Practical Automobile Instruction

A Complete Cyclopedia of Practical Information for Garage Men, Chauffeurs, Repair Men and Automobile Designers and Engineers

with

Special Reference to Carburetion, Ignition, Starting and Lighting, Motor Troubles and Repairs, Machine Shop Practice, Oxy - Acetylene Welding and Cutting and Carbon Removal by the Oxygen Process

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Arithmetic is the science of numbers, and as numbers treat of magnitude or quantity, whatever is capable of increase or decrease may be considered as of magnitude or quantity.

A Number is a unit or collection of units, as two, five, six.

An **Integer** is a number which represents an unbroken quantity.

An **Odd Number** is a number which cannot be divided by two.

An **Even Number** is a number which can be exactly divided by two.

Factors of a number are those numbers which, when multiplied together, make that number.

A **Prime Number** is a number exactly divisible by one.

An **Exact Divisor** is a whole number which will divide another number without a remainder.

The **Greatest Common Divisor** of two or more numbers is the greatest number which will divide each of the numbers exactly.

A **Multiple** of a number is any number exactly divisible by that number.

The **Least Common Multiple** of two or more numbers is the smallest number which is exactly divisible by each of the other numbers.

Addition is uniting two or more numbers into one. The result of the adition is called the **Sum.**

The sign of **Addition** is (+), thus: **90+10=100.**

Subtraction is taking a lesser sum from a greater one.

The answer is called the **Remainder or the Difference.**

The sign of **Subtraction** is (—), thus **90—10=80.**

Multiplication is finding the amount of one number increased as many times as there are units in another.

The answer is called the **Product.**

The sign of **Multiplication** is (×), thus: $90 \times 10 = 900$.

Division may be defined as the dividing of a number of quantity into any other number of parts.

When one number has to be divided by another number, the first one is called the **Dividend**, and the second one the **Divisor**, and the result is the **Quotient.**

The sign of **Division** is (÷), thus: $90 \div 10 = 9$.

A number is exactly divisible by 2 when the number ends in an even number or in 0, by 3, when the sum of the figures is exactly divisible by 3, by 4, when the number formed by the last two figures of the number is exactly divisible by 4, by 5, when the number ends in 5 or 0.

Addition.

Example: Add together 397,495 and 6,350.

```
397495
  6350
------
403,845—Answer.
```

Example: Add together 28,673 and 973.

```
28673
  973
-----
29,646—Answer.
```

Example: Add 6,593 to 37.

```
 6593
   37
-----
6,630—Answer.
```

Subtraction.

Example: Subtract 397,495 from 403,845.

```
403845
397495
------
 6,350—Answer.
```

Example: Subtract 28,673 from 29,646.

```
 29646
 28673
 -----
   973—Answer.
```

Example: Subtract 6,593 from 6,630.

```
 6630
 6593
 ----
   37—Answer
```

Multiplication.

Example: Multiply 144 by 12.

```
  144
   12
 ----
  288
 144
 -----
 1,728—Answer.
```

Example: Multiply 3,645 by 468.

```
     3645
      468
    -----
    29160
   21870
  14580
 ---------
 1,705,860—Answer.
```

Example: Multiply 86,540 by 1,236.

```
     86540
      1236
    ------
    519240
   259620
  173080
  86540
 -----------
 106,963,440—Answer.
```

Division.

Example: Divide 12 into 1728.

```
12)1728(144—Answer.
   12
   --
    52
    48
    ..
     48
     48
     --
```

Example: Divide 468 into 1,705,860.

```
468)1705860(3,645—Answer.
    1404
    ----
     3018
     2808
     ----
      2106
      1872
      ----
       2340
       2340
       ----
```

Example: Divide 1,236 into 106,963,440.

```
1236)106963440(86,540—Answer.
      9888
      ----
       8083
       7416
       ----
        6674
        6180
        ----
         4944
         4944
         ----
            0
```

Algebraic Signs and Symbols.

= The sign of equality. It denotes that the quantities connected by this sign are equal to one another, thus: **12 inches = 1 foot.**

+ The sign of addition. It signifies plus or more, thus: **7+5=12.**

— The sign of subtraction. It signifies minus or less, thus: 7—5=2.

$\times$ The sign of multiplication. It denotes that the quantities connected by the sign are to be multiplied together, thus: $7\times5=35$.

$\div$ This is the sign of division. It signifies divided by, thus: $7\div5=1.4$.

( ) or [ ] These signs are called brackets and denote that the numbers between them are to be taken collectively and treated as one quantity, thus: $12(7+5)=12\times12=144$, $12(7-5)=12\times2=24$.

— This sign is called the bar or vinculum. It is sometimes used in place of the brackets, thus: $12\ \overline{7+5}=12\times12=144$, $12\ \overline{7-5}=12\times2=24$.

Quantities in Algebra are expressed by letters and are used to shorten or simplify the formula, thus: $a\times b$ signifies that **a** is to be multiplied by **b**.

When it is desired to express division in a simple form, the division is written under the dividend, thus: $(a+b)\div c=a+b$.

a^2 This denotes that **a** is to be multiplied by itself, thus: $a\times a=a^2$, or is some number multiplied by itself, thus $3\times3=9$.

a^3 This signifies that **a** is to be multiplied by itself twice, thus: $a\times a\times a=a^3$, or it is some number multiplied by itself twice, thus: $3\times3\times3=27$.

$\sqrt{}$ This is called the radical sign and when placed before a letter or number, denotes that some root of the number is to be extracted, thus: $\sqrt{a}$ means the square root of a, or $\sqrt[3]{a}$ means the cube root of **a**.

$\frac{\sqrt{a}}{b}$ This signifies that the square root of **a** has to be extracted and then divided by **b**.

$\frac{a}{\sqrt{b}}$ This denotes that **a** is to be divided by the square root of **b**.

$\sqrt{\frac{a}{b}}$ This signifies that **a** is to be divided by **b** and the square root of the result extracted.

:, : :, : These are the signs of proportion or the rule of three. The sign : means—is to, the sign : : means—as, thus: 1:4::4:16 or 1 is to 4 as 4 is to 16.

°, ′, ″ These signs are used to express the value of an angle in degrees, minutes and seconds, thus: 30 degrees, 20 minutes, 10 seconds may be written 30° 20′ 10″.

′, ″ These two signs are also used to represent feet and inches, thus: 3 feet 6 inches may be written 3′ 6″.

— The Greek letter is used to denote the ratio of the circumference of a circle to its diameter, which is 3.14159.

g This sign is used to represent the value of the gravity constant, which is 32.2.

Decimal Fractions.

Decimal Fractions are those which have 10, 100, 1000, &c. for a denominator, and are expressed by writing the numerator only and placing a decimal point before it on the left hand, as for example:

$$\tfrac{1}{10}=.1 \qquad \tfrac{76}{100}=.76 \qquad \tfrac{876}{1000}=.876$$

$$\tfrac{3}{10}=.3 \qquad \tfrac{3}{100}=.03 \qquad \tfrac{3}{1000}=.003$$

$$113.3=113\tfrac{3}{10}=\tfrac{113.3}{10}=\tfrac{11330}{100}$$

$$113.03=\tfrac{113.03}{1}=\tfrac{1130.3}{10}=\tfrac{11303}{100}$$

Addition of Decimals. Arrange the numbers so that all the decimal points come directly under one another, add them together as in whole numbers, and point off as many figures for decimals as are equal to the greatest number of decimals in any of the given numbers.

Example: Add together 3.79, .117, 87.225, 478.91

```
  3.79
   .117
 87.225
478.91
-------
570.042 Answer.
```

Subtraction of Decimals. Place the numbers under one another, as in addition, subtract as in whole numbers, keeping the decimal point in the remainder directly under those above it.

```
Example: From 97.378
         take 46.4972
              -------
              50.8808 Answer.
```

Multiplication of Decimals. Multiply the factors together, as in whole numbers, then point off from the product as many decimal places as there are in both factors, supplying any deficiency by annexing ciphers to the left hand.

```
Example: Multiply 4.735
               by  .374
               ------
                18940
               33145
              14205
              --------
              1.770890 Answer.
```

```
Example: Multiply .04735
               by  .0374
                   -----
                   18940
                  33145
                 14205
              ----------
              .001770890 Answer.
```

Division of Decimals. Remove the decimal point in the dividend as many places to the right as there are decimal places in the divisor and supply any deficiency by annexing ciphers. Then make the divisor a whole number, and proceed as in the division of simple numbers, and the quotient will contain as many decimal places as are used in the dividend.

Example: Divide 74.23973 by 6.12.

```
612)7423.973(12.130 Answer.
    612
    1303
    1224
     799
     612
     1877
     1836
      413
```

Example: Divide .7423973 by 612

```
612).7423973(.0012130 Answer.
     612
     1303
     1224
      799
      612
      1877
      1836
       413
```

To Reduce any Vulgar Fraction to a Decimal. Annex ciphers to the numerator till it be equal to or greater than the denominator; divide by the denominator, as in division of decimals, and the quotient will be the decimal required.

Reduce $\frac{7}{256}$ to a decimal fraction.

```
256)7.00000000(.02734375 Answer.
     512
     1880
     1792
      880
      768
      1120
      1024
       960
       768
       1920
       1792
        1280
        1280
```

Reduce $\frac{7}{12}$ to a decimal fraction.

```
12)7.00000000
   .58333333 Answer.
```

Reading Decimals. When reading decimals, the idea of a denominator should be omitted and the decimals read, thus: .36 as point—3-6, or .568 as point—5—6—8.

Examples of the use of decimal fractions:

Add into one sum the following numbers:

16.625, 11.4, 20.7831, 12.125, 8.04 and 7.002

```
16.625
11.4
20.7831
12.125
 8.04
 7.002
75.9751 the sum required.
```

Subtract 119.80764 from 234.98276

```
234.98276
119.80764
115.17512 the remainder required.
```

Subtract .002 from 100

```
100.
   .002
 99.998 the remainder required.
```

Multiply .002 by .016

```
 .002
 .016
.00032 the product required.
```

Multiply 62.10372 by 16.732

```
     62.10372
       16.732
     12420744
    18631116
   43472604
  37262232
  6210372
1039.11944304 the product required.
```

Always notice that the number of figures in the product to the right of the decimal point equal to the number of decimals in the multiplier and multiplicand taken together.

Roots of Numbers.

To Extract the Square Root of a Number. If there be decimals in the given number, make them to consist of two, four, six, &c., places by annexing ciphers to the right hand. Then separate the whole into periods of two figures each, beginning at the right hand, and the left-hand period will consist of one or two figures, according as the number of figures in the whole number is odd or even. Find a square number equal to or the next less than the left-hand period, and put the root of it in the quotient. Subtract this square from the left-hand period, and to the remainder bring down the next period for a dividend, and to the left hand of it write double the quotient for a divisor. Then consider what figure if annexed to the divisor and the result multiplied by it the product may be equal to or the next less number than the dividend, and it will be the second figure of the root. From the dividend subtract the product, and to the remainder bring down the next period for a new dividend. Double the figures in the quotient for a divisor, and continue the operation as above till all the periods are used.

Example: Extract the square root of 10291264

Example: Extract the square root of 177746.56

	10291264	3208 Answer.
	9	
62	129	
20	124	
6408	51264	
	51264	

	177746.56	42.6 Answer.
	16	
82	177	
2	164	
841	1346	
1	841	
8426	50556	
	50556	

To Extract the Square Root of a Vulgar Fraction.

Reduce the given fraction to its lowest terms. Then extract the square root of the numerator for a new numerator, and the square root of the denominator for a new denominator. If the fraction will not extract even, reduce it to a decimal and then extract the square root.

To Extract the Cube Root of a Number.

If there be decimals in the given number, make them to consist of three, six, nine, &c., places by annexing ciphers to the right hand, if necessary. Then separate the whole into periods of three figures each, beginning at the right hand. The left-hand period may consist of one, two, or three figures. Find the nearest cube to the first period, subtract it therefrom, and put the root in the quotient. Then three times the square of this root will be the trial divisor for finding the next figure. Multiply the root figure, or figures already found by three, and prefix the product to the next new root-figure, which will be seen by the trial divisor. Then multiply this number by the new root-figure, and place the product two figures to the right below the trial divisor, and add it to the trial divisor. This sum will be the true divisor. Under this divisor write the square of the last root-figure, which add to the two sums above, and the result is the next trial divisor. The true divisor being found as before directed.

Example: **Extract the cube root of 4088324799**

			4088324799 | 1599 Answer.
True divisor 1^3	=		1
Trial divisor $1^2 \times 3 = 3$			3088
	$35 \times 5 = 175$		
True divisor		475×5	2375
5^2	=	25	713324
Trial divisor		675	
	$459 \times 9 =$	4131	
		71631×9	644679
9^2	=	81	68645799
Trial divisor		=75843	
	$4779 \times 9 =$	43011	
True divisor		$=7627311 \times 9$	68645799

The square and cube roots of numbers from 1 to 500 **are** given in the fourth and fifth column of Table No. 1.

Reciprocals of Numbers.

The **Reciprocal of a Number** is another number, which when multiplied by the original **Number** will give 1 or unity as a result. In other words the **Reciprocal of a Number** is the result obtained by dividing the number into 1. The Reciprocals of Numbers will be found a great help as a substitute for Division in all ordinary calculations which are within the limits of the Table.

Example: Divide 3 by 89.

Answer: From Table No. 2 the reciprocal of 89 is found to be .011,235, this multiplied by 3, equals .033,705, which is the same result as if 3 were divided by 89.

Example: Divide 5 by 473.

Answer: From Table No. 2 the reciprocal of 473 is .002,114, this multiplied by 5, gives .010,570 as the result, which is equivalent to dividing 5 by 473.

The reciprocal of 367 is .002,724, the reciprocal of 36.7 is .02724, the reciprocal of 3.67 is .2724, and the reciprocal of .367 is 2.724.

In a like manner the reciprocal of any number within the limits of the Table may be found by simply moving the decimal point as shown.

Table No. 1 gives the Squares, Cubes, Square and Cube Roots and the Reciprocals of numbers from 1 to 500 respectively.

TABLE NO. 1—SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS AND RECIPROCALS OF NUMBERS FROM 1 TO 500.

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1	1	1	1.00000	1.00000	1.00000
2	4	8	1.41421	1.25992	.50000
3	9	27	1.73205	1.44224	.33333
4	16	64	2.00000	1.58740	.25000
5	25	125	2.23606	1.70997	.20000
6	36	216	2.44948	1.81712	.16666
7	49	343	2.64575	1.91293	.14285
8	64	512	2.82842	2.00000	.12500
9	81	729	3.00000	2.08008	.11111
10	100	1000	3.16227	2.15443	.10000
11	121	1331	3.31662	2.22398	.09090
12	144	1728	3.46410	2.28942	.08333
13	169	2197	3.60555	2.35133	.07602
14	196	2744	3.74165	2.41014	.07142
15	225	3375	3.87298	2.46621	.06666
16	256	4096	4.00000	2.51984	.06250
17	289	4913	4.12310	2.57128	.05882
18	324	5832	4.24264	2.62074	.05555
19	361	6859	4.35889	2.66840	.05263
20	400	8000	4.47213	2.71441	.05000
21	441	9621	4.58257	2.75892	.04761
22	484	10648	4.69041	2.80203	.04545
23	529	12167	4.79583	2.84386	.04347
24	576	13824	4.89897	2.88449	.04166
25	625	15625	5.00000	2.92401	.04000
26	676	17576	5.09901	2.96249	.03846
27	729	19683	5.19615	3.00000	.03703
28	784	21952	5.29150	3.03658	.03571
29	841	24389	5.38516	3.07231	.03448
30	900	27000	5.47722	3.10723	.03333
31	961	29791	5.56776	3.14138	.03225
32	1024	32768	5.65685	3.17480	.03125
33	1089	35937	5.74456	3.20753	.03030
34	1156	39304	5.83095	3.23961	.02941
35	1225	42875	5.91607	3.27106	.02857
36	1296	46656	6.00000	3.30192	.02777
37	1369	50653	6.08276	3.33222	.02702
38	1444	54872	6.16441	3.36197	.02631

No.	Square	Cube	Square Root	Cube Root	Reciprocal
39	1521	59319	6.24499	3.39121	.02564
40	1600	64000	6.32455	3.41995	.02500
41	1681	68921	6.40312	3.44821	.02439
42	1764	74088	6.48074	3.47602	.02380
43	1849	79507	6.55743	3.50339	.02325
44	1936	85184	6.63324	3.53034	.02272
45	2025	91125	6.70820	3.55689	.02222
46	2116	97336	6.78233	3.58304	.02173
47	2209	103823	6.85565	3.60882	.02127
48	2304	110592	6.92820	3.63424	.02083
49	2401	117649	7.00000	3.65930	.02040
50	2500	125000	7.07106	3.68403	.02000
51	2601	132651	7.14142	3.70842	.01960
52	2704	140608	7.21110	3.73251	.01923
53	2809	148877	7.28010	3.75628	.01886
54	2916	157464	7.34846	3.77976	.01851
55	3025	166375	7.41619	3.80295	.01818
56	3136	175616	7.48331	3.82586	.01785
57	3249	185193	7.54983	3.84850	.01754
58	3364	195112	7.61577	3.87087	.01724
59	3481	205379	7.68114	3.89299	.01694
60	3600	216000	7.74596	3.91486	.01666
61	3721	226981	7.81024	3.93649	.01639
62	3844	238328	7.87400	3.95789	.01612
63	3969	250047	7.93725	3.97905	.01587
64	4096	262144	8.00000	4.00000	.01562
65	4225	274625	8.06225	4.02072	.01538
66	4356	287496	8.12403	4.04124	.01515
67	4489	300763	8.18535	4.06154	.01492
68	4624	314432	8.24621	4.08165	.01470
69	4761	328509	8.30662	4.10156	.01449
70	4900	343000	8.36660	4.12128	.01428
71	5041	357911	8.42614	4.14081	.01408
72	5184	373248	8.48528	4.16016	.01388
73	5329	389017	8.54400	4.17933	.01369
74	5476	405224	8.60232	4.19833	.01351
75	5625	421875	8.66025	4.21716	.01333
76	5776	438976	8.71779	4.23582	.01315
77	5929	456533	8.77496	4.25432	.01298
78	6084	474552	8.83176	4.27265	.01282
79	6241	493039	8.88819	4.29084	.01265
80	6400	512000	8.94427	4.30886	.01250

No.	Square	Cube	Square Root	Cube Root	Reciprocal
81	6561	531441	9.00000	4.32674	.01234
82	6724	551368	9.05538	4.34448	.01219
83	6889	571787	9.11043	4.36207	.01204
84	7056	592704	9.16515	4.37951	.01190
85	7225	614125	9.21954	4.39682	.01176
86	7396	636056	9.27361	4.41400	.01162
87	7569	658503	9.32737	4.43104	.01149
88	7744	681472	9.38083	4.44796	.01136
89	7921	704969	9.43398	4.46474	.01123
90	8100	729000	9.48683	4.48140	.01111
91	8281	753571	9.53939	4.49794	.01098
92	8464	778688	9.59166	4.51435	.01086
93	8649	804357	9.64365	4.53065	.01075
94	8836	830584	9.69535	4.54683	.01063
95	9025	857375	9.74679	4.56290	.01052
96	9216	884736	9.79795	4.57885	.01041
97	9409	912673	9.84885	4.59470	.01030
98	9604	941192	9.89949	4.61043	.01020
99	9801	970299	9.94987	4.62606	.01010
100	10000	1000000	10.00000	4.64158	.01000
101	10201	1030301	10.04987	4.65700	.00990
102	10404	1061208	10.09950	4.67232	.00980
103	10609	1092727	10.14889	4.68754	.00970
104	10816	1124864	10.19803	4.70266	.00961
105	11025	1157625	10.24695	4.71769	.00952
106	11236	1191016	10.29563	4.73262	.00943
107	11449	1225043	10.34408	4.74745	.00934
108	11664	1259712	10.39230	4.76220	.00925
109	11881	1295029	10.44030	4.77685	.00917
110	12100	1331000	10.48808	4.79141	.00909
111	12321	1367631	10.53565	4.80589	.00900
112	12544	1404928	10.58300	4.82028	.00892
113	12769	1442897	10.63014	4.83458	.00884
114	12996	1481544	10.67707	4.84880	.00877
115	13225	1520875	10.72380	4.86294	.00869
116	13456	1560896	10.77032	4.87699	.00862
117	13689	1601613	10.81665	4.89097	.00854
118	13924	1643032	10.86278	4.90486	.00847
119	14161	1685159	10.90871	4.91868	.00840
120	14400	1728000	10.95445	4.93242	.00833
121	14641	1771561	11.00000	4.94608	.00826
122	14884	1815848	11.04536	4.95967	.00819

No.	Square	Cube	Square Root	Cube Root	Reciprocal
123	15129	1860867	11.09053	4.97318	.00813
124	15376	1906624	11.13552	4.98663	.00806
125	15625	1953125	11.18033	5.00000	.00800
126	15876	2000376	11.22497	5.01329	.00793
127	16129	2048383	11.26942	5.02652	.00787
128	16384	2097152	11.31370	5.03968	.00781
129	16641	2146689	11.35781	5.05277	.00775
130	16900	2197000	11.40175	5.06579	.00769
131	17161	2248091	11.44552	5.07875	.00763
132	17424	2299968	11.48912	5.09164	.00757
133	17689	2352637	11.53256	5.10446	.00751
134	17956	2406104	11.57583	5.11722	.00746
135	18225	2460375	11.61895	5.12992	.00740
136	18496	2515456	11.66190	5.14256	.00735
137	18769	2571353	11.70469	5.15513	.00729
138	19044	2628072	11.74734	5.16764	.00724
139	19321	2685619	11.78982	5.18010	.00719
140	19600	2744000	11.83215	5.19249	.00714
141	19881	2803221	11.87434	5.20482	.00709
142	20164	2863288	11.91637	5.21710	.00704
143	20449	2924207	11.95826	5.22932	.00699
144	20736	2985984	12.00000	5.24148	.00694
145	21025	3048625	12.04159	5.25358	.00689
146	21316	3112136	12.08304	5.26563	.00684
147	21609	3176523	12.12435	5.27763	.00680
148	21904	3241792	12.16552	5.28957	.00675
149	22201	3307949	12.20655	5.30145	.00671
150	22500	3375000	12.24744	5.31329	.00666
151	22801	3442951	12.28820	5.32507	.00662
152	23104	3511808	12.32882	5.33680	.00657
153	23409	3581577	12.36931	5.34848	.00653
154	23716	3652264	12.40967	5.36010	.00649
155	24025	3723875	12.44989	5.37168	.00645
156	24336	3796416	12.48999	5.38321	.00641
157	24649	3869893	12.52996	5.39469	.00636
158	24964	3944312	12.56980	5.40612	.00632
159	25281	4019679	12.60952	5.41750	.00628
160	25600	4096000	12.64911	5.42883	.00625
161	25921	4173281	12.68857	5.44012	.00621
162	26244	4251528	12.72792	5.45136	.00617
163	26569	4330747	12.76714	5.46255	.00613
164	26896	4410944	12.80624	5.47370	.00609

No.	Square	Cube	Square Root	Cube Root	Reciprocal
165	27225	4492125	12.84523	5.48480	.00606
166	27556	4574296	12.88409	5.49586	.00602
167	27889	4657463	12.92284	5.50687	.00598
168	28224	4741632	12.96148	5.51784	.00595
169	28561	4826809	13.00000	5.52877	.00591
170	28900	4913000	13.03840	5.53965	.00588
171	29241	5000211	13.07669	5.55049	.00584
172	29584	5088448	13.11487	5.56129	.00581
173	29929	5177717	13.15294	5.57205	.00578
174	30276	5268024	13.19090	5.58277	.00574
175	30625	5359375	13.22875	5.59344	.00571
176	30976	5451776	13.26649	5.60407	.00568
177	31329	5545233	13.30413	5.61467	.00564
178	31684	5639752	13.34166	5.62522	.00561
179	32041	5735339	13.37908	5.63574	.00558
180	32400	5832000	13.41640	5.64621	.00555
181	32761	5929741	13.45362	5.65665	.00552
182	33124	6028568	13.49073	5.66705	.00549
183	33489	6128487	13.52774	5.67741	.00546
184	33856	6229504	13.56466	5.68773	.00543
185	34225	6331625	13.60147	5.69801	.00540
186	34596	6434856	13.63818	5.70826	.00537
187	34969	6539203	13.67479	5.71847	.00534
188	35344	6644672	13.71130	5.72865	.00531
189	35721	6751269	13.74772	5.73879	.00529
190	36100	6859000	13.78404	5.74889	.00526
191	36481	6967871	13.82027	5.75896	.00523
192	36864	7077888	13.85640	5.76899	.00520
193	37249	7189057	13.89244	5.77899	.00518
194	37636	7301384	13.92838	5.78896	.00515
195	38025	7414875	13.96424	5.79889	.00512
196	38416	7529536	14.00000	5.80878	.00510
197	38809	7645373	14.03566	5.81864	.00507
198	39204	7762392	14.07124	5.82847	.00505
199	39601	7880599	14.10673	5.83827	.00502
200	40000	8000000	14.14213	5.84803	.00500
201	40401	8120601	14.17744	5.85776	.00497
202	40804	8242408	14.21267	5.86746	.00495
203	41209	8365427	14.24780	5.87713	.00492
204	41616	8489664	14.28285	5.88676	.00490
205	42025	8615125	14.31782	5.89636	.00487
206	42436	8741816	14.35270	5.90594	.00485

No.	Square	Cube	Square Root	Cube Root	Reciprocal
207	42849	8869743	14.38749	5.91548	.00483
208	43264	8998912	14.42220	5.92499	.00480
209	43681	9129329	14.45683	5.93447	.00478
210	44100	9261000	14.49137	5.94392	.00476
211	44521	9393931	14.52583	5.95334	.00473
212	44944	9528128	14.56021	5.96273	.00471
213	45369	9663597	14.59451	5.97209	.00469
214	45796	9800344	14.62873	5.98142	.00467
215	46225	9938375	14.66287	5.99072	.00465
216	46656	10077696	14.69693	6.00000	.00462
217	47089	10218313	14.73091	6.00924	.00460
218	47524	10360232	14.76482	6.01846	.00458
219	47961	10503459	14.79864	6.02765	.00456
220	48400	10648000	14.83239	6.03681	.00454
221	48841	10793861	14.86606	6.04594	.00452
222	49284	10941048	14.89966	6.05504	.00450
223	49729	11089567	14.93318	6.06412	.00448
224	50176	11239424	14.96662	6.07317	.00446
225	50625	11390625	15.00000	6.08220	.00444
226	51076	11543176	15.03329	6.09119	.00442
227	51529	11697083	15.06651	6.10017	.00440
228	51984	11852352	15.09966	6.10911	.00438
229	52441	12008989	15.13274	6.11803	.00436
230	52900	12167000	15.16575	6.12692	.00434
231	53361	12326391	15.19868	6.13579	.00432
232	53824	12487168	15.23154	6.14463	.00431
233	54289	12649337	15.26433	6.15344	.00429
234	54756	12812904	15.29705	6.16224	.00427
235	55225	12977875	15.32970	6.17100	.00425
236	55696	13144256	15.36229	6.17974	.00423
237	56169	13312053	15.39480	6.18846	.00421
238	56644	13481272	15.42724	6.19715	.00420
239	57121	13651919	15.45962	6.20582	.00418
240	57600	13824000	15.49193	6.21446	.00416
241	58081	13997521	15.52417	6.22308	.00414
242	58564	14172488	15.55634	6.23167	.00413
243	59049	14348907	15.58845	6.24025	.00411
244	59536	14526784	15.62049	6.24879	.00409
245	60025	14706125	15.65247	6.25732	.00408
246	60516	14886936	15.68438	6.26582	.00406
247	61009	15069223	15.71623	6.27430	.00404
248	61504	15252992	15.74801	6.28276	.00403

No.	Square	Cube	Square Root	Cube Root	Reciprocal
249	62001	15438249	15.77973	6.29119	.00401
250	62500	15625000	15.81138	6.29960	.00400
251	63001	15813251	15.84297	6.30799	.00398
252	63504	16003008	15.87450	6.31635	.00396
253	64009	16194277	15.90597	6.32470	.00395
254	64516	16387064	15.93737	6.33302	.00393
255	65025	16581375	15.96871	6.34132	.00392
256	65536	16777216	16.00000	6.34960	.00390
257	66049	16974593	16.03121	6.35786	.00389
258	66564	17173512	16.06237	6.36609	.00387
259	67081	17373979	16.09347	6.37431	.00386
260	67600	17576000	16.12451	6.38250	.00384
261	68121	17779581	16.15549	6.39067	.00383
262	68644	17984728	16.18641	6.39882	.00381
263	69169	18191447	16.21727	6.40695	.00380
264	69696	18399744	16.24807	6.41506	.00378
265	70225	18609625	16.27882	6.42315	.00377
266	70756	18821096	16.30950	6.43122	.00375
267	71289	19034163	16.34013	6.43927	.00374
268	71824	19248832	16.37070	6.44730	.00373
269	72361	19465109	16.40121	6.45531	.00371
270	72900	19683000	16.43167	6.46330	.00370
271	73441	19902511	16.46207	6.47127	.00369
272	73984	20123648	16.49242	6.47922	.00367
273	74529	20346417	16.52271	6.48715	.00366
274	75076	20570824	16.55294	6.49506	.00364
275	75625	20796875	16.58312	6.50295	.00363
276	76176	21024576	16.61324	6.51083	.00362
277	76729	21253933	16.64331	6.51868	.00361
278	77284	21484952	16.67333	6.52651	.00359
279	77841	21717639	16.70329	6.53433	.00358
280	78400	21952000	16.73320	6.54213	.00357
281	78961	22188041	16.76305	6.54991	.00355
282	79524	22425768	16.79285	6.55767	.00354
283	80089	22665187	16.82260	6.56541	.00353
284	80656	22906304	16.85229	6.57313	.00352
285	81225	23149125	16.88194	6.58084	.00350
286	81796	23393656	16.91153	6.58853	.00349
287	82369	23639903	16.94107	6.59620	.00348
288	82944	23887872	16.97056	6.60385	.00347
289	83521	24137569	17.00000	6.61148	.00346
290	84100	24389000	17.02938	6.61910	.00344

No.	Square	Cube	Square Root	Cube Root	Reciprocal
291	84681	24642171	17.05872	6.62670	.00343
292	85264	24897088	17.08800	6.63428	.00342
293	85849	25153757	17.11724	6.64185	.00341
294	86436	25412184	17.14642	6.64939	.00340
295	87025	25672375	17.17556	6.65693	.00338
296	87616	25934336	17.20465	6.66444	.00337
297	88209	26198073	17.23368	6.67194	.00336
298	88804	26463592	17.26267	6.67942	.00335
299	89401	26730899	17.29161	6.68688	.00334
300	90000	27000000	17.32050	6.69432	.00333
301	90601	27270901	17.34935	6.70175	.00332
302	91204	27543608	17.37814	6.70917	.00331
303	91809	27818127	17.40689	6.71657	.00330
304	92416	28094464	17.43559	6.72395	.00328
305	93025	28372625	17.46424	6.73131	.00327
306	93636	28652616	17.49285	6.73866	.00326
307	94249	28934443	17.52141	6.74599	.00325
308	94864	29218112	17.54992	6.75331	.00324
309	95481	29503629	17.57839	6.76061	.00323
310	96100	29791000	17.60681	6.76789	.00322
311	96721	30080231	17.63519	6.77516	.00321
312	97344	30371328	17.66352	6.78242	.00320
313	97969	30664297	17.69180	6.78966	.00319
314	98596	30959144	17.72004	6.79688	.00318
315	99225	31255875	17.74823	6.80409	.00317
316	99856	31554496	17.77638	6.81128	.00316
317	100489	31855013	17.80449	6.81846	.00315
318	101124	32157432	17.83255	6.82562	.00314
319	101761	32461759	17.86057	6.83277	.00313
320	102400	32768000	17.88854	6.83990	.00312
321	103041	32076161	17.91647	6.84702	.00311
322	103684	33386248	17.94435	6.85412	.00310
323	104329	33698267	17.97220	6.86121	.00309
324	104976	34012224	18.00000	6.86828	.00308
325	105625	34328125	18.02775	6.87534	,00307
326	106276	34645976	18.05547	6.88238	.00306
327	106929	34965783	18.08314	6.88941	.00305
328	107584	35287552	18.11077	6.89643	.00304
329	108241	35611289	18.13835	6.90343	.00303
330	108900	35937000	18.16590	6.91042	.00303
331	109561	36264691	18.19340	6.91739	.00302
332	110224	36594368	18.22086	6.92435	.00301

No.	Square	Cube	Square Root	Cube Root	Reciprocal
333	110889	36926037	18.24828	6.93130	.00300
334	111556	37259704	18.27566	6.93823	.00299
335	112225	37595375	18.30300	6.94514	·00298
336	112896	37933056	18.33030	6.95205	.00297
337	113569	38272753	18.35755	6.95894	.00296
338	114244	38614472	18.38477	6.96581	.00295
339	114921	38958219	18.41195	6.97268	.00294
340	115600	39304000	18.43908	6.97953	.00294
341	116281	39651821	18.46618	6.98636	.00293
342	116964	40001688	18.49324	6.99319	.00292
343	117649	40353607	18.52025	7.00000	.00291
344	118336	40707584	18.54723	7.00679	.00290
345	119025	41063625	18.57417	7.01357	.00289
346	119716	41421736	18.60107	7.02034	.00289
347	120409	41781923	18.62793	7.02710	.00288
348	121104	42144192	18.65475	7.03384	.00287
349	121801	42508549	18.68151	7.04058	.00286
350	122500	42875000	18.70828	7.04729	.00285
351	123201	43243551	18.73499	7.05400	.00284
352	123904	43614208	18.76166	7.06069	.00284
353	124609	43986977	18.78829	7.06737	.00283
354	125316	44361864	18.81488	7.07404	.00282
355	126025	44738875	18.84144	7.08069	.00281
356	126736	45118016	18.86796	7.08734	.00280
357	127449	45499293	18.89444	7.09397	.00280
358	128164	45882712	18.92088	7.10058	.00279
359	128881	46268279	18.94729	7.10719	.00278
360	129600	46656000	18.97366	7.11378	.00277
361	130321	47045881	19.00000	7.12036	.00277
362	131044	47437928	19.02629	7.12693	.00276
363	131769	47832147	19.05255	7.13349	.00275
364	132496	48228544	19.07878	7.14003	.00274
365	133225	48627125	19.10497	7.14656	.00273
366	133956	49027896	19.13112	7.15309	.00273
367	134689	49430863	19.15724	7.15959	.00272
368	135424	49836032	19.18332	7.16609	.00271
369	136161	50243409	19.20937	7.17258	.00271
370	136900	50653000	19.23538	7.17905	.00270
371	137641	51064811	19.26136	7.18551	.00269
372	138384	51478848	19.28730	7.19196	.00268
373	139129	51895117	19.31320	7.19840	.00268
374	139876	52313624	19.33907	7.20483	.00267

No.	Square	Cube	Square Root	Cube Root	Reciprocal
375	140625	52734375	19.36491	7.21124	.00266
376	141376	53157376	19.39071	7.21765	.00265
377	142129	53582633	19.41648	7.22404	.00265
378	142884	54010152	19.44222	7.23042	.00264
379	143641	54439939	19.46792	7.23679	.00263
380	144400	54872000	19.49358	7.24315	.00263
381	145161	55306341	19.51922	7.24950	.00262
382	145924	55742968	19.54482	7.25584	.00261
383	146689	56181887	19.57038	7.26216	.00261
384	147456	56623104	19.59591	7.26848	.00260
385	148225	57066625	19.62141	7.27478	.00259
386	148996	57512456	19.64688	7.28107	.00259
387	149769	57960603	19.67231	7.28736	.00258
388	150544	58411072	19.69771	7.29363	.00257
389	151321	58863869	19.72308	7.29989	.00257
390	152100	59319000	19.74841	7.30614	.00256
391	152881	59776471	19.77371	7.31238	.00255
392	153664	60236288	19.79898	7.31861	.00255
393	154449	60698457	19.82422	7.32482	.00254
394	155236	61162984	19.84943	7.33103	.00253
395	156025	61629875	19.87460	7.33723	.00253
396	156816	62099136	19.89974	7.34342	.00252
397	157609	62570773	19.92485	7.34959	.00251
398	158404	63044792	19.94993	7.35576	.00251
399	159201	63521199	19.97498	7.36191	.00250
400	160000	64000000	20.00000	7.36806	.00250
401	160801	64481201	20.02498	7.37419	.00249
402	161604	64964808	20.04993	7.38032	.00248
403	162409	65450827	20.07485	7.38643	.00248
404	163216	65939264	20.09975	7.39254	.00247
405	164025	66430125	20.12461	7.39863	.00246
406	164836	66923416	20.14944	7.40472	.00246
407	165649	67419143	20.17424	7.41079	.00245
408	166464	67917312	20.19900	7.41685	.00245
409	167281	68417929	20.22374	7.42291	.00244
410	168100	68921000	20.24845	7.42895	.00243
411	168921	69426531	20.27313	7.43499	.00243
412	169744	69934528	20.29778	7.44101	.00242
413	170569	70444997	20.32240	7.44703	.00242
414	171396	70957944	20.34698	7.45303	.00241
415	172225	71473375	20.37154	7.45903	.00240
416	173056	71991296	20.39607	7.46502	.00240

No.	Square	Cube	Square Root	Cube Root	Reciproca
417	173889	72511713	20.42057	7.47099	.00239
418	174724	73034632	20.44504	7.47696	.00239
419	175561	73560059	20.46948	7.48292	.00238
420	176400	74088000	20.49390	7.48887	.00238
421	177241	74618461	20.51828	7.49481	.00237
422	178084	75151448	20.54263	7.50074	.00236
423	178929	75686967	20.56696	7.50666	.00236
424	179776	76225024	20.59126	7.51257	.00235
425	180625	76765625	20.61552	7.51847	.00235
426	181476	77308776	20.63976	7.52436	.00234
427	182329	77854483	20.66397	7.53024	.00234
428	183184	78402752	20.68816	7.53612	.00233
429	184041	78953589	20.71231	7.54198	.00233
430	184900	79507000	20.73644	7.54784	.00232
431	185761	80062991	20.76053	7.55368	.00232
432	186624	80621568	20.78460	7.55952	.00231
433	187489	81182737	20.80865	7.56535	.00230
434	188356	81746504	20.83266	7.57117	.00230
435	189225	82312875	20.85665	7.57689	.00229
436	190096	82881856	20.88061	7.58278	.00229
437	190969	83453453	20.90454	7.58857	.00228
438	191844	84027672	20.92844	7.59436	.00228
439	192721	84604519	20.95232	7.60013	.00227
440	193600	85184000	20.97617	7.60590	.00227
441	194481	85766121	21.00000	7.61166	.00226
442	195364	86350888	21.02379	7.61741	.00226
443	196249	86938307	21.04756	7.62315	.00225
444	197136	87528384	21.07130	7.62888	.00225
445	198025	88121125	21.09502	7.63460	.00224
446	198916	88716536	21.11871	7.64032	.00224
447	199809	89314623	21.14237	7.64602	.00223
448	200704	89915392	21.16601	7.65172	.00223
449	201601	90518849	21.18962	7.65741	.00222
450	202500	91125000	21.21320	7.66309	.00222
451	203401	91733851	21.23676	7.66876	.00221
452	204304	92345408	21.26029	7.67443	.00221
453	205209	92959677	21.28379	7.68008	.00220
454	206116	93576664	21.30727	7.68573	.00220
455	207025	94196375	21.33072	7.69137	.00219
456	207936	94818816	21.35415	7.69700	.00219
457	208849	95443993	21.37755	7.70262	.00218
458	209764	96071912	21.40093	7.70823	.00218

No.	Square	Cube	Square Root	Cube Root	Reciprocal
459	210681	96702579	21.42428	7.71384	.00217
460	211600	97336000	21.44761	7.71944	.00217
461	212521	97972181	21.47091	7.72503	.00216
462	213444	98611128	21.49418	7.73061	.00216
463	214369	99252847	21.51743	7.73618	.00215
464	215296	99897344	21.54065	7.74175	.00215
465	216225	100544625	21.56385	7.74731	.00215
466	217156	101194696	21.58703	7.75286	.00214
467	218089	101847563	21.61018	7.75840	.00214
468	219024	102503232	21.63330	7.76393	.00213
469	219961	103161709	21.65640	7.76946	.00213
470	220900	103823000	21.67948	7.77498	.00212
471	221841	104487111	21.70253	7.78049	.00212
472	222784	105154048	21.72556	7.78599	.00211
473	223729	105823817	21.74856	7.79148	.00211
474	224676	106496424	21.77154	7.79697	.00210
475	225625	107171875	21.79449	7.80245	.00210
476	226576	107850176	21.81742	7.80792	.00210
477	227529	108531333	21.84032	7.81338	.00209
478	228484	109215352	21.86321	7.81884	.00209
479	229441	109902239	21.88606	7.82429	.00208
480	230400	110592000	21.90890	7.82973	.00208
481	231361	111284641	21.93171	7.83516	.00207
482	232324	111980168	21.95449	7.84059	.00207
483	233289	112678587	21.97726	7.84601	.00207
484	234256	113379904	22.00000	7.85142	.00206
485	235225	114084125	22.02271	7.85682	.00206
486	236196	114791256	22.04540	7.86222	.00205
487	237169	115501303	22.06807	7.86761	.00205
488	238144	116214272	22.09072	7.87299	.00204
489	239121	116930169	22.11334	7.87836	.00204
490	240100	117649000	22.13594	7.88373	.00204
491	241081	118370771	22.15851	7.88909	.00203
492	242064	119095488	22.18107	7.89454	.00203
493	243049	119823157	22.20360	7.89979	.00202
494	244036	120553784	22.22611	7.90512	.00202
495	245025	121287375	22.24859	7.91045	.00202
496	246016	122023936	22.27105	7.91578	.00201
497	247009	122763473	22.29349	7.92109	.00201
498	248004	123505992	22.31591	7.92640	.00200
499	249001	124251499	22.33830	7.93171	.00200
500	250000	125000000	22.36067	7.93700	.00200

Logarithms of Numbers.

Logarithms are the exponents of a series of powers and roots of numbers. The logarithm of a number is that exponent of some other number, which renders the power of the other number, which is denoted by the exponent, equal to the former. In other words the logarithm of a number is the exponent of the power to which the number must be raised to give a given base.

When the logarithms of numbers from a series in arithmetical progression, their corresponding natural numbers form a series in geometrical progression, thus:

Common logarithms	0	1	2	3	4
Natural numbers	1	10	100	1,000	10,000

Natural logarithms were the invention of Lord Napier. Common logarithms, the kind in general use, were invented by Prof. Briggs of Oxford, England. Logarithms are extremely useful in shortening the labor of mathematical calculations.

The addition and subtraction of common logarithms correspond to the multiplication and division of their natural numbers.

In a like manner, involution is performed by multiplying the common logarithm of any number by the number denoting the required power, and evolution by dividing the common logarithm of the number denoting the required root.

The common logarithm of a number consists of two parts, an integral part or whole number, which is called the characteristic, and a decimal called the mantissa.

To find the common logarithm of a given number from Table No. 2, proceed as follows:

The first two figures of the number will be found in the vertical column to the extreme left in the table, and the third figure of the number in the horizontal row at either the top or bottom of the table. Having found the first two figures of the number, always neglecting the decimal, pass along the line opposite these figures until the column headed by the third figure of the number is reached. The number thus found will be the mantissa or decimal fraction of the logarithm. The characteristic will depend upon the number of integers or whole numbers, less one, in the number, counting from the left of the decimal point. If the decimal point be entirely to the left of the number, the characteristic is obtained by counting the number of cyphers before the first number, to the right and adjacent to the decimal point.

Example: Find the common logarithm of 5.06 from Table No. 2.

Answer: In the row of figures opposite 50 and in the column under 6, the mantissa of the logarithm is .7042. Counting from the decimal place of the number to the left, the characteristic will be one less than the number of figures to the right of the decimal point, which is, in this case 1, and 1 minus 1 equals zero, which is the characteristic of the mantissa .7042, the complete logarithm of 5.06 will then be 0.7042.

The logarithm of 0.506	is	— 1.7042
The logarithm of 5.06	is	0.7042
The logarithm of 50.6	is	1.7042
The logarithm of 506	is	2.7042

To find the number corresponding to a given logarithm: As the mantissa of the given logarithm is not usually found in the table, select the four figures corresponding nearest to the given mantissa. The first two figures of the number will be found in the column marked "No." at the left of the row in which is the mantissa elected, and the third or last figure of the number at the top or bottom of the vertical row of figures.

Example: Find the number from Table No. 2 corresponding to logarithm 1.0334.

Answer: The first two figures of the number corresponding to the mantissa .0334 are 10, and at the top of the vertical column the third figures given as 8, making the three figures 108. As the characteristic is 1 therefore the actual number is 10.8.

The number corresponding to — 1.0334 is .108
The number corresponding to 0.0334 is 1.08
The number corresponding to 1.0334 is 10.8
The number corresponding to 2.0334 is 108

To multiply one or more numbers together, add the common logarithms of the numbers together, the sum will be the logarithm of the required number.

To divide a number by one or more numbers, subtract the sum of the common logarithms of the numbers from the logarithms of the number to be divided.

The mantissa of the common logarithm of 6 is the same as the mantissa of 60 or 600, the characteristic only being changed thus:

Common logarithm of .600 = — 1.7782
Common logarithm of 6.00 = 0.7782
Common logarithm of 60.0 = 1.7782
Common logarithm of 600 = 2.7782

Table No. 2 gives the common logarithms of numbers from 100 to 999.

Note. A decimal point must always be prefixed to the mantissa of a logarithm obtained from the table, before affixing the characteristic.

Table No. 2.

Logarithms of Numbers from 100 to 999.

No.	0	1	2	3	4	5	6	7	8	9	Diff.
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	40
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	37
12	0792	0828	0865	0899	0934	0969	1004	1038	0172	1106	33
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	31
14	1561	1492	1523	1553	1548	1614	1644	1673	1703	1732	29
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	27
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	25
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	24
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	23
19	2788	2810	2833	2856	2878	2900	2923	2459	2967	2989	21
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	21
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	20
22	3424	3444	3464	3483	3502	3522	3541	3460	3579	3598	19
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	18
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	17
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	17
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	16
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	16
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	15
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	14
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	14
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	13
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	13
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	13
No.	0	1	2	3	4	5	6	7	8	9	Diff.

TABLE No. 2—CONTINUED.

Logarithms of Numbers from 100 to 999.

No.	0	1	2	3	4	5	6	7	8	9	Diff.
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	13
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	12
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	12
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	12
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	12
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	12
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	11
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	10
42	6232	6234	6253	6263	6274	6284	6294	6304	6314	6325	10
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	10
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	10
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	10
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	9
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	9
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	9
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	9
50	6990	6998	6007	7016	7024	7033	7042	7050	7059	7067	9
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	8
52	7160	7186	7177	7185	7193	7202	7210	7218	7226	7235	8
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	8
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	8
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	8
56	7482	7490	7497	7505	7512	7520	7528	7536	7543	7551	8
No.	0	1	2	3	4	5	6	7	8	9	Diff.

TABLE NO. 2—CONTINUED.

Logarithms of Numbers from 100 to 999.

No.	0	1	2	3	4	5	6	7	8	9	Diff.
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	8
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	8
60	7782	7789	7796	7803	7710	7818	7825	7832	7839	7846	7
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	7
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	7
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	7
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	7
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	6
68	8325	8331	8338	8334	8351	8357	8363	8370	8376	8382	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	7
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	6
72	8573	8579	8585	8591	8597	8503	8609	8615	8621	8627	6
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	6
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	6
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	6
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	6
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	6
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	6
No.	0	1	2	3	4	5	6	7	8	9	Diff.

TABLE No. 2—CONTINUED.

Logarithms of Numbers from 100 to 999.

No.	0	1	2	3	4	5	6	7	8	9	Diff.
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	6
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	5
86	9345	9350	9355	9460	9465	9469	9474	9479	9484	9489	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	5
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	5
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	5
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	5
93	9685	9689	9694	9699	9603	9701	9713	9717	9722	9724	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	4
95	9777	9782	9786	9790	9795	9800	9805	9809	9814	9818	5
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	5
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	4
No.	0	1	2	3	4	5	6	7	8	9	Diff.

PRACTICAL GEOMETRY

PRACTICAL GEOMETRY.

To bisect a straight line—Fig. 1. Let BC be the straight line to be bisected. With any convenient radius greater than AB or AC describe arcs cutting each other at D and E. A line drawn through D and E will bisect or divide the line BC into two equal parts.

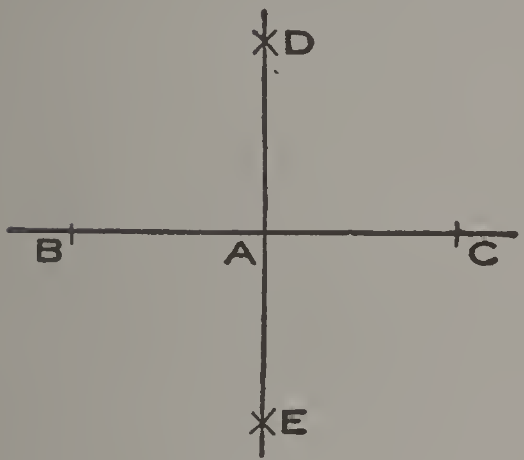


Fig. 1.

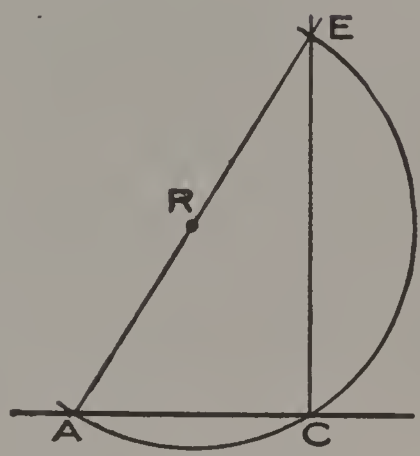


Fig. 2.

To erect a perpendicular line at or near the end of a straight line—Fig 2. With any convenient radius and at any distance from the line AC, describe an arc of a circle as ACE, cutting the line at A and C. Through the center R of the circle draw the line ARE, cutting the arc at point E. A line drawn from C to E will be the required perpendicular.

To divide a straight line into any number of equal parts—Fig. 3. Let AB be the straight line to be divided into a certain number of equal parts: From the points A and B, draw two parallel lines AD and BC, at any convenient angle with the line AB. Upon AD and BC set off one less than the number of equal parts required, as A-1, 1-2, 2-D, etc. Join C-1, 2-2, 1-D, the line AB will then be divided into the required number of equal parts.

To find the length of an arc of a circle—Fig. 4. Divide the chord AC of the arc into four equal parts as shown.

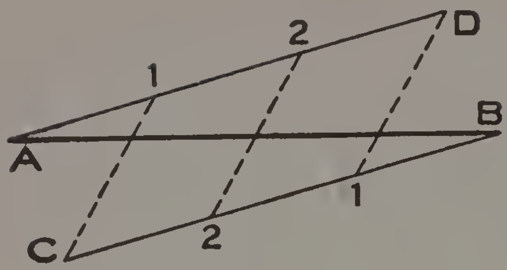


Fig. 3.

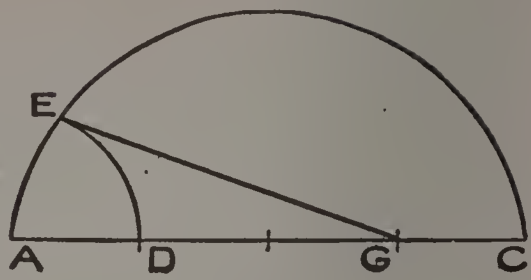


Fig. 4.

With the radius AD equal to one-fourth of the chord of the arc and with A as the center describe the arc DE. Draw the line EG and twice its length will be the length of the arc AEC.

