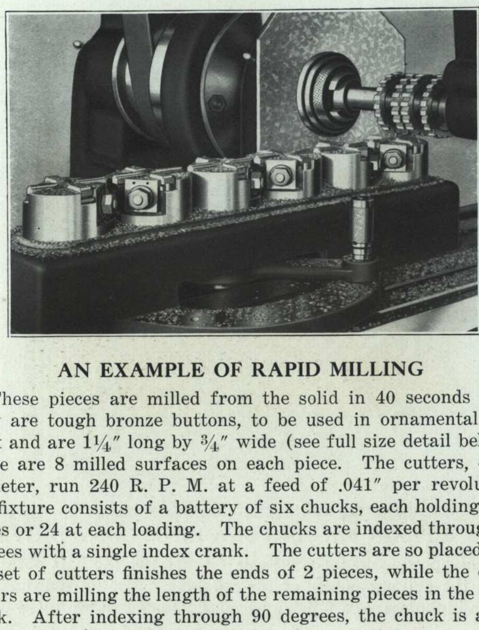
The speeds and feeds on this job are not the best obtainable from the driving power of the machine. They are adjusted to give a high degree of finish or accuracy necessary on these pieces.

The largest cutter is 8″ diameter, the smaller 6″.

Feed, .105″ per revolution of spindle. R. P. M., 28.

The pieces are handled with a crane and located on the table by hardened jig plates, not visible.

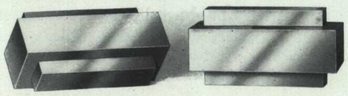
The total finishing time is seven (7) minutes each, including handling. A machine of less rigidity or convenience than our No. 4 Cone Drive Miller would not be capable of such production.



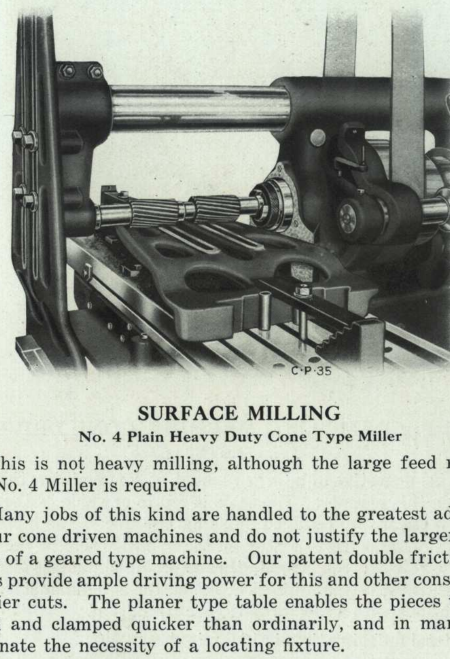
AN EXAMPLE OF RAPID MILLING

These pieces are milled from the solid in 40 seconds each. They are tough bronze buttons, to be used in ornamental iron work and are 1¼" long by ¾" wide (see full size detail below). There are 8 milled surfaces on each piece. The cutters, 4" in diameter, run 240 R. P. M. at a feed of .041" per revolution. The fixture consists of a battery of six chucks, each holding four pieces or 24 at each loading. The chucks are indexed through 90 degrees with a single index crank. The cutters are so placed that one set of cutters finishes the ends of 2 pieces, while the other cutters are milling the length of the remaining pieces in the same chuck. After indexing through 90 degrees, the chuck is again passed under the cutters, completing the operations.

The machine is a No. 3 LeBlond Heavy Duty Cone Type Miller equipped with our Patent Rapid Power Traverse. The rapid traverse is a large factor in enabling a single machine to finish the pieces at this remarkable rate, and a miller not equipped with this device could never equal this production.



Full Size Detail of Buttons



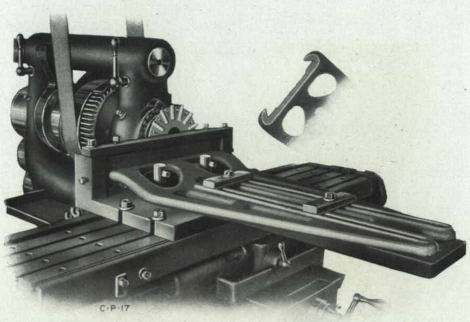
SURFACE MILLING

No. 4 Plain Heavy Duty Cone Type Miller

This is not heavy milling, although the large feed range of our No. 4 Miller is required.

Many jobs of this kind are handled to the greatest advantage on our cone driven machines and do not justify the larger investment of a geared type machine. Our patent double friction back gears provide ample driving power for this and other considerably heavier cuts. The planer type table enables the pieces to be located and clamped quicker than ordinarily, and in many cases eliminate the necessity of a locating fixture.

The feed is .078" per revolution.
R. P. M., 57.
Diameter of cutters, 4".
Length of cut, 28½".
Total finishing time, 21 minutes for both sides.
This includes handling and chucking; a crane is used.



C-P-17

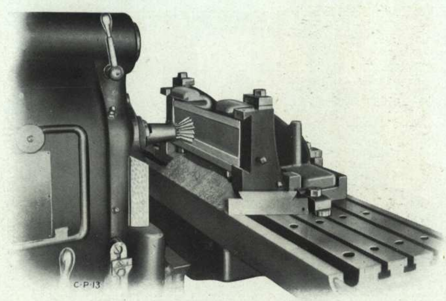
No. 3 PLAIN MILLING MACHINE, CONE DRIVEN

A 45° Form Face Milling Job

This is suggestive of a large amount of form milling that can be done in this manner. The table is fed to one side of the piece and the vertical feed engaged finishing one side. The table feed then engaged and fed to a stop on the opposite side of the piece where the vertical feed is again thrown in, finishing this side. A close limit must be maintained. The cutter is 9″ diameter, runs 23 revolutions with a feed of .062″ per revolution.

The total finishing time is 16.6 minutes.

This job does not tax the pulling capacity of the machine. The delicate points of the cutter prevent the use of heavier feeds and faster speed, possible on our No. 3 Miller.



C-P-13

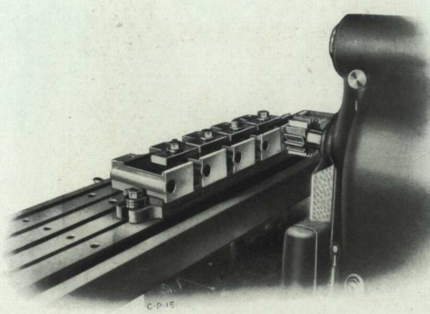
No. 3 HEAVY DUTY MILLING MACHINE

These castings are taper attachment brackets, cast iron. The operation consists of milling a 30 degree dovetail and surfacing the face bearings. Measuring is eliminated by the hardened gauge plates for setting the cutter at either end of the fixture.

One side of the dovetail is milled, the knee dropped to a stop, locating the second cut. The cutter is 3½″ diameter, a 30-degree form face mill.

Feed, $4\frac{1}{16}$″ per minute. R. P. M., 60.

The pieces are finished complete, with a high degree of finish, in 12 minutes each.



No. 2 PLAIN SINGLE PULLEY DRIVE MILLER

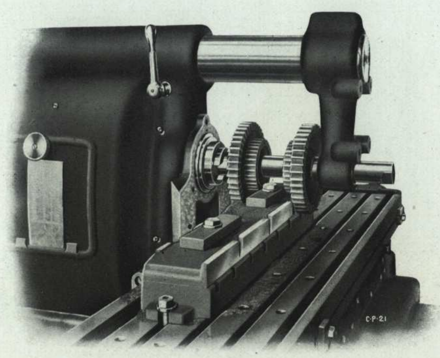
Face Milling

This is the second milling operation on these gray iron castings. They are clamped in a simple chuck from finished surfaces and fed past the cutter, the operator removing the finished pieces and rechucking others while the machine is in operation. This is practically continuous milling.

The face mill is 3″ diameter.

R. P. M., 84. Feed, $5\frac{3}{16}''$ per minute.

The total finishing time each is 3.1 minutes, including chucking time.



No. 3 PLAIN HEAVY DUTY SINGLE PULLEY DRIVE MILLER

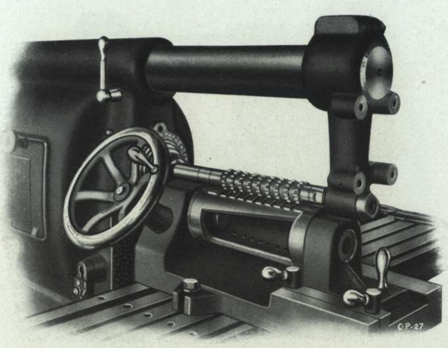
Gang Milling, Semi-Steel Vise Jaws

The large cutters are $7\frac{1}{4}''$ diameter. The smaller ones $3\frac{1}{4}''$. The pieces are chucked in a string fixture, 4 at a time and milled rapidly. The operator removing the finished pieces and rechucking others while the machine is in operation. The convenient location of the controlling levers, and the powerful geared spindle drive make this production possible.

R. P. M., 29.

Feed, $2\frac{1}{2}''$ per minute.

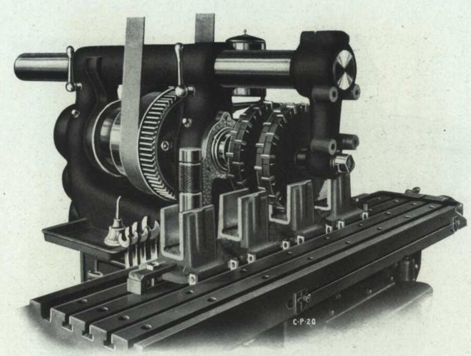
Total finishing time each, 6.1 minutes.



LeBLOND No. 3 HEAVY DUTY SINGLE PULLEY DRIVE MILLER

This operation consists of milling 9 slots in the periphery of the cast iron barrel illustrated. The barrel is rotated about the cutter gang through a worm and segment provided with a stop to give the proper length slots. The slots are 3/8″ wide, 5/32″ deep. The No. 3 Miller completes the operation in 3.3 minutes, including chucking.

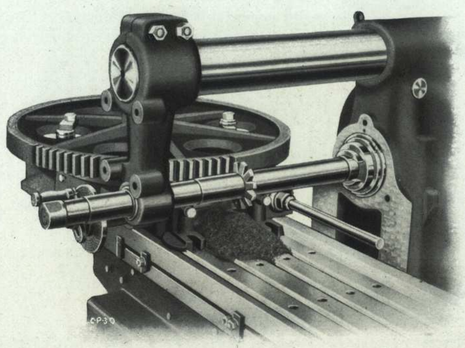
This operation clearly illustrates the necessity of correctly designed jigs and fixtures for manufacturing service. Our long experience on milling methods enables us to offer suggestions of value in the design of fixtures to secure the maximum output possible from any miller.



No. 3 PLAIN HEAVY DUTY CONE TYPE MILLER

The gray iron machine castings are roughed and finished at one setting. The inserted blade cutters, 12″ diameter x 2½″ wide are adjustable for width and the pieces are finished to gauge. The operation consists of milling straight through with a roughing cutter, moving the table over to a positive micrometer cross stop, until the finishing cutter is brought into position for its work.

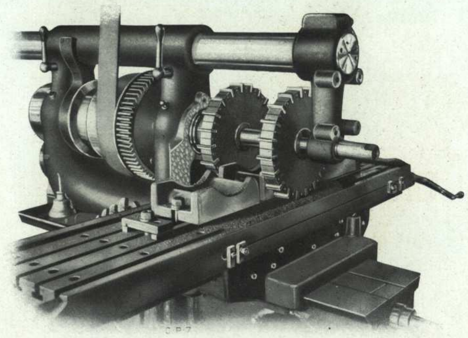
Rough cut, R. P. M., 19.
Feed, .062″ per revolution.
Finishing cut, R. P. M., 23.
Feed, .083″ per revolution.
Total finishing time per piece, 14 minutes.



No. 3 PLAIN SINGLE PULLEY DRIVE MILLER WITH CIRCULAR MILLING ATTACHMENT

While this is not the most commercial method of cutting spur gears, many large gears beyond the range of the gear cutters in a shop can be cut satisfactorily in this manner. The blanks are mounted on a circular milling attachment with a spacing device and the vertical feed used. The gear illustrated is 28″ diameter, 3 pitch, 84 teeth, width of face 3″.

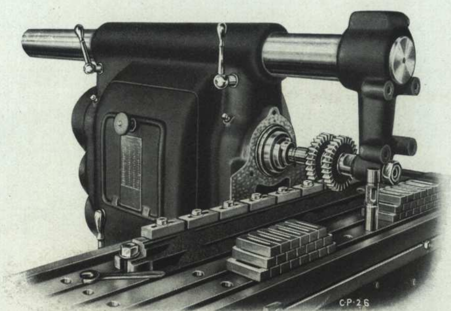
Gears up to 40″ in diameter can be cut on our No. 4 Miller. This is possible on account of our rigid saddle construction and the support it affords at the extremities of the table travel.



STRADDLE MILLING

No. 3 Heavy Duty Cone Type Miller

The pieces are dividing head bottoms of close grained cast iron. They are finished to micrometer gauge and must interchange. The straddle mills are 14″ diameter, feed .125″ per revolution, speed 15 R. P. M., amount of metal removed on side, $\frac{3}{16}$″. This is a job that is being done every day on one of our No. 3 Heavy Duty Cone Type Millers. Total finishing time, including chucking, 8 minutes each.



STRADDLE MILLING

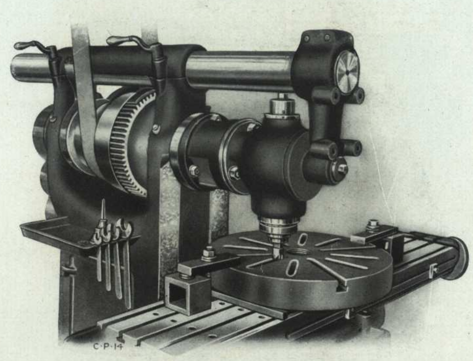
No. 2 Single Pulley Drive Miller

The pieces are cast iron steady rest jaws, $3\frac{1}{2}''$ long x $\frac{5}{8}''$ thick; $\frac{3}{32}''$ metal removed on each side.

Six of them are finished complete in 3.96 minutes or .66 minutes for each, including handling time.

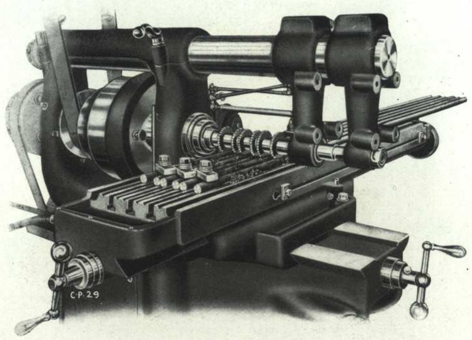
The cutters are coarse pitch side mills 5″ diameter, running 49 revs. Feed, .148″ per revolution of cutter or $7\frac{1}{4}''$ per minute.

The milling is practically continuous, the operator removing and rechucking pieces as they are completed. Our right handed control scheme and the placing of the start, stop and quick return levers on the same side of the machine enable the pieces to be finished at this remarkable rate.



THIS METHOD IS CHEAPER THAN FILING

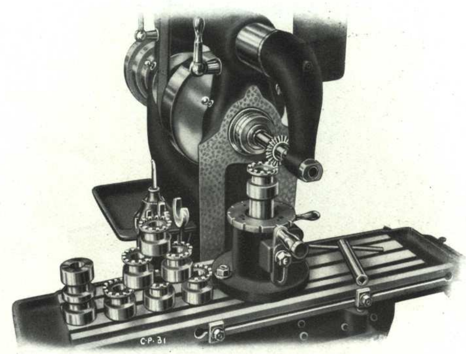
Jobs of this kind are more profitable milled than filed. The corners of this face plate are beveled in this manner in 10 minutes, including chucking and handling time. The total length of the slots is 61″. The table is fed by hand, the slot lined up by a straight edge against stops on the table. The machine is a No. 2 LeBlond Heavy Duty Cone Type Miller, equipped with a vertical spindle milling attachment.



No. 1 PLAIN CONE DRIVE MILLER

The milling of splines in feed shafts, etc., is not an operation that would justify a large investment. A plain, simple belt feed machine with a wide driving belt, such as our No. 1 Miller, meets the requirements admirably. The feed cones are well proportioned and capable of delivering ample power to the table feed mechanism.

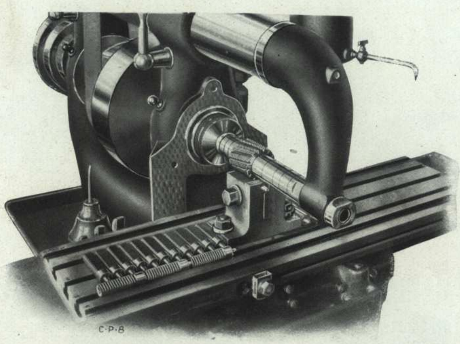
The job illustrated is that of cutting six $\frac{3}{16}$" splines in machinery steel shafting. The LEBLOND No. 1 does this at 3½" per minute on the 6 shafts with a 2½" diameter cutter.



No. 0 PLAIN MILLER

The rapidity and facility with which this miller is handled particularly adapt it to clutch milling operations. The clutches are of 3½ per cent nickel steel, and each must conform to gauge. They are chucked on a vertical index head, and the 13 teeth milled complete in 9 minutes. Feed, .046" per rev. R. P. M., 83.

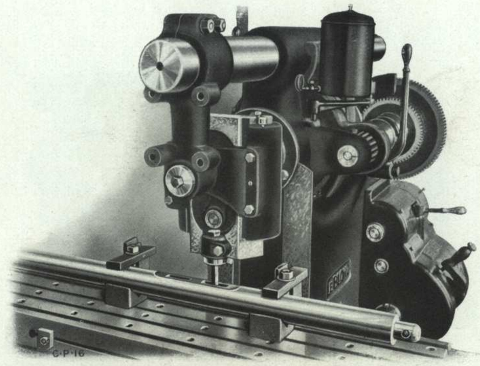
Our No. 0 Millers are capable of doing this class of work contінously.



No. 0 PLAIN MILLER

The rack milling job illustrated is completed in 1½ minutes each. The pieces are of 40 point carbon steel. The rack 12 pitch, 16 T cut from the solid at one cut. Feed, 3½″ per minute. R. P. M., 98. Cutter diameter, 2½″.

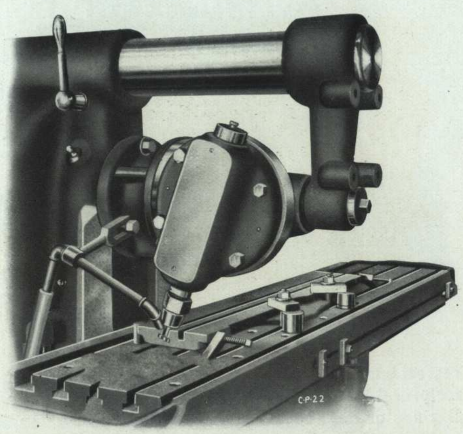
This illustrates an operation typical of the class of work for which our belt feed machines are adapted. The pieces, cylindrical in form, are inserted in a quick clamping fixture designed for this particular operation. The economy of this is apparent at a glance.



SLOTTING ATTACHMENT

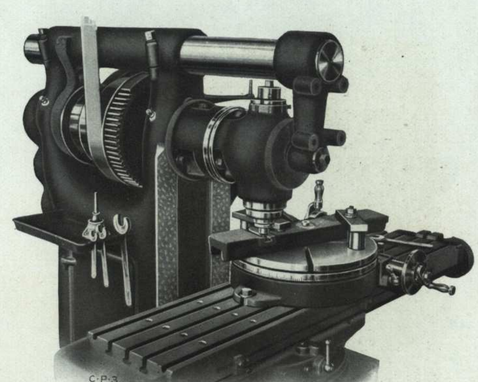
This attachment changes the circular motion of the miller to a reciprocal motion, as in the shaper or slotter, and adapts it for all kinds of die and tool making. It will also handle many kinds of manufacturing jobs that require slotting, key-waying or splining.

The attachment is furnished with a base to fit the machine on which it is to be used. It is bolted to the face of the column and the outer end is supported in the arbor support of the machine. The housing is graduated and can be set at any angle throughout 360 degrees, enabling slotting to be done at any angle, from vertical to horizontal. The slotter head is driven from the clutch on the spindle nose and is adjustable to any length of stroke, from zero to full capacity. The tool holder is graduated and can be swiveled in its bearing and clamped, enabling the cutting edge of the tool to be set in correct relation to the work without disturbing its adjustment.



THE UNIVERSAL MILLING ATTACHMENT

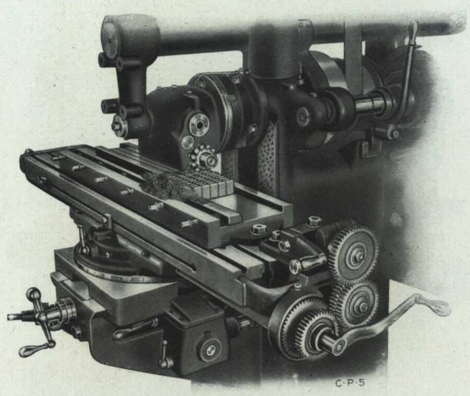
With this attachment milling can be done at any plane or angle within the range of the machine. It can be turned completely around from the vertical to horizontal on either side. The job illustrated is under-cutting an angular T slot in one of our cutter grinder tables. It is a standard ½″ T slot. The cutter runs 286 revolutions per minute at a feed of .025″ per revolution. The work is 29 inches long. The operation is completed in 6 minutes, including handling and chucking time.



VERTICAL ATTACHMENT AND CIRCULAR MILLING TABLE

A ⅝″ circular T slot milling operation. The bars are centered by a locating stud on the circular table, clamped and the circular feed engaged. The slot is cleared of chips by a high pressure air blast. The table is fed rapidly over the space between the cuts by hand, with the crank provided for that purpose.

The cutter runs 286 R. P. M., the feed is $6\frac{3}{16}$″ per minute. This operation is completed in 5 minutes. The machine is a No. 1½ LeBlond Cone Driven Miller.

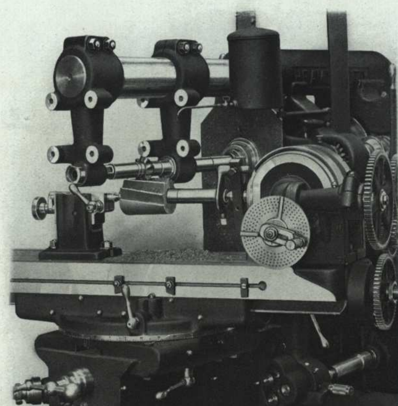


No. 2 LeBLOND UNIVERSAL CONE DRIVEN MILLER

Rack Cutting and Spacing Attachment

With this attachment rack up to 3 pitch in steel can be cut. The spacing attachment eliminates the necessity of using the graduated dial for the spacing. Change gear combination permit of the spacing being done with a single notched disc. The disc making a half or whole revolution, as indicated in the table.

Tables for spacing on plain and universal millers are furnished with each machine which enable the operator to space for all diametral and circular pitches.



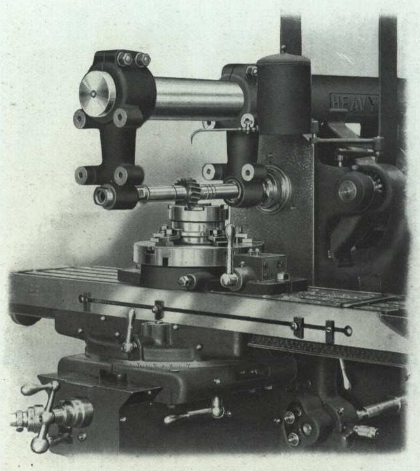
MILLING LARGE SPIRAL SURFACE MILL

This milling cutter is of high grade tool steel — 4⅜″ diameter, 8 teeth, 1⅝″ pitch, ½″ depth. The teeth are milled from the solid at a single cut.

Absolute rigidity of the dividing head centers is necessary for this class of work.

The placing of the dividing head and quick return lever on the operating (right hand) side of the machine, adds greatly to its productiveness on this class of work.

The operator has full operating control of the machine and the work without leaving his position at the right of table.



SPECIAL INDEX FIXTURES

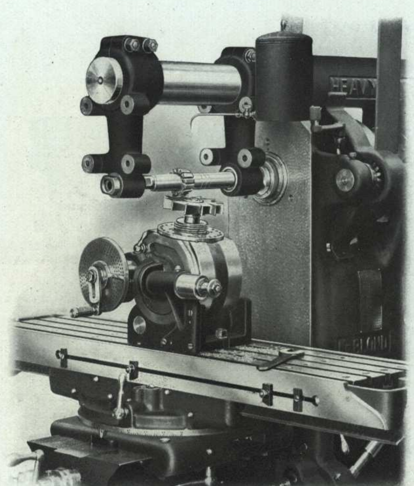
This is one of the many special index fixtures we have developed for individual requirements.

The fixture is for milling 4-5-6-7-8-10 radial jaw clutches by means of interchangeable index rings.

We are always ready to give our customers the result of our experience in developing special jigs and fixtures.

We will furnish design of fixtures for application to any of our millers, worked out to suit the convenience of a right handed operator.

That's the way all LEBLOND Millers are built.

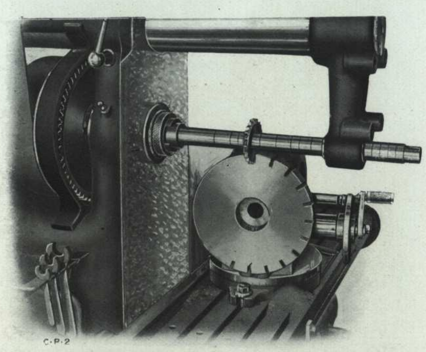


MILLING SIDE CLEARANCE ON SOLID MILLING CUTTER

Dividing head swivel set to clearance angle. Swivel table set to zero.

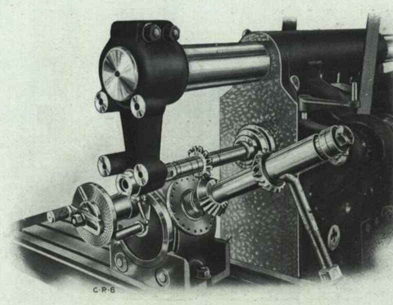
We have developed a table of these clearance angles and cutting data that will be furnished anyone interested.

A dividing head whose swivel clamps are of faulty design is very apt to cause trouble on this class of work. We refer the reader to detail of the efficient plug clamps shown on page 113.



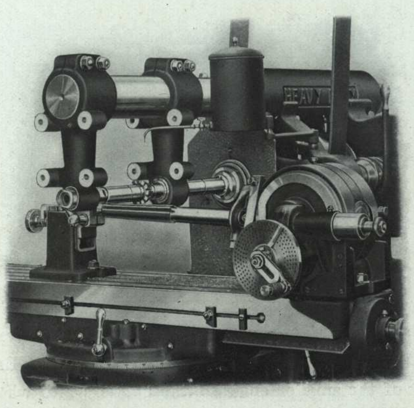
USING THE SWIVEL BASE AS A RAISING BLOCK

Many jobs, large cutter blanks, etc., require more than the normal swing of the dividing head. The swing can be increased 2½" to 3" by mounting the head on the swivel base of the vise with which it is interchangeable. A similar block can be provided for the tail center for swings beyond the range of the vertical adjustment.



MILLING A PAIR OF REVERSE BEVEL GEARS

Many of the smaller engine lathe builders into whose shops the gear shaper has not been introduced, cut their apron bevels on the milling machine. For every small jobbing shop a LeBlond Dividing Head is a necessity and an investment that will pay for itself in a very short period. Milling cutters, taps, reamers, drills, counterbores, worms and wheels, bevel, spur and spiral gears furnish but a few examples of the very extensive uses to which it can be put.



FLUTING A TAPER REAMER

Our dividing head tailstocks are provided with a vertical screw adjustment to provide for taper milling, the flutes of reamers, twist drills, etc.

The table opposite gives the taper per foot and corresponding angle.

EQUIVALENT INCHES AND TAPERS PER FOOT

Taper per Foot		Angle with Center Line		Included Angle		Taper per Ft.	Angle with Center Line		Included Angle	
		Deg.	Min.	Deg.	Min.		Deg.	Min.	Deg.	Min.
1/8″	.125″	......	18	......	36	1 5/8″	3	53	7	46
3/16″	.1875″	......	27	......	54	1 11/16″	4	1	8	2
1/4″	.250″	......	36	1	12	1 3/4″	4	10	8	20
5/16″	.3125″	......	45	1	30	1 13/16″	4	19	8	38
3/8″	.375″	......	54	1	47	1 7/8″	4	28	8	56
7/16″	.4375″	1	2	2	5	1 15/16″	4	35	9	10
1/2″	.5″	1	12	2	23	2″	4	46	9	32
9/16″	.5625″	1	21	2	41	2 1/8″	5	4	10	8
5/8″	.625″	1	30	3	......	2 1/4″	5	22	10	44
11/16″	.6875″	1	38	3	16	2 3/8″	5	34	11	8
3/4″	.750″	1	47	3	35	2 1/2″	6	......	12	......
13/16″	.8125″	1	56	3	53	2 5/8″	6	16	12	32
7/8″	.875″	2	5	4	10	2 3/4″	6	32	13	4
15/16″	.9375″	2	14	4	28	2 7/8″	6	46	13	32
1″		2	23	4	46	3″	7	10	14	20
1 1/16″	1.0625″	2	32	5	4	3 1/8″	7	28	14	56
1 1/8″		2	41	5	22	3 1/4″	7	46	15	32
1 3/16″		2	47	5	34	3 3/8″	8	2	16	4
1 1/4″		3	......	6	......	3 1/2″	8	20	16	40
1 5/16″		3	8	6	16	3 5/8″	8	38	17	16
1 3/8″		3	16	6	32	3 3/4″	8	56	17	52
1 7/16″		3	23	6	46	3 7/8″	9	10	18	20
1 1/2″		3	35	7	10	4″	9	32	19	4
1 9/16″		3	44	7	28	......	......	......	......	......

EQUIVALENTS—Inches to Millimeters

Inch	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
0	0.0	1.6	3.2	4.8	6.4	7.9	9.5	11.1	12.7	14.3	15.9	17.5	19.1	20.6	22.2	23.8
1	25.4	27.0	28.6	30.2	31.7	33.3	34.9	36.5	38.1	39.7	41.3	42.9	44.4	46.0	47.6	49.2
2	50.8	52.4	54.0	55.6	57.1	58.7	60.3	61.9	63.5	65.1	66.7	68.3	69.8	71.4	73.0	74.6
3	76.2	77.8	79.4	81.0	82.5	84.1	85.7	87.3	88.9	90.5	92.1	93.7	95.2	96.8	98.4	100.0
4	101.6	103.2	104.8	106.4	108.0	109.5	111.1	112.7	114.3	115.9	117.5	119.1	120.7	122.2	123.8	125.4
5	127.0	128.6	130.2	131.8	133.4	134.9	136.5	138.1	139.7	141.3	142.9	144.5	146.1	147.6	149.2	150.8
6	152.4	154.0	155.6	157.2	158.8	160.3	161.9	163.5	165.1	166.7	168.3	169.9	171.5	173.0	174.6	176.2
7	177.8	179.4	181.0	182.6	184.2	185.7	187.3	188.9	190.5	192.1	193.7	195.3	196.9	198.4	200.0	201.6
8	203.2	204.8	206.4	208.0	209.6	211.1	212.7	214.3	215.9	217.5	219.1	220.7	222.3	223.8	225.4	227.0
9	228.6	230.2	231.8	233.4	235.0	236.5	238.1	239.7	241.3	242.9	244.5	246.1	247.7	249.2	250.8	252.4
10	254.0	255.6	257.2	258.8	260.4	261.9	263.5	265.1	266.7	268.3	269.9	271.5	273.1	274.6	276.2	277.8
11	279.4	281.0	282.6	284.2	285.7	287.3	288.9	290.5	292.1	293.7	295.3	296.9	298.4	300.0	301.6	303.2
12	304.8	306.4	308.0	309.6	311.1	312.7	314.3	315.9	317.5	319.1	320.7	322.3	323.8	325.4	327.0	328.6
13	330.2	331.8	333.4	335.0	336.5	338.1	339.7	341.3	342.9	344.5	346.1	347.7	349.2	350.8	352.4	354.0
14	355.6	357.2	358.8	360.4	361.9	363.5	365.1	366.7	368.3	369.9	371.5	373.1	374.6	376.2	377.8	379.4
15	381.0	382.6	384.2	385.8	387.3	388.9	390.5	392.1	393.7	395.3	396.9	398.5	400.0	401.6	403.2	404.8
16	406.4	408.0	409.6	411.2	412.7	414.3	415.9	417.5	419.1	420.7	422.3	423.9	425.4	427.0	428.6	430.2
17	431.8	433.4	435.0	436.6	438.1	439.7	441.3	442.9	444.5	446.1	447.7	449.3	450.8	452.4	454.0	455.6
18	457.2	458.8	460.4	462.0	463.5	465.1	466.7	468.3	469.9	471.5	473.1	474.7	476.2	477.8	479.4	481.0
19	482.6	484.2	485.8	487.4	488.9	490.5	492.1	493.7	495.3	496.9	498.5	500.1	501.6	503.2	504.8	506.4
20	508.0	509.6	511.2	512.8	514.3	515.9	517.5	519.1	520.7	522.3	523.9	525.5	527.0	528.6	530.2	531.8
21	533.4	535.0	536.6	538.2	539.7	541.3	542.9	544.5	546.1	547.7	549.3	550.9	552.4	554.0	555.6	557.2
22	558.8	560.4	562.0	563.6	565.1	566.7	568.3	569.9	571.5	573.1	574.7	576.3	577.8	579.4	581.0	582.6
23	584.2	585.8	587.4	589.0	590.5	592.1	593.7	595.3	596.9	598.5	600.1	601.7	603.2	604.8	606.4	608.0

39.37 inches = 1 m. = 10 dm. = 100cm. = 1000 mm.