To draw radial lines from the circumference of a circle when the center is inaccessible—Fig. 5. Divide the circumference into any desired number of parts as AB, BC, CD, DE. Then with a radius greater than the length of one

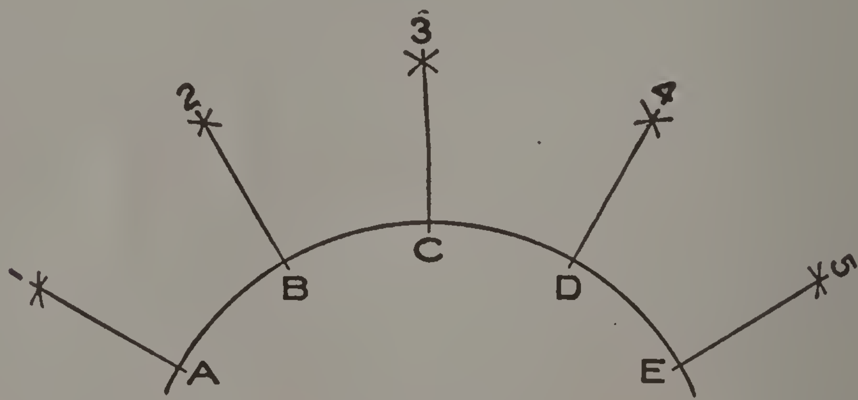


Fig. 5.

part, describe arcs cutting each other as A-2, C-2, B-3, D-3, etc, also B-1, D-5. Describe the end arcs A-1, E-5 with a radius equal to B-2. Lines joining A-1, B-2, C-3, D-4 and E-5 will all be radial.

To inscribe any regular polygon in a circle—Fig. 6. Divide the diameter AB of the circle into as many equal parts as the polygon is to have sides. With the points A and B as centers and radius AB, describe arcs cutting each other at C. Draw the line CE through the second point of division of the diameter of AB, intersecting the circumference of the circle D. A line drawn from B to D is one of the sides of the polygon.

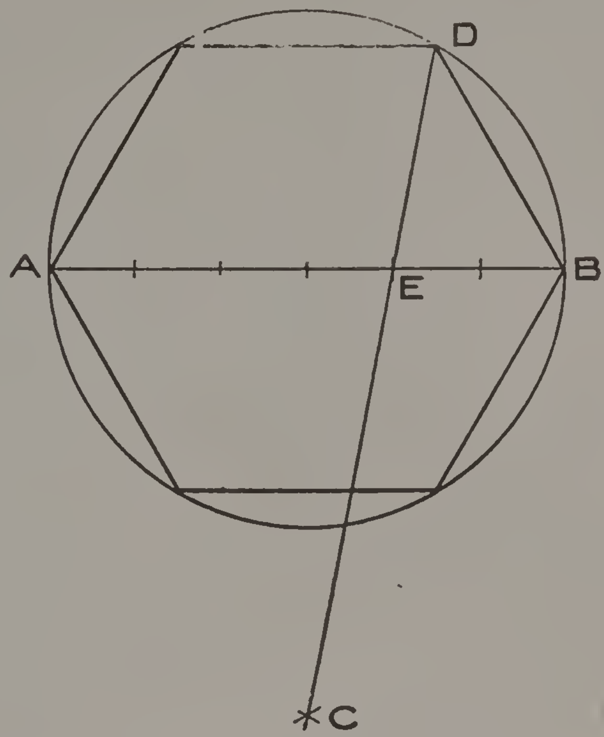


Fig. 6.

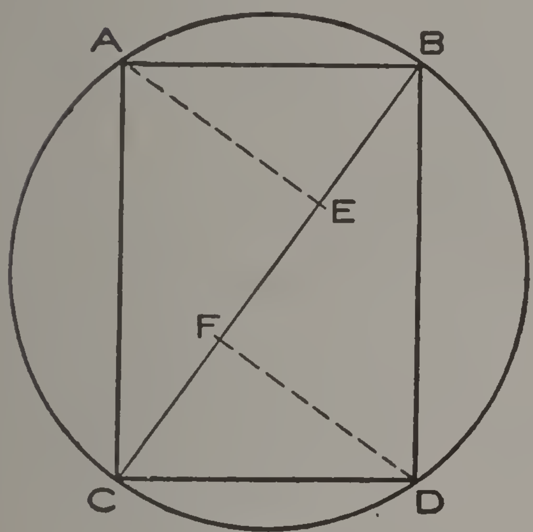


Fig. 7.

To cut a beam of the strongest shape from a circular section—Fig. 7. Divide any diameter CB of the circle into three equal parts as CF, FE and EB. At E and F erect perpendiculars EA and FD on opposite sides of the diameter CB. Join AB, BD, DC and CF. The rectangle ABCD will be the required shape of the beam.

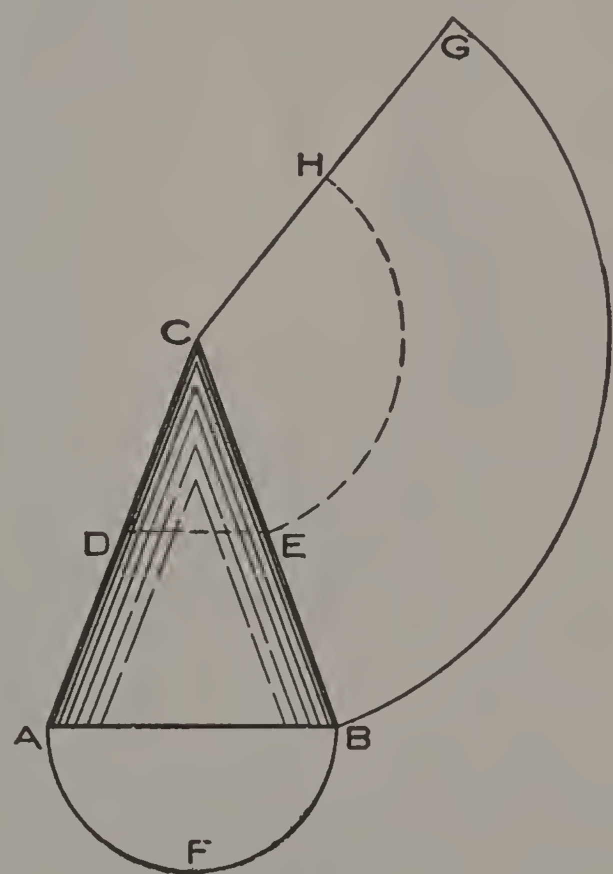


Fig. 8.

To develop the surface of a cone or the frustum of a cone—Fig. 8. Let ABC represent the cone and DEAB the frustum of the cone. On the base AB of the cone describe the semicircle AFB. With C as a center and radius CB, describe the arc BG. Make BG equal to twice the length of AFB and join CG. The sector CBG will be required surface of the cone. With center C and radius CE draw the arc EH, intersecting the line CG at H. The shape EHBG will be the required surface of the frustum of the cone.

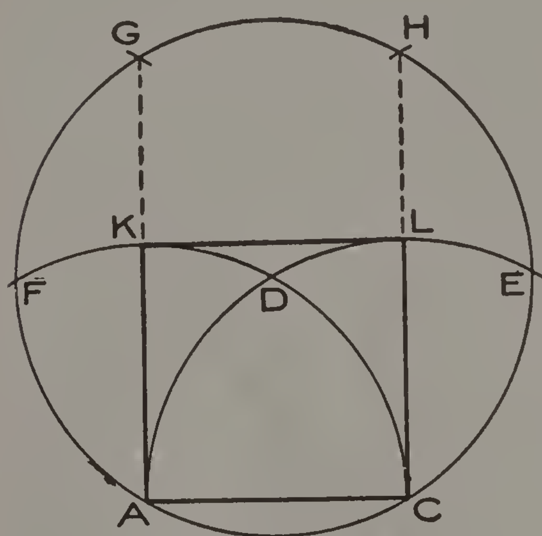


Fig. 9.

To construct a square upon a straight line of given length—Fig. 9. With A and C as centers and radius AC, describe the arcs AF and AE, cutting each other at D. With center D and radius AC describe the circle ACEHGF and with the same radius and centers E and F, describe the arcs EH, FG. Draw the lines AG, CH and KL, which completes the square required.

To construct a square equal in area to a given triangle—Fig. 10. Let ABC be the given triangle: Let fall the perpendicular BD, produce the line CA at A and make AE equal to half the perpendicular height BD. Bisect CE at F and describe the semicircle CGE. Erect the perpendicular, AG at G and this will be one of the sides of the required square AGHM.

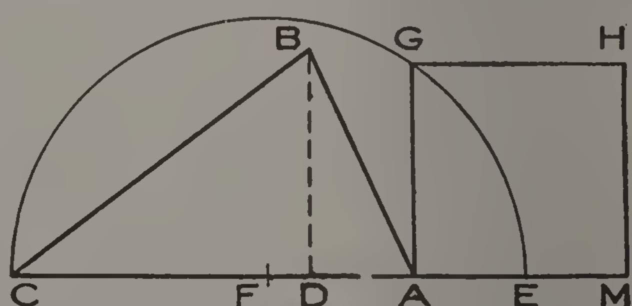


Fig. 10.

To construct a square equal in area to a given rectangle—Fig. 11. Produce the base AB of the rectangle ABGH at A and make AC equal to AG. Bisect CB and D and describe the semicircle AEB. Produce the line AG until it intersects the circumference of the semicircle at E, then AE is one side of the required square AELK.

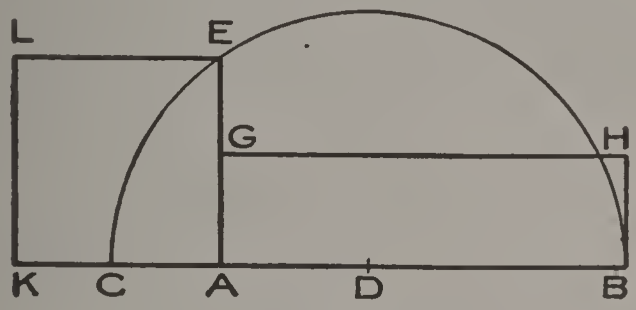


Fig. 11.

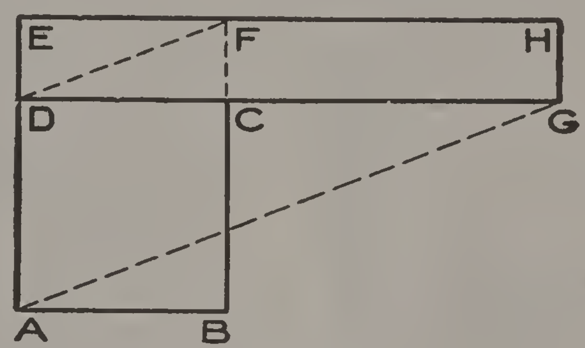


Fig. 12.

To find the length of a rectangle equal in area to a given square when the width of the rectangle is given—Fig. 12. Let ABCD be the given square and DE the width of the rectangle whose length is required. From E draw EH parallel to DC and produce DC to G and BC to F. Join DF and draw AG parallel to DF, cutting DC produced at G. Draw GH parallel to DE and DEGH is the required rectangle.

To divide any triangle into two parts of equal area—Fig. 13. Let ABC be the given triangle: Bisect one of its sides AB at D and describe the semicircle AEB. At D erect the perpendicular DE and with center B and radius

BE describe the arc EF which intersects the line AB at F. At F draw the line AG parallel at AC, this divides the triangle into two parts of equal area.

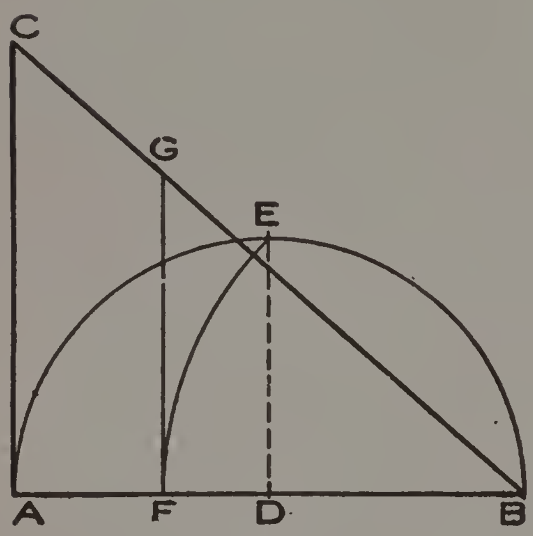


Fig. 13.

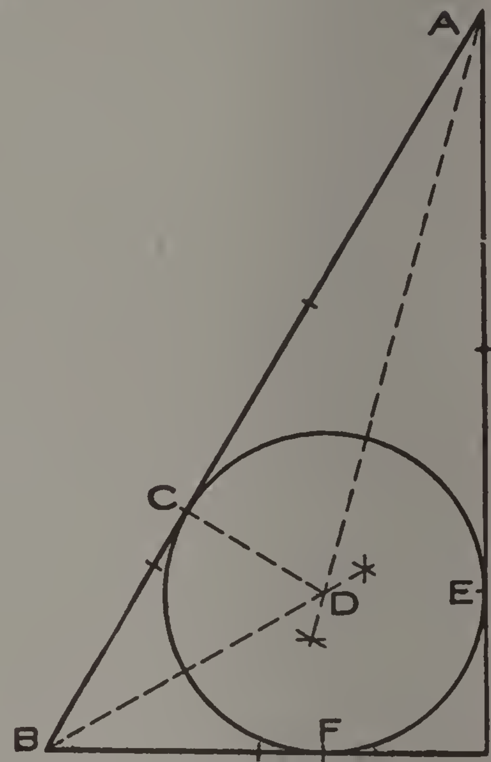


Fig. 14.

To inscribe a circle of the greatest possible diameter in a given triangle—Fig. 14. Bisect the angles A and B, and draw the lines AD, BD which intersect each other at D. From D draw the line CD perpendicular to AB. Then CB will be the radius of the required circle CEF.

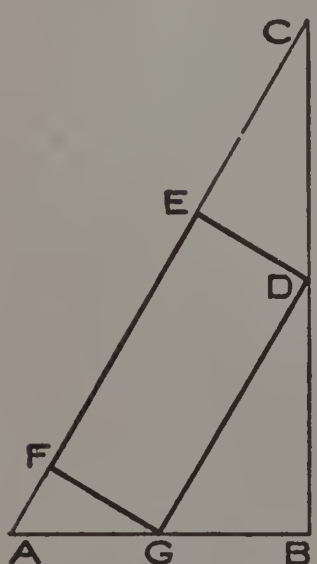


Fig. 15.

To construct a rectangle of the greatest possible area in a given triangle—Fig. 15. Let ABC be the given triangle: Bisect the sides AB and BC at G and F. Draw the line GD and from the points G and D, draw the lines GF and DE perpendicular to GD, ther **EFGD** is the required rectangle.

To construct a rectangle equal in area to a given triangle —Fig. 16. Let ABC be the given triangle: Bisect the base AB of the triangle at D and erect the perpendiculars DE and BF at D and B. Through C draw the line ECF intersecting the perpendiculars DE and BE at E and F. Then BDEF is the required rectangle.

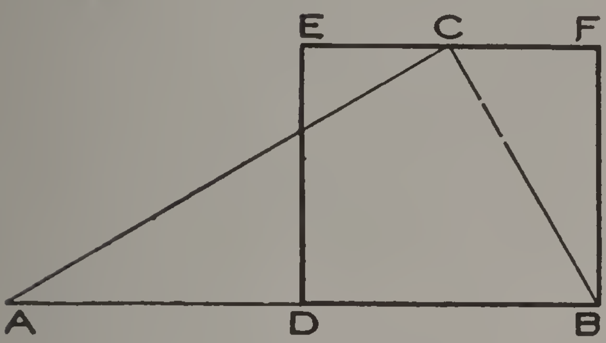


Fig. 16.

To construct a triangle equal in area to a given parallelogram—Fig. 17. Let ABCD be the given parallelogram: Produce the line AB at B and make BE equal to AB. Joint the points A and C and ACE will be the triangle required.

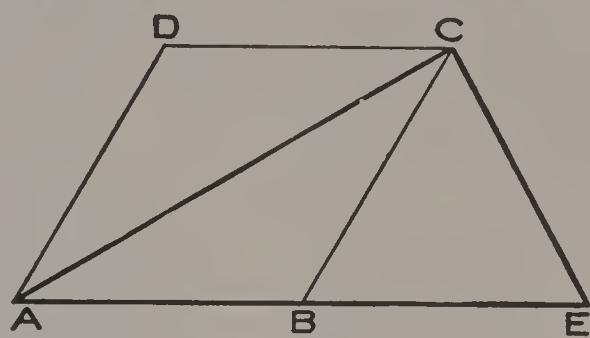


Fig. 17.

To construct a square equal in area to a given circle— Fig. 18. Let ACBD be the given circle: Draw the diameters AB and CD at right angles to each other, then bisect the half diameter or radius DB at E and draw the line CEF also from the point F draw the line FL, parallel to BA. At the points C and F erect the perpendiculars CH and FG, equal in length to CF. Join HG, then CFGH is the required square. The dotted line FL is equal to one-fourth the circle ACBD.

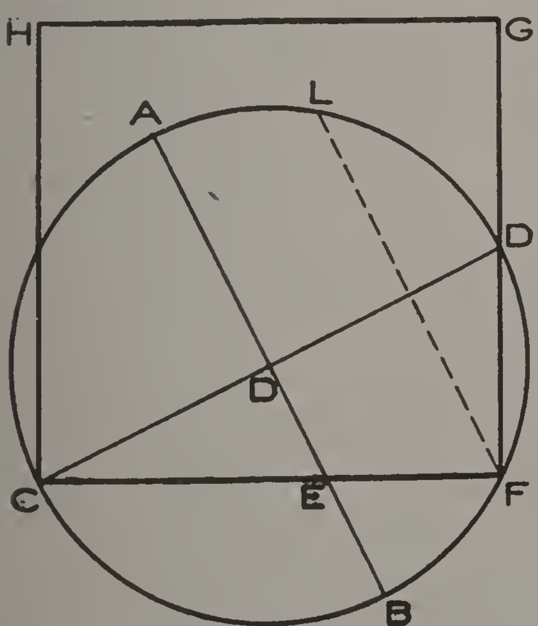


Fig. 18.

To inscribe a square within a given circle—Fig. 19. Let ADBC be the given circle: Draw the diameters AB and CD at right angles to each other. Join AD, DB and CA, then ACBD is the inscribed square.

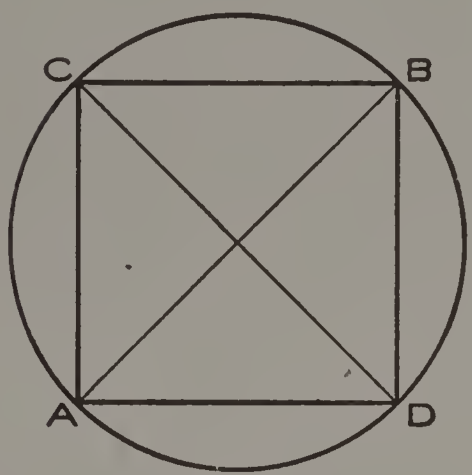


Fig. 19.

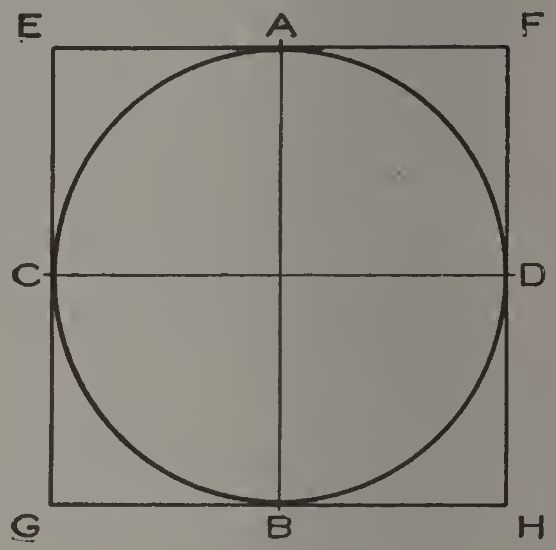


Fig. 20.

To describe a square without a given circle—Fig. 20. Draw the diameters AB and CD at right angles to each other. Through A and B draw the lines EF and GH, parallel to CD, also draw the lines EG and FH through the points C and D and parallel to AB, this completes the required square EFGH.

To construct an octagon in a given square—Fig. 21. Let ABCD be the given square: Draw the diagonal lines AC and BD, which intersect each other at the point O. With a radius equal to AO or OC, describe the arcs EF, GH, IK and LM. Connect the points EK, LG, FI and HM, then GFIHMKEL is the required octagon.

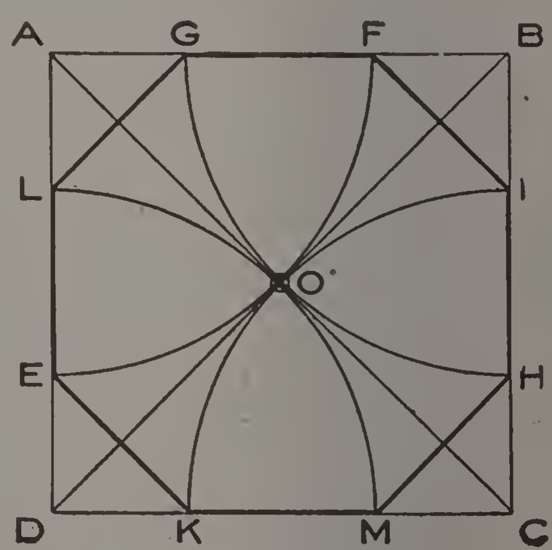


Fig. 21.

To describe an octagon about a given circle—Fig. 22. Let ACBD be the given circle: Draw the diameters AB and CD at right angles to each other. With any convenient radius and centers A, C, B and D describe arcs intersecting each other at E, H, F and G. Join EF and GH which form two additional diameters. At the points AB and CD draw the lines KL, PR, MN and ST, parallel with the diameters CD and AB respectively. At the points of intersection of the circumference of the circle by the lines EF and GH, draw the lines KP, RM, NT and SL parallel with the lines EF and HG respectively, then PRMNTSLK is the required octagon.

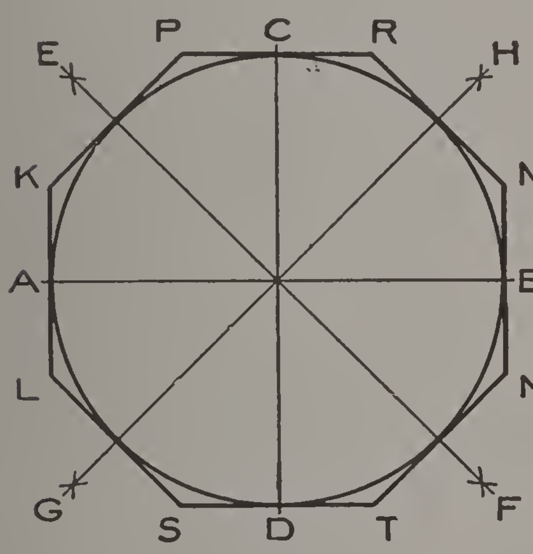


Fig. 22.

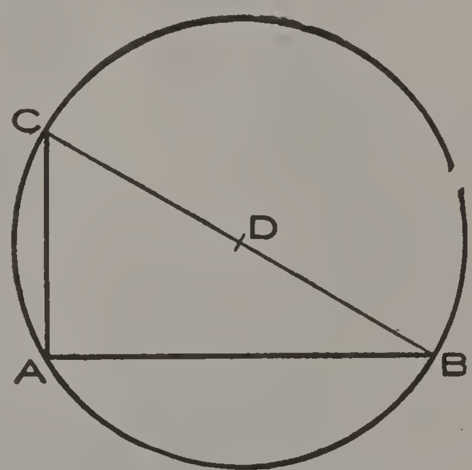


Fig. 23.

To construct a circle equal in area to two given circles —Fig. 23. Let AB and AC equal the diameters of the given circles: Erect AC at A and at right angles to AB. Connect B and C, then bisect the line BC at D and describe the circle ACB which is the circle required and is equal in area to the two given circles.

To construct a square equal in area to two given squares —Fig. 24. Let AC and AD be the length of the sides of the given squares: Make AD perpendicular to AC and connect DC, then DC is one of the sides of the square DCEG which is equal to the two given squares.

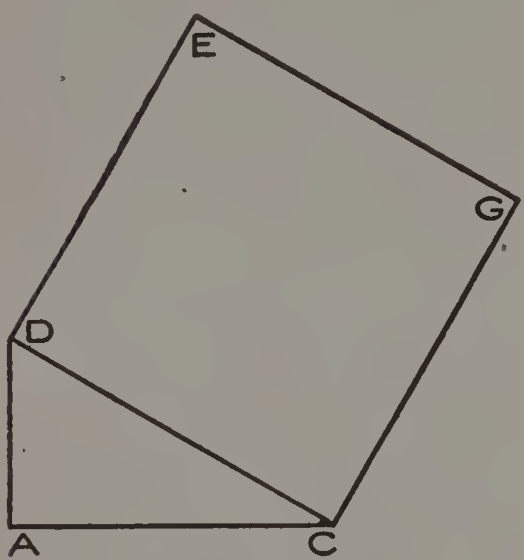


Fig. 24.

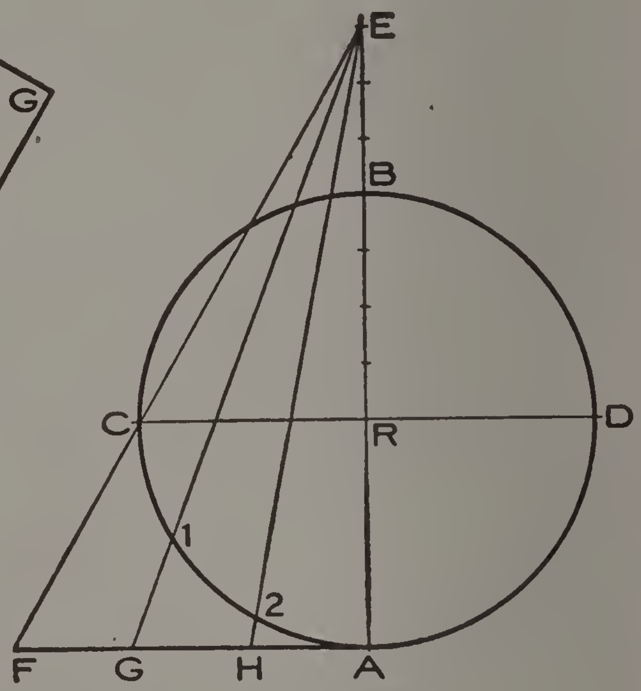


Fig. 25.

To draw a straight line equal in length to a given portion of the circumference of a circle—Fig. 25. Let ACBD be the given circle: Draw the diameters AB and CD at right angles with each other. Divide the radius RB into four equal parts. Produce the diameter AB at B and make BE equal to three of the four parts of RB. At A draw the line AF parallel to CD and then draw the line ECF which is to one-fourth of the circumference of the circle ACBD. If lines be drawn from E through points in the circumference of the circle as 1 and 2, meeting the line AF at G and H, then C-1, 1-2 and 2-A will equal FG, GH and HA respectively.

To inscribe a hexagon in a given circle—Fig. 26. Draw a diameter of the circle as AB: With centers A and B and radius AC or BG, describe arcs cutting the circumference of the circle at D, E, F and G. Join EF, FB, BG, GD, DA and AE, this gives the required hexagon.

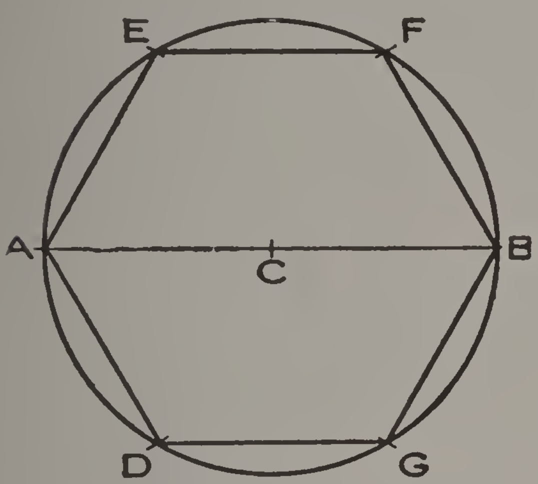


Fig. 26.

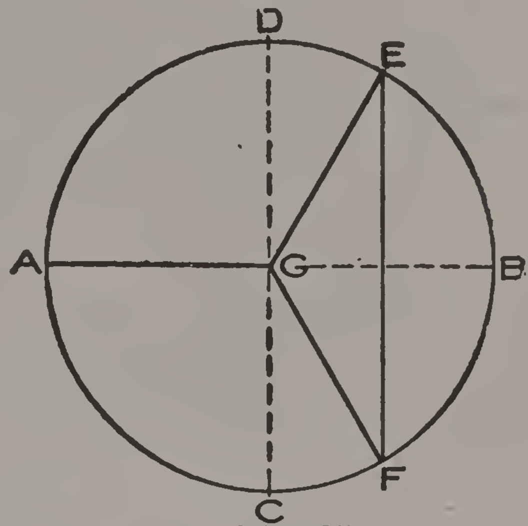


Fig. 27.

To find the correct position of an eccentric in relation to the crank, the travel of the slide valve being given—Fig. 27. Draw the line AB equal to the travel of the valve and with center G describe a circle ADBC. The line AG represents the position of the crank at the beginning of the piston stroke. Draw the diameter CD perpendicular to AB, then draw the line EF, which should be equal to the sum of the lap and lead of the valve. Connect EG and FG, and E will be correct position for the forward eccentric and F the correct position for the backward eccentric.

To lay out the throw of an eccentric for operating a slide-valve—Fig. 28. The throw of an eccentric is equal to the distance between the center of the shaft and the center of the eccentric, as at AB. The travel of the valve necessary to open the port its full width, is equal to twice the sum of the width of the port and the lap of the valve.

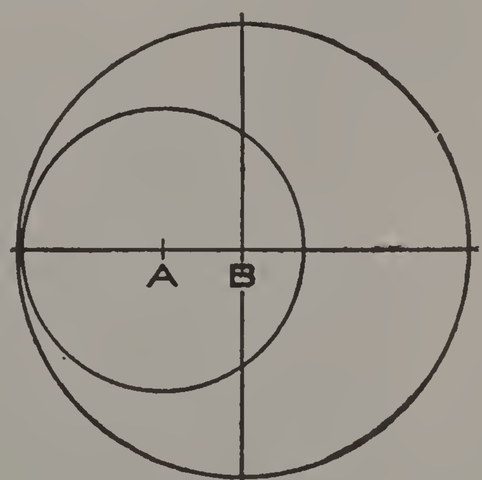


Fig. 28.

To describe a cycloid, the diameter of the generating circle being given—Fig. 29. Let BD be the generating circle: Draw the line ABC equal in length to the circumference of the generating circle. Divide the circumference of the generating circle into 12 parts as shown. Draw lines from the points of division, 1, 2, 3, etc., of the circumference of the generating circle parallel to the line ABC and on both sides of the circle. Lay off one division of the generating circle on the lines 5 and 7, two divisions on the lines 4 and 8, three divisions on the lines 3 and 9, four divisions on the lines 2 and 10, and five divisions on the lines 1 and 11. A line traced through the points thus obtained will be the cycloid curve required.

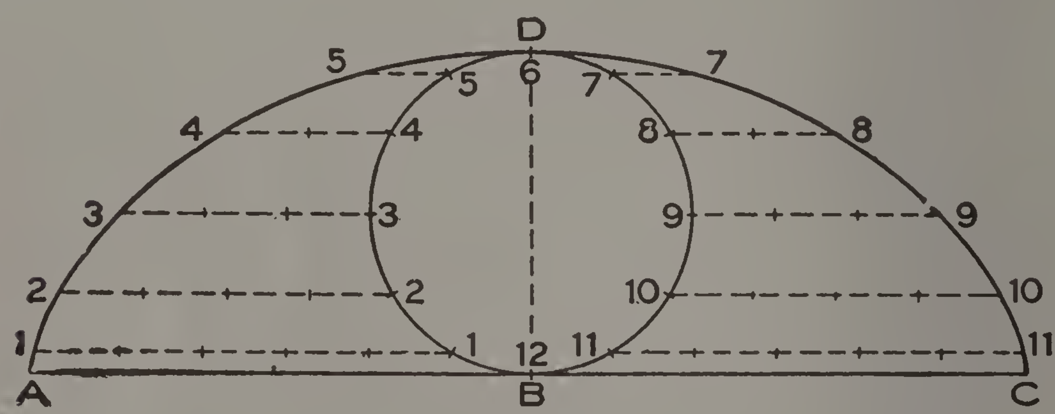


Fig. 29.

To develop a spiral with uniform spacing—Fig. 30. Divide the line BE into as many equal parts as there are required turns in the spiral. Then subdivide one of these spaces into four equal parts. Produce the line BE to 4, making the extension E-4 equal to two of the subdivisions. At 1 draw the line 1-D, lay off 1-2 equal to one of the subdivisions. At 2 draw 2-A perpendicular to 1-D and at 3 in 2-A draw 3-C, etc. With center 1 and raduis 1-B describe the arc BD, with center 2 and radius 2-D describe the arc DA, with center 3 and radius 3-A, etc. until the spiral is completed. If carefully laid out the spiral should terminate at E as shown in the drawing.

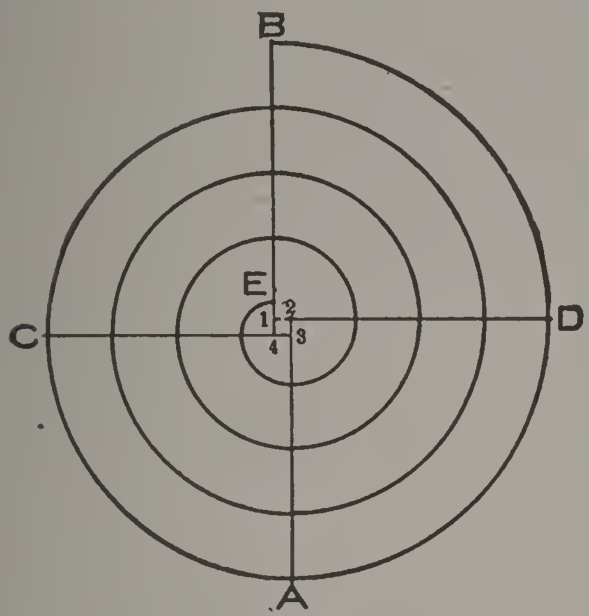


Fig. 30.

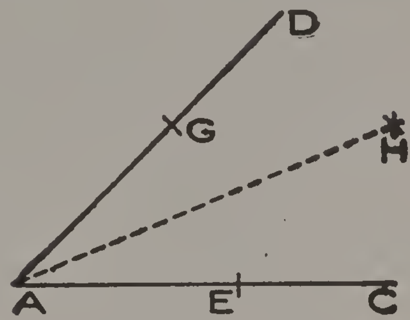


Fig. 31.

To bisect a given angle, that is to divide it into two equal parts—Fig. 31. Let CAD be the angle to be bisected. With any convenient radius describe equal arcs, cutting AC and AD in E and G respectively. With the points E and C as centers and with any radius greater than EG, describe equal arcs intersecting each other at H. Join the points and H and the angle CAD is bisected as required.

To construct a 90° angle or a right-angle—Fig. 32. Draw the line AC of any convenient length and on AC mark off any distance AE. With centers A and E and radius AE, describe arcs cutting at F and with F as a center and radius FA describe the arcs AGD. With radius FA mark off the distances AG and GD on the arc AGD. Join the points D and A and the angle DAC is equal to 90°.

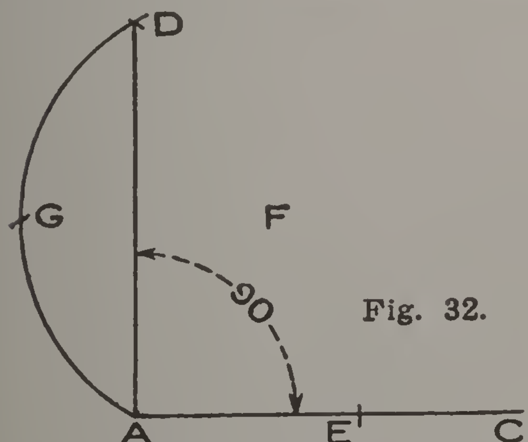


Fig. 32.

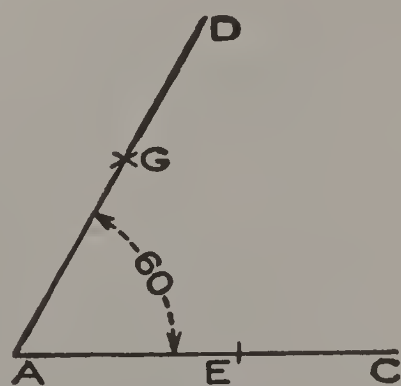


Fig. 33.

To construct a 60° angle—Fig. 33. Draw the line AC as before and mark off the distance AE. With centers A and

E and radius AE, describe arcs cutting at G. Draw the line AD from the point G through C and DAC is the required 60° angle.

To construct a 45° angle—Fig. 34. Upon the line AC locate the point E, at any suitable distance from A. With centers A and E and radius AE, describe arcs cutting each other at F. Draw the line EFG and make the distance FG, equal to FE. Join the points AG, and on the line AG lay off AH equal to AE. With any suitable radius greater than the distance EH, and with centers E and H, describe arcs cutting each other in L. The line AD drawn from the point A through L completes the 45° angle.

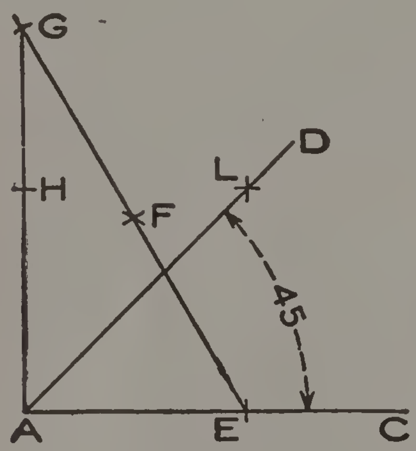


Fig. 34.

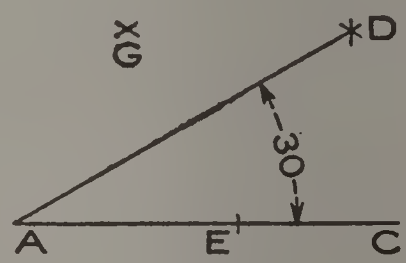


Fig. 35.

To construct a 30° angle—Fig. 35. Draw the line AC and mark off any distance AE, with centers A and E and radius AE describe arcs cutting each other at G. With any radius greater than the distance EG and with centers E and G describe arcs cutting each other at D, draw the line AD and this completes the 30° angle required.

MENSURATION

MENSURATION OF PLANE SURFACES.

To find the area of a circle—Fig. 36. Multiply the square of the diameter by .7854.

To find the circumference of a circle. Multiply the diameter by 3.1416.

Circle: Area = $.7854D^2$
Circ. = 3.1416D

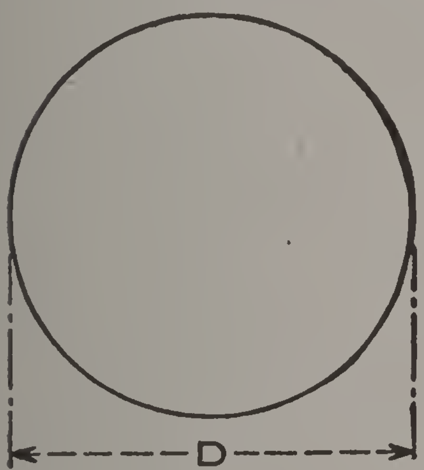


Fig. 36.

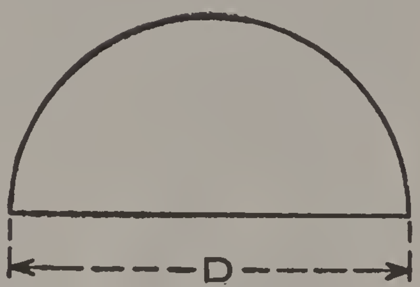


Fig. 37.

To find the area of a semi-circle—Fig. 37. Multiply the square of the diameter by .3927.

To find the circumference of a semi-circle. Multiply the diameter by 2.5708.

Semi-circle: Area = $.3927D^2$
Circ. = 2.5708D

To find the area of an annular ring—Fig. 38. From the area of the outer circle subtract the area of the inner circle, the result will be the area of the annular ring.

To find the outer circumference of an annular ring. Multiply the outer diameter by 3.1416.

To find the inner circumference of an annular ring. Multiply the inner diameter by 3.1416.

Annular ring: Area = .7854 $(D^2—H^2)$

Out. circ. = 3.1416 D
Inn. circ. = 3.1416 H

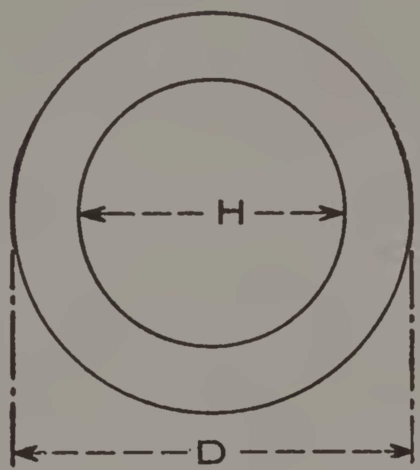


Fig. 38.

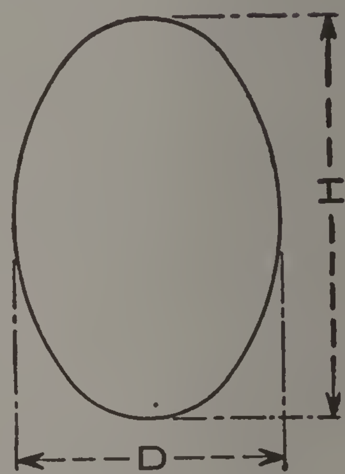


Fig. 39.

To find the area of an ellipse.—Fig. 39. Multiply the long diameter by the short diameter and by .7854.

To find the area of a flat-oval—Fig. 40. Multiply the sum of the long and short distance by 1.5708.

Ellipse: Area=.7854 (D×H)
Circ.=1.5708 (D×H)

To find the area of a flat-oval—Fig. 40. Multiply the length by the width and substract .214 times the square of the width from the result.

To find the circumference of a flat-oval. The circumference of a flat-oval is equal to twice its length plus 1.142 times its width.

Flat-oval: Area = D (H—0.214D)
Circ.=2 (H×0.571D)

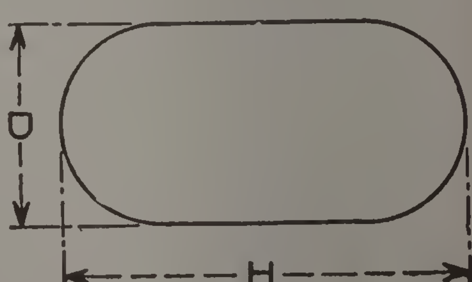


Fig. 40.

To find the area of a parabola—Fig. 41. Multiply the base by the height and by .667.

Parabola: Area = .667 (D×H)

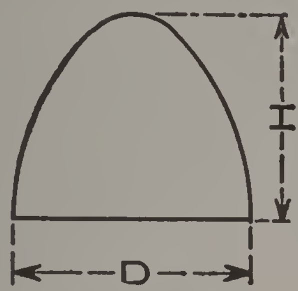


Fig. 41.

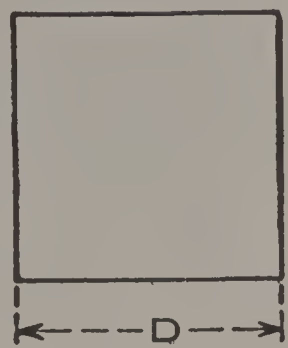


Fig. 42.

To find the area of a square—Fig. 42. Multiply the length by the width or in other words the area is equal to square of the diameter.

To find the circumference of a square. The circumference of a square is equal to the sum of the lengths of the sides.

Square: Area = D^2
Circ. = 4D

To find the area of a rectangle—Fig. 43. Multiply the length by the width, the result is the area of the rectangle.

To find the circumference of a rectangle. The circumference of a rectangle is equal to twice the sum of the length and width.

Rectangle: Area = D×H.
Circ. = 2(D×H)

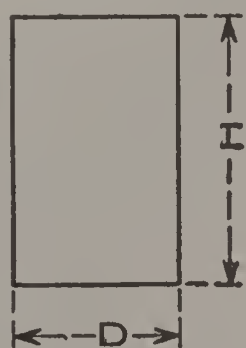


Fig. 43.

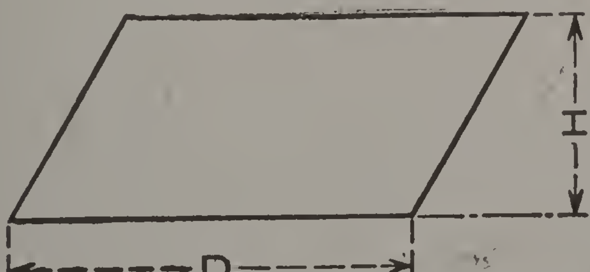


Fig. 44.

To find the area of a parallelogram—Fig. 44. Multiply the base by the perpendicular height.

Parallelogram: Area $= D \times H$

To find the area of a trapezoid—Fig. 45. Multiply half the sum of the two parallel sides by the perpendicular distance between the sides.

Trapezoid: Area $= \frac{(HE+D)}{2}$

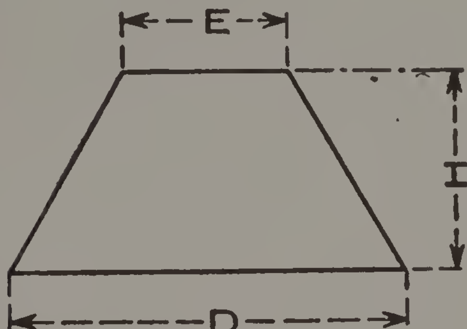


Fig. 45.

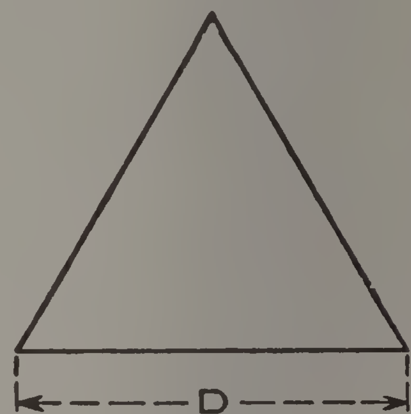


Fig. 46.

To find the area of an equilateral triangle—Fig. 46. The area of an equilateral triangle is equal to the square of one side multipled. by .433.

To find the circumference of an equilateral triangle. The circumference of an equilateral triangle is equal to the sum of the length of the sides.

Equilateral triangle: Area $= .433D^2$
Circ. $= 3D$

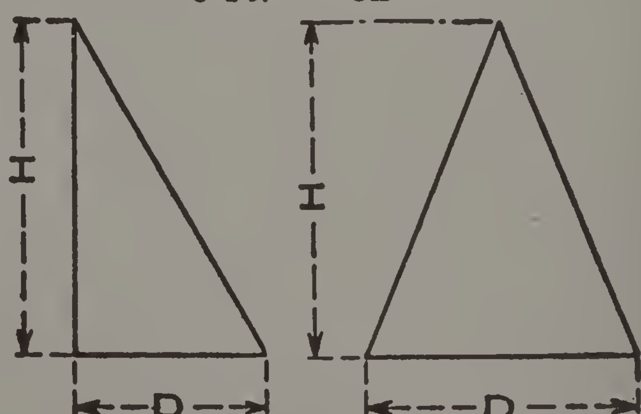


Fig. 47.

To find the area of a right-angle or an isosceles triangle —Fig. 47. Multiply the base by half the perpendicular height.

To find the circumference of a right-angle or an isosceles triangle:

Right angle or isosceles triangle:

$$\text{Area} = \frac{D \times H}{2}$$

$$\text{Circ.} = \sqrt{(4H^2 + D^2)} + D$$

To find the area of an hexagon—Fig. 48. Multiply the square of one side by 2.598.

To find the circumference of a hexagon: The circumference of a hexagon is equal to the sum of the length of the sides.

Hexagon: $\text{Area} = 2.598S^2$

$\text{Circ.} = 6S$

$D = 1.732\,S$

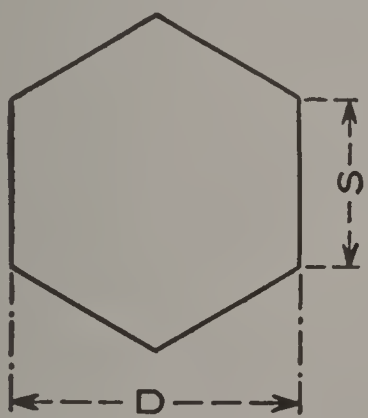


Fig. 48.

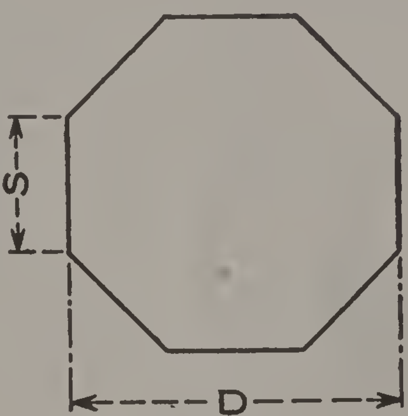


Fig. 49.

To find the area of an octagon—Fig. 49. Multiply the square of the short diameter by .828.

To find the circumference of an octagon. The circumference of an octagon is equal to the sum of the length of the sides.

Octagon: $\text{Area} = .828D^2$

$\text{Circ.} = 8S$

$S = .414D$

To find the area of any regular polygon—Fig. 50. Multiply half the sum of the sides by the perpendicular distance from the center of one of the sides.

To find the circumference of any regular polygon. The circumference of any polygon is equal to the sum of the length of the sides.

Polygon: $\text{Area} = \frac{\text{No. of sides} \times D \times P}{2}$

Circ. = No. of sides × D
D = Length of one side.
P = Perpendicular distance from the center to one side.

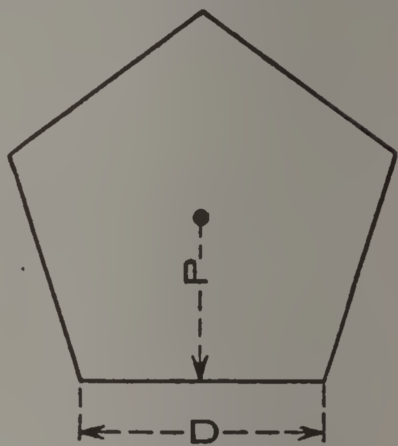


Fig. 50.

MENSURATION OF VOLUME AND SURFACE OF SOLIDS.

To find the cubic contents of a sphere—Fig. 51. Multiply the cubic of the diameter by .5236.

To find the superficial area of a sphere. Multiply the square of the diameter by 3.1416.

Sphere. Cubic contents $= .5236D^3$

Superficial area $= 3.1416D^2$

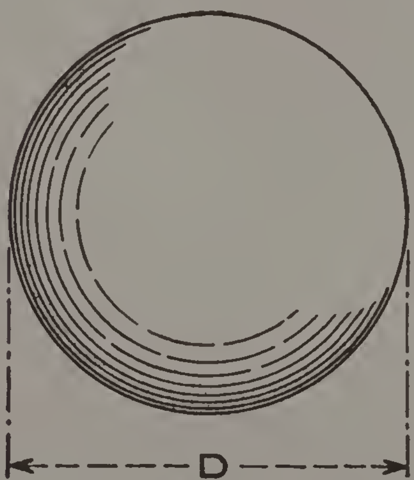


Fig. 51.

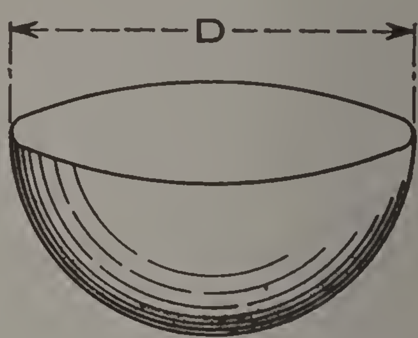


Fig. 52.

To find the cubic contents of a hemisphere—Fig. 52. Multiply the cube of the diameter by .2618.