EQUIVALENTS—Millimeters to Inches

$\frac{1}{100}$ mm. = .0003937″

mm.	Inches.	mm.	Inches.	mm.	Inches.	mm.	Inches.
1/50 =	.00079	39/50 =	.03071	27 =	1.06299	64 =	2.51968
2/50 =	.00157	40/50 =	.03150	28 =	1.10236	65 =	2.55905
3/50 =	.00236	41/50 =	.03228	29 =	1.14173	66 =	2.59842
4/50 =	.00315	42/50 =	.03307	30 =	1.18110	67 =	2.63779
5/50 =	.00394	43/50 =	.03386	31 =	1.22047	68 =	2.67716
6/50 =	.00472	44/50 =	.03465	32 =	1.25984	69 =	2.71653
7/50 =	.00551	45/50 =	.03543	33 =	1.29921	70 =	2.75590
8/50 =	.00630	46/50 =	.03622	34 =	1.33858	71 =	2.79527
9/50 =	.00709	47/50 =	.03701	35 =	1.37795	72 =	2.83464
10/50 =	.00787	48/50 =	.03780	36 =	1.41732	73 =	2.87401
11/50 =	.00866	49/50 =	.03858	37 =	1.45669	74 =	2.91338
12/50 =	.00945	1 =	.03937	38 =	1.49606	75 =	2.95275
13/50 =	.01024	2 =	.07874	39 =	1.53543	76 =	2.99212
14/50 =	.01102	3 =	.11811	40 =	1.57480	77 =	3.03149
15/50 =	.01181	4 =	.15748	41 =	1.61417	78 =	3.07086
16/50 =	.01260	5 =	.19685	42 =	1.65354	79 =	3.11023
17/50 =	.01339	6 =	.23622	43 =	1.69291	80 =	3.14960
18/50 =	.01417	7 =	.27559	44 =	1.73228	81 =	3.18897
19/50 =	.01496	8 =	.31496	45 =	1.77165	82 =	3.22834
20/50 =	.01575	9 =	.35433	46 =	1.81102	83 =	3.26771
21/50 =	.01654	10 =	.39370	47 =	1.85039	84 =	3.30708
22/50 =	.01732	11 =	.43307	48 =	1.88976	85 =	3.34645
23/50 =	.01811	12 =	.47244	49 =	1.92913	86 =	3.38582
24/50 =	.01890	13 =	.51181	50 =	1.96850	87 =	3.42519
25/50 =	.01969	14 =	.55118	51 =	2.00787	88 =	3.46456
26/50 =	.02047	15 =	.59055	52 =	2.04724	89 =	3.50393
27/50 =	.02126	16 =	.62992	53 =	2.08661	90 =	3.54330
28/50 =	.02205	17 =	.66929	54 =	2.12598	91 =	3.58267
29/50 =	.02283	18 =	.70866	55 =	2.16535	92 =	3.62204
30/50 =	.02362	19 =	.74803	56 =	2.20472	93 =	3.66141
31/50 =	.02441	20 =	.78740	57 =	2.24409	94 =	3.70078
32/50 =	.02520	21 =	.82677	58 =	2.28346	95 =	3.74015
33/50 =	.02598	22 =	.86614	59 =	2.32283	96 =	3.77952
34/50 =	.02677	23 =	.90551	60 =	2.36220	97 =	3.81889
35/50 =	.02756	24 =	.94488	61 =	2.40157	98 =	3.85826
36/50 =	.02835	25 =	.98425	62 =	2.44094	99 =	3.89763
37/50 =	.02913	26 =	1.02362	63 =	2.48031	100 =	3.93700
38/50 =	.02992						

10 mm. = 1 Centimeter = 0.3937 inches.
10 cm. = 1 Decimeter = 3.937 "
10 dm. = 1 Meter = 39.37 "
25.4 mm. = 1 English Inch.

MORSE TAPERS

Number of Taper	Diam. of Plug at Small End	Diameter at End of Socket	Standard Plug Depth	Whole Length of Shank	Depth of Hole	End of Socket to Keyway	Length of Keyway	Width of Keyway	Length of Tongue	Diameter of Tongue	Thickness of Tongue	Radius of Mill for Tongue	Radius of Tongue	Shank Depth	Taper per Foot	Taper per Inch	Number of Key
	D	A	P	B	H	K	L	W	T	d	t	R	a	S			
0	.252	.356	2	2 3/8	2 1/32	1 15/16	9/16	.160	9/32	.24	5/32	5/32	.04	2 1/4	.625	.05208	0
1	.369	.475	2 1/8	2 5/8	2 3/16	2 1/16	3/4	.213	3/8	.35	13/64	3/16	.05	2 7/16	.600	.05	1
2	.572	.700	2 9/16	3 1/8	2 5/8	2 1/2	7/8	.260	7/16	.55	1/4	1/4	.06	2 15/16	.602	.05016	2
3	.778	.938	3 3/16	3 7/8	3 1/4	3 1/16	1 1/16	.322	9/16	.75	5/16	9/32	.08	3 11/16	.602	.05016	3
4	1.02	1.231	4 1/16	4 7/8	4 1/8	3 7/8	1 1/4	.478	5/8	.98	15/32	5/16	.10	4 5/8	.623	.05191	4
5	1.475	1.748	5 3/16	6 1/8	5 1/4	4 15/16	1 1/2	.635	3/4	1.41	5/8	3/8	.12	5 7/8	.630	.0525	5
6	2.116	2.494	7 1/4	8 5/8	7 3/8	7	1 3/4	.76	1 1/8	2.00	3/4	1/2	.15	8 1/4	.626	.05216	6
7	2.75	3.27	10	11 3/4	10 1/8	9 1/2	2 5/8	1.135	1 1/2	2 11/16	1 1/8	3/4	.18	11 3/8	.625	.05208	7

B. & S. TAPERS WITH TONGUES

Number of Taper	Diam. of Plug at Small End	Diameter at End of Socket	Standard Plug Depth	Whole Length of Shank	Depth of Hole	End of Socket to Keyway	Length of Keyway	Width of Keyway	Length of Tongue	Diameter of Tongue	Thickness of Tongue	Radius of Mill for Tongue	Radius of Tongue	Shank Depth	Taper per Foot	Taper per Inch
	D	A	P	B	H	K	L	W	T	d	t	R	a	S		
4	.35	.402	1 1/4	1 3/4	1 3/8	1 13/64	11/16	.228	11/32	.320	7/32	5/16	.050	1 21/32	.500	.0416
5	.45	.5229	1 3/4	2 9/32	1 7/8	1 11/16	3/4	.260	3/8	.420	1/4	5/16	.060	2 3/16	.500	.0416
6	.50	.599	2 3/8	2 31/32	2 1/2	2 19/64	7/8	.291	7/16	.460	9/32	5/16	.060	2 7/8	.500	.0416
6	.50	.6354	3 1/4	3 27/32	3 3/8	3 11/64	7/8	.291	7/16	.460	9/32	5/16	.060	3 3/4	.500	.0416
7	.60	.725	3	3 5/8	3 1/8	2 29/32	15/16	.322	15/32	.560	5/16	3/8	.070	3 17/32	.500	.0416
7	.60	.7667	4	4 5/8	4 1/8	3 29/32	15/16	.322	15/32	.560	5/16	3/8	.070	4 17/32	.500	.0416
8	.75	.8985	3 9/16	4 1/4	3 11/16	3 29/32	1	.353	1/2	.710	11/32	3/8	.080	4 1/8	.500	.0416
9	.90	1.0667	4	4 3/4	4 1/8	3 7/8	1 1/8	.385	9/16	.860	3/8	7/16	.100	4 5/8	.500	.0416
10	1.0446	1.26	5	6 1/16	5 1/8	4 27/32	1 5/16	.447	21/32	1.01	7/16	1/2	.110	5 23/32	.5161	.043
10	1.0446	1.289	5 11/16	6 3/4	5 13/16	5 17/32	1 5/16	.447	21/32	1.01	7/16	1/2	.110	6 13/32	.5161	.043
10	1.0446	1.312	6 7/32	7 9/32	6 11/32	6 1/16	1 5/16	.447	21/32	1.01	7/16	1/2	.110	6 15/16	.5161	.043
11	1.25	1.53	6 3/4	7 13/16	6 7/8	6 19/32	1 5/16	.447	21/32	1.21	7/16	1/2	.130	7 15/32	.500	.0416
12	1.50	1.797	7 1/8	8 9/32	7 1/4	6 15/16	1 1/2	.510	3/4	1.46	1/2	1/2	.150	7 15/16	.500	.0416

TABLE OF CUTTING SPEEDS

Feet Per Minute

Diam. Inches.	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
	REVOLUTIONS PER MINUTE.														
1/16	917.	1223.	1528.	1834.	2140.	2445	2751	3057	3363	3668	3974	4280	4586	4891	5197
1/8	459.	611.	764.	917.	1070.	1222.	1375.	1528.	1681	1834	1986	2139	2292	2445	2598
3/16	306.	408.	509.	611.	713.	815.	917.	1019.	1121	1222	1325	1426	1529	1630	1732
1/4	229.	306.	382.	458.	535.	611.	688.	764.	851	917	994	1070	1147	1222	1300
5/16	183.	245.	306.	367.	428.	489.	550.	611.	672	733	794	856	917	978	1039
3/8	153.	204.	255.	306.	357.	408.	458.	509	560	611	662	713	764	815	865
7/16	131.	175.	218.	262.	306.	349.	393.	437.	481	524	568	611	656	699	743
1/2	115.	153.	191.	229.	268.	306.	344.	382.	420	459	497	535	573	611	649
9/16	102.	136.	170.	204.	238.	272.	306.	340.	373	407	441	475	509	543	577
5/8	91.8	123.	153.	184.	214.	245.	276.	306.	337	367	398	428	459	489	520
11/16	83.3	111.	138.	167.	194	222.	249.	273.	300	333	360	389	416	444	472
3/4	76.3	102.	127.	153.	178.	203.	229.	254.	279	306	330	357	381	408	432
13/16	71.1	94.8	119.	142.	166.	190.	213.	237.	261	284	308	332	356	379	403
7/8	65.5	87.3	109.	131.	153.	175.	196.	219.	241	262	285	306	329	349	372
15/16	61.0	81.4	101.	122.	142.	163.	183.	204.	224	244	265	285	305	326	346
1	57.3	76.4	95.5	115.	134.	153.	172.	191	210	229	258	267	287	306	325
1 1/16	53.9	71.8	89.8	108.	126	144.	162.	180.	197	215	233	251	269	287	305
1 1/8	51.0	68.0	85.0	102.	119	136.	153.	170.	187	204	221	238	255	272	289
1 3/16	48.3	64.4	80.5	96.6	113.	129.	145.	161.	177	193	209	225	242	258	274
1 1/4	45.8	61.2	76.3	91.8	107.	123	137	153.	168	183	199	214	230	245	260
1 5/16	43.6	58.2	72.8	87.3	102.	116.	131	146.	160	175	189	204	218	233	247
1 3/8	41.7	55.6	69.5	83.3	97.2	111.	125.	139.	153	167	180	195	208	222	236
1 7/16	39.8	53.0	66.3	79.5	92.8	106.	119.	133	146	159	172	186	199	212	225
1 1/2	38.2	50.8	63.7	76.3	89.2	102.	115.	127	140	153	165	178	191	204	216
1 9/16	36.6	48.8	61.0	73.2	85.4	97.6	110.	122.	134	146	159	171	183	195	207
1 5/8	35.0	47.0	58.8	70.5	82.2	93.9	106.	117.	129	141	152	165	176	188	199
1 11/16	33.9	45.2	56.5	67.8	79.1	90.4	102.	113	124	136	147	158	170	181	192
1 3/4	32.7	43.6	54.5	65.5	76.4	87.3	98.2	109.	120	131	142	153	164	175	185
1 13/16	31.7	42.2	52.8	63.3	73.9	84.4	95.0	106.	116	127	137	148	158	169	179
1 7/8	30.6	40.7	50.9	61.1	71.3	81.5	91.9	102.	112	122	133	143	153	163	173
1 15/16	29.6	39.4	49.3	59.1	69.0	78.8	88.7	98.5	108	118	128	138	148	158	167
2	28.7	38.2	47.8	57.3	66.9	76.4	86.0	95.5	105	115	124	134	143	153	162

TABLE OF CUTTING SPEEDS—Continued

Feet Per Minute

Diam. Inches	90	95	100	110	120	125	130	140	150	160	170	175	180	190	200
	REVOLUTIONS PER MINUTE.														
2 1/8	162.	171.	180.	198.	216.	225.	234.	252.	270.	288.	306.	315.	324.	342.	360.
2 1/4	153.	162.	170.	187.	204.	213.	221.	238.	255.	272.	289.	298.	306.	313.	340.
2 3/8	145.	153.	161.	177.	193.	201.	209.	225.	242.	258.	274.	282.	290.	306.	322.
2 1/2	138.	145.	153.	168.	184.	191.	199.	213.	230.	245.	260.	268.	275.	291.	306.
2 5/8	131.	138.	145.	160.	174.	181.	189.	203.	218.	232.	247.	254.	261.	276.	290.
2 3/4	125.	132.	139.	153.	167.	174.	181.	195.	209.	222.	236.	242.	250.	264.	278.
2 7/8	119.	125.	132.	145.	158.	165.	172.	185.	198.	211.	224.	231.	238.	251.	264.
3	114.	121.	127.	140.	152.	159.	165.	178.	191.	203.	216.	222.	228.	241.	254.
3 1/8	110.	116.	122.	134.	146.	153.	159.	171.	183.	195.	207.	214.	219.	232.	244.
3 1/4	105.	111.	117.	129.	140.	146.	152.	164.	176.	188.	199.	205.	211.	222.	234.
3 3/8	102.	108.	113.	124.	136.	141.	147.	158.	170.	181.	192.	198.	203.	215.	226.
3 1/2	98.1	104.	109.	120.	131.	136.	142.	153.	164.	174.	186.	191.	196.	207.	218.
3 5/8	94.5	99.8	105.	116.	126.	131.	137.	147.	158.	168.	179.	184.	189.	200.	210.
3 3/4	91.8	96.9	102.	112.	122.	128.	133.	143.	153.	163.	175.	179.	184.	194.	205.
3 7/8	88.6	93.6	98.5	108.	118.	123.	128.	138.	148.	158.	167.	172.	177.	186.	197.
4	86.0	90.8	95.6	105.	115.	120.	124.	134.	143.	153.	163.	167.	172.	182.	191.
4 1/4	80.8	85.3	89.8	98.8	108.	112.	117.	126.	135.	144.	153.	157.	162.	171.	180.
4 1/2	76.3	80.6	84.8	93.3	102.	106.	110.	119.	127.	136.	144.	148.	153.	161.	170.
4 3/4	72.4	76.4	80.4	88.4	96.9	101.	105.	113.	121.	129.	137.	141.	145.	153.	161.
5	68.8	72.6	76.4	84.0	91.7	95.5	99.3	107.	115.	122.	130.	134.	138.	145.	153.
5 1/4	65.4	69.1	72.7	80.0	87.2	90.9	94.5	102.	109.	116.	124.	127.	131.	138.	145.
5 1/2	62.5	65.9	69.4	76.3	83.3	86.8	90.2	97.2	104.	111.	118.	121.	125.	132.	139.
5 3/4	59.8	63.1	66.4	73.0	80.0	83.0	86.3	93.0	99.6	106.	113.	116.	120.	126.	133.
6	57.2	60.5	63.6	70.0	76.3	79.5	82.7	89.0	95.4	102.	108.	111.	114.	121.	127.
6 1/4	55.0	58.0	61.1	67.2	73.3	76.4	79.4	85.5	91.7	97.7	104.	107.	110.	116.	122.
6 1/2	52.8	55.8	58.7	64.6	70.4	73.4	76.3	82.2	88.1	93.9	100.	103.	106.	112.	117.
6 3/4	50.9	53.8	56.6	62.3	67.9	70.8	73.6	79.2	84.9	90.6	96.2	99.0	102.	108.	113.
7	49.1	51.9	54.6	60.1	65.5	68.3	71.0	76.4	81.9	87.4	92.8	95.6	98.3	104.	109.
7 1/4	47.4	50.1	52.7	58.0	63.2	65.9	68.5	73.8	79.1	84.3	89.6	92.2	94.9	100.	105.
7 1/2	45.8	48.4	50.9	56.0	61.1	63.6	66.2	71.0	76.4	81.4	86.5	89.1	91.6	96.7	102.
7 3/4	44.3	46.7	49.2	54.1	59.0	61.5	64.0	68.9	73.8	78.7	83.6	86.1	88.6	93.5	98.4
8	43.0	45.4	47.8	52.6	57.4	59.8	62.1	66.9	71.7	76.5	81.3	83.7	86.0	90.8	95.6

DECIMAL EQUIVALENTS

By 8ths, 16ths, 32ds, and 64ths

8ths.

- 1/8 = .125
- 1/4 = .250
- 3/8 = .375
- 1/2 = .500
- 5/8 = .625
- 3/4 = 750
- 7/8 = .875

16ths.

- 1/16 = .0625
- 3/16 = .1875
- 5/16 = .3125
- 7/16 = .4375
- 9/16 = .5625
- 11/16 = .6875
- 13/16 = .8125
- 15/16 = .9375

32ds.

- 1/32 = .03125
- 3/32 = .09375
- 5/32 = .15625
- 7/32 = .21875
- 9/32 = .28125
- 11/32 = .34375
- 13/32 = .40625
- 15/32 = .46875
- 17/32 = .53125
- 19/32 = .59375
- 21/32 = .65625
- 23/32 = .71875
- 25/32 = .78125
- 27/32 = .84375
- 29/32 = .90625
- 31/32 = .96875

64ths.

- 1/64 = .015625
- 3/64 = .046875
- 5/64 = .078125
- 7/64 = .109375
- 9/64 = .140625
- 11/64 = .171875
- 13/64 = .203125
- 15/64 = .234375
- 17/64 = .265625
- 19/64 = .296875
- 21/64 = .328125
- 23/64 = .359375
- 25/64 = .390625
- 27/64 = .421875
- 29/64 = .453125
- 31/64 = .484375
- 33/64 = .515625
- 35/64 = .546875
- 37/64 = .578125
- 39/64 = .609375
- 41/64 = .640625
- 43/64 = .671875
- 45/64 = .703125
- 47/64 = .734375
- 49/64 = .765625
- 51/64 = .796875
- 53/64 = .828125
- 55/64 = .859375
- 57/64 = .890625
- 59/64 = .921875
- 61/64 = .953125
- 63/64 = .984375

ANGLES FOR FLUTING SPIRAL MILLING CUTTERS

We list below the results of our investigation along this line. They are for general purpose cutters, and we recommend these angles for the greatest efficiency in general shop practice.

Angles and Change Gears

For Fluting Surface Milling Cutters

Diameter of Work	Lead in Inches	Driven B. & D.		Drivers A. & C.		Angle to Set Swivel
2″	35.64	28	56	20	44	10° 0′
2¼″	40.00	40	24	20	24	10° 1′
2½″	44.45	20	64	24	24	10° 1′
2¾″	48.89	44	64	24	48	10° 1′
3″	53.33	56	64	28	48	10° 1′
3¼″	57.60	48	72	24	50	10° 3′
3½″	40.95	32	86	28	48	15° 1′
3¾″	43.98	72	86	44	64	15° 0′
4″	46.88	50	72	24	64	15° 1′
4¼″	49.77	50	86	24	72	15° 3′
4½″	52.56	44	86	20	72	15° 2′
4¾″	55.56	32	50	24	24	20° 4′
5″	43.00	24	86	40	24	20° 4′
5½″	47.30	44	86	32	50	20° 4′
6″	51.60	24	86	20	40	20° 2′
6½″	55.99	50	86	32	48	20° 4′
7″	60.20	28	86	20	40	20° 4′
7½″	64.50	72	86	40	48	20° 4′
8″	68.80	32	86	20	40	20° 4′

Number of Teeth in Standard Surface Milling Cutters

Diameter Cutter	ROUGHING	FINISHING
	No. of Teeth	No. of Teeth
2″	8	12
2⅛″	8	12
2¼″	8	12
2¾″	8	12
3″	8	12
3½″	9	14
4″	9	14
4½″	10	16
5″	10	16
5½″	11	18
6″	12	20
6½″	12	20
7″	14	22
7½″	14	22
8″	16	26
8½″	16	26

ANGLES AND CHANGE GEARS

For Milling 3 and 4-Lip Drills

Diameter of Work	Lead in Inches	Driven B. & D.		Drivers A. & C.		Angle to Set Swivel
¼″	1.744	20	24	64	86	24° 15′
⅜″	2.500	24	24	64	72	25° 14′
½″	3.349	24	24	40	86	25° 8′
⅝″	4.186	24	48	64	86	25° 8′
¾″	5.000	20	40	50	64	25° 14′
⅞″	5.833	20	28	40	48	25° 14′
1″	6.667	20	32	40	48	25° 14′
1⅛″	7.500	24	28	32	56	25° 14′
1¼″	8.333	40	24	32	72	25° 14′
1⅜″	9.167	28	44	48	56	25° 14′
1½″	10.000	24	32	24	64	25° 14′
1¾″	11.733	44	48	50	72	25° 7′
2″	13.440	24	28	20	50	25° 3′
2¼″	15.151	48	50	44	72	25° 0′
2½″	15.555	28	40	20	72	26° 49′
2¾″	17.067	32	64	48	50	26° 51′
3″	18.663	50	86	64	72	26° 48′
3¼″	20.200	50	64	44	72	26° 49′
3½″	21.770	28	56	20	72	26° 48′
3¾″	23.330	24	56	24	48	26° 48′
4	24.880	50	86	48	72	26° 48′

ANGLES AND CHANGE GEARS

For Milling Counterbores

Diameter of Work	Lead in Inches	Driven B. & D.		Drivers A. & C.		Angle to Set Swivel
¼″	2.171	24	28	86	72	19° 53′
⅜″	3.230	20	50	86	72	20° 2′
½″	4.286	20	24	40	56	20° 7′
⅝″	5.426	28	40	48	86	19° 53′
¾″	6.460	40	50	86	72	19° 59′
⅞″	7.543	24	44	50	56	20° 1′
1″	8.681	20	50	32	72	19° 53′
1⅛″	9.690	20	50	24	86	20° 4′
1¼″	10.750	20	86	50	64	20° 4′
1⅜″	11.839	40	56	44	86	20° 2′
1½″	12.929	32	64	44	72	20° 1′
1¾″	15.086	44	48	50	56	20° 1′
2″	17.200	24	86	48	50	20° 4′
2¼″	19.380	40	50	24	86	20° 2′
2½″	21.500	40	86	50	64	20° 4′
2¾″	23.650	44	86	50	64	20° 4′
3″	25.800	48	86	50	64	20° 6′
3¼″	27.990	50	86	48	64	20° 0′
3½″	30.100	28	86	32	50	20° 4′
3¾″	32.250	24	86	32	40	20° 4′
4″	34.460	24	86	24	50	20° 2′

ANGLES AND CHANGE GEARS

For Milling Spiral End Mills

Diameter of Work	Lead in Inches	Driven B. & D.		Drivers A. & C.		Angle to Set Swivel
¼″	4.445	20	40	50	72	10° 1′
½″	8.929	32	50	56	64	10° 7′
¾″	13.330	24	32	24	48	10° 1′
1″	17.818	28	56	40	44	10° 0′
1¼″	22.220	40	56	28	72	10° 1′
1½″	26.750	56	86	50	72	10° 8′
1¾″	31.170	40	48	28	44	10° 7′
2″	35.640	28	56	20	44	10° 7′
2¼″	40.130	28	86	24	50	10° 8′
2½″	44.640	40	50	28	32	10° 8′
2¾″	49.000	28	56	20	32	10° 9′
3″	53.570	50	72	28	48	10° 8′
3½″	62.220	32	56	24	24	10° 1′
4″	71.110	32	64	24	24	10° 1′
4½″	80.260	56	86	24	50	10° 8′
5″	89.350	64	86	28	44	10° 7′
5½″	97.780	44	64	24	24	10° 1′
6″	106.670	40	64	20	24	10° 1′

COMPLETE TABLE OF LEADS

Obtainable with the Change Gears Regularly Furnished with LeBlond Spiral Cutting Head

A and C = DRIVING GEARS. B and D = DRIVEN GEARS.

Gears Furnished:
20-24-24-28-32-40-44-48-56-64-72-86 tooth gears.

FIG. 1

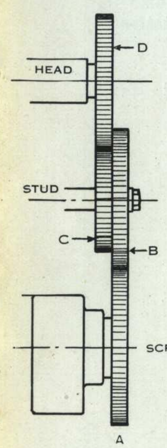


FIG. 2

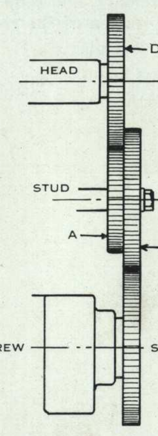


FIG. 3

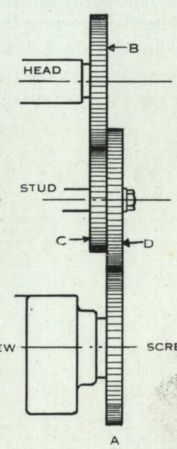
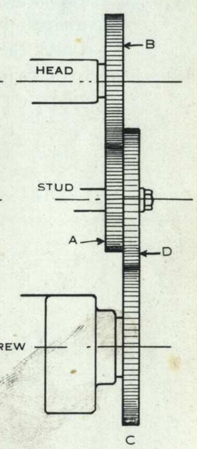


FIG. 4



In any train of four gears it is possible to place the gears in four combinations without changing the speed of the last driven gear — that is, by transposing the two driven gears or the two driving gears, but never transposing driver for driven. Figures 1, 2, 3 and 4 show the possible gear combinations to obtain the same number of revolutions of the last driven gear.

$$\frac{B\times D\times 20}{A\times C} \text{ or } \frac{B\times D\times 20}{C\times A} \text{ or } \frac{D\times B\times 20}{A\times C} \text{ or } \frac{D\times B\times 20}{C\times A} = \text{Lead.}$$

In many cases any one of the four combinations is practical. In some cases the first driven gear (the inner gear on the stud) may interfere with the quadrant shaft. To avoid interference of gears —

1 — Select the larger of the driven gears for the gear on the head.

2 — Select the larger of the driving gears for the gear on the screw.

3 — If the gears interfere after observing these rules, introduce idlers or look for another combination giving the same or practically the same lead.

4 — Do not use idler gears unless necessary, and remember that a single idler will reverse the direction of the rotation.

5 — Check the lead by the following formula:

$$\frac{\text{PRODUCT OF THE DRIVEN GEARS} \times 20}{\text{PRODUCT OF THE DRIVING GEARS}} = \text{Lead in Inches.}$$

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
1.550	20	24	86	72	2.907	20	40	64	86	3.500	20	28	50	64
1.744	20	24	64	86	2.917	24	28	64	72	3.535	20	28	44	72
1.809	20	28	86	72	2.960	20	28	44	86	3.552	24	28	44	86
1.860	24	24	86	72	2.977	20	32	50	86	3.556	20	32	50	72
1.993	20	24	56	86	3.000	20	24	50	64	3.571	20	32	56	64
2.035	20	28	64	86	3.030	20	24	44	72	3.571	20	24	48	56
2.067	20	32	86	72	3.044	24	24	44	86	3.572	24	32	50	86
2.083	20	24	64	72	3.101	20	48	86	72	3.600	24	24	50	64
2.093	24	24	64	86	3.101	20	32	48	86	3.618	20	56	86	72
2.171	24	28	86	72	3.101	40	24	86	72	3.618	28	40	86	72
2.233	20	24	50	86	3.111	20	28	50	72	3.634	20	50	64	86
2.326	20	28	56	86	3.125	20	28	56	64	3.636	24	24	44	72
2.326	20	24	48	86	3.125	20	24	48	64	3.646	20	28	48	64
2.326	20	32	64	86	3.126	24	28	50	86	3.654	20	44	56	86
2.381	20	24	56	72	3.175	20	32	56	72	3.704	20	32	48	72
2.392	24	24	56	86	3.189	24	32	56	86	3.721	24	32	48	86
2.431	20	28	64	72	3.198	20	44	64	86	3.721	20	40	50	86
2.442	24	28	64	86	3.200	24	24	50	72	3.721	28	32	56	86
2.481	24	32	86	72	3.214	24	24	56	64	3.721	20	32	40	86
2.500	24	24	64	72	3.230	20	50	86	72	3.721	24	48	86	72
2.537	20	24	44	86	3.241	20	28	48	72	3.733	24	28	50	72
2.584	20	40	86	72	3.256	24	28	48	86	3.750	24	24	48	64
2.605	20	28	50	86	3.256	28	32	64	86	3.750	24	28	56	64
2.658	20	32	56	86	3.256	20	28	40	86	3.750	20	24	40	64
2.667	20	24	50	72	3.323	20	40	56	86	3.810	24	32	56	72
2.679	24	24	50	86	3.333	20	24	40	72	3.819	20	44	64	72
2.679	20	24	56	64	3.333	24	28	56	72	3.838	24	44	64	86
2.713	20	28	48	86	3.333	24	24	48	72	3.876	24	50	86	72
2.778	20	24	48	72	3.333	24	32	64	72	3.876	20	40	48	86
2.778	20	28	56	72	3.349	24	24	40	86	3.889	28	32	64	72
2.778	20	32	64	72	3.383	20	32	44	86	3.889	24	28	48	72
2.791	20	24	40	86	3.409	20	24	44	64	3.889	20	28	40	72
2.791	24	32	64	86	3.411	24	44	86	72	3.896	20	24	44	56
2.791	24	24	48	86	3.429	20	24	50	56	3.907	24	28	40	86
2.791	24	28	56	86	3.472	20	40	64	72	3.968	20	40	56	72
2.842	20	44	86	72	3.488	40	24	64	86	3.979	28	44	86	72
2.857	24	24	56	72	3.488	20	48	64	86	3.977	20	28	44	64
2.894	28	32	86	72	3.488	20	24	32	86	3.987	40	24	56	86

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
3.987	20	48	56	86	4.364	20	24	44	50	4.784	24	24	28	86
3.987	20	24	28	86	4.365	20	44	56	72	4.784	24	48	56	86
4.000	20	28	50	56	4.375	24	28	48	64	4.800	20	24	40	50
4.000	20	24	48	50	4.375	20	28	40	64	4.800	24	32	50	64
4.000	20	32	50	64	4.385	24	44	56	86	4.800	24	24	48	50
4.000	24	24	40	72	4.444	24	32	48	72	4.800	24	28	50	56
4.040	20	32	44	72	4.445	20	32	40	72	4.845	20	50	48	86
4.059	24	32	44	86	4.445	28	32	56	72	4.848	24	32	44	72
4.070	28	40	64	86	4.445	20	40	50	72	4.861	20	56	64	72
4.070	20	28	32	86	4.464	20	40	56	64	4.861	20	28	32	72
4.070	20	56	64	86	4.465	24	32	40	86	4.861	28	40	64	72
4.091	24	24	44	64	4.465	40	24	50	86	4.884	28	48	64	86
4.093	20	44	50	86	4.465	20	48	50	86	4.884	24	28	32	86
4.114	24	24	50	56	4.477	28	44	64	86	4.884	24	56	64	86
4.134	20	64	86	72	4.500	24	24	40	64	4.889	20	44	50	72
4.134	32	40	86	72	4.522	28	50	86	72	4.911	20	44	56	64
4.152	20	50	56	86	4.545	20	28	44	56	4.912	24	44	50	86
4.167	20	28	48	56	4.546	20	32	44	64	4.960	20	50	56	72
4.167	20	24	32	72	4.546	20	24	44	48	4.961	32	48	86	72
4.167	20	48	64	72	4.548	32	44	86	72	4.961	24	64	86	72
4.167	20	32	48	64	4.571	20	32	50	56	4.978	28	32	50	72
4.167	40	24	64	72	4.583	24	44	64	72	4.983	24	50	56	86
4.168	28	32	50	86	4.630	20	40	48	72	5.000	24	28	48	56
4.186	24	24	32	86	4.651	20	....	86	....	5.000	20	32	40	64
4.186	24	48	64	86	4.651	28	40	56	86	5.000	20	28	40	56
4.200	24	28	50	64	4.651	32	40	64	86	5.000	20	24	40	48
4.228	20	40	44	86	4.651	20	24	24	86	5.000	20	40	50	64
4.242	24	28	44	72	4.651	40	24	48	86	5.000	28	32	56	64
4.264	20	44	48	86	4.667	20	28	48	50	5.000	24	48	64	72
4.267	24	32	50	72	4.667	24	28	40	72	5.000	24	32	48	64
4.286	24	24	48	56	4.675	24	24	44	56	5.000	24	24	32	72
4.286	24	32	56	64	4.688	20	24	32	64	5.051	20	40	44	72
4.286	20	24	40	56	4.736	28	32	44	86	5.065	28	56	86	72
4.340	20	50	64	72	4.762	20	32	48	56	5.074	20	48	44	86
4.341	24	56	86	72	4.762	40	24	56	72	5.074	40	24	44	86
4.341	28	48	86	72	4.762	20	24	28	72	5.087	28	50	64	86
4.341	28	32	48	86	4.762	20	48	56	72	5.091	20	28	44	50
4.360	24	50	64	86	4.773	24	28	44	64	5.093	20	44	48	72

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
5.116	32	44	64	86	5.455	24	28	44	56	5.818	20	32	44	50
5.116	28	44	56	86	5.469	20	28	32	64	5.833	28	48	64	72
5.116	20	44	40	86	5.486	24	32	50	56	5.833	24	56	64	72
5.116	24	44	48	86	5.500	20	44	50	64	5.833	20	28	40	48
5.143	24	24	40	56	5.556	20	....	72	....	5.833	28	32	48	64
5.168	32	50	86	72	5.556	28	40	56	72	5.833	24	28	32	72
5.185	28	32	48	72	5.556	32	40	64	72	5.847	32	44	56	86
5.195	20	32	44	56	5.556	20	24	24	72	5.867	24	44	50	72
5.208	24	50	64	72	5.556	40	24	48	72	5.893	24	44	56	64
5.209	28	40	50	86	5.580	20	50	56	64	5.920	28	40	44	86
5.209	28	32	40	86	5.581	24	....	86	....	5.920	20	56	44	86
5.209	20	40	48	64	5.581	32	48	64	86	5.952	20	40	48	56
5.209	20	56	50	86	5.581	20	48	40	86	5.952	24	50	56	72
5.233	20	72	64	86	5.581	28	48	56	86	5.953	20	64	50	86
5.236	24	24	44	50	5.600	20	28	40	50	5.953	32	40	50	86
5.238	24	44	56	72	5.600	28	32	50	64	5.969	28	44	48	86
5.250	24	28	40	64	5.600	24	28	48	50	5.980	20	72	56	86
5.285	20	50	44	86	5.625	24	24	32	64	6.000	20	48	50	64
5.303	20	28	44	48	5.657	28	32	44	72	6.000	20	24	32	50
5.316	20	64	56	86	5.682	20	40	44	64	6.000	40	24	50	64
5.316	32	40	56	86	5.685	40	44	86	72	6.000	24	32	40	64
5.316	20	32	28	86	5.698	28	56	64	86	6.000	24	28	40	56
5.333	20	48	50	72	5.714	20	40	50	56	6.000	24	24	40	48
5.333	20	32	48	50	5.714	20	32	40	56	6.061	20	48	44	72
5.333	40	24	50	72	5.714	24	48	56	72	6.061	40	24	44	72
5.333	24	32	40	72	5.714	24	32	48	56	6.061	20	32	44	48
5.347	28	44	64	72	5.714	24	24	28	72	6.076	28	50	64	72
5.357	20	48	56	64	5.729	20	44	48	64	6.089	24	48	44	86
5.357	20	24	28	64	5.730	28	44	50	86	6.109	24	28	44	50
5.357	20	24	32	56	5.760	24	24	40	50	6.111	32	44	64	72
5.357	40	24	56	64	5.787	20	50	48	72	6.111	28	44	56	72
5.358	24	48	50	86	5.788	28	64	86	72	6.111	20	44	40	72
5.426	28	40	48	86	5.788	32	56	86	72	6.111	24	44	48	72
5.426	20	28	24	86	5.814	28	50	56	86	6.122	20	24	28	56
5.426	20	56	48	86	5.814	32	50	64	86	6.140	24	44	40	86
5.454	24	24	44	48	5.814	24	50	48	86	6.202	40	48	86	72
5.455	20	24	40	44	5.814	20	40	32	86	6.202	20	64	48	86
5.455	24	32	44	64	5.815	20	50	40	86	6.202	32	40	48	86