To find the superficial area of a hemisphere.

Hemisphere: Cubic contents $= .2618D^2$

Superficial area $= 2.3562D^2$

To find the cubic contents of a cylindrical ring—Fig. 53. To the cross-sectional diameter of the ring add the inner diameter of the ring, multiply the sum by the square of the cross-sectional diameter of the ring and by 2.4674, the product is the cubic contents.

To find the superficial area of a cylindrical ring. To the cross-sectional diameter of the ring add the inner diameter of the ring. Multiply the sum by the cross-sectional diameter of the ring and by 9.8696, the product is the superficial area.

Cylindrical Ring: Cubic contents $= 2.4674T^2(T+H)$

Superficial area $= 9.8696T(T+H)$

$D = (H+2T)$

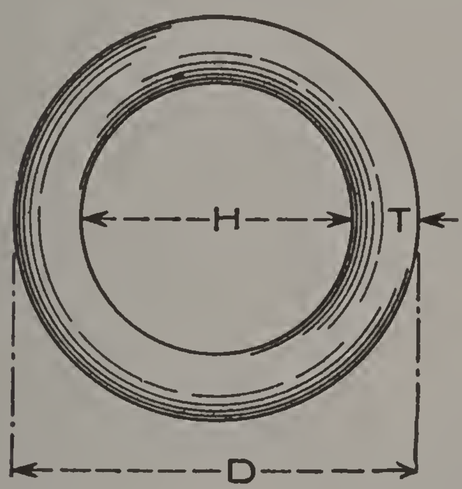


Fig. 53.

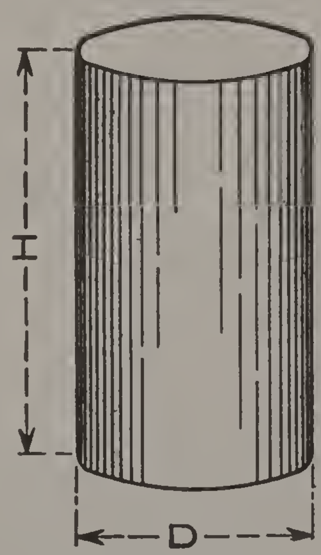


Fig. 54.

To find the cubic contents of a cylinder—Fig. 54. Multiply the area of one end by the length of the cylinder, the product will be the cubic contents of the cylinder.

To find the superficial area of a cylinder. Multiply the circumference of one end by the length of the cylinder and add to the product the area of both ends.

Cylinder: Cubic contents=.7854(D+H)
Superficial area=1.5708D(2H+D)

To find the cubic contents of a cone—Fig. 55. Multiply the square of the base by the perpendicular height and by .2618.

To find the superficial area of a cone. Multiply the circumference of the base by one-half the slant height and add to the product the area of the base.

Cone: Cubic contents = $.2618(D^2 \times H)$
Superficial area=.7854D(2S+D)

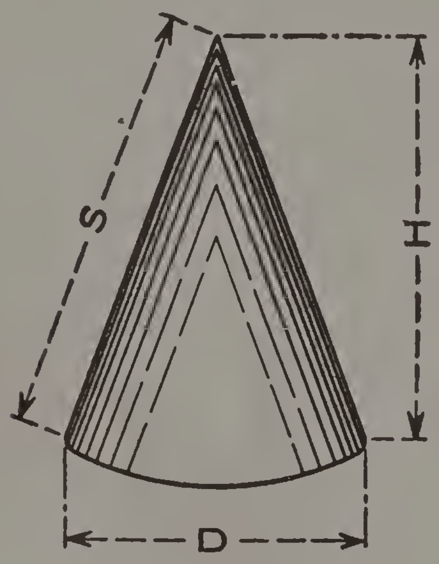


Fig. 55.

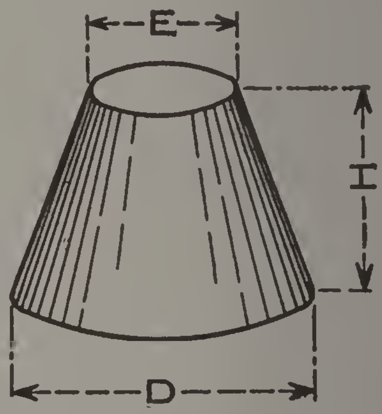


Fig. 56.

To find the cubic contents of the frustum of a cone—Fig. 56. To the sum of the areas of the two ends of the frustum, add the square root of the product of the diameters of the two ends, this result multiplied by one-third of the perpendicular height of the frustum will give the cubic contents.

To find the superficial area of the surface of the frustum of a cone. Multiply the sum of the diameters of the ends by 3.1416 and by half the slant height. Add to the result the area of both ends and the sum of the two will be superficial area.

Frustum of cone:

$$\text{Cubic contents}=\frac{H(.2618(E^2+D^2)\sqrt{E\times D})}{3}$$

$$\text{Superficial area}=3.1416S\left(\frac{D+E}{2}\right)+.7854(E^2+D^2)$$

$$S=\sqrt{\left(\frac{D-E}{2}\right)^2+H^2}$$

To find the contents of a cube—Fig. 57. The contents of equal to the cube of its diameter.

To find the superficial area of a cube. The superficial area of a cube is equal to six times the square of its diameter.

Cube: Cubic contents $=D^3$

Superficial area $=6D^2$

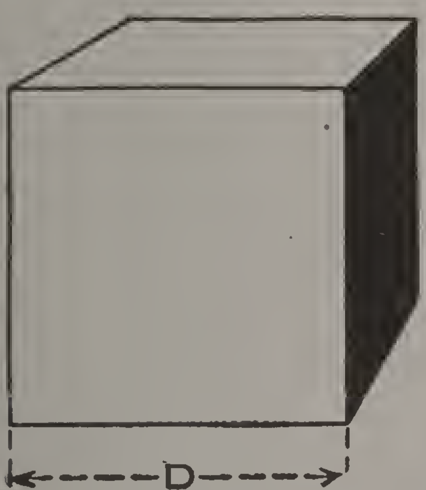


Fig. 57.

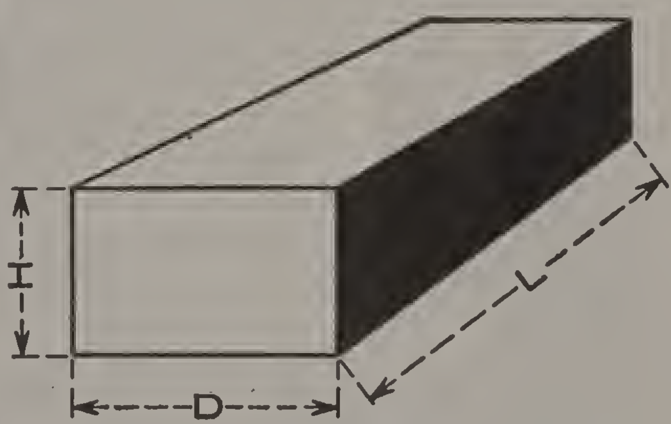


Fig. 58.

To find the cubic contents of a rectangle solid—Fig. 58. Multiplying together the length, width and height will give the cubic contents of the rectangular solid.

To find the superfiicial area of a rectangular solid. Multiply the width by the sum of the height and length and add to it the product of the height multiplied by the length, twice this sum is the superficial area of the rectangular solid.

Rectangular solid:

$$\text{Cubic contents} = D \times H \times L$$
$$\text{Superficial area} = 2(D(H+L)+HL)$$

To find the cubic contents of a pyramid—Fig. 59. Multiply the area of the base by one-third the perpendicular height and the product will be the cubic contents of the pyramid.

To find the superficial area of a pyramid. Multiply the circumference of the base by half the slant height and to this add the area of the base, the sum will be the superficial area.

$$\text{Pyramid: Cubic contents} = \frac{D^2 \times H}{3}$$

$$\text{Superficial area} = \left(\frac{4D+S}{2}+4D\right)$$

$$S = \sqrt{\frac{D^2}{4}+H^2}$$

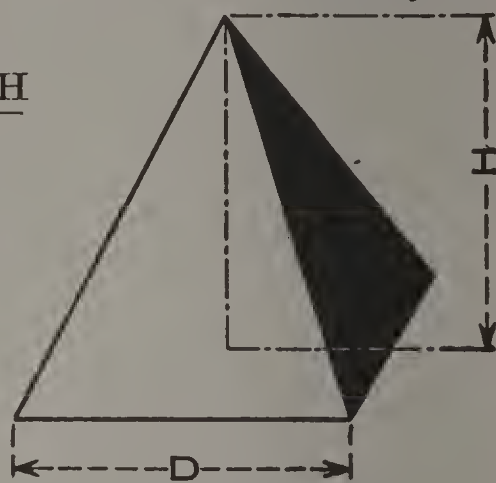


Fig. 59.

MENSURATION OF TRIANGLES.

To find the base of a right-angle triangle when the perpendicular and the hypothenuse are given—Fig. 60. Subtract the square of the perpendicular from the square of the hypothenuse, the square root of the difference is equal to the length of the base.

$$\text{Base} = \sqrt{\text{Hypotenuse}^2 - \text{Perpendicular}^2} \text{ or } B = \sqrt{C^2 - H^2}$$

To find the perpendicular of a right-angle triangle when the base and hypothenuse are given. Subtract the square of the base from the square of the hypothenuse, the square root of the difference is equal to the length of the perpendicular.

$$\text{Perpendicular}=\sqrt{\text{Hypotenuse}^2-\text{Base}^2} \text{ or } H=\sqrt{C^2-B^2}$$

To find the hypothenuse of a right-angle triangle when the base and the perpendicular are given. The square root of the sum of the squares of the base and the perpendicular is equal to the length of the hypothenuse.

$$\text{Hypotenuse}=\sqrt{\text{Base}^2+\text{Perpendicular}^2}$$
$$C=\sqrt{B^2+H^2}$$

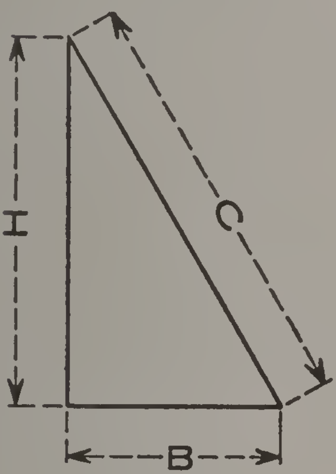


Fig. 60.

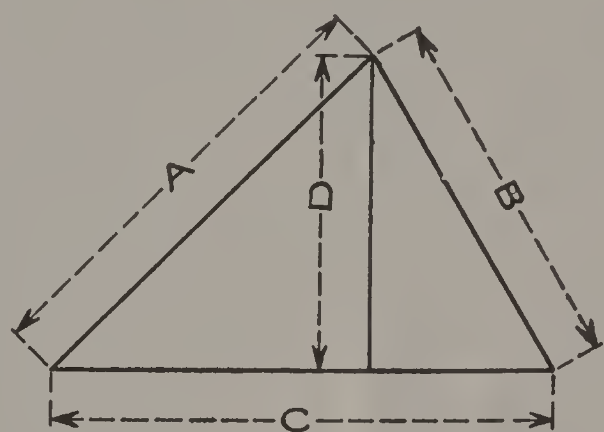


Fig. 61.

To find the perpendicular height of any oblique angled triangle—Fig. 61. From half the sum of the three sides of the triangle, subtract each side severally. Multiply the half sum and the three remainders together and twice the square root of the result divided by the base of the triangle will be the height of the perpendicular.

$$D=\frac{2\sqrt{S(S-A)\ (S-B)\ (S-C)}}{C}$$

$$S=\frac{\text{Sum of sides}}{2}$$

To find the area of any oblique angled triangle when only the three sides are given. From half the sum of the three sides, substract each side severally. Multiply the half sum and the three remainders together and the square root of the product is equal to the area required.

$$\text{Area} = \sqrt{S(S-A)\,(S-B)\,(S-C)}$$

To find the height of the perpendicular and the two sides of any triangle inscribed in a semi-circle, when the base of the triangle and the location of the perpendicular are given —Fig. 62.

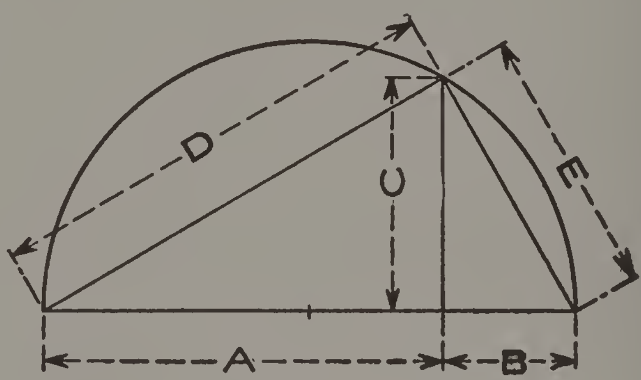


Fig. 62.

$$A = \frac{C^2}{B} \qquad B = \frac{C^2}{A} \qquad C = \sqrt{A \times B}$$

$$D = \sqrt{A(A+B)} \qquad E = \sqrt{B(A+B)}$$

PROPERTIES OF THE CIRCLE.

A circle contains a greater area than any other plane figure bounded by the same length of circumference or outline.

The areas of circles are to each other as the squares of their diameters. Any circle twice the diameter of another contains four times the area of the other.

The **radius** of a circle is a straight line drawn from the centre to the circumference as LM—Fig. 63.

The **diameter** of a circle is a straight line drawn through the centre, and terminated both ways at the circumference, as ALC.

A **chord** is a straight line joining any two points of the circumference, as DE.

The **versed sine** is a perpendicular joining the middle of the chord and circumference, as GH.

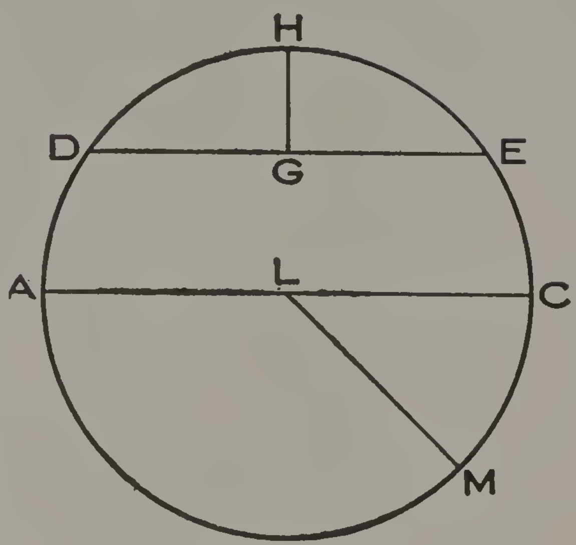


Fig. 63.

An **arc** is any part of the circumference, as DHE.

A **semicircle** is half the circumference cut off by a diameter, as AHC.

A **segment** is any portion of a circle cut off by a chord, as DHE.

A **sector** is a part of a circle cut off by two radii, as ALM or CLM.

Circumference. Multiply the diameter by 3.1416, the product is the circumference.

Diameter. Multiply the circumference by .31831, the product is the diameter, or multiply the square root of the area by 1.12837, the product is the diameter.

Area. Multiply the square of the diameter by .7854, the product is the area.

Side of square. Multiply the diameter by .8862, the product is the side of a square of equal area.

Diameter of circle. Multiply the side of a square by 1.128, the product is the diameter of a circle of equal area.

To find the versed sine, chord of an arc or the radius when any two of the three factors are given—Fig. 64.

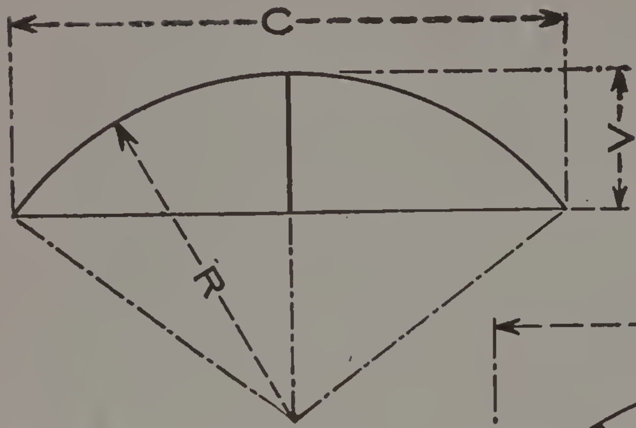


Fig. 64.

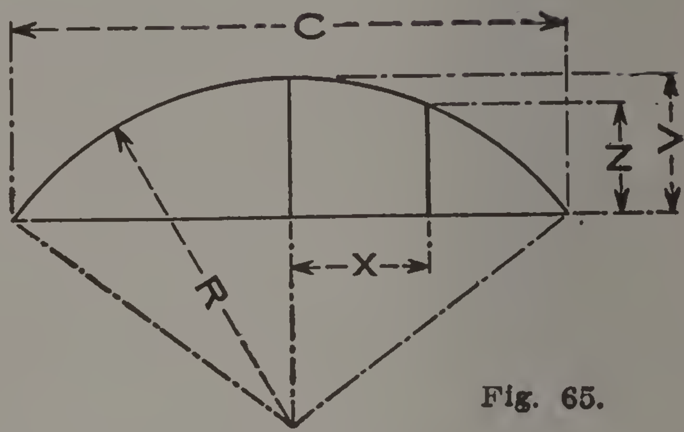


Fig. 65.

$$R=\frac{C^2+4V^2}{8V} \qquad C=2\sqrt{V(2R-V)}$$

$$V=R-\sqrt{\frac{4R^2-C^2}{4}}$$

To find the length of any line perpendicular to the chord of an arc, when the distance of the line from the center of the chord, the radius of the arc and the length of the versed sine are given—Fig. 65.

$$N=\sqrt{(R^2-X^2)-(R-H)} \qquad R=\frac{C^2+4V^2}{8V}$$

$$C=2\sqrt{V(2R-V)} \qquad V=R-\sqrt{\frac{4R^2-C^2}{4}}$$

To find the diameter of a circle when the chord and versed sine of the arc are given.

$$AC=\frac{DG^2+GH^2}{GH}$$

To find the length of any arc of a circle, when the chord of the whole arc and the chord of half the arc are given —Fig. 66.

$$\text{Arc DHE}=\frac{8DH-DE}{3}$$

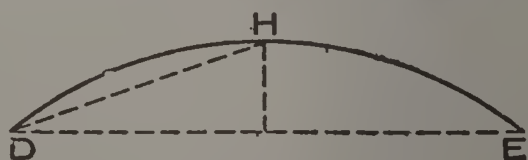


Fig. 66.

TABLE NO. 3.—AREAS OF CIRCLES, FROM 0.1 TO 99.9, ADVANCING BY 10THS.

Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.
0	.0000	.0078	.0314	.0706	.1256	.1963	.2827	.3848	.5026	.6361	0
1	.7854	.9503	1.1309	1.3273	1.5393	1.7671	2.0106	2.2698	2.5446	2.8352	1
2	3.1416	3.4636	3.8013	4.1547	4.5239	4.9087	5.3093	5.7255	6.1575	6.6052	2
3	7.0686	7.5476	8.0424	8.5530	9.0792	9.6211	10.1787	10.7521	11.3411	11.9459	3
4	12.5664	13.2025	13.8544	14.5220	15.2053	15.9043	16.6190	17.3494	18.0956	18.8574	4
5	19.6350	20.4282	21.2372	22.0618	22.9022	23.7583	24.6301	25.5176	26.4208	27.3397	5
6	28.2744	29.2247	30.1907	31.1725	32.1699	33.1831	34.2120	35.2566	36.3168	37.3928	6
7	38.4846	39.5920	40.7151	41.8539	43.0085	44.1787	45.3647	46.5663	47.7837	49.0168	7
8	50.2656	51.5300	52.8102	54.1062	55.4178	56.7451	58.0881	56.4469	60.8213	62.2115	8
9	63.6174	65.0389	66.4762	67.9292	69.3979	70.8823	72.3824	73.8982	75.4298	76.9770	9
10	78.5400	80.1186	81.7130	83.2320	84.9488	86.5903	88.2475	89.9204	91.6090	93.3133	10
11	95.0334	96.7691	98.5205	100.2877	102.0705	103.8691	105.6834	107.5134	109.3590	111.2204	11
12	113.0976	114.9904	116.8989	118.8231	120.7631	122.7187	124.6901	126.6771	128.6799	130.6984	12
13	132.7326	134.7824	136.8480	138.9294	141.0264	143.1391	145.2675	147.4117	149.5715	151.7471	13
14	153.9384	156.1453	158.3680	160.6064	162.8605	165.1303	167.4158	169.7170	172.0340	174 3666	14
15	176.7150	179.0790	181.4588	183.8542	186.2654	188.6923	191.1349	193.5932	196.0672	198.5569	15
16	201.0624	203.5835	206.1209	208.6723	211.1411	213.8251	216.4248	219.0402	221.6712	224.3189	16
17	226.9086	229.6588	232.3527	235.0623	237.7877	240.5287	243.2855	246.0579	248.8461	251.6500	17
18	254.4696	257.3048	260.1558	263.0226	265.9050	268.8031	271.7169	274.6465	277.5917	280.5527	18
19	283.5294	286.5217	289.5298	292.5536	295.5931	298.6483	301.7192	304.8060	307.9082	311.0252	19
Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.

TABLE NO. 3.—AREAS OF CIRCLES (continued)

Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.
20	314.1600	317.3094	320.4746	323.6554	326.8520	330.0643	333.2923	336.3360	339.7954	343.0705	20
21	346.3614	349.6679	352.9901	356.3281	359.6817	363.0511	366.4362	369.8370	373.2534	376.6856	21
22	380.1336	383.5972	387.0765	390.5751	394.0823	397.6087	101.1509	404.7087	408.2823	411.8716	22
23	415.4766	419.0972	422.7336	426.3858	430.0536	433.7371	437.4363	441.1511	444.8819	448.6283	23
24	452.3904	456.1681	459.9616	463.7708	467.5957	471.4363	475.2926	479.1646	483.0524	486.9558	24
25	490.8750	494.8098	498.7604	502.7266	506.7086	510.7063	514.7196	518.7488	522.7936	526.8541	25
26	530.9304	535.0223	539.1299	543.2533	547.3923	551.5471	555.7176	559.9038	564.1056	568.3232	26
27	572.5566	576.8056	581.0703	585.3507	589.6469	593.9587	598.2863	602.6295	606.9885	611.3632	27
28	615.7536	620.1596	624.5814	629.0190	633.4722	637.9411	642.4257	646.9261	651.4421	655.9739	28
29	660.5214	665.0845	669.6634	674.2580	678.8683	683.4943	688.1360	692.7934	697.4666	702.1554	29
30	706.8600	711.5802	716.3162	721.0678	725.8352	730.6183	735.4171	740.2316	745.0618	749.9077	30
31	754.7694	759.6467	764.5397	769.4485	774.3729	779.3131	784.2689	789.2406	794.2278	799.2308	31
32	804.2496	809.2840	814.3341	819.3999	824.4815	829.5787	834.6917	839.8203	844.9647	850.1248	32
33	855.3006	860.4920	865.6992	870.9222	876.1608	881.4151	886.6851	891.9709	897.2723	902.5895	33
34	907.9224	913.2709	918.6352	924.0115	929.4109	934.8223	940.2494	945.6922	951.1508	956.6250	34
35	962.1150	967.6206	973.1420	978.6790	984.2318	989.8003	995.3845	1000.984	1006.600	1012.231	35
36	1017.878	1023.541	1029.220	1034.913	1040.624	1046.349	1052.090	1057.8474	1063.620	1069.408	36
37	1075.213	1081.032	1086.868	1092.719	1098.586	1104.469	1110.367	1116.281	1122.211	1128.156	37
38	1134.118	1140.095	1146.087	1152.095	1158.119	1164.159	1170.215	1176.286	1182.373	1188.465	38
39	1194.539	1200.727	1206.877	1213.042	1219.224	1225.420	1231.633	1237.861	1244.121	1250.365	39
Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.

TABLE No. 3.—AREAS OF CIRCLES (continued)

Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.
40	1256.640	1262.931	1269.239	1275.560	1281.898	1288.252	1294.622	1301.007	1307.408	1313.825	40
41	1320.257	1326.706	1333.169	1339.649	1346.144	1352.655	1359.182	1365.724	1372.282	1378.856	41
42	1385.446	1392.051	1398.672	1405.308	1411.961	1418.629	1425.313	1432.012	1438.727	1445.458	42
43	1452.205	1458.967	1465.745	1472.539	1479.348	1486.173	1493.014	1499.871	1506.743	1513.629	43
44	1520.534	1527.454	1534.389	1541.340	1548.306	1555.288	1562.286	1569.300	1576.329	1583.374	44
45	1590.435	1597.511	1604.604	1611.711	1618.835	1625.974	1633.129	1640.302	1647.486	1654.689	45
46	1661.906	1669.140	1676.389	1683.654	1690.935	1698.231	1705.543	1712.871	1720.214	1727.574	46
47	1734.949	1742.339	1749.746	1757.168	1764.605	1772.059	1779.528	1787.013	1794.513	1802.030	47
48	1809.562	1817.109	1824.673	1832.252	1839.847	1847.457	1855.083	1862.725	1870.383	1878.056	48
49	1885.745	1893.450	1901.171	1908.907	1916.659	1924.426	1932.210	1940.009	1947.823	1955.654	49
50	1963.500	1971.362	1979.239	1987.133	1995.042	2002.966	2010.907	2018.863	2026.835	2034.877	50
51	2042.825	2050.844	2058.878	2066.929	2074.995	2083.077	2091.175	2099.288	2107.417	2115.561	51
52	2123.722	2131.898	2140.089	2148.297	2156.520	2164.759	2173.013	2181.284	2189.570	2197.871	52
53	2206.189	2214.522	2222.870	2231.235	2239.615	2248.011	2256.423	2264.870	2273.293	2281.752	53
54	2290.226	2298.717	2307.222	2315.744	2324.281	2332.834	2341.403	2349.987	2358.588	2367.203	54
55	2375.835	2384.482	2393.145	2401.824	2410.518	2419.228	2427.954	2436.696	2445.453	2454.226	55
56	2463.014	2471.819	2480.639	2489.475	2498.326	2507.193	2516.076	2524.974	2533.889	2542.819	56
57	2551.765	2560.726	2569.703	2578.696	2587.705	2596.729	2605.769	2614.824	2623.896	2632.983	57
58	2642.086	2651.205	2660.338	2669.488	2678.654	2687.835	2697.032	2706.245	2715.473	2724.718	58
59	2733.977	2743.253	2752.544	2761.851	2771.174	2780.512	2789.866	2799.236	2808.622	2818.023	59
Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.

TABLE No. 3.—AREAS OF CIRCLES (continued)

Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.
60	2827.440	2836.873	2846.321	2855.785	2865.265	2874.760	2884.262	2893.798	2903.341	2912.899	60
61	2922.473	2932.063	2941.669	2957.290	2960.927	2970.579	2980.247	2989.931	2999.630	3009.346	61
62	3019.078	3028.824	3038.587	3048.365	3058.159	3067.969	3077.794	3087.634	3097.492	3107.364	62
63	3117.253	3127.156	3137.076	3147.011	3156.966	3166.929	3176.912	3186.910	3196.924	3206.953	63
64	3216.998	3227.059	3237.136	3247.228	3257.337	3267.460	3277.600	3287.755	3297.926	3308.113	64
65	3318.315	3328.534	3338.767	3349.016	3359.281	3369.562	3379.859	3390.171	3400.499	3410.843	65
66	3421.202	3431.578	3441.963	3452.375	3462.797	3473.235	3483.689	3494.164	3504.643	3515.143	66
67	3525.661	3536.193	3546.741	3557.304	3567.884	3578.479	3589.090	3599.716	3610.358	3621.016	67
68	3631.690	3642.379	3653.084	3663.804	3674.541	3685.293	3696.006	3706.845	3717.644	3728.459	68
69	3739.289	3750.136	3760.998	3771.876	3782.769	3793.678	3804.603	3815.544	3826.500	3837.472	69
70	3848.460	3859.495	3870.483	3881.517	3892.568	3903.634	3914.716	3925.814	3936.927	3948.057	70
71	3959.201	3970.362	3981.538	3992.730	4003.937	4015.161	4026.400	4037.655	4048.925	4060.212	71
72	4071.514	4082.833	4094.165	4105.513	4116.879	4128.259	4139.652	4151.067	4162.494	4173.938	72
73	4185.397	4196.871	4208.361	4219.868	4231.390	4242.927	4254.480	4236.049	4277.634	4289.234	73
74	4300.850	4312.482	4324.130	4335.793	4347.472	4359.166	4370.877	4382.603	4394.345	4406.102	74
75	4417.875	4429.664	4441.468	4453.289	4465.125	4476.976	4488.844	4500.727	4512.626	4524.540	75
76	4536.470	4548.416	4560.379	4572.355	4584.358	4596.357	4608.382	4620.422	4632.478	4644.549	76
77	4656.637	4668.740	4680.858	4692.993	4705.143	4717.309	4729.490	4741.688	4753.961	4766.129	77
78	4778.374	4790.634	4802.909	4815.201	4827.508	4839.831	4852.170	4864.524	4876.897	4889.280	78
79	4901.681	4914.099	4926.531	4938.982	4951.444	4963.924	4976.484	4988.931	5001.459	5014.001	79
Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.

TABLE No. 3.—AREAS OF CIRCLES (concluded)

Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.
80	5026.560	5039.134	5051.724	5064.330	5076.955	5089.588	5102.241	5114.910	5127.594	5140.294	80
81	5153.009	5165.741	5178.488	5191.251	5204.029	5216.823	5229.633	5242·459	5255.300	5268.157	81
82	5281.030	5293.918	5306.822	5319.744	5332.678	5345.629	5358.596	5371.598	5384.576	5397.591	82
83	5410.621	5423.666	5436.727	5449.804	5462.897	5476.005	5489.129	5502.269	5515.424	5528.596	83
84	5541.782	5554.985	5568.203	5581.437	5594.687	5607.952	5621.233	5634.568	5647.843	5661.171	84
85	5674.515	5687.875	5701.250	5714.641	5728.048	5741.470	5754 909	5768.362	5781.832	5795.317	85
86	5808.818	5822.335	5835.868	5849.416	5862.980	5876.559	5890.154	5903.765	5917.392	5931.034	86
87	5944.693	5958.364	5972.056	5985.769	5999.482	6013.219	6026.971	6040.739	6054.515	6068.322	87
88	6082.138	6095.968	6109.815	6123.677	6137.555	6151.449	6165.359	6179.284	6193.225	6207.181	88
89	6221.153	6235.141	6249.145	6263.164	6277.200	6291.204	6305.317	6319.399	6333.497	6347.681	89
90	6361.740	6375.885	6390.046	6404.222	6418.414	6432.622	6446.844	6461.085	6475.340	6489.611	90
91	6503.897	6518.200	6532.517	6546.891	6561.208	6575.565	6589.946	6604.322	6618.754	6633.182	91
92	6647.626	6662.085	6676.560	6691.016	6705.557	6720.079	6734.617	6749.170	6763.739	6778.324	92
93	6792.925	6807.541	6822.173	6836.821	6851.484	6866.163	6880.858	6895.569	6910.295	6925.037	93
94	6939.794	6954.568	6969.357	6984.161	6998.982	7013.818	7028.670	7043.503	7058.418	7073.320	94
95	7088.235	7103.165	7118.112	7133.073	7148.051	7163.044	7178.053	7193.078	7208.118	7223.175	95
96	7238.246	7253.334	7268.437	2283.556	7298 691	7313.841	7329.007	7344.189	7359.386	7374.600	96
97	7389.829	7405.073	7420.334	7435.610	7450:901	7466.209	7481.532	7496.871	7512.225	7527.596	97
98	7542.982	7558.383	7573.801	7589.234	7604.683	7620.147	7635.627	7651.193	7666.635	7682.162	98
99	7697.705	7713.264	7728.839	7744.429	7760.035	7775.656	7791.294	7806.947	7822.615	7838.300	99
Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.

TABLE No. 4.—CIRCUMFERENCES OF CIRCLES FROM 0.1 TO 99.9, ADVANCING BY 10THS.

Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.
0	.0000	.3142	.6823	.9425	1.2566	1.5708	1.8850	2.1991	2.5133	2.8274	0
1	3.1416	3.4557	3.7699	4.0840	4.3982	4.7124	5.0265	5.3407	5.6548	5.9690	1
2	6.2832	6.5973	6.9115	7.2256	7.5398	7.8540	8.1681	8.4823	8.7964	9.1106	2
3	9.4248	9.7389	10.0531	10.3672	10.6814	10.9956	11.3097	11.6239	11.9380	12.2522	3
4	12.5664	12.8805	13.1947	13.5088	13.8230	14.1372	14.4513	14.7655	15.0796	15.3938	4
5	15.7080	16.0221	16.3363	16.6504	16.9646	17.2788	17.5929	17.9071	18.2212	18.5354	5
6	18.8496	19.1637	19.4779	19.7920	20.1062	20.4204	20.7345	21.0487	21.3628	21.6770	6
7	21.9912	22.3053	22.6195	22.9336	23.2478	23.5620	23.8761	24.1903	24.5044	24.8186	7
8	25.1328	25.4469	25.7611	26.0752	26.3894	26.7036	27.0177	27.3319	27.6460	27.9602	8
9	28.2744	28.5885	28.9027	29.2168	29.5310	29.8452	30.1593	30.4735	30.7876	31.1018	9
10	31.4160	31.7301	32.0443	32.3580	32.6726	32.9868	33.3009	33.6150	33.9292	34.2434	10
11	34.5576	34.8717	35.1859	35.5010	35.8142	36.1284	36.4425	36.7567	37.0708	37.3840	11
12	37.6992	38.0133	38.3275	38.6416	38.9558	39.2700	39.5841	39.8983	40.2124	40.5266	12
13	40.8408	41.1549	41.4691	41.7832	42.0974	42.4116	42.7257	43.0399	43.3540	43.6682	13
14	43.9824	44.2965	44.6107	44.9248	45.2390	45.5532	45.8673	46.1815	46.4956	46.8098	14
15	47.1240	47.4381	47.7523	48.0664	48.3806	48.6948	49.0089	49.3321	49.6372	49.9514	15
16	50.2656	50.5797	50.8939	51.2080	51.5224	51.8364	52.1505	52.4647	52.7788	53.0930	16
17	53.4072	53.7213	54.0355	54.3496	54.6038	54.9780	55.2921	55.6063	55.9204	56.2346	17
18	56.5488	56.8629	57.1771	57.4912	57.8054	58.1196	58.4337	59.7479	59.0620	59.3762	18
19	59.6904	60.0045	60.3187	60.6328	60.9470	61.2612	61.5753	61.8895	62.2036	62.5178	19
Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.

TABLE NO. 4.—CIRCUMFERENCES OF CIRCLES (continued)

Dia	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.
20	62.8320	63.1461	63.4603	63.7744	64.0886	64.4028	64.7161	65.0311	65.3452	65.6594	20
21	65.9736	66.2870	66.6012	66.7916	67.2930	67.5444	67.8585	68.1727	68.4868	68.8010	21
22	69.1152	69.4293	69.7435	70.0576	70.3718	70.6860	71.0001	71.3143	71.6284	71.9426	22
23	72.2568	72.5709	72.8851	73.1992	73.5134	73.8276	74.1417	74.4559	74.7680	75.0882	23
24	75.3984	75.7125	76.0267	76.3408	76.6523	76.9602	77.2833	77.5975	77.9116	78.2258	24
25	78.5400	78.8541	79.1683	79.4824	79.7966	80.8108	80.4249	80.7391	81.0532	81.3674	25
26	81.6816	82.3099	82.6240	82.6240	82.9382	83.2524	83.5665	83.8807	84.1948	84.5090	26
27	84.8232	85.1373	85.4515	85.7656	86.0798	86.3940	86.7081	87.0223	87.3364	87.6506	27
28	87.9648	88.2789	88.5931	88.9072	89.2214	89.5315	89.8497	90.1639	90.4780	90.7922	28
29	91.1064	91.4205	91.7347	92.0488	92.3630	92.6772	92.9913	93.3055	93.6196	93.9338	29
30	94.2480	94.5621	94.8763	95.1904	95.5046	95.8188	96.1329	96.4471	96.7612	97.0754	30
31	97.3896	97.7037	98.0179	98.3320	98.6452	98.9604	99.2745	99.5887	99.9028	100.217	31
32	100.531	100.845	101.160	101.474	101.748	102.102	102.416	102.730	103.044	103.359	32
33	103.673	103.987	104.301	104.615	104.929	105.244	105.558	105.872	106.186	106.500	33
34	106.814	107.129	107.427	107.757	108.071	108.385	108.699	109.035	109.308	109.642	34
35	109.956	110.270	110.584	110.898	112.213	111.527	111.841	112.155	112.469	112.783	35
36	113.098	113.412	113 726	114.040	114.354	114.668	114.983	115.297	115.611	115.925	36
37	116.239	116.553	116.868	117.182	117.496	117.810	118.124	118.438	118.752	119.067	37
38	119.381	119.695	120.009	120.323	120 637	120.952	121.266	121.580	121.894	122.208	38
39	122.522	122.837	123.151	123.465	123.779	124.093	124.407	124.722	125.036	125.350	39
Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.

TABLE NO. 4.—CIRCUMFERENCES OF CIRCLES (continued)

Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.
40	125.664	125.978	126.292	126.606	126.921	127.235	127.549	127.863	128.177	128.491	40
41	128.806	129.120	129.432	129.748	130.062	130.376	130.691	131.005	131.319	131.632	41
42	131.947	132.261	132.576	132.800	133.204	133.518	133.832	134.146	134.460	134.775	42
43	135 089	135.403	135.717	136.033	136.345	136.660	136.974	137.288	137.602	137.916	43
44	138.230	138.545	138.859	139.173	139.487	139.801	140.115	140.430	140.744	141.058	44
45	141.372	141.686	142.000	142.314	142.629	142.943	143.257	143.571	143.885	144.199	45
46	144.514	144.828	145.142	145.456	145.770	146.084	146.399	146.713	147.027	147.341	46
47	147 655	147.969	148.284	148.598	148.912	149.226	149.536	149.854	150.168	150.483	47
48	150.797	151.111	151.425	151.739	152.053	152.368	152.682	152.996	153.310	153.624	48
49	153.938	154.253	154.567	154.881	155.195	155.509	155.823	156.138	156.452	156.756	49
50	157.080	157.394	157.708	158.022	158.337	158.651	158.965	159.279	159.593	159.907	50
51	160.222	160.536	160.850	161.164	161.478	161.792	162.107	162.421	162.734	163.049	51
52	163.363	163.677	163.994	164.306	164.620	164.934	165.248	165.562	165.876	166.191	52
53	166.505	166.819	167.133	167.447	167.761	168.076	168.390	168.705	169.018	169.332	53
54	169.646	169.961	170.275	170.589	170.903	171.217	171.531	171.846	172.160	172.474	54
55	172.788	173.102	173.416	173.730	174.045	174.359	174.673	174.977	175.309	175.615	55
56	175.930	176.244	176.558	176.872	177.186	177.500	177.815	178.129	178.443	178.757	56
57	179.071	179.385	179.700	180.014	180.328	180.642	180.956	181.280	181.584	181.899	57
58	182.213	182.527	182.841	183.155	183.469	183.784	184.098	184.412	184.726	185.040	58
59	185.354	185.669	185.983	186.270	186.611	186.925	187.239	187.554	187.868	188.182	59
Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.

TABLE NO. 4.—CIRCUMFERENCES OF CIRCLES (continued)

Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.
60	188.496	188.810	189.124	189.438	189.753	190.067	190.381	190.695	191.009	191.323	60
61	191.638	191.952	192.266	192.580	192.894	193.208	193.523	193.837	194.151	194.465	61
62	194.779	195.093	195.408	195.722	196.036	196.350	196.664	196.978	197.292	197.607	62
63	197.921	198.235	198.549	198.863	199.177	199.492	199.806	200.120	200.434	200.748	63
64	201.062	201.377	201.691	202.005	202.319	202.633	202.947	203.262	203.576	203.890	64
65	204.204	204.518	204.832	205.146	205.461	205.775	206.089	206.403	206.717	207.031	65
66	207.346	207.660	207.974	208.288	208.602	208.916	209.231	209.545	209.859	210.173	66
67	210.487	210.801	211.116	211.430	211.744	212.058	212.372	212.686	213.000	213.315	67
68	213.629	213.943	214.257	214.571	214.885	215.200	215.514	215.828	216.142	216.456	68
69	216.770	217.085	217.399	217.713	218.027	218.341	218.655	218.970	219.284	219.598	69
70	219.912	220.226	220.540	220.854	221.169	221.483	221.797	222.111	222.425	222.739	70
71	223.054	223.368	223.682	223.996	224.310	224.624	224.939	225.253	225.567	225.881	71
72	226.195	226.509	226.824	227.138	227.452	227.766	228.080	228.394	228.708	229.023	72
73	229.337	229.651	229.965	230.279	230.593	230.908	231.222	231.536	231.850	232.164	73
74	232.478	232.793	233.107	233.421	233.735	234.049	234.363	234.678	234.992	235.306	74
75	235.620	235.934	236.248	236.562	236.877	237.191	237.505	237.819	238.133	238.447	75
76	238.762	239.076	239.390	239.704	240.018	240.332	240.647	240.961	241.275	241.599	76
77	241.903	242.217	242.532	242.846	243.160	243.474	243.788	244.102	244.416	244.731	77
78	245.045	245.359	245.673	245.987	246.301	246.616	246.930	247.244	247.548	247.872	78
79	248.186	248.501	248.815	249.129	249.443	249.757	250.071	250.386	250.700	251.014	79
Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.

TABLE No. 4.—CIRCUMFERENCES OF CIRCLES (concluded)

Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.
80	251.328	251.624	251.956	252.270	252.585	252.899	253.213	253.527	253.841	254.155	80
81	254.470	254.784	255.098	255.412	255.726	256.040	256.355	256.669	256.983	257.297	81
82	257.611	257.925	258.240	258.554	258.865	259.182	259.496	259.810	260.124	260.439	82
83	260.753	261.067	261.381	261.695	262.009	262.324	262.638	262.952	263.264	263.580	83
84	263.894	264.209	264.523	264.837	265.151	265.465	265.779	266.094	266.408	266.722	84
85	267.036	267.350	267.664	267.978	268.293	268.607	268.921	269.235	269.549	269.863	85
86	270.178	270.492	270.806	271.120	271.434	271.748	272.067	272.377	272.691	273.005	86
87	273.319	273.633	273.988	274.262	274.576	274.890	275.204	275.518	275.832	276.147	87
88	276.461	276.775	277.089	277.403	277.717	278.032	278.346	278.660	278.975	279.288	88
89	279.602	279.917	280.231	280.545	280.859	281.173	281.487	281.883	282.116	282.430	89
90	282.744	283.058	283.372	283.686	284.001	284.315	284.629	284.943	285.257	285.571	90
91	285.886	286.200	286.514	286.829	287.142	287.456	287.771	288.085	288.399	288.713	91
92	289.027	289.341	289.656	289.970	290.284	290.598	290 912	291.226	291.540	291.855	92
93	292.169	292.483	292.797	293.111	293.425	293.740	294.054	294.368	294.682	294.996	93
94	295.310	295.625	295.939	296.244	296.567	296.881	297.195	297.510	297.824	298.138	94
95	298.452	298.766	299.072	299.394	299.709	300.023	300.337	300.651	300.965	301.279	95
96	301.594	301.908	302.222	302.536	302.850	303.164	303.479	303.793	304.107	304.421	96
97	304.735	305.049	305.364	305.678	305.992	306.306	306.620	306.936	307.248	307.563	97
98	307.877	308.191	308.505	308.819	309.133	309.448	309.762	310.076	310.396	310.704	98
99	311.018	311.333	311.647	311.961	312.275	312.589	312.903	313.218	313.512	313.846	99
Dia.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Dia.

APPLIED MECHANICS

Mechanical Powers consist of simple mechanical devices whereby weights may be raised or resistances overcome with the exertion of less power than would be necessary without them.

They are six in number: The **lever**, the **wheel** and **pinion**, the **pulley**, the **inclined plane**, the **wedge**, and the **screw**. Properly two of these comprise the whole, namely, the **lever** and the **inclined plane**,—the wheel and pinion being only a lever of the first kind, and the pulley a lever of the second, the wedge and screw being also similarly allied to that of the inclined plane. Although such seems to be the case, yet they each require, on account of their various modifications, a different rule of calculation adapted expressly to the different circumstances in which they are required to act.

The primary elements of machinery are therefore two only in number, the **lever and the inclined plane.**

The Lever.

Levers, according to the method of application, are of the first, second, or third kind. Although levers of equal lengths produce different effects, the general principles of estimation in all are the same, namely, the power is to the weight, as the distance of one end of the fulcrum is to the distance of the other end to the same point.

In a lever of the first kind the fulcrum is between the power and the weight, as in Fig. 67. A pair of pliers or scissors are double levers of the first kind.

In a lever of the second kind, the weight is between the power and the fulcrum, as in Fig. 68. A wheel-barrow, or the oars of a boat where the water is considered the fulcrum, and a door, represent levers of the second kind.

In a lever of the third kind, the power is between the fulcrum and the weight, as in Fig. 69. Levers of the third kind are instruments such as tongs, shears, &c.

In the **first kind**, the power is to the weight, as the distance W F is to the distance F P.

In the **second**, the power is to the weight, as the distance F W is to that of F P; and,

In the **third**, the weight is to the power, as the distance F P is to that of F W.

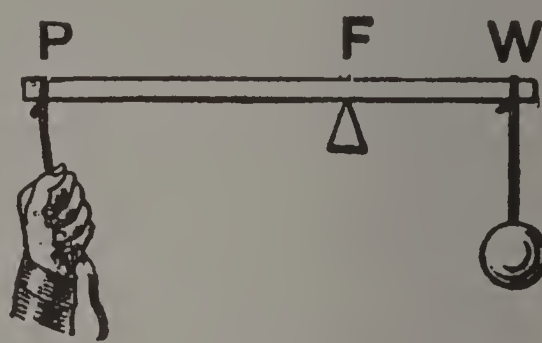


Fig. 67.

To find the power. Multiply the weight by its distance from the fulcrum, and divide by the distance of the power from the fulcrum.

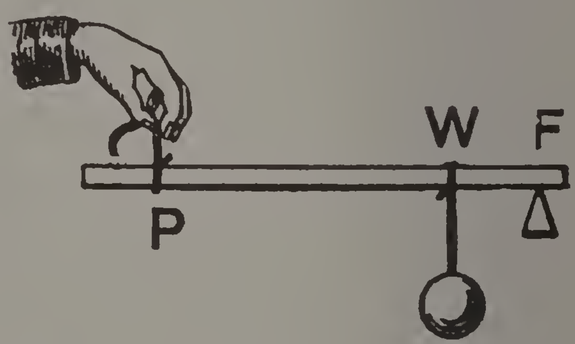


Fig. 68.

To find the weight. Multiply the power by its distance from the fulcrum, and divide by the distance of the weight from the fulcrum.

To find the distance of the power from the fulcrum. Multiply the weight by its distance from the fulcrum, and divide by the power.

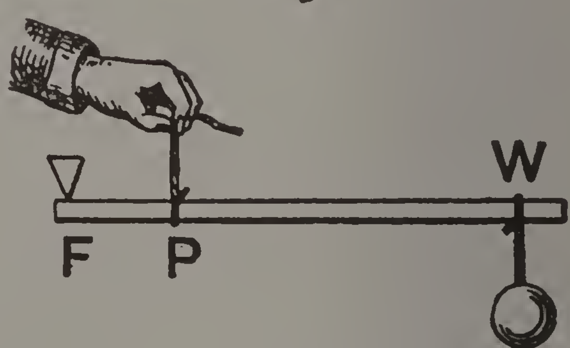


Fig. 69.

To find the distance of the weight from the fulcrum. Multiply the power by its distance from the fulcrum, and divide by the weight.

Let **P** be the power, **F** the fulcrum and **W** the weight, then for a lever of the **first kind.** (Fig. 67.)

$$P = W\frac{FW}{FP} \qquad W = P\frac{FP}{FW}$$

And for a lever of the **second kind.** (Fig 68.)

$$P = W\frac{FW}{FP} \qquad W = P\frac{FP}{FW}$$

And for a lever of the **third kind.** (Fig. 69.)

$$P = W\frac{FW}{FP} \qquad W = P\frac{FP}{FW}$$

The Wheel and Pinion.

The mechanical advantage of the wheel and pinion system, Fig. 70, is as the velocity of the weight to the velocity of the power, and being only a modification of the **first kind** of lever, it of course partakes of the same principles.

To find the power.—Multiply the weight by the radius of the drum, and divide by the radius of the wheel.

To find the radius of the wheel.—Multiply the weight by the radius of the drum, and divide by the power.

To find the radius of the drum.—Multiply the power by the radius of the wheel, and divide by the weight.

To find the weight.—Multiply the power by the radius of the wheel, and divide by the radius of the drum.

Let **W** be the weight, **D** the radius of the drum, **R** the radius of the wheel and **P** the power required to lift the weight, then for a **Wheel and Drum system:** (Fig. 70.)

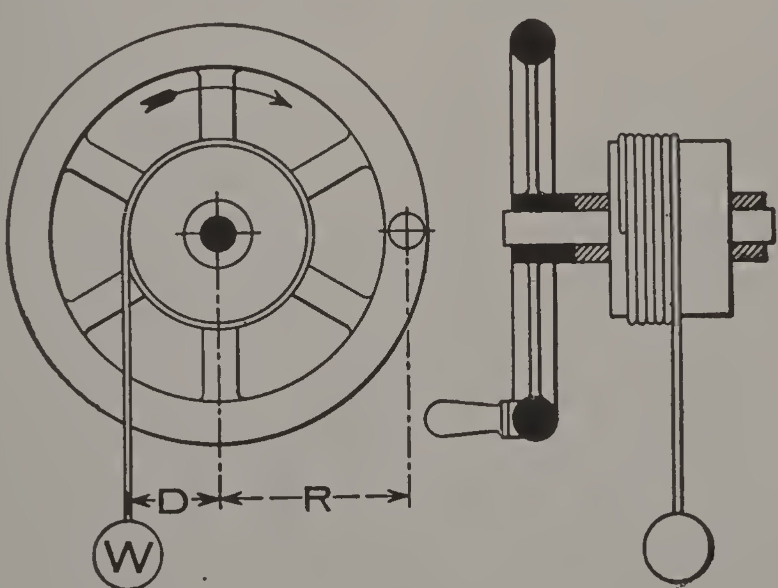


Fig. 70.

$$P=\frac{W\times D}{R} \qquad D=\frac{P\times R}{W} \qquad R=\frac{W\times D}{P} \qquad W=\frac{P\times R}{D}$$

For a **Crank, Pinion and Gear and Drum system:** (Fig. 71.)

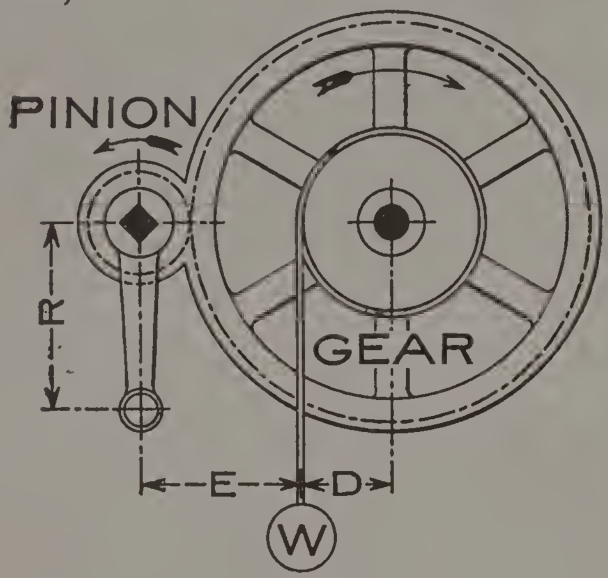


Fig. 71.

$$P=\frac{W\times D\times P}{R\times G}$$

$$W=\frac{P\times R\times G}{D\times P}$$

To determine the amount of effective power produced from a given power by means of a crank, pinion and gear, and drum system.—Multiply the diameter of the circle described by the crank or turning handle by the number of revolutions of the pinion to one of the wheel. Divide the product by the diameter of the drum and the quotient is the ratio of the effective power to the exertive force. Fig. 71.

Given any two parts of a crank, pinion and gear, and drum system, to find the third, that shall produce any required proportion of mechanical effect.—Multiply the two given parts together, and divide the product by the required proportion of effect, the quotient is the dimensions of the other part.

$$D=\frac{P\times R\times G}{W\times P} \qquad R=\frac{W\times D\times P}{P\times G}$$

p=Either pitch diameter or number of teeth in the pinion.
G=Either pitch diameter or number of teeth in the gear.

Let E be the **ratio** of the **effective power** to the **effective force** produced, then

$$E=3.1416\frac{R\times G}{D\times P}$$

The Pulley or Sheave.

The pulley or sheave is a wheel over which a rope is passed to transmit the force applied to the cord in another direction. There are two kinds of pulleys, the one turning on fixed centers, the other turning on traversing centers.

The fixed or stationary pulley (Fig 72). This acts like a lever of the first kind. It affords no mechanical advantage, and merely changes the direction of the force, and does not alter its intensity, but it affords great facilities in the application of force, as it is easier to pull downwards than upwards. In this class of pulley the power is equal to the weight to be raised.

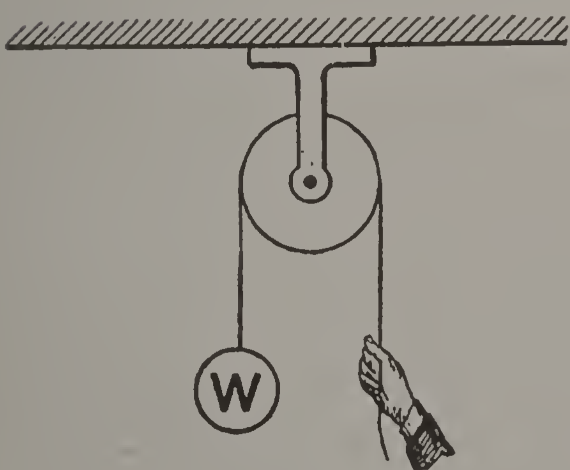


Fig. 72.

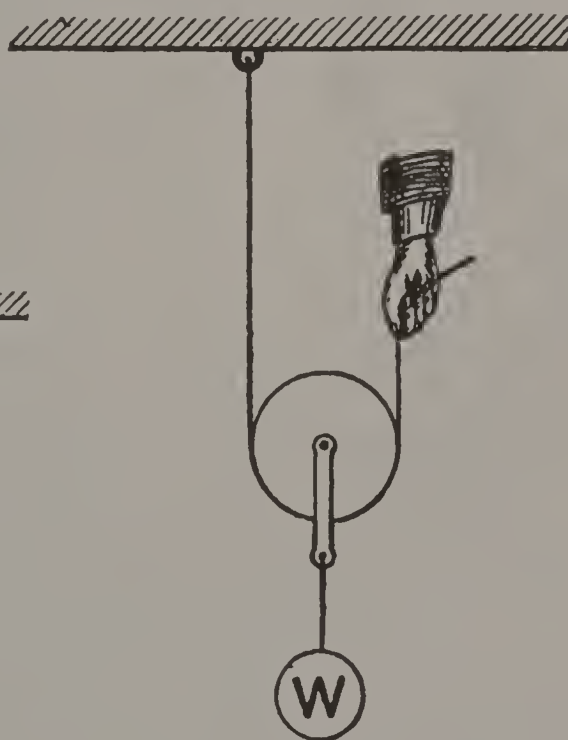


Fig. 73.

The movable pulley (Fig. 73).—This acts like a lever of the second kind. One end of the rope is suspended to a fixed point, as a fulcrum, in a beam, and the weight is attached to the axis of the pulley. This kind of pulley doubles the power at the expense of the speed, and the product of the power by the diameter of the pulley, is equal to the product of the weight by the radius of the pulley.

A movable pulley acting as a lever of the third kind is shown at Fig. 74. One end of the cord is fixed to a floor, and the weight is attached to the other end, the power being applied to the axis. The power is equal to twice the weight, and the product of the power by the radius of the pulley is equal to the product of the weight by the diameter of pulley. In the arrangement shown at Fig. 75 the power is equal to one-half the weight.

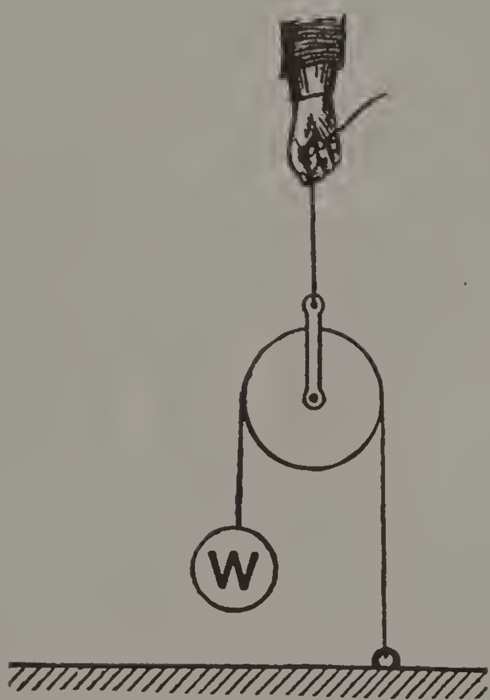


Fig. 74.

A combination of movable pulleys with separate and parallel cords is shown at Fig. 76. Each system reduces the resistance to the extent of one-half, hence the power may be found by dividing and subdividing the weight successively by 2, as many times as there are moveable pulleys. The weight may be found by multiplying the power successively by 2, as many times as there are moveable pulleys.

To find the power.—Divide the weight to be raised by the number of cords leading **to, from,** or **attached,** to the power block. The quotient is the power required to produce an equilibrium, provided friction did not exist.

When the fixed end of the rope is attached to the fixed block, the power may be found by dividing the weight by twice the number of moveable pulleys. When the fixed

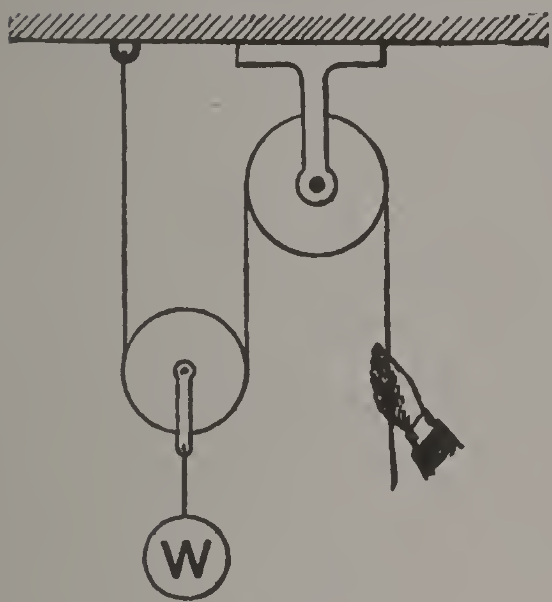


Fig. 75.

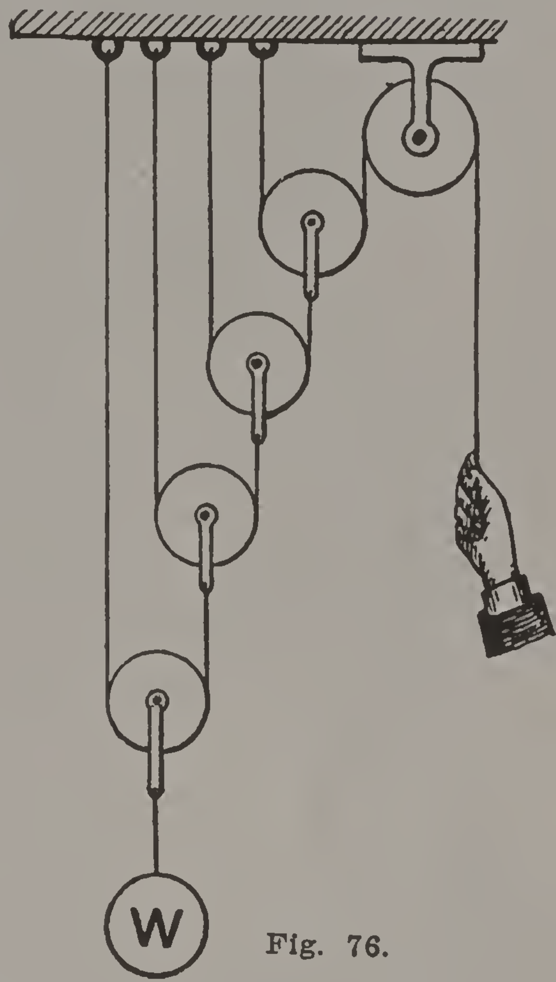


Fig. 76.

end of the rope is attached to the moveable block, the power may be found by dividing the weight by twice the number of moveable pulleys plus 1.

To find the number of sheaves or pulleys required. Divide the power to be raised by the power to be applied; the quotient is the number of sheaves in, or cords attached to the rising block.

To find the weight that will be balanced by a given power.—When the rope is attached to the fixed block, multiply the power by twice the number of moveable pulleys.

When the rope is attached to the moveable block multiply the power by twice the number of moveable pulleys plus 1.

The Inclined Plane.

The inclined plane (Fig. 77) is properly the second elementary power, and may be defined the lifting of a load by regular instalments. In principle it consists of any right line not coinciding with, but laying in a sloping direction to, that of the horizon; the standard of comparison of which commonly consists in referring the rise to

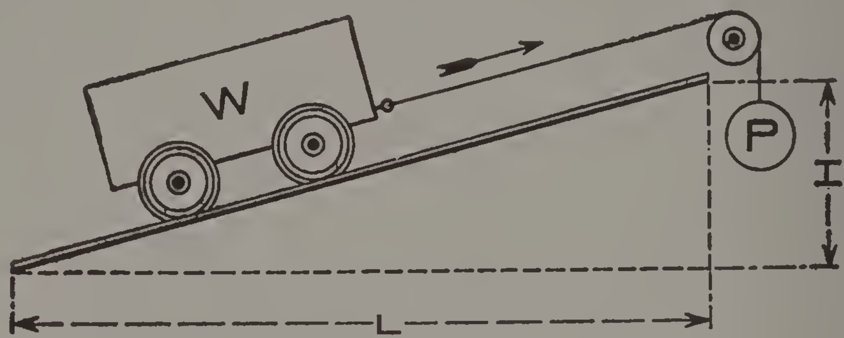


Fig. 77.

so many parts in a certain length or distance, as 1 in 100, 1 in 200, etc., the first number representing the perpendicular height, and the latter the horizontal length in attaining such height, both numbers being of the same denomination, unless otherwise expressed.

In using an inclined plane for the purpose of raising loads to a higher level, the power is applied parallel to the inclined plane, and the weight is raised in opposition to gravity, the work done on it is expressed by the product of the weight and the vertical height of the inclined plane.

The advantage gained by the inclined plane, when the power acts in a parallel direction to the plane, is as the length to the height.

To find the power.—Multiply the weight by the height of the plane, and divide by the slant length. The quotient is the power.

To find the weight.—Multiply the power by the slant length of the plane, and divide by the height.

To find the height of the inclined plane.—Multiply the power by the slant length, and divide by the weight.

To find the slant length of the inclined plane.—Multiply the weight by the height of the plane, and divide by the power.

Let **W** be the weight to be drawn up the inclined plane, **H** the height and **S** the slant length of the incline. If **P** be the power required to draw the weight **W** up the inclined plane, then

$$P=\frac{W\times H}{S} \qquad W=\frac{P\times S}{H} \qquad H=\frac{P\times S}{W}$$

$$S=\sqrt{L^2+H^2}$$

The Wedge.

The wedge is a double inclined plane, consequently its principles are the same. When two bodies are forced asunder by means of the wedge in a direction parallel to its head: Multiply the resisting power by half the thickness of the head or back of the wedge, and divide the product by the length of one of its slant sides. The quotient is the force required equal to the resistance.

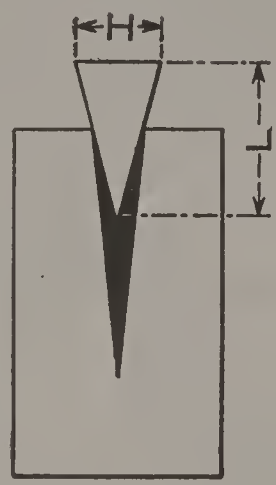


Fig. 78.

F=Force required. **P**=Resisting power.

$$F=\frac{P\times H}{25} \qquad P=\frac{F\times 25}{H} \quad \text{(Fig. 78.)}$$

$$S=\text{Slant side of wedge}=\sqrt{\frac{H^2}{4}+L^2}$$

When only one of the bodies is moveable, the whole breadth of the wedge is taken for the multiplier, and the following rules are for such wedges, acting under pressure only on the head of the wedge, or at the point of the wedge by drawing.

To find the transverse resistance to the wedge or weight.—Multiply the power by the length of the slant side of the wedge, and divide by the breadth of the head.

To find the power.—Multiply the weight or transverse resistance by the breadth of the head and divide by the length of the slant side of the wedge.

To find the length of the slant side of the wedge.—Multiply the weight by the breadth of the wedge and divide by the power.

To find the breadth of the wedge.—Multiply the power by the length of the slant side of the wedge, and divide by the weight.

F=Force required. P=Resisting power.

$$F=\frac{P\times H}{S} \quad P=\frac{F\times S}{H} \quad \text{(Fig. 79.)}$$

$$S=\text{Slant side of wedge}=\sqrt{H^2+L^2}$$

Note.—For all practical purposes the length L may be used instead of the slant length S of the side.

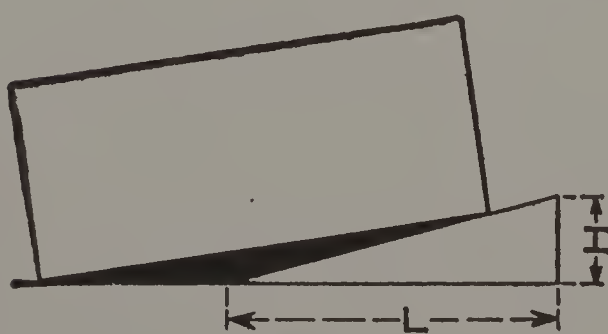


Fig. 79.

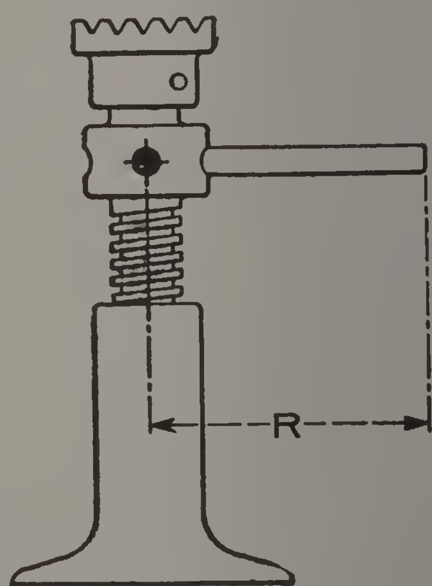


Fig. 80.

The Screw.

The screw, Fig. 80, in principle, is that of an inclined plane wound around a cylinder which generates a spiral of uniform inclination, each revolution producing a rise or traverse motion equal to the pitch of the screw, or distance between two consecutive threads. The pitch being the height or angle of inclination, and the circumference the length of the plane when a lever is not applied. The lever being a necessary qualification of the screw, the circle which it describes is taken, instead of the screw's circumference, as the length of the plane, the mechanical advantage is therefore as the circumference of the circle described by the lever where the power acts, is to the pitch of the screw, so is the force to the resistance.

As the circumference of a circle is equal to the radius multiplied by twice 3.1416, or 6.2832, hence the following rules for the screw.

To find the power.—Multiply the weight by the pitch of the screw and divide by the product of the radius of the handle by 6.2832.

To find the weight.—Multiply the power by the product of the radius of the handle by 6.2832 and divide by the pitch of the screw.

To find the pitch of the screw.—Multiply the power by the product of the radius of the handle by 6.2832 and divide by the weight.

To find the length or radius of the handle.—Multiply the weight by the pitch of the screw and divide by the product of the power by 6.2832.

P=Lifting power of jack. R=Length of lever.
F=Force required at end of lever.
N=Number of threads per inch of jack screw.

$$P=6.283(N\times R\times F) \qquad F=\frac{P}{6.283\,(N\times R)}$$

$$N=\frac{P}{6.283\,(R\times F)} \qquad R=\frac{P}{6.283\,(N\times F)}$$

The Safety Valve.

Safety Valves. In order to find the weight to be placed on the end of a safety valve lever to balance a given pressure of steam on the valve, it is necessary to ascertain the load on the valve due to the weight of the lever. The leverage with which the weight of the lever acts is measured by the distance of its center of gravity from the fulcrum. The center of gravity may be found by balancing the lever on a knife edge, and the weight of the lever and valve may be obtained by weighing them.

In Fig. 81, W is the weight at the end of the lever, L is the distance between the weight and the fulcrum, G is the distance of center of gravity of the lever from the fulcrum, R is the distance between the center of the valve V and the fulcrum.

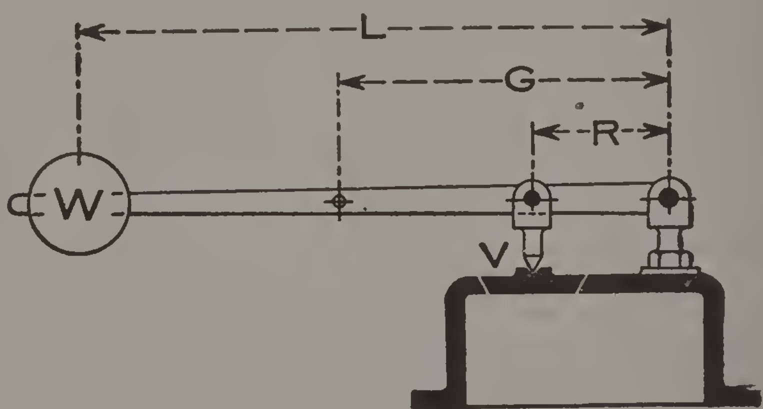


Fig. 81.

To find the weight to be placed on the end of the lever proceed as follows. Multiply the area of the valve V by the pressure in pounds per square inch above the atmosphere, and call the product A.

Multiply the weight of the lever by the distance of the center of gravity of the lever from the fulcrum, and divide by the distance between the center of the valve and the fulcrum, and add the weight of the valve to the quotient, and call the result B.

Subtract B from A, multiply the remainder by the distance between the center of the valve and the fulcrum, and divide by the distance between the weight and the fulcrum, the quotient will be the weight to place on the valve.

To find the pressure on the valve in pounds per square inch above the atmosphere. Multiply the weight of the lever by the distance of the center of gravity of the lever from the fulcrum, and call the product C.

Multiply the distance between the weight and the fulcrum by the weight at the end of the lever, and call the product D, add C to D, divide by the distance between the center of the valve and the fulcrum, and add the weight of the valve to the quotient, then divide by the area of the valve V; the quotient will be the steam pressure in pounds per square inch, at which the valve will rise.

To find the length of lever, or distance between the weight and the fulcrum. Multiply the pressure of the steam in pounds per square inch above the atmosphere by the area of the valve V, and call the product E.

Multiply the weight of the lever by the distance of the center of gravity of the lever from the fulcrum, divide by the distance between the center of the valve and the fulcrum, and add the weight of the valve to the quotient, and call the result F.

Subtract F from E, multiply the remainder by the distance between the center of the valve V, and the fulcrum, and divide by the weight at the end of the lever, the quotient will be the distance between the weight and the fulcrum.

Counterbalanced safety-valve levers. If the lever be prolonged beyond the fulcrum, and provided with a weight sufficient to balance the weight of the lever, valve, and connections, the rules become simplified, and are as follows:

To find the weight to be placed on the lever. Multiply the pressure in pounds per square inch above the atmosphere by the area of the valve V, and by the distance between the center of the valve and the fulcrum, and divide by the distance between the weight and the fulcrum.

To find the length of lever or distance between the weight and the fulcrum. Multiply the pressure in pounds per square inch above the atmosphere by the area of the valve V, and by the distance between the center of the valve and the fulcrum, and divide by the weight at the end of the lever.

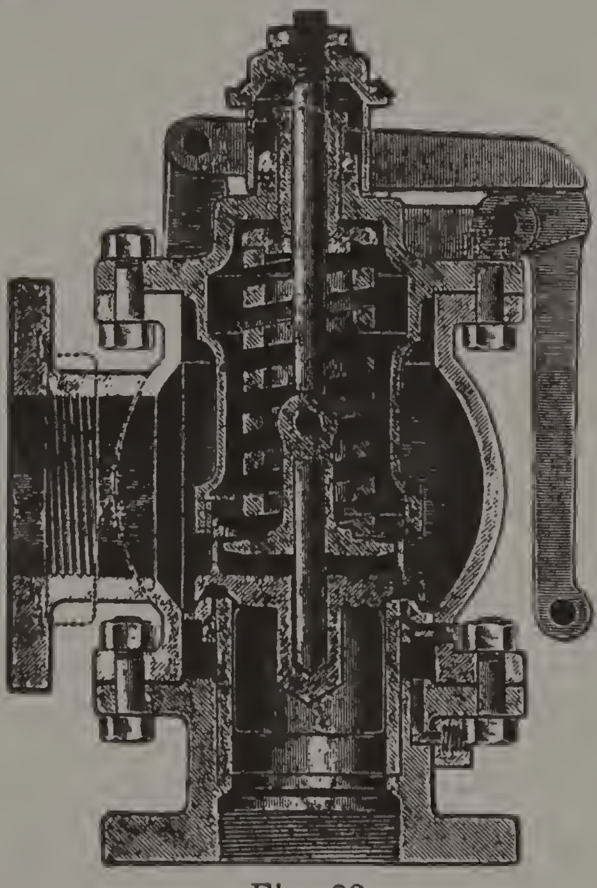


Fig. 82.

To find the pressure on the valve in pounds per square inch above the atmosphere. Multiply the weight at the end of the lever by the distance between the weight and the fulcrum, and divide by the product of the area of the valve V by the distance between the center of the valve and the fulcrum.

Safety-valve with spring balance. When the valve V is held down by a spring, the lever is generally dispensed with as shown in Fig. 82.

Gravity and the Velocity of Falling Bodies.

Gravity is the action of universal attraction which draws all bodies towards each other, and by which bodies on the surface of the earth are drawn towards its centre. The line which a falling body describes, or the direction of gravity, is called the vertical line, the curvature of the earth being quite unappreciable for small distances. Gravity is considered to act in parallel lines, and its direction is indicated by the plumb-line.

The center of gravity is that point in a body or system of bodies on which, if rested or suspended, the whole will remain in a state of rest. Thus, if a wall or other structure be raised perpendicular to the base, it will remain secure whilst in that state, but if the foundation be not sufficiently solid and allow it to depart so far from the vertical position that the center of gravity overhangs the edge of the base, the structure must fall unless the parts anchored anchored together.

The center of gravity of a cylinder, prism, or any other body, the parallel sections of which are equal, is in the middle of the axis of that body.

In a cone or any other pyramid, the distance of the center of gravity from the base is one-fourth of the axis.

In a hemisphere the distance of the center of gravity is three-eighths of the radius from the center.

Force of gravity or gravitation is an accelerated velocity which heavy bodies acquire, in falling freely from a state of rest. Thus the velocity that a body will acquire in one second of time equals 32.2 feet, the distance fallen being 16.1 feet; and if the times or seconds be in an arithmetical ratio, as 1, 2, 3, 4, etc., the spaces fallen through will be successively as the numbers 1, 3, 5, 7, etc., and the total space passed through as the geometrical progression, 1, 4, 9, 16, etc. The velocity is 32.2 feet multiplied by the number of seconds in falling from rest, and the square of the velocity is equal to twice 32.2 times the space fallen through. The space fallen through is equal to 16.1 multiplied by the square of the number of seconds.

Weight is the force apparent when gravity acts upon mass. Mass is matter without reference to weight. When mass or matter is prevented from moving under the stress of gravity, its weight can be appreciated.

v=Velocity in feet per second.
t=Time in seconds
h=Height in feet
g=gravity constant=32.2

$v^2=2\times g\times h$ $v=\sqrt{2\times g\times h}$

$h=\frac{g\times t^2}{2}$ $t^2=\frac{2\times h}{g}$ $t=\sqrt{\frac{(2\times h)}{g}}$

Weight does not enter into consideration in the above formulas. In a perfect vacuum a feather should fall from a given height in the same time that a pound weight would.

To find the final velocity in feet per second. Multiply the time in seconds by 32.2.

To find the height of the fall in feet. Multiply the square of the time in seconds by 16.1.

To find the time of falling in seconds. Divide the height in feet by 16.1 and extract the square root of the quotient.

Example: Find the velocity that a body will acquire in five seconds: $32.2\times 5=161$ feet.

Example: Find the space fallen through in seven seconds: $16.1\times 7^2=788.9$ feet.

Example: Find the velocity that a body will acquire in falling through 120 feet: $\sqrt{120\times 64.4}=\sqrt{7728}=87.9$ feet.

The velocity acquired by a body falling through a given height is the same, whether it fall freely or descend upon a plane any way inclined.

Force of gravity is the cause of retarded and of accelerated motion on inclined planes, the acting force being as the height of the plane to its length. Eight pounds traction will overcome 2,000 pounds, or one ton of weight, but on an incline or rise of 1 in 350, the amount of traction to overcome the same weight must be $\frac{2240}{350}=6.4+8$ $=14.4$ pounds. Again, if the weight be descending, then the force of traction is diminished in an equal ratio, and

Table No. 5—Velocity of Falling Bodies: Table of Accelerated Motion.			
Time in seconds the body is falling.	Space in feet that a falling body passes through during each second.	Space in feet through which a body will fall in a given time.	Velocity in feet per second that a falling body will acquire during the time given.
1	16.1	16.1	32.2
2	48.3	64.4	64.4
3	80.5	144.9	96.6
4	112.7	257.6	128.8
5	144.9	402.5	161.0
6	177.1	579.6	193.2
7	209.3	788.9	225.4
8	241.5	1030.4	257.6
9	273.7	1304.1	289.8
10	305.9	1610.0	322.0

the weight accelerated by gravity, thus 8—6.4=1.6 pounds, the force of traction on the descending plane.

Force of gravity is also the restrictive cause to a pendulum's motion. Consequently its motion at any place is dependent upon the energy of the force of gravity at that place.

Pendulums of the same length vibrate slower, the nearer they are brought to the equator, on account of the earth's spheroidal form, its polar axis being about twenty-six miles shorter than its equatorial diameter, for which reason gravity is lessened 1-289th part, the centrifugal force arising from the diurnal motion of the earth being greater at the equator than at the poles.

The measure of the force of gravity in feet per second at any place, is equal to the length of a pendulum in feet, divided by the square of the time in seconds between each of its oscillations, and the quotient multiplied by 9.8696, the product equals the number of feet by which gravity will at that place increase the velocity of the descent of a falling body in each second of time.

The space through which a body will fall during the time of one vibration of a pendulum vibrating seconds, is to half the pendulum's length as the square of the circumference of a circle is to the square of its diameter.

The length of a Pendulum to vibrate Seconds, or Sixty Times in a Minute.

At the Equator, equals	39.0152 inches.
In the latitude of London	39.1393 inches.
In the latitude of Edinburgh	39.1555 inches.
In the latitude of Paris	39.1286 inches.
In the latitude of New York	39.1011 inches.
In the latitude of Madras	39.0263 inches.
In the latitude of Greenland	39.2033 inches.

SPECIFIC GRAVITY, CENTER OF OSCILLATION, CENTRIFUGAL FORCE, ETC.

Specific Gravity. The comparative density of various substances is expressed by the term specific gravity, which affords the means of readily determining the bulk from the known weight, or the weight from the known bulk. This is found especially useful in cases where the substance is too large to admit of being weighed, or too irregular in shape to allow of correct measurement. The standard with which all solids and liquids are thus compared, is that of distilled water, one cubic foot of which weighs 1000 ounces avoirdupois. The specific gravity of a solid body is determined by the difference between its weight in the air and in water. Thus: If the body be heavier than water, it will displace a quantity equal to its own bulk, and will lose as much weight on immersion as that of an equal bulk of the water. If the body be weighed first in the air, and then in the water, and its weight in the air be divided by the difference between the two weights, and the quotient will be its specific gravity, that of water being unity.

If the body be lighter than water, it will float, and displace a quantity of the water equal to it in weight, the bulk of which will be equal to that only of the part immersed. A heavier substance must therefore be attached to it, so that the two may sink in the fluid. Then the weight of the lighter substance in the air must be added to that of the heavier substance in water, and the weight of both united in water be subtracted from the sum; the weight of the lighter body in the air must then be divided by the difference, and the quotient will be the specific gravity of the lighter substance required.

The specific gravity of a fluid may be determined by taking a solid body, heavy enough to sink in the fluid, and of known specific gravity, and weighing it both in the air and in the fluid. The difference between the two weights must be multiplied by the specific gravity of the solid body, and the product divided by the weight of the solid in the air, the quotient will be the specific gravity of the fluid, that of water being unity.

TABLE No. 6.—**Specific Gravity and Weight per Cubic Foot of Metals.**

Metal	Specific Gravity.	Wt. in Lbs. per Cu. ft.	Metal	Specific Gravity.	Wt. in Lbs. per Cu. ft.
Aluminum	2592	162	Gun Metal	8560	535
Antimony	6704	418	Iron—Cast	7200	450
Bismuth	9808	613	" —Ma'lble	7360	460
Brass—Cast	8064	504	" —Wrought	7680	480
" —Sheet	8160	510	Lead	11360	710
Bronze—Aluminum	8000	500	Nickel	8272	517
" —Phosphor	8480	530	Platinum	20976	1313
Cadmium	8608	538	Silver (pure)	10480	655
Copper—Cast	8672	542	Steel—Cast	7776	486
" —Sheet	8768	548	" —Mild	7840	490
" —Wire	8768	548	Tin, Cast.	7296	456
Gold (pure)	19254	1204	Zinc, Cast.	7008	438

TABLE No. 7.— **Specific Gravity and Weight per Cubic Foot of Substances.**

Substance	Specific Gravity.	Wt. in Lbs. per Cu. ft.	Substance	Specific Gravity.	Wt. in Lbs. per Cu. ft.
Ash, White	608	38	Mahogany	848	53
Asphaltum	1392	87	Maple	784	49
Brick—Pressed	2400	150	Marble	2688	168
" —Common	2000	125	Mica	2928	183
Cement—Portland	1440	90	Oak, White	800	50
" —Louisville	800	50	Pine—White	400	25
Cherry	672	42	" —Northern	544	34
Chestnut	656	41	" —Southern	720	45
Clay—Common	1920	120	Quartz	2640	165
—Potters	1760	110	Rosin	1104	69
Coal—Anthracite	1488	93	Salt	720	45
" —Bituminous	1344	84	Sand—Dry	1568	98
Coke	416	26	" —Wet	2240	140
Earth	1520	95	Sandstone	2416	151
Ebony	1216	76	Shale	2592	162
Elm	560	35	Slate	2800	175
Flint	2592	162	Spruce	400	25
Glass, plate	2448	153	Sulphur	2000	125
Granite	2656	166	Sycamore	592	37
Gravel	1920	120	Peat	416	26
Hemlock	400	25	Teak	752	47
Hickory	848	53	Walnut, Black	608	38
Ice	960	60	Wax, Bees	960	60
Ivory	1824	114	Willow	576	36
Lignum Vitæ	1328	83	Yew—Spanish	800	50
Magnesium	1744	109	" —Dutch	768	48

TABLE NO. 8—**Specific Gravity and Weight per Cubic Foot of Liquids.**

Liquid.	Specific Gravity.	Weight in Lbs. per Cubic Foot.
Alcohol—Commercial		$51\frac{1}{2}$
" —Absolute	797	49.8
Acid—Muratic	1200	75
" —Nitric	1216	76
" —Sulphuric	1856	116
Ether—Nitric	908	63
" —Muratic	730	45.6
Oil—Linseed	941	58.8
" —Olive	914	57.1
" —Whale	923	57.7
Petroleum—Crude	880	55
Spirit—Proof	922	57.5
" —of Wine	830	51.9
Tar—Gas	1008	62
" —Wood	992	63
Turpentine	864	54
Water—Distilled	997	$62\frac{1}{3}$
" —Sea	1024	64

The Centre of Oscillation is a certain point in a vibrating body into which all its force is collected, and at which, if an obstacle be applied, motion will instantly cease. The most simple means by which to ascertain the centre of oscillation in a compound pendulum, is to suspend a small ball by a fine thread in front of that in which the centre of oscillation is required, then to lengthen or shorten the thread until the vibrations of each are alike, then stop both and let them hang freely. Opposite the centre of the ball is the centre of oscillation.

Specific Gravity of Bodies.

As one cubic foot of fresh water at 62 degrees Fahrenheit, weighs 1000 ounces avoirdupois, it (1000) is therefore adopted as the standard of comparison to which the densities of other bodies are referred.

Table No. 9—Comparative Weights of Different Metals, etc.

Cast Iron=1.		Gun Metal=1.	
Wrought Iron	1.049	Cast Iron	.829
Steel	1.080	Wrought Iron	.879
Brass	1.160	Steel	.898
Copper	1.219	Brass	.958
Gun Metal	1.209	Copper	1.001
Lead	1.560	Lead	1.296
Wrought Iron=1.		**Copper=1.**	
Cast Iron	.95	Cast Iron	.831
Steel	1.026	Wrought Iron	.868
Brass	1.097	Steel	.888
Gun Metal	1.150	Brass	.949
Copper	1.152	Gun Metal	.998
Lead	1.500	Lead	1.298
Steel=1.		**White Metal=1.**	
Cast Iron	.929	Cast Iron	.793
Wrought Iron	.974	Wrought Iron	.814
Brass	1.071	Steel	.846
Gun Metal	1.121	Gun Metal	.912
Copper	1.124	Copper	.954
Lead	1.454	Lead	1.201
Brass=1.		**Lead=1.**	
Cast Iron	.865	Cast Iron	.641
Wrought Iron	.915	Wrought Iron	.670
Steel	.934	Steel	.689
Gun Metal	1.045	Brass	.739
Copper	1.051	Gun Metal	.771
Lead	1.355	Copper	.778

Yellow Pine=1.

Cast Iron	16.00	Brass	18.80	Copper	19.30
Steel	17.00	Gun Metal	19.00	Lead	24.00

Example: A Wrought-Iron plate weighs 700 pounds, required the weight of a similar plate of Gun Metal.

Answer: $700 \times 1.15 = 805$ pounds.

Centrifugal force signifies the tendency that bodies acquire, by velocity of circular motion, to fly off in a tangential line from the centre of revolution, the amount of tendency being as the square of the velocity of the body in motion. Multiply the square of the number of revolutions per minute by the radius of the circle in feet, by the weight of the body, and by .000331. The product is the centrifugal force in terms of the body's weight.

Centripetal force is that force by which a body would tend to the centre of motion, if not urged from it by centrifugal force. The balls of the governor of a steam-engine conspicuously indicate this force when the velocity of the engine is becoming reduced by over resisting force, or by a scant supply of steam.

The Centre of gyration, in a revolving body, is a certain point into which the whole momentum of the mass is concentrated, and from which point the greatest amount of effective energy is transmitted. Any point in the circumference of a circle, whose radius is the distance of the centre of rotation from the centre of gyration, is equally entitled to be called a centre of gyration. The radius of this circle is the radius of gyration.

To find the distance of the centre of gyration from the centre of revolution. Multiply the amount of acting force, the distance at which it is applied from the centre of revolution, by the time of revolution observed in seconds, and by 32.2 and divide the product by the weight multiplied by its velocity, and the quotient is the distance from the centre of motion to the centre of gyration.

Momentum, or quantity of motion, signifies the product of the moving weight multiplied by the velocity, and is usually estimated in pounds, moving at the given velocity in feet per second. A body weighing 10 pounds and moving at the rate of 10 feet per second, has a momentum of 100.

Percussion. The quantity of work stored in a moving body is the same as that which would be accumulated in it by gravity, if it fell from a height sufficient to give it the same velocity. The effect of percussive machines is produced by expending the work accumulated in the striking body.

Pile driving. In a pile-driving machine, with a ram weighing 336 pounds and 10 feet fall, the work accumulated in the monkey in each fall, will be 336 pounds × 10 feet=3360 foot-lbs. If this work be expended in driving the pile 1 inch into the ground the force exerted will be 3360 foot-pounds × 12 inches=40320 pounds.

To find the work accumulated in a moving body in foot-pounds. Multiply the weight in pounds by the square of the velocity in feet per second, and divide by 64.4.

Level properly signifies points equidistant from the centre of the earth on its surface. Any level taken by an instrument is only a tangent line to the earth's curvature, and is generally termed the apparent level. The earth is nearly a sphere, with a mean diameter of 7925 miles, and if the square of the distance between any two points on its surface be divided by its diameter, the quotient will equal the excess of altitude between the summit of the vertical diameter and that of the other point. At one mile distance the excess by level with an instrument becomes 7.962 inches, at two miles it is 31.848, being as the square of the distance. The excess subtracted from the apparent level, equals true level as required for extensive levelling operations.

Capillary attraction is a property observable in small tubes, flat, thin spaces, porous substances, as sponge, wick, worsted, threads, etc., of raising water or other fluids above the natural level. The principle is used for obtaining a continuous supply of lubricating fluid between surfaces in motion by a syphon of threads; one end of which is immersed in oil, the other being inserted in and supported by the tube through which the fluid is conducted.

FRICTION.

Friction is an effect produced by bodies rubbing one upon another, which acts as a retarding influence in the motion of all mechanical devices, but might be considerably diminished by a due regard to its laws, and a proper attention to the selection of materials on which a smooth surface may be attained, and which are least liable to wear or become hot, and cause a roughness to arise when in working contact.

The ordinary theory of friction may be briefly stated to be as follows: When no lubricant is interposed, the friction of any two surfaces is directly proportional to the force with which they are pressed perpendicularly together, so that for any two given surfaces of contact, there is a constant ratio of the friction to the perpendicular pressure. That is, a double pressure will produce a double amount of friction, or a triple pressure a triple amount.

When no lubricant is interposed, the amount of the friction is in every case wholly independent of the extent of the surfaces in contact, so that the force with which two surfaces are pressed together being the same, their friction is the same, whatever may be the extent of their surfaces of contact.

When lubricants are interposed, the amount of friction depends more upon the nature of the lubricant than upon that of the surfaces of contact, and the nature of the lubricant to be applied must be governed by the pressure or weight. The consistency of a lubricant should be such as just prevent the bodies coming into contact with each other.

The friction of metals, without a stratum of lubricant interposed, varies as their hardness, the harder metals producing less friction than the softer ones.

Without lubricants, and within the limits of 32 pounds pressure per square inch, the friction of hard metal upon hard metal may be estimated at about one-sixth of the whole pressure.

The sliding friction of plane surfaces in contact is increased by heat, and is diminished by polishing and efficient lubrication; and it is less in motion than at starting. That portion of the pressure required to overcome friction is called the coefficient of friction. For oak and other woods, and cast-iron and other metals, each sliding on each other, and lubricated, the coefficient varies according to the efficiency of the lubrication, from .07 to .04 for sliding friction. Rolling friction is considerably less than sliding friction.

The friction of motion was formerly considered to be wholly independent of the velocity of the motion. The results of recent experiments show that the resistance of friction increases with the velocity, and that the coefficient of friction is extremely low, amounting in some cases to only .001, or a mere fraction of what it was formerly considered to be.

The experiments also show that the friction of lubricated bearings varies considerably with temperature.

Belt Pulleys.

Where motion has to be communicated from one shaft to another by means of a belt passing over pulleys, to find the diameter of either pulley, to suit that of another with increased or diminished velocity, so that the same length of belt may be suitable without alteration, the question unavoidably divides itself into two, as the pulley whose diameter is required is less or greater than that of a pulley which is known. When this point is uncertain, multiply the radius of the known pulley by 3.1416, and increase the product by the distance between the centres of the shafts in inches. If this sum which may be called the trial number, is greater than half the length of the belt, the required pulley is less than the given one, but if less, then the required pulley is the greater. In both of these cases, divide the difference between the trial number and half the length of the belt, by the distance between the centres of the shafts.

When the required pulley is less than the given one. Take double the number from 2.4674, and subtract the square root of the remainder from 1.5708, and call the difference A. Multiply the number A by the distance between the centres of the shafts, and the remainder, taken from the radius of the large pulley, will give the radius of the less one.

When the required pulley is greater than the given one. Add double the number to 2.4674, and from the square root of the sum subtract 1.5708, and call the remainder B. Multiply the number B by the distance between the centres of the shafts and the product, added to the radius of the given or less pulley, will give the radius of the required, or greater pulley.

Gear Wheels.

Motion is in many cases transmitted by means of gear wheels, and accordingly as the driving and driven are of equal or unequal diameters, so are equal or unequal velocities produced.

When time is not taken into account. Divide the greater diameter, or number of teeth, by the lesser diameter, or number of teeth, and the quotient is the number of revolutions the lesser will make for 1 of the greater.

Example: How many revolutions will a pinion of 20 teeth make for 1 of a gear with 125 teeth?

Answer: 125÷20=6.25, or 6¼ revolutions.

Intermediate gears of any diameter, used to connect other gears at any required distance apart, cause no variation of velocity more than otherwise would result if the first and last gears were in mesh.

To find the number of revolutions of the last, to 1 of the first, in a train of gears and pinions. Divide the product of all the teeth in the driving by the product of all the teeth in the driven gears, and the quotient will equal the ratio of velocity required.

Example: A gear of 42 teeth giving motion to one of 12 teeth, on which shaft is a pulley of 21 inches diameter, driving one of 6 inches diameter, required the number of revolutions of the last pulley to one of the first gear.

Answer: $(42 \times 21) \div (12 \times 6) = 12.25$, or $12\frac{1}{4}$ revolutions.

Where increase or decrease of velocity is required to be communicated by gears, it has been demonstrated that the number of teeth on the pinion should not be less than 1 to 6 of its wheel, unless there be other reasons for a higher ratio.

When time must be regarded. Multiply the diameter, or number of teeth in the driving gear, by its velocity in any given time, and divide the product by the required velocity of the driven gear, the quotient equals the number of teeth, or diameter of the driven gear, to produce the velocity required.

Example: If a gear containing 84 teeth makes 20 revolutions per minute, how many teeth must another contain to work in contact, and make 60 revolutions in the same time?

Answer: $(84 \times 20) \div 60 = 28$ teeth.

The distance between the centres and velocities of two gears being given, to find their proper diameters. Divide the greatest velocity by the least. The quotient is the ratio of diameter the wheels must bear to each other. Hence, divide the distance between the centres by the ratio plus 1. The quotient will equal the radius of the smaller gear, and subtract the radius thus obtained from the distance between the centres, the remainder will equal the radius of the other gear.

Example: The distance of two shafts from centre to centre is 50 inches, and the velocity of one shaft is 25 revolutions per minute, the other shaft is to make 80 revolutions in the same time. Required the proper diameters of the gears at the pitch lines.

Answer: $8 \div 25 = 3.2$, the ratio of velocity, and $50 \div (3.2+1) = 11.9$, the radius of the smaller wheel; then $50-(11.9 \times 38.1)$ the radius of the larger gear. Their diameters are therefore $11.9 \times 2 = 23.8$, and $38.1 \times 2 = 76.2$ inches.

To obtain or diminish an accumulated velocity by means of gears and pinions, or gears, pinions, and pulleys, it is necessary that a proportional ratio of velocity should exist, and which is obtained thus: Multiply the given and required velocities together, and the square root of the product is the mean or proportionate velocity.

Example: Let the given velocity of a gear containing 54 teeth equal 16 revolutions per minute, and the given diameter of an intermediate pulley equal 25 inches, to obtain a velocity of 81 revolutions in a machine. Required the number of teeth in the intermediate gear, and the diameter of the last pulley.

Answer: $\sqrt{81 \times 16} = 36$ the mean velocity, $(54 \times 16) \div 36 = 24$ teeth, and $(25 \times 36) \div 81 = 11.1$ inches, the diameter of the pulley.

Diametral Pitch System of Gears.

The **Diametral pitch** system is based on the number of teeth to one inch diameter of the pitch circle. Formulas are herewith given so that if the number of teeth in the gear and the diametral pitch are known, the pitch diameter of the gear may be found, also the outside diameter, the working depth and clearance at the bottom of the tooth. Let **P** be the pitch diameter in inches, **D** the diametral pitch of the gear, **C** the circular pitch in inches, **O** the outside diameter in inches, **T** the thickness of the tooth at the pitch line in inches, **W** the working depth of the tooth in inches, and **N** the number of teeth in the gear, then

$$P = \text{Pitch diameter} = \frac{N}{D} \quad (1.)$$

$$O = \text{Outside diameter} = P + \frac{2}{D} \quad (2.)$$

$$D = \text{Diametral pitch} = \frac{N}{P} \quad (3.)$$

$$C = \text{Circular pitch} = \frac{3.142}{D} \quad (4.)$$

$$W = \text{Working depth of tooth} = \frac{2}{D} = 2 \div D \quad (5.)$$

$$N = \text{Number of teeth} = P \times D \quad (6.)$$

$$T = \text{Thickness of tooth} = 1.571 \div D \quad (7.)$$

$$\text{Clearance at bottom of tooth} = \frac{0.157}{D} \quad (8.)$$

Example: Required, the pitch diameter of a gear with 20 teeth and 4 diametral pitch.

Answer: From Formula 1, as the pitch diameter is equal to the number of teeth divided by the diametral pitch, then 20 divided by 4 equals 5, as the required pitch diameter in inches.

Example: What is the outside diameter of the same gear?

Answer: From Formula 2, as the pitch diameter is 5 inches and the diametral pitch 4, then 4 plus 2-4 equals 4½ as the proper outside diameter for the gear.

Example: What should be the diametral pitch of a gear with 30 teeth and 6 inches pitch diameter?

Answer: From Formula 3, 30 divided by 6 squals 5, as the diametral pitch to be used for the gear.

Example: Required the circular pitch of the teeth of a gear whose diametral pitch is 6.

Answer: From Formula 4, 3.142 divided by 6 gives 0.524 inches as the circular pitch of the teeth of the gear.

Example: What should be the working depth of a tooth of 4 diametral pitch?

Answer: From Formula 5, 2 divided by 4 gives 0.5 or one-half an inch as the working depth of the tooth.

Example: How many teeth are there in a gear of 7 inches pitch diameter and 7 diametral pitch?

Answer: From Formula 6 the number of teeth is equal to 7 multiplied by 7, or 49 teeth in the gear.

Example: What is the thickness at the pitch line of a tooth of 8 diametral pitch?

Answer: By Formula 7 the thickness of the tooth at the pitch line is 1.571 divided by the diametral pitch, then 1.571÷8 gives 0.196 inches as the thickness of the tooth.

Example: What should be the correct clearance at the bottom of a tooth of 3 diametral pitch?

Answer: From Formula 8 the clearance at the bottom of the tooth is equal to 0.157 divided by 3, which gives 0.052 as the required clearance.

Table No. 10 gives the dimensions of Involute Tooth Spur Gears from 1 to 16 Diametral pitch.

TABLE No. 10—DIMENSIONS OF INVOLUTE TOOTH SPUR GEARS.

Diametral Pitch.	* Circular Pitch.	Width of Tooth on Pitch Line.	Working Depth of Tooth.	Actual Depth of Tooth.	Clearance at Bottom of Tooth.
1	3.142	1.571	2.000	2.157	0.157
2	1.571	0.785	1.000	1.078	0.078
3	1.047	0.524	0.667	0.719	0.052
4	0.785	0.393	0.500	0.539	0.039
5	0.628	0.314	0.400	0.431	0.031
6	0.524	0.262	0.333	0.360	0.026
7	0.447	0.224	0.286	0.308	0.022
8	0.393	0.196	0.250	0.270	0.019
10	0.314	0.157	0.200	0.216	0.016
12	0.262	0.131	0.167	0.180	0.013
14	0.224	0.112	0.143	0.154	0.011
16	0.196	0.098	0.125	0.135	0.009

*The circular pitch corresponding to any diametral pitch number, may be found by dividing the constant 3.1416 by the diametral pitch.

EXAMPLE: What is the circular pitch in inches corresponding to 4 diametral pitch?

ANSWER: Dividing 3.1416 by 4 gives 0.7854 inches as the required circular pitch.

PROPERTIES OF STEAM

Steam contains heat which is sensible to the thermometer, and also a quantity of heat of which the thermometer affords no indication, which is therefore called latent heat, hence, the vapor rising from water contains more heat than the water. In proof of the existence of latent heat, if one part by weight of steam at 212 degrees, be mixed with nine parts of water at 62 degrees, the result is water at 178.6 degrees, therefore, each of the nine parts of water has received from the steam 116.6 degrees of heat, and consequently the steam has diffused or given out 116.6×9=1049.4—33.4=1016 degrees of heat which it must have contained. Again, if one gallon of water be transformed into steam at 212 degrees, and if that steam be mixed with water at 52 degrees, the whole will be raised to the boiling point, or 212 degrees. From experiments, it is ascertained that the latent heat in steam varies from 940 degrees to 1044 degrees, the ratio of accumulation advancing from 212 degrees, as the steam becomes more dense and of greater elastic force.

The latent heat in steam makes it useful for heating, boiling and drying purposes. In the heating of buildings, it is applied with economy, efficiency, and simplicity. The steam becomes condensed during its circulation round the building, through the pipes of the heating apparatus, the latent heat being thus given to the pipes and diffused by radiation. In boiling, its efficiency is considerably increased, if advantage be taken of sufficiently enclosing the fluid and reducing the pressure on its surface by means of an air-pump; thus, water in a vacuum boils at about a temperature of 98 degrees, and in sugar-refining, where such means are employed, the syrup is boiled at 150 degrees.

To calculate the amount of advantage gained by using steam expansively in a steam engine.

When steam of a uniform force throughout the whole length of stroke of the piston is used, the amount of effect produced is as the quantity of steam expended. But let the steam be shut off at any portion of the stroke, say at one half, it expands by degrees until the termination of the stroke, and then exerts half its original force.

Divide the length of the stroke by the distance or space into which the boiler steam is admitted, and find the natural logarithm of the quotient, to which add 1, and the sum is the ratio of the gain.

Example: An engine with a stroke of 6 feet has the steam cut off when the piston has moved through 2 feet. Required the ratio of gain by uniform and expansive force.

Answr: $6 \div 2 = 3$. From Table No. 11 the natural logarithm of $3 = 1.098$, and $1.098 + 1 = 2.098$ ratio of effect, that is, supposing the whole effect of the steam to be 3, the effect by the steam being cut off at one-third of the stroke $= 2.098$.

Let the greatest force of steam in the cylinder of an engine equal 48 pounds per square inch, and let it be cut off when the piston has moved 4½ inches, the whole stroke being 18. Required the equivalent force of the steam throughout the whole stroke.

Answer: $18 \div 4.5 = 4$, and $48 \div 4 = 12$. Nat. Log. of $4 = 1.386$, and $1.386 + 1 = 2.386$. Then $2.386 \times 12 = 28.63$ pounds per square inch.

From Table No. 11 it may be plainly seen that, if the steam is cut off at one-third of the stroke, and expanded to the end of the stroke the work done is about twice that done by the steam during admission.

TABLE No. 11—**Work Done by Steam During Admission and Expansion.**

Point of Cut Off.	Ratio of Expansion =R	Work done during Admission.	Work done during expansion = nat. log. R.	Total work done.
Cut off at $\frac{3}{4}$ stroke	$1\frac{1}{2}$	1	0.262	1.262
Cut off at $\frac{1}{2}$ stroke	2	1	0.693	1.693
Cut off at $\frac{1}{3}$ stroke	3	1	1.098	2.098
Cut off at $\frac{1}{4}$ stroke	4	1	1.386	2.386
Cut off at $\frac{1}{5}$ stroke	5	1	1.609	2.609
Cut off at $\frac{1}{8}$ stroke	8	1	2.079	3.079
Cut off at $\frac{1}{9}$ stroke	9	1	2.197	3.197
Cut off at $\frac{1}{10}$ stroke	10	1	2.302	3.302

The exact proportion is 1:2.098

If the steam had been admitted at its initial pressure throughout the whole stroke, three times the weight of steam would have been used, and the proportion of the work done in the two cases, supplying steam through the whole length of the stroke, or cutting off at one-third and expanding, would be as 3 to 2.098, in other words, to get half as much more work out of the engine, three times the weight of steam, and therefore also weight of fuel, will be consumed in the first case as compared with the second.