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
6.202	20	32	24	86	6.481	20	56	48	72	6.857	24	32	40	56
6.222	28	40	50	72	6.494	20	40	44	56	6.857	40	24	50	56
6.222	28	32	40	72	6.510	20	50	48	64	6.857	20	24	28	50
6.222	20	56	50	72	6.512	28	....	86	....	6.857	20	48	50	56
6.234	24	32	44	56	6.512	24	56	48	86	6.875	28	44	56	64
6.250	20	....	64	....	6.512	32	56	64	86	6.875	20	44	40	64
6.250	28	40	56	64	6.512	20	56	40	86	6.875	24	44	48	64
6.250	20	28	32	56	6.512	24	28	24	86	6.944	32	50	64	72
6.250	20	24	24	64	6.545	24	24	40	44	6.944	24	50	48	72
6.250	20	24	32	48	6.548	20	44	48	56	6.944	20	50	40	72
6.250	40	24	48	64	6.549	32	44	50	86	6.945	20	40	32	72
6.251	24	56	50	86	6.563	24	28	32	64	6.945	28	50	56	72
6.251	28	48	50	86	6.600	24	44	50	64	6.977	20	72	48	86
6.279	24	72	64	86	6.615	32	64	86	72	6.977	40	48	64	86
6.286	20	44	50	56	6.644	32	50	56	86	6.977	24	50	40	86
6.313	20	50	44	72	6.645	20	40	28	86	6.977	20	48	32	86
6.343	24	50	44	86	6.667	24	....	72	....	6.977	40	24	32	86
6.349	20	64	56	72	6.667	32	48	64	72	6.982	24	32	44	50
6.349	32	40	56	72	6.667	28	48	56	72	6.984	32	44	56	72
6.349	20	32	28	72	6.667	20	48	40	72	7.000	28	40	50	64
6.364	28	32	44	64	6.667	20	40	48	50	7.000	20	28	32	50
6.364	20	28	40	44	6.667	28	32	48	56	7.000	28	32	40	64
6.364	24	28	44	48	6.667	20	32	40	48	7.000	24	28	40	48
6.379	24	64	56	86	6.696	24	50	56	64	7.000	20	56	50	64
6.379	32	48	56	86	6.698	20	72	50	86	7.071	20	56	44	72
6.379	24	32	28	86	6.698	24	48	40	86	7.071	28	40	44	72
6.395	40	44	64	86	6.698	24	24	20	86	7.102	20	50	44	64
6.395	20	44	32	86	6.720	24	28	40	50	7.104	28	48	44	86
6.400	28	32	50	56	6.765	32	40	44	86	7.104	24	56	44	86
6.400	20	32	40	50	6.765	20	64	44	86	7.106	44	50	86	72
6.400	24	32	48	50	6.783	28	50	48	86	7.111	20	64	50	72
6.400	24	48	50	72	6.806	28	56	64	72	7.111	32	40	50	72
6.429	24	48	56	64	6.818	20	48	44	64	7.130	28	44	48	72
6.429	24	24	28	64	6.818	20	24	32	44	7.143	20	....	56	....
6.429	24	24	32	56	6.818	40	24	44	64	7.143	32	40	56	64
6.460	40	50	86	72	6.822	44	48	86	72	7.143	20	24	24	56
6.481	20	28	24	72	6.822	32	44	48	86	7.143	20	24	28	48
6.481	28	40	48	72	6.845	28	44	50	72	7.143	20	32	28	64

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
7.143	40	24	48	56	7.467	28	48	50	72	7.814	24	56	40	56
7.144	24	64	50	86	7.467	28	32	48	50	7.814	28	48	40	86
7.144	32	48	50	86	7.500	24	....	64	...	7.814	24	28	20	86
7.163	28	44	40	86	7.500	28	48	56	64	7.822	32	44	50	72
7.176	24	72	56	86	7.500	20	48	40	64	7.587	32	44	56	64
7.200	24	24	32	50	7.500	20	24	32	40	7.857	20	44	40	56
7.200	24	48	50	64	7.500	24	24	32	48	7.857	24	44	48	56
7.235	40	56	86	72	7.500	24	28	32	56	7.937	32	50	56	72
7.267	40	50	64	86	7.543	24	44	50	56	7.937	20	40	28	72
7.267	20	50	32	86	7.576	24	50	44	72	7.955	28	40	44	64
7.273	20	40	44	50	7.576	20	40	44	48	7.955	20	28	32	44
7.273	28	32	44	56	7.597	28	56	48	86	7.955	20	56	44	64
7.273	20	32	40	44	7.611	20	72	44	86	7.973	40	48	56	86
7.273	24	32	44	48	7.619	24	64	56	72	7.973	20	48	28	86
7,273	24	48	44	72	7.619	32	48	56	72	7.973	40	24	28	86
7.292	28	40	48	64	7.619	24	32	28	72	7.994	44	50	64	86
7.292	20	28	24	64	7.636	24	28	40	44	8.000	20	....	50	...
7.292	20	28	32	48	7.639	40	44	64	72	8.000	40	24	48	50
7.292	20	56	48	64	7.639	20	44	32	72	8.000	28	40	50	56
7.293	28	56	50	86	7.674	44	48	64	86	8.000	24	48	40	72
7.309	40	44	56	86	7.674	24	44	32	86	8.000	24	24	20	72
7.309	20	44	28	86	7.680	24	32	40	50	8.000	32	40	50	64
7.326	28	72	64	86	7.700	28	44	50	64	8.000	20	24	24	50
7.333	20	44	48	50	7.752	32	50	48	86	8.000	28	32	40	56
7.333	24	44	40	72	7.752	48	50	86	72	8.000	24	32	40	48
7.347	24	24	28	56	7.752	20	40	24	86	8.021	28	44	48	64
7.400	28	50	44	86	7.778	28	....	72	....	8.035	20	72	56	64
7.407	20	64	48	72	7.778	24	56	48	72	8.037	24	72	50	86
7.407	32	40	48	72	7.778	32	56	64	72	8.081	32	40	44	72
7.407	20	32	24	72	7.778	20	56	40	72	8.081	20	64	44	72
7.440	20	50	48	56	7.778	24	28	24	72	8.102	28	50	48	72
7.442	32	....	86	....	7.792	20	48	44	56	8.117	20	50	44	56
7.442	24	64	48	86	7.792	20	24	28	44	8.118	32	48	44	86
7.442	28	64	56	86	7.792	40	24	44	56	8.118	24	64	44	86
7.442	20	64	40	86	7.812	20	50	40	64	8.140	40	56	64	86
7.442	24	32	24	86	7.813	28	50	56	64	8.140	28	50	40	86
7.465	20	86	64	72	7.813	24	50	48	64	8.140	20	56	32	86
7.467	24	56	50	72	7.813	20	40	32	64	8.140	28	40	32	86

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
8.146	28	32	44	50	8.505	32	64	56	86	8.800	28	44	50	56
8.148	32	44	48	72	8.523	24	50	44	64	8.800	20	44	40	50
8.163	20	32	28	56	8.527	20	44	24	86	8.800	24	44	48	50
8.182	24	48	44	64	8.527	40	44	48	86	8.838	28	50	44	72
8.186	32	44	40	86	8.532	20	86	56	72	8.889	32	....	72	....
8.186	40	44	50	86	8.533	24	64	50	72	8.889	24	64	48	72
8.182	24	24	32	44	8.534	32	48	50	72	8.889	28	64	56	72
8.229	24	48	50	56	8.556	28	44	40	72	8.889	20	64	40	72
8.229	24	24	28	50	8.571	24	....	56	....	8.889	24	32	24	72
8.250	24	44	40	64	8.571	24	24	28	48	8.929	32	50	56	64
8.269	40	64	86	72	8.571	24	32	28	64	8.929	24	50	48	56
8.288	28	56	44	86	8.571	20	24	28	40	8.929	20	40	28	64
8.306	20	50	28	86	8.571	20	48	40	56	8.929	20	40	32	56
8.306	40	50	56	86	8.571	32	48	56	64	8.929	20	50	40	56
8.333	20	....	48	....	8.594	20	44	32	64	8.930	40	48	50	86
8.333	40	48	64	72	8.681	40	50	64	72	8.930	24	32	20	86
8.333	28	40	48	56	8.681	20	50	32	72	8.930	32	48	40	86
8.333	20	28	24	56	8.682	32	56	48	86	8.930	24	64	40	86
8.333	24	50	40	72	8.682	28	64	48	86	8.953	28	44	32	86
8.333	32	40	48	64	8.682	48	56	86	72	8.958	24	86	64	72
8.333	40	24	32	72	8.682	28	32	24	86	8.960	28	32	40	50
8.333	20	32	24	64	8.711	28	56	50	72	9.000	20	72	50	64
8.333	20	24	24	48	8.721	24	50	32	86	9.000	24	48	40	64
8.333	20	48	32	72	8.721	48	50	64	86	9.000	24	24	20	64
8.335	32	56	50	86	8.727	40	24	44	50	9.000	24	24	32	40
8.335	28	64	50	86	8.727	20	48	44	50	9.044	50	56	86	72
8.372	20	72	40	86	8.727	24	32	40	44	9.074	28	56	48	72
8.372	28	72	56	86	8.730	40	44	56	72	9.091	20	....	44	....
8.372	32	72	64	86	8.730	20	44	28	72	9.091	32	40	44	64
8.372	24	72	48	86	8.750	28	....	64	....	9.091	20	24	24	44
8.372	24	48	32	86	8.750	24	28	24	64	9.091	40	24	44	48
8.400	24	56	50	64	8.750	24	28	32	48	9.091	28	40	44	56
8.400	28	48	50	64	8.750	20	28	32	40	9.096	44	64	86	72
8.400	24	28	32	50	8.750	20	56	40	64	9.115	28	50	48	64
8.457	32	50	44	86	8.750	24	56	48	64	9.116	28	56	40	86
8.485	24	56	44	72	8.771	44	48	56	86	9.133	24	72	44	86
8.485	28	48	44	72	8.771	24	44	28	86	9.133	44	50	56	86
8.485	28	32	44	48	8.800	32	44	50	64	9.143	20	64	50	56

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
9.143	32	40	50	56	9.524	20	32	28	48	9.821	20	44	32	56
9.143	20	32	28	50	9.524	40	24	28	72	9.823	44	48	50	86
9.167	32	44	48	64	9.524	40	48	56	72	9.899	28	56	44	72
9.167	24	44	32	72	9.525	32	64	50	86	9.921	40	50	56	72
9.167	20	44	40	48	9.545	28	48	44	64	9.921	20	50	28	72
9.167	28	44	48	56	9.545	24	56	44	64	9.922	48	64	86	72
9.167	44	48	64	72	9.545	24	28	32	44	9.923	32	64	48	86
9.259	20	40	24	72	9.549	44	50	64	72	9.943	28	50	44	64
9.259	32	50	48	72	9.556	20	86	50	72	9.954	20	86	48	72
9.302	40	....	86	....	9.568	32	72	56	86	9.956	28	64	50	72
9.302	32	50	40	86	9.568	24	48	28	86	9.956	32	56	50	72
9.302	20	64	32	86	9.598	20	86	56	64	9.967	24	50	28	86
9.302	20	48	24	86	9.600	24	...	50	....	9.967	48	50	56	86
9.302	40	24	24	86	9.600	28	48	50	56	10.000	32	....	64	....
9.302	20	56	28	86	9.600	20	48	40	50	10.000	20	....	40	....
9.333	28	32	40	48	9.600	32	48	50	64	10.000	24	....	48	....
9.333	28	48	40	72	9.625	28	44	40	64	10.000	28	....	56	....
9.333	24	56	40	72	9.643	24	72	56	64	10.000	24	28	24	56
9.333	28	40	48	50	9.690	20	50	24	86	10.000	24	48	32	72
9.333	24	28	20	72	9.690	40	50	48	86	10.000	24	32	24	64
9.333	20	28	24	50	9.697	24	64	44	72	10.000	20	40	32	50
9.333	20	56	48	50	9.697	32	48	44	72	10.000	20	24	40	24
9.351	24	48	44	56	9.722	20	28	24	48	10.046	24	72	40	86
9.351	24	24	28	44	9.722	28	40	32	72	10.057	32	44	50	56
9.375	40	24	32	64	9.722	20	56	32	72	10.101	32	50	44	72
9.375	20	48	32	64	9.722	40	56	64	72	10.148	40	48	44	86
9.375	24	50	40	54	9.740	24	50	44	56	10.159	32	64	56	72
9.375	20	72	48	64	9.766	20	50	32	64	10.174	50	56	64	86
9.377	28	72	50	86	9.767	28	72	48	86	10.174	28	50	32	86
9.429	24	44	40	56	9.767	28	48	32	86	10.182	28	32	40	44
9.470	20	50	44	48	9.767	24	56	32	86	10.182	20	56	44	50
9.471	32	56	44	86	9.767	48	56	64	86	10.182	28	40	44	50
9.472	28	64	44	86	9.778	32	44	40	72	10.185	40	44	48	72
9.501	28	50	40	72	9.778	40	44	50	72	10.185	20	44	24	72
9.524	20	64	48	56	9.796	24	32	28	56	10.204	20	40	28	56
9.524	32	40	48	56	9.800	28	56	50	64	10.208	28	56	48	64
9.524	20	48	28	72	9.821	40	44	56	64	10.233	44	...	86	....
9.524	20	32	24	56	9.821	20	44	28	64	10.233	24	44	24	86

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
10.238	24	86	56	72	10.606	28	40	44	48	10.909	20	48	40	44
10.267	28	44	48	50	10.606	20	28	24	44	10.913	44	50	56	72
10.286	20	72	50	56	10.608	20	56	44	48	10.937	28	50	40	64
10.286	24	48	40	56	10.631	40	64	56	86	10.937	28	40	32	64
10.288	24	24	20	56	10.631	20	64	28	86	10.937	20	56	32	64
10.288	24	24	28	40	10.631	32	40	28	86	10.971	24	64	50	56
10.313	24	44	32	64	10.655	28	72	44	86	10.971	32	48	50	56
10.336	50	64	86	72	10.659	44	50	48	86	10.971	24	32	28	50
10.370	28	32	24	72	10.666	24	32	20	72	11.000	24	44	40	48
10.370	32	56	48	72	10.666	20	32	24	50	11.000	20	44	32	50
10.371	28	64	48	72	10.667	32	40	48	50	11.000	28	44	40	56
10.389	32	40	44	56	10.667	40	48	50	72	11.000	40	44	50	64
10.390	20	64	44	56	10.667	32	48	40	72	11.000	32	44	40	64
10.390	20	32	28	44	10.667	24	64	40	72	11.111	40	....	72	....
10.416	20	40	32	48	10.668	20	64	48	50	11.111	20	56	28	72
10.417	20	50	40	48	10.694	44	56	64	72	11.111	40	24	24	72
10.417	20	40	24	64	10.695	28	44	32	72	11.111	20	32	24	48
10.417	48	50	64	72	10.711	32	72	50	86	11.111	20	48	24	72
10.417	24	50	32	72	10.714	20	72	48	56	11.111	20	64	32	72
10.417	32	50	48	64	10.714	40	48	56	64	11.111	32	50	40	72
10.417	28	50	48	56	10.714	24	50	40	56	11.136	28	56	44	64
10.418	28	64	40	86	10.714	20	48	28	64	11.161	40	50	56	64
10.418	28	32	20	86	10.714	20	48	32	56	11.161	20	50	32	56
10.419	32	56	40	86	10.714	20	24	28	32	11.161	20	50	28	64
10.419	40	56	50	86	10.714	40	24	28	64	11.163	48	....	86	....
10.451	28	86	64	72	10.714	40	24	32	56	11.163	24	56	28	86
10.465	20	72	32	86	10.750	20	86	50	64	11.163	24	64	32	86
10.465	40	72	64	86	10.800	24	72	50	64	11.163	32	72	48	86
10.473	24	48	44	50	10.824	32	64	44	86	11.163	40	24	20	86
10.476	32	44	48	56	10.853	40	56	48	86	11.163	24	48	24	86
10.476	44	48	56	72	10.853	28	40	24	86	11.199	20	86	48	64
10.476	24	44	28	72	10.853	20	56	24	86	11.200	28	....	50	....
10.500	28	48	40	64	10.858	20	86	44	72	11.200	24	56	48	50
10.500	24	56	40	64	10.889	28	56	40	72	11.200	24	28	24	50
10.500	24	28	20	64	10.909	24	....	44	....	11.200	20	56	40	50
10.500	24	28	32	40	10.909	32	....	44	....	11.200	32	56	50	64
10.560	24	44	40	50	10.909	32	48	44	64	11.225	20	44	28	56
10.571	40	50	44	86	10.909	28	48	44	56	11.250	24	72	48	64

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
11.250	20	72	40	64	11.667	20	56	40	48	12.000	40	48	50	64
11.250	28	72	56	64	11.667	28	32	24	64	12.000	20	48	32	50
11.250	24	48	32	64	11.667	20	28	40	24	12.000	40	24	32	50
11.313	32	56	44	72	11.667	32	56	48	64	12.000	24	32	20	64
11.313	28	64	44	72	11.667	48	56	64	72	12.000	24	24	20	48
11.364	20	50	40	44	11.667	24	56	32	72	12.000	24	28	20	56
11.364	20	40	32	44	11.667	28	48	32	72	12.031	28	44	32	64
11.364	24	50	44	48	11.688	20	72	44	56	12.121	40	48	44	72
11.364	32	50	44	64	11.694	32	44	28	86	12.121	20	64	44	48
11.364	28	50	44	56	11.694	44	64	56	86	12.121	32	40	44	48
11.378	32	64	50	72	11.719	24	50	32	64	12.121	20	32	24	44
11.396	28	56	32	86	11.721	28	72	40	86	12.153	50	56	64	72
11.428	24	48	28	72	11.733	44	48	50	72	12.153	28	50	32	72
11.428	24	32	28	48	11.733	32	44	48	50	12.177	32	72	44	86
11.428	24	32	24	56	11.785	44	48	56	64	12.216	20	86	44	64
11.428	20	40	28	50	11.786	24	44	28	64	12.218	24	56	44	50
11.428	20	64	40	56	11.786	24	44	32	56	12.218	28	48	44	50
11.428	24	64	48	56	11.839	40	56	44	86	12.222	44	....	72	....
11.429	32	....	56	....	11.852	32	64	48	72	12.222	24	44	24	72
11.429	20	32	28	40	11.905	20	40	28	48	12.245	20	48	28	56
11.458	40	44	48	64	11.905	20	40	24	56	12.245	40	24	28	56
11.459	20	44	32	48	11.905	24	50	28	72	12.250	28	56	40	64
11.459	20	44	24	64	11.905	48	50	56	72	12.273	24	72	44	64
11.461	44	56	50	86	11.905	32	50	48	56	12.277	44	50	56	64
11.467	24	86	50	72	11.907	40	64	50	86	12.279	44	48	40	86
11.512	44	72	64	86	11.907	32	64	40	86	12.279	24	44	20	86
11.518	24	86	56	64	11.938	28	44	24	86	12.286	20	86	50	56
11.520	24	24	20	50	11.938	44	56	48	86	12.320	28	44	40	50
11.520	24	48	40	50	11.944	24	86	48	72	12.343	24	72	50	56
11.574	20	50	24	72	11.944	28	86	56	72	12.403	32	40	24	86
11.574	40	50	48	72	11.944	32	86	64	72	12.403	40	64	48	86
11.576	56	64	86	72	11.945	20	86	40	72	12.403	20	64	24	86
11.628	50	....	86	....	11.960	40	72	56	86	12.444	28	32	20	72
11.628	24	50	24	86	11.960	20	72	28	86	12.444	32	56	40	72
11.636	32	40	44	50	12.000	24	....	40	....	12.445	40	56	50	72
11.636	20	64	44	50	12.000	28	48	40	56	12.445	28	64	40	72
11.667	28	....	48	....	12.000	32	48	40	64	12.467	24	32	28	44
11.667	24	28	24	48	12.000	20	72	48	50	12.467	24	64	44	56

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
12.500	40	....	64	....	12.800	24	32	24	50	13.125	28	48	32	64
12.500	20	....	32	....	12.800	28	64	50	56	13.156	44	72	56	86
12.500	20	48	24	64	12.800	24	64	48	50	13.200	44	48	50	64
12.500	20	24	24	32	12.800	20	64	40	50	13.200	24	44	32	50
12.500	40	24	24	64	12.833	28	44	40	48	13.258	28	50	44	48
12.500	40	24	32	48	12.857	24	24	28	32	13.289	32	50	28	86
12.500	20	56	28	64	12.857	24	48	32	56	13.289	50	64	56	86
12.500	24	50	40	48	12.857	24	48	28	64	13.333	48	....	72	....
12.500	28	40	32	56	12.857	32	72	56	64	13.333	32	....	48	....
12.500	32	50	40	64	12.857	20	72	40	56	13.333	24	64	32	72
12.500	28	50	40	56	12.857	24	72	48	56	13.333	24	56	28	72
12.502	48	56	50	86	12.900	24	86	50	64	13.333	28	64	48	56
12.558	24	72	32	86	12.929	32	64	44	72	13.333	20	64	40	48
12.558	48	72	64	86	12.963	20	56	24	72	13.333	20	40	24	50
12.571	32	44	40	56	12.963	28	40	24	72	13.333	28	32	24	56
12.571	40	44	50	56	12.963	40	56	48	72	13.333	20	32	40	24
12.571	20	44	28	50	12.987	20	40	28	44	13.333	40	24	20	72
12.600	28	72	50	64	12.987	32	50	44	56	13.333	24	32	24	48
12.636	40	50	44	72	13.021	20	50	24	64	13.333	24	48	24	72
12.668	40	48	44	64	13.021	20	50	32	48	13.378	28	86	50	72
12.685	48	50	44	86	13.021	40	50	48	64	13.393	24	50	28	64
12.698	40	64	56	72	13.023	56	....	86	....	13.393	24	50	32	56
12.698	20	64	28	72	13.023	24	56	24	86	13.393	48	50	56	64
12.698	32	40	28	72	13.023	28	48	24	86	13.395	40	72	50	86
12.727	28	....	44	....	13.023	28	64	32	86	13.395	32	72	40	86
12.727	24	28	24	44	13.023	28	40	20	86	13.395	24	48	20	86
12.727	20	56	40	44	13.030	24	86	44	72	13.437	28	86	56	64
12.727	32	56	44	64	13.067	28	56	48	50	13.437	24	86	48	64
12.727	24	56	44	48	13.081	50	72	64	86	13.438	20	86	40	64
12.731	44	50	48	72	13.091	24	24	20	44	13.440	24	56	40	50
12.755	20	50	28	56	13.091	24	48	40	44	13.440	28	48	40	50
12.757	24	64	28	86	13.091	20	72	44	50	13.440	24	28	20	50
12.757	32	48	28	86	13.095	20	44	28	48	13.469	24	44	28	56
12.757	48	64	56	86	13.095	20	44	24	56	13.500	24	72	40	64
12.791	40	44	32	86	13.095	40	44	48	56	13.531	40	64	44	86
12.791	44	50	40	86	13.098	44	64	50	86	13.566	28	50	24	86
12.798	20	86	48	56	13.125	28	72	48	64	13.566	50	56	48	86
12.800	32	....	50	....	13.125	24	56	32	64	13.611	28	56	32	72

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
13.636	20	72	44	48	14.000	20	56	32	50	14.400	32	72	50	64
13.636	24	50	40	44	14.000	28	32	20	64	14.400	28	72	50	56
13.636	20	48	32	44	14.000	32	56	40	64	14.400	24	72	48	50
13.636	40	24	32	44	14.000	28	40	32	50	14.400	20	72	40	50
13.643	32	44	24	86	14.000	40	56	50	64	14.531	40	50	32	86
13.644	44	64	48	86	14.000	24	56	40	48	14.545	24	64	44	48
13.651	32	86	56	72	14.026	24	72	44	56	14.545	24	32	24	44
13.672	28	50	32	64	14.062	20	72	32	64	14.546	20	64	40	44
13.688	44	56	50	72	14.080	32	44	40	50	14.546	28	64	44	56
13.714	40	48	50	56	14.141	40	56	44	72	14.583	28	50	40	48
13.714	24	64	40	56	14.205	20	50	32	44	14.583	40	56	48	64
13.714	32	48	40	56	14.205	40	50	44	64	14.583	28	40	24	64
13.714	20	48	28	50	14.207	48	56	44	86	14.583	28	40	32	48
13.714	40	24	28	50	14.222	32	64	40	72	14.583	20	28	24	32
13.714	24	32	20	56	14.222	40	64	50	72	14.583	20	56	32	48
13.714	24	32	28	40	14.235	28	44	20	86	14.583	20	56	24	64
13.750	44	....	64	....	14.255	28	56	44	50	14.617	40	44	28	86
13.750	28	44	32	56	14.259	44	56	48	72	14.629	32	64	50	56
13.750	20	44	32	40	14.260	28	44	24	72	14.651	28	72	32	86
13.750	24	44	24	64	14.284	48	64	50	86	14.651	56	72	64	86
13.750	24	44	32	48	14.286	40	....	56	....	14.659	24	86	44	64
13.889	50	....	72	....	14.286	20	....	28	....	14.666	40	44	48	50
13.889	20	40	24	48	14.286	32	50	40	56	14.666	20	44	24	50
13.889	24	50	24	72	14.286	20	64	32	56	14.666	24	44	20	72
13.936	28	86	48	72	14.286	32	40	28	64	14.667	44	48	40	72
13.952	40	72	48	86	14.286	20	24	24	28	14.667	32	44	40	48
13.953	20	72	24	86	14.286	20	48	24	56	14.694	24	48	28	56
13.953	24	50	20	86	14.286	40	24	24	56	14.735	44	72	50	86
13.953	48	50	40	86	14.286	40	24	28	48	14.743	24	86	50	56
13.954	40	48	32	86	14.318	28	72	44	64	14.799	50	56	44	86
13.961	20	86	44	56	14.323	44	50	48	64	14.815	32	40	24	72
13.963	24	64	44	50	14.326	44	56	40	86	14.815	40	64	48	72
13.963	32	48	44	50	14.333	24	86	40	72	14.815	20	64	24	72
13.968	32	44	28	72	14.333	20	86	48	50	14.848	28	56	44	48
13.968	44	64	56	72	14.352	24	72	28	86	14.881	40	50	48	56
14.000	28	....	40	....	14.352	48	72	56	86	14.881	20	50	24	56
14.000	24	28	40	24	14.400	24	24	20	40	14.881	20	50	28	48
14.000	24	28	20	48	14.40[illegible]	24	48	32	50	14.884	64	....	86	....

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
14.884	32	48	24	86	15.278	40	44	32	72	15.709	24	72	44	50
14.884	24	64	24	86	15.289	32	86	50	72	15.714	32	44	28	64
14.884	32	56	28	86	15.306	24	50	28	56	15.714	24	44	24	56
14.884	32	40	20	86	15.313	28	56	32	64	15.714	24	44	28	48
14.931	20	86	32	72	15.349	44	72	48	86	15.715	44	...	56	...
14.931	40	86	64	72	15.349	44	48	32	86	15.716	20	44	28	40
14.933	28	32	24	50	15.357	32	86	56	64	15.750	28	72	40	64
14.933	48	56	50	72	15.357	20	86	40	56	15.873	32	50	28	72
14.933	32	56	48	50	15.357	24	86	48	56	15.873	50	64	56	72
14.934	28	64	48	50	15.360	24	64	40	50	15.909	40	56	44	64
14.950	50	72	56	86	15.360	32	48	40	50	15.909	28	50	40	44
15.000	48	....	64	....	15.360	24	32	20	50	15.910	20	56	32	44
15.000	24	....	32	....	15.400	44	56	50	64	15.910	28	40	32	44
15.000	40	24	20	64	15.400	28	44	32	50	15.926	32	86	48	72
15.000	24	48	24	64	15.428	24	72	40	56	15.947	40	48	28	86
15.000	20	48	32	40	15.504	32	50	24	86	15.988	44	50	32	86
15.000	28	72	48	56	15.504	50	64	48	86	16.000	32	....	40	...
15.000	32	72	48	64	15.555	28	40	20	72	16.000	40	...	50	....
15.000	24	56	28	64	15.555	28	32	24	48	16.000	28	64	40	56
15.000	20	72	40	48	15.556	56	...	72	...	16.000	20	64	32	50
15.000	28	48	32	56	15.556	24	56	24	72	16.000	20	48	24	50
15.050	28	86	50	64	15.556	28	48	24	72	16.000	28	32	20	56
15.086	44	48	50	56	15.556	28	64	32	72	16.000	40	24	24	50
15.086	24	44	28	50	15.584	40	48	44	56	16.000	24	32	20	48
15.151	48	50	44	72	15.584	40	24	28	44	16.000	24	48	20	72
15.152	20	40	24	44	15.584	20	48	28	44	16.000	20	56	28	50
15.152	32	50	44	48	15.624	28	48	20	86	16.000	24	64	40	48
15.194	28	56	24	86	15.625	50	..	64	..	16.000	24	32	40	24
15.202	28	86	44	72	15.625	28	50	32	56	16.042	28	44	32	48
15.222	40	72	44	86	15.625	24	50	24	64	16.042	28	44	24	64
15.238	32	64	48	56	15.625	24	50	32	48	16.042	44	56	48	64
15.238	24	64	28	72	15.625	20	50	32	40	16.071	20	72	28	64
15.238	32	48	28	72	15.628	24	56	20	86	16.071	20	72	32	56
15.238	48	64	56	72	15.628	48	56	40	86	16.071	40	72	56	64
15.273	24	56	40	44	15.637	20	86	44	50	16.074	48	72	50	86
15.273	28	48	40	44	15.645	44	64	50	72	16.125	24	86	40	64
15.278	44	50	40	72	15.677	28	86	48	64	16.161	40	64	44	72
15.278	20	44	24	48	15.680	28	56	40	50	16.204	28	50	24	72

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
16.204	50	56	48	72	16.667	24	50	20	72	17.143	20	48	28	40
16.234	40	50	44	56	16.667	48	50	40	72	17.143	32	72	48	56
16.234	20	50	28	44	16.667	32	50	40	48	17.187	40	44	32	64
16.236	48	64	44	86	16.667	32	40	24	64	17.188	44	50	40	64
16.279	40	56	32	86	16.670	56	64	50	86	17.200	32	86	50	64
16.279	50	56	40	86	16.722	28	86	40	72	17.200	20	86	40	50
16.279	28	50	20	86	16.744	72	....	86	....	17.200	24	86	48	50
16.288	20	86	44	48	16.744	24	72	24	86	17.200	28	86	50	56
16.291	32	56	44	50	16.753	24	86	44	56	17.280	24	72	40	50
16.291	28	64	44	50	16.797	20	86	32	64	17.361	20	50	24	48
16.296	32	44	24	72	16.800	24	28	20	40	17.361	40	50	32	72
16.296	44	64	48	72	16.800	28	72	48	50	17.364	56	64	48	86
16.327	20	64	28	56	16.800	28	48	32	50	17.364	32	56	24	86
16.327	32	40	28	56	16.800	48	56	50	64	17.364	28	64	24	86
16.333	28	56	40	48	16.800	24	56	32	50	17.374	32	86	44	72
16.364	32	72	44	64	16.875	24	72	32	64	17.442	50	72	48	86
16.364	28	72	44	56	16.914	50	64	44	86	17.442	48	50	32	86
16.364	24	72	44	48	16.970	28	64	44	48	17.455	24	64	40	44
16.364	20	72	40	44	16.970	48	56	44	72	17.455	24	32	20	44
16.364	24	48	32	44	16.970	32	56	44	48	17.455	40	48	44	50
16.369	44	50	48	56	16.970	28	32	24	44	17.455	32	48	40	44
16.372	44	64	40	86	17.010	32	64	28	86	17.460	40	44	28	72
16.372	32	44	20	86	17.045	24	50	32	44	17.467	32	48	44	56
16.424	44	86	64	72	17.045	48	50	44	64	17.541	44	48	28	86
16.457	32	72	50	56	17.054	40	44	24	86	17.500	56	40	64	28
16.457	24	48	28	50	17.061	48	64	50	72	17.500	28	....	32	....
16.500	44	48	40	64	17.064	20	86	28	72	17.500	24	28	24	32
16.500	24	44	20	64	17.064	40	86	56	72	17.500	20	56	32	40
16.500	24	44	32	40	17.067	32	64	48	50	17.500	28	40	20	64
16.611	40	50	28	86	17.102	28	86	44	64	17.500	28	48	24	64
16.624	32	64	44	56	17.111	44	56	40	72	17.500	24	56	32	48
16.667	20	....	24	....	17.111	28	44	20	72	17.500	24	56	24	64
16.667	40	....	48	....	17.143	24	....	28	....	17.600	44	....	50	....
16.667	28	40	24	56	17.143	48	....	56	....	17.600	24	44	24	50
16.667	20	64	32	48	17.143	32	48	28	64	17.677	50	56	44	72
16.667	20	56	28	48	17.143	24	64	32	56	17.679	44	72	56	64
16.667	40	24	24	48	17.143	24	48	24	56	17.778	64	....	72	....
16.667	40	48	32	72	17.143	40	24	20	56	17.778	32	40	20	72

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Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
17.778	32	56	28	72	18.229	28	50	32	48	18.667	32	56	40	48
17.778	32	48	24	72	18.229	28	50	24	64	18.701	32	72	44	56
17.778	24	64	24	72	18.229	50	56	48	64	18.701	24	48	28	44
17.818	28	56	40	44	18.233	28	56	20	86	18.750	20	72	24	64
17.857	20	50	28	40	18.266	48	72	44	86	18.750	20	72	32	48
17.857	20	40	28	32	18.272	44	50	28	86	18.750	40	72	48	64
17.857	24	50	28	48	18.286	32	64	40	56	18.750	24	50	20	64
17.857	24	50	24	56	18.286	32	40	28	50	18.750	24	50	32	40
17.857	32	50	28	64	18.286	20	64	28	50	18.750	48	50	40	64
17.860	48	64	40	86	18.286	40	64	50	56	18.753	56	72	50	86
17.860	32	48	20	86	18.327	28	72	44	50	18.764	24	86	44	50
17.860	24	64	20	86	18.333	44	....	48	....	18.770	44	86	56	72
17.875	50	....	56	....	18.333	32	44	24	64	18.813	28	86	40	64
17.907	44	56	32	86	18.333	44	48	32	72	18.857	24	44	20	56
17.917	28	86	48	56	18.333	24	44	24	48	18.857	24	44	28	40
17.917	48	86	64	72	18.333	28	44	24	56	18.860	44	48	40	56
17.917	24	86	32	72	18.333	20	44	40	24	18.940	40	50	44	48
17.917	32	86	48	64	18.367	20	72	28	56	18.940	20	50	24	44
17.917	20	86	40	48	18.419	44	72	40	86	18.943	56	64	44	86
17.920	28	32	20	50	18.428	24	86	40	56	19.027	50	72	44	86
17.920	32	56	40	50	18.519	32	50	24	72	19.048	40	48	28	72
17.920	28	64	40	50	18.519	50	64	48	72	19.048	20	32	24	28
17.959	32	44	28	56	18.604	32	50	20	86	19.048	32	40	28	48
18.000	40	72	50	64	18.605	40	56	28	86	19.048	32	40	24	56
18.000	24	48	20	64	18.605	40	48	24	86	19.048	20	64	28	48
18.000	28	72	40	56	18.605	40	64	32	86	19.048	20	64	24	56
18.000	24	24	20	32	18.605	50	64	40	86	19.048	40	64	48	56
18.000	32	72	40	64	18.618	32	64	44	50	19.091	24	56	32	44
18.000	24	48	32	40	18.663	50	86	64	72	19.091	28	48	32	44
18.000	20	72	32	50	18.666	28	40	24	50	19.091	48	56	44	64
18.000	24	72	40	48	18.666	28	32	20	48	19.091	28	72	44	48
18.148	28	56	24	72	18.666	28	32	40	24	19.097	44	50	32	72
18.182	40	....	44	....	18.666	20	56	24	50	19.111	32	86	40	72
18.182	20	48	24	44	18.667	48	56	40	72	19.111	40	86	50	72
18.182	20	64	32	44	18.667	24	56	20	72	19.136	64	72	56	86
18.182	40	24	24	44	18.667	28	48	20	72	19.136	32	72	28	86
18.182	32	50	40	44	18.667	40	56	48	50	19.196	20	86	28	64
18.182	20	56	28	44	18.667	28	64	40	48	19.196	20	86	32	56

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
19.196	40	86	56	64	19.636	24	72	40	44	20.32	32	64	28	72
19.200	48	....	50	....	19.643	20	44	28	32	20.35	50	56	32	86
19.200	24	56	28	50	19.643	40	44	32	56	20.36	32	56	40	44
19.200	24	64	32	50	19.643	40	44	28	64	20.36	40	56	44	50
19.200	32	72	48	50	19.643	44	50	40	56	20.36	28	64	40	44
19.200	24	32	20	40	19.657	32	86	50	56	20.36	28	32	20	44
19.200	40	24	20	50	19.688	28	72	32	64	20.37	40	44	24	72
19.200	24	48	24	50	19.800	44	72	50	64	20.41	32	50	28	56
19.250	44	56	40	64	19.841	40	50	28	72	20.42	28	56	32	48
19.250	28	44	32	40	19.845	32	64	24	86	20.42	28	56	24	64
19.250	28	44	20	64	19.887	50	56	44	64	20.45	20	72	32	44
19.286	24	72	32	56	19.887	28	50	32	44	20.45	40	72	44	64
19.286	24	72	28	64	19.908	20	86	24	72	20.46	44	64	32	86
19.286	48	72	56	64	19.908	40	86	48	72	20.46	40	44	20	86
19.380	40	50	24	86	19.911	56	64	50	72	20.46	44	56	28	86
19.394	32	64	44	48	19.934	48	50	28	86	20.46	44	48	24	86
19.394	48	64	44	72	20.000	24	....	24	....	20.48	24	86	28	72
19.444	50	56	40	72	20.000	28	48	24	56	20.48	32	64	40	50
19.444	20	56	24	48	20.000	24	64	32	48	20.48	32	86	48	56
19.445	40	56	32	72	20.000	32	48	24	64	20.48	48	86	56	72
19.445	28	50	20	72	20.000	24	56	28	48	20.52	40	72	50	56
19.445	28	40	24	48	20.000	28	64	32	56	20.53	28	44	24	50
19.455	20	28	24	24	20.000	28	40	20	56	20.53	44	56	48	50
19.480	48	50	44	56	20.000	32	56	28	64	20.56	24	24	20	28
19.480	24	50	28	44	20.000	20	64	32	40	20.57	20	72	28	50
19.531	40	50	32	64	20.000	32	40	20	64	20.57	32	72	40	56
19.535	48	56	32	86	20.000	20	48	40	24	20.57	24	48	28	40
19.535	28	72	24	86	20.000	40	24	20	48	20.57	24	48	20	56
19.535	56	72	48	86	20.000	20	56	28	40	20.62	44	48	32	64
19.544	20	86	40	44	20.070	28	86	48	50	20.63	44	72	48	64
19.545	32	86	44	64	20.090	24	72	20	86	20.64	24	86	40	50
19.545	24	86	44	48	20.090	50	72	56	64	20.74	28	64	24	72
19.546	28	86	44	56	20.090	48	72	40	86	20.74	32	56	24	72
19.555	44	64	40	72	20.110	32	44	28	50	20.74	56	64	48	72
19.555	32	44	20	72	20.110	44	64	50	56	20.78	32	40	28	44
19.592	24	64	28	56	20.160	24	86	32	64	20.78	20	64	28	44
19.592	32	48	28	56	20.160	28	72	40	50	20.78	40	64	44	56
19.600	28	56	32	50	20.200	50	64	44	72	20.83	50	....	48	....