Condensation of steam is generally effected by cold water, the quantity of which may be estimated by the following rule. From 1000 plus the temperature of the steam, subtract the required temperature of the condensed water, divide the remainder by the temperature of the condensed water minus the temperature of the cold or condensing water, and the quotient will equal the number of times that the quantity, for condensation, must exceed that by which the steam is formed.

Example: Required the ratio or quantity of water for condensation to 1 of water for the formation of steam, the temperature of the steam being 220 degrees and the required temperature of condensed water 18 degrees.

Answer: $\frac{(1000+220)-180}{180-52}$=8 times the quantity.

Pressure and Expansion of Steam.

The pressure of steam is equal in all directions, and it is usual to measure the pressure with reference to that of the atmosphere, which is equal to 14.7 pounds per square inch of surface, and is the measure of one atmosphere of pressure. Vapors, of which steam is one, do not follow the law of permanent gases, according to which the volume of a given weight is inversely as the pressure. It has been demonstrated, on the contrary, that there exists a constant relation between the pressure, the density, and the temperature of steam, such that the pressure cannot be raised above a given maximum, without, at the same time, a certain elevation of temperature.

Volume and Pressure of Steam. If the volume be forcibly reduced, and the vapor compressed, without any change of temperature, the compression has not the effect of augmenting the pressure, as would happen if air was similarly treated, it only results in liquefying a portion of the steam, according as the volume is reduced, so that the volume, however reduced, will only contain so much proportionally the less of steam of the original pressure. In order to increase the pressure, the temperature must be raised.

Point of Saturation of Steam. When the vapor has attained the limit of density and pressure, corresponding to the temperature, the steam is said to be saturated, and it is always in the state of saturation when in contact with water. For one pressure there is one density and one temperature, and the higher the pressure, the greater is the density and the higher is the temperature.

Expansion of Steam. When a quantity of steam is placed out of contact with water, as in the cylinder of a steam-engine, it may be expanded, and again compressed up to the limit of saturation, and it will follow approximately, though not precisely, the law of Boyle or Mariotte, that is to say, the pressure is nearly in the inverse ratio of the volume, insomuch that when the volume is doubled, the pressure is reduced to about one-half, and when the volume is trebled, the pressure is reduced to about a third.

Superheated Steam. Superheated steam is amenable to the laws of permanent gases, and behaves as one of them, expanding and contracting in the inverse ratio of the pressure, when the temperature is constant, without the condensation of any portion of it.

Density, Pressure, and Temperature of Steam. It follows from the above, that one density and one pressure relative to one temperature are attained in a steam-boiler. These several qualities are in equilibrium, and the steam is in a state of saturation. That so long as the state of saturation corresponding to a given temperature is not attained, evaporation continues; and when attained, evaporation ceases. If the capacity of the boiler be increased, evaporation is resumed, until the state of saturation is again arrived at. Likewise, if the temperature be increased, evaporation is resumed, and continues till the steam again becomes saturated. If the temperature falls, the pressure and the density fall also. If the boiler be closed, and the steam remain at the same temperature, the conditions remain unchanged. But, if an opening be made for the outflow of steam, the pressure will fall, and evaporation will be recommenced, until saturation is re-established. This new generation of steam is very rapid, so much so that the pressure does not sensibly vary between and during the charges of steam taken from the boiler for each stroke of the piston.

Flow of Steam.

It is known that gases and vapors act like liquids in flowing through tubes and orifices. The velocity of flow of liquids is given by the ordinary formula of gravity: which is

$$V = \sqrt{2gh}, \text{ or } V = 8\sqrt{h};$$

in which V is the velocity in feet per second, g the velocity acquired by a body falling from a state of rest, at the end of one second, being 32.2 feet per second, and h the height in feet through which the body falls. The velocity acquired in falling through a given height, is equal to 8 times the square root of the height in feet, the product being the velocity expressed in feet per second. A modification of the same formula is applicable for calculating the flow of gases. There is this distinction, that while for liquids, the height through which the water falls, to the orifice of flow, can be easily ascertained by measurement, for gases it is necessary to ascertain the height by calculation.

The Pressure of Gas or vapor is equal to that of a column of the gas of which the weight is equal to the pressure, and if the pressure per square inch be divided by the weight of a prism of the gas, one inch square and one foot high, the quotient is the height in feet of the equivalent column of gas, from which the velocity of flow is to be calculated. The velocity so calculated applies to the discharge of the gas into a vacuum. But, under ordinary circumstances, a counter-pressure exists, being the pressure of the medium into which the gas is discharged, and the value of the counter-pressure has to be deducted from the total pressure, when the difference, the net pressure of the column is to be calculated. The head is expressed by the formula, **h**=(**P**—**p**)÷**a**, in which **h** is the head of height of the column, **P** and **p** are the total pressures per square inch of the gas and the medium into which it flows, and **d** is the density or weight of a prism of the gas, one inch square and one foot high.

The application of the formula for gravity is limited to cases in which the resisting pressure does not exceed about 58 per cent. of the absolute pressure which causes the flow. The flow is neither increased nor diminished by reducing the resisting pressure below about 58 per cent. of the absolute pressure in the boiler. For example, the same weight of steam would flow from a boiler under a total pressure of 100 pounds per square inch into steam of 58 pounds total pressure, as into the atmosphere.

Velocity of Efflux of Steam. The following are a few examples of the velocity of efflux of steam of absolute pressure, varying from 25.37 pounds to 100 pounds per square inch, into the atmosphere, the velocity being calculated as for steam of the initial density, unexpanded.

Total Pressure in Pounds per square inch.	Velocity of Efflux in Feet per secoud.
25 37	863
30	867
45	877
60	885
75	891
100	898

Velocities thus calculated in terms of simple pressure and density, are of course greater than are arrived at in practice, as there are sundry hindrances to the flow of steam in steam-engines. There is, however, ample margin, and in well-constructed engines the speed of the actual flow of steam, though much below what it would attain if the flow were free, is, nevertheless, sufficiently rapid for the proper performance of the steam in passing into and passing out of the engine. To reduce as much as possible the effects of contraction and friction in retarding the flow of steam, it is necessary to observe the following precautions. To reduce as much as possible the lengths, and increase the sectional areas, of the pipes and passages through which the steam is to pass. To avoid sudden changes of direction in the parts or passages. To obtain the steam as dry as possible.

Lead of the valve. If the lead of the valve is too late the maximum pressure of the steam in the cylinder is not attained until after a portion of the stroke is traversed by the piston. When the lead of the valve is too early, the steam is admitted so readily as to be momentarily compressed, and to cause, in some cases, an unfavorable pulsatory action of the steam. The total absence of lead of the valve likewise occasions an unsteady pulsatory action of steam in the cylinder.

It is important to use dry steam, because, when the steam is condensed within the cylinder, or if it be loaded with water by priming, it causes back-pressure and loss of power.

Absolute Temperature.

The zero of temperature on the Centigrade and Fahrenheit scales has been chosen arbitrarily, on one the zero being the freezing point of water, and on the other a point 32 degrees Fahrenheit below it.

For scientific purposes it is necessary to have a uniform zero, and such a point, called the zero of absolute temperature, has been chosen, the position of which is 461 degrees Fahrenheit, below the zero Fahrenheit, or 273 degrees Centigrade, below the zero Centigrade.

Hence to express degrees Fahrenheit in degrees of absolute temperature, add 461. Thus the boiling point of water at atmosphere pressure=212 degrees Fahrenheit=212+461 =673 degrees absolute temperature.

To convert degrees Fahrenheit into degrees Centigrade:

Subtract 32, multiply the remainder by 5, and divide by 9.

Thus, convert 158 degrees Fahrenheit to degrees Centigrade.

Then $(158-32)\frac{5}{9}=70$ degrees Centigrade.

Or, to convert degrees Centigrade into degrees Fahrenheit:

Multiply by 9, divide by 5, and add 32.

Thus, convert 70 degrees Centigrade into degrees Fahrenheit.

Then $(70\times\frac{9}{5})+32=158$ degrees Fahrenheit.

Specific Heat.

The ratio of the amount of heat required to raise the temperature of a substance one degree to the amount of heat required to raise an equal weight of water one degree is called the specific heat of the substance.

The specific heat of bodies varies very considerably, as will be seen from the following table:

Water=1.000	Wrought Iron=0.113	Lead=0.031
Cast Iron=0.130	Copper=0.100	Mercury=0.333
Steel=0.118	Bismuth=0.031	Coal=0.241

Water has the highest specific heat of any substance except hydrogen, and the metals have the lowest. In other words it takes more heat to raise the temperature of a given weight of water than any other substance.

Heat.

If one pound of cold water be heated in a closed vessel till the water becomes warm, although the temperature of the water has changed, its weight remains the same; and if the heat be continued until all the water is converted into steam, provided none of the steam can escape, the total weight of the steam is still exactly the same as that of the water from which it is produced.

It is evident, therefore, that the heat which produced these changes is without weight. Heat cannot, therefore, be a material substance. It was formerly thought to be some kind of subtle fluid, which flowed from hot bodies into colder ones. This theory is no longer accepted, because it was found that heat could be developed to an unlimited extent from cold bodies merely by rubbing them together.

A piece of cold iron can be made red hot by hammering it. A carpenter's saw or machinist's chisel or turning tool soon get hot when a rubbing action or friction, is set up between the tool and the work, although they are all quite cold to begin with.

All bodies are assumed to be composed of minute particles called molecules, held together by mutual attraction or cohesion and these molecules are in a state of continual agitation or vibration. The hotter the body the more vigorous the vibration of its constituent particles. In solid bodies the vibrations are limited in extent. If this limit is exceeded, owing to addition of heat, cohesion is sufficiently overcome to enable the particles to move about freely and without restriction, and the solid has now become a liquid. On still continuing the heat, further separation of the molecules takes place, cohesion is completely overcome, and they fly off in all directions. The liquid then becomes a gas.

The unit of heat is the amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit when the water is at its greatest density, namely, from 39 to 40 degrees Fahrenheit.

The rate of transfer of heat from a hot body to a cold is proportional to the difference of temperature between the two bodies. The greater the difference of temperature the greater the rate of flow of heat.

The transfer of heat from one to the other may take place in any of the following ways: namely, by radiation, convection, or conduction.

Heat is given off from hot bodies in rays which radiate in all directions in straight lines. The heat from the burning coal in a furnace is transferred to the crown and sides of the furnace by radiation, it passes through the furnace plates by conduction and the water is heated by convection. The process by which heat passes from hotter to colder parts of the same body, or from a hot body to a colder body in contact with it, is called conduction. A bar of iron having one end placed in the fire soon becomes hot at the other extremity, the heat being conducted from particle to particle throughout its entire length.

A piece of burning wood can be held with the hand close to the burning part. Some bodies, therefore, conduct heat much more readily than others.

Let water at 32 degrees Fahrenheit be heated in a closed vessel, such as an ordinary steam boiler, containing space for the accumulation of steam, and let heat be gradually applied. Then the temperature of the water will gradually rise to that corresponding to the pressure within the boiler, after which evaporation commences and steam is formed.

As the heat is increased, the temperature, pressure, and density, or weight per cubic foot, of the steam increases indefinitely, so long as the strength of the boiler is not exceeded and the relation between the temperature, pressure, and density always bears a certain fixed relation.

If just sufficient heat is supplied as to maintain the temperature constant, the pressure and density remain constant also, and evaporation ceases. If a communication be opened between the boiler and engine, on escape of steam from the boiler the pressure is momentarily reduced and re-evaporation commences rapidly. So long as the temperature is maintained, no sensible variation of pressure is noticeable in a boiler supplying steam to an engine.

THE INDICATOR

The uses to which an indicator is generally applied may be briefly stated as follows:

To obtain a diagram showing the condition or the behavior of the gases in the cylinder of an engine, the promptness of the admission, the fall in pressure from heat losses, the extent and character of the expansion, the efficiency of the exhaust, the extent of the back pressure upon the piston and the amount of compression at the end of the stroke.

To find the average effective pressure exerted by the steam upon the piston, from which to calculate the **Indicated horsepower of the engine.**

To determine whether the valves have sufficient area and also whether they are set correctly, by taking diagrams from the cylinder and noting the points of admission, cut-off, exhaust and compression.

An indicator consists primarily of a small steam cylinder, containing a piston, and a spring to regulate the movement of the piston according to the pressure. A pencil or recording device, carried by an arrangement of small rods and levers, constituting a parallel motion, by means of which the pencil reproduces the vertical movement of the indicator piston but exaggerated four or five times. A drum, to which a paper, called a card, is attached, and which receives a partial forward and backward rotation on its axis by means of a reducing gear operated from the crosshead or other suitable part of the engine.

By the combined vertical movement of the pencil and the horizontal movement of the paper or card, a closed figure is drawn which is called an indicator diagram. The diagram as traced on the card by the pencil of the indicator, differs more or less from a theoretical diagram, but an actual indicator diagram is considered the more perfect the closer it approaches the outlines of a theoretical diagram.

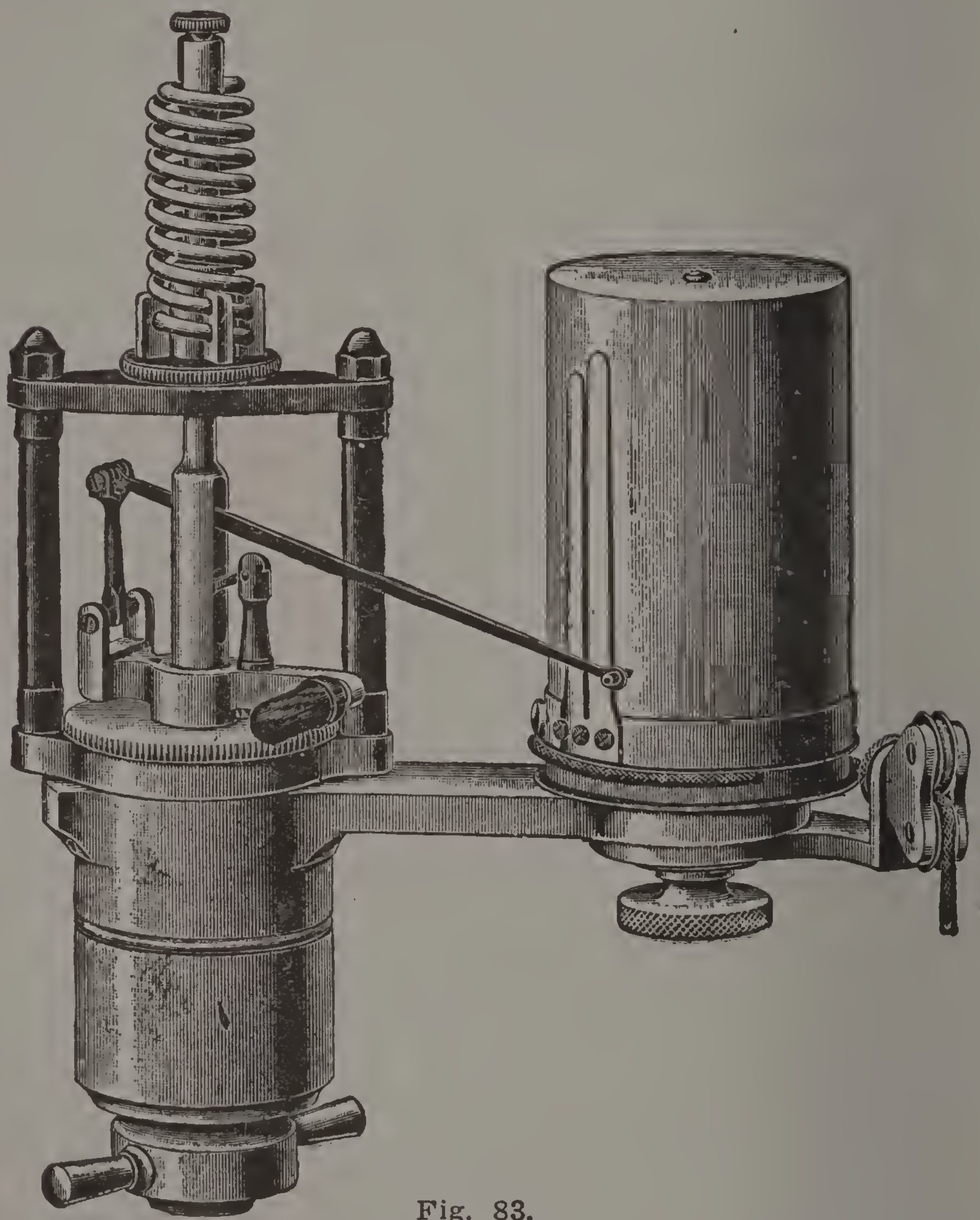


Fig. 83.

Figs. 83 and 84 show external and cross-sectional views of a new form of Indicator. This instrument is in some ways a departure from the ordinary steam engine indicator. One difference is in the location of the piston spring. This has been removed from the cylindrical case near the piston to the outside, and is affixed above the moving parts,

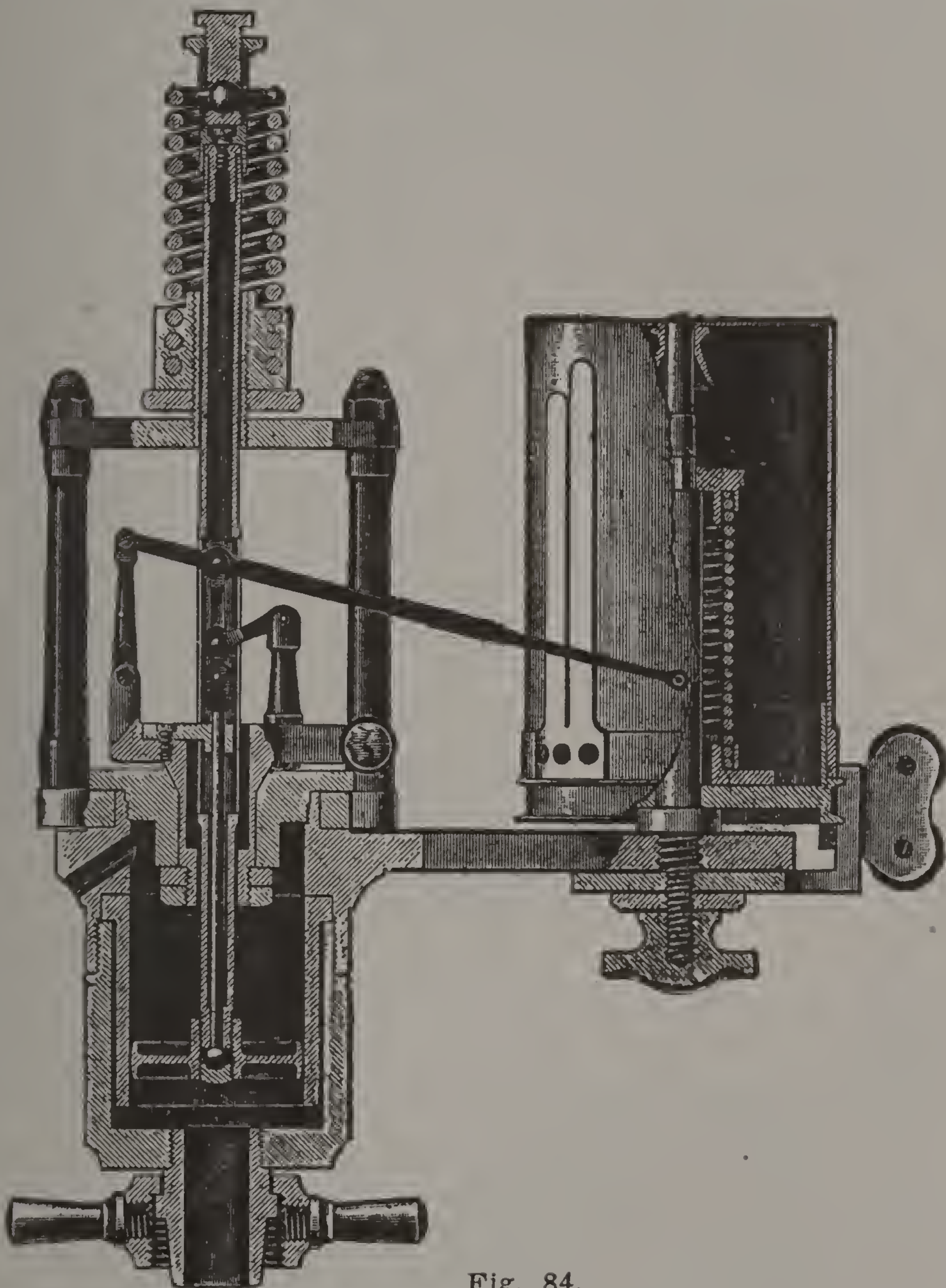


Fig. 84.

where it will remain cool under all conditions of use. Whatever error arises from heat, as affecting the spring in the ordinary type of indicator, is not present in this instrument.

The other and more important difference lies in the size and shape of the piston. This piston is one square inch in area, and is in the form of a central zone of a sphere. It is attached by a rod directly to the upper part of the spring, and moves freely and without restraint notwithstanding there may be some eccentricity in the action of the spring. In other words, this piston serves as a universal joint to take care of the torsional strains of the spring when it operates the pencil mechanism of the indicator. The pencil mechanism is connected to the piston by a ball and socket joint.

This rod slides through a sleeve attached to the base of the pencil mechanism, and, moving in a vertical line, compels the pencil to move also in a vertical line.

Any motion of the piston due to the movements of the spring which causes the spring rod to deviate, will not affect the pencil mechanism in its vertical path. The contact of the piston with the interior side of the cylinder is a line, and does not induce friction. The piston of an indicator is usually a short cylinder fitted to slide easily within another cylinder. This form of piston is usually about one half inch long, and in use will develop friction about its circumference. A piston made in this manner must resist and overcome if possible the eccentricities of the spring in action, even then there is a want of freedom, notwithstanding the use of devices to relieve the piston friction. This condition tending to error is recognized by engineers, and considered in the computations made of the diagram taken by the indicator. The freedom of the piston movement in the indicator illustrated dispenses with the necessity of the correction of these errors.

Another feature is the adjustment of the pencil to any desired position on the drum by loosening the binding nut below the spring and screwing the spring upward or downward, carrying with it the entire pencil mechanism. When relocated and the binding nut screwed firmly into place, the pencil is firmly held in its new position.

The **Indicator Diagram** gives the initial pressure in the cylinder before expansion takes place. It also indicates whether the volume of the charge is diminished during its admission to the cylinder. It indicates when the expansion begins and the average pressure of expansion during the stroke. It gives the terminal pressure at the opening of the exhaust. It shows the point of opening of the exhaust. It shows the rapidity of the exhaust. It indicates the back pressure on the piston due to the exhaust. It gives the average pressure during the stroke.

The usual method of obtaining the **average pressure** from an indicator diagram is by ascertaining its area by means of an instrument known as a planimeter, which is used to calculate the area of irregular surfaces. By moving the tracing point attached to the planimeter over the irregular outline of the diagram, its area is obtained. The area of the diagram divided by its horizontal length, gives the mean vertical height or ordinate of the diagram. The initial presurre in pounds as shown by the diagram multiplied by this mean ordinate, gives the average pressure in pounds per square inch during the entire piston stroke.

For the purpose of ascertaining the average pressure, it is sometimes sufficiently accurate to calculate the mean ordinate by means of vertical measurement lines, or ordinates, drawn upon the diagram, which should divide the diagram into any desired number of rectangular panels of equal width. The sum of the length of these vertical ordinates, divided by the number of the ordinates will give the mean ordinate required, which, multiplied by the initial pressure, will give the average pressure required. From this the indicated horsepower may readily be found by the use of Formula 1 or 6—Horsepower of Steam Engines.

Example: With 64.7 pounds average pressure calculated from the indicator diagram taken from an engine of 5 inches bore and stroke at 300 revolutions of the crank shaft per minute, what will be the indicated horsepower of the engine?

Answer: The average effective pressure on the piston in pounds per square inch will be 64.7 less 14.7, which equals 50 pounds. The area of the piston is 19.64 square inches and the total piston stroke 0.83 feet. As the speed is 300 revolutions of the crank shaft per minute, then by Formula No. 1, if IHP be the indicated horsepower, then

$$IHP=\frac{50\times0.83\times19.64\times300}{33,000}=7.44 \text{ horsepower.}$$

By Formula No. 6, as the square of the diameter of the cylinder is 25, then,

$$IHP=\frac{50\times0.83\times25\times300}{42,000}=7.44 \text{ horsepower.}$$

The **expansion curves** of indicator diagrams vary considerably, and they do not obey any definite law. They are the resultant effect of a variety of causes operating differently in different engines, and even in the same engine by change of conditions.

An ideal indicator diagram is illustrated in Fig. 85.

The **release point** D occurs just before the end of the stroke. With high-speed engines it is important to have an early exhaust, as the trouble is usually not to get the steam **into** the cylinder, but to get it **out.**

The **exhaust curve** DE represents the fall of pressure which occurs in the cylinder when the exhaust port opens. A late opening to exhaust is a very grave defect in an indicator.

The **back-pressure line** EF shows the amount of the pressure against the piston during its return stroke. In non-condensing engines the back-pressure line coincides the more nearly with the atmospheric line, as the exhaust passages permit of a free exit for the steam. In condensing engines this line coincides the more nearly with the zero line, as the condensing water temperature is lower, and as air leaks are absent.

The **compression curve** FA commences from the point of closure F of the exhaust port. This point depends upon the amount of inside lap on the valve, and the angular advance of the eccentric, and the nature of the curve will depend upon the pressure of the steam and upon the volume of the clearance space.

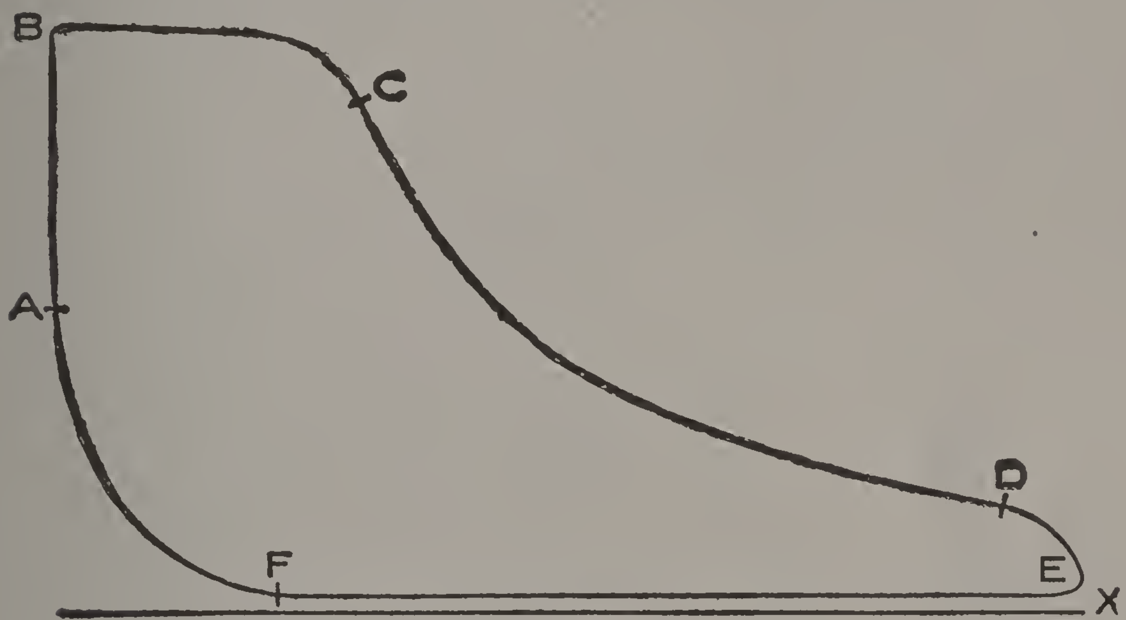


Fig. 85.

A—Point of Admission. AB—Admission Line. BC—Steam Line. CD—Expansion Curve. DE—Exhaust Curve. EF—Back-pressure Line. F—Point of Closing Exhaust. FA—Compression Curve. X—Atmospheric Pressure Line D—Release Point

HORSEPOWER

HORSEPOWER OF STEAM ENGINES.

The standard of horsepower is the amount of energy that will raise a weight of 33,000 pounds one foot high in a minute, or 550 pounds one foot high in one second. An engine or motor exerting one actual horsepower will raise a weight of 10 pounds 3,300 feet in one minute, but will require 10 minutes to raise 330,000 pounds one foot high.

Horsepower is of three kinds: Calculated, actual or brake, and indicated horsepower. Calculated horsepower is always greatly in excess of actual or brake horsepower, as heat and friction losses do not enter into consideration in the formulas used.

Actual or Brake horsepower is obtained by the use of a Prony brake, so called after its inventor. This simple device gives the actual energy in foot-pounds per minute, delivered at the driving shaft.

Indicated horsepower represents the actual thermo-dynamic (heat pressure) conditions within the engine cylinder, but does not take into account friction or other external power losses.

The factors entering into the calculation of the horsepower of a steam engine are, the effective temperature of the steam in the cylinder as indicated by the average pressure throughout the piston stroke, the cubic contents of the cylinder, which are given by the length of the stroke and the area of the piston, and the number of working strokes or impulses per minute.

The product of these factors, which is found by multiplying them together, will give the available energy in foot-pounds per minute. This product, divided by 33,000, gives the horsepower required.

To ascertain the horsepower when the average pressure upon the piston in pounds per square inch is known.

Find the area of the piston in square inches, by multiplying the square of its diameter by 0.7854.

Find the total pressure in pounds on the piston by multiplying its area by the average effective pressure in pounds per square inch. The average effective pressure is the average pressure in pounds per square inch less 14.7, which must be deducted to allow for the atmospheric pressure against the piston.

Find the useful piston travel in feet per minute by multiplying twice the length of the piston stroke in feet by the number of revolutions per minute of the crank shaft, for a double-acting steam engine. Find the energy in foot pounds per minute by multiplying the total pressure in pounds on the piston by the useful piston travel in feet per minute.

The horsepower may then be ascertained by dividing the energy in foot-pounds per minute by 33,000.

While there are numerous formulas in use for calculating the horsepower of an engine, one of the most simple is as follows:

$$HP=\frac{P\times L\times A\times N}{33,000} \qquad (1)$$

Where P is the average effective pressure in pounds per square inch, L twice the length of the piston stroke in feet, A the area of the piston in square inches and N the number of revolutions of the crank shaft per minute.

Example: What horsepower will a steam engine of 4-inch bore and 6-inch stroke develop at 300 revolutions of the crank shaft per minute, cutting off at one-third stroke and having an initial pressure of 150 pounds per square inch?

Answer: The average pressure from Table No. 12, corresponding to 150 pounds initial pressure, with one-third cut-off, is 104.9 pounds. From this must be deducted 14.7

pounds, which represents the back or atmospheric pressure in the case of a single expansion engine, giving 90.2 pounds as the average effective pressure per square inch on the piston. From Table No. 3 the area of a circle 4 inches in diameter is 12.57 square inches, and twice the length of the piston stroke, which is 6 inches, is equal to one foot, then

$$HP=\frac{90.2\times 1\times 12.57\times 300}{33,000}=10.31 \text{ horsepower.}$$

The following formulas, 2, 3, 4 and 5, are merely transpositions of Formula 1, but will be found very useful in ascertaining the value of any one of the five factors in Formula 1, when the other four are known.

$$P=33,000\frac{HP}{L\times A\times N} \qquad (2)$$

Where P is the average effective pressure on the piston in pounds per square inch.

Example: What is the average effective pressure on the piston of an engine, with a cylinder 12 inches in diameter and piston stroke of 18 inches, the number of revolutions of the crank shaft being 100 per minute, and the horsepower 40?

Answer: As the area corresponding to 12 inches diameter is 113.09, or in round numbers, 113, then formula 2.

$$P\times 33,000\frac{40}{3\times 113\times 100}=38.9 \text{ pounds.}$$

To ascertain the required length of the piston stroke in feet, when the other terms in the equation are known:

$$L=33,000\frac{HP}{P\times A\times N} \qquad (3)$$

Where L is equal to twice the piston stroke in feet.

Example: An engine is required to develop 40 horsepower, with 38.9 pounds average effective pressure per square inch on a piston 12 inches in diameter and a speed of the crank shaft of 100 revolutions per minute. What should be the length of the piston stroke?

Answer: The average effective pressure being 38.9 pounds, then by Formula 3,

$$L = 33{,}000 \frac{40}{38.9 \times 113 \times 100} = 3.0 \text{ feet.}$$

Given a piston stroke of 18 inches.

To find the required cylinder diameter, other conditions being as before stated:

$$A = 33{,}000 \frac{HP}{P \times L \times N} \qquad (4)$$

Where A is the area of the cylinder in square inches.

Example: An engine is required to develop 40 horsepower with an average effective pressure on the piston of 38.9 pounds per square inch. The length of the stroke is 18 inches and the speed of the engine crank shaft is 100 revolutions per minute, what should be the cylinder diameter?

Answer: The area of the cylinder by Formula 4 is therefore

$$A = 33{,}000 \frac{40}{38.9 \times 3 \times 100} = 113.1 \text{ square inches.}$$

And from Table No. 3 the nearest diameter corresponding to an area of 113.1 square inches is 12 inches.

The speed of the crank shaft of an engine may be readily ascertained from Formula 5, that is, if N be the speed of the crank shaft of the engine in revolutions per minute, then

$$N = 33{,}000 \frac{HP}{P \times L \times A} \qquad (5)$$

Example: What should be the speed of the crank shaft of an engine with a cylinder of 12-inch bore and 18-inch piston stroke, to develop 40 horsepower with an average effective pressure of 38.9 pounds per square inch on the piston?

Answer: The speed of the crank shaft of the engine in revolutions per minute by Formula 5, will therefore be

$$N=33,000\frac{40}{38.9\times3\times113}=100 \text{ revolutions per minute.}$$

The following formula may be used in place in Formula 1, if so desired:

$$HP=\frac{P\times L\times D^2\times N}{42,000} \qquad (6)$$

Where D is the diameter of the piston in inches, the remainder of the terms used being the same as in Formula 1.

Example: Calculate the horsepower of the same engine by formula 6.

Answer: As the square of the diameter of the piston is $4\times4=16$, then

$$HP=\frac{90.2\times1\times16\times300}{42,000}=10.31 \text{ horsepower.}$$

On the basis of these formulas, two simple rules may be derived for calculating the horsepower of a steam engine:

1. The horsepower is equal to the average effective pressure in pounds per square inch, multiplied by twice the piston stroke in feet, by the area of the piston in square inches and by the number of revolutions of the crank shaft per minute, divided by 33,000.

2. The horsepower is equal to the average effective pressure in pounds per square inch, multiplied by twice the piston stroke in feet, by the square of the diameter of the piston in inches and by the number of revolutions of the crank shaft per minute, divided by 42,000.

It should always be borne in mind that 14.7 pounds must in any case be deducted from the average pressure to obtain the average effective pressure on the piston, whether the average pressure is obtained from an indicator diagram, from Table No. 12, or from Formula 2.

Squares of diameters and areas of circles, are given in Tables No. 1 and 3. These may be used in connection with Formulas 1 to 6.

Table No. 12—Average Steam Pressure on Piston, in Pounds per Square Inch.

Average Pressure throughout the Piston Stroke. Initial Pressure =1.		.966	.937	.919	.846	.743	.699	.596	.385
Number of Volumes to which the Steam is Expanded.		$1\frac{1}{3}$	$1\frac{1}{2}$	$1\frac{3}{5}$	2	$2\frac{2}{3}$	3	4	8
Point of Cut-off.		$\frac{3}{4}$	$\frac{2}{3}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{8}$
Initial Pressure in Pounds per Square Inch.	50	48.2	46.7	45.9	42.3	37.1	35.0	29.8	19.2
	55	53.0	51.3	50.5	46.6	40.8	38.4	32.8	21.2
	60	57.8	56.0	55.1	50.8	44.5	41.9	35.8	23.1
	65	62.8	60.7	59.7	55.0	48.2	45.4	38.8	24.9
	70	67.4	65.3	64.3	59.2	52.4	48.9	41.6	26.7
	75	72.3	70.0	68.9	63.5	56.1	52.4	44.7	28.6
	80	77.1	75.7	73.5	67.7	59.3	55.9	47.7	30.8
	85	81.9	80.3	78.1	72.0	63.0	59.8	50.7	32.7
	90	86.7	84.0	82.7	76.2	66.8	62.9	53.7	34.6
	95	91.5	88.7	87.3	80.4	70.4	66.4	56.7	36.6
	100	96.4	93.3	91.9	84.6	74.2	69.9	59.6	38.5
	105	101.2	98.0	96.5	88.9	77.9	73.4	62.6	40.4
	110	106.0	101.7	101.0	93.1	81.6	76.9	66.6	42.3
	115	110.8	106.3	105.6	97.4	85.2	80.4	69.6	44.2
	120	115.6	112.0	110.2	101.6	89.0	83.9	71.6	46.2
	125	120.5	115.7	114.8	105.8	102.8	87.4	74.6	48.1
		1	2	3	4	5	6	7	8

TABLE NO. 12 CONTINUED—**Average Steam Pressure on Piston, in Pounds per Square Inch.**

Average Pressure throughout the Piston Stroke. Initial Pressure =1.		.966	.937	.919	.846	.743	.699	.596	.385
Number of Volumes to which the Steam is Expanded.		1⅓	1½	1⅗	2	2⅔	3	4	8
Point of Cut-off.		¾	⅔	⅝	½	⅜	⅓	¼	⅛
Initial Pressure in Pounds per Square Inch.	130	125.3	121.3	119.4	110.0	96.4	90.9	77.5	59.8
	140	134.9	130.7	128.6	118.5	103.8	97.9	85.3	53.9
	150	144.6	139.3	137.8	126.5	111.3	104.9	89.5	57.7
	160	154.2	151.3	147.0	135.4	118.7	111.8	95.4	61.6
	170	163.8	160.7	156.2	143.9	126.1	118.8	101.4	65.4
	180	173.5	168.0	165.4	152.4	133.5	125.8	107.4	69.3
	190	183.1	177.3	174.5	160.8	140.9	132.8	113.3	73.1
	200	192.8	186.7	183.8	169.3	148.4	139.0	119.3	77.0
	210	202.4	195.0	192.9	177.8	154.8	146.8	125.3	80.8
	220	212.0	203.3	202.1	186.2	163.2	153.8	133.2	84.6
	230	221.6	212.7	211.3	194.7	170.4	160.8	139.2	98.5
	240	231.3	224.0	220.5	203.2	178.1	167.8	143.2	92.4
	250	240.9	233.3	229.7	211.6	185.4	174.7	149.1	96.2
	260	250.6	242.7	238.9	220.1	192.9	181.8	155.1	99.7
	280	269.8	261.3	257.2	237.0	207.7	195.7	170.6	107.8
	300	289.1	280.0	275.6	254.0	222.5	208.7	179.0	115.5
		1	2	3	4	5	6	7	8

HORSEPOWER OF GAS AND GASOLINE ENGINES.

As the formulas used for the calculation of the horsepower of steam engines are not as a rule directly applicable to gas and gasoline engines, formulas are here given that will be found better suited to the purpose.

From a theoretical standpoint a two-cycle engine should not only have as great a speed as a four-cycle engine, but should be capable of developing almost twice the power. It is a fact, however, that in actual practice the performance of a two-cycle engine is far different.

The horsepower of a two or four-cycle engine may be calculated from the following formulas:

$$HP=\frac{D^2\times S\times N}{21,000}\text{(Two-cycle).} \qquad (1)$$

Where D is the diameter and S the stroke of the piston in inches, N the number of revolutions of the crank shaft per minute and HP the required horsepower.

Example: Required the horsepower of a two-cycle engine of 6 inches bore and stroke at 600 revolutions of the crank shaft per minute?

Answer: The square of the bore multiplied by the stroke is equal to 216, which multiplied by 600 and divided by 21,000, gives 6.17 as the required horsepower, or by Formula 1.

$$HP=\frac{36\times 6\times 600}{21,000}=6.17 \text{ horsepower.}$$

For a four-cycle engine, the formula is:

$$HP=\frac{D^2\times S\times N}{18,000}\text{(Four-cycle).} \qquad (2)$$

Example: What horsepower should be developed by a four-cycle engine of 6 inches bore and stroke at 600 revolutions of the crank shaft per minute?

Answer: As the bore and stroke of the engine are like, the square of the bore multiplied by the stroke is equal to the cube of 6, which is 216, this multiplied by 600, and divided by 18,000, gives 7.20 as the horsepower of the engine, or by Formula 2,

$$HP=\frac{216\times600}{18,000}=7.20 \text{ horsepower.}$$

A four-cycle gas or gasoline engine has only one working stroke or impulse for each two revolutions of the crank shaft. During these two revolutions which complete the cycle of the engine, six operations are performed:

1. Admission of an explosive charge of gas or gasoline vapor and air to the cylinder of the engine.
2. Compression of the explosive charge.
3. Ignition of the compressed charge by a hot tube or an electric spark.
4. Explosion or extremely sudden rise in the pressure of the compressed charge, from the increase in temperature after ignition.
5. Expansion of the burning charge during the working stroke of the piston of the engine.
6. Exhaust or expulsion of the burned gases from cylinder of the engine.

As pressure increases with a rise in temperature, which in a gas or gasoline engine the moment after ignition has taken place is about 2,700 degrees Fahrenheit, the higher the temperature of the ignited gases, the greater would be the pressure. As this pressure is expended in work on the piston of the engine, the whole of it might, if expansion of the burning gases were continued long enough, be utilized. Full utilization of the expansion of the bases is however impossible from a mechanical standpoint. The expansion of the gases should be as rapid as possible, as the faster the piston uncovers the cylinder wall, the less time will be left for the transmission of heat or energy to the cylinder wall. Gasoline vapor or gas, in themselves are not combustible, but must be mixed with a certain amount of air before ignition and consequent combustion of the charge can be effected. The combustion of the gases is not instantaneous as might be imagined, but continues during the entire working stroke of the piston of the engine. The extremely high temperature produced by the combustion necessitates the use of a cooling device round the exterior of the cylinder of the engine in the form of a water jacket.

Gas and gasoline possess many advantages over steam engines, and compare favourably with them as regards the cost of fuel.

Electrical Horsepower. One electrical horsepower is equal to the current in amperes multiplied by the electromotive force or voltage of the circuit and divided by 746.

Let C be the current in amperes and E the voltage of the circuit. If EHP be the required electrical horsepower, then

$$EHP = \frac{E \times C}{746} \qquad (1)$$

Example: What is the electrical horsepower of a 200-volt motor, which takes a current of 80 amperes?

Answer: As the voltage is 200 and the current 80 amperes then by Formula 1,

$$EHP = \frac{200 \times 80}{746} = 21.44 \text{ horsepower.}$$

One electrical horsepower is also equal to 746 watts.

If C be the current in amperes, E the electro-motive force or voltage, R the resistance, and EHP the electrical horsepower, then

$$EHP = \frac{C^2 \times R}{746} = \frac{E^2}{746 \times R} \qquad (2)$$

In practice with motors or small power, **1,000 watts** are necessary to deliver **one mechanical or brake horsepower** at the driving shaft of the motor.

If the **actual or brake horsepower** of an electric motor be known, the **efficiency** of the motor may be readily found by the following formula:

If E be the voltage of the circuit and C the current in amperes consumed by the motor, let BHP be the brake horsepower of the motor and e the efficiency of the motor, then

$$e=\frac{BHP\times 746}{E\times C} \qquad (3)$$

Example: What is the mechanical efficiency of a 200-volt motor, which when taking a current of 80 amperes, snows on a brake-test, 17.16 horsepower?

Answer: As the brake horsepower is 17.16, the voltage 200 volts, and the current 80 amperes, then by Formula 3,

$$e=\frac{17.16\times 746}{200\times 80}=80 \text{ per cent.}$$

HORSEPOWER OF GEAR WHEELS.

1. When the circular pitch is given—to find the horsepower capable of being transmitted by cast iron gears with cut teeth: Multiply the pitch diameter of the gear by the circular pitch of the teeth, by the width of the teeth, (all in inch measurements), and by the number of revolutions of the gear per minute. Divide the product by 550 and the result will be the horsepower the gear is capable of transmitting.

Let **D** be the pitch diameter of the gear, **C** the **circular pitch** and **E** the width of the tooth, (all in inch measurements, **R** the number of revolutions of the gear per minute and **H. P.** the horsepower the gear is capable of transmitting, then

$$HP=\frac{D\times C\times F\times R}{550} \qquad (1)$$

Example: What horsepower will the following cast iron gear with cut teeth transmit at 100 revolutions per minute? The circular pitch of the gear is 2 inches, the number of teeth 33 and the width of the face of the tooth 2 inches.

Answer: As the pitch diameter of the gear is approximately 21 inches, then

$$HP=\frac{21\times2\times2\times100}{550}=15.27$$

Note: A cast iron gear with cut teeth of 1 inch circular pitch and 1.048 inches width of tooth and with 33 teeth will transmit 1 horsepower at 50 revolutions per minute. As the pitch diameter of the gear approximately 10½ inches, then

$$\frac{10.5\times1\times1.048\times50}{550}=1 \text{ horsepower.}$$

2. When the diameter pitch is given to find the horsepower capable of being transmitted by cast iron gears with cut teeth: Multiply the pitch diameter of the gear by the width of the tooth (both in inch measurements), and by the number of revolutions of the gear per minute. Divide the product by the **Diametral pitch** and by 175, and the result will be the horsepower the gear is capable of transmitting.

Let **D** be the pitch diameter of the gear, **F** the width of the tooth (both in inch measurements), **R** the number of revolutions of the gear per minute of the gear, **P** the diametral pitch and H.P the horsepower, then

$$HP=\frac{D\times F\times R}{P\times175} \qquad (2)$$

Example: What horsepower will the following cast iron gear with cut teeth transmit at 100 revolutions per minute? The diametral pitch of the gear is 1½, the width of the face of the tooth 2 inches, and the pitch diameter 20 inches.

Answer: $$\frac{20\times2\times100}{1.5\times175}=15.24 \text{ horsepower.}$$

3. To find the horsepower capable of being transmitted by a gear with cut teeth of any given material. Multiply the results obtained by Rule 1 or 2, or by Formula 1 or **2**, **by** the coefficients for the various metals given herewith.

Cast iron being taken as 1 or unity, then: Malleable Iron=1.25, Brass=1.33, Bronze=1.66, Gun Metal=2.00, Phosphor Bronze=3.00, Wrought Iron=3.33, Steel=4.00.

Example: If a cast iron gear of given dimensions will transmit 2 horsepower, what horsepower will a similar gear if made of phosphor bronze?

Answer: As the coefficient for phosphor bronze is 3, then $2 \times 3 = 6$ horsepower that the gear will transmit if made of phosphor bronze in place of cast iron.

Note: If the **diametral** instead of the **circular pitch** be given. To find the circular pitch of the teeth, divide 3.1416 by the diametral pitch of the gear.

Example: Required the circular pitch of the teeth of a gear of 4 diametral pitch?

Answer: 3.1416 divided by 4, gives .7854 as the circular pitch in inches of the gear teeth.

Example: What is the circular pitch of a gear of 2 diametral pitch?

Answer: 3.1416 divided by 2, gives 1.5708 inches as the circular pitch of the gear teeth.

ELECTRICITY

Electricity or electrical energy may be generated in several ways: Mechanically, by means of a dynamo, and statically or by friction. By whatever means it is produced, there are many properties which are common to all. There are also distinctive properties. The current supplied by a storage battery will flow continuously until the battery is practically exhausted, while the current from a dry battery can only be used intermittently: that is, it must have slight periods of rest, no matter how short they may be.

Electrical Rules and Formulas. Force is any cause of change of motion of matter. It is usually expressed by volts, pounds or other units.

Resistance is a counter-force or whatever opposes the action of another force.

Work is force exercised in traversing or crossing a space against a resistance of counter-force. Force multiplied by space or distance represents work in foot-pounds.

Energy is the capacity for doing work, and is measured by the work done.

The cause of a manifestation of energy is force. If this be electro-motive energy or electric energy in current form it is called **Electro-motive force.** The practical unit of electro- motive force is the **Volt.**

When electro-motive force does work in a closed electric circuit a current is produced. The practical unit of current is called the **Ampere.**

A current of electricity, when flowing in a closed electric circuit, passes through some substances more easily than through others.

The relative ease of passage of the electric current is known as conductive. In practical calculations its reciprocal, which is called resistance, is generally used. This practical unit is known as the **Ohm.**

A current of one **Ampere** is maintained by one **Volt** through a resistance of one **Ohm.**

Ohm's Law may be generally stated under the following heads:

The current is in direct proportion to the voltage of the circuit, and inversely proportional to its resistance.

1. The current is equal to the voltage divided by the resistance of the circuit.

2. The voltage is equal to the current multiplied by the resistance of the circuit.

3. The resistance of the circuit should equal the voltage divided by the current required.

Let **C** be the current in amperers flowing in the closed electric circuit, and **E** the electro-motive force or voltage of the circuit, if **R** be the resistance in Ohm's of the circuit when closed, then

$$C=\frac{E}{R} \qquad (1)$$

$$E=C\times R \qquad (2)$$

$$R=\frac{E}{C} \qquad (3)$$

Example: What will be the current flowing in a closed electric circuit with an electro-motive force of 50 volts and a resistance of 2 Ohms?

Answer: By Formula 1, the current will be 50 divided by 2, which gives 25 amperes.

Example: What must be the voltage of an electric circuit to force 25 amperes through 2 Ohms resistance?

Answer: From Formula 2, the voltage will equal 25 multiplied by 2, or 50 volts.

Example: Through what amount of resistance will an electro-motive force of 50 volts, force a current of 25 amperes?

Answer: By formula 3, 50 divided by 25 equals 2 Ohms as the required resistance.

Ampere-hour. The term ampere-hour is used to denote the capacity of a storage of a closed-circuit primary battery for current. A storage battery that will keep a 2 ampere lamp burning for 8 hours is said to have a 16 ampere-hour capacity. In a similar manner an 80 ampere-hour battery would operate the same lamp 40 hours. The voltage of a battery does not enter into the calculation of its ampere-hour capacity.

Watt-hour. A current of **one ampere** flowing in a closed electric circuit, with an electro-motive force of **one volt**, is equal to **one** volt-ampere or **one watt.** The voltage of a circuit, multiplied by the rate of the current flowing in amperes, gives the rate of work, or energy expended in **watt-hours.**

An electro-motive force of **one volt**, with a current strength of **one ampere**, is capable of developing an amount of work or energy called a **watt.**

4. **One volt** multiplied by **one ampere** is therefore equal to **one watt.**

5. The square of **current** multiplied by the **resistance** is also equal to the number of **watts.**

6. The square of the **electro-motive force or voltage,** divided by the **resistance** is also equal to the **watts.**

Let **E** be the electro-motive force of an electric circuit supposed close. If **C** be the current in amperes, **R** the resistance in Ohms and **W** the watts, that is the product of the Volts multiplied by the Amperes, then

$$W = E \times C \qquad (4)$$

$$= C^2 \times R \qquad (5)$$

$$= \frac{E^2}{R} \qquad (6)$$

Example: What is the rate of work or energy of an electric circuit, which has an electro-motive force of 50 volts and a current of 25 amperes?

Answer: By Formula 4, the energy is 50 multiplied by 25, or 1250 watts.