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
20.83	28	50	24	56	21.33	40	64	48	50	21.87	50	56	40	64
20.83	32	50	24	64	21.33	32	64	40	48	21.88	28	50	32	40
20.83	24	50	24	48	21.33	24	64	20	72	21.89	28	86	44	50
20.83	48	50	32	72	21.33	32	48	20	72	21.90	44	86	48	72
20.83	20	40	24	32	21.33	48	64	40	72	21.94	20	86	28	56
20.83	20	50	40	24	21.39	28	44	24	48	21.94	24	64	28	50
20.84	56	64	40	86	21.39	44	56	32	72	21.94	32	48	28	50
20.84	32	56	20	86	21.43	40	24	28	32	21.94	48	64	50	56
20.84	28	64	20	86	21.43	20	48	28	32	22.00	44	....	40	....
20.90	56	86	64	72	21.43	64	72	50	86	22.00	40	44	32	50
20.90	28	86	32	72	21.43	48	50	40	56	22.00	28	44	20	56
20.93	50	72	40	86	21.43	24	50	28	40	22.00	24	44	20	48
20.93	40	72	32	86	21.43	24	50	20	56	22.00	24	44	40	24
20.95	32	72	44	50	21.43	40	72	48	56	22.00	32	44	20	64
20.95	44	64	48	56	21.43	40	48	32	56	22.04	24	72	28	56
20.95	44	48	28	72	21.43	40	48	28	64	22.22	40	56	28	72
20.95	32	44	28	48	21.43	20	72	24	56	22.22	40	48	24	72
20.95	32	44	24	56	21.43	20	72	28	48	22.22	32	50	20	72
21.00	24	56	20	64	21.48	44	50	32	64	22.22	40	64	32	72
21.00	48	56	40	64	21.50	40	86	50	64	22.22	50	64	40	72
21.00	24	28	20	32	21.50	20	86	32	50	22.22	20	64	24	48
21.00	28	72	40	48	21.50	24	86	40	48	22.22	32	40	24	48
21.00	24	56	32	40	21.50	28	86	40	56	22.22	20	32	24	24
21.00	28	48	32	40	21.50	32	86	40	64	22.27	28	56	32	44
21.00	28	48	20	64	21.60	24	72	32	50	22.32	20	50	28	32
21.02	44	86	50	72	21.60	48	72	50	64	22.32	40	50	28	64
21.12	24	44	20	50	21.71	40	56	24	86	22.33	48	64	32	86
21.12	44	86	56	64	21.72	40	86	44	72	22.33	32	72	24	86
21.12	44	48	40	50	21.77	28	56	20	72	22.33	40	48	20	86
21.21	28	40	24	44	21.82	48	....	44	....	22.33	48	56	28	86
21.21	40	56	44	48	21.82	24	56	28	44	22.33	64	72	48	86
21.21	20	56	24	44	21.82	24	64	32	44	22.34	32	86	44	56
21.26	40	64	28	86	21.82	24	48	24	44	22.36	40	50	32	56
21.31	56	72	44	86	21.82	40	24	20	44	22.40	56	....	50	....
21.32	44	50	24	86	21.82	32	72	44	48	22.40	28	48	24	50
21.33	50	86	56	72	21.83	44	50	28	72	22.40	24	56	24	50
21.33	32	40	24	50	21.87	40	56	32	64	22.40	28	64	32	50
21.33	20	64	24	50	21.87	28	50	20	64	22.40	28	40	20	50

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
22.40	20	86	24	64	23.26	40	50	20	86	23.89	86	....	72	....
22.40	20	86	32	48	23.26	50	56	28	86	23.89	24	86	24	72
22.40	40	86	48	64	23.26	50	64	32	86	23.92	40	72	28	86
22.40	28	32	20	40	23.26	48	50	24	86	24.00	24	....	20	....
22.43	32	48	24	56	23.27	32	64	40	44	24.00	48	....	40	....
22.45	40	44	28	56	23.27	40	64	44	50	24.00	32	48	20	64
22.50	72	....	64	....	23.33	56	....	48	....	24.00	28	48	20	56
22.50	28	72	32	56	23.33	28	....	24	....	24.00	24	64	32	40
22.50	24	72	32	48	23.33	24	56	24	48	24.00	24	56	28	40
22.50	24	72	24	64	23.33	28	64	32	48	24.00	24	48	40	24
22.50	20	72	32	40	23.33	48	56	32	72	24.00	20	72	24	50
22.63	44	72	50	56	23.33	28	40	20	48	24.00	40	48	32	50
22.63	56	64	44	72	23.33	32	56	24	64	24.00	40	72	48	50
22.72	50	....	44	....	23.33	20	56	40	24	24.00	32	72	40	48
22.73	24	50	24	44	23.38	20	72	28	44	24.00	50	86	56	64
22.80	28	86	44	48	23.38	40	72	44	56	24.06	44	56	32	64
22.86	32	....	28	....	23.39	44	64	28	86	24.08	28	86	40	50
22.86	64	....	56	....	23.44	28	72	20	86	24.24	32	40	24	44
22.86	24	64	28	48	23.44	56	72	40	86	24.24	20	64	24	44
22.86	24	64	24	56	23.44	48	50	32	64	24.24	40	64	44	48
22.86	20	64	28	40	23.44	50	72	48	64	24.30	50	56	32	72
22.86	32	40	20	56	23.46	24	86	40	44	24.31	28	50	24	48
22.86	24	32	24	28	23.47	32	44	24	50	24.36	64	72	44	86
22.91	28	72	40	44	23.47	44	64	48	50	24.43	20	86	32	44
22.92	40	44	24	64	23.52	28	86	32	64	24.43	40	86	44	64
22.92	40	44	32	48	23.57	44	72	48	56	24.44	44	64	32	72
22.92	44	50	40	48	23.57	44	48	28	64	24.44	48	56	44	50
22.92	20	44	24	32	23.57	44	48	32	56	24.44	40	44	20	72
22.93	48	86	50	72	23.57	24	44	28	32	24.44	44	56	28	72
22.93	32	86	48	50	23.65	44	86	50	64	24.44	44	48	24	72
23.02	44	72	32	86	23.70	32	64	24	72	24.44	32	44	24	48
23.04	48	86	56	64	23.81	32	64	20	86	24.49	40	48	28	56
23.04	24	86	28	64	23.81	32	50	24	56	24.50	28	56	20	64
23.04	24	86	32	56	23.81	32	50	28	48	24.50	28	56	32	40
23.04	32	72	40	50	23.81	50	64	48	56	24.55	48	72	44	64
23.04	24	48	20	50	23.81	48	50	28	72	24.55	44	50	32	56
23.07	44	86	50	56	23.81	20	40	24	28	24.55	44	50	28	64
23.16	40	50	24	72	23.88	44	56	24	86	24.55	24	72	32	44

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
24.56	44	48	20	86	25.20	56	72	50	64	26.05	48	56	24	86
24.57	32	86	40	56	25.40	40	64	28	72	26.05	56	64	32	86
24.57	40	86	50	56	25.45	56	....	44	....	26.06	48	86	44	72
24.57	20	86	28	50	25.45	28	48	24	44	26.06	32	86	44	48
24.64	44	56	40	50	25.45	24	56	24	44	26.12	32	64	28	56
24.64	44	86	48	64	25.45	28	64	32	44	26.13	28	56	24	50
24.64	28	44	20	50	25.45	28	40	20	44	26.17	50	72	32	86
24.69	24	72	28	50	25.46	44	50	24	72	26.18	40	72	44	50
24.69	48	72	50	56	25.51	40	50	28	56	26.18	32	72	40	44
24.75	44	72	40	64	25.51	48	64	28	86	26.18	24	48	20	44
24.81	40	64	24	86	25.57	50	72	44	64	26.19	40	44	24	56
24.88	50	86	48	72	25.58	44	50	20	86	26.19	40	44	28	48
24.89	56	64	40	72	25.60	64	....	50	....	26.19	20	44	24	28
24.89	32	56	20	72	25.60	32	56	28	50	26.25	48	56	32	64
24.89	28	64	20	72	25.60	40	86	48	56	26.25	28	72	24	64
24.93	48	64	44	56	25.60	32	40	20	50	26.25	28	72	32	48
24.94	32	48	28	44	25.60	32	48	24	50	26.25	56	72	48	64
24.94	24	64	28	44	25.60	24	64	24	50	26.28	44	86	40	72
25.00	40	....	32	....	25.60	20	86	24	56	26.31	44	72	28	86
25.00	50	....	40	....	25.60	20	86	28	48	26.33	24	86	28	56
25.00	40	56	28	64	25.67	28	44	20	48	26.40	24	44	20	40
25.00	20	56	28	32	25.67	44	56	40	48	26.40	44	48	32	50
25.00	40	48	24	64	25.67	28	44	40	24	26.40	44	72	48	50
25.00	32	50	20	64	25.71	72	....	56	....	26.52	50	56	44	48
25.00	24	50	20	48	25.71	20	72	28	40	26.52	28	50	24	44
25.00	24	50	40	24	25.71	24	72	24	56	26.58	50	64	28	86
25.00	20	48	24	32	25.71	24	72	28	48	26.67	32	....	24	....
25.00	40	24	24	32	25.71	32	72	28	64	26.67	64	....	48	....
25.00	28	50	20	56	25.71	24	48	28	32	26.67	48	64	32	72
25.00	20	72	24	48	25.80	24	86	32	50	26.67	24	64	24	48
25.02	32	86	44	50	25.80	48	86	50	64	26.67	48	56	28	72
25.08	28	86	40	48	25.93	40	56	24	72	26.67	40	48	20	72
25.12	48	72	32	86	25.97	32	50	28	44	26.67	28	64	24	56
25.14	32	44	20	56	25.97	50	64	44	56	26.67	32	56	28	48
25.14	32	44	28	40	26.04	40	50	32	48	26.67	20	64	40	24
25.14	40	44	28	50	26.04	40	50	24	64	26.67	32	40	20	48
25.14	44	64	40	56	26.04	20	50	24	32	26.75	56	86	50	72
25.20	28	72	32	50	26.05	40	56	20	86	26.79	50	72	48	56

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
26.79	32	72	20	86	27.50	44	....	32	....	28.52	44	56	24	72
26.79	64	72	40	86	27.50	44	56	28	64	28.57	40	....	28	....
26.79	48	50	28	64	27.50	44	48	24	64	28.57	40	48	24	56
26.79	48	50	32	56	27.52	32	86	40	50	28.57	32	50	20	56
26.79	24	50	28	32	27.78	20	40	24	24	28.57	32	50	28	40
26.87	28	86	32	56	27.78	48	50	24	72	28.57	40	64	32	56
26.87	24	86	24	64	27.78	50	64	32	72	28.57	50	64	40	56
26.87	24	86	32	48	27.78	32	50	24	48	28.57	20	64	28	32
26.87	20	86	32	40	27.78	50	56	28	72	28.57	40	86	44	56
26.88	28	48	20	50	27.78	40	50	20	72	28.57	20	48	24	28
26.88	24	56	20	50	27.87	28	86	24	72	28.57	40	24	24	28
26.88	48	56	40	50	27.87	56	86	48	72	28.64	28	72	32	44
26.94	44	48	28	56	27.91	40	72	24	86	28.64	56	72	44	64
27.00	24	72	32	40	27.91	48	50	20	86	28.65	44	56	20	86
27.00	24	72	20	64	27.92	20	86	28	44	28.65	44	50	24	64
27.00	48	72	40	64	27.93	48	64	44	50	28.65	44	50	32	48
27.13	50	56	24	86	27.94	44	64	28	72	28.67	48	86	40	72
27.15	50	86	44	72	27.99	50	86	48	64	28.67	32	86	40	48
27.22	28	56	24	48	28.00	28	....	20	....	28.67	24	86	20	72
27.27	40	48	32	44	28.00	56	....	40	....	28.67	20	86	24	50
27.27	20	72	24	44	28.00	28	48	40	24	28.67	40	86	48	50
27.27	48	50	40	44	28.00	24	56	40	24	28.70	48	72	28	86
27.27	40	72	44	48	28.00	24	56	20	48	28.80	72	....	50	....
27.27	24	50	20	44	28.00	40	56	32	50	28.80	24	48	20	40
27.29	44	64	24	86	28.00	28	64	32	40	28.80	24	72	24	50
27.30	32	86	28	72	28.00	32	56	20	64	29.09	64	....	44	....
27.30	64	86	56	72	28.00	24	28	20	24	29.09	32	40	20	44
27.34	50	56	32	64	28.05	48	72	44	56	29.09	32	56	28	44
27.36	28	86	40	44	28.05	24	72	28	44	29.09	24	64	24	44
27.43	24	32	20	28	28.06	44	50	28	56	29.09	32	48	24	44
27.43	40	48	28	50	28.12	50	72	40	64	29.17	20	56	24	32
27.43	24	64	20	56	28.13	40	72	32	64	29.17	28	40	24	32
27.43	24	64	28	40	28.15	44	86	48	56	29.17	40	56	32	48
27.43	32	48	20	56	28.16	32	44	20	50	29.17	40	56	24	64
27.43	32	48	28	40	28.16	44	64	40	50	29.17	28	50	20	48
27.43	48	64	40	56	28.29	44	72	40	56	29.17	28	50	40	24
27.50	24	44	24	32	28.41	40	50	32	44	29.17	50	56	40	48
27.50	40	44	20	64	28.44	32	64	20	72	29.22	50	72	44	56

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
29.26	32	64	28	50	30.00	32	72	24	64	31.11	48	56	24	72
29.30	56	72	32	86	30.00	24	50	20	40	31.11	32	56	24	48
29.32	48	86	50	56	30.10	28	86	32	50	31.11	56	64	32	72
29.32	48	86	44	64	30.10	56	86	50	64	31.11	28	32	24	24
29.32	24	86	32	44	30.17	44	48	28	50	31.17	40	48	28	44
29.33	44	64	40	48	30.30	50	64	44	48	31.25	50	....	32	....
29.33	40	44	24	50	30.33	32	50	24	44	31.25	40	50	20	64
29.33	44	48	20	72	30.40	56	86	44	72	31.25	50	56	28	64
29.33	32	44	40	24	30.48	32	64	24	56	31.25	24	50	24	32
29.33	32	44	20	48	30.48	48	64	28	72	31.25	48	50	24	64
29.39	32	72	28	56	30.49	32	64	28	48	31.26	48	56	20	86
29.49	24	86	28	50	30.54	50	86	44	64	31.27	40	86	44	50
29.56	44	86	40	64	30.55	28	48	20	44	31.27	32	86	40	44
29.60	40	64	24	72	30.55	24	56	20	44	31.35	56	86	48	64
29.70	28	56	24	44	30.55	48	56	40	44	31.35	28	86	24	64
29.76	40	50	24	56	30.56	40	44	24	48	31.35	28	86	32	48
29.76	40	50	28	48	30.56	44	50	20	72	31.36	28	56	20	50
29.76	20	50	24	28	30.56	20	44	24	24	31.42	48	72	44	50
29.77	56	64	28	86	30.58	64	86	50	72	31.43	44	....	28	....
29.77	40	64	20	86	30.61	48	50	28	56	31.43	44	48	24	56
29.77	48	64	24	86	30.70	44	72	24	86	31.43	40	44	20	56
29.86	20	86	24	48	30.71	86	....	56	....	31.43	44	64	32	56
29.86	40	86	32	72	30.71	32	86	28	64	31.43	24	44	24	28
29.86	50	86	40	72	30.71	24	86	24	56	31.50	28	72	20	64
29.87	56	64	48	50	30.71	24	86	28	48	31.50	28	72	32	40
29.87	32	56	24	50	30.71	20	86	28	40	31.50	56	72	40	64
29.87	28	64	24	50	30.72	24	64	20	50	31.53	44	86	48	50
29.90	50	72	28	86	30.72	32	48	20	50	31.68	44	72	40	50
30.00	48	....	32	....	30.72	48	64	40	50	31.75	50	64	28	72
30.00	72	....	48	....	30.80	44	56	32	50	31.82	28	50	20	44
30.00	24	56	28	32	30.80	28	44	20	40	31.82	50	56	40	44
30.00	20	72	40	24	30.86	48	72	40	56	31.82	40	56	32	44
30.00	24	48	24	32	30.86	24	72	20	56	31.85	32	86	24	72
30.00	24	72	24	48	30.86	24	72	28	40	31.85	64	86	48	72
30.00	40	48	20	64	30.94	44	72	32	64	31.99	50	86	48	56
30.00	48	56	28	64	31.01	50	64	24	86	32.00	32	....	20	....
30.00	28	72	24	56	31.11	40	56	20	72	32.00	64	....	40	....
30.00	40	24	20	32	31.11	28	64	24	48	32.00	32	48	40	24

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
32.00	24	64	40	24	33.00	44	48	32	40	34.20	28	86	32	44
32.00	24	64	20	48	33.00	44	48	20	64	34.22	44	56	20	72
32.00	40	56	28	50	33.25	32	64	28	44	34.29	48	....	28	....
32.00	28	64	20	56	33.33	40	....	24	....	34.29	24	48	24	28
32.00	40	48	24	50	33.33	32	50	20	48	34.29	40	24	20	28
32.00	32	56	28	40	33.33	40	56	28	48	34.29	64	72	48	56
32.00	40	64	32	50	33.33	32	50	40	24	34.29	32	72	28	48
32.00	24	32	20	24	33.33	40	64	32	48	34.29	32	72	24	56
32.03	28	44	24	32	33.33	50	64	40	48	34.29	40	48	20	56
32.08	44	56	24	64	33.33	48	50	20	72	34.29	48	64	32	56
32.08	44	56	32	48	33.33	20	64	24	32	34.29	24	64	28	32
32.14	40	72	32	56	33.33	20	48	24	24	34.37	44	50	32	40
32.14	40	72	28	64	33.33	20	56	24	28	34.37	44	50	20	64
32.14	20	72	28	32	33.44	28	86	20	72	34.40	86	....	50	....
32.14	50	72	40	56	33.44	56	86	40	72	34.46	24	86	24	50
32.25	48	86	40	64	33.49	40	72	20	86	34.55	72	86	56	64
32.25	24	86	20	64	33.49	56	72	28	86	34.56	24	72	20	50
32.25	24	86	32	40	33.49	64	72	32	86	34.56	48	72	40	50
32.41	50	56	24	72	33.49	48	72	24	86	34.72	40	50	24	48
32.47	40	50	28	44	33.51	24	86	28	44	34.72	20	50	24	24
32.56	50	56	20	86	33.51	48	86	44	56	34.73	56	64	24	86
32.57	20	86	24	44	33.59	50	86	40	64	34.75	64	86	44	72
32.58	40	86	44	48	33.59	40	86	32	64	34.88	50	72	24	86
32.58	56	64	44	50	33.60	24	56	20	40	34.90	50	86	44	56
32.59	44	64	24	72	33.60	28	48	20	40	34.91	24	64	20	44
32.65	40	64	28	56	33.60	48	56	32	50	34.91	32	48	20	44
32.67	28	56	20	48	33.60	28	72	24	50	34.91	48	64	40	44
32.67	28	56	40	24	33.60	56	72	48	50	35.00	56	....	32	....
32.73	72	....	44	....	33.75	48	72	32	64	35.00	28	40	20	32
32.73	24	72	24	44	33.79	44	86	40	56	35.00	28	72	24	48
32.74	44	50	24	56	33.94	56	64	44	48	35.00	48	56	24	64
32.74	44	50	28	48	33.94	32	56	24	44	35.00	40	56	20	64
32.74	44	64	20	86	33.94	28	64	24	44	35.00	28	50	20	40
32.85	44	86	32	72	34.09	48	50	32	44	35.00	24	56	24	32
32.91	64	72	50	56	34.09	50	72	44	48	35.00	28	48	24	32
32.91	32	72	28	50	34.13	40	86	28	72	35.10	32	86	28	56
33.00	44	72	40	48	34.13	32	64	24	50	35.16	50	72	32	64
33.00	24	44	20	32	34.20	56	86	44	64	35.20	44	64	32	50

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
35.20	40	44	20	50	36.36	50	64	40	44	37.53	48	86	44	50
35.20	44	56	28	50	36.46	50	56	32	48	37.54	44	86	28	72
35.20	44	48	24	50	36.46	50	56	24	64	37.63	28	86	32	40
35.20	32	44	20	40	36.46	28	50	24	32	37.63	28	86	20	64
35.36	44	72	28	64	36.57	40	64	28	50	37.63	56	86	40	64
35.36	44	72	32	56	36.57	32	64	28	40	37.71	44	48	20	56
35.56	56	64	28	72	36.57	32	64	20	56	37.71	44	48	28	40
35.56	40	64	20	72	36.67	44	....	24	....	37.71	24	44	20	28
35.56	32	64	24	48	36.67	56	72	44	50	37.84	44	86	40	50
35.56	48	64	24	72	36.67	44	64	32	48	37.88	40	50	24	44
35.64	28	56	20	44	36.67	40	44	20	48	38.10	40	64	24	56
35.71	50	....	28	....	36.67	44	56	28	48	38.10	40	64	28	48
35.71	40	50	20	56	36.73	40	72	28	56	38.10	20	64	24	28
35.71	48	50	24	56	36.83	44	72	20	86	38.10	32	40	24	28
35.71	50	64	32	56	36.86	24	86	28	40	38.18	48	56	32	44
35.71	24	50	24	28	36.86	24	86	20	56	38.18	28	72	24	44
35.72	48	64	20	86	36.86	48	86	40	56	38.18	56	72	44	48
35.83	20	86	40	24	36.95	44	86	32	64	38.19	44	50	24	48
35.83	48	86	32	72	37.04	50	64	24	72	38.22	64	86	40	72
35.83	32	86	24	64	37.21	50	64	20	86	38.22	32	86	20	72
35.83	28	86	24	56	37.33	50	86	32	72	38.27	64	72	28	86
35.83	24	86	24	48	37.33	56	64	40	48	38.39	20	86	28	32
35.83	86	....	48	....	37.33	32	56	40	24	38.39	50	86	40	56
35.84	32	56	20	50	37.33	32	56	20	48	38.39	40	86	32	56
35.84	28	64	20	50	37.33	28	64	40	24	38.39	40	86	28	64
35.84	56	64	40	50	37.33	28	64	20	48	38.40	24	64	20	40
35.92	44	64	28	56	37.33	48	56	20	72	38.40	32	48	20	40
36.00	72	....	40	....	37.33	40	56	24	50	38.40	48	64	32	50
36.00	24	48	20	32	37.33	28	32	20	24	38.40	40	48	50	20
36.00	32	72	20	64	37.40	64	72	44	56	38.40	48	56	28	50
36.00	40	72	32	50	37.40	32	72	28	44	38.40	32	72	24	50
36.00	28	72	20	56	37.50	20	72	24	32	38.40	64	72	48	50
36.00	24	72	40	24	37.50	40	72	24	64	38.50	44	56	20	64
36.00	24	72	20	48	37.50	40	72	32	48	38.50	44	56	32	40
36.36	40	56	28	44	37.50	24	50	20	32	38.50	28	44	20	32
36.36	40	48	24	44	37.50	50	72	40	48	38.57	48	72	28	64
36.36	32	50	20	44	37.50	48	50	20	64	38.57	48	72	32	56
36.36	40	64	32	44	37.50	48	50	32	40	38.57	24	72	28	32

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
38.70	72	86	50	64	40.19	48	72	20	86	41.80	56	86	32	72
38.79	32	64	24	44	40.23	20	72	44	64	41.81	28	86	24	48
38.89	50	56	20	72	40.23	44	64	28	50	41.86	50	72	20	86
38.89	40	56	24	48	40.31	48	86	32	64	41.89	64	72	44	50
38.89	28	40	24	24	40.31	72	86	48	64	41.90	44	64	24	56
38.89	20	56	24	24	40.32	28	72	20	50	41.90	44	64	28	48
38.96	48	50	28	44	40.32	56	72	40	50	41.90	32	44	24	28
39.07	56	72	24	86	40.41	44	72	28	56	41.99	50	86	32	64
39.09	86	....	44	....	40.72	50	86	44	48	42.00	56	72	40	48
39.09	24	86	24	44	40.73	28	64	20	44	42.00	28	72	40	24
39.11	44	64	20	72	40.73	32	56	20	44	42.00	28	72	20	48
39.18	48	64	28	56	40.73	56	64	40	44	42.00	48	56	32	40
39.20	28	56	20	40	40.82	50	64	28	56	42.00	48	56	20	64
39.27	24	72	20	44	40.83	28	56	24	32	42.00	24	56	20	32
39.20	24	74	44	78	40.91	50	72	40	44	42.00	28	48	20	32
39.29	44	50	28	40	40.91	40	72	32	44	42.23	44	86	32	56
39.29	44	50	20	56	40.95	32	86	24	56	42.23	44	86	28	64
39.29	40	44	28	32	40.95	32	86	28	48	42.24	44	48	20	50
39.31	64	86	50	56	40.95	48	86	28	72	42.43	40	56	24	44
39.31	32	86	28	50	40.95	64	86	48	56	42.66	50	86	28	72
39.37	56	72	32	64	40.96	32	64	20	50	42.67	40	64	24	50
39.42	44	86	40	48	41.07	44	56	24	50	42.67	32	64	40	24
39.60	44	72	32	50	41.14	24	48	20	28	42.67	32	64	20	48
39.77	50	56	32	44	41.14	64	72	40	56	42.67	48	64	20	72
39.82	40	86	24	72	41.14	32	72	28	40	42.78	28	44	24	24
40.00	56	....	28	....	41.14	32	72	20	56	42.78	44	56	24	48
40.00	40	...	20	....	41.14	40	72	28	50	42.86	48	50	28	40
40.00	48	....	24	....	41.25	44	72	32	48	42.86	48	50	20	56
40.00	64	....	32	....	41.25	44	72	24	64	42.86	24	50	20	28
40.00	24	56	24	28	41.28	48	86	40	50	42.86	40	72	28	48
40.00	24	64	24	32	41.28	24	86	20	50	42.86	40	72	24	56
40.00	32	50	20	40	41.48	56	64	24	72	42.86	40	48	28	32
40.00	32	72	24	48	41.56	40	64	28	44	42.86	20	72	24	28
40.00	40	24	20	24	41.67	50	....	24	....	43.00	32	86	20	64
40.13	28	86	24	50	41.67	50	56	28	48	43.00	86	....	40	....
40.13	56	86	48	50	41.67	50	64	32	48	43.00	28	86	20	56
40.18	50	72	32	56	41.67	40	50	20	48	43.00	24	86	20	48
40.18	50	72	28	64	41.68	56	64	20	86	43.00	24	86	40	24

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
43.00	40	86	32	50	44.80	48	56	24	50	46.67	28	64	24	32
43.20	48	72	32	50	44.80	40	56	20	50	46.67	28	40	20	24
43.20	24	72	20	40	45.00	72	....	32	....	46.67	56	64	32	48
43.64	48	64	32	44	45.00	56	72	28	64	46.75	40	72	28	44
43.64	48	56	28	44	45.00	40	72	20	64	46.88	50	72	24	64
43.64	40	48	20	44	45.00	24	72	24	32	46.88	50	72	32	43
43.64	32	72	24	44	45.00	48	72	24	64	46.88	56	72	20	86
43.64	64	72	44	48	45.26	44	72	28	50	46.91	48	86	40	44
43.75	28	50	20	32	45.45	48	50	24	44	46.91	24	86	20	44
43.75	50	56	20	64	45.45	50	56	28	44	46.93	44	64	24	50
43.75	50	56	32	40	45.46	40	50	20	44	47.03	56	86	32	64
43.78	56	86	44	50	45.46	50	64	32	44	47.14	44	48	28	32
43.80	44	86	24	72	45.60	56	86	44	48	47.14	44	72	24	56
43.88	40	86	28	56	45.61	28	86	24	44	47.14	44	72	28	48
43.89	48	64	28	50	45.71	64	....	28	....	47.30	44	86	32	50
43.98	72	86	44	64	45.71	32	40	20	28	47.62	50	64	28	48
44.00	44	....	20	....	45.71	40	64	20	56	47.62	50	64	24	56
44.00	24	44	20	24	45.71	32	48	24	28	47.62	32	50	24	28
44.00	44	64	32	40	45.71	48	64	24	56	47.77	56	86	28	72
44.00	44	56	28	40	45.71	24	64	24	28	47.78	32	86	24	48
44.00	44	48	40	24	45.82	28	72	20	44	47.78	48	86	24	72
44.08	48	72	28	56	45.82	56	72	40	44	47.78	40	86	20	72
44.23	72	86	50	56	45.83	44	50	40	24	47.78	64	86	32	72
44.44	32	40	24	24	45.83	40	44	24	32	47.99	50	86	28	64
44.45	20	64	24	24	45.83	44	50	20	48	47.99	50	86	32	56
44.45	50	64	20	72	45.87	64	86	48	50	48.00	48	....	20	....
44.45	40	64	24	48	45.87	32	86	24	50	48.00	24	48	20	24
44.64	40	50	28	32	45.92	50	72	28	56	48.00	64	72	40	48
44.65	64	72	24	86	46.07	72	86	48	56	48.00	40	72	24	50
44.68	32	86	28	44	46 07	48	86	32	56	48.00	48	56	40	28
44.68	64	86	44	56	46.07	48	86	28	64	48.00	32	72	40	24
44.79	40	86	32	48	46.07	24	86	28	32	48.00	32	72	20	48
44.79	40	86	24	64	46.08	32	72	20	50	48.00	24	56	20	28
44.79	50	86	40	48	46.08	64	72	40	50	48.00	24	64	20	32
44.79	20	86	24	32	46.55	32	64	20	44	48.00	48	64	32	40
44.80	56	64	32	50	46.67	56	....	24	....	48.16	28	86	20	50
44.80	32	56	20	40	46.67	28	48	24	24	48.16	56	86	40	50
44.80	28	64	20	40	46.67	40	56	20	48	48.27	44	86	28	56