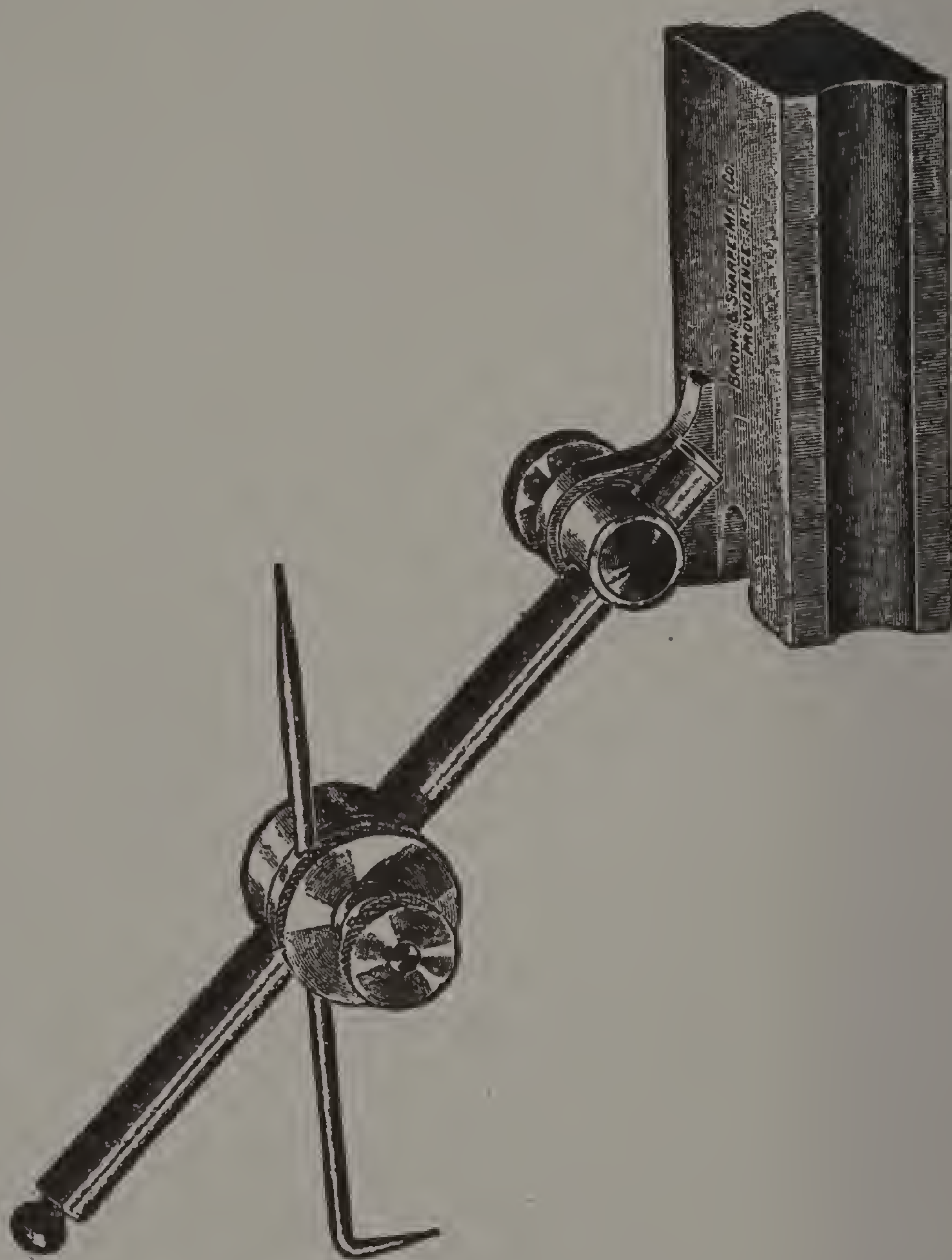
Example: With a current of 25 amperes and a resistance of 2 Ohms, what is the rate of work or energy in the circuit in watts.

Answer: From Formula 5, the work or energy in the circuit is equal to $25 \times 25 \times 2 = 1250$ watts.

Example: What is the rate of work or energy in an electric circuit having an electro-motive force of 50 volts and a current of 25 amperes.

Answer: By Formula 6, the rate of work or energy is 50×50 divided by 2, or 1250 watts.

MEASURING DEVICES


BROWN & SHARPE MFG. CO.
PROVIDENCE, R.I.

If a machinist wishes to become a first class workman he must learn to thoroughly understand the necessity of close or accurate measurements. With the aid of a micrometer he will soon learn to detect the difference between one-half and one-thousandth of an inch, and will then begin to appreciate the value of delicate or fine measurements and accurate workmanship.

At the present time when the making of interchangeable parts for machinery is an established factor in all large shops, the fitting of one part to another is no longer a question of guesswork, but of working to gauges and templets, the absolute sizes of which are definitely fixed. Hence the necessity for accurate measuring devices as are herewith illustrated, which were formerly to be found only in a few large shops.

Micrometers.

Micrometers form convenient and accurate instruments for fine external measurements. They are made in different sizes and styles to measure all sizes. They are graduated to read to thousandths of an inch, and one-half and one-quarter thousandths are readily estimated. Some micrometers have verniers by which sizes can be obtained to ten-thousandths.

The gauge screws are encased and protected from dirt and liability to injury. The parts most subject to wear are hardened and means of adjustment are provided to compensate for wear of the screw or nut. The decimal equivalents stamped on the frame are very convenient and render possible the immediate expression of readings in eights, sixteenths, thirty-seconds and sixty-fourths of an inch.

Fig. 86.

The chief mechanical principle embodied in the construction of a micrometer is that of a screw free to move in a fixed nut. An opening, to receive the work to be measured, is afforded by the backward movement of the screw and the size of the opening is indicated by the graduations.

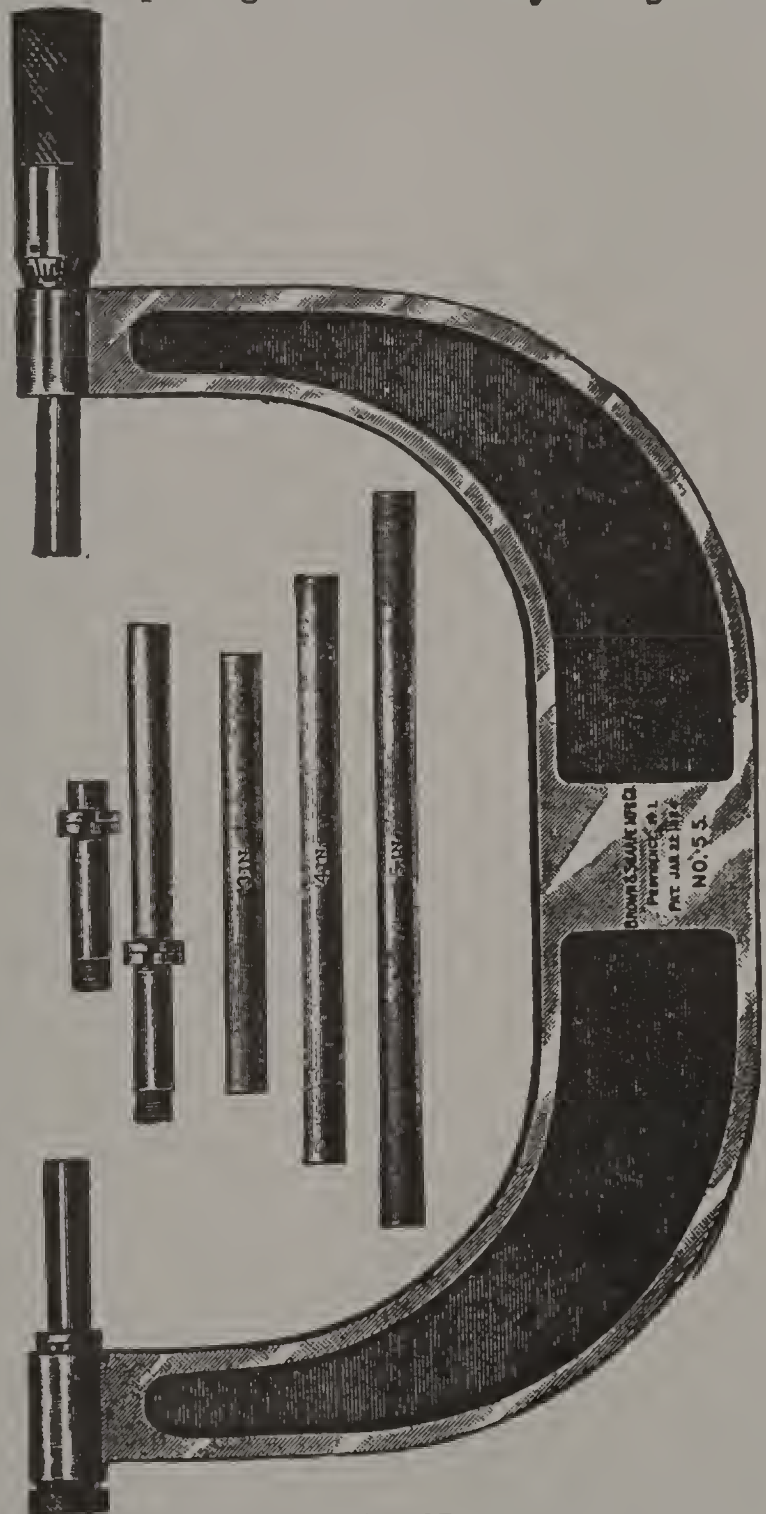


Fig. 87.

A standard form of micrometer is shown in Fig. 86 which will measure up to 1 inch by one-thousandths of an inch.

Fig. 87 illustrates a micrometer with removable anvils for quick changes of measurements.

How to Read a Micrometer

The spindle C, Fig. 88, is attached to the thimble E at the point H. The part of the spindle which is concealed within the sleeve and thimble is threaded to fit a nut in the frame A. The frame being held stationary, the thimble E is revolved by the thumb and finger, and the spindle C being attached to the thimble revolves with it, and moves through the nut in the frame, approaching or re-

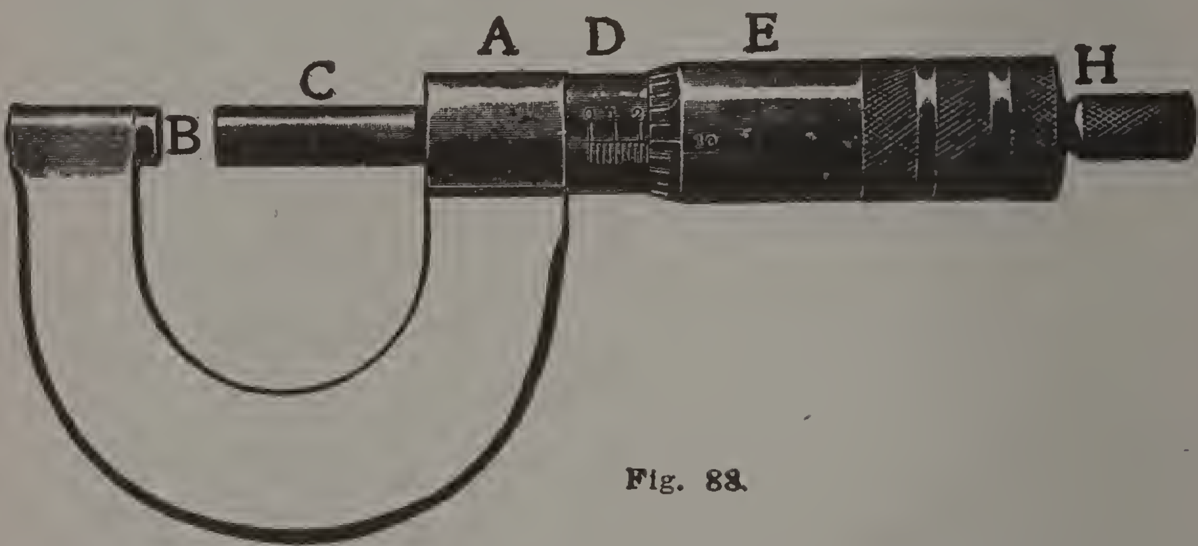


Fig. 88.

ceding from the anvil B. The article to be measured is placed between the anvil B and the spindle C. The measurement of the opening between the anvil and the spindle is shown by the lines and figures on the sleeve D and the thimble E.

The pitch of the screw threads on the concealed part of the spindle is 40 to an inch. One complete revolution of the spindle therefore moves it longitudinally one fortieth (or twenty-five thousandths) of an inch. The sleeve D is marked with 40 lines to the inch, corresponding to the number of threads on the spindle. When the micrometer is closed, the beveled edge of the thimble coincides with the line marked 0 on the sleeve, and the 0 line on the thimble agrees with the horizontal line on the sleeve. Open the micrometer by revolving the thimble one full revolution, or until the 0 line on the thimble again coincides with the horizontal line on the sleeve. The distance between the anvil B and the spindle C is then 1-40 (or .025) of an inch, and the beveled edge of the thimble will coincide with the second vertical line on the sleeve. Each vertical line on the sleeve indicates a distance of 1-40 of an inch. Every fourth line is made longer than the others, and is numbered 0, 1, 2, 3, etc. Each numbered line indicates a distance of four times 1-40 of an inch, or one tenth.

The beveled edge of the thimble is marked in twenty-five divisions, and every fifth line is numbered, from 0 to 25. Rotating the thimble from one of these marks to the next moves the spindle longitudinally 1-26 of twenty-five thousandths, or one thousandth of an inch. Rotating it two divisions indicates two thousandths, etc. Twenty-five divisions will indicate a complete revolution, .025 or 1-40 of an inch.

To read the micrometer, therefore, multiply the number of vertical divisions visible on the sleeve by 25, and add the number of divisions on the bevel of the thimble, from 0 to the line which coincides with the horizontal line on the sleeve. For example, as the tool is represented in the engraving, there are ten divisions visible on the sleeve. Multiply this number by 25, and add the number of divisions shown on the bevel of the thimble, which is 10. The micrometer is therefore open two-hundred and sixty-thousandths. ($10 \times 25 = 250 + 10 = 260$).

How to Read a Micrometer to Ten-Thousandths.

Readings in ten thousandths of an inch are obtained by the use of a vernier, so named from Pierre Vernier, who invented the device in 1631. As applied to a micrometer this consists of ten divisions on the adjustable sleeve, which occupy the same space as nine divisions on the thimble. The difference between the width of one of the ten spaces on the sleeve and one of the nine spaces on the thimble is therefore one tenth of a space on the thimble. In Fig. 89

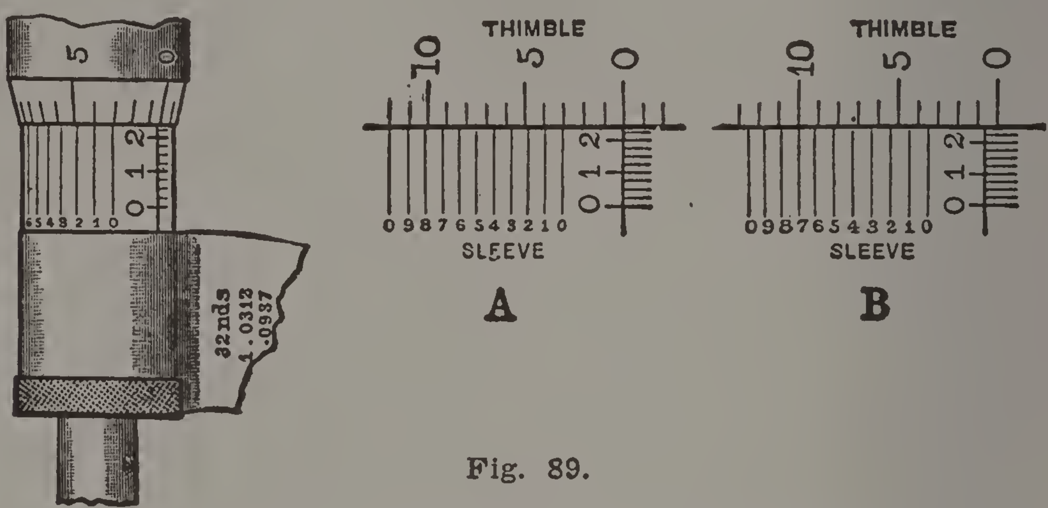


Fig. 89.

at A the third line from 0 on thimble coincides with the first line on the sleeve. The next two lines on thimble and sleeve do not coincide by one tenth of a space on thimble. The next two, marked 5 and 2, are two tenths apart, and so on. In opening the micrometer, by turning the thimble to the left, each space on the thimble represents an opening of one thousandth of an inch. If therefore the thimble be turned so that the lines marked 5 and 2 coincide, the micrometer will be opened two tenths of one thausandth or two ten thousandths. Turning the thimble further, until the line 10 coincides with the line 7 on the sleeve, as in Fig. 89 at B, the micrometer has been opened seven ten thousandths and the reading is .2257.

To read a ten thousandths micrometer, first note the thousandths as in the ordinary micrometer, then observe the line on the sleeve which coincides with a line on the thimble. If it is the second line, marked 1, add one ten thousandth; if the third, marked 2, add two ten thousandths, etc.

Screw Thread Micrometer.

The micrometer shown in Fig. 90 is intended for the accurate measurement of V threads on screws, taps, thread gauges, etc., by measuring the actual thread.

The distinctive feature in the construction of this micrometer is that the end of the movable spindle is pointed and the fixed end or anvil is V shaped. Enough is taken from the end of the point and the bottom of the V is carried down low enough, so that they will not rest on the bottom or top of the thread to be measured but on the cut surface. As the thread itself is measured, it will be seen that the actual outside diameter of the piece does not enter into consideration.

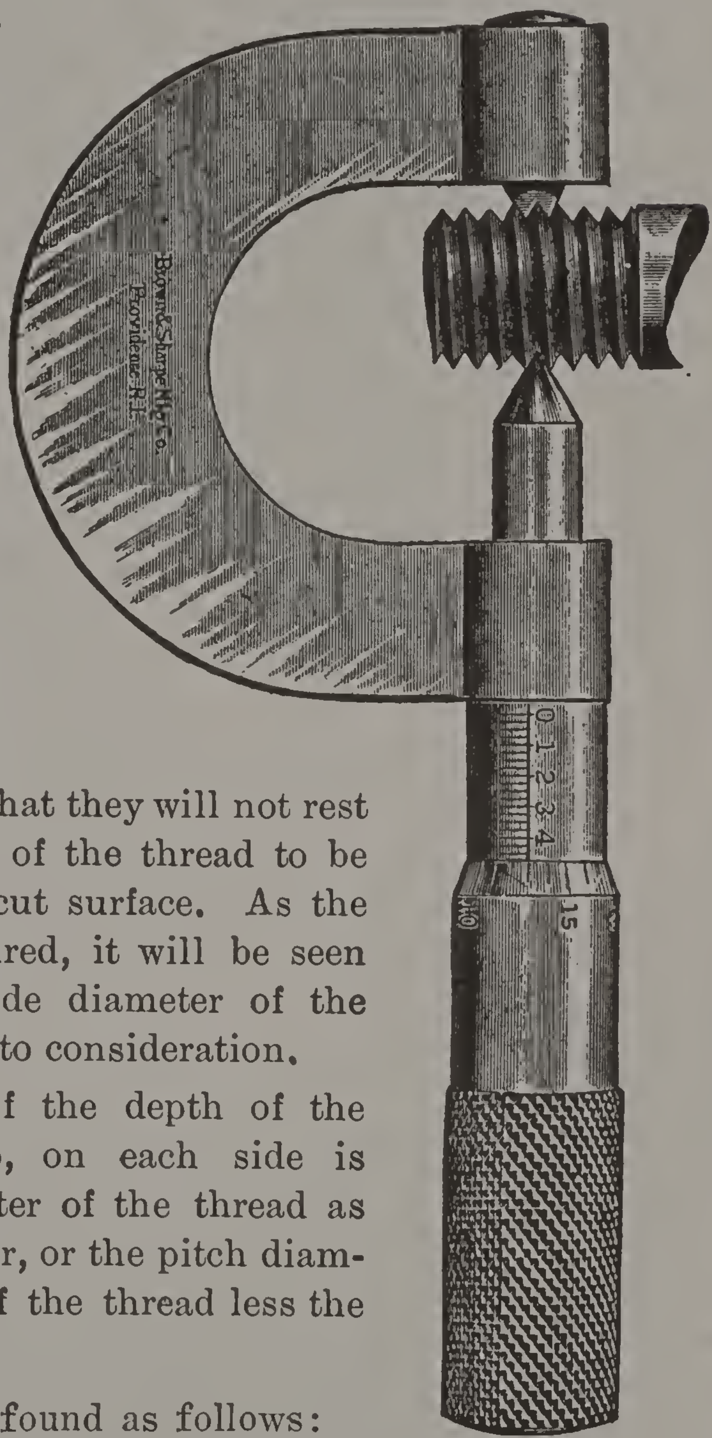


Fig. 90.

As only one-half of the depth of the thread from the top, on each side is measured, the diameter of the thread as indicated by the caliper, or the pitch diameter, is the full size of the thread less the depth of one thread.

This depth may be found as follows:

Depth of	V	threads	= .866 ÷	number	of	threads	to	1 inch.
"	" U. S. Std.	"	= .6495 ÷	"	"	"	"	"
"	" Whitworth	"	= .64 ÷	"	"	"	"	"

As the U. S. standard thread is flatted 1-8 of its own depth on top, it follows that the pitch diameter of the thread is increased 1-8 on each side, equaling 1-4 of the whole depth and instead of the constant .866 the constant .6495 in used, which is three-fourths of .866.

While the movable point measures all pitches, the fixed anvil is limited in its capacity, for if made large enough to measure a 4 pitch thread is would be too wide at the top to measure a 24 pitch thread and if made to measure a 24 pitch thread it would be so small that the thread would not obtain a proper bearing in the anvil. Thus each micrometer is necessarily limited in the range of threads that the anvil can measure.

Ratchet Stop for Micrometers.

When using the device shown in Fig. 91, the ratchet slips by the pawl when more than a certain amount of pressure

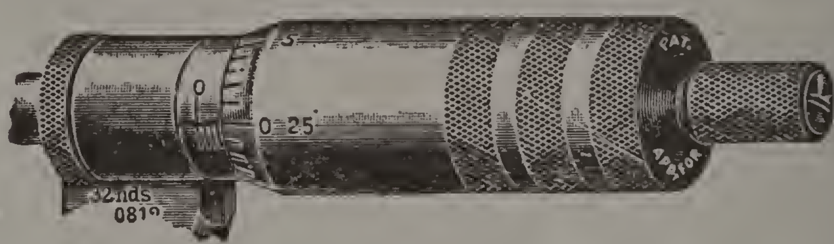


Fig. 91.

is applied, and so prevents the measuring spindle from turning farther and perhaps springing the instrument.

It is valuable where a number of measurements have to be taken quickly and especially where measurements are taken by more than one person with the same micrometer, as by its use the same amount of pressure is applied to the article to be measured, in every case.

Sheet Metal Micrometer.

The Micrometer shown in Fig. 92, is recommended as especially convenient for sheet metal workers.

By placing the middle finger of the right hand through the ring, the micrometer is readily held at right angles to the sheet to be measured and readings made while in this position. The thimble can be operated by the forefinger and thumb of the same hand.

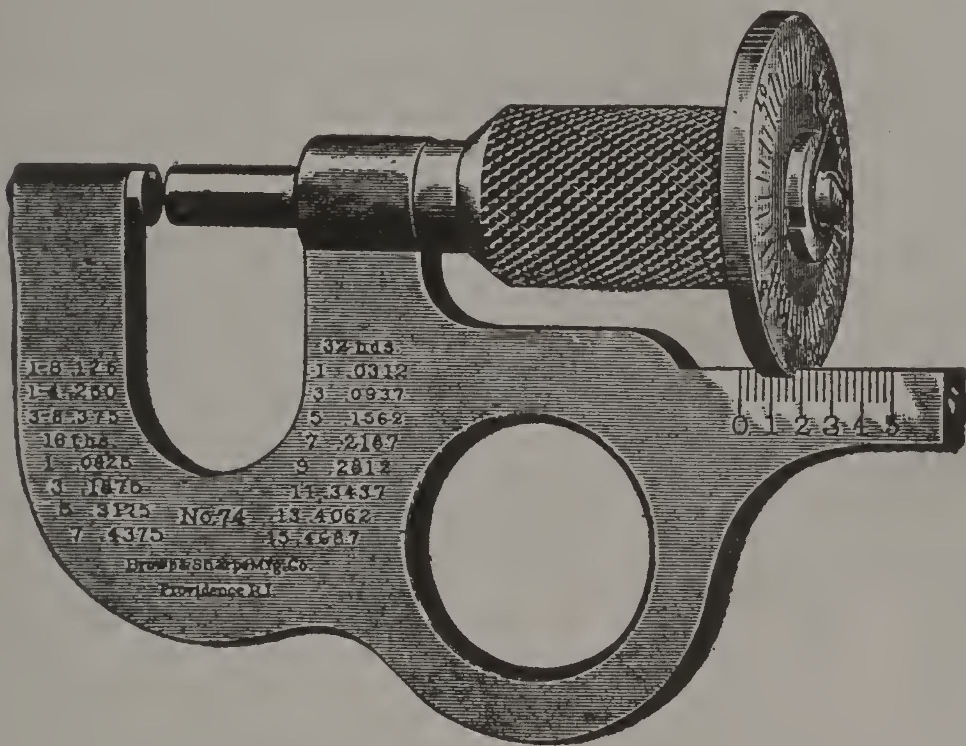


Fig. 92.

The micrometer measures all sizes less than four-tenths of an inch by one-half thousandths of an inch, but one-quarter thousandths are readily estimated.

To facilitate the reading of the micrometer while held in position, the one-half thousandths readings are taken from the dial at the top of the spindle, the readings being indicated by the pointer. The twenty-five thousandths readings, or those corresponding to the readings on the barrel of an ordinary Micrometer, are taken from the scale at the top of the frame.

The decimal equivalents stamped on the frame are convenient and render possible the immediate expression of readings in 8ths, 16ths, 32ds and 64ths of an inch.

Inside Micrometer Gauges.

The Inside Micrometer Gauge, shown in Fig. 93, is designed for making internal measurements, as in measuring rings, cylinders, setting calipers, comparing gauges, and

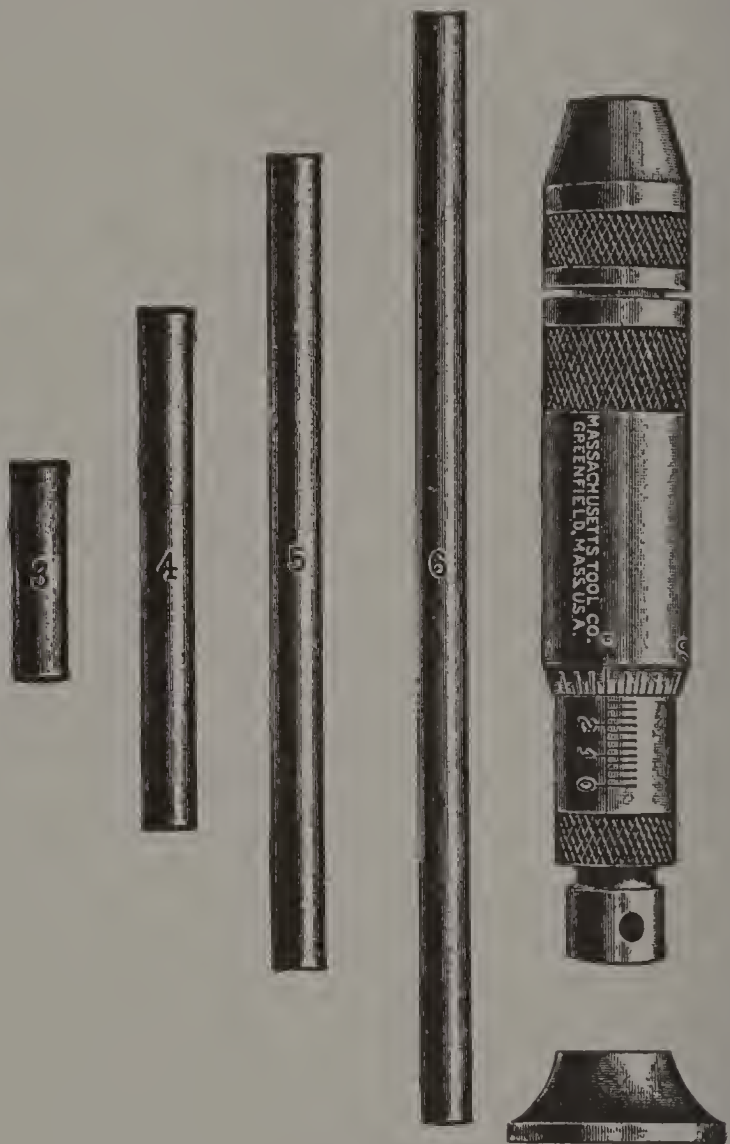


Fig. 93.

work of a similar character. It is also well adapted for measuring parallel surfaces.

The Gauge consists of a holder provided with a micrometer screw and thimble. The screw has a movement of three-tenths of an inch; and, by the use of the extension rods furnished, measurements from 3 to 6 inches may be made by thousandths of an inch.

The extension rods vary by inches, and should be readjusted only when the point of the rod has become worn.

Provision is made for adjustment to compensate for wear of the screw and measuring surfaces. The measuring surfaces are hardened.

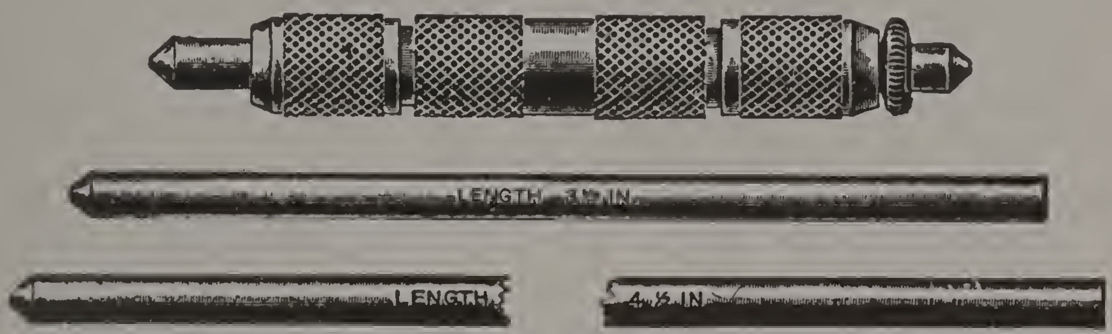


Fig. 94.

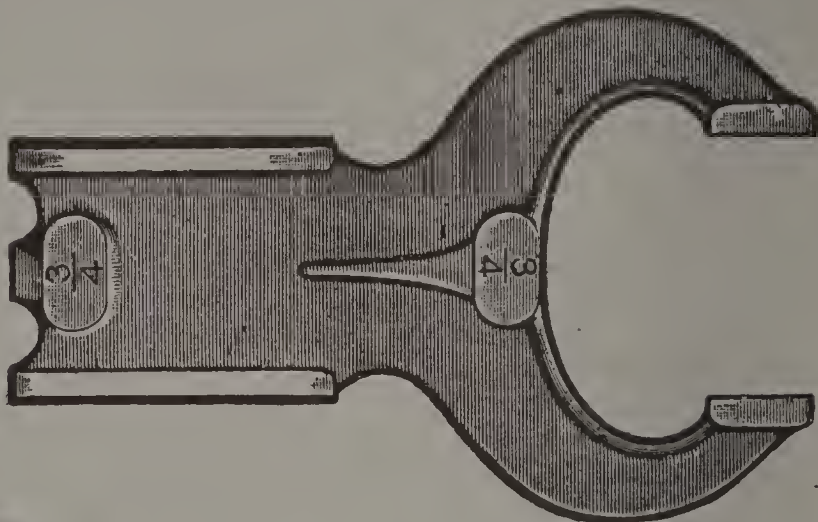
The micrometer gauge illustrated in Fig. 94 is designed for internal measurements of large cylinders and of distances between uprights. The body of the tool is a steel tube provided with a binding chuck on each of its ends. Into one end is clamped a plain rod, which, when the chuck is loosened, can be quickly adjusted to any approximate size. Into the other end is screwed a threaded anvil for fine adjustment.

To set the gauge it is only necessary to loosen the chuck that clamps the wire rod, slide the rod out or in to the required size, and clamp it. If not quite correct, loosen the chuck on the opposite end and turn the anvil out or in what little is needed.

Caliper Gauges.

The Caliper Gauge shown in Fig. 95 is hardened and ground accurately, one end for outside and the other for inside measurements. By their use, mistakes in the setting of calipers and variations in measurements may be in a great measure avoided. Their form gives lightness and strength, making them preferable to plugs and rings for frequent use. As furnishing convenient and reliable standard sizes for every day use in the workshop, they are of

Fig. 95.



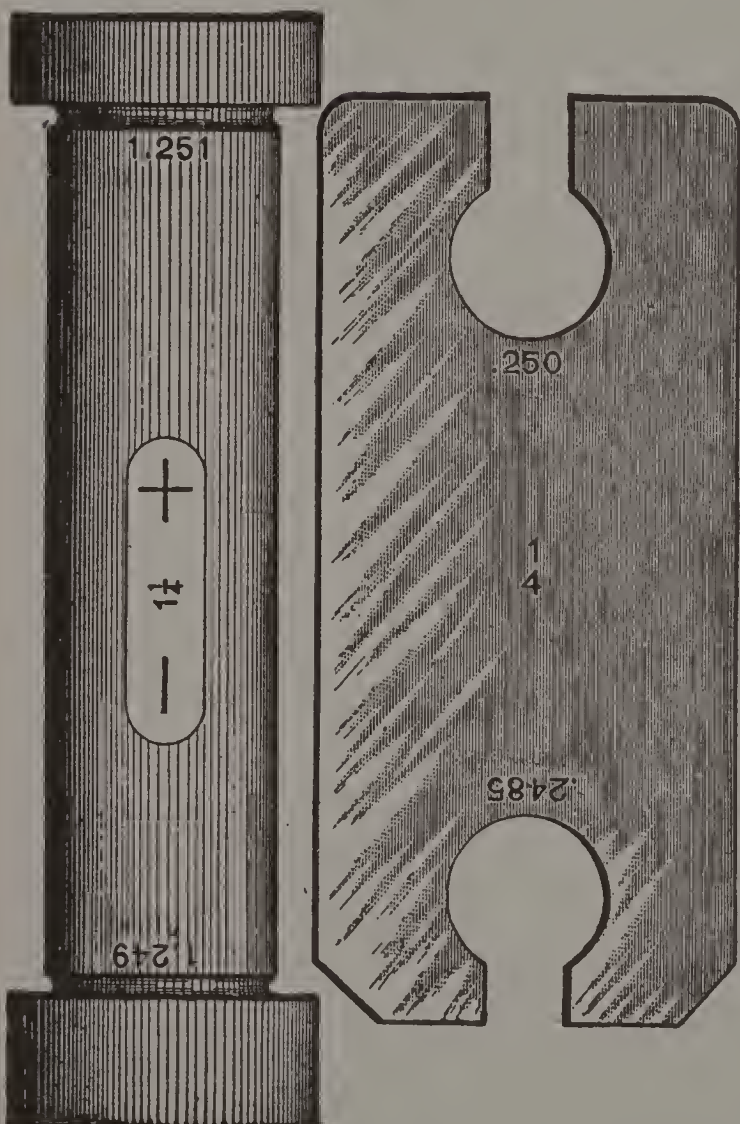


Fig. 96.

great advantage and their use contributes to uniformity in the production of the working parts of machinery.

Sizes larger than three inches are made in two parts for convenience in handling.

Limit Gauges.

The accurate production of duplicate parts, as required in the economical manufacture of machinery, tools, instruments, etc., demands accurate Gauges and, in order to secure the most economical production, Limit Gauges are necessary to avoid time being wasted in finishing the work unduly accurate and still leaving it so that two or more parts when brought together will fit sufficiently well to meet requirements.

The advantages derived from the use of Limit Gauges are being appreciated more and more, as, by their use, the time consumed in testing and gauging is reduced to a minimum, and the duplication of parts is insured.

The cuts shown in Fig. 96 represent the most common form of Internal and External Limit Gauges.

The two ends of Gauges of this type are of different shape. The workman is thus enabled to easily and quickly distinguish the large from the small end without looking at the sizes stamped upon the Gauge.

These Gauges are not only used as references for finishing operations but are of great advantage in roughing work for finishing. When used in this way the same amount of stock is left on each piece, thus enabling the operator, who finishes the pieces, to work to better advantage than if they were of various sizes.

Depth Gauges.

The gauge shown in Fig. 97 is designed for measuring the depth of grooves, holes or irregular parts. It has a one half inch movement of the screw, reading in thousandths, and with two one-half inch and one 1 inch standard collars to slip off or on the spindle 2½ inches, reading in thousandths, can be obtained. The split nut is covered and protected by a graduated sleeve, which not only protects the nut from dirt, but provides a quick and accurate way of taking up wear and adjusting the micrometer to insure correct reading. The sleeves, being held by a stiff friction, may be rotated by a spanner wrench, accompanying each gauge, so that the zero lines will always coincide for correct reading.

The head carries with it a knurled set screw for locking the spindle to prevent changing after being set.

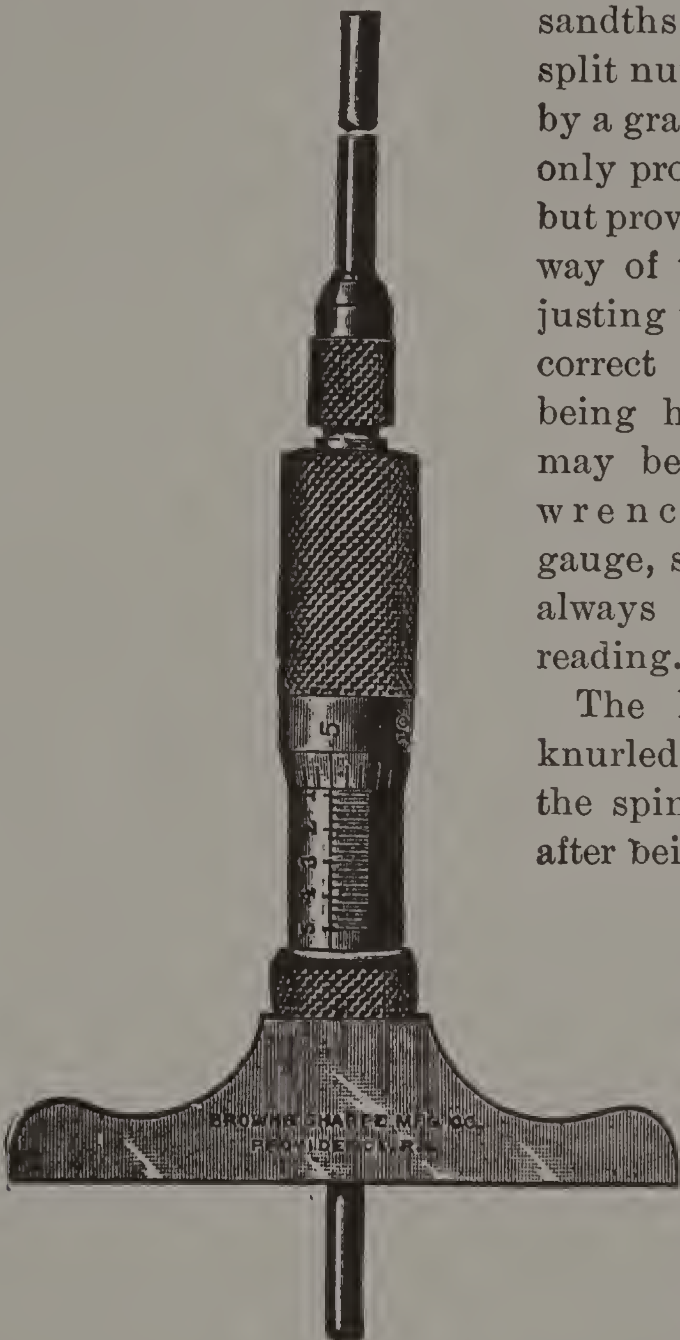


Fig. 97.

The Depth Gauge shown in Fig. 98 is used to obtain the depth of holes, recesses in dies, distance from a plane surface to a projection, etc. The blade is 5 inches long and one-quarter wide and allows for measurements up to 3½ inches being made, and is graduated on the front to read, by means of a vernier, to thousandths of an inch. The back of the blade is graduated to 64ths of an inch.

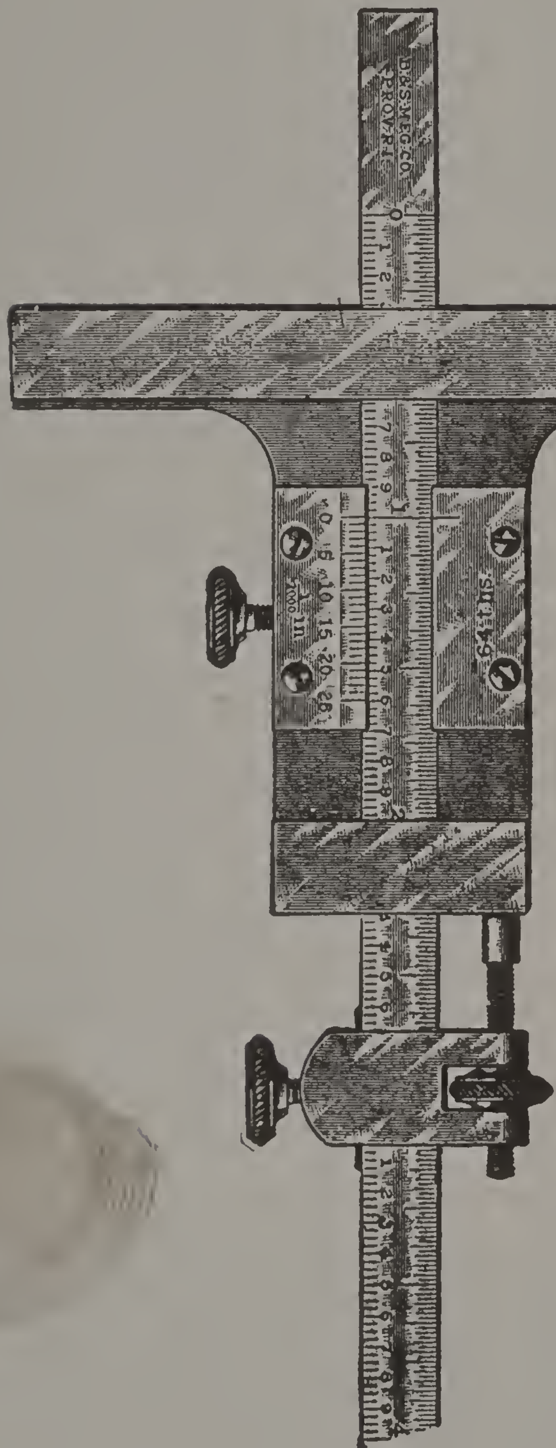


Fig. 98.

Surface Gauges.

The Surface Gauge shown in Fig. 99 in admirably adapted for large work. The sleeve and needle clasp, when loosened for adjustment, are both held by a slight spring friction, and by a single knurled nut both are rigidly clamped. For fine adjustment, the spindle in the base is raised or lowered by a knurled nut, and all backlash is taken up by a spiral spring in the base.

For heights above 12 inches an extension rod is provided to couple on to the spindle.

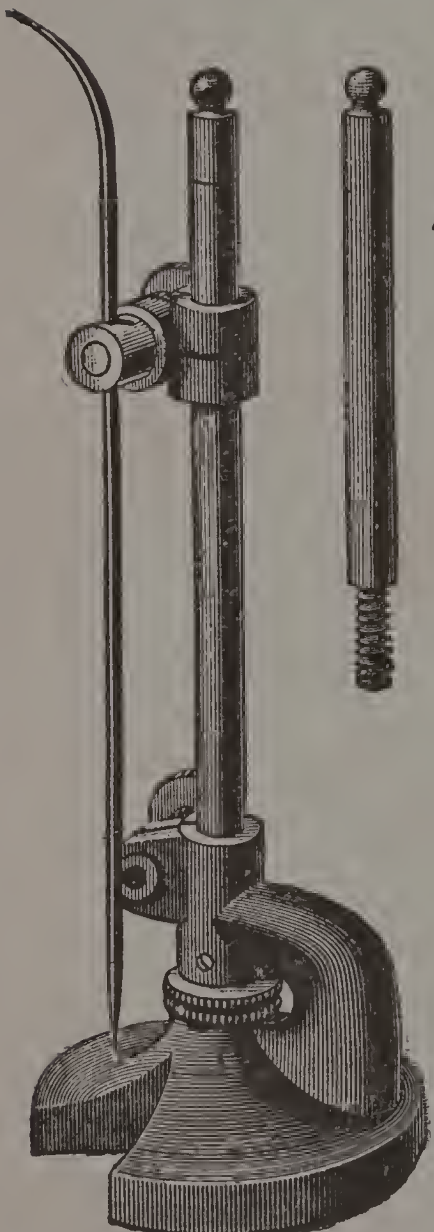


Fig. 99.

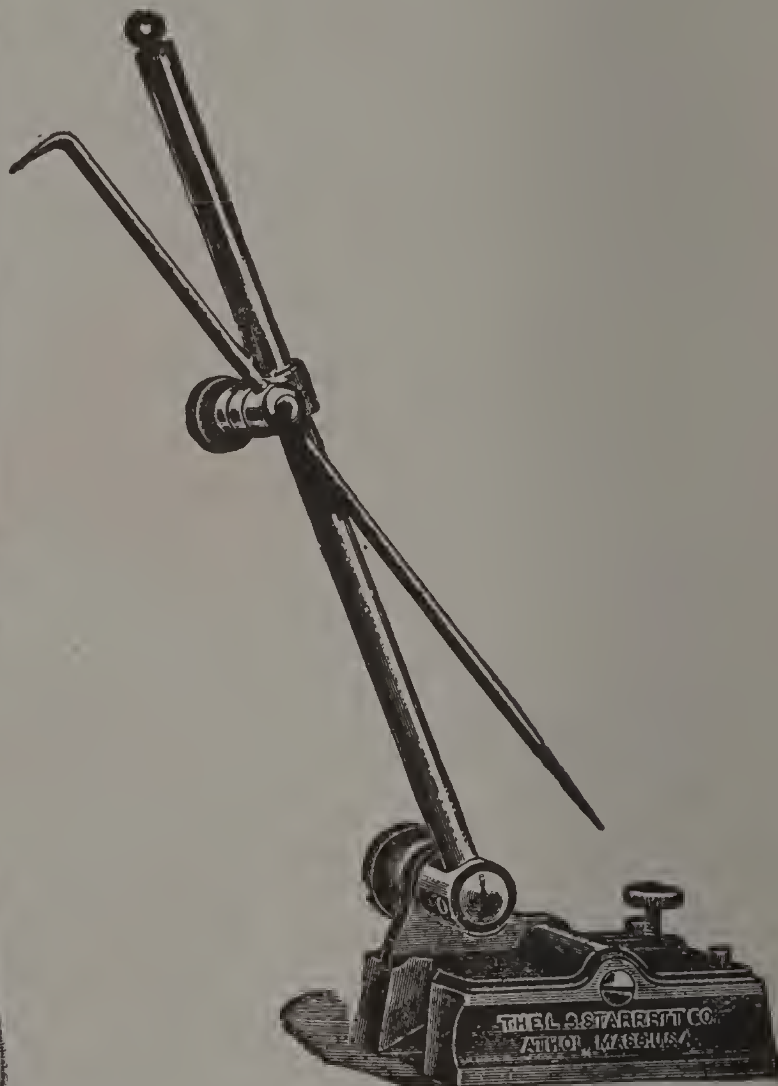


Fig. 100.

Fig. 100 illustrates a form of universal surface gauge which has a V-shaped groove in one end and another in the base which makes it adaptable for use on circular work.

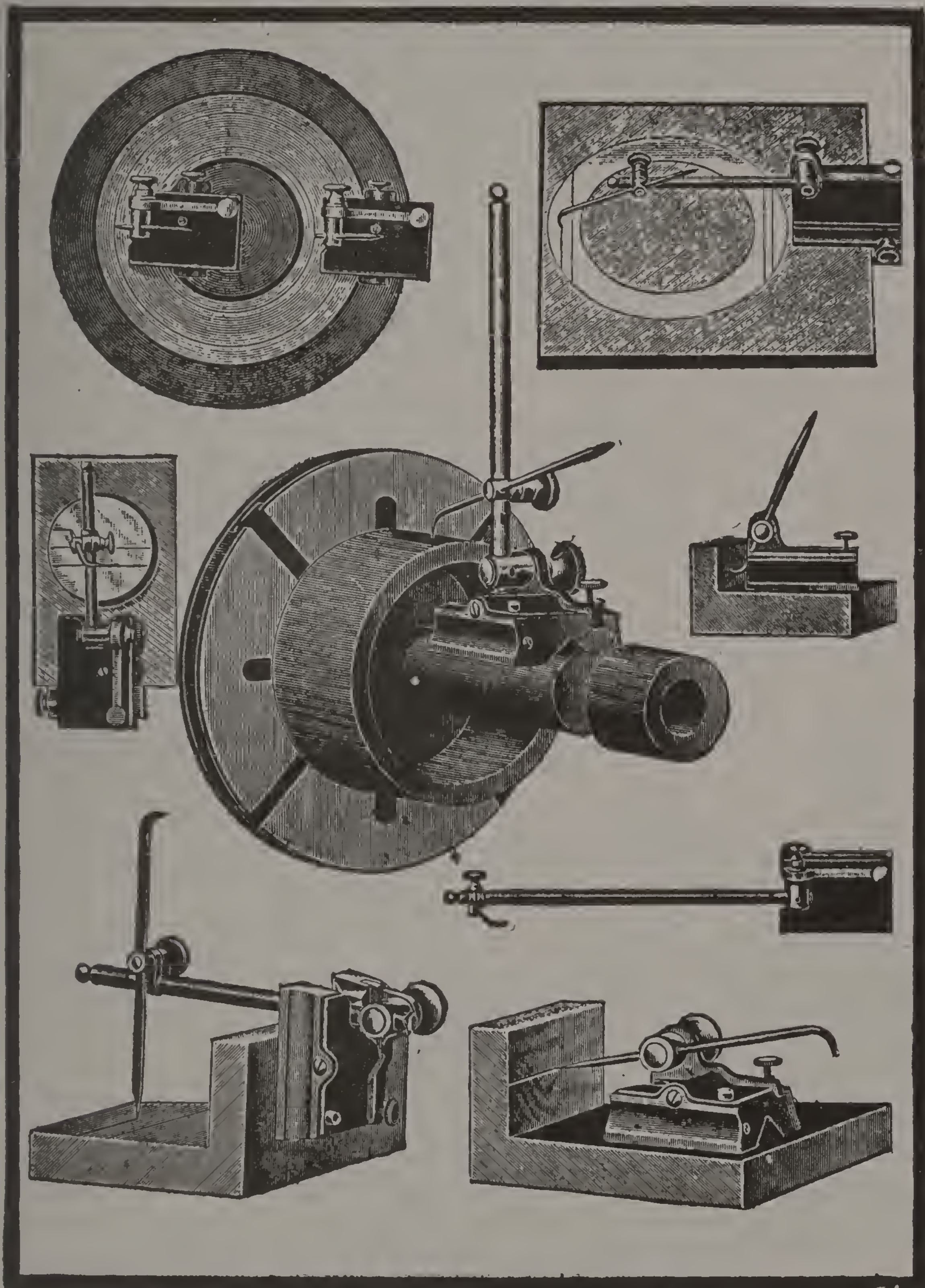


Fig. 101.

Fig. 101 illustrates some of the uses to which the surface gauge shown in Fig. 100 may be adapted.

The spindle passes through a rotating head, jointed to a rocking bracket, pivoted in base. This bracket is adjusted by a knurled screw in one end against a stiff spring in the other, the spindle may be set upright or at any angle, or turned so as to work under the base and be adjusted to any position. The snug and head carrying the scriber are so made that when the clamp nut is loosened, all may be freely moved to any position and by friction springs retained in place until a slight turn of the clamp nut holds them firm.

In the rear end of the base are two gauge pins frictionally held which may be pushed to bear against the edge of a surface plate or in the slot of a planer bed for line work.

For small work the spindle may be removed and the scriber inserted in the hole provided for the purpose, where it may be adjusted and used to advantage on bench work.

The Vernier Caliper and Its Use.