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
48.37	72	86	40	64	50.29	44	64	20	56	52.65	48	86	28	56
48.49	40	64	24	44	50.29	44	64	28	40	52.80	44	48	20	40
48.61	50	56	24	48	50.29	32	44	20	28	52.80	44	72	24	50
48.61	28	50	24	24	50.40	56	72	32	50	53.03	50	56	24	44
48.86	40	86	32	44	50.40	28	72	20	40	53.33	64	....	24	....
48.86	50	86	40	44	50.91	56	64	32	44	53.33	56	64	28	48
48.89	44	64	24	48	50.91	48	56	24	44	53.33	32	40	20	24
48.89	32	44	24	24	50.91	40	56	20	44	53.33	40	64	20	48
49.00	28	56	20	32	51.14	50	72	32	44	53.33	32	56	24	28
49.09	48	72	32	44	51.19	20	86	24	28	53.33	32	48	24	24
49.11	44	50	28	32	51.19	40	86	24	56	53.57	50	72	28	48
49.14	64	86	40	56	51.19	40	86	28	48	53.57	50	72	24	56
49.14	40	86	28	50	51.20	48	64	24	50	53.57	48	50	28	32
49.14	32	86	28	40	51.20	40	64	20	50	53.58	64	72	20	86
49.14	32	86	20	56	51.20	32	64	20	40	53.75	86	....	32	....
49.27	44	86	32	48	51.20	56	64	28	50	53.75	48	86	24	64
49.27	44	86	24	64	51.33	28	44	20	24	53.75	56	86	28	64
49.28	44	56	20	50	51.33	44	56	40	24	53.75	40	86	20	64
49.37	48	72	28	50	51.33	44	56	20	48	53.75	24	86	24	32
49.50	44	72	20	64	51.43	72	....	28	....	53.76	48	56	20	50
49.50	44	72	32	40	51.43	64	72	32	56	54.00	24	72	20	32
49.77	50	86	24	72	51.43	40	72	20	56	54.00	48	72	20	64
49.78	56	64	20	72	51.43	24	72	24	28	54.00	48	72	32	40
49.87	48	64	28	44	51.43	48	72	24	56	54.06	44	86	28	50
50.00	50	....	20	....	51.60	48	86	32	50	54.44	28	56	24	24
50.00	48	50	40	24	51.60	24	86	20	40	54.54	48	50	20	44
50.00	24	50	20	24	51.60	72	86	48	50	54.55	40	72	24	44
50.00	40	72	24	48	51.95	50	64	28	44	54.60	64	86	28	72
50.00	40	48	24	32	52.08	40	50	24	32	54.72	56	86	40	44
50.00	50	64	32	40	52.12	64	86	44	48	54.73	28	86	20	44
50.00	40	56	28	32	52.12	32	86	24	44	54.85	50	86	28	56
50.00	20	72	24	24	52.36	32	72	20	44	54.86	32	48	20	28
50.00	50	56	28	40	52.36	64	72	40	44	54.86	48	64	20	56
50.04	64	86	44	50	52.38	40	44	24	28	54.86	48	64	28	40
50.16	56	86	40	48	52.50	56	72	32	48	54.86	24	64	20	28
50.17	28	86	40	24	52.50	56	72	24	64	55.00	44	50	20	40
50.17	28	86	20	48	52.50	28	72	24	32	55.00	40	44	20	32
50.26	72	86	44	56	52.56	44	86	20	72	55.00	44	56	28	32

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
55.00	44	48	24	32	57.60	64	72	32	50	60.95	32	64	24	28
55.00	44	72	24	48	57.60	32	72	20	40	61.08	50	86	32	44
55.04	64	86	40	50	57.60	40	72	20	50	61.09	48	56	20	44
55.04	32	86	20	50	57.60	56	72	28	50	61.11	40	44	24	24
55.29	72	86	40	56	57.60	48	72	24	50	61.43	86	....	28	....
55.56	50	64	24	48	58.18	56	64	28	44	61.43	64	86	32	56
55.56	32	50	24	24	58.18	40	64	20	44	61.43	40	86	20	56
55.74	56	86	24	72	58.18	48	64	24	44	61.43	24	86	24	28
55.84	40	86	28	44	58.33	28	50	20	24	61.43	48	86	24	56
55.99	50	86	32	48	58.33	50	56	20	48	61.44	48	64	20	50
55.99	50	86	24	64	58.33	50	56	40	24	61.60	44	56	20	40
56.00	56	....	20	....	58.34	40	56	24	32	61.71	24	72	20	28
56.00	56	64	32	40	58.44	50	72	28	44	61.71	48	72	28	40
56.00	48	56	40	24	58.64	72	86	44	48	61.71	48	72	20	56
56.00	28	64	20	32	58.64	48	86	32	44	61.92	72	86	40	50
56.00	28	48	20	24	58.67	44	64	40	24	62.22	56	64	24	48
56.00	24	56	20	24	58.67	44	64	20	48	62.22	32	56	24	24
56.10	48	72	28	44	58.67	32	44	20	24	62.22	28	64	24	24
56.25	50	72	20	64	58.78	64	72	28	56	62.50	48	50	24	32
56.25	50	72	32	40	58.97	48	86	28	50	62.50	50	72	24	48
56.29	72	86	44	50	59.13	44	86	32	40	62.50	50	56	28	32
56.31	44	86	24	56	59.13	44	86	20	64	62.50	40	50	20	32
56.31	44	86	28	48	59.17	40	86	24	48	62.55	64	86	40	44
56.32	44	64	20	50	59.52	40	50	24	28	62.55	32	86	20	44
56.57	44	72	20	56	59.72	20	86	24	24	62.70	56	86	32	48
56.57	44	72	28	40	59.72	50	86	20	72	62.70	56	86	24	64
57.14	50	64	28	40	59.73	56	64	24	50	62.71	28	86	24	32
57.14	50	64	20	56	60.00	72	....	24	....	62.86	44	64	28	32
57.14	40	64	28	32	60.00	48	50	20	40	62.86	40	44	20	28
57.14	32	50	20	28	60.00	64	72	32	48	62.86	44	48	24	28
57.14	40	48	24	28	60.00	40	72	20	48	63.00	28	72	20	32
57.27	56	72	32	44	60.00	40	48	20	32	63.00	56	72	20	64
57.29	44	50	24	32	60.00	56	72	28	48	63.00	56	72	32	40
57.33	40	86	24	50	60.00	48	56	28	32	63.07	44	86	24	50
57.33	64	86	40	48	60.20	28	86	20	40	63.36	44	72	20	50
57.33	48	86	20	72	60.20	56	86	32	50	63.64	50	56	20	44
57.33	32	86	40	24	60.47	72	86	64	32	63.70	64	86	24	72
57.33	32	86	20	48	60.61	50	64	44	24	63.99	50	86	24	56

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
63.99	50	86	28	48	67.20	48	56	20	40	71.67	40	86	20	48
64.00	64	....	20	....	67.23	40	86	20	50	71.67	64	86	32	48
64.00	56	64	28	40	67.57	44	86	28	40	71.68	56	64	20	50
64.00	32	56	20	28	67.57	44	86	20	56	72.00	64	72	32	40
64.00	32	48	20	24	67.88	56	64	24	44	72.00	72	....	20	....
64.00	48	64	40	24	68.18	50	72	24	44	72.00	56	72	28	40
64.00	24	64	20	24	68.40	56	86	32	44	72.00	24	72	20	24
64.17	44	56	24	32	68.57	64	72	28	48	72.00	48	72	40	24
64.29	40	72	28	32	68.57	64	72	24	56	72.73	50	64	20	44
64.29	50	72	28	40	68.57	32	72	24	28	72.92	50	56	24	32
64.29	50	72	20	56	68.57	48	64	28	32	73.14	32	64	20	28
64.50	24	86	20	32	68.57	40	48	20	28	73.33	44	64	24	32
64.50	48	86	20	64	68.75	44	50	20	32	73.33	44	48	24	24
64.50	48	86	32	40	68.80	56	86	28	50	73.33	40	44	20	24
64.50	72	86	40	48	68.80	32	86	20	40	73.33	44	56	24	28
65.15	40	86	24	44	68.80	48	86	24	50	73.71	48	86	28	40
65.33	28	56	20	24	68.80	64	86	32	50	73.71	48	86	20	56
65.45	48	72	24	44	69.11	72	86	32	56	73.71	24	86	20	28
65.45	64	72	32	44	69.11	72	86	28	64	74.65	50	86	24	48
65.45	56	72	28	44	69.12	48	72	20	50	74.67	56	64	40	24
65.45	40	72	20	44	69.44	40	50	24	24	74.67	32	56	20	24
65.48	44	50	24	28	69.80	50	86	28	44	74.67	56	64	20	48
65.69	44	86	24	48	69.82	48	64	20	44	74.67	28	64	20	24
65.83	64	72	28	50	70.00	56	72	24	48	74.81	64	72	28	44
66.00	44	48	20	32	70.00	28	72	24	24	75.00	48	50	20	32
66.00	44	72	20	48	70.00	48	56	24	32	75.00	40	72	24	32
66.00	44	72	40	24	70.00	40	56	20	32	75.00	50	72	40	24
66.67	50	64	40	24	70.00	50	56	20	40	75.00	50	72	20	48
66.67	50	64	20	48	70.20	64	86	28	56	75.25	28	86	20	32
66.67	40	64	24	32	70.36	72	86	40	44	75.25	56	86	32	40
66.67	32	50	20	24	70.40	44	64	20	40	75.25	56	86	20	64
66.67	40	48	24	24	70.72	44	72	28	32	75.43	44	48	20	28
66.67	40	56	24	28	71.11	32	64	24	24	75.86	44	86	20	50
66.88	56	86	20	72	71.43	48	50	24	28	76.19	40	64	24	28
67.01	48	86	28	44	71.43	50	64	28	32	76.36	56	72	24	44
67.19	50	86	20	64	71.43	40	50	20	28	76.39	44	50	24	24
67.19	50	86	32	40	71.67	86	....	24	....	76.44	64	86	20	72
67.20	56	72	24	50	71.67	56	86	28	48	76.79	50	86	28	40

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
76.79	50	86	20	56	81.90	64	86	28	48	89.53	44	56	64	86
76.79	40	86	28	32	81.91	32	86	24	28	89.58	50	86	20	48
76.80	48	64	20	40	82.29	64	72	28	40	89.58	50	86	40	24
76.80	64	72	24	50	82.29	64	72	20	56	89.58	40	86	24	32
77.00	44	56	20	32	82.29	32	72	20	28	89.60	56	64	20	40
77.14	48	72	28	32	82.50	44	72	24	32	90.00	40	72	20	32
77.40	72	86	32	50	82.56	48	86	20	50	90.00	50	72	20	40
77.78	40	56	24	24	83.33	48	50	24	24	90.00	48	72	24	32
78.18	56	86	28	44	83.33	50	64	24	32	90.00	56	72	28	32
78.18	48	86	24	44	83.33	50	56	24	28	91.21	56	86	24	44
78.18	40	86	20	44	83.33	40	50	20	24	91.43	40	64	20	28
78.18	64	86	32	44	83.61	56	86	24	48	91.43	48	64	24	28
78.55	48	72	20	44	83.61	28	86	24	24	91.64	56	72	20	44
78.57	44	50	20	28	83.81	44	64	24	28	91.67	44	50	20	24
78.63	64	86	28	50	84.00	56	72	20	48	91.73	64	86	24	50
78.83	44	86	20	48	84.00	56	72	40	24	92.14	72	86	24	56
78.83	44	86	40	24	84.00	48	56	20	32	92.14	72	86	28	48
78.98	72	86	28	56	84.00	28	72	20	24	92.14	48	86	28	32
79.20	44	72	20	40	84.46	44	86	28	32	92.16	64	72	20	50
79.59	44	56	86	72	85.33	32	64	20	24	93.33	40	56	20	24
80.00	48	64	24	32	85.56	44	56	24	24	93.33	48	56	24	24
80.00	40	56	20	28	85.71	40	72	24	28	93.33	56	64	24	32
80.00	40	48	20	24	85.71	48	50	20	28	93.75	50	72	24	32
80.00	48	56	24	28	85.99	56	86	28	40	93.82	48	86	20	44
80.00	40	64	20	32	86.00	86	....	20	....	94.29	44	72	24	28
80.00	32	72	24	24	86.00	24	86	20	24	94.60	44	86	20	40
80.00	50	64	20	40	86.00	48	86	40	24	95.24	50	64	24	28
80.00	56	64	28	32	86.00	64	86	32	40	95.55	32	86	24	24
80.00	64	72	24	48	86.40	48	72	20	40	95.56	64	86	24	48
80.26	56	86	24	50	87.27	64	72	24	44	95.98	50	86	28	32
80.36	50	72	28	32	87.50	50	56	20	32	96.00	48	64	20	32
80.63	72	86	24	64	87.95	72	86	32	44	96.00	48	56	20	28
80.63	72	86	32	48	88.00	44	48	20	24	96.00	32	72	20	24
80.64	56	72	20	50	88.00	44	56	20	28	96.00	64	72	20	48
81.44	50	86	24	44	88.00	44	64	20	32	96.00	64	72	40	24
81.46	56	64	20	44	88.46	72	86	28	50	96.32	56	86	20	50
81.82	50	72	20	44	88.89	40	64	24	24	96.75	72	86	32	40
81.90	64	86	24	56	89.35	64	86	28	44	96.75	72	86	20	64

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
97.22	50	56	24	24	109.45	56	86	20	44	127.98	50	86	24	28
97.73	50	86	20	44	109.71	48	64	20	28	128.00	56	64	20	28
97.78	44	64	24	24	110.00	44	72	24	24	128.00	48	64	20	24
98.29	32	86	20	28	110.08	64	86	20	50	128.57	50	72	20	28
98.29	64	86	20	56	110.57	72	86	28	40	129.00	48	86	20	32
98.29	64	86	28	40	110.57	72	86	20	56	129.00	72	86	20	48
98.54	44	86	24	32	111.11	50	64	24	24	129.00	72	86	40	24
99.00	44	72	20	32	111.98	50	86	24	32	131.31	44	86	24	24
100.00	50	56	20	28	112.00	48	56	20	24	132.00	44	72	20	24
100.00	48	50	20	24	112.00	56	64	20	32	133.33	50	64	20	42
100.00	50	64	20	32	112.50	50	72	20	32	134.37	50	86	20	32
100.00	40	72	24	24	112.62	44	86	24	28	135.14	44	86	20	28
100.33	56	86	40	24	113.14	44	72	20	28	137.14	64	72	24	28
100.33	56	86	20	48	114.28	50	64	20	28	137.60	64	86	20	40
100.52	72	86	28	44	114.67	32	86	20	24	138.21	72	86	28	32
100.57	44	64	20	28	114.67	64	86	40	24	140.00	56	72	24	24
100.80	56	72	20	40	114.67	64	86	20	48	140.73	72	86	20	44
100.83	23	86	20	24	115.20	64	72	20	40	143.33	56	86	24	28
102.38	40	86	24	28	116.67	50	56	20	24	143.33	48	86	24	24
102.67	44	56	20	24	117.27	72	86	24	44	143.33	64	86	24	32
102.86	40	72	20	28	117.33	44	64	20	24	143.33	40	86	20	24
102.86	48	72	24	28	118.25	44	86	20	32	144.00	48	72	20	24
102.86	64	72	28	32	119.45	40	86	24	24	144.00	56	72	20	28
103.20	48	86	20	40	120.00	48	72	24	24	144.00	64	72	20	32
103.20	72	86	24	50	120.00	40	72	20	24	147.43	48	86	20	28
104.24	64	86	24	44	120.00	56	72	24	28	149.31	50	86	24	24
104.73	64	72	20	44	120.00	64	72	24	32	149.33	56	64	20	24
105.00	56	72	24	32	120.39	56	86	20	40	150.00	50	72	20	24
106.67	48	64	24	24	122.86	48	86	24	28	150.49	56	86	20	32
106.67	40	64	20	24	122.86	40	86	20	28	153.57	50	86	20	28
106.67	56	64	24	28	122.86	64	86	28	32	154.80	72	86	20	40
107.14	50	72	24	28	123.43	48	72	20	28	157.67	44	86	20	24
107.49	56	86	28	32	123.84	72	86	20	50	160.00	64	72	24	24
107.50	48	86	24	32	124.45	56	64	24	24	161.25	72	86	24	32
107.50	72	86	24	48	125.00	50	72	24	24	163.81	64	86	24	28
107.50	40	86	20	32	125.09	64	86	20	44	164.57	64	72	20	28
107.50	50	86	20	40	125.41	56	86	24	23	167.22	56	86	24	24
108.00	48	72	20	32	126.00	56	72	20	32	168.00	56	72	20	24

Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers		Lead in Inches	Driven		Drivers	
172.00	**56**	**86**	**20**	**28**	**191.11**	**64**	**86**	**24**	**24**	**215.00**	**72**	**86**	**24**	**24**
172.00	**48**	**86**	**20**	**24**	**192.00**	**64**	**72**	**20**	**24**	**221.14**	**72**	**86**	**20**	**28**
172.00	**64**	**86**	**20**	**32**	**193.50**	**72**	**86**	**20**	**32**	**229.33**	**64**	**86**	**20**	**24**
179.17	**50**	**86**	**20**	**24**	**196.57**	**64**	**86**	**20**	**28**	**258.00**	**72**	**86**	**20**	**24**
184.28	**72**	**86**	**24**	**28**	**200.66**	**56**	**86**	**20**	**24**					

TABLE OF NATURAL SINES AND COSINES

′	0°		1°		2°		3°		4°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.00000	I.	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	60
1	.00029	I.	.01774	.99984	.03519	.99938	.05263	.99861	.07005	.99754	59
2	.00058	I.	.01803	.99984	.03548	.99937	.05292	.99860	.07034	.99752	58
3	.00087	I.	.01832	.99983	.03577	.99936	.05321	.99858	.07063	.99750	57
4	.00116	I.	.01862	.99983	.03606	.99935	.05350	.99857	.07092	.99748	56
5	.00145	I.	.01891	.99982	.03635	.99934	.05379	.99855	.07121	.99746	55
6	.00175	I.	.01920	.99982	.03664	.99933	.05408	.99854	.07150	.99744	54
7	.00204	I.	.01949	.99981	.03693	.99932	.05437	.99852	.07179	.99742	53
8	.00233	I.	.01978	.99980	.03723	.99931	.05466	.99851	.07208	.99740	52
9	.00262	I.	.02007	.99980	.03752	.99930	.05495	.99849	.07237	.99738	51
10	.00291	I.	.02036	.99979	.03781	.99929	.05524	.99847	.07266	.99736	50
11	.00320	.99999	.02065	.99979	.03810	.99927	.05553	.99846	.07295	.99734	49
12	.00349	.99999	.02094	.99978	.03839	.99926	.05582	.99844	.07324	.99731	48
13	.00378	.99999	.02123	.99977	.03868	.99925	.05611	.99842	.07353	.99729	47
14	.00407	.99999	.02152	.99977	.03897	.99924	.05640	.99841	.07382	.99727	46
15	.00436	.99999	.02181	.99976	.03926	.99923	.05669	.99839	.07411	.99725	45
16	.00465	.99999	.02211	.99976	.03955	.99922	.05698	.99838	.07440	.99723	44
17	.00495	.99999	.02240	.99975	.03984	.99921	.05727	.99836	.07469	.99721	43
18	.00524	.99999	.02269	.99974	.04013	.99919	.05756	.99834	.07498	.99719	42
19	.00553	.99998	.02298	.99974	.04042	.99918	.05785	.99833	.07527	.99716	41
20	.00582	.99998	.02327	.99973	.04071	.99917	.05814	.99831	.07556	99714	40
21	.00611	.99998	.02356	.99972	.04100	.99916	.05844	.99829	.07585	.99712	39
22	.00640	.99998	.02385	.99972	.04129	.99915	.05873	.99827	.07614	.99710	38
23	.00669	.99998	.02414	.99971	.04159	.99913	.05902	.99826	.07643	.99708	37
24	.00698	.99998	.02443	.99970	.04188	.99912	.05931	.99824	.07672	.99705	36
25	.00727	.99997	.02472	.99969	.04217	.99911	.05960	.99822	.07701	.99703	35
26	.00756	.99997	.02501	.99969	.04246	.99910	.05989	.99821	.07730	.99701	34
27	.00785	.99997	.02530	.99968	.04275	.99909	.06018	.99819	.07759	.99699	33
28	.00814	.99997	.02560	.99967	.04304	.99907	.06047	99817	.07788	.99696	32
29	.00844	.99996	.02589	.99966	.04333	.99906	.06076	.99815	.07817	.99694	31
30	.00873	.99996	.02618	.99966	.04362	.99905	.06105	99813	.07846	.99692	30
31	.00902	.99996	.02647	.99965	.04391	.99904	.06134	.99812	.07875	.99689	29
32	.00931	.99996	.02676	.99964	.04420	.99902	.06163	.99810	.07904	.99687	28
33	.00960	.99995	.02705	.99963	.04449	.99901	.06192	.99808	.07933	.99685	27
34	.00989	.99995	.02734	.99963	.04478	.99900	.06221	.99806	.07962	.99683	26
35	.01018	.99995	.02763	.99962	.04507	.99898	.06250	.99804	.07991	.99680	25
36	.01047	.99995	.02792	.99961	.04536	.99897	.06279	.99803	.08020	.99678	24
37	.01076	.99994	.02821	.99960	.04565	.99896	.06308	99801	.08049	.99676	23
38	.01105	.99994	.02850	.99959	.04594	.99894	.06337	.99799	.08078	.99673	22
39	.01134	.99994	.02879	.99959	.04623	.99893	.06366	.99797	.08107	.99671	21
40	.01164	.99993	.02908	.99958	.04653	.99892	.06395	.99795	.08136	.99668	20
41	.01193	.99993	.02938	.99957	.04682	.99890	.06424	.99793	.08165	.99666	19
42	.01222	.99993	.02967	.99956	.04711	.99889	.06453	.99792	.08194	.99664	18
43	.01251	.99992	.02996	.99955	.04740	.99888	.06482	.99790	.08223	.99661	17
44	.01280	.99992	.03025	.99954	.04769	.99886	.06511	.99788	.08252	.99659	16
45	.01309	.99991	.03054	.99953	.04798	.99885	.06540	.99786	.08281	.99657	15
46	.01338	.99991	.03083	.99952	.04827	.99883	.06569	.99784	.08310	.99654	14
47	.01367	.99991	.03112	.99952	.04856	.99882	.06598	.99782	.08339	.99652	13
48	.01396	.99990	.03141	.99951	.04885	.99881	.06627	.99780	.08368	.99649	12
49	.01425	.99990	.03170	.99950	.04914	.99879	.06656	.99778	.08397	.99647	11
50	.01454	.99989	.03199	.99949	.04943	.99878	.06685	.99776	.08426	.99644	10
51	.01483	.99989	.03228	.99948	.04972	.99876	.06714	.99774	.08455	.99642	9
52	.01513	.99989	.03257	.99947	.05001	.99875	.06743	.99772	.08484	.99639	8
53	.01542	.99988	.03286	.99946	05030	.99873	.06773	.99770	.08513	.99637	7
54	.01571	.99988	.03316	.99945	.05059	.99872	.06802	.99768	.08542	.99635	6
55	.01600	.99987	.03345	.99944	.05088	.99870	.06831	.99766	.08571	.99632	5
56	.01629	.99987	.03374	.99943	.05117	.99869	.06860	.99764	.08600	.99630	4
57	.01658	.99986	.03403	.99942	.05146	.99867	.06889	.99762	.08629	.99627	3
58	.01687	.99986	.03432	.99941	.05175	.99866	.06918	.99760	.08658	.99625	2
59	.01716	.99985	.03461	.99940	.05205	.99864	.06947	.99758	.08687	.99622	1
60	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	.08716	.99619	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	
′	89°		88°		87°		86°		85°		′

′	5°		6°		7°		8°		9°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.08716	.99619	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	60
1	.08745	.99617	.10482	.99449	.12216	.99251	.13946	.99023	.15672	.98764	59
2	.08774	.99614	.10511	.99446	.12245	.99248	.13975	.99019	.15701	.98760	58
3	.08803	.99612	.10540	.99443	.12274	.99244	.14004	.99015	.15730	.98755	57
4	.08831	.99609	.10569	.99440	.12302	.99240	.14033	.99011	.15758	.98751	56
5	.08860	.99607	.10597	.99437	.12331	.99237	.14061	.99006	.15787	.98746	55
6	.08889	.99604	.10626	.99434	.12360	.99233	.14090	.99002	.15816	.98741	54
7	.08918	.99602	.10655	.99431	.12389	.99230	.14119	.98998	.15845	.98737	53
8	.08947	.99599	.10684	.99428	.12418	.99226	.14148	.98994	.15873	.98732	52
9	.08976	.99596	.10713	.99424	.12447	.99222	.14177	.98990	.15902	.98728	51
10	.09005	.99594	.10742	.99421	.12476	.99219	.14205	.98986	.15931	.98723	50
11	.09034	.99591	.10771	.99418	.12504	.99215	.14234	.98982	.15959	.98718	49
12	.09063	.99588	.10800	.99415	.12533	.99211	.14263	.98978	.15988	.98714	48
13	.09092	.99586	.10829	.99412	.12562	.99208	.14292	.98973	.16017	.98709	47
14	.09121	.99583	.10858	.99409	.12591	.99204	.14320	.98969	.16046	.98704	46
15	.09150	.99580	.10887	.99406	.12620	.99200	.14349	.98965	.16074	.98700	45
16	.09179	.99578	.10916	.99402	.12649	.99197	.14378	.98961	.16103	.98695	44
17	.09208	.99575	.10945	.99399	.12678	.99193	.14407	.98957	.16132	.98690	43
18	.09237	.99572	.10973	.99396	.12706	.99189	.14436	.98953	.16160	.98686	42
19	.09266	.99570	.11002	.99393	.12735	.99186	.14464	.98948	.16189	.98681	41
20	.09295	.99567	.11031	.99390	.12764	.99182	.14493	.98944	.16218	.98676	40
21	.09324	.99564	.11060	.99386	.12793	.99178	.14522	.98940	.16246	.98671	39
22	.09353	.99562	.11089	.99383	.12822	.99175	.14551	.98936	.16275	.98667	38
23	.09382	.99559	.11118	.99380	.12851	.99171	.14580	.98931	.16304	.98662	37
24	.09411	.99556	.11147	.99377	.12880	.99167	.14608	.98927	.16333	.98657	36
25	.09440	.99553	.11176	.99374	.12908	.99163	.14637	.98923	.16361	.98652	35
26	.09469	.99551	.11205	.99370	.12937	.99160	.14666	.98919	.16390	.98648	34
27	.09498	.99548	.11234	.99367	.12966	.99156	.14695	.98914	.16419	.98643	33
28	.09527	.99545	.11263	.99364	.12995	.99152	.14723	.98910	.16447	.98638	32
29	.09556	.99542	.11291	.99360	.13024	.99148	.14752	.98906	.16476	.98633	31
30	.09585	.99540	.11320	.99357	.13053	.99144	.14781	.98902	.16505	.98629	30
31	.09614	.99537	.11349	.99354	.13081	.99141	.14810	.98897	.16533	.98624	29
32	.09642	.99534	.11378	.99351	.13110	.99137	.14838	.98893	.16562	.98619	28
33	.09671	.99531	.11407	.99347	.13139	.99133	.14867	.98889	.16591	.98614	27
34	.09700	.99528	.11436	.99344	.13168	.99129	.14896	.98884	.16620	.98609	26
35	.09729	.99526	.11465	.99341	.13197	.99125	.14925	.98880	.16648	.98604	25
36	.09758	.99523	.11494	.99337	.13226	.99122	.14954	.98876	.16677	.98600	24
37	.09787	.99520	.11523	.99334	.13254	.99118	.14982	.98871	.16706	.98595	23
38	.09816	.99517	.11552	.99331	.13283	.99114	.15011	.98867	.16734	.98590	22
39	.09845	.99514	.11580	.99327	.13312	.99110	.15040	.98863	.16763	.98585	21
40	.09874	.99511	.11609	.99324	.13341	.99106	.15069	.98858	.16792	.98580	20
41	.09903	.99508	.11638	.99320	.13370	.99102	.15097	.98854	.16820	.98575	19
42	.09932	.99506	.11667	.99317	.13399	.99098	.15126	.98849	.16849	.98570	18
43	.09961	.99503	.11696	.99314	.13427	.99094	.15155	.98845	.16878	.98565	17
44	.09990	.99500	.11725	.99310	.13456	.99091	.15184	.98841	.16906	.98561	16
45	.10019	.99497	.11754	.99307	.13485	.99087	.15212	.98836	.16935	.98556	15
46	.10048	.99494	.11783	.99303	.13514	.99083	.15241	.98832	.16964	.98551	14
47	.10077	.99491	.11812	.99300	.13543	.99079	.15270	.98827	.16992	.98546	13
48	.10106	.99488	.11840	.99297	.13572	.99075	.15299	.98823	.17021	.98541	12
49	.10135	.99485	.11869	.99293	.13600	.99071	.15327	.98818	.17050	.98536	11
50	.10164	.99482	.11898	.99290	.13629	.99067	.15356	.98814	.17078	.98531	10
51	.10192	.99479	.11927	.99286	.13658	.99063	.15385	.98809	.17107	.98526	9
52	.10221	.99476	.11956	.99283	.13687	.99059	.15414	.98805	.17136	.98521	8
53	.10250	.99473	.11985	.99279	.13716	.99055	.15442	.98800	.17164	.98516	7
54	.10279	.99470	.12014	.99276	.13744	.99051	.15471	.98796	.17193	.98511	6
55	.10308	.99467	.12043	.99272	.13773	.99047	.15500	.98791	.17222	.98506	5
56	.10337	.99464	.12071	.99269	.13802	.99043	.15529	.98787	.17250	.98501	4
57	.10366	.99461	.12100	.99265	.13831	.99039	.15557	.98782	.17279	.98496	3
58	.10395	.99458	.12129	.99262	.13860	.99035	.15586	.98778	.17308	.98491	2
59	.10424	.99455	.12158	.99258	.13889	.99031	.15615	.98773	.17336	.98486	1
60	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	.17365	.98481	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	
′	84°		83°		82°		81°		80°		′

′	10°		11°		12°		13°		14°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.17365	.98481	.19081	.98163	.20791	.97815	.22495	.97437	.24192	.97030	60
1	.17393	.98476	.19109	.98157	.20820	.97809	.22523	.97430	.24220	.97023	59
2	.17422	.98471	.19138	.98152	.20848	.97803	.22552	.97424	.24249	.97015	58
3	.17451	.98466	.19167	.98146	.20877	.97797	.22580	.97417	.24277	.97008	57
4	.17479	.98461	.19195	.98140	.20905	.97791	.22608	.97411	.24305	.97001	56
5	.17508	.98455	.19224	.98135	.20933	.97784	.22637	.97404	.24333	.96994	55
6	.17537	.98450	.19252	.98129	.20962	.97778	.22665	.97398	.24362	.96987	54
7	.17565	.98445	.19281	.98124	.20990	.97772	.22693	.97391	.24390	.96980	53
8	.17594	.98440	.19309	.98118	.21019	.97766	.22722	.97384	.24418	.96973	52
9	.17623	.98435	.19338	.98112	.21047	.97760	.22750	.97378	.24446	.96966	51
10	.17651	.98430	.19366	.98107	.21076	.97754	.22778	.97371	.24474	.96959	50
11	.17680	.98425	.19395	.98101	.21104	.97748	.22807	.97365	.24503	.96952	49
12	.17708	.98420	.19423	.98096	.21132	.97742	.22835	.97358	.24531	.96945	48
13	.17737	.98414	.19452	.98090	.21161	.97735	.22863	.97351	.24559	.96937	47
14	.17766	.98409	.19481	.98084	.21189	.97729	.22892	.97345	.24587	.96930	46
15	.17794	.98404	.19509	.98079	.21218	.97723	.22920	.97338	.24615	.96923	45
16	.17823	.98399	.19538	.98073	.21246	.97717	.22948	.97331	.24644	.96916	44
17	.17852	.98394	.19566	.98067	.21275	.97711	.22977	.97325	.24672	.96909	43
18	.17880	.98389	.19595	.98061	.21303	.97705	.23005	.97318	.24700	.96902	42
19	.17909	.98383	.19623	.98056	.21331	.97698	.23033	.97311	.24728	.96894	41
20	.17937	.98378	.19652	.98050	.21360	.97692	.23062	.97304	.24756	.96887	40
21	.17966	.98373	.19680	.98044	.21388	.97686	.23090	.97298	.24784	.96880	39
22	.17995	.98368	.19709	.98039	.21417	.97680	.23118	.97291	.24813	.96873	38
23	.18023	.98362	.19737	.98033	.21445	.97673	.23146	.97284	.24841	.96866	37
24	.18052	.98357	.19766	.98027	.21474	.97667	.23175	.97278	.24869	.96858	36
25	.18081	.98352	.19794	.98021	.21502	.97661	.23203	.97271	.24897	.96851	35
26	.18109	.98347	.19823	.98016	.21530	.97655	.23231	.97264	.24925	.96844	34
27	.18138	.98341	.19851	.98010	.21559	.97648	.23260	.97257	.24954	.96837	33
28	.18166	.98336	.19880	.98004	.21587	.97642	.23288	.97251	.24982	.96829	32
29	.18195	.98331	.19908	.97998	.21616	.97636	.23316	.97244	.25010	.96822	31
30	.18224	.98325	.19937	.97992	.21644	.97630	.23345	.97237	.25038	.96815	30
31	.18252	.98320	.19965	.97987	.21672	.97623	.23373	.97230	.25066	.96807	29
32	.18281	.98315	.19994	.97981	.21701	.97617	.23401	.97223	.25094	.96800	28
33	.18309	.98310	.20022	.97975	.21729	.97611	.23429	.97217	.25122	.96793	27
34	.18338	.98304	.20051	.97969	.21758	.97604	.23458	.97210	.25151	.96786	26
35	.18367	.98299	.20079	.97963	.21786	.97598	.23486	.97203	.25179	.96778	25
36	.18395	.98294	.20108	.97958	.21814	.97592	.23514	.97196	.25207	.96771	24
37	.18424	.98288	.20136	.97952	.21843	.97585	.23542	.97189	.25235	.96764	23
38	.18452	.98283	.20165	.97946	.21871	.97579	.23571	.97182	.25263	.96756	22
39	.18481	.98277	.20193	.97940	.21899	.97573	.23599	.97176	.25291	.96749	21
40	.18509	.98272	.20222	.97934	.21928	.97566	.23627	.97169	.25320	.96742	20
41	.18538	.98267	.20250	.97928	.21956	.97560	.23656	.97162	.25348	.96734	19
42	.18567	.98261	.20279	.97922	.21985	.97553	.23684	.97155	.25376	.96727	18
43	.18595	.98256	.20307	.97916	.22013	.97547	.23712	.97148	.25404	.96719	17
44	.18624	.98250	.20336	.97910	.22041	.97541	.23740	.97141	.25432	.96712	16
45	.18652	.98245	.20364	.97905	.22070	.97534	.23769	.97134	.25460	.96705	15
46	.18681	.98240	.20393	.97899	.22098	.97528	.23797	.97127	.25488	.96697	14
47	.18710	.98234	.20421	.97893	.22126	.97521	.23825	.97120	.25516	.96690	13
48	.18738	.98229	.20450	.97887	.22155	.97515	.23853	.97113	.25545	.96682	12
49	.18767	.98223	.20478	.97881	.22183	.97508	.23882	.97106	.25573	.96675	11
50	.18795	.98218	.20507	.97875	.22212	.97502	.23910	.97100	.25601	.96667	10
51	.18824	.98212	.20535	.97869	.22240	.97496	.23938	.97093	.25629	.96660	9
52	.18852	.98207	.20563	.97863	.22268	.97489	.23966	.97086	.25657	.96653	8
53	.18881	.98201	.20592	.97857	.22297	.97483	.23995	.97079	.25685	.96645	7
54	.18910	.98196	.20620	.97851	.22325	.97476	.24023	.97072	.25713	.96638	6
55	.18938	.98190	.20649	.97845	.22353	.97470	.24051	.97065	.25741	.96630	5
56	.18967	.98185	.20677	.97839	.22382	.97463	.24079	.97058	.25769	.96623	4
57	.18995	.98179	.20706	.97833	.22410	.97457	.24108	.97051	.25798	.96615	3
58	.19024	.98174	.20734	.97827	.22438	.97450	.24136	.97044	.25826	.96608	2
59	.19052	.98168	.20763	.97821	.22467	.97444	.24164	.97037	.25854	.96600	1
60	.19081	.98163	.20791	.97815	.22495	.97437	.24192	.97030	.25882	.96593	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	
′	79°		78°		77°		76°		75°		′