On the bar of the Vernier Caliper shown in Fig. 102 is a line of inches numbered 0, 1, 2, etc., each inch being divided into ten parts and each tenth into four parts, making forty divisions to the inch. On the sliding jaw is a line of division of twenty-five parts, numbered 0, 5, 10, 15, 20, 25. The twenty-five parts on the Vernier correspond, in extreme length, with twenty-four parts or twenty-four fortieths of the bar, consequently each division on the Vernier is smaller than each division on the bar by one thousandth part of an inch. If the sliding jaw of the Caliper is pushed up to the other, so that the line marked 0 on the Vernier corresponds with that marked 0 on the bar, then the two next lines to the right will differ from each other by one thousandth or an inch and so the difference will continue to increase, one thousandth of an inch for each division, till they again correspond at the line marked 25 on the Vernier. To read the distance the Caliper is open, commence by noticing how many inches, tenths and parts of tenths, the zero point on the Vernier has been moved from the zero point on the bar. Now count upon the Vernier the number of divisions, until one is found which coincides with one on the bar, which will be the number of thousandths to be added to the distance read off on the bar. The best way of expressing the value of the divisions on the bar, is to call the tenths one hundred thousandths (.100) and the fourths of tenths, or fortieths, twenty-five thousandths (.025). Referring to Fig. 99, 102, it will be

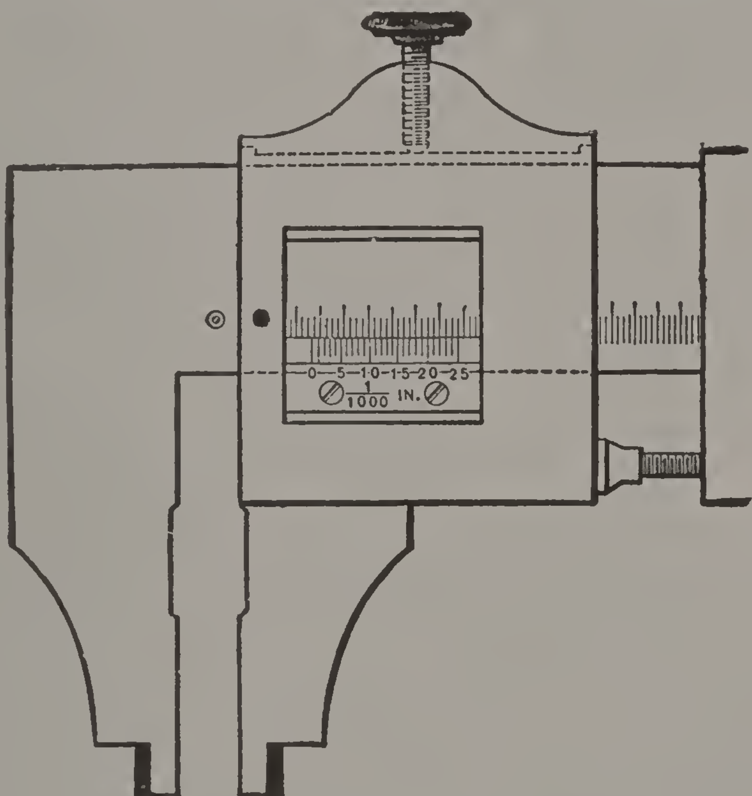


Fig. 102.

seen that the jaw is opened two-tenths and three quarters, which is equal to two hundred and seventy-five thousandths (.275). Now suppose the Vernier is moved to the right so that the tenth division would coincide with the next one on the scale, which will make ten thousandths (.010) more to be added to two hundred and seventh-five thousandths (.275), making the jaws open two hundred and eighty-five thousandths (.285).

A form of Vernier Caliper is shown in Fig. 103 which is graduated on the front to read to thousands of an inch and on the back to 64ths of an inch.

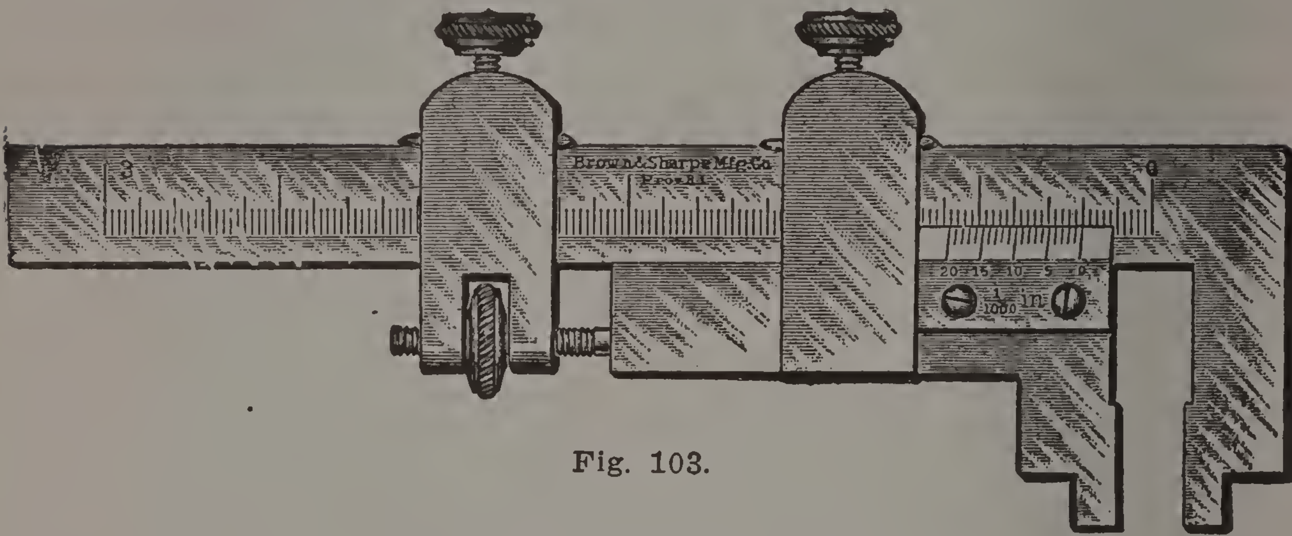


Fig. 103.

The Combination Bevel.

The combination bevel shown in Fig. 104 has a stud riveted in the straight edge stock or head, on which its split blade is hinged, so as to swing over the stock, and be clamped at any angle. The slotted auxiliary blade with

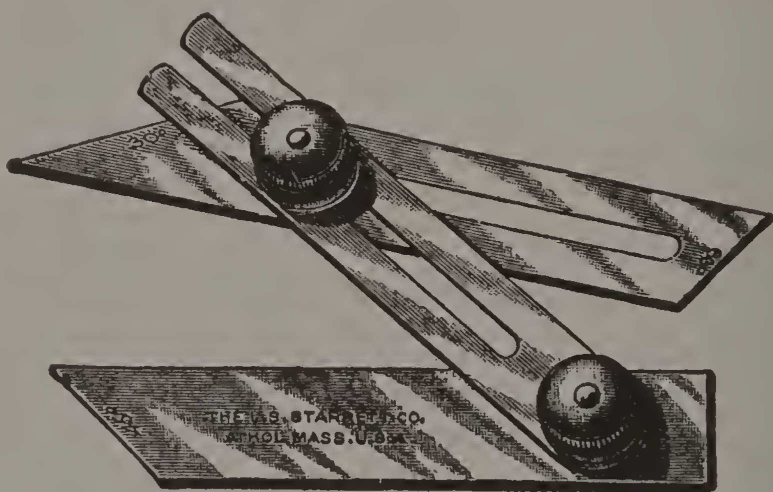


Fig. 104.

clamp bolt may be slipped on to the split blade and be clamped at any desired angle and used, in combination with the stock of the other, for laying out work, measuring, or showing any angle desired, and, when so combined, will lie flat upon its work.

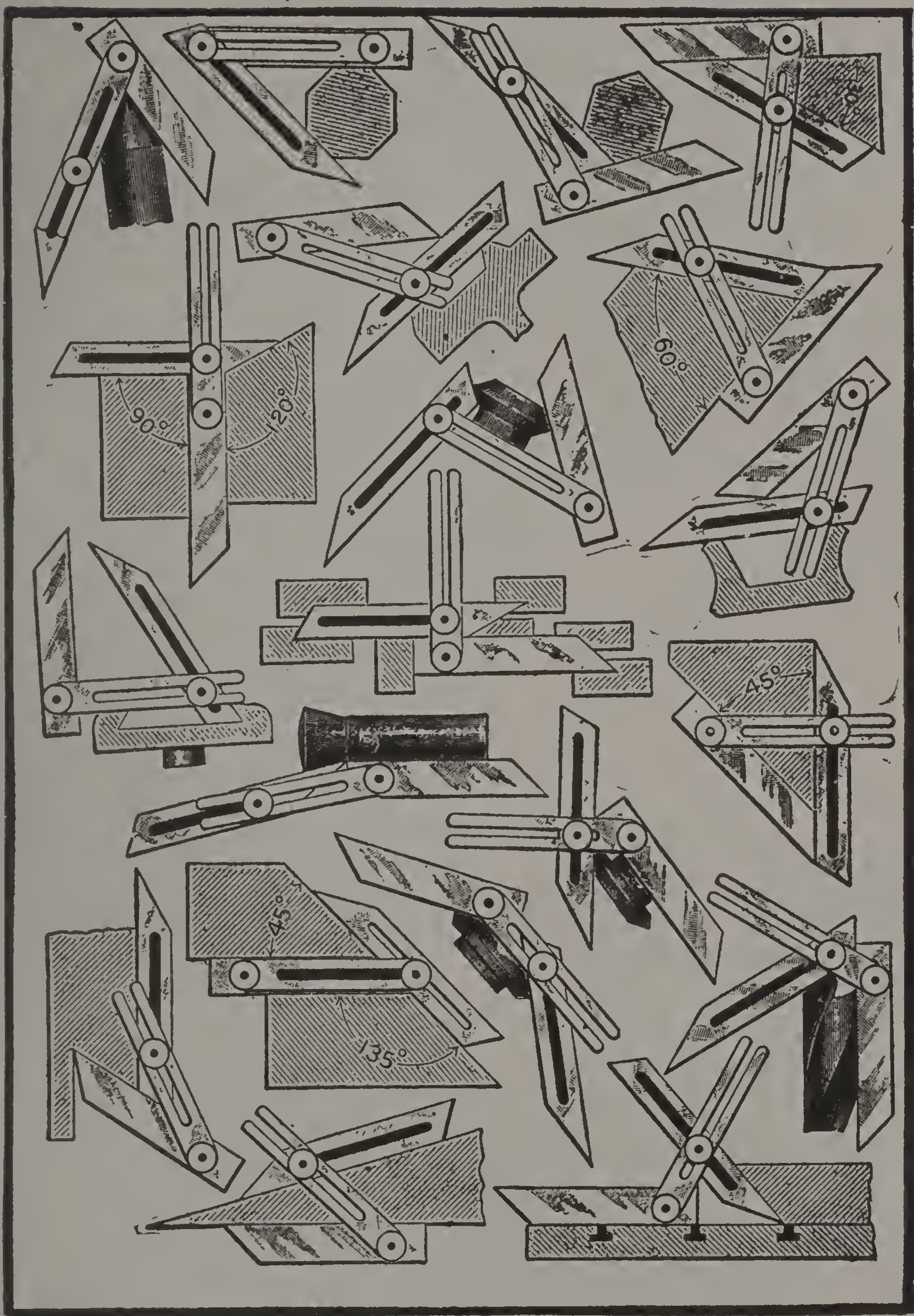


Fig. 105.

Fig. 105 shows some of the many uses to which the combination bevel shown in Fig. 104 may be put.

The Protractor.

A universal bevel protractor is illustrated in Fig. 106. The disc is graduated in degrees from 0 to 90 each way, and rotates the entire circle on a central stud inside the case. The blade which is clamped by an eccentric stud against the edge of the disc, may be slipped back and forth its full length, or turned at any angle around the circle and firmly clamped at any point, adapting it for work in positions where others cannot be used, and rendering the common universal bevel generally used for transferring angles unnecessary. One side of the stock being flat, makes it a convenient tool for laying on paper in drafting, and it has double the utility of any other tool of the kind.

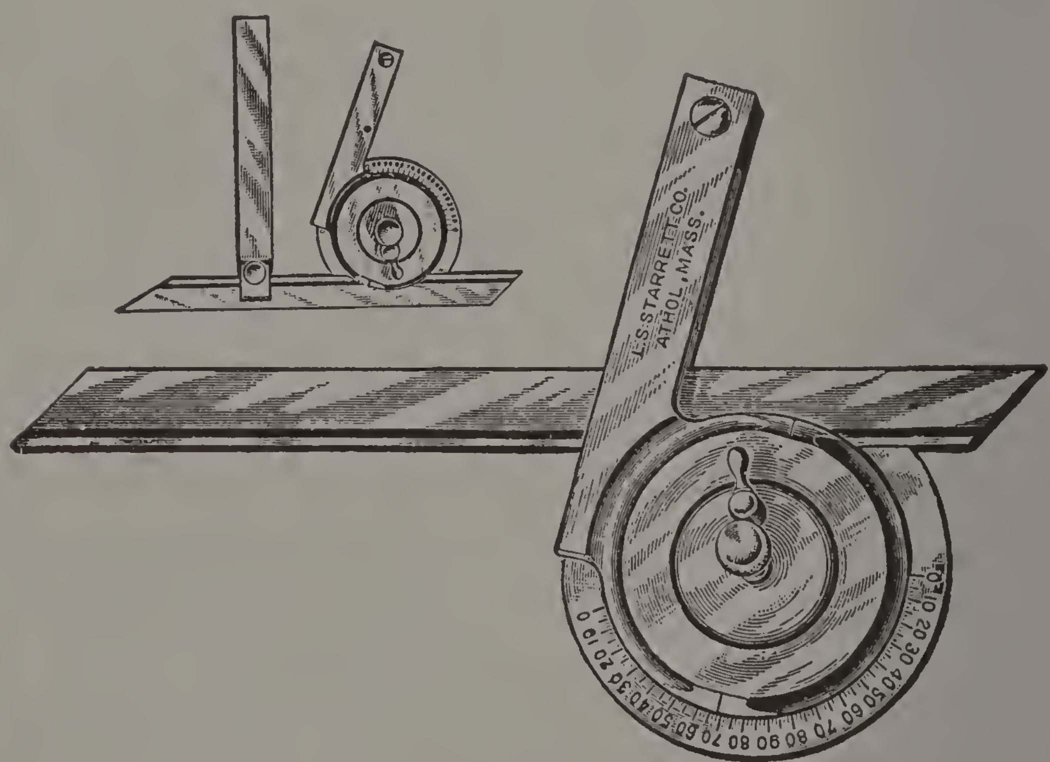


Fig. 106.

The attachment shown in the smaller view in Fig. 106 will be found very convenient for grinding worm thread tools, tapers on lathe centers, and all long tapers.

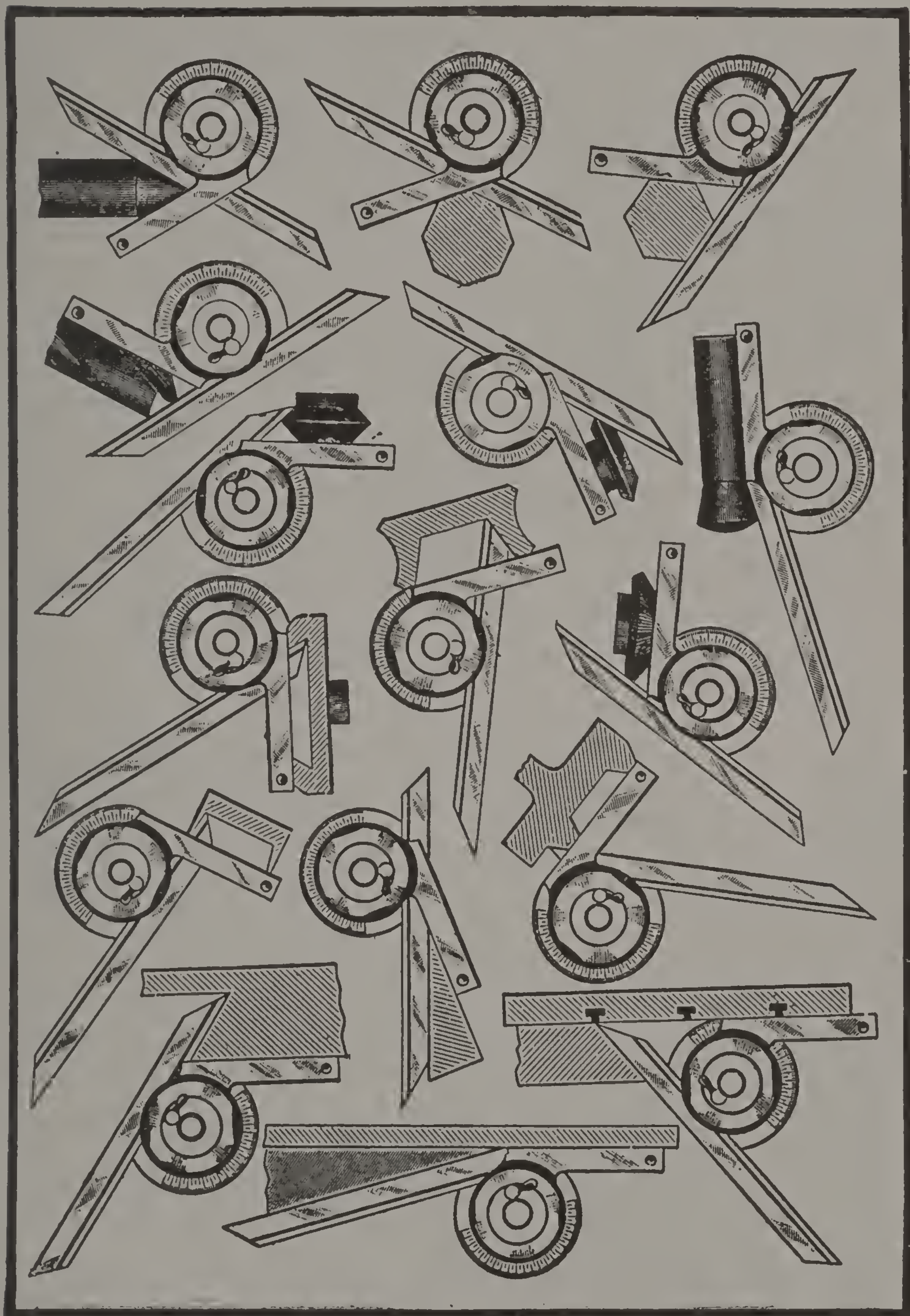


Fig. 107.

Fig. 107 shows some of the various uses of the Universal bevel protractor. A form of bevel protractor is illustrated

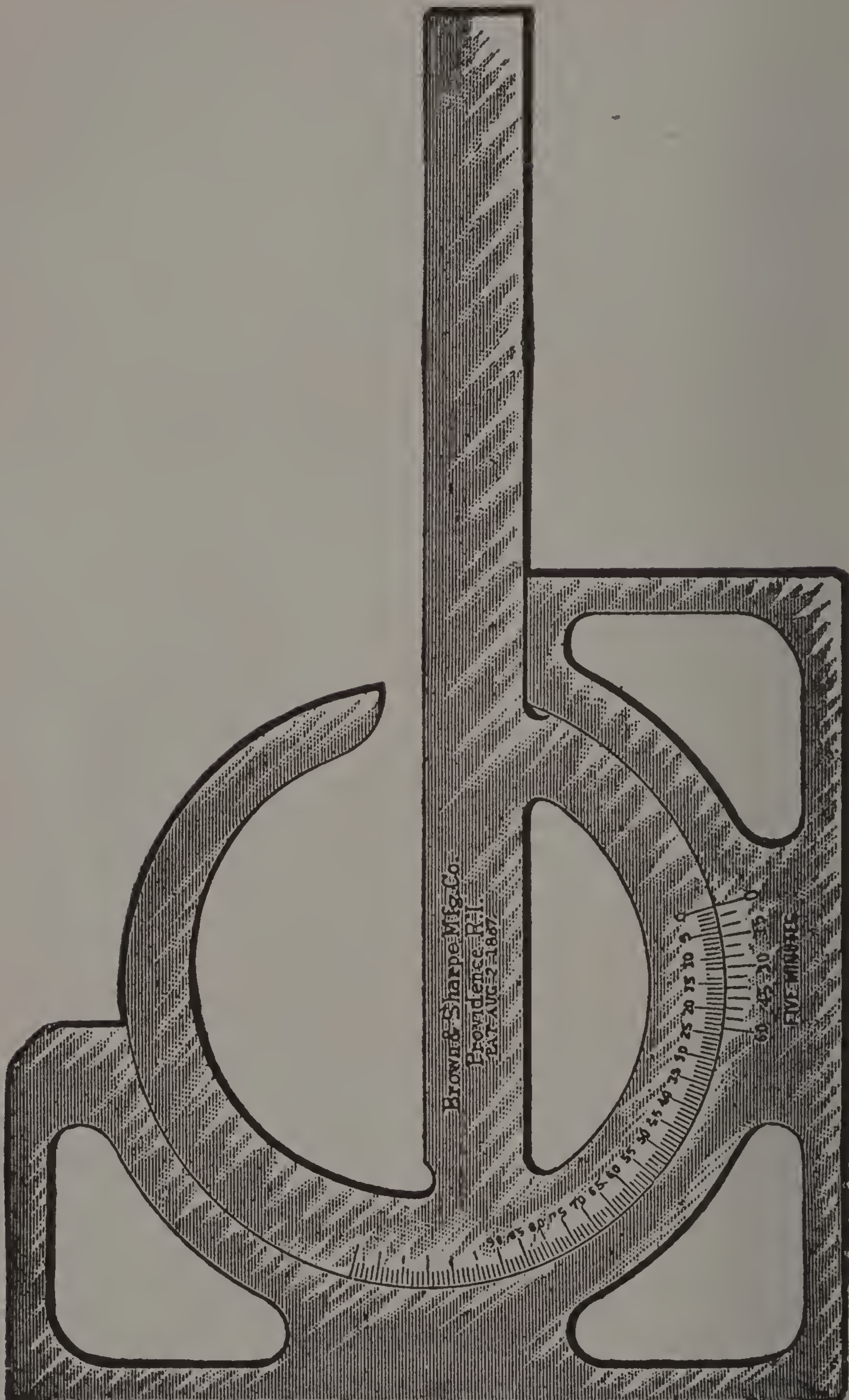

Brown & Sharpe Mfg. Co.
Providence R.I.
PAT. AUG. 7 1867
FIVE MINUTES

Fig. 108.

in Fig. 108, which will be found to be very useful to draftsmen and others when very great accuracy in laying out work is required.

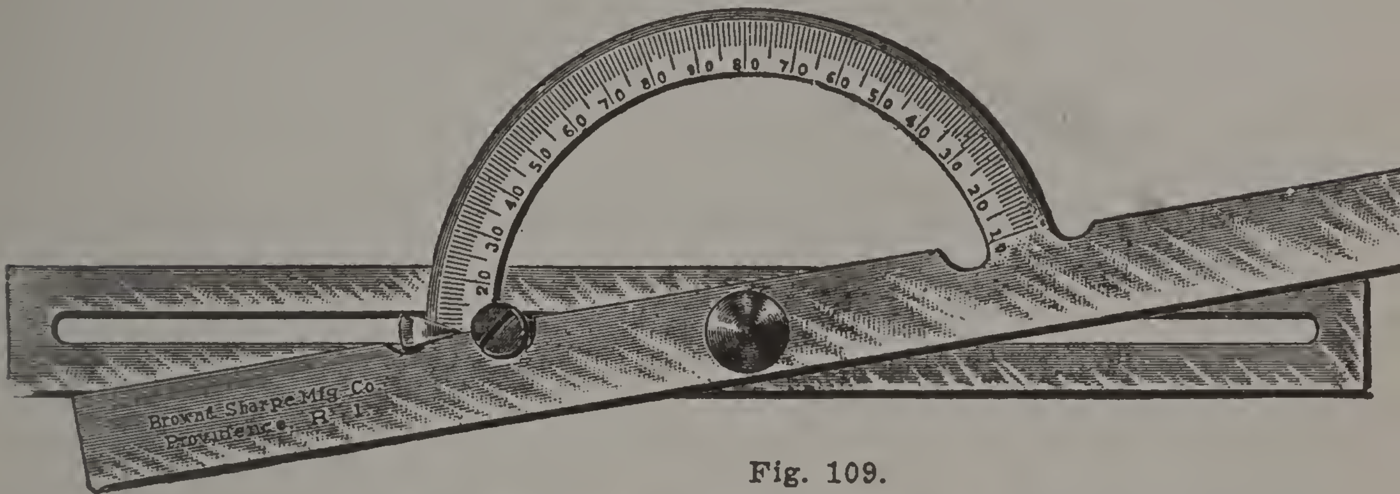


Fig. 109.

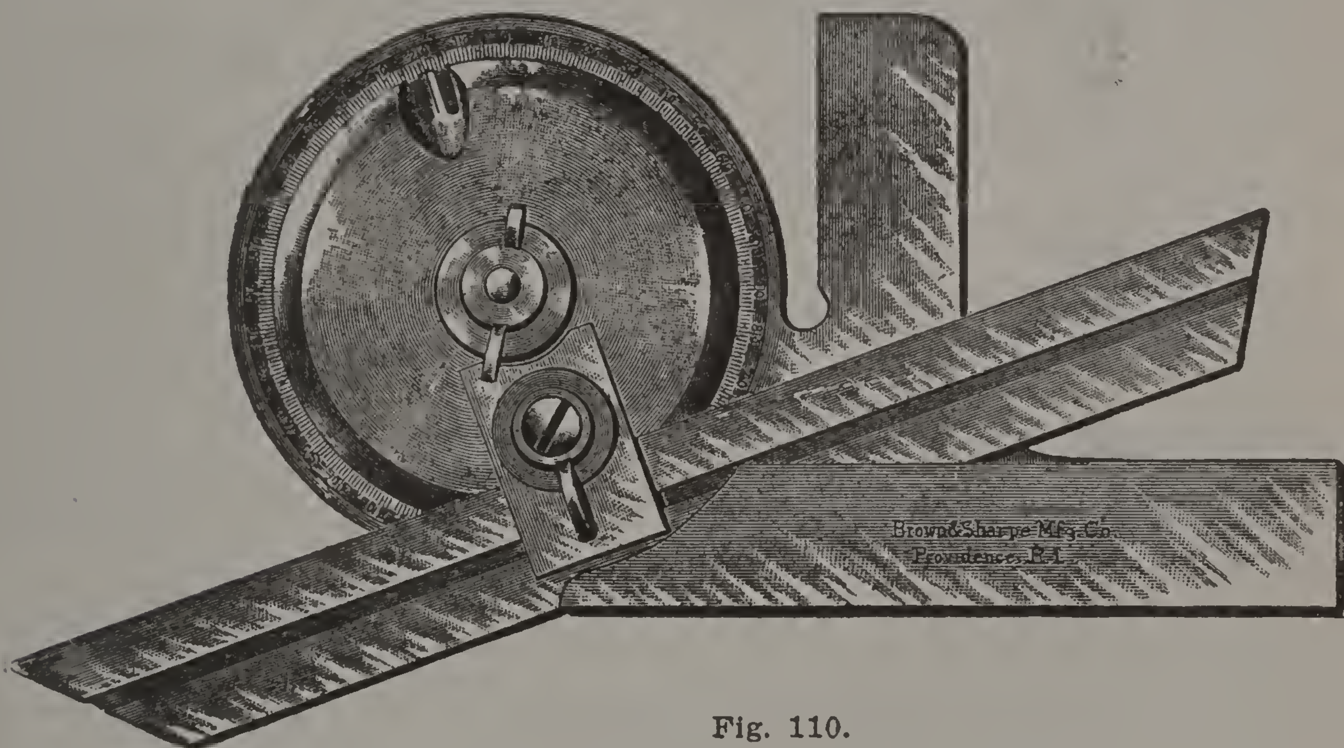


Fig. 110.

This Protractor can be quickly set to any angle. It can be used either side up and on either of the two straight edges and it is of great advantage in dividing a circle, transferring angles or laying off a given angle, without resetting, on either side of a line.

The Vernier reads to five minutes.

It also forms a convenient extension to a T square and freqeuntly takes the place of 45° and 60° triangles.

Two other styles of bevel protractors are shown in Figs. 109 and 110.

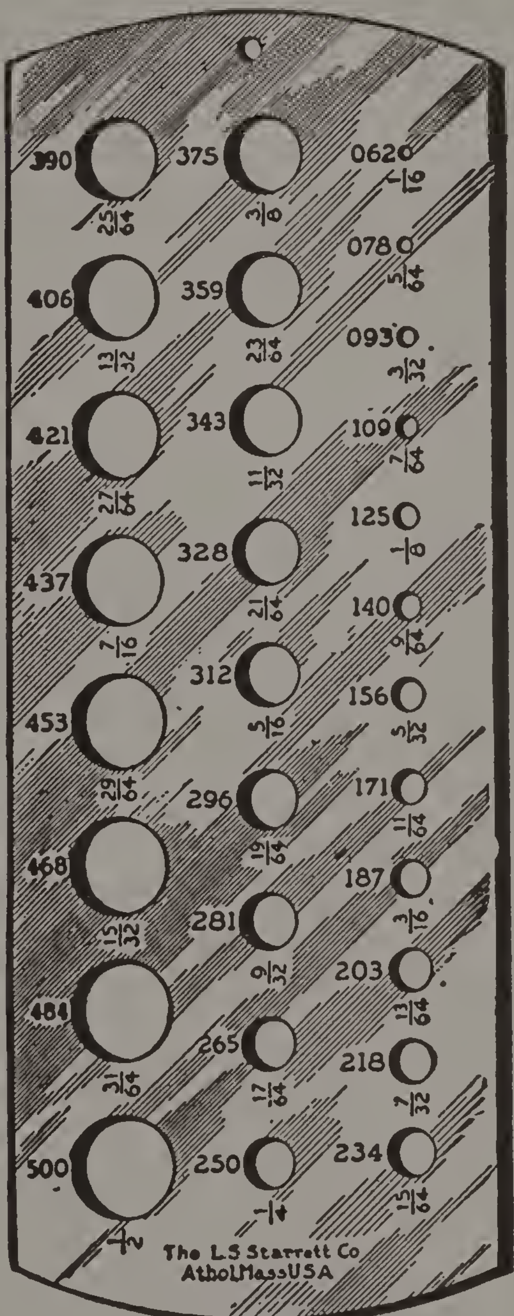


Fig. 111.

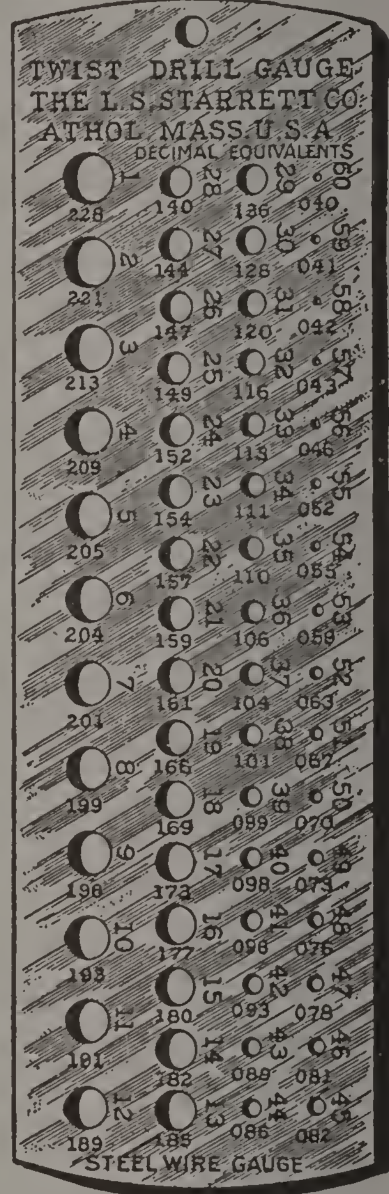


Fig. 112.

Gauges.

The gauge shown in Fig. 111 is for twist drills, from one-quarter to one-half an inch in diameter. Each size of drill is designated by both vulgar or common fractions and also by decimal fractions.

Fig. 112 illustrates a guage for Number Drills from No. 1 to 60 inclusive. The size of each drill is given in decimal

Fig. 113.

fractions. Gauges for sheet metal and plates, standard wire gauge and music or piano wire gauges, are shown in Figs. 113, 114 and 115, respectively.

Test Indicators.

The dial test indicator shown in Fig. 116 is reliable, easily read and very sensitive. The slightest pressure upon the contact point produces a movement of the hand on the dial. The circumference of the dial is divided into 125

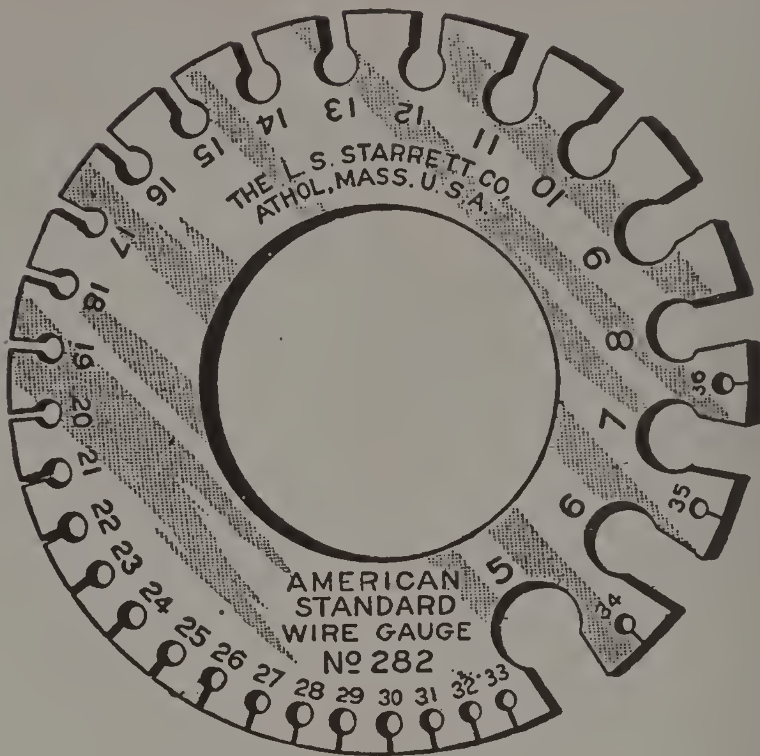


Fig. 114.

equal spaces, each one representing a movement of the contact point of one-half thousandth of an inch. One revolution of the hand therefore indicates 1-16 inch, and two revolutions 1-8 inch, which is the capacity of the instrument.

Fig. 115.

The dials are figured in two different ways. A is marked from 0 to $62\frac{1}{2}$, the figures denoting thousandths, and is most useful in greater forward movement, measuring, indexing, spacing, etc. B is marked from 0 to $31\frac{1}{4}$ to right and left, and is best for general use. By bringing contact point against the work with just enough pressure to give the hand one full turn, then seting it at 0, an opportunity is given for one full revolution of the hand to both right and left of 0, showing a rise or drop in the work and

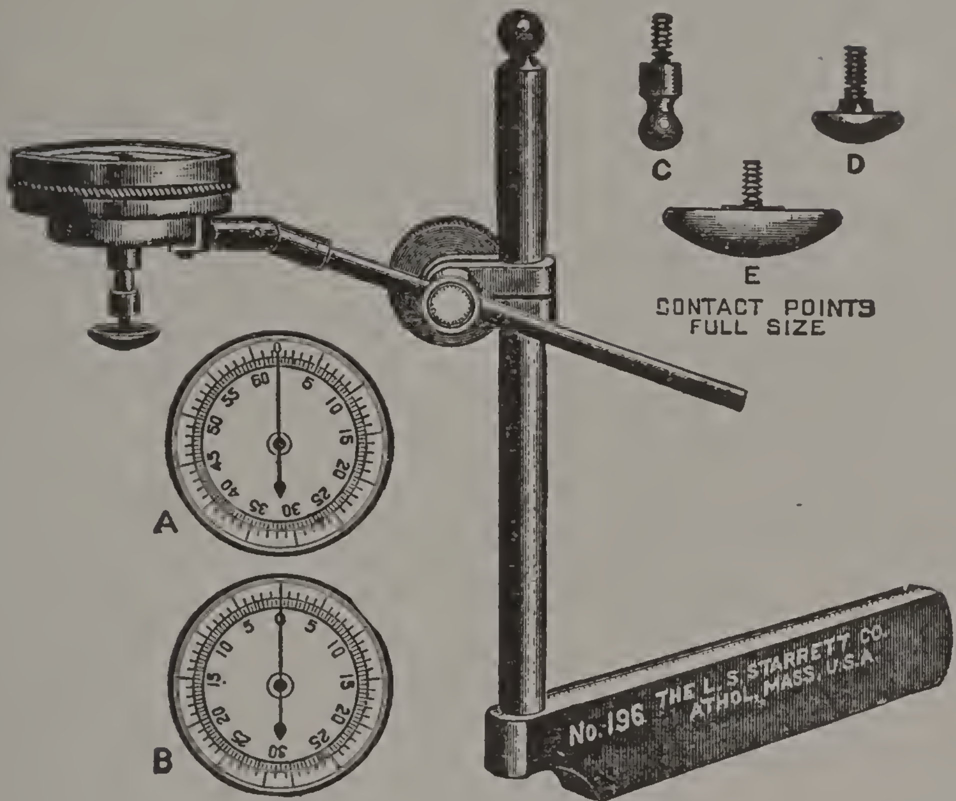


Fig. 116.

the amount of variation. A most valuable feature is the adjustable dial. By turning the knurled rim the dial may be instantly moved to bring the 0 mark to any point desired in relation to the hand. Each indicator is fitted with a friction joint and removable 3 inch rod, adapting it for use in any position, at the top, bottom or side of the work, also with three hardened and ground contact points adapted for different classes of work. The special tool post and sleeve as shown above are useful in lathe work. For general work the indicator is adapted for use with a 9 inch or 12 inch surface gauge. On lathe, planer, milling machine and in setting up machinery, this tool will be found very useful. Applications of the dial test indicator are shown in Fig. 117.

The test indicator shown in Fig. 118 may be used to test and show the imperfections or truth of inside, outside or surface work. It can be instantly attached to the spindle or to the needle of any surface gauge and used in connec-

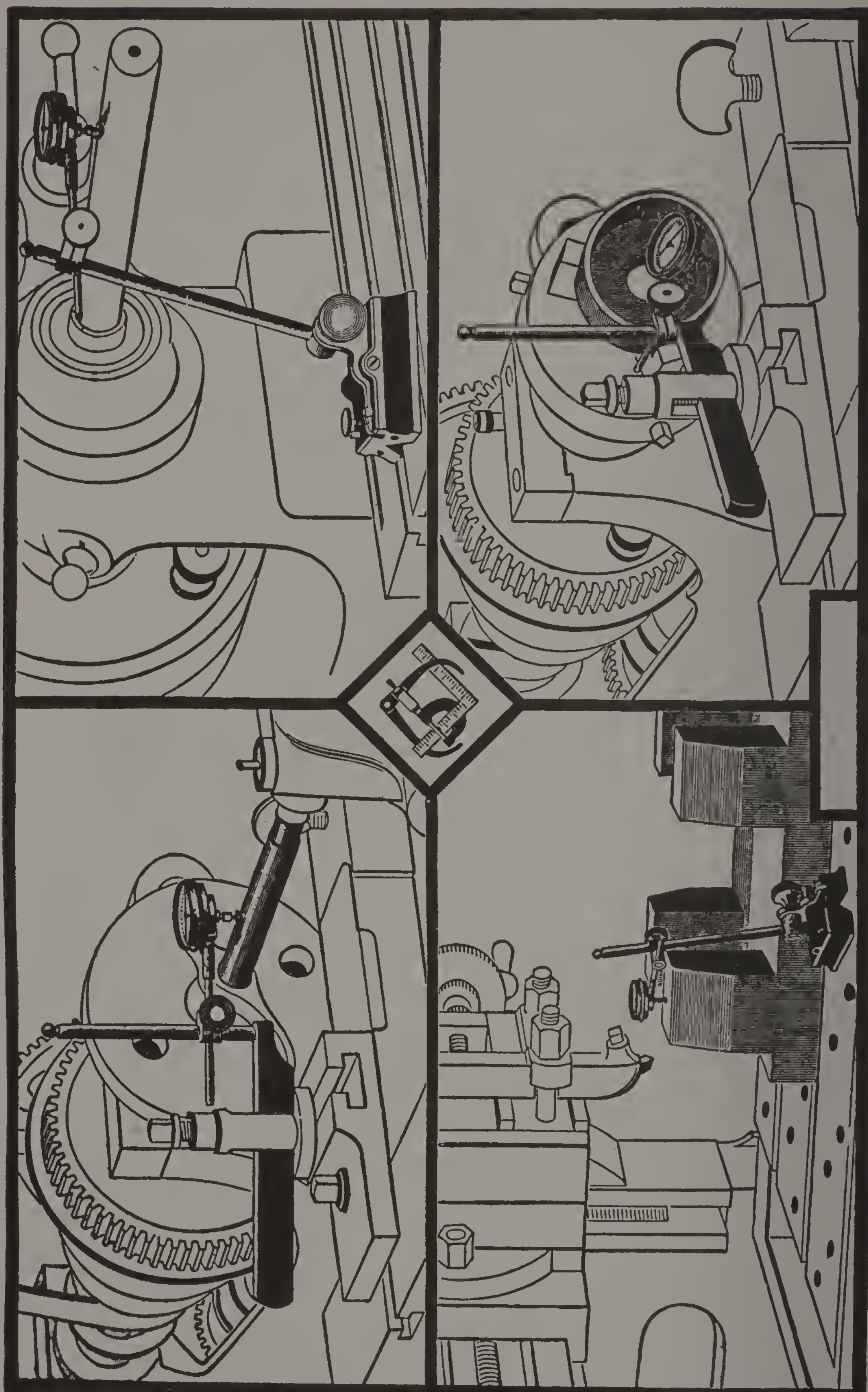


Fig. 117.

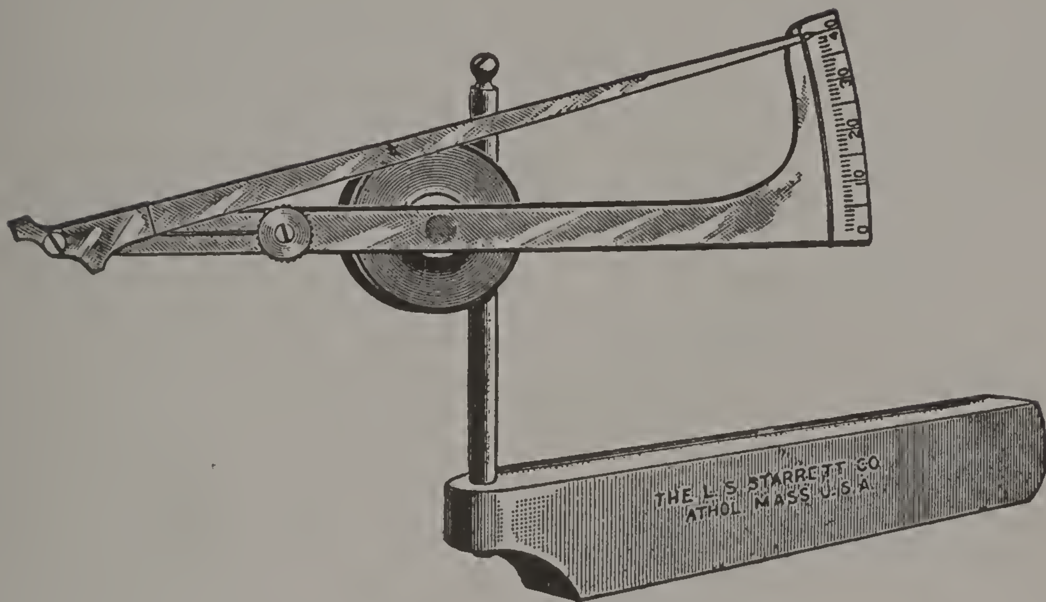


Fig. 118.

tion with same to show the slightest variation in thousandths. A special holder, as shown in Fig. 118, is designed to go in the tool-post of a lathe, adapting it for use to show the accuracy of all kinds of lathe work, turning, chucking, or locating and centering work on a face plate. The head of the needle has three working points, equal distance from its fulcrum, so the telltale needle will vibrate, reading in thousandths, when the work is in contact with either point—in front, above or below it. When in front, the spring operating the telltale needle needs to be reversed to throw point of needle up instead of down as when used above or below the work. This may be instantly done by a slight turn of the disc to which the vibrating spring is attached.

Speed Indicators.

A form of speed indicator is shown in Fig. 119, which is used in connection with a watch to time the speed of shafting or machinery.

The instrument will register 5,000 revolutions. The large dial is graduated into one hundred lines, each one representing a revolution of the spindle. The small dial has fifty lines cut upon its face, each representing one hundred revolutions of the spindle, or one complete turn of the large dial. A spring finger trip attached to the case engages with one of the lines in the small dial and holds it from revolving until the large dial makes one complete turn, when the trip pin passing under the spring trip lifts

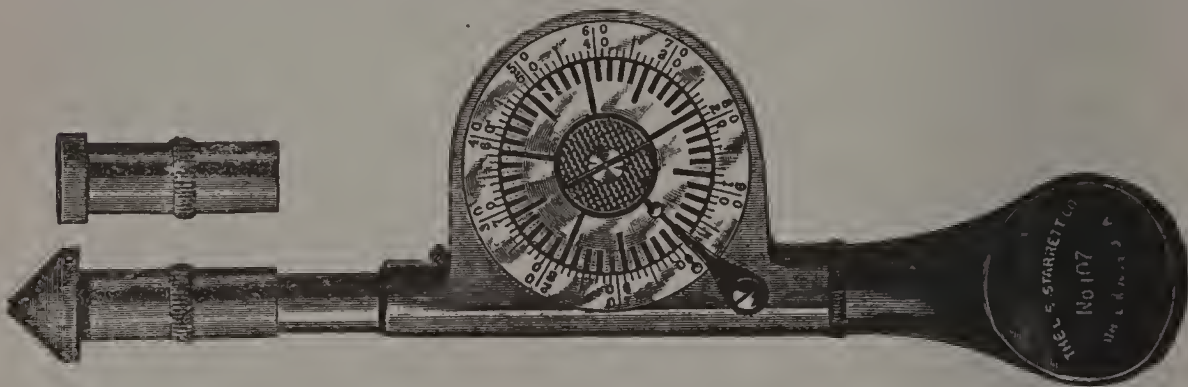


Fig. 119.

it, and the dial is frictionally carried along by the large plate one line, thus showing that one hundred revolutions of the spindle have been made. The instrument has a hard rubber handle, making a safe insulator when used on electrical machinery. It is provided with rubber tips for both pointed and hollow centers.

Fig. 120.

Fig. 120 is an attachment to be used in connection with a speed indicator of the form shown in Fig. 119, and speed is designed to show the number of lineal feet per minute the periphery of a shaft or pulley is running and thus enable a workman to know if the speed is too fast, or is too slow to get the most work the tool will stand For instance, the speed of a cone pulley being turned needs to be changed at every step. Heretofore it has been all guess work as to the number of feet per minute the periphery of the work is traveling. It may be so fast as to heat and spoil the tool, or it may not be nearly fast enough to perform what should be done. The same is true when shifting the tool from the hub to the rim of a pulley. The rubber-banded indicator wheel may be instantly slipped on the spindle of the speed indicator, and when held against the periphery of a shaft or pulley a half minute or a minute, by dividing the figures showing the revolutions on the dial of the indicator by 2, the number of feet the surface of the thing is traveling is obtained, as each revolution of the indicator wheel shows six inches. Twice around is therefore equal to one foot.

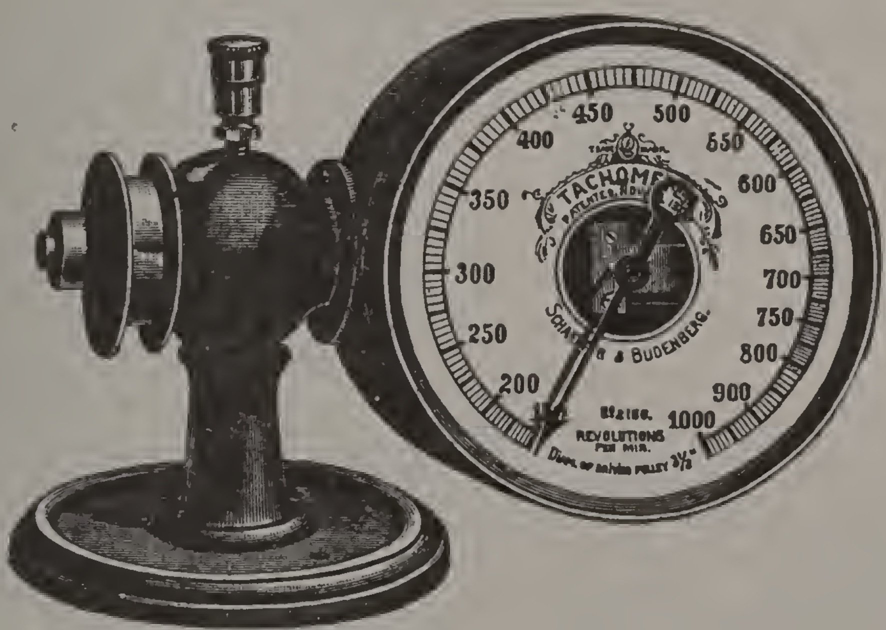


Fig. 121.

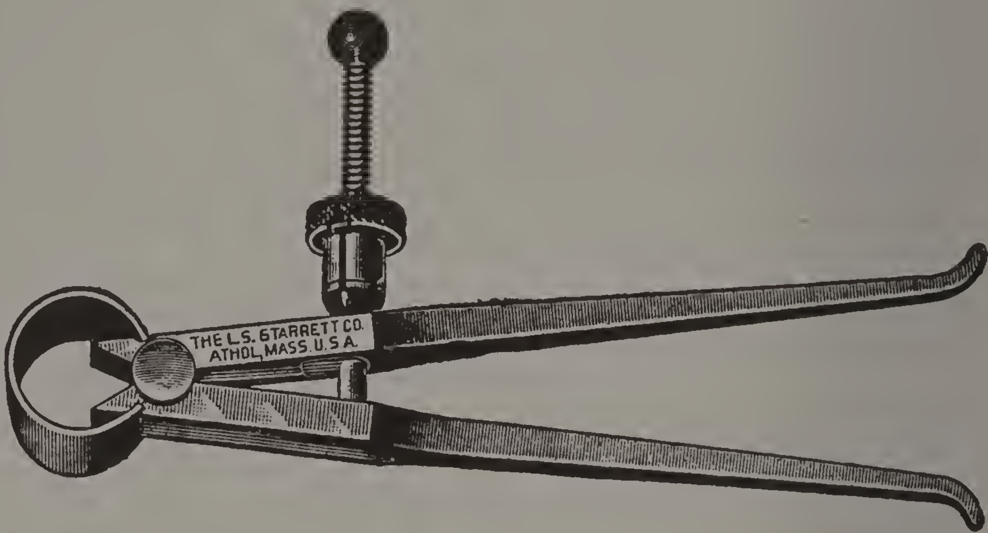
A tachometer or automatic speed indicator is shown in Fig. 121. This device indicates the speed of a shaft or any rotating body in revolutions per minute, without the aid of a watch. It will also automatically indicate any variation or fluctuation in the speed of the machine being tested.