′	15°		16°		17°		18°		19°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.25882	.96593	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	60
1	.25910	.96585	.27592	.96118	.29265	.95622	.30929	.95097	.32584	.94542	59
2	.25938	.96578	.27620	.96110	.29293	.95613	.30957	.95088	.32612	.94533	58
3	.25966	.96570	.27648	.96102	.29321	.95605	.30985	.95079	.32639	.94523	57
4	.25994	.96562	.27676	.96094	.29348	.95596	.31012	.95070	.32667	.94514	56
5	.26022	.96555	.27704	.96086	.29376	.95588	.31040	.95061	.32694	.94504	55
6	.26050	.96547	.27731	.96078	.29404	.95579	.31068	.95052	.32722	.94495	54
7	.26079	.96540	.27759	.96070	.29432	.95571	.31095	.95043	.32749	.94485	53
8	.26107	.96532	.27787	.96062	.29460	.95562	.31123	.95033	.32777	.94476	52
9	.26135	.96524	.27815	.96054	.29487	.95554	.31151	.95024	.32804	.94466	51
10	.26163	.96517	.27843	.96046	.29515	.95545	.31178	.95015	.32832	.94457	50
11	.26191	.96509	.27871	.96037	.29543	.95536	.31206	.95006	.32859	.94447	49
12	.26219	.96502	.27899	.96029	.29571	.95528	.31233	.94997	.32887	.94438	48
13	.26247	.96494	.27927	.96021	.29599	.95519	.31261	.94988	.32914	.94428	47
14	.26275	.96486	.27955	.96013	.29626	.95511	.31289	.94979	.32942	.94418	46
15	.26303	.96479	.27983	.96005	.29654	.95502	.31316	.94970	.32969	.94409	45
16	.26331	.96471	.28011	.95997	.29682	.95493	.31344	.94961	.32997	.94399	44
17	.26359	.96463	.28039	.95989	.29710	.95485	.31372	.94952	.33024	.94390	43
18	.26387	.96456	.28067	.95981	.29737	.95476	.31399	.94943	.33051	.94380	42
19	.26415	.96448	.28095	.95972	.29765	.95467	.31427	.94933	.33079	.94370	41
20	.26443	.96440	.28123	.95964	.29793	.95459	.31454	.94924	.33106	.94361	40
21	.26471	.96433	.28150	.95956	.29821	.95450	.31482	.94915	.33134	.94351	39
22	.26500	.96425	.28178	.95948	.29849	.95441	.31510	.94906	.33161	.94342	38
23	.26528	.96417	.28206	.95940	.29876	.95433	.31537	.94897	.33189	.94332	37
24	.26556	.96410	.28234	.95931	.29904	.95424	.31565	.94888	.33216	.94322	36
25	.26584	.96402	.28262	.95923	.29932	.95415	.31593	.94878	.33244	.94313	35
26	.26612	.96394	.28290	.95915	.29960	.95407	.31620	.94869	.33271	.94303	34
27	.26640	.96386	.28318	.95907	.29987	.95398	.31648	.94860	.33298	.94293	33
28	.26663	.96379	.28346	.95898	.30015	.95389	.31675	.94851	.33326	.94284	32
29	.26696	.96371	.28374	.95890	.30043	.95380	.31703	.94842	.33353	.94274	31
30	.26724	.96363	.28402	.95882	.30071	.95372	.31730	.94832	.33381	.94264	30
31	.26752	.96355	.28429	.95874	.30098	.95363	.31758	.94823	.33408	.94254	29
32	.26780	.96347	.28457	.95865	.30126	.95354	.31786	.94814	.33436	.94245	28
33	.26808	.96340	.28485	.95857	.30154	.95345	.31813	.94805	.33463	.94235	27
34	.26836	.96332	.28513	.95849	.30182	.95337	.31841	.94795	.33490	.94225	26
35	.26864	.96324	.28541	.95841	.30209	.95328	.31868	.94786	.33518	.94215	25
36	.26892	.96316	.28569	.95832	.30237	.95319	.31896	.94777	.33545	.94206	24
37	.26920	.96308	.28597	.95824	.30265	.95310	.31923	.94768	.33573	.94196	23
38	.26948	.96301	.28625	.95816	.30292	.95301	.31951	.94758	.33600	.94186	22
39	.26976	.96293	.23652	.95807	.30320	.95293	.31979	.94749	.33627	.94176	21
40	.27004	.96285	.28680	.95799	.30348	.95284	.32006	.94740	.33655	.94167	20
41	.27032	.96277	.28708	.95791	.30376	.95275	.32034	.94730	.33682	.94157	19
42	.27060	.96269	.28736	.95782	.30403	.95266	.32061	.94721	.33710	.94147	18
43	.27088	.96261	.28764	.95774	.30431	.95257	.32089	.94712	.33737	.94137	17
44	.27116	.96253	.28792	.95766	.30459	.95248	.32116	.94702	.33764	.94127	16
45	.27144	.96246	.28820	.95757	.30486	.95240	.32144	.94693	.33792	.94118	15
46	.27172	.96238	.28847	.95749	.30514	.95231	.32171	.94684	.33819	.94108	14
47	.27200	.96230	.28875	.95740	.30542	.95222	.32199	.94674	.33846	.94098	13
48	.27228	.96222	.28903	.95732	.30570	.95213	.32227	.94665	.33874	.94088	12
49	.27256	.96214	.28931	.95724	.30597	.95204	.32254	.94656	.33901	.94078	11
50	.27284	.96206	.28959	.95715	.30625	.95195	.32282	.94646	.33929	.94068	10
51	.27312	.96198	.28987	.95707	.30653	.95186	.32309	.94637	.33956	.94058	9
52	.27340	.96190	.29015	.95698	.30680	.95177	.32337	.94627	.33983	.94049	8
53	.27368	.96182	.29042	.95690	.30708	.95168	.32364	.94618	.34011	.94039	7
54	.27396	.96174	.29070	.95681	.30736	.95159	.32392	.94609	.34038	.94029	6
55	.27424	.96166	.29098	.95673	.30763	.95150	.32419	.94599	.34065	.94019	5
56	.27452	.96158	.29126	.95664	.30791	.95142	.32447	.94590	.34093	.94009	4
57	.27480	.96150	.29154	.95656	.30819	.95133	.32474	.94580	.34120	.93999	3
58	.27508	.96142	.29182	.95647	.30846	.95124	.32502	.94571	.34147	.93989	2
59	.27536	.96134	.29209	.95639	.30874	.95115	.32529	.94561	.34175	.93979	1
60	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	.34202	.93969	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	74°		73°		72°		71°		70°		

′	20°		21°		22°		23°		24°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.34202	.93969	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	60
1	.34229	.93959	.35864	.93348	.37488	.92707	.39100	.92039	.40700	.91343	59
2	.34257	.93949	.35891	.93337	.37515	.92697	.39127	.92028	.40727	.91331	58
3	.34284	.93939	.35918	.93327	.37542	.92686	.39153	.92016	.40753	.91319	57
4	.34311	.93929	.35945	.93316	.37569	.92675	.39180	.92005	.40780	.91307	56
5	.34339	.93919	.35973	.93306	.37595	.92664	.39207	.91994	.40806	.91295	55
6	.34366	.93909	.36000	.93295	.37622	.92653	.39234	.91982	.40833	.91283	54
7	.34393	.93899	.36027	.93285	.37649	.92642	.39260	.91971	.40860	.91272	53
8	.34421	.93889	.36054	.93274	.37676	.92631	.39287	.91959	.40886	.91260	52
9	.34448	.93879	.36081	.93264	.37703	.92620	.39314	.91948	.40913	.91248	51
10	.34475	.93869	.36108	.93253	.37730	.92609	.39341	.91936	.40939	.91236	50
11	.34503	.93859	.36135	.93243	.37757	.92598	.39367	.91925	.40966	.91224	49
12	.34530	.93849	.36162	.93232	.37784	.92587	.39394	.91914	.40992	.91212	48
13	.34557	.93839	.36190	.93222	.37811	.92576	.39421	.91902	.41019	.91200	47
14	.34584	.93829	.36217	.93211	.37838	.92565	.39448	.91891	.41045	.91188	46
15	.34612	.93819	.36244	.93201	.37865	.92554	.39474	.91879	.41072	.91176	45
16	.34639	.93809	.36271	.93190	.37892	.92543	.39501	.91868	.41098	.91164	44
17	.34666	.93799	.36298	.93180	.37919	.92532	.39528	.91856	.41125	.91152	43
18	.34694	.93789	.36325	.93169	.37946	.92521	.39555	.91845	.41151	.91140	42
19	.34721	.93779	.36352	.93159	.37973	.92510	.39581	.91833	.41178	.91128	41
20	.34748	.93769	.36379	.93148	.37999	.92499	.39608	.91822	.41204	.91116	40
21	.34775	.93759	.36406	.93137	.38026	.92488	.39635	.91810	.41231	.91104	39
22	.34803	.93748	.36434	.93127	.38053	.92477	.39661	.91799	.41257	.91092	38
23	.34830	.93738	.36461	.93116	.38080	.92466	.39688	.91787	.41284	.91080	37
24	.34857	.93728	.36488	.93106	.38107	.92455	.39715	.91775	.41310	.91068	36
25	.34884	.93718	.36515	.93095	.38134	.92444	.39741	.91764	.41337	.91056	35
26	.34912	.93708	.36542	.93084	.38161	.92432	.39768	.91752	.41363	.91044	34
27	.34939	.93698	.36569	.93074	.38188	.92421	.39795	.91741	.41390	.91032	33
28	.34966	.93688	.36596	.93063	.38215	.92410	.39822	.91729	.41416	.91020	32
29	.34993	.93677	.36623	.93052	.38241	.92399	.39848	.91718	.41443	.91008	31
30	.35021	.93667	.36650	.93042	.38268	.92388	.39875	.91706	.41469	.90996	30
31	.35048	.93657	.36677	.93031	.38295	.92377	.39902	.91694	.41496	.90984	29
32	.35075	.93647	.36704	.93020	.38322	.92366	.39928	.91683	.41522	.90972	28
33	.35102	.93637	.36731	.93010	.38349	.92355	.39955	.91671	.41549	.90960	27
34	.35130	.93626	.36758	.92999	.38376	.92343	.39982	.91660	.41575	.90948	26
35	.35157	.93616	.36785	.92988	.38403	.92332	.40008	.91648	.41602	.90936	25
36	.35184	.93606	.36812	.92978	.38430	.92321	.40035	.91636	.41628	.90924	24
37	.35211	.93596	.36839	.92967	.38456	.92310	.40062	.91625	.41655	.90911	23
38	.35239	.93585	.36867	.92956	.38483	.92299	.40088	.91613	.41681	.90899	22
39	.35266	.93575	.36894	.92945	.38510	.92287	.40115	.91601	.41707	.90887	21
40	.35293	.93565	.36921	.92935	.38537	.92276	.40141	.91590	.41734	.90875	20
41	.35320	.93555	.36948	.92924	.38564	.92265	.40168	.91578	.41760	.90863	19
42	.35347	.93544	.36975	.92913	.38591	.92254	.40195	.91566	.41787	.90851	18
43	.35375	.93534	.37002	.92902	.38617	.92243	.40221	.91555	.41813	.90839	17
44	.35402	.93524	.37029	.92892	.38644	.92231	.40248	.91543	.41840	.90826	16
45	.35429	.93514	.37056	.92881	.38671	.92220	.40275	.91531	.41866	.90814	15
46	.35456	.93503	.37083	.92870	.38698	.92209	.40301	.91519	.41892	.90802	14
47	.35484	.93493	.37110	.92859	.38725	.92198	.40328	.91508	.41919	.90790	13
48	.35511	.93483	.37137	.92849	.38752	.92186	.40355	.91496	.41945	.90778	12
49	.35538	.93472	.37164	.92838	.38778	.92175	.40381	.91484	.41972	.90766	11
50	.35565	.93462	.37191	.92827	.38805	.92164	.40408	.91472	.41998	.90753	10
51	.35592	.93452	.37218	.92816	.38832	.92152	.40434	.91461	.42024	.90741	9
52	.35619	.93441	.37245	.92805	.38859	.92141	.40461	.91449	.42051	.90729	8
53	.35647	.93431	.37272	.92794	.38886	.92130	.40488	.91437	.42077	.90717	7
54	.35674	.93420	.37299	.92784	.38912	.92119	.40514	.91425	.42104	.90704	6
55	.35701	.93410	.37326	.92773	.38939	.92107	.40541	.91414	.42130	.90692	5
56	.35728	.93400	.37353	.92762	.38966	.92096	.40567	.91402	.42156	.90680	4
57	.35755	.93389	.37380	.92751	.38993	.92085	.40594	.91390	.42183	.90668	3
58	.35782	.93379	.37407	.92740	.39020	.92073	.40621	.91378	.42209	.90655	2
59	.35810	.93368	.37434	.92729	.39046	.92062	.40647	.91366	.42235	.90643	1
60	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	.42262	.90631	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	69°		68°		67°		66°		65°		

′	25°		26°		27°		28°		29°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.42262	.90631	.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	60
1	.42288	.90618	.43863	.89867	.45425	.89087	.46973	.88281	.48506	.87448	59
2	.42315	.90606	.43889	.89854	.45451	.89074	.46999	.88267	.48532	.87434	58
3	.42341	.90594	.43916	.89841	.45477	.89061	.47024	.88254	.48557	.87420	57
4	.42367	.90582	.43942	.89828	.45503	.89048	.47050	.88240	.48583	.87406	56
5	.42394	.90569	.43968	.89816	.45529	.89035	.47076	.88226	.48608	.87391	55
6	.42420	.90557	.43994	.89803	.45554	.89021	.47101	.88213	.48634	.87377	54
7	.42446	.90545	.44020	.89790	.45580	.89008	.47127	.88199	.48659	.87363	53
8	.42473	.90532	.44046	.89777	.45606	.88995	.47153	.88185	.48684	.87349	52
9	.42499	.90520	.44072	.89764	.45632	.88981	.47178	.88172	.48710	.87335	51
10	.42525	.90507	.44098	.89752	.45658	.88968	.47204	.88158	.48735	.87321	50
11	.42552	.90495	.44124	.89739	.45684	.88955	.47229	.88144	.48761	.87306	49
12	.42578	.90483	.44151	.89726	.45710	.88942	.47255	.88130	.48786	.87292	48
13	.42604	.90470	.44177	.89713	.45736	.88928	.47281	.88117	.48811	.87278	47
14	.42631	.90458	.44203	.89700	.45762	.88915	.47306	.88103	.48837	.87264	46
15	.42657	.90446	.44229	.89687	.45787	.88902	.47332	.88089	.48862	.87250	45
16	.42683	.90433	.44255	.89674	.45813	.88888	.47358	.88075	.48888	.87235	44
17	.42709	.90421	.44281	.89662	.45839	.88875	.47383	.88062	.48913	.87221	43
18	.42736	.90408	.44307	.89649	.45865	.88862	.47409	.88048	.48938	.87207	42
19	.42762	.90396	.44333	.89636	.45891	.88848	.47434	.88034	.48964	.87193	41
20	.42788	.90383	.44359	.89623	.45917	.88835	.47460	.88020	.48989	.87178	40
21	.42815	.90371	.44385	.89610	.45942	.88822	.47486	.88006	.49014	.87164	39
22	.42841	.90358	.44411	.89597	.45968	.88808	.47511	.87993	.49040	.87150	38
23	.42867	.90346	.44437	.89584	.45994	.88795	.47537	.87979	.49065	.87136	37
24	.42894	.90334	.44464	.89571	.46020	.88782	.47562	.87965	.49090	.87121	36
25	.42920	.90321	.44490	.89558	.46046	.88768	.47588	.87951	.49116	.87107	35
26	.42946	.90309	.44516	.89545	.46072	.88755	.47614	.87937	.49141	.87093	34
27	.42972	.90296	.44542	.89532	.46097	.88741	.47639	.87923	.49166	.87079	33
28	.42999	.90284	.44568	.89519	.46123	.88728	.47665	.87909	.49192	.87064	32
29	.43025	.90271	.44594	.89506	.46149	.88715	.47690	.87896	.49217	.87050	31
30	.43051	.90259	.44620	.89493	.46175	.88701	.47716	.87882	.49242	.87036	30
31	.43077	.90246	.44646	.89480	.46201	.88688	.47741	.87868	.49268	.87021	29
32	.43104	.90233	.44672	.89467	.46226	.88674	.47767	.87854	.49293	.87007	28
33	.43130	.90221	.44698	.89454	.46252	.88661	.47793	.87840	.49318	.86993	27
34	.43156	.90208	.44724	.89441	.46278	.88647	.47818	.87826	.49344	.86978	26
35	.43182	.90196	.44750	.89428	.46304	.88634	.47844	.87812	.49369	.86964	25
36	.43209	.90183	.44776	.89415	.46330	.88620	.47869	.87798	.49394	.86949	24
37	.43235	.90171	.44802	.89402	.46355	.88607	.47895	.87784	.49419	.86935	23
38	.43261	.90158	.44828	.89389	.46381	.88593	.47920	.87770	.49445	.86921	22
39	.43287	.90146	.44854	.89376	.46407	.88580	.47946	.87756	.49470	.86906	21
40	.43313	.90133	.44880	.89363	.46433	.88566	.47971	.87743	.49495	.86892	20
41	.43340	.90120	.44906	.89350	.46458	.88553	.47997	.87729	.49521	.86878	19
42	.43366	.90108	.44932	.89337	.46484	.88539	.48022	.87715	.49546	.86863	18
43	.43392	.90095	.44958	.89324	.46510	.88526	.48048	.87701	.49571	.86849	17
44	.43418	.90082	.44984	.89311	.46536	.88512	.48073	.87687	.49596	.86834	16
45	.43445	.90070	.45010	.89298	.46561	.88499	.48099	.87673	.49622	.86820	15
46	.43471	.90057	.45036	.89285	.46587	.88485	.48124	.87659	.49647	.86805	14
47	.43497	.90045	.45062	.89272	.46613	.88472	.48150	.87645	.49672	.86791	13
48	.43523	.90032	.45088	.89259	.46639	.88458	.48175	.87631	.49697	.86777	12
49	.43549	.90019	.45114	.89245	.46664	.88445	.48201	.87617	.49723	.86762	11
50	.43575	.90007	.45140	.89232	.46690	.88431	.48226	.87603	.49748	.86748	10
51	.43602	.89994	.45166	.89219	.46716	.88417	.48252	.87589	.49773	.86733	9
52	.43628	.89981	.45192	.89206	.46742	.88404	.48277	.87575	.49798	.86719	8
53	.43654	.89968	.45218	.89193	.46767	.88390	.48303	.87561	.49824	.86704	7
54	.43680	.89956	.45243	.89180	.46793	.88377	.48328	.87546	.49849	.86690	6
55	.43706	.89943	.45269	.89167	.46819	.88363	.48354	.87532	.49874	.86675	5
56	.43733	.89930	.45295	.89153	.46844	.88349	.48379	.87518	.49899	.86661	4
57	.43759	.89918	.45321	.89140	.46870	.88336	.48405	.87504	.49924	.86646	3
58	.43785	.89905	.45347	.89127	.46896	.88322	.48430	.87490	.49950	.86632	2
59	.43811	.89892	.45373	.89114	.46921	.88308	.48456	.87476	.49975	.86617	1
60	.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	.50000	.86603	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	
′	64°		63°		62°		61°		60°		′

′	30°		31°		32°		33°		34°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.50000	.86603	.51504	.85717	.52992	.84805	.54464	.83867	.55919	.82904	60
1	.50025	.86588	.51529	.85702	.53017	.84789	.54488	.83851	.55943	.82887	59
2	.50050	.86573	.51554	.85687	.53041	.84774	.54513	.83835	.55968	.82871	58
3	.50076	.86559	.51579	.85672	.53066	.84759	.54537	.83819	.55992	.82855	57
4	.50101	.86544	.51604	.85657	.53091	.84743	.54561	.83804	.56016	.82839	56
5	.50126	.86530	.51628	.85642	.53115	.84728	.54586	.83788	.56040	.82822	55
6	.50151	.86515	.51653	.85627	.53140	.84712	.54610	.83772	.56064	.82806	54
7	.50176	.86501	.51678	.85612	.53164	.84697	.54635	.83756	.56088	.82790	53
8	.50201	.86486	.51703	.85597	.53189	.84681	.54659	.83740	.56112	.82773	52
9	.50227	.86471	.51728	.85582	.53214	.84666	.54683	.83724	.56136	.82757	51
10	.50252	.86457	.51753	.85567	.53238	.84650	.54708	.83708	.56160	.82741	50
11	.50277	.86442	.51778	.85551	.53263	.84635	.54732	.83692	.56184	.82724	49
12	.50302	.86427	.51803	.85536	.53288	.84619	.54756	.83676	.56208	.82708	48
13	.50327	.86413	.51828	.85521	.53312	.84604	.54781	.83660	.56232	.82692	47
14	.50352	.86398	.51852	.85506	.53337	.84588	.54805	.83645	.56256	.82675	46
15	.50377	.86384	.51877	.85491	.53361	.84573	.54829	.83629	.56280	.82659	45
16	.50403	.86369	.51902	.85476	.53386	.84557	.54854	.83613	.56305	.82643	44
17	.50428	.86354	.51927	.85461	.53411	.84542	.54878	.83597	.56329	.82626	43
18	.50453	.86340	.51952	.85446	.53435	.84526	.54902	.83581	.56353	.82610	42
19	.50478	.86325	.51977	.85431	.53460	.84511	.54927	.83565	.56377	.82593	41
20	.50503	.86310	.52002	.85416	.53484	.84495	.54951	.83549	.56401	.82577	40
21	.50528	.86295	.52026	.85401	.53509	.84480	.54975	.83533	.56425	.82561	39
22	.50553	.86281	.52051	.85385	.53534	.84464	.54999	.83517	.56449	.82544	38
23	.50578	.86266	.52076	.85370	.53558	.84448	.55024	.83501	.56473	.82528	37
24	.50603	.86251	.52101	.85355	.53583	.84433	.55048	.83485	.56497	.82511	36
25	.50628	.86237	.52126	.85340	.53607	.84417	.55072	.83469	.56521	.82495	35
26	.50654	.86222	.52151	.85325	.53632	.84402	.55097	.83453	.56545	.82478	34
27	.50679	.86207	.52175	.85310	.53656	.84386	.55121	.83437	.56569	.82462	33
28	.50704	.86192	.52200	.85294	.53681	.84370	.55145	.83421	.56593	.82446	32
29	.50729	.86178	.52225	.85279	.53705	.84355	.55169	.83405	.56617	.82429	31
30	.50754	.86163	.52250	.85264	.53730	.84339	.55194	.83389	.56641	.82413	30
31	.50779	.86148	.52275	.85249	.53754	.84324	.55218	.83373	.56665	.82396	29
32	.50804	.86133	.52299	.85234	.53779	.84308	.55242	.83356	.56689	.82380	28
33	.50829	.86119	.52324	.85218	.53804	.84292	.55266	.83340	.56713	.82363	27
34	.50854	.86104	.52349	.85203	.53828	.84277	.55291	.83324	.56736	.82347	26
35	.50879	.86089	.52374	.85188	.53853	.84261	.55315	.83308	.56760	.82330	25
36	.50904	.86074	.52399	.85173	.53877	.84245	.55339	.83292	.56784	.82314	24
37	.50929	.86059	.52423	.85157	.53902	.84230	.55363	.83276	.56808	.82297	23
38	.50954	.86045	.52448	.85142	.53926	.84214	.55388	.83260	.56832	.82281	22
39	.50979	.86030	.52473	.85127	.53951	.84198	.55412	.83244	.56856	.82264	21
40	.51004	.86015	.52498	.85112	.53975	.84182	.55436	.83228	.56880	.82248	20
41	.51029	.86000	.52522	.85096	.54000	.84167	.55460	.83212	.56904	.82231	19
42	.51054	.85985	.52547	.85081	.54024	.84151	.55484	.83195	.56928	.82214	18
43	.51079	.85970	.52572	.85066	.54049	.84135	.55509	.83179	.56952	.82198	17
44	.51104	.85956	.52597	.85051	.54073	.84120	.55533	.83163	.56976	.82181	16
45	.51129	.85941	.52621	.85035	.54097	.84104	.55557	.83147	.57000	.82165	15
46	.51154	.85926	.52646	.85020	.54122	.84088	.55581	.83131	.57024	.82148	14
47	.51179	.85911	.52671	.85005	.54146	.84072	.55605	.83115	.57047	.82132	13
48	.51204	.85896	.52696	.84989	.54171	.84057	.55630	.83098	.57071	.82115	12
49	.51229	.85881	.52720	.84974	.54195	.84041	.55654	.83082	.57095	.82098	11
50	.51254	.85866	.52745	.84959	.54220	.84025	.55678	.83066	.57119	.82082	10
51	.51279	.85851	.52770	.84943	.54244	.84009	.55702	.83050	.57143	.82065	9
52	.51304	.85836	.52794	.84928	.54269	.83994	.55726	.83034	.57167	.82048	8
53	.51329	.85821	.52819	.84913	.54293	.83978	.55750	.83017	.57191	.82032	7
54	.51354	.85806	.52844	.84897	.54317	.83962	.55775	.83001	.57215	.82015	6
55	.51379	.85792	.52869	.84882	.54342	.83946	.55799	.82985	.57238	.81999	5
56	.51404	.85777	.52893	.84866	.54366	.83930	.55823	.82969	.57262	.81982	4
57	.51429	.85762	.52918	.84851	.54391	.83915	.55847	.82953	.57286	.81965	3
58	.51454	.85747	.52943	.84836	.54415	.83899	.55871	.82936	.57310	.81949	2
59	.51479	.85732	.52967	.84820	.54440	.83883	.55895	.82920	.57334	.81932	1
60	.51504	.85717	.52992	.84805	.54464	.83867	.55919	.82904	.57358	.81915	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	
′	59°		58°		57°		56°		55°		′

′	35°		36°		37°		38°		39°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.57358	.81915	.58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	60
1	.57381	.81899	.58802	.80885	.60205	.79846	.61589	.78783	.62955	.77696	59
2	.57405	.81882	.58826	.80867	.60228	.79829	.61612	.78765	.62977	.77678	58
3	.57429	.81865	.58849	.80850	.60251	.79811	.61635	.78747	.63000	.77660	57
4	.57453	.81848	.58873	.80833	.60274	.79793	.61658	.78729	.63022	.77641	56
5	.57477	.81832	.58896	.80816	.60298	.79776	.61681	.78711	.63045	.77623	55
6	.57501	.81815	.58920	.80799	.60321	.79758	.61704	.78694	.63068	.77605	54
7	.57524	.81798	.58943	.80782	.60344	.79741	.61726	.78676	.63090	.77586	53
8	.57548	.81782	.58967	.80765	.60367	.79723	.61749	.78658	.63113	.77568	52
9	.57572	.81765	.58990	.80748	.60390	.79706	.61772	.78640	.63135	.77550	51
10	.57596	.81748	.59014	.80730	.60414	.79688	.61795	.78622	.63158	.77531	50
11	.57619	.81731	.59037	.80713	.60437	.79671	.61818	.78604	.63180	.77513	49
12	.57643	.81714	.59061	.80696	.60460	.79653	.61841	.78586	.63203	.77494	48
13	.57667	.81698	.59084	.80679	.60483	.79635	.61864	.78568	.63225	.77476	47
14	.57691	.81681	.59108	.80662	.60506	.79618	.61887	.78550	.63248	.77458	46
15	.57715	.81664	.59131	.80644	.60529	.79600	.61909	.78532	.63271	.77439	45
16	.57738	.81647	.59154	.80627	.60553	.79583	.61932	.78514	.63293	.77421	44
17	.57762	.81631	.59178	.80610	.60576	.79565	.61955	.78496	.63316	.77402	43
18	.57786	.81614	.59201	.80593	.60599	.79547	.61978	.78478	.63338	.77384	42
19	.57810	.81597	.59225	.80576	.60622	.79530	.62001	.78460	.63361	.77366	41
20	.57833	.81580	.59248	.80558	.60645	.79512	.62024	.78442	.63383	.77347	40
21	.57857	.81563	.59272	.80541	.60668	.79494	.62046	.78424	.63406	.77329	39
22	.57881	.81546	.59295	.80524	.60691	.79477	.62069	.78405	.63428	.77310	38
23	.57904	.81530	.59318	.80507	.60714	.79459	.62092	.78387	.63451	.77292	37
24	.57928	.81513	.59342	.80489	.60738	.79441	.62115	.78369	.63473	.77273	36
25	.57952	.81496	.59365	.80472	.60761	.79424	.62138	.78351	.63496	.77255	35
26	.57976	.81479	.59389	.80455	.60784	.79406	.62160	.78333	.63518	.77236	34
27	.57999	.81462	.59412	.80438	.60807	.79388	.62183	.78315	.63540	.77218	33
28	.58023	.81445	.59436	.80420	.60830	.79371	.62206	.78297	.63563	.77199	32
29	.58047	.81428	.59459	.80403	.60853	.79353	.62229	.78279	.63585	.77181	31
30	.58070	.81412	.59482	.80386	.60876	.79335	.62251	.78261	.63608	.77162	30
31	.58094	.81395	.59506	.80368	.60899	.79318	.62274	.78243	.63630	.77144	29
32	.58118	.81378	.59529	.80351	.60922	.79300	.62297	.78225	.63653	.77125	28
33	.58141	.81361	.59552	.80334	.60945	.79282	.62320	.78206	.63675	.77107	27
34	.58165	.81344	.59576	.80316	.60968	.79264	.62342	.78188	.63698	.77088	26
35	.58189	.81327	.59599	.80299	.60991	.79247	.62365	.78170	.63720	.77070	25
36	.58212	.81310	.59622	.80282	.61015	.79229	.62388	.78152	.63742	.77051	24
37	.58236	.81293	.59646	.80264	.61038	.79211	.62411	.78134	.63765	.77033	23
38	.58260	.81276	.59669	.80247	.61061	.79193	.62433	.78116	.63787	.77014	22
39	.58283	.81259	.59693	.80230	.61084	.79176	.62456	.78098	.63810	.76996	21
40	.58307	.81242	.59716	.80212	.61107	.79158	.62479	.78079	.63832	.76977	20
41	.58330	.81225	.59739	.80195	.61130	.79140	.62502	.78061	.63854	.76959	19
42	.58354	.81208	.59763	.80178	.61153	.79122	.62524	.78043	.63877	.76940	18
43	.58378	.81191	.59786	.80160	.61176	.79105	.62547	.78025	.63899	.76921	17
44	.58401	.81174	.59809	.80143	.61199	.79087	.62570	.78007	.63922	.76903	16
45	.58425	.81157	.59832	.80125	.61222	.79069	.62592	.77988	.63944	.76884	15
46	.58449	.81140	.59856	.80108	.61245	.79051	.62615	.77970	.63966	.76866	14
47	.58472	.81123	.59879	.80091	.61268	.79033	.62638	.77952	.63989	.76847	13
48	.58496	.81106	.59902	.80073	.61291	.79016	.62660	.77934	.64011	.76828	12
49	.58519	.81089	.59926	.80056	.61314	.78998	.62683	.77916	.64033	.76810	11
50	.58543	.81072	.59949	.80038	.61337	.78980	.62706	.77897	.64056	.76791	10
51	.58567	.81055	.59972	.80021	.61360	.78962	.62728	.77879	.64078	.76772	9
52	.58590	.81038	.59995	.80003	.61383	.78944	.62751	.77861	.64100	.76754	8
53	.58614	.81021	.60019	.79986	.61406	.78926	.62774	.77843	.64123	.76735	7
54	.58637	.81004	.60042	.79968	.61429	.78908	.62796	.77824	.64145	.76717	6
55	.58661	.80987	.60065	.79951	.61451	.78891	.62819	.77806	.64167	.76698	5
56	.58684	.80970	.60089	.79934	.61474	.78873	.62842	.77788	.64190	.76679	4
57	.58708	.80953	.60112	.79916	.61497	.78855	.62864	.77769	.64212	.76661	3
58	.58731	.80936	.60135	.79899	.61520	.78837	.62887	.77751	.64234	.76642	2
59	.58755	.80919	.60158	.79881	.61543	.78819	.62909	.77733	.64256	.76623	1
60	.58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	.64279	.76604	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	54°		53°		52°		51°		50°		

′	40°		41°		42°		43°		44°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.64279	.76604	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	60
1	.64301	.76586	.65628	.75452	.66935	.74295	.68221	.73116	.69487	.71914	59
2	.64323	.76567	.65650	.75433	.66956	.74276	.68242	.73096	.69508	.71894	58
3	.64346	.76548	.65672	.75414	.66978	.74256	.68264	.73076	.69529	.71873	57
4	.64368	.76530	.65694	.75395	.66999	.74237	.68285	.73056	.69549	.71853	56
5	.64390	.76511	.65716	.75375	.67021	.74217	.68306	.73036	.69570	.71833	55
6	.64412	.76492	.65738	.75356	.67043	.74198	.68327	.73016	.69591	.71813	54
7	.64435	.76473	.65759	.75337	.67064	.74178	.68349	.72996	.69612	.71792	53
8	.64457	.76455	.65781	.75318	.67086	.74159	.68370	.72976	.69633	.71772	52
9	.64479	.76436	.65803	.75299	.67107	.74139	.68391	.72957	.69654	.71752	51
10	.64501	.76417	.65825	.75280	.67129	.74120	.68412	.72937	.69675	.71732	50
11	.64524	.76398	.65847	.75261	.67151	.74100	.68434	.72917	.69696	.71711	49
12	64546	.76380	.65869	.75241	.67172	.74080	.68455	.72897	.69717	.71691	48
13	.64568	.76361	.65891	.75222	.67194	.74061	.68476	.72877	.69737	.71671	47
14	.64590	.76342	.65913	.75203	.67215	.74041	.68497	.72857	.69758	.71650	46
15	.64612	.76323	.65935	.75184	.67237	.74022	.68518	.72837	.69779	.71630	45
16	.64635	.76304	.65956	.75165	.67258	.74002	.68539	.72817	.69800	.71610	44
17	.64657	.76286	.65978	.75146	.67280	.73983	.68561	.72797	.69821	.71590	43
18	.64679	.76267	.66000	.75126	.67301	.73963	.68582	.72777	.69842	.71569	42
19	.64701	.76248	.66022	.75107	.67323	.73944	.68603	.72757	.69862	.71549	41
20	.64723	.76229	.66044	.75088	.67344	.73924	.68624	.72737	.69883	.71529	40
21	.64746	.76210	.66066	.75069	.67366	.73904	.68645	.72717	.69904	.71508	39
22	.64768	.76192	.66088	.75050	.67387	.73885	.68666	.72697	.69925	.71488	38
23	.64790	.76173	.66109	.75030	.67409	.73865	.68688	.72677	.69946	.71468	37
24	.64812	.76154	.66131	.75011	.67430	.73846	.68709	.72657	.69966	.71447	36
25	.64834	.76135	.66153	.74992	.67452	.73826	.68730	.72637	.69987	.71427	35
26	.64856	.76116	.66175	.74973	.674[illegible]3	.73806	.68751	.72617	.70008	.71407	34
27	.64878	.76097	.66197	.74953	.67495	.73787	.68772	.72597	.70029	.71386	33
28	.64901	.76078	.66218	.74934	.67516	.73767	.68793	.72577	.70049	.71366	32
29	.64923	.76059	.66240	.74915	.67538	.73747	.68814	.72557	.70070	.71345	31
30	.64945	.76041	.66262	.74896	.67559	.73728	.68835	.72537	.70091	.71325	30
31	.64967	.76022	.66284	.74876	.67580	.73708	.68857	.72517	.70112	.71305	29
32	.64989	.76003	.66306	.74857	.67602	.73688	.68878	.72497	.70132	.71284	28
33	.65011	.75984	.66327	.74838	.67623	.73669	.68899	.72477	.70153	.71264	27
34	.650[illegible]3	.75965	.66349	.74818	.67645	.73649	.68920	.72457	.70174	.71243	26
35	.65055	.75946	.66371	.74799	.67666	.73629	.68941	.72437	.70195	.71223	25
36	.65077	.75927	.66393	.74780	.67688	.73610	.68962	.72417	.70215	.71203	24
37	.65100	.75908	.66414	.74760	.67709	.73590	.68983	.72397	.70236	.71182	23
38	.65122	.75889	.66436	.74741	.67730	.73570	.69004	.72377	.70257	.71162	22
39	.65144	.75870	.66458	.74722	.67752	.73551	.69025	.72357	.70277	.71141	21
40	.65166	.75851	.66480	.74703	.67773	.73531	.69046	.72337	.70298	.71121	20
41	.65188	.75832	.66501	.74683	.67795	.73511	.69067	.72317	.70319	.71100	19
42	.65210	.75813	.66523	.74664	.67816	.73491	.69088	.72297	.70339	.71080	18
43	.65232	.75794	.66545	.74644	.67837	.73472	.69109	.72277	.70360	.71059	17
44	.65254	.75775	.66566	.74625	.67859	.73452	.69130	.72257	.70381	.71039	16
45	.65276	.75756	.66588	.74606	.67880	.73432	.69151	.72236	.70401	.71019	15
46	.65298	.75738	66610	.74586	.67901	.73413	.69172	.72216	.70422	.70998	14
47	.65320	.75719	.66632	.74567	.67923	.73393	.69193	.72196	.70443	.70978	13
48	.65342	.75700	.66653	.74548	.67944	.73373	.69214	.72176	.70463	.70957	12
49	.65364	.75680	.66675	.74528	.67965	.73353	.69235	.72156	.70484	.70937	11
50	.65386	.75661	.66697	.74509	.67987	.73333	.69256	.72136	.70505	.70916	10
51	.65408	.75642	.66718	.74489	.68008	.73314	.69277	.72116	.70525	.70896	9
52	.65430	.75623	.66740	.74470	.68029	.73294	.69298	.72095	.70546	.70875	8
53	.65452	.75604	.66762	.74451	.68051	.73274	.69319	.72075	.70567	.70855	7
54	.65474	.75585	.66783	.74431	.68072	.73254	.69340	.72055	.70587	.70834	6
55	.65496	.75566	.66805	.74412	.68093	.73234	.69361	.72035	.70608	.70813	5
56	.65518	.75547	.66827	.74392	.68115	.73215	.69382	.72015	.70628	.70793	4
57	.65540	.75528	.66848	.74373	.68136	.73195	.69403	.71995	.70649	.70772	3
58	.65562	.75509	.66870	.74353	.68157	.73175	.69424	.71974	.70670	.70752	2
59	.65584	.75490	.66891	.74334	.68179	.73155	.69445	.71954	.70690	.70731	1
60	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	.70711	.70711	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	49°		48°		47°		46°		45°		

TABLE OF NATURAL TANGENTS AND CO-TANGENTS

′	0°		1°		2°		3°		4°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.00000	Infinite	.01746	57.2900	.03492	28.6363	.05241	19.0811	.06993	14.3007	60
1	.00029	3437.75	.01775	56.3506	.03521	28.3994	.05270	18.9755	.07022	14.2411	59
2	.00058	1718.87	.01804	55.4415	.03550	28.1664	.05299	18.8711	.07051	14.1821	58
3	.00087	1145.92	.01833	54.5613	.03579	27.9372	.05328	13.7678	.07080	14.1235	57
4	.00116	859.436	.01862	53.7086	.03609	27.7117	.05357	18.6656	.07110	14.0655	56
5	.00145	687.549	.01891	52.8821	.03638	27.4899	.05387	18.5645	.07139	14.0079	55
6	.00175	572.957	.01920	52.0807	.03667	27.2715	.05416	18.4645	.07168	13.9507	54
7	.00204	491.106	.01949	51.3032	.03696	27.0566	.05445	18.3655	.07197	13.8940	53
8	.00233	429.718	.01978	50.5485	.03725	26.8450	.05474	18.2677	.07227	13.8378	52
9	.00262	381.971	.02007	49.8157	.03754	26.6367	.05503	18.1708	.07256	13.7821	51
10	.00291	343.774	.02036	49.1039	.03783	26.4316	.05533	18.0750	.07285	13.7267	50
11	.00320	312.521	.02066	48.4121	.03812	26.2296	.05562	17.9802	.07314	13.6719	49
12	.00349	286.478	.02095	47.7395	.03842	26.0307	.05591	17.8863	.07344	13.6174	48
13	.00378	264.441	.02124	47.0853	.03871	25.8348	.05620	17.7934	.07373	13.5634	47
14	.00407	245.552	.02153	46.4489	.03900	25.6418	.05649	17.7015	.07402	13.5098	46
15	.00436	229.182	.02182	45.8294	.03929	25.4517	.05678	17.6106	.07431	13.4566	45
16	.00465	214.858	.02211	45.2261	.03958	25.2644	.05708	17.5205	.07461	13.4039	44
17	.00495	202.219	.02240	44.6386	.03987	25.0798	.05737	17.4314	.07490	13.3515	43
18	.00524	190.984	.02269	44.0661	.04016	24.8978	.05766	17.3432	.07519	13.2996	42
19	.00553	180.932	.02298	43.5081	.04046	24.7185	.05795	17.2558	.07548	13.2480	41
20	.00582	171.885	.02328	42.9641	.04075	24.5418	.05824	17.1693	.07578	13.1969	40
21	.00611	163.700	.02357	42.4335	.04104	24.3675	.05854	17.0837	.07607	13.1461	39
22	.00640	156.259	.02386	41.9158	.04133	24.1957	.05883	16.9990	.07636	13.0958	38
23	.00669	149.465	.02415	41.4106	.04162	24.0263	.05912	16.9150	.07665	13.0458	37
24	.00698	143.237	.02444	40.9174	.04191	23.8593	.05941	16.8319	.07695	12.9962	36
25	.00727	137.507	.02473	40.4358	.04220	23.6945	.05970	16.7496	.07724	12.9469	35
26	.00756	132.219	.02502	39.9655	.04250	23.5321	.05999	16.6681	.07753	12.8981	34
27	.00785	127.321	.02531	39.5059	.04279	23.3718	.06029	16.5874	.07782	12.8496	33
28	.00815	122.774	.02560	39.0568	.04308	23.2137	.06058	16.5075	.07812	12.8014	32
29	.00844	118.540	.02589	38.6177	.04337	23.0577	.06087	16.4283	.07841	12.7536	31
30	.00873	114.589	.02619	38.1885	.04366	22.9038	.06116	16.3499	.07870	12.7062	30
31	.00902	110.892	.02648	37.7686	.04395	22.7519	.06145	16.2722	.07899	12.6591	29
32	.00931	107.426	.02677	37.3579	.04424	22.6020	.06175	16.1952	.07929	12.6124	28
33	.00960	104.171	.02706	36.9560	.04454	22.4541	.06204	16.1190	.07958	12.5660	27
34	.00989	101.107	.02735	36.5627	.04483	22.3081	.06233	16.0435	.07987	12.5199	26
35	.01018	98.2179	.02764	36.1776	.04512	22.1640	.06262	15.9687	.08017	12.4742	25
36	.01047	95.4895	.02793	35.8006	.04541	22.0217	.06291	15.8945	.08046	12.4288	24
37	.01076	92.9085	.02822	35.4313	.04570	21.8813	.06321	15.8211	.08075	12.3838	23
38	.01105	90.4633	.02851	35.0695	.04599	21.7426	.06350	15.7483	.08104	12.3390	22
39	.01135	88.1436	.02881	34.7151	.04628	21.6056	.06379	15.6762	.08134	12.2946	21
40	.01164	85.9398	.02910	34.3678	.04658	21.4704	.06408	15.6048	.08163	12.2595	20
41	.01193	83.8435	.02939	34.0273	.04687	21.3369	.06437	15.5340	.08192	12.2067	19
42	.01222	81.8470	.02968	33.6935	.04716	21.2049	.06467	15.4638	.08221	12.1632	18
43	.01251	79.9434	.02997	33.3662	.04745	21.0747	.06496	15.3943	.08251	12.1201	17
44	.01280	78.1263	.03026	33.0452	.04774	20.9460	.06525	15.3254	.08280	12.0772	16
45	.01309	76.3900	.03055	32.7303	.04803	20.8188	.06554	15.2571	.08309	12.0346	15
46	.01338	74.7292	.03084	32.4213	.04833	20.6932	.06584	15.1893	.08339	11.9923	14
47	.01367	73.1390	.03114	32.1181	.04862	20.5691	.06613	15.1222	.08368	11.9504	13
48	.01396	71.6151	.03143	31.8205	.04891	20.4465	.06642	15.0557	.08397	11.9087	12
49	.01425	70.1533	.03172	31.5284	.04920	20.3253	.06671	14.9898	.08427	11.8673	11
50	.01455	68.7501	.03201	31.2416	.04949	20.2056	.06700	14.9244	.08456	11.8262	10
51	.01484	67.4019	.03230	30.9599	.04978	20.0872	.06730	14.8596	.08485	11.7853	9
52	.01513	66.1055	.03259	30.6833	.05007	19.9702	.06759	14.7954	.08514	11.7448	8
53	.01542	64.8580	.03288	30.4116	.05037	19.8546	.06788	14.7317	.08544	11.7045	7
54	.01571	63.6567	.03317	30.1446	.05066	19.7403	.06817	14.6685	.08573	11.6645	6
55	.01600	62.4992	.03346	29.8823	.05095	19.6273	.06847	14.6059	.08602	11.6248	5
56	.01629	61.3829	.03376	29.6245	.05124	19.5156	.06876	14.5438	.08632	11.5853	4
57	.01658	60.3058	.03405	29.3711	.05153	19.4051	.06905	14.4823	.08661	11.5461	3
58	.01687	59.2659	.03434	29.1220	.05182	19.2959	.06934	14.4212	.08690	11.5072	2
59	.01716	58.2612	.03463	28.8771	.05212	19.1879	.06963	14.3607	.08720	11.4685	1
60	.01746	57.2900	.03492	28.6363	.05241	19.0811	.06993	14.3007	.08749	11.4301	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	89°		88°		87°		86°		85°		

′	5°		6°		7°		8°		9°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.08749	11.4301	.10510	9.51436	.12278	8.14435	.14054	7.11537	.15838	6.31375	60
1	.08778	11.3919	.10540	9.48781	.12308	8.12481	.14084	7.10038	.15868	6.30189	59
2	.08807	11.3540	.10569	9.46141	.12338	8.10536	.14113	7.08546	.15898	6.29007	58
3	.08837	11.3163	.10599	9.43515	.12367	8.08600	.14143	7.07059	.15928	6.27829	57
4	.08866	11.2789	.10628	9.40904	.12397	8.06674	.14173	7.05579	.15958	6.26655	56
5	.08895	11.2417	.10657	9.38307	.12426	8.04756	.14202	7.04105	.15988	6.25486	55
6	.08925	11.2048	.10687	9.35724	.12456	8.02848	.14232	7.02637	.16017	6.24321	54
7	.08954	11.1681	.10716	9.33155	.12485	8.00948	.14262	7.01174	.16047	6.23160	53
8	.08983	11.1316	.10746	9.30599	.12515	7.99058	.14291	6.99718	.16077	6.22003	52
9	.09013	11.0954	.10775	9.28058	.12544	7.97176	.14321	6.98268	.16107	6.20851	51
10	.09042	11.0594	.10805	9.25530	.12574	7.95302	.14351	6.96823	.16137	6.19703	50
11	.09071	11.0237	.10834	9.23016	.12603	7.93438	.14381	6.95385	.16167	6.18559	49
12	.09101	10.9882	.10863	9.20516	.12633	7.91582	.14410	6.93952	.16196	6.17419	48
13	.09130	10.9529	.10893	9.18028	.12662	7.89734	.14440	6.92525	.16226	6.16283	47
14	.09159	10.9178	.10922	9.15554	.12692	7.87895	.14470	6.91104	.16256	6.15151	46
15	.09189	10.8829	.10952	9.13093	.12722	7.86064	.14499	6.89688	.16286	6.14023	45
16	.09218	10.8483	.10981	9.10646	.12751	7.84242	.14529	6.88278	.16316	6.12899	44
17	.09247	10.8139	.11011	9.08211	.12781	7.82428	.14559	6.86874	.16346	6.11779	43
18	.09277	10.7797	.11040	9.05789	.12810	7.80622	.14588	6.85475	.16376	6.10664	42
19	.09306	10.7457	.11070	9.03379	.12840	7.78825	.14618	6.84082	.16405	6.09552	41
20	.09335	10.7119	.11099	9.00983	.12869	7.77035	.14648	6.82694	.16435	6.08444	40
21	.09365	10.6783	.11128	8.98598	.12899	7.75254	.14678	6.81312	.16465	6.07340	39
22	.09394	10.6450	.11158	8.96227	.12929	7.73480	.14707	6.79936	.16495	6.06240	38
23	.09423	10.6118	.11187	8.93867	.12958	7.71715	.14737	6.78564	.16525	6.05143	37
24	.09453	10.5789	.11217	8.91520	.12988	7.69957	.14767	6.77199	.16555	6.04051	36
25	.09482	10.5462	.11246	8.89185	.13017	7.68208	.14796	6.75838	.16585	6.02962	35
26	.09511	10.5136	.11276	8.86862	.13047	7.66466	.14826	6.74483	.16615	6.01878	34
27	.09541	10.4813	.11305	8.84551	.13076	7.64732	.14856	6.73133	.16645	6.00797	33
28	.09570	10.4491	.11335	8.82252	.13106	7.63005	.14886	6.71789	.16674	5.99720	32
29	.09600	10.4172	.11364	8.79964	.13136	7.61287	.14915	6.70450	.16704	5.98646	31
30	.09629	10.3854	.11394	8.77689	.13165	7.59575	.14945	6.69116	.16734	5.97576	30
31	.09658	10.3538	.11423	8.75425	.13195	7.57872	.14975	6.67787	.16764	5.96510	29
32	.09688	10.3224	.11452	8.73172	.13224	7.56176	.15005	6.66463	.16794	5.95448	28
33	.09717	10.2913	.11482	8.70931	.13254	7.54487	.15034	6.65144	.16824	5.94390	27
34	.09746	10.2602	.11511	8.68701	.13284	7.52806	.15064	6.63831	.16854	5.93335	26
35	.09776	10.2294	.11541	8.66482	.13313	7.51132	.15094	6.62523	.16884	5.92283	25
36	.09805	10.1988	.11570	8.64275	.13343	7.49465	.15124	6.61219	.16914	5.91236	24
37	.09834	10.1683	.11600	8.62078	.13372	7.47806	.15153	6.59921	.16944	5.90191	23
38	.09864	10.1381	.11629	8.59893	.13402	7.46154	.15183	6.58627	.16974	5.89151	22
39	.09893	10.1080	.11659	8.57718	.13432	7.44509	.15213	6.57339	.17004	5.88114	21
40	.09923	10.0780	.11688	8.55555	.13461	7.42871	.15243	6.56055	.17033	5.87080	20
41	.09952	10.0483	.11718	8.53402	.13491	7.41240	.15272	6.54777	.17063	5.86051	19
42	.09981	10.0187	.11747	8.51259	.13521	7.39616	.15302	6.53503	.17093	5.85024	18
43	.10011	9.98931	.11777	8.49128	.13550	7.37999	.15332	6.52234	.17123	5.84001	17
44	.10040	9.96007	.11806	8.47007	.13580	7.36389	.15362	6.50970	.17153	5.82982	16
45	.10069	9.93101	.11836	8.44896	.13609	7.34786	.15391	6.49710	.17183	5.81966	15
46	.10099	9.90211	.11865	8.42795	.13639	7.33190	.15421	6.48456	.17213	5.80953	14
47	.10128	9.87338	.11895	8.40705	.13669	7.31600	.15451	6.47206	.17243	5.79944	13
48	.10158	9.84482	.11924	8.38625	.13698	7.30018	.15481	6.45961	.17273	5.78938	12
49	.10187	9.81641	.11954	8.36555	.13728	7.28442	.15511	6.44720	.17303	5.77936	11
50	.10216	9.78817	.11983	8.34496	.13758	7.26873	.15540	6.43484	.17333	5.76937	10
51	.10246	9.76009	.12013	8.32446	.13787	7.25310	.15570	6.42253	.17363	5.75941	9
52	.10275	9.73217	.12042	8.30406	.13817	7.23754	.15600	6.41026	.17393	5.74949	8
53	.10305	9.70441	.12072	8.28376	.13846	7.22204	.15630	6.39804	.17423	5.73960	7
54	.10334	9.67680	.12101	8.26355	.13876	7.20661	.15660	6.38587	.17453	5.72974	6
55	.10363	9.64935	.12131	8.24345	.13906	7.19125	.15689	6.37374	.17483	5.71992	5
56	.10393	9.62205	.12160	8.22344	.13935	7.17594	.15719	6.36165	.17513	5.71013	4
57	.10422	9.59490	.12190	8.20352	.13965	7.16071	.15749	6.34961	.17543	5.70037	3
58	.10452	9.56791	.12219	8.18370	.13995	7.14553	.15779	6.33761	.17573	5.69064	2
59	.10481	9.54106	.12249	8.16398	.14024	7.13042	.15809	6.32566	.17603	5.68094	1
60	.10510	9.51436	.12278	8.14435	.14054	7.11537	.15838	6.31375	.17633	5.67128	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	84°		83°		82°		81°		80°		

′	10°		11°		12°		13°		14°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	17633	5.67128	.19438	5.14455	.21256	4.70463	.23087	4.33148	.24933	4.01078	60
1	.17663	5.66165	.19468	5.13658	.21286	4.69791	.23117	4.32573	.24964	4.00582	59
2	.17693	5.65205	.19498	5.12862	.21316	4.69121	.23148	4.32001	.24995	4.00086	58
3	.17723	5.64248	.19529	5.12069	.21347	4.68452	.23179	4.31430	.25026	3.99592	57
4	.17753	5.63295	.19559	5.11279	.21377	4.67786	.23209	4.30860	.25056	3.99099	56
5	.17783	5.62344	.19589	5.10490	.21408	4.67121	.23240	4.30291	.25087	3.98607	55
6	.17813	5.61397	.19619	5.09704	.21438	4.66458	.23271	4.29724	.25118	3.98117	54
7	.17843	5.60452	.19649	5.08921	.21469	4.65797	.23301	4.29159	.25149	3.97627	53
8	.17873	5.59511	.19680	5.08139	.21499	4.65138	.23332	4.28595	.25180	3.97139	52
9	.17903	5.58573	.19710	5.07360	.21529	4.64480	.23363	4.28032	.25211	3.96651	51
10	.17933	5.57638	.19740	5.06584	.21560	4.63825	.23393	4.27471	.25242	3.96165	50
11	.17963	5.56706	.19770	5.05809	.21590	4.63171	.23424	4.26911	.25273	3.95680	49
12	.17993	5.55777	.19801	5.05037	.21621	4.62518	.23455	4.26352	.25304	3.95196	48
13	.18023	5.54851	.19831	5.04267	.21651	4.61868	.23485	4.25795	.25335	3.94713	47
14	.18053	5.53927	.19861	5.03499	.21682	4.61219	.23516	4.25239	.25366	3.94232	46
15	.18083	5.53007	.19891	5.02734	.21712	4.60572	.23547	4.24685	.25397	3.93751	45
16	.18113	5.52090	.19921	5.01971	.21743	4.59927	.23578	4.24132	.25428	3.93271	44
17	.18143	5.51176	.19952	5.01210	.21773	4.59283	.23608	4.23580	.25459	3.92793	43
18	.18173	5.50264	.19982	5.00451	.21804	4.58641	.23639	4.23030	.25490	3.92316	42
19	.18203	5.49356	.20012	4.99695	.21834	4.58001	.23670	4.22481	.25521	3.91839	41
20	.18233	5.48451	.20042	4.98940	.21864	4.57363	.23700	4.21933	.25552	3.91364	40
21	.18263	5.47548	.20073	4.98188	.21895	4.56726	.23731	4.21387	.25583	3.90890	39
22	.18293	5.46648	.20103	4.97438	.21925	4.56091	.23762	4.20842	.25614	3.90417	38
23	.18323	5.45751	.20133	4.96690	.21956	4.55458	.23793	4.20298	.25645	3.89945	37
24	.18353	5.44857	.20164	4.95945	.21986	4.54826	.23823	4.19756	.25676	3.89474	36
25	.18384	5.43966	.20194	4.95201	.22017	4.54196	.23854	4.19215	.25707	3.89004	35
26	.18414	5.43077	.20224	4.94460	.22047	4.53568	.23885	4.18675	.25738	3.88536	34
27	.18444	5.42192	.20254	4.93721	.22078	4.52941	.23916	4.18137	.25769	3.88068	33
28	.18474	5.41309	.20285	4.92984	.22108	4.52316	.23946	4.17600	.25800	3.87601	32
29	.18504	5.40429	.20315	4.92249	.22139	4.51693	.23977	4.17064	.25831	3.87136	31
30	.18534	5.39552	.20345	4.91516	.22169	4.51071	.24008	4.16530	.25862	3.86671	30
31	.18564	5.38677	.20376	4.90785	.22200	4.50451	.24039	4.15997	.25893	3.86208	29
32	.18594	5.37805	.20406	4.90056	.22231	4.49832	.24069	4.15465	.25924	3.85745	28
33	.18624	5.36936	.20436	4.89330	.22261	4.49215	.24100	4.14934	.25955	3.85284	27
34	.18654	5.36070	.20466	4.88605	.22292	4.48600	.24131	4.14405	.25986	3.84824	26
35	.18684	5.35206	.20497	4.87882	.22322	4.47986	.24162	4.13877	.26017	3.84364	25
36	.18714	5.34345	.20527	4.87162	.22353	4.47374	.24193	4.13350	.26048	3.83906	24
37	.18745	5.33487	.20557	4.86444	.22383	4.46764	.24223	4.12825	.26079	3.83449	23
38	.18775	5.32631	.20588	4.85727	.22414	4.46155	.24254	4.12301	.26110	3.82992	22
39	.18805	5.31778	.20618	4.85013	.22444	4.45548	.24285	4.11778	.26141	3.82537	21
40	.18835	5.30928	.20648	4.84300	.22475	4.44942	.24316	4.11256	.26172	3.82083	20
41	.18865	5.30080	.20679	4.83590	.22505	4.44338	.24347	4.10736	.26203	3.81630	19
42	.18895	5.29235	.20709	4.82882	.22536	4.43735	.24377	4.10216	.26235	3.81177	18
43	.18925	5.28393	.20739	4.82175	.22567	4.43134	.24408	4.09699	.26266	3.80726	17
44	.18955	5.27553	.20770	4.81471	.22597	4.42534	.24439	4.09182	.26297	3.80276	16
45	.18986	5.26715	.20800	4.80769	.22628	4.41936	.24470	4.08666	.26328	3.79827	15
46	.19016	5.25880	.20830	4.80068	.22658	4.41340	.24501	4.08152	.26359	3.79378	14
47	.19046	5.25048	.20861	4.79370	.22689	4.40745	.24532	4.07639	.26390	3.78931	13
48	.19076	5.24218	.20891	4.78673	.22719	4.40152	.24562	4.07127	.26421	3.78485	12
49	.19106	5.23391	.20921	4.77978	.22750	4.39560	.24593	4.06616	.26452	3.78040	11
50	.19136	5.22566	.20952	4.77286	.22781	4.38969	.24624	4.06107	.26483	3.77595	10
51	.19166	5.21744	.20982	4.76595	.22811	4.38381	.24655	4.05599	.26515	3.77152	9
52	.19197	5.20925	.21013	4.75906	.22842	4.37793	.24686	4.05092	.26546	3.76709	8
53	.19227	5.20107	.21043	4.75219	.22872	4.37207	.24717	4.04586	.26577	3.76268	7
54	.19257	5.19293	.21073	4.74534	.22903	4.36623	.24747	4.04081	.26608	3.75828	6
55	.19287	5.18480	.21104	4.73851	.22934	4.36040	.24778	4.03578	.26639	3.75388	5
56	.19317	5.17671	.21134	4.73170	.22964	4.35459	.24809	4.03076	.26670	3.74950	4
57	.19347	5.16863	.21164	4.72490	.22995	4.34879	.24840	4.02574	.26701	3.74512	3
58	.19378	5.16058	.21195	4.71813	.23026	4.34300	.24871	4.02074	.26733	3.74075	2
59	.19408	5.15256	.21225	4.71137	.23056	4.33723	.24902	4.01576	.26764	3.73640	1
60	.19438	5.14455	.21256	4.70463	.23087	4.33148	.24933	4.01078	.26795	3.73205	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	79°		78°		77°		76°		75°		

′	15°		16°		17°		18°		19°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.26795	3.73205	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34433	2.90421	60
1	.26826	3.72771	.28706	3.48359	.30605	3.26745	.32524	3.07464	.34465	2.90147	59
2	.26857	3.72338	.28738	3.47977	.30637	3.26406	.32556	3.07160	.34498	2.89873	58
3	.26888	3.71907	.28769	3.47596	.30669	3.26067	.32588	3.06857	.34530	2.89600	57
4	.26920	3.71476	.28800	3.47216	.30700	3.25729	.32621	3.06554	.34563	2.89327	56
5	.26951	3.71046	.28832	3.46837	.30732	3.25392	.32653	3.06252	.34596	2.89055	55
6	.26982	3.70616	.28864	3.46458	.30764	3.25055	.32685	3.05950	.34628	2.88783	54
7	.27013	3.70188	.28895	3.46080	.30796	3.24719	.32717	3.05649	.34661	2.88511	53
8	.27044	3.69761	.28927	3.45703	.30828	3.24383	.32749	3.05349	.34693	2.88240	52
9	.27076	3.69335	.28958	3.45327	.30860	3.24049	.32782	3.05049	.34726	2.87970	51
10	.27107	3.68909	.28990	3.44951	.30891	3.23714	.32814	3.04749	.34758	2.87700	50
11	.27138	3.68485	.29021	3.44576	.30923	3.23381	.32846	3.04450	.34791	2.87430	49
12	.27169	3.68061	.29053	3.44202	.30955	3.23048	.32878	3.04152	.34824	2.87161	48
13	.27201	3.67638	.29084	3.43829	.30987	3.22715	.32911	3.03854	.34856	2.86892	47
14	.27232	3.67217	.29116	3.43456	.31019	3.22384	.32943	3.03556	.34889	2.86624	46
15	.27263	3.66796	.29147	3.43084	.31051	3.22053	.32975	3.03260	.34922	2.86356	45
16	.27294	3.66376	.29179	3.42713	.31083	3.21722	.33007	3.02963	.34954	2.86089	44
17	.27326	3.65957	.29210	3.42343	.31115	3.21392	.33040	3.02667	.34987	2.85822	43
18	.27357	3.65538	.29242	3.41973	.31147	3.21063	.33072	3.02372	.35020	2.85555	42
19	.27388	3.65121	.29274	3.41604	.31178	3.20734	.33104	3.02077	.35052	2.85289	41
20	.27419	3.64705	.29305	3.41236	.31210	3.20406	.33136	3.01783	.35085	2.85023	40
21	.27451	3.64289	.29337	3.40869	.31242	3.20079	.33169	3.01489	.35118	2.84758	39
22	.27482	3.63874	.29368	3.40502	.31274	3.19752	.33201	3.01196	.35150	2.84494	38
23	.27513	3.63461	.29400	3.40136	.31306	3.19426	.33233	3.00903	.35183	2.84229	37
24	.27545	3.63048	.29432	3.39771	.31338	3.19100	.33266	3.00611	.35216	2.83965	36
25	.27576	3.62636	.29463	3.39406	.31370	3.18775	.33298	3.00319	.35248	2.83702	35
26	.27607	3.62224	.29495	3.39042	.31402	3.18451	.33330	3.00028	.35281	2.83439	34
27	.27638	3.61814	.29526	3.38679	.31434	3.18127	.33363	2.99738	.35314	2.83176	33
28	.27670	3.61405	.29558	3.38317	.31466	3.17804	.33395	2.99447	.35346	2.82914	32
29	.27701	3.60996	.29590	3.37955	.31498	3.17481	.33427	2.99158	.35379	2.82653	31
30	.27732	3.60588	.29621	3.37594	.31530	3.17159	.33460	2.98868	.35412	2.82391	30
31	.27764	3.60181	.29653	3.37234	.31562	3.16838	.33492	2.98580	.35445	2.82130	29
32	.27795	3.59775	.29685	3.36875	.31594	3.16517	.33524	2.98292	.35477	2.81870	28
33	.27826	3.59370	.29716	3.36516	.31626	3.16197	.33557	2.98004	.35510	2.81610	27
34	.27858	3.58966	.29748	3.36158	.31658	3.15877	.33589	2.97717	.35543	2.81350	26
35	.27889	3.58562	.29780	3.35800	.31690	3.15558	.33621	2.97430	.35576	2.81091	25
36	.27921	3.58160	.29811	3.35443	.31722	3.15240	.33654	2.97144	.35608	2.80833	24
37	.27952	3.57758	.29843	3.35087	.31754	3.14922	.33686	2.96858	.35641	2.80574	23
38	.27983	3.57357	.29875	3.34732	.31786	3.14605	.33718	2.96573	.35674	2.80316	22
39	.28015	3.56957	.29906	3.34377	.31818	3.14288	.33751	2.96288	.35707	2.80059	21
40	.28046	3.56557	.29938	3.34023	.31850	3.13972	.33783	2.96004	.35740	2.79802	20
41	.28077	3.56159	.29970	3.33670	.31882	3.13656	.33816	2.95721	.35772	2.79545	19
42	.28109	3.55761	.30001	3.33317	.31914	3.13341	.33848	2.95437	.35805	2.79289	18
43	.28140	3.55364	.30033	3.32965	.31946	3.13027	.33881	2.95155	.35838	2.79033	17
44	.28172	3.54968	.30065	3.32614	.31978	3.12713	.33913	2.94872	.35871	2.78778	16
45	.28203	3.54573	.30097	3.32264	.32010	3.12400	.33945	2.94591	.35904	2.78523	15
46	.28234	3.54179	.30128	3.31914	.32042	3.12087	.33978	2.94309	.35937	2.78269	14
47	.28266	3.53785	.30160	3.31565	.32074	3.11775	.34010	2.94028	.35969	2.78014	13
48	.28297	3.53393	.30192	3.31216	.32106	3.11464	.34043	2.93748	.36002	2.77761	12
49	.28329	3.53001	.30224	3.30868	.32139	3.11153	.34075	2.93468	.36035	2.77507	11
50	.28360	3.52609	.30255	3.30521	.32171	3.10842	.34108	2.93189	.36068	2.77254	10
51	.28391	3.52219	.30287	3.30174	.32203	3.10532	.34140	2.92910	.36101	2.77002	9
52	.28423	3.51829	.30319	3.29829	.32235	3.10223	.34173	2.92632	.36134	2.76750	8
53	.28454	3.51441	.30351	3.29483	.32267	3.09914	.34205	2.92354	.36167	2.76498	7
54	.28486	3.51053	.30382	3.29139	.32299	3.09606	.34238	2.92076	.36199	2.76247	6
55	.28517	3.50666	.30414	3.28795	.32331	3.09298	.34270	2.91799	.36232	2.75996	5
56	.28549	3.50279	.30446	3.28452	.32363	3.08991	.34303	2.91523	.36265	2.75746	4
57	.28580	3.49894	.30478	3.28109	.32396	3.08685	.34335	2.91246	.36298	2.75496	3
58	.28612	3.49509	.30509	3.27767	.32428	3.08379	.34368	2.90971	.36331	2.75246	2
59	.28643	3.49125	.30541	3.27426	.32460	3.08073	.34400	2.90696	.36364	2.74997	1
60	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34433	2.90421	.36397	2.74748	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	74°		73°		72°		71°		70°		

′	20°		21°		22°		23°		24°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.36397	2.74748	.38386	2.60509	.40403	2.47509	.42447	2.35585	.44523	2.24604	60
1	.36430	2.74499	.38420	2.60283	.40436	2.47302	.42482	2.35395	.44558	2.24428	59
2	.36463	2.74251	.38453	2.60057	.40470	2.47095	.42516	2.35205	.44593	2.24252	58
3	.36496	2.74004	.38487	2.59831	.40504	2.46888	.42551	2.35015	.44627	2.24077	57
4	.36529	2.73756	.38520	2.59606	.40538	2.46682	.42585	2.34825	.44662	2.23902	56
5	.36562	2.73509	.38553	2.59381	.40572	2.46476	.42619	2.34636	.44697	2.23727	55
6	.36595	2.73263	.38587	2.59156	.40606	2.46270	.42654	2.34447	.44732	2.23553	54
7	.36628	2.73017	.38620	2.58932	.40640	2.46065	.42688	2.34258	.44767	2.23378	53
8	.36661	2.72771	.38654	2.58708	.40674	2.45860	.42722	2.34069	.44802	2.23204	52
9	.36694	2.72526	.38687	2.58484	.40707	2.45655	.42757	2.33881	.44837	2.23030	51
10	.36727	2.72281	.38721	2.58261	.40741	2.45451	.42791	2.33693	.44872	2.22857	50
11	.36760	2.72036	.38754	2.58038	.40775	2.45246	.42826	2.33505	.44907	2.22683	49
12	.36793	2.71792	.38787	2.57815	.40809	2.45043	.42860	2.33317	.44942	2.22510	48
13	.36826	2.71548	.38821	2.57593	.40843	2.44839	.42894	2.33130	.44977	2.22337	47
14	.36859	2.71305	.38854	2.57371	.40877	2.44636	.42929	2.32943	.45012	2.22164	46
15	.36892	2.71062	.38888	2.57150	.40911	2.44433	.42963	2.32756	.45047	2.21992	45
16	.36925	2.70819	.38921	2.56928	.40945	2.44230	.42998	2.32570	.45082	2.21819	44
17	.36958	2.70577	.38955	2.56707	.40979	2.44027	.43032	2.32383	.45117	2.21647	43
18	.36991	2.70335	.38988	2.56487	.41013	2.43825	.43067	2.32197	.45152	2.21475	42
19	.37024	2.70094	.39022	2.56266	.41047	2.43623	.43101	2.32012	.45187	2.21304	41
20	.37057	2.69853	.39055	2.56046	.41081	2.43422	.43136	2.31826	.45222	2.21132	40
21	.37090	2.69612	.39089	2.55827	.41115	2.43220	.43170	2.31641	.45257	2.20961	39
22	.37123	2.69371	.39122	2.55608	.41149	2.43019	.43205	2.31456	.45292	2.20790	38
23	.37157	2.69131	.39156	2.55389	.41183	2.42819	.43230	2.31271	.45327	2.20619	37
24	.37190	2.68892	.39190	2.55170	.41217	2.42618	.43274	2.31086	.45362	2.20449	36
25	.37223	2.68653	.39223	2.54952	.41251	2.42418	.43308	2.30902	.45397	2.20278	35
26	.37256	2.68414	.39257	2.54734	.41285	2.42218	.43343	2.30718	.45432	2.20108	34
27	.37289	2.68175	.39290	2.54516	.41319	2.42019	.43378	2.30534	.45467	2.19938	33
28	.37322	2.67937	.39324	2.54299	.41353	2.41819	.43412	2.30351	.45502	2.19769	32
29	.37355	2.67700	.39357	2.54082	.41387	2.41620	.43447	2.30167	.45538	2.19599	31
30	.37388	2.67462	.39391	2.53865	.41421	2.41421	.43481	2.29984	.45573	2.19430	30
31	.37422	2.67225	.39425	2.53648	.41455	2.41223	.43516	2.29801	.45608	2.19261	29
32	.37455	2.66989	.39458	2.53432	.41490	2.41025	.43550	2.29619	.45643	2.19092	28
33	.37488	2.66752	.39492	2.53217	.41524	2.40827	.43585	2.29437	.45678	2.18923	27
34	.37521	2.66516	.39526	2.53001	.41558	2.40629	.43620	2.29254	.45713	2.18755	26
35	.37554	2.66281	.39559	2.52786	.41592	2.40432	.43654	2.29073	.45748	2.18587	25
36	.37588	2.66046	.39593	2.52571	.41626	2.40235	.43689	2.28891	.45784	2.18419	24
37	.37621	2.65811	.39626	2.52357	.41660	2.40038	.43724	2.28710	.45819	2.18251	23
38	.37654	2.65576	.39660	2.52142	.41694	2.39841	.43758	2.28528	.45854	2.18084	22
39	.37687	2.65342	.39694	2.51929	.41728	2.39645	.43793	2.28348	.45889	2.17916	21
40	.37720	2.65109	.39727	2.51715	.41763	2.39449	.43828	2.28167	.45924	2.17749	20
41	.37754	2.64875	.39761	2.51502	.41797	2.39253	.43862	2.27987	.45960	2.17582	19
42	.37787	2.64642	.39795	2.51289	.41831	2.39058	.43897	2.27806	.45995	2.17416	18
43	.37820	2.64410	.39829	2.51076	.41865	2.38863	.43932	2.27626	.46030	2.17249	17
44	.37853	2.64177	.39862	2.50864	.41899	2.38668	.43966	2.27447	.46065	2.17083	16
45	.37887	2.63945	.39896	2.50652	.41933	2.38473	.44001	2.27267	.46101	2.16917	15
46	.37920	2.63714	.39930	2.50440	.41968	2.38279	.44036	2.27088	.46136	2.16751	14
47	.37953	2.63483	.39963	2.50229	.42002	2.38084	.44071	2.26909	.46171	2.16585	13
48	.37986	2.63252	.39997	2.50018	.42036	2.37891	.44105	2.26730	.46206	2.16420	12
49	.38020	2.63021	.40031	2.49807	.42070	2.37697	.44140	2.26552	.46242	2.16255	11
50	.38053	2.62791	.40065	2.49597	.42105	2.37504	.44175	2.26374	.46277	2.16090	10
51	.38086	2.62561	.40098	2.49386	.42139	2.37311	.44210	2.26196	.46312	2.15925	9
52	.38120	2.62332	.40132	2.49177	.42173	2.37118	.44244	2.26018	.46348	2.15760	8
53	.38153	2.62103	.40166	2.48967	.42207	2.36925	.44279	2.25840	.46383	2.15596	7
54	.38186	2.61874	.40200	2.48758	.42242	2.36733	.44314	2.25663	.46418	2.15432	6
55	.38220	2.61646	.40234	2.48549	.42276	2.36541	.44349	2.25486	.46454	2.15268	5
56	.38253	2.61418	.40267	2.48340	.42310	2.36349	.44384	2.25309	.46489	2.15104	4
57	.38286	2.61190	.40301	2.48132	.42345	2.36158	.44418	2.25132	.46525	2.14940	3
58	.38320	2.60963	.40335	2.47924	.42379	2.35967	.44453	2.24956	.46560	2.14777	2
59	.38353	2.60736	.40369	2.47716	.42413	2.35776	.44488	2.24780	.46595	2.14614	1
60	.38386	2.60509	.40403	2.47509	.42447	2.35585	.44523	2.24604	.46631	2.14451	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
′	69°		68°		67°		66°		65°		′

′	25°		26°		27°		28°		29°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.46631	2.14451	.48773	2.05030	.50953	1.96261	.53171	1.88073	.55431	1.80405	60
1	.46666	2.14288	.48809	2.04879	.50989	1.96120	.53208	1.87941	.55469	1.80281	59
2	.46702	2.14125	.48845	2.04728	.51026	1.95979	.53246	1.87809	.55507	1.80158	58
3	.46737	2.13963	.48881	2.04577	.51063	1.95838	.53283	1.87677	.55545	1.80034	57
4	.46772	2.13801	.48917	2.04426	.51099	1.95698	.53320	1.87546	.55583	1.79911	56
5	.46808	2.13639	.48953	2.04276	.51136	1.95557	.53358	1.87415	.55621	1.79788	55
6	.46843	2.13477	.48989	2.04125	.51173	1.95417	.53395	1.87283	.55659	1.79665	54
7	.46879	2.13316	.49026	2.03975	.51209	1.95277	.53432	1.87152	.55697	1.79542	53
8	.46914	2.13154	.49062	2.03825	.51246	1.95137	.53470	1.87021	.55736	1.79419	52
9	.46950	2.12993	.49098	2.03675	.51283	1.94997	.53507	1.86891	.55774	1.79296	51
10	.46985	2.12832	.49134	2.03526	.51319	1.94858	.53545	1.86760	.55812	1.79174	50
11	.47021	2.12671	.49170	2.03376	.51356	1.94718	.53582	1.86630	.55850	1.79051	49
12	.47056	2.12511	.49206	2.03227	.51393	1.94579	.53620	1.86499	.55888	1.78929	48
13	.47092	2.12350	.49242	2.03078	.51430	1.94440	.53657	1.86369	.55926	1.78807	47
14	.47128	2.12190	.49278	2.02929	.51467	1.94301	.53694	1.86239	.55964	1.78685	46
15	.47163	2.12030	.49315	2.02780	.51503	1.94162	.53732	1.86109	.56003	1.78563	45
16	.47199	2.11871	.49351	2.02631	.51540	1.94023	.53769	1.85979	.56041	1.78441	44
17	.47234	2.11711	.49387	2.02483	.51577	1.93885	.53807	1.85850	.56079	1.78319	43
18	.47270	2.11552	.49423	2.02335	.51614	1.93746	.53844	1.85720	.56117	1.78198	42
19	.47305	2.11392	.49459	2.02187	.51651	1.93608	.53882	1.85591	.56156	1.78077	41
20	.47341	2.11233	.49495	2.02039	.51688	1.93470	.53920	1.85462	.56194	1.77955	40
21	.47377	2.11075	.49532	2.01891	.51724	1.93332	.53957	1.85333	.56232	1.77834	39
22	.47412	2.10916	.49568	2.01743	.51761	1.93195	.53995	1.85204	.56270	1.77713	38
23	.47448	2.10758	.49604	2.01596	.51798	1.93057	.54032	1.85075	.56309	1.77592	37
24	.47483	2.10600	.49640	2.01449	.51835	1.92920	.54070	1.84946	.56347	1.77471	36
25	.47519	2.10442	.49677	2.01302	.51872	1.92782	.54107	1.84818	.56385	1.77351	35
26	.47555	2.10284	.49713	2.01155	.51909	1.92645	.54145	1.84689	.56424	1.77230	34
27	.47590	2.10126	.49749	2.01008	.51946	1.92508	.54183	1.84561	.56462	1.77110	33
28	.47626	2.09969	.49786	2.00862	.51983	1.92371	.54220	1.84433	.56501	1.76990	32
29	.47662	2.09811	.49822	2.00715	.52020	1.92235	.54258	1.84305	.56539	1.76869	31
30	.47698	2.09654	.49858	2.00569	.52057	1.92098	.54296	1.84177	.56577	1.76749	30
31	.47733	2.09498	.49894	2.00423	.52094	1.91962	.54333	1.84049	.56616	1.76629	29
32	.47769	2.09341	.49931	2.00277	.52131	1.91826	.54371	1.83922	.56654	1.76510	28
33	.47805	2.09184	.49967	2.00131	.52168	1.91690	.54409	1.83794	.56693	1.76390	27
34	.47840	2.09028	.50004	1.99986	.52205	1.91554	.54446	1.83667	.56731	1.76271	26
35	.47876	2.08872	.50040	1.99841	.52242	1.91418	.54484	1.83540	.56769	1.76151	25
36	.47912	2.08716	.50076	1.99695	.52279	1.91282	.54522	1.83413	.56808	1.76032	24
37	.47948	2.08560	.50113	1.99550	.52316	1.91147	.54560	1.83286	.56846	1.75913	23
38	.47984	2.08405	.50149	1.99406	.52353	1.91012	.54597	1.83159	.56885	1.75794	22
39	.48019	2.08250	.50185	1.99261	.52390	1.90876	.54635	1.83033	.56923	1.75675	21
40	.48055	2.08094	.50222	1.99116	.52427	1.90741	.54673	1.82906	.56962	1.75556	20
41	.48091	2.07939	.50258	1.98972	.52464	1.90607	.54711	1.82780	.57000	1.75437	19
42	.48127	2.07785	.50295	1.98828	.52501	1.90472	.54748	1.82654	.57039	1.75319	18
43	.48163	2.07630	.50331	1.98684	.52538	1.90337	.54786	1.82528	.57078	1.75200	17
44	.48198	2.07476	.50368	1.98540	.52575	1.90203	.54824	1.82402	.57116	1.75082	16
45	.48234	2.07321	.50404	1.98396	.52613	1.90069	.54862	1.82276	.57155	1.74964	15
46	.48270	2.07167	.50441	1.98253	.52650	1.89935	.54900	1.82150	.57193	1.74846	14
47	.48306	2.07014	.50477	1.98110	.52687	1.89801	.54938	1.82025	.57232	1.74728	13
48	.48342	2.06860	.50514	1.97966	.52724	1.89667	.54975	1.81899	.57271	1.74610	12
49	.48378	2.06706	.50550	1.97823	.52761	1.89533	.55013	1.81774	.57309	1.74492	11
50	.48414	2.06553	.50587	1.97681	.52798	1.89400	.55051	1.81649	.57348	1.74375	10
51	.48450	2.06400	.50623	1.97538	.52836	1.89266	.55089	1.81524	.57386	1.74257	9
52	.48486	2.06247	.50660	1.97395	.52873	1.89133	.55127	1.81399	.57425	1.74140	8
53	.48521	2.06094	.50696	1.97253	.52910	1.89000	.55165	1.81274	.57464	1.74022	7
54	.48557	2.05942	.50733	1.97111	.52947	1.88867	.55203	1.81150	.57503	1.73905	6
55	.48593	2.05790	.50769	1.96969	.52985	1.88734	.55241	1.81025	.57541	1.73788	5
56	.48629	2.05637	.50806	1.96827	.53022	1.88602	.55279	1.80901	.57580	1.73671	4
57	.48665	2.05485	.50843	1.96685	.53059	1.88469	.55317	1.80777	.57619	1.73555	3
58	.48701	2.05333	.50879	1.96544	.53096	1,88337	.55355	1.80653	.57657	1.73438	2
59	.48737	2.05182	.50916	1.96402	.53134	1.88205	.55393	1.80529	.57696	1.73321	1
60	.48773	2.05030	.50953	1.96261	.53171	1.88073	.55431	1.80405	.57735	1.73205	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
′	64°		63°		62°		61°		60°		′

′	30°		31°		32°		33°		34°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.57735	1.73205	.60086	1.66428	.62487	1.60033	.64941	1.53986	.67451	1.48256	60
1	.57774	1.73089	.60126	1.66318	.62527	1.59930	.64982	1.53888	.67493	1.48163	59
2	.57813	1.72973	.60165	1.66209	.62568	1.59826	.65024	1.53791	.67536	1.48070	58
3	.57851	1.72857	.60205	1.66099	.62608	1.59723	.65065	1.53693	.67578	1.47977	57
4	.57890	1.72741	.60245	1.65990	.62649	1.59620	.65106	1.53595	.67620	1.47885	56
5	.57929	1.72625	.60284	1.65881	.62689	1.59517	.65148	1.53497	.67663	1.47792	55
6	.57968	1.72509	.60324	1.65772	.62730	1.59414	.65189	1.53400	.67705	1.47699	54
7	.58007	1.72393	.60364	1.65663	.62770	1.59311	.65231	1.53302	.67748	1.47607	53
8	.58046	1.72278	.60403	1.65554	.62811	1.59208	.65272	1.53205	.67790	1.47514	52
9	.58085	1.72163	.60443	1.65445	.62852	1.59105	.65314	1.53107	.67832	1.47422	51
10	.58124	1.72047	.60483	1.65337	.62892	1.59002	.65355	1.53010	.67875	1.47330	50
11	.58162	1.71932	.60522	1.65228	.62933	1.58900	.65397	1.52913	.67917	1.47238	49
12	.58201	1.71817	.60562	1.65120	.62973	1.58797	.65438	1.52816	.67960	1.47146	48
13	.58240	1.71702	.60602	1.65011	.63014	1.58695	.65480	1.52719	.68002	1.47053	47
14	.58279	1.71588	.60642	1.64903	.63055	1.58593	.65521	1.52622	.68045	1.46962	46
15	.58318	1.71473	.60681	1.64795	.63095	1.58490	.65563	1.52525	.68088	1.46870	45
16	.58357	1.71358	.60721	1.64687	.63136	1.58388	.65604	1.52429	.68130	1.46778	44
17	.58396	1.71244	.60761	1.64579	.63177	1.58286	.65646	1.52332	.68173	1.46686	43
18	.58435	1.71129	.60801	1.64471	.63217	1.58184	.65688	1.52235	.68215	1.46595	42
19	.58474	1.71015	.60841	1.64363	.63258	1.58083	.65729	1.52139	.68258	1.46503	41
20	.58513	1.70901	.60881	1.64256	.63299	1.57981	.65771	1.52043	.68301	1.46411	40
21	.58552	1.70787	.60921	1.64148	.63340	1.57879	.65813	1.51946	.68343	1.46320	39
22	.58591	1.70673	.60960	1.64041	.63380	1.57778	.65854	1.51850	.68386	1.46229	38
23	.58631	1.70560	.61000	1.63934	.63421	1.57676	.65896	1.51754	.68429	1.46137	37
24	.58670	1.70446	.61040	1.63826	.63462	1.57575	.65938	1.51658	.68471	1.46046	36
25	.58709	1.70332	.61080	1.63719	.63503	1.57474	.65980	1.51562	.68514	1.45955	35
26	.58748	1.70219	.61120	1.63612	.63544	1.57372	.66021	1.51466	.68557	1.45864	34
27	.58787	1.70106	.61160	1.63505	.63584	1.57271	.66063	1.51370	.68600	1.45773	33
28	.58826	1.69992	.61200	1.63398	.63625	1.57170	.66105	1.51275	.68642	1.45682	32
29	.58865	1.69879	.61240	1.63292	.63666	1.57069	.66147	1.51179	.68685	1.45592	31
30	.58905	1.69766	.61280	1.63185	.63707	1.56969	.66189	1.51084	.68728	1.45501	30
31	.58944	1.69653	.61320	1.63079	.63748	1.56868	.66230	1.50988	.68771	1.45410	29
32	.58983	1.69541	.61360	1.62972	.63789	1.56767	.66272	1.50893	.68814	1.45320	28
33	.59022	1.69428	.61400	1.62866	.63830	1.56667	.66314	1.50797	.68857	1.45229	27
34	.59061	1.69316	.61440	1.62760	.63871	1.56566	.66356	1.50702	.68900	1.45139	26
35	.59101	1.69203	.61480	1.62654	.63912	1.56466	.66398	1.50607	.68942	1.45049	25
36	.59149	1.69091	.61520	1.62548	.63953	1.56366	.66440	1.50512	.68985	1.44958	24
37	.59179	1.68979	.61561	1.62442	.63994	1.56265	.66482	1.50417	.69028	1.44868	23
38	.59218	1.68866	.61601	1.62336	.64035	1.56165	.66524	1.50322	.69071	1.44778	22
39	.59258	1.68754	.61641	1.62230	.64076	1.56065	.66566	1.50228	.69114	1.44688	21
40	.59297	1.68643	.61681	1.62125	.64117	1.55966	.66608	1.50133	.69157	1.44598	20
41	.59336	1.68531	.61721	1.62019	.64158	1.55866	.66650	1.50038	.69200	1.44508	19
42	.59376	1.68419	.61761	1.61914	.64199	1.55766	.66692	1.49944	.69243	1.44418	18
43	.59415	1.68308	.61801	1.61808	.64240	1.55666	.66734	1.49849	.69286	1.44329	17
44	.59454	1.68196	.61842	1.61703	.64281	1.55567	.66776	1.49755	.69329	1.44239	16
45	.59494	1.68085	.61882	1.61598	.64322	1.55467	.66818	1.49661	.69372	1.44149	15
46	.59533	1.67974	.61922	1.61493	.64363	1.55368	.66860	1.49566	.69416	1.44060	14
47	.59573	1.67863	.61962	1.61388	.64404	1.55269	.66902	1.49472	.69459	1.43970	13
48	.59612	1.67752	.62003	1.61283	.64446	1.55170	.66944	1.49378	.69502	1.43881	12
49	.59651	1.67641	.62043	1.61179	.64487	1.55071	.66986	1.49284	.69545	1.43792	11
50	.59691	1.67530	.62083	1.61074	.64528	1.54972	.67028	1.49190	.69588	1.43703	10
51	.59730	1.67419	.62124	1.60970	.64569	1.54873	.67071	1.49097	.69631	1.43614	9
52	.59770	1.67309	.62164	1.60865	.64610	1.54774	.67113	1.49003	.69675	1.43525	8
53	.59809	1.67198	.62204	1.60761	.64652	1.54675	.67155	1.48909	.69718	1.43436	7
54	.59849	1.67088	.62245	1.60657	.64693	1.54576	.67197	1.48816	.69761	1.43347	6
55	.59888	1.66978	.62285	1.60553	.64734	1.54478	.67239	1.48722	.69804	1.43258	5
56	.59928	1.66867	.62325	1.60449	.64775	1.54379	.67282	1.48629	.69847	1.43169	4
57	.59967	1.66757	.62366	1.60345	.64817	1.54281	.67324	1.48536	.69891	1.43080	3
58	.60007	1.66647	.62406	1.60241	.64858	1.54183	.67366	1.48442	.69934	1.42992	2
59	.60046	1.66538	.62446	1.60137	.64899	1.54085	.67409	1.48349	.69977	1.42903	1
60	.60086	1.66428	.62487	1.60033	.64941	1.53986	.67451	1.48256	.70021	1.42815	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	59°		58°		57°		56°		55°		

′	35°		36°		37°		38°		39°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.70021	1.42815	.72654	1.37638	.75355	1.32704	.78129	1.27994	.80978	1.23490	60
1	.70064	1.42726	.72699	1.37554	.75401	1.32624	.78175	1.27917	.81027	1.23416	59
2	.70107	1.42638	.72743	1.37470	.75447	1.32544	.78222	1.27841	.81075	1.23343	58
3	.70151	1.42550	.72788	1.37386	.75492	1.32464	.78269	1.27764	.81123	1.23270	57
4	.70194	1.42462	.72832	1.37302	.75538	1.32384	.78316	1.27688	.81171	1.23196	56
5	.70238	1.42374	.72877	1.37218	.75584	1.32304	.78363	1.27611	.81220	1.23123	55
6	.70281	1.42286	.72921	1.37134	.75629	1.32224	.78410	1.27535	.81268	1.23050	54
7	.70325	1.42198	.72966	1.37050	.75675	1.32144	.78457	1.27458	.81316	1.22977	53
8	.70368	1.42110	.73010	1.36967	.75721	1.32064	.78504	1.27382	.81364	1.22904	52
9	.70412	1.42022	.73055	1.36883	.75767	1.31984	.78551	1.27306	.81413	1.22831	51
10	.70455	1.41934	.73100	1.36800	.75812	1.31904	.78598	1.27230	.81461	1.22758	50
11	.70499	1.41847	.73144	1.36716	.75858	1.31825	.78645	1.27153	.81510	1.22685	49
12	.70542	1.41759	.73189	1.36633	.75904	1.31745	.78692	1.27077	.81558	1.22612	48
13	.70586	1.41672	.73234	1.36549	.75950	1.31666	.78739	1.27001	.81606	1.22539	47
14	.70629	1.41584	.73278	1.36466	.75996	1.31586	.78786	1.26925	.81655	1.22467	46
15	.70673	1.41497	.73323	1.36383	.76042	1.31507	.78834	1.26849	.81703	1.22394	45
16	.70717	1.41409	.73368	1.36300	.76088	1.31427	.78881	1.26774	.81752	1.22321	44
17	.70760	1.41322	.73413	1.36217	.76134	1.31348	.78928	1.26698	.81800	1.22249	43
18	.70804	1.41235	.73457	1.36134	.76180	1.31269	.78975	1.26622	.81849	1.22176	42
19	.70848	1.41148	.73502	1.36051	.76226	1.31190	.79022	1.26546	.81898	1.22104	41
20	.70891	1.41061	.73547	1.35968	.76272	1.31110	.79070	1.26471	.81946	1.22031	40
21	.70935	1.40974	.73592	1.35885	.76318	1.31031	.79117	1.26395	.81995	1.21959	39
22	.70979	1.40887	.73637	1.35802	.76364	1.30952	.79164	1.26319	.82044	1.21886	38
23	.71023	1.40800	.73681	1.35719	.76410	1.30873	.79212	1.26244	.82092	1.21814	37
24	.71066	1.40714	.73726	1.35637	.76456	1.30795	.79259	1.26169	.82141	1.21742	36
25	.71110	1.40627	.73771	1.35554	.76502	1.30716	.79306	1.26093	.82190	1.21670	35
26	.71154	1.40540	.73816	1.35472	.76548	1.30637	.79354	1.26018	.82238	1.21598	34
27	.71198	1.40454	.73861	1.35389	.76594	1.30558	.79401	1.25943	.82287	1.21526	33
28	.71242	1.40367	.73906	1.35307	.76640	1.30480	.79449	1.25867	.82336	1.21454	32
29	.71285	1.40281	.73951	1.35224	.76686	1.30401	.79496	1.25792	.82385	1.21382	31
30	.71329	1.40195	.73996	1.35142	.76733	1.30323	.79544	1.25717	.82434	1.21310	30
31	.71373	1.40109	.74041	1.35060	.76779	1.30244	.79591	1 25642	.82483	1.21238	29
32	.71417	1.40022	.74086	1.34978	.76825	1.30166	.79639	1.25567	.82531	1.21166	28
33	.71461	1.39936	.74131	1.34896	.76871	1.30087	.79686	1.25492	.82580	1.21094	27
34	.71505	1.39850	.74176	1.34814	.76918	1.30009	.79734	1.25417	.82629	1.21023	26
35	.71549	1.39764	.74221	1.34732	.76964	1.29931	.79781	1.25343	.82678	1.20951	25
36	.71593	1.39679	.74267	1.34650	.77010	1.29853	.79829	1.25268	.82727	1.20879	24
37	.71637	1.39593	.74312	1.34568	.77057	1.29775	.79877	1.25193	.82776	1.20808	23
38	.71681	1.39507	.74357	1.34487	.77103	1.29696	.79924	1.25118	.82825	1.20736	22
39	.71725	1.39421	.74402	1.34405	.77149	1.29618	.79972	1.25044	.82874	1.20665	21
40	.71769	1.39336	.74447	1.34323	.77196	1.29541	.80020	1.24969	.82923	1.20593	20
41	.71813	1.39250	.74492	1.34242	.77242	1.29463	.80067	1.24895	.82972	1.20522	19
42	.71857	1.39165	.74538	1.34160	.77289	1.29385	.80115	1.24820	.83022	1.20451	18
43	.71901	1.39079	.74583	1.34079	.77335	1.29307	.80163	1.24746	.83071	1.20379	17
44	.71946	1.38994	.74628	1.33998	.77382	1.29229	.80211	1.24672	.83120	1.20308	16
45	.71990	1.38909	.74674	1.33916	.77428	1.29152	.80258	1.24597	.83169	1.20237	15
46	.72034	1.38824	.74719	1.33835	.77475	1.29074	.80306	1.24523	.83218	1.20166	14
47	.72078	1.38738	.74764	1.33754	.77521	1.28997	.80354	1.24449	.83268	1.20095	13
48	.72122	1.38653	.74810	1.33673	.77568	1.28919	.80402	1.24375	.83317	1.20024	12
49	.72167	1.38568	.74855	1.33592	.77615	1.28842	.80450	1.24301	.83366	1.19953	11
50	.72211	1.38484	.74900	1.33511	.77661	1.28764	.80498	1.24227	.83415	1.19882	10
51	.72255	1.38399	.74946	1.33430	.77708	1.28687	.80546	1.24153	.83465	1.19811	9
52	.72299	1.38314	.74991	1.33349	.77754	1.28610	.80594	1.24079	.83514	1.19740	8
53	.72344	1.38229	.75037	1.33268	.77801	1.28533	.80642	1.24005	.83564	1.19669	7
54	.72388	1.38145	.75082	1.33187	.77848	1.28456	.80690	1.23931	.83613	1.19599	6
55	.72432	1.38060	.75128	1.33107	.77895	1.28379	.80738	1.23858	.83662	1.19528	5
56	.72477	1.37976	.75173	1.33026	.77941	1.28302	.80786	1.23784	.83712	1.19457	4
57	.72521	1.37891	.75219	1.32946	.77988	1.28225	.80834	1.23710	.83761	1.19387	3
58	.72565	1.37807	.75264	1.32865	.78035	1.28148	.80882	1.23637	.83811	1.19316	2
59	.72610	1.37722	.75310	1.32785	.78082	1.28071	.80930	1.23563	.83860	1.19246	1
60	.72654	1.37638	.75355	1.32704	.78129	1.27994	.80978	1.23490	.83910	1.19175	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	54°		53°		52°		51°		50°		

′	40°		41°		42°		43°		44°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.83910	1.19175	.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.03553	60
1	.83960	1.19105	.86980	1.14969	.90093	1.10996	.93306	1.07174	.96625	1.03493	59
2	.84009	1.19035	.87031	1.14902	.90146	1.10931	.93360	1.07112	.96681	1.03433	58
3	.84059	1.18964	.87082	1.14834	.90199	1.10867	.93415	1.07049	.96738	1.03372	57
4	.84108	1.18894	.87133	1.14767	.90251	1.10802	.93469	1.06987	.96794	1.03312	56
5	.84158	1.18824	.87184	1.14699	.90304	1.10737	.93524	1.06925	.96850	1.03252	55
6	.84208	1.18754	.87236	1.14632	.90357	1.10672	.93578	1.06862	.96907	1.03192	54
7	.84258	1.18684	.87287	1.14565	.90410	1.10607	.93633	1.06800	.96963	1.03132	53
8	.84307	1.18614	.87338	1.14498	.90463	1.10543	.93688	1.06738	.97020	1.03072	52
9	.84357	1.18544	.87389	1.14430	.90516	1.10478	.93742	1.06676	.97076	1.03012	51
10	.84407	1.18474	.87441	1.14363	.90569	1.10414	.93797	1.06613	.97133	1.02952	50
11	.84457	1.18404	.87492	1.14296	.90621	1.10349	.93852	1.06551	.97189	1.02892	49
12	.84507	1.18334	.87543	1.14229	.90674	1.10285	.93906	1.06489	.97246	1.02832	48
13	.84556	1.18264	.87595	1.14162	.90727	1.10220	.93961	1.06427	.97302	1.02772	47
14	.84606	1.18194	.87646	1.14095	.90781	1.10156	.94016	1.06365	.97359	1.02713	46
15	.84656	1.18125	.87698	1.14028	.90834	1.10091	.94071	1.06303	.97416	1.02653	45
16	.84706	1.18055	.87749	1.13961	.90887	1.10027	.94125	1.06241	.97472	1.02593	44
17	.84756	1.17986	.87801	1.13894	.90940	1.09963	.94180	1.06179	.97529	1.02533	43
18	.84806	1.17916	.87852	1.13828	.90993	1.09899	.94235	1.06117	.97586	1.02474	42
19	.84856	1.17846	.87904	1.13761	.91046	1.09834	.94290	1.06056	.97643	1.02414	41
20	.84906	1.17777	.87955	1.13694	.91099	1.09770	.94345	1.05994	.97700	1.02355	40
21	.84956	1.17708	.88007	1.13627	.91153	1.09706	.94400	1.05932	.97756	1.02295	39
22	.85006	1.17638	.88059	1.13561	.91206	1.09642	.94455	1.05870	.97813	1.02236	38
23	.85057	1.17569	.88110	1.13494	.91259	1.09578	.94510	1.05809	.97870	1.02176	37
24	.85107	1.17500	.88162	1.13428	.91313	1.09514	.94565	1.05747	.97927	1.02117	36
25	.85157	1.17430	.88214	1.13361	.91366	1.09450	.94620	1.05685	.97984	1.02057	35
26	.85207	1.17361	.88265	1.13295	.91419	1.09386	.94676	1.05624	.98041	1.01998	34
27	.85257	1.17292	.88317	1.13228	.91473	1.09322	.94731	1.05562	.98098	1.01939	33
28	.85308	1.17223	.88369	1.13162	.91526	1.09258	.94786	1.05501	.98155	1.01879	32
29	.85358	1.17154	.88421	1.13096	.91580	1.09195	.94841	1.05439	.98213	1.01820	31
30	.85408	1.17085	.88473	1.13029	.91633	1.09131	.94896	1.05378	.98270	1.01761	30
31	.85458	1.17016	.88524	1.12963	.91687	1.09067	.94952	1.05317	.98327	1.01702	29
32	.85509	1.16947	.88576	1.12897	.91740	1.09003	.95007	1.05255	.98384	1.01642	28
33	.85559	1.16878	.88628	1.12831	.91794	1.08940	.95062	1.05194	.98441	1.01583	27
34	.85609	1.16809	.88680	1.12765	.91847	1.08876	.95118	1.05133	.98499	1.01524	26
35	.85660	1.16741	.88732	1.12699	.91901	1.08813	.95173	1.05072	.98556	1.01465	25
36	.85710	1.16672	.88784	1.12633	.91955	1.08749	.95229	1.05010	.98613	1.01406	24
37	.85761	1.16603	.88836	1.12567	.92008	1.08686	.95284	1.04949	.98671	1.01347	23
38	.85811	1.16535	.88888	1.12501	.92062	1.08622	.95340	1.04888	.98728	1.01288	22
39	.85862	1.16466	.88940	1.12435	.92116	1.08559	.95395	1.04827	.98786	1.01229	21
40	.85912	1.16398	.88992	1.12369	.92170	1.08496	.95451	1.04766	.98843	1.01170	20
41	.85963	1.16329	.89045	1.12303	.92224	1.08432	.95506	1.04705	.98901	1.01112	19
42	.86014	1.16261	.89097	1.12238	.92277	1.08369	.95562	1.04644	.98958	1.01053	18
43	.86064	1.16192	.89149	1.12172	.92331	1.08306	.95618	1.04583	.99016	1.00994	17
44	.86115	1.16124	.89201	1.12106	.92385	1.08243	.95673	1.04522	.99073	1.00935	16
45	.86166	1.16056	.89253	1.12041	.92439	1.08179	.95729	1.04461	.99131	1.00876	15
46	.86216	1.15987	.89306	1.11975	.92493	1.08116	.95785	1.04401	.99189	1.00818	14
47	.86267	1.15919	.80358	1.11909	.92547	1.08053	.95841	1.04340	.99247	1.00759	13
48	.86318	1.15851	.89410	1.11844	.92601	1.07990	.95897	1.04279	.99304	1.00701	12
49	.86368	1.15783	.89463	1.11778	.92655	1.07927	.95952	1.04218	.99362	1.00642	11
50	.86419	1.15715	.89515	1.11713	.92709	1.07864	.96008	1.04158	.99420	1.00583	10
51	.86470	1.15647	.89567	1.11648	.92763	1.07801	.96064	1.04097	.99478	1.00525	9
52	.86521	1.15579	.89620	1.11582	.92817	1.07738	.96120	1.04036	.99536	1.00467	8
53	.86572	1.15511	.89672	1.11517	.92872	1.07676	.96176	1.03976	.99594	1.00408	7
54	.86623	1.15443	.89725	1.11452	.92926	1.07613	.96232	1.03915	.99652	1.00350	6
55	.86674	1.15375	.89777	1.11387	.92980	1.07550	.96288	1.03855	.99710	1.00291	5
56	.86725	1.15308	.89830	1.11321	.93034	1.07487	.96344	1.03794	.99768	1.00233	4
57	.86776	1.15240	.89883	1.11256	.93088	1.07425	.96400	1.03734	.99826	1.00175	3
58	.86827	1.15172	.89935	1.11191	.93143	1.07362	.96457	1.03674	.99884	1.00116	2
59	.86878	1.15104	.89988	1.11126	.03197	1.07299	.96513	1.03613	.99942	1.00058	1
60	.86929	1.15037	.00040	1.11061	.93252	1.07237	.96569	1.03553	1.00000	1.00000	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	49°		48°		47°		46°		45°		

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