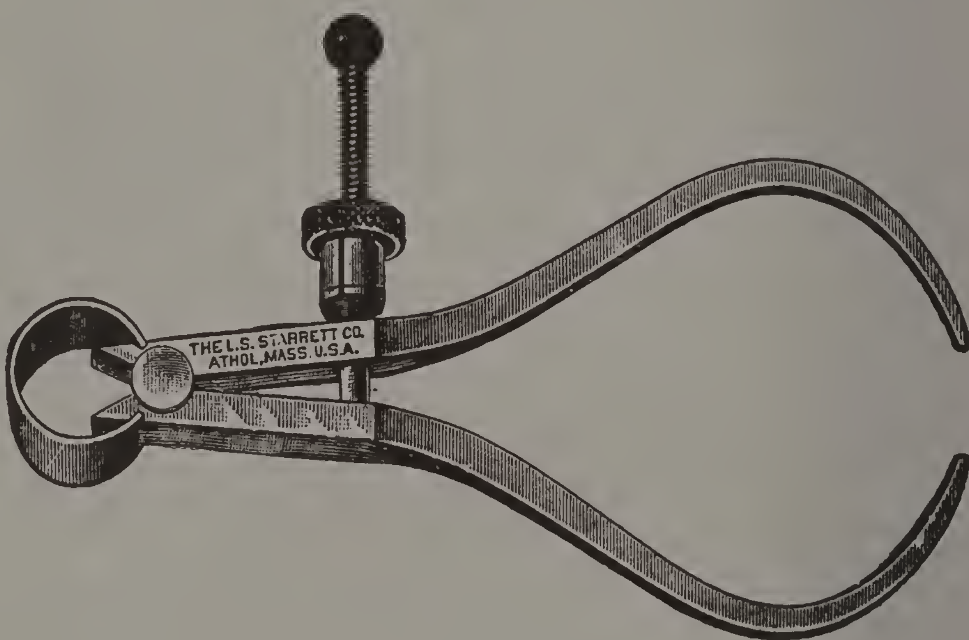
These instruments have been designed for the purpose of ascertaining at a glance the number of revolutions made by rotating shafts. Their construction is based upon centrifugal force, and they consist of a case in which are mounted a pendulum ring, in connection with a fixed shaft, a sliding rod and an indicating movement.

The apparatus is very sensitive and will indicate the slightest deviation in speed.

Tachometers have been applied, with great success, to electric light engines, flour and cotton mills, and can be used to advantage on all machinery of which it is essential to know at all times, the exact speed at which it is moving.

MACHINISTS' TOOLS


THE L.S. STARRETT CO.
ATHOL, MASS. U.S.A.


THE L.S. STARRETT CO.
ATHOL, MASS. U.S.A.

A good workman will always have a good kit of tools, in which he will take pride. As a man is known by the company he keeps, so will a machinist be judged by the number and quality of the tools in his kit. A machinist who has a complete kit of tools, will not only get a job more readily but is liable to hold it longer than a mechanic who carries his outfit of tools in his pockets.

In some large shops the workmen are furnished with a great many of the tools they use, on account of the special character of the work in hand, but in small or jobbing shops the machinist who has the best and largest kit of tools usually gets the best jobs. The tools illustrated herewith, are not shown as being a complete outfit, but are of sufficient variety to enable a mechanic to form some idea as to the class of tools necessary for general and even for some kinds of special work.

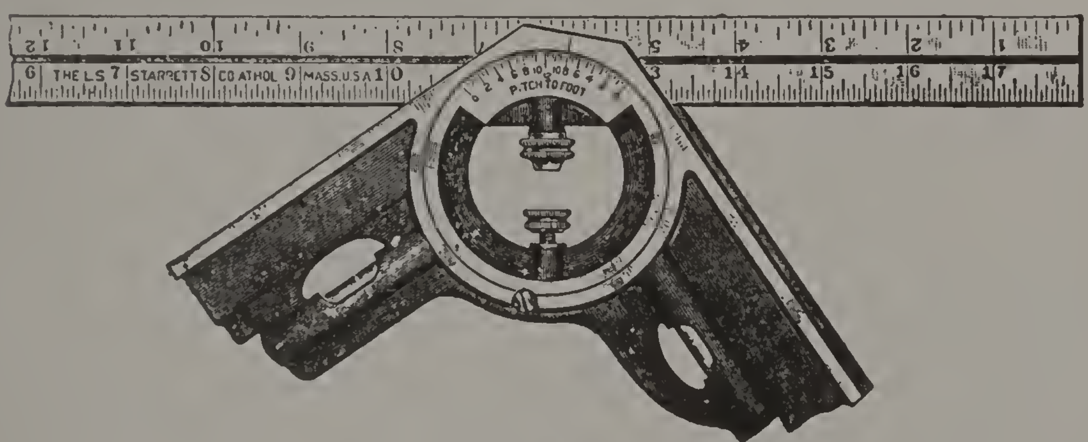


Fig. 122.

Bevel Protractor. The blade of the protractor shown in Fig. 122, closes in the stock either way against a stop, making a perfect square, plumb, and level. The turret is graduated on both sides, one in degrees, the other to show pitch to the foot, so that the blade may be set by the graduation for laying off angles to any degree or any pitch, and the opposite branch of the stock will be right to lay out the complementary angle without mental calculation or error, for valley roofs, bridge work, stair gauges, etc. The levels are so arranged that work can be leveled up to any degree or pitch underneath or on top of a roof, rafter, stair stringer, etc.

As a square or protractor with the sliding blade it can be used in places where a fixed blade could not and is a substitute for a kit of squares from the shortest to the full length of blade, making a depth gauge for squaring in mortises and transferring measurements. It may be used in place of the carpenter's old time steel square with the advantage of being packed in a chest without taking up so much room.

Without the blade the stock may be used in contracted places as a 6-inch level and plumb, while with an 18 or 24-inch blade, a level and plumb of corresponding length is obtained.

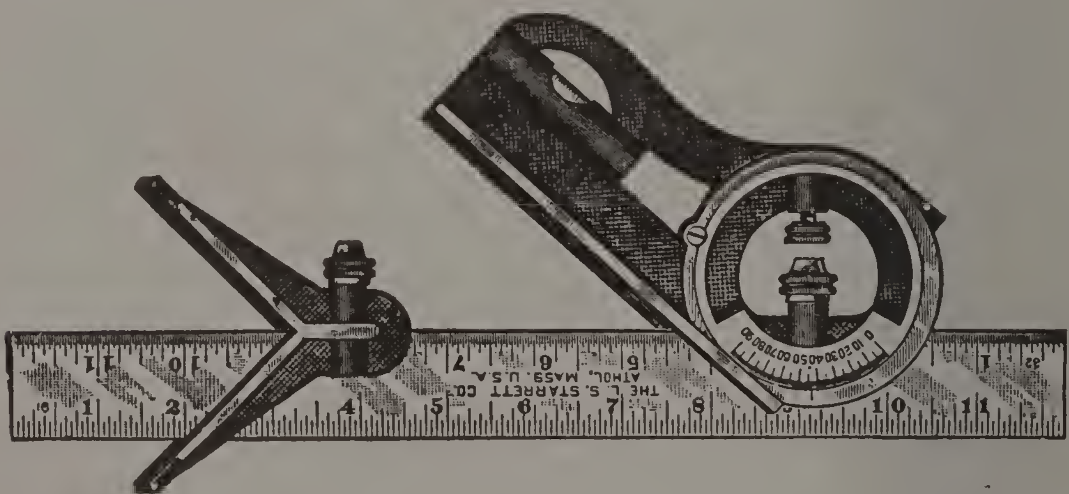


Fig. 123.

Combination Bevel Protractor. Fig. 123 represents an inclinometer, try square, and bevel protractor combined.

It is compact, convenient, and a complete substitute for several tools.

It consists of a stock and disc, both slotted to receive the blade, which folds in the stock. The blade attached to the graduated rotary disc may be secured at any angle from 0 to 90 degrees, and by loosening the clamp screw it may be shortened or extended full length, or removed for a straight edge.

The working face of the stock, extending both sides of the blade, admits of its being reversed, so that the same angle may be laid off in opposite directions without changing the angle in the tool, thus requiring but one-quarter of a graduated circle to obtain all angles both ways.

At 90 degrees, the blade brings up against a casehardened screw, accurately adjusted, thus forming a try square. By holding the blade perpendicular, a plumb. By folding the tool, a level the full length of the blade.

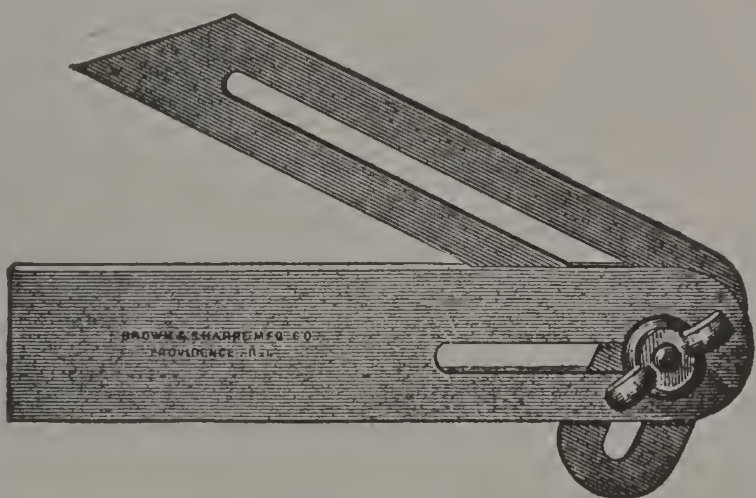


Fig. 124.

Bevel. The advantages of the form of bevel, shown in Fig. 124, over other tools of this kind, consist in its having not only the blade slotted but the stock as well, thus admitting adjustments that cannot be obtained with an ordinary bevel. The clamping screw head is let into a rabbet, flush with the surface of the stock, which lies flat on the work.

Spring Calipers. The calipers shown in Fig. 125 may be used with either plain or spring nut as shown. The view at the right in the cut shows a new inside transfer caliper with either a spring or solid nut. The bow is stiff, making the caliper reliable. After calipering the inside of a chambered cavity by springing in the legs they may be withdrawn, and as they spring back they will show the exact size of of the opening calipered.

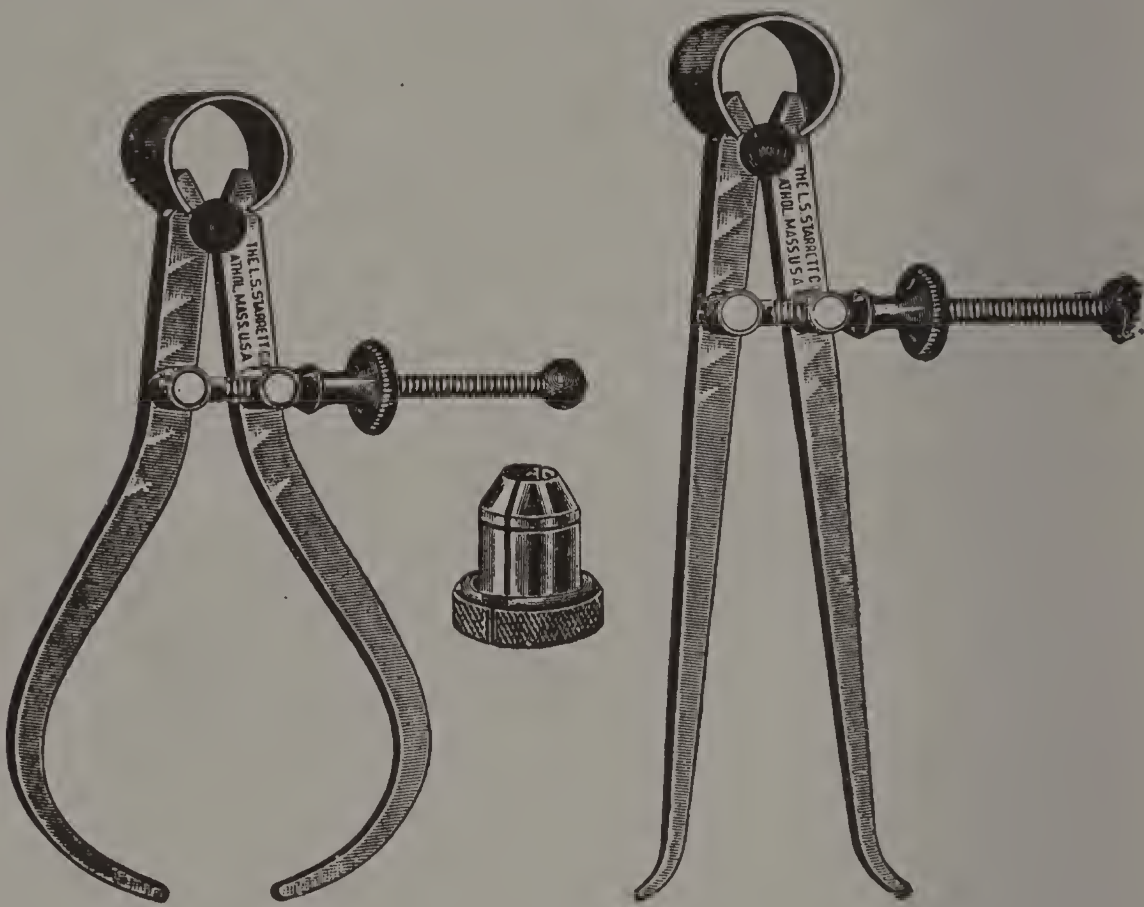


Fig. 125.

Screw Thread Caliperes. Figures 126 and 127 show views of both outside and inside thread calipers with solid adjusting nuts.

Keyhole Caliper. What is known as a keyhole caliper is illustrated in Fig. 128. This caliper may be put to a variety of uses and is an extremely handy tool. If the straight leg be ground off to a point it makes an excellent Hermaphrodite caliper.

Firm Joint Caliper. The improvement in the calipers shown in Fig. 129 consists in the construction of the joint,

Fig. 126.

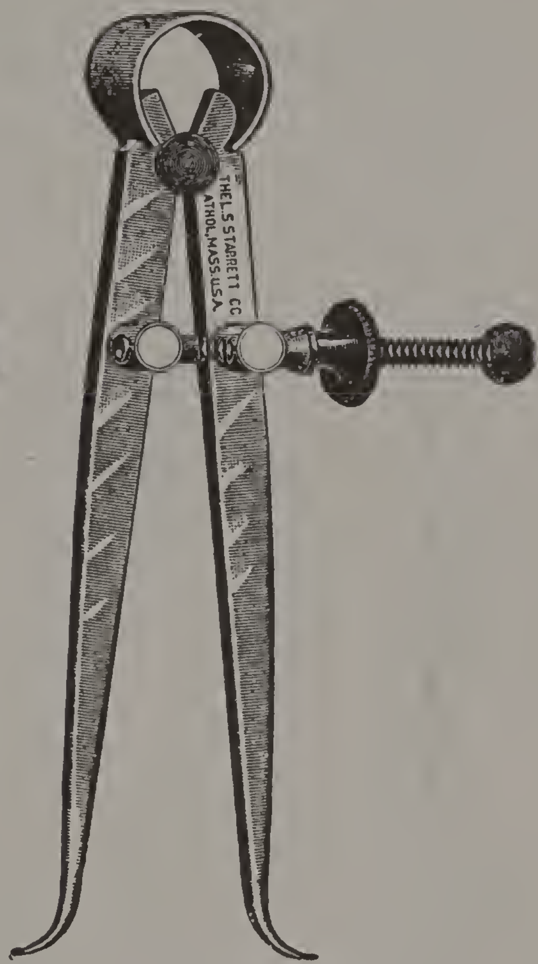


Fig. 127.

which is so made as to be drawn together by means of a screw. The main stud is squared and fitted to one leg, thus preventing the stud from turning when loosening and tightening, and insuring a smooth and uniform friction, of more or less tension to suit the user.

Adjustable Firm Joint Calipers. The calipers shown in Fig. 130 can be instantly adjusted to their full extent, and as quickly locked firm in the joint, and yet provided with a sensitive adjustment. The improvement consists, first, in a socket joint made tapering, and locked or released by a partial turn of the knurled disc drawing it together. A spring washer under the disc maintains an easy friction in the joint when unlocked.

In the under side of the short arm is a slot containing a stiff spring. Riveted into the middle leg and projecting through an opening in the arm, is a threaded stud on which is a knurled nut having a beveled hub, bearing against a cone in the arm, the action of the spring holding them together turns the nut, presses them apart and adjusts the leg when the point is locked. As the spring takes up all backlash the legs are consequently firm.

Fig. 128.

Caliper Rule. A caliper rule or scale is shown in Fig. 131. It may be set to any desired measurement and locked in position by the button shown in the drawing.

Caliper Square. The tool shown in Fig. 132 has a double function—being graduated to read the circumference as well as the diameter of the article measured, the relation of circumference to diameter being shown by the graduations on upper corners of the rule. The rule is graduated in 32ds of an inch standard and 16ths of an inch circumference measure. All corners of the tool are rounded smooth to make it fit to carry in the pocket and agreeable to handle. The circumference measure will assist in calculating how many feet a minute the cutting tool in a lathe is doing on any diameter within the scope of the rule and so help to determine whether the tools should have a faster or slower speed.

Rule. Multiply the circumference shown by the gauge by the speed the lathe runs per minute and the result will

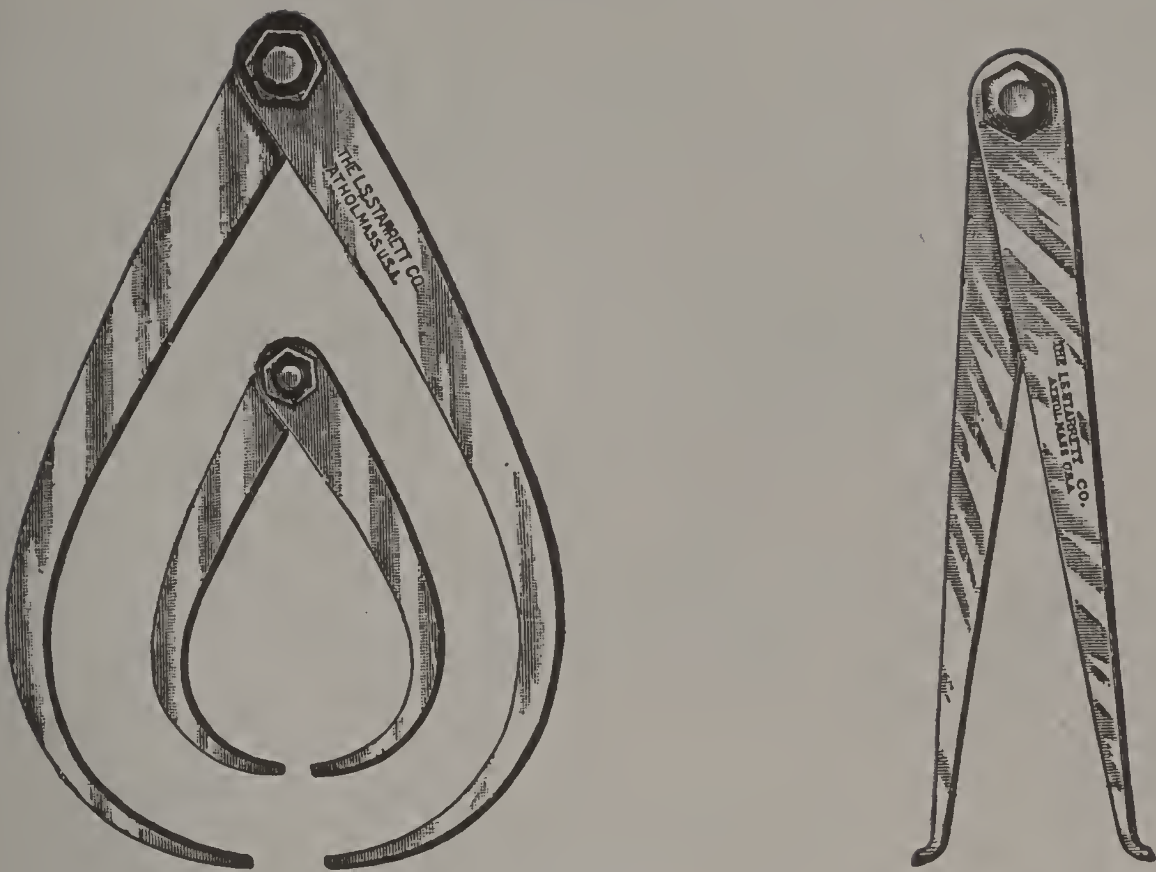


Fig. 129.

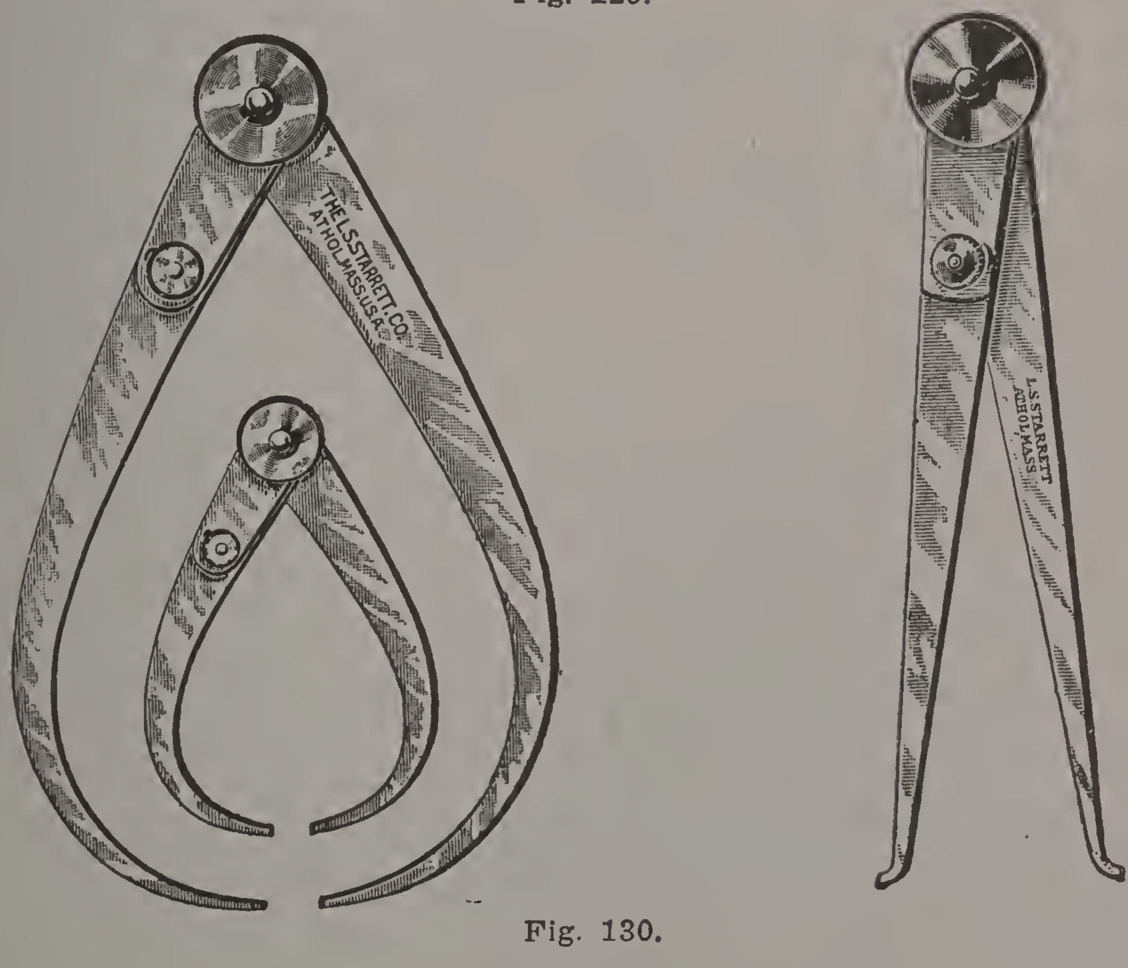


Fig. 130.

show the number of inches per minute the circumference is running and the tool consequently cutting.

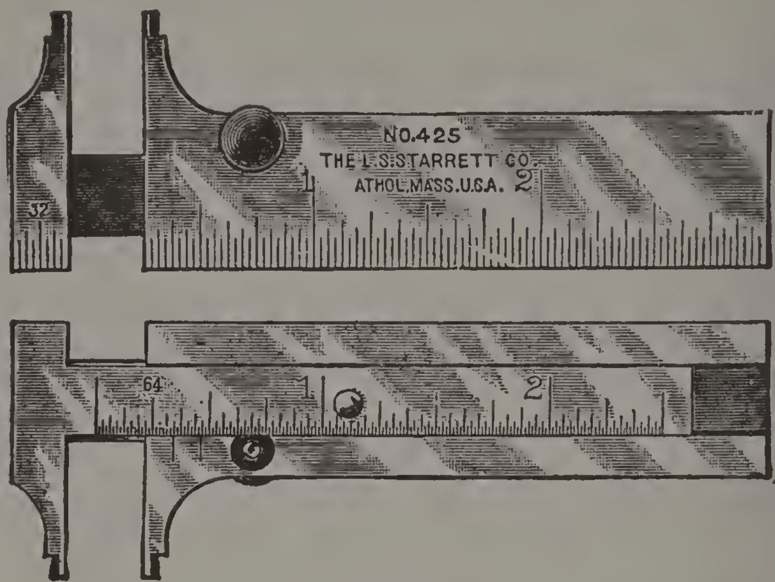


Fig. 131.

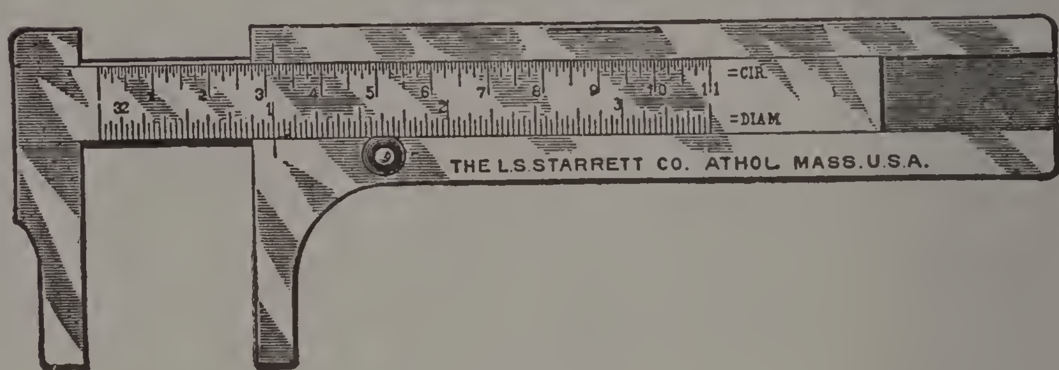


Fig. 132.

Center Punch. The center punch shown in Fig. 133 is entirely new in design and combines features that make it much more convenient for laying out work to be machined or drilled than the ordinary center punch and hammer.

The tool is of steel and is entirely self-contained, the striking mechanism being enclosed in the knurled handle, which is of such a size and form as to be held conveniently in the hand.

A downward pressure releases the striking block and makes the impression. The punch marks are of uniform depth and, therefore, easily and accurately followed.

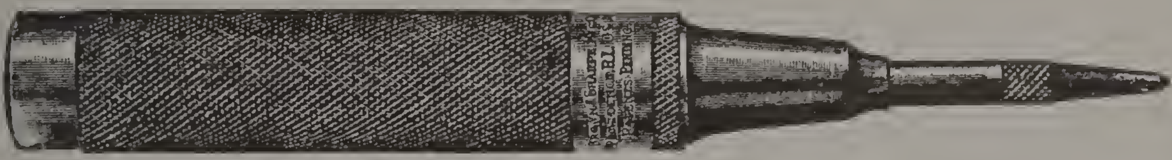


Fig. 133.

The points can be taken out for grinding and are easily replaced if broken.

Combination Square. With the adjustable scale the square shown in Fig. 134 forms one of the most con-

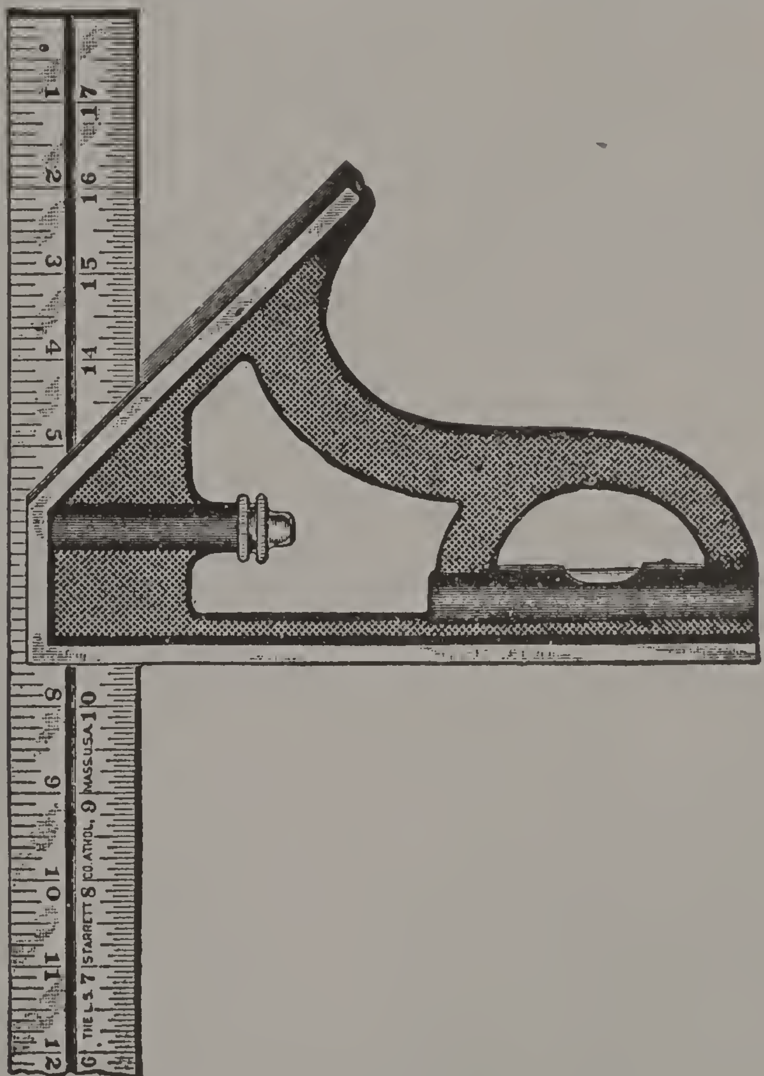


Fig. 134.

venient and useful tools for mechanics' use. It is also a substitute for a set of common try squares, and is one of the best gauges made for transferring exact measurements or laying out work. It is convenient for a depth gauge, or to square in a mortise, while with an auxiliary center head it forms a centering square, both inside and outside.

Depth Gauge. The wire in the gauge illustrated in Fig. 135 is held in a groove by a friction spring inside the nut while adjusting, and may be used close to the end, as well as in the middle of the straight edge.

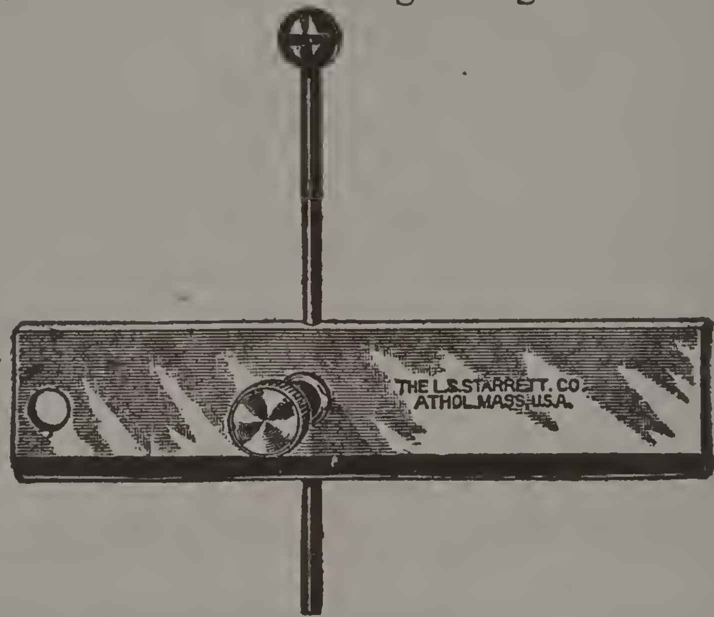


Fig. 135.

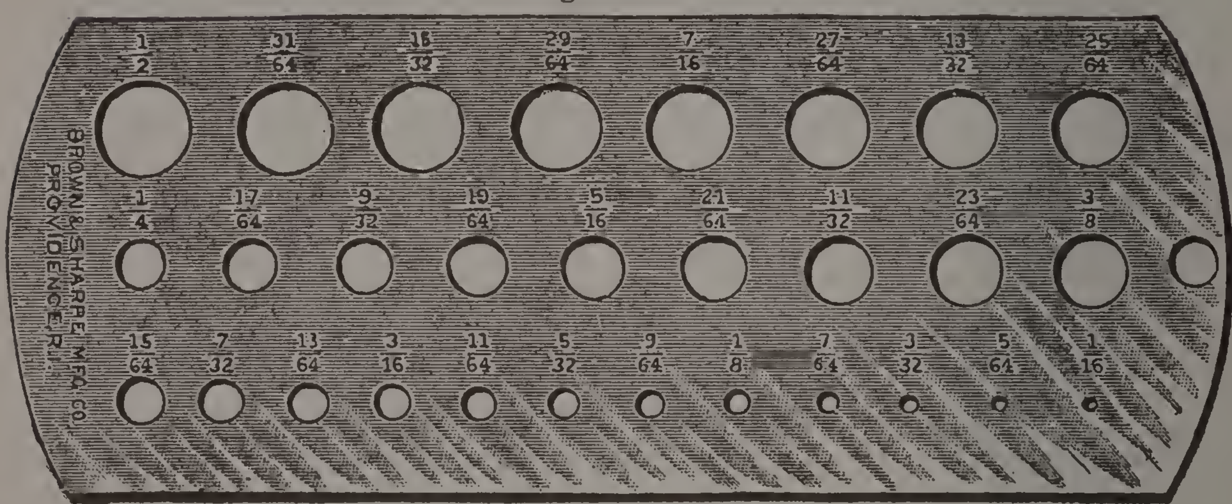


Fig. 136.

By loosening the nut, the gauge may be neatly folded.

Drill and Wire Gauges. A standard drill gauge is shown in Fig. 136 which will measure drills from one-sixteenth to three-eighths of an inch diameter. A standard wire gauge is illustrated in Fig. 137 which has a range from No. 5 to No. 36 wire.

Fig. 137.

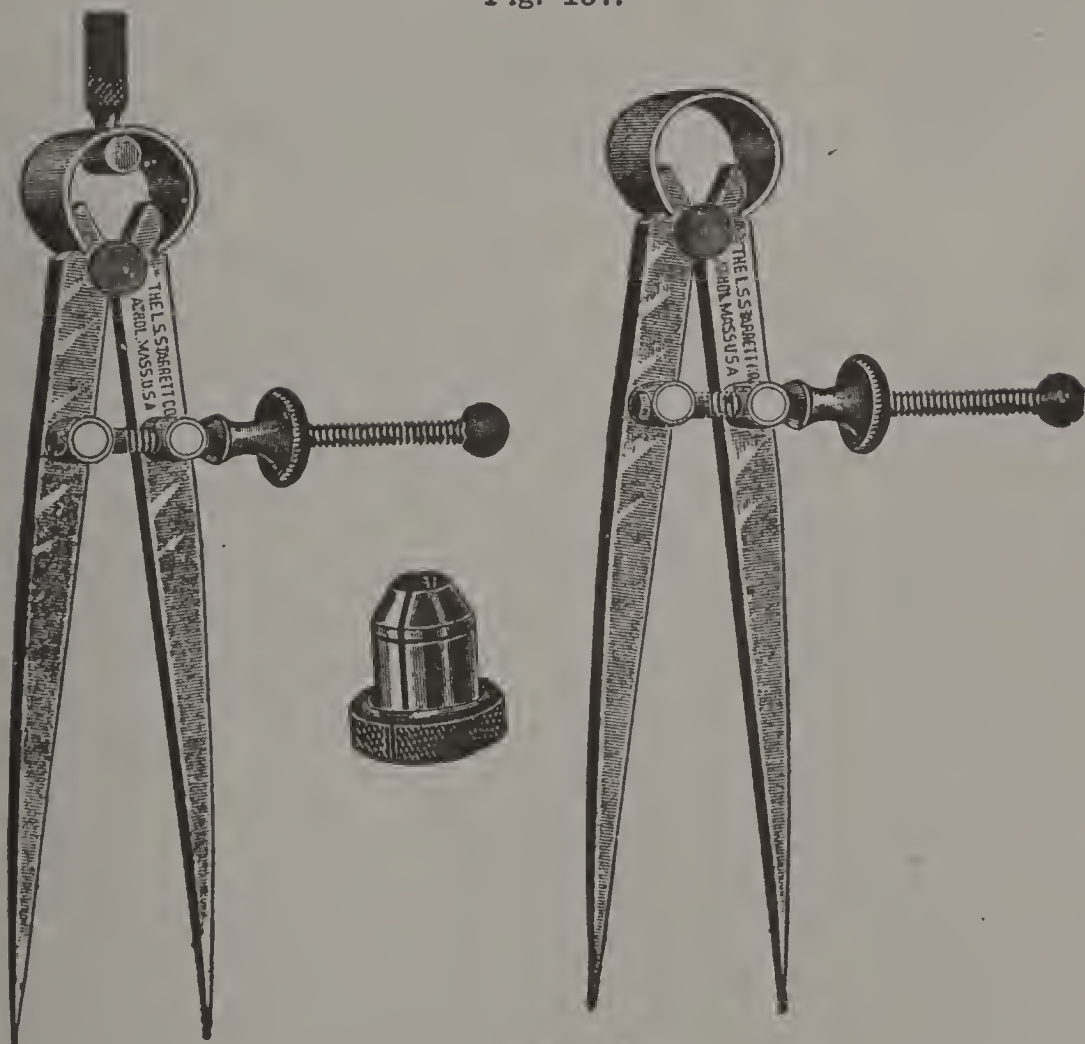


Fig. 138.

Dividers. Two forms of spring dividers are shown in Fig. 138, with solid adjusting nuts. A spring nut as shown in the drawing may be used instead of the solid nuts. One of the spring dividers is fitted with a small handle or twirler.

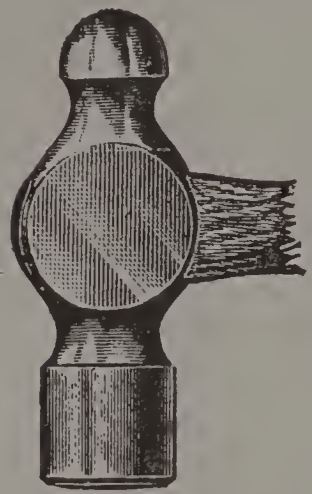


Fig. 139.

Hammers. A machinist's hammer with straight and ball-pens is illustrated in Fig. 139. This is the form of hammer most generaly used by machinists for all round work.

Key Seat Rule. The device shown in Fig. 140 is designed to transform any common steel scale into a key set rule.

They can be put on or off almost instantly, and are a complete substitute for a more costly tool.

They may be used with a combination square blade, or with any straight rule, with accurate results.

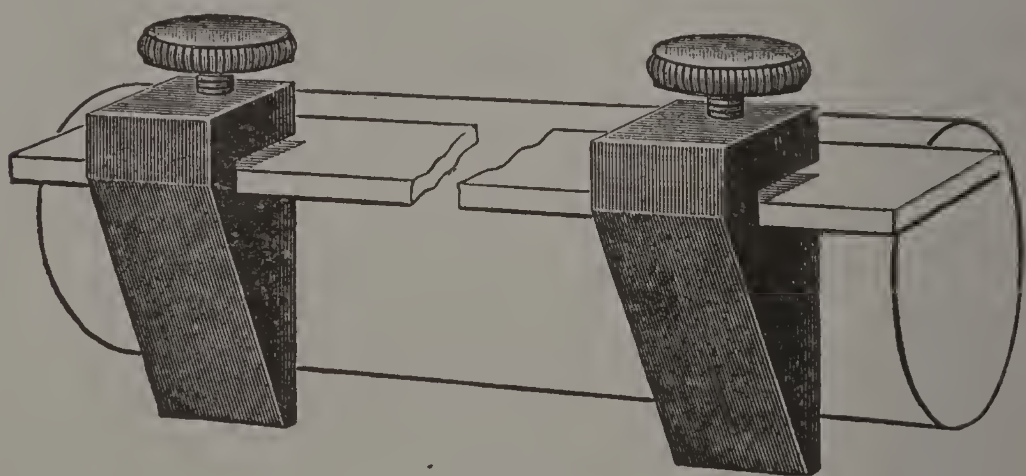


Fig. 140.

Hand Vises. Two forms of hand vises are shown in Fig. 141. These are very useful tools for holding small work. The vise shown in the upper view is fitted with a handle, while the one in the lower view is intended to be held in a bench vise.

Levels. The level shown in Fig. 142 is so constructed that it can be accurately adjusted, and when so adjusted is not liable to get out of truth, the vial being set in tubes having solid ends which are firmly clamped to the base. The outer tube may be turned so as to protect the glass when not in use.

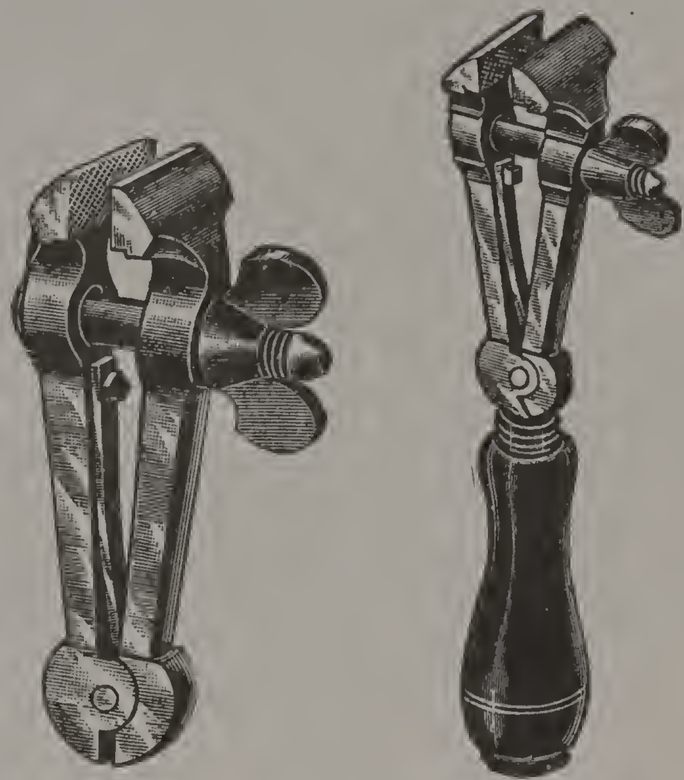


Fig. 141.

In lining up shafting or erecting machinery a level is absolutely indispensible.

Micrometers. A small micrometer reading to thousandths of an inch, as shown in Fig. 143, should be a part of every machinist's kit as its uses are many and varied, more especially on small work.

Pliers. In the cutting-plier illustrated in Fig. 144, the jaws are detachable, so that they can be removed, ground, and adjusted when they have become worn. Each jaw can

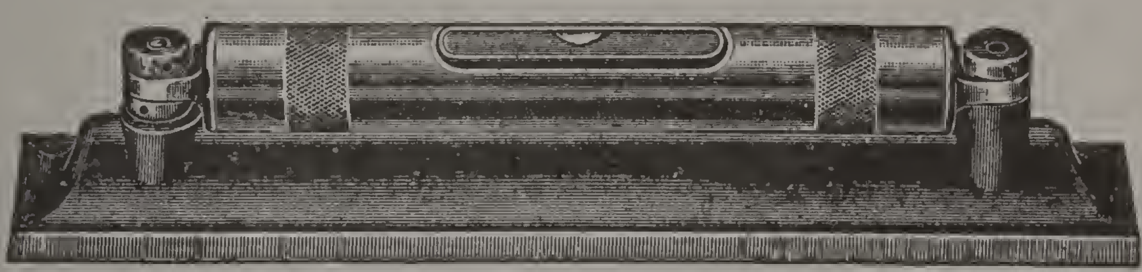


Fig. 142.

be ground away to the extent of one-quarter of an inch, remaining as good as new for practical use, and when used up new jaws can be procured.

A screw through the jaw engages with a spline in the

Fig. 143.

frame and draws the jaw firmly down to the toothed seat, holding it securely.

Another feature in this cutting-plier is a flat spring below the cutting edges and over the joint, forming a yielding seat for the end of the wire to press against while being cut. This obviates the danger of breaking the jaws, as often happens with other styles of pliers which allow the wire to be inserted against a solid surface.

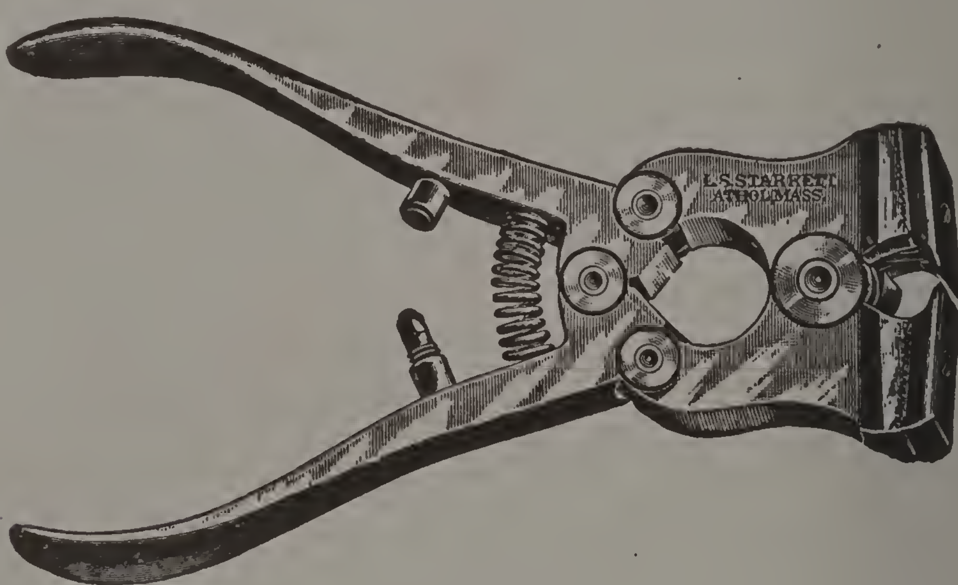


Fig. 144.

A pair of flat pliers or nippers are shown in Fig. 145, which may be put to a great many uses, especially when assembling small work.

Plumb-bob. A plumb-bob such as shown in Fig. 146 will be found to be an invaluable adjunct to a kit of tools. In

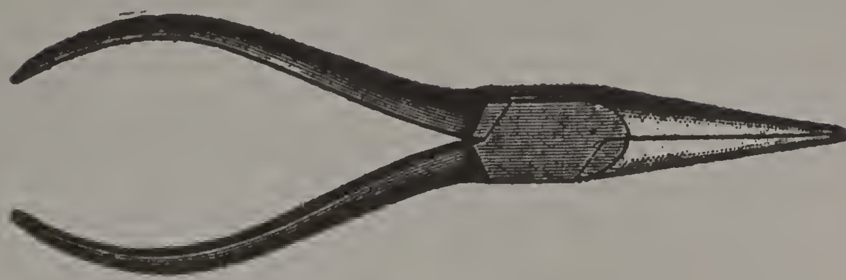


Fig. 145.

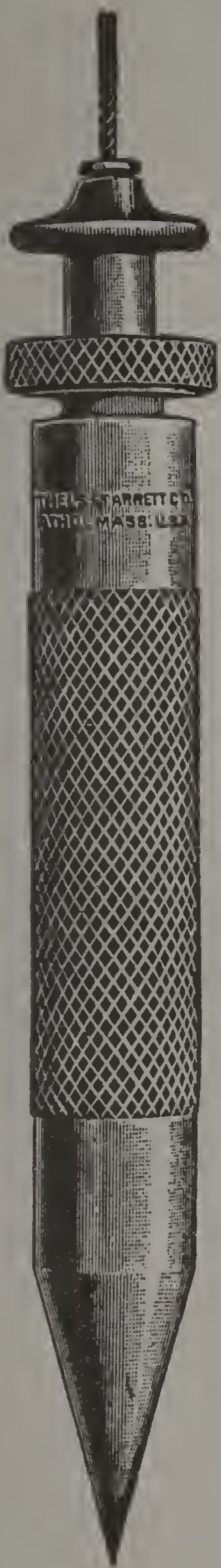


Fig. 146.

lining up shafting from one floor to another and sometimes in erecting machinery its use will be found to be almost indispensable.

Surface Gauge.

The gauge illustrated in Fig. 147 has in addition to the V-shaped groove in the end, a corresponding groove in the bottom adapting the gauge for use in cylinderical work. It is also provided with two gauge pins in the rear end of the base that can be pushed down and used against the edge of the plate or the side of the T slot.

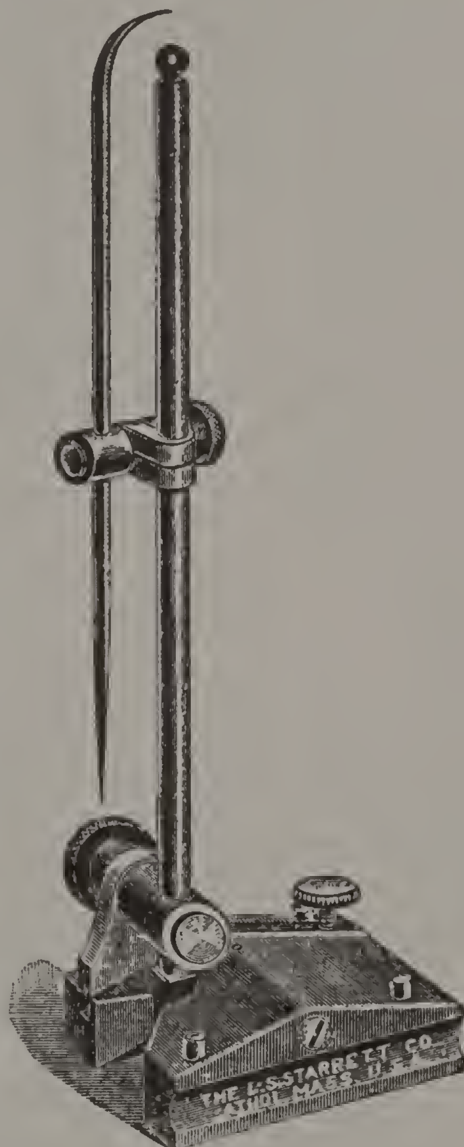


Fig. 147.

The post swivel can be set and rigidly clamped in any position from the vertical to the horizontal, and the scriber used below the base as a depth gauge.

The scriber has a fine adjustment that can be used after the sliding block is set at the approximate height. This device is simple and cannot get out of order. The adjustment is made by means of the large knurled nut, shown in the drawing, which, when turned, revolves the scriber clasp slowly and continuously, and allows the scriber to be set at any position within its range.

Fig. 148.

Screw Drivers. Figure 148 shows a pocket screw driver and brad awl made in one piece, this being telescoped within the handle when not in use. The shape of the handle enables it to be used as an emergency wrench, which is often of the greatest convenience.

It takes the place of a number of tools usually carried in a kit.

Fig. 149.

The screw driver shown in Fig. 149 has a knurled hardwood handle, large enough to fill the hand and give leverage. Its steel shank has a socketed end to which is fitted a set of three screw driver tips of different sizes, adapted for screw heads from very small up to three-eighths of an inch. Either size may be instantly withdrawn and another inserted, thus supplying a full set of screw drivers at a fraction of the cost of others requiring as many handles as drivers. The tips are shaped and tempered so as to give the greatest strength.

Fig. 150.

A plain wood handle screw driver is shown in Fig. 150. This is a very useful bench tool.

Screw-Pitch Gauges. The gauge shown in Fig. 151 has the following pitches: 4, 4½, 5, 5½, 6, 7, 8, 9, 10, 11, 11½, 12, 13, 14, 15, 16, 18, 20, 22, 24, 26, 27, 28; 30. The

Fig. 151.

teeth are sharp and clean cut, and it can be used inside of a nut as well as on the outside of a screw or bolt. It is also a convenient and reliable tool to use as a 60-degree center gauge and gauge to test the grinding of either an inside or outside threading tool.

Steel Scales or Rules. Figure 152 illustrates a machinist's pocket scale or rule. These are made in different lengths and thickness, and may be had graduated in inches or in millimeters.

Fig. 152.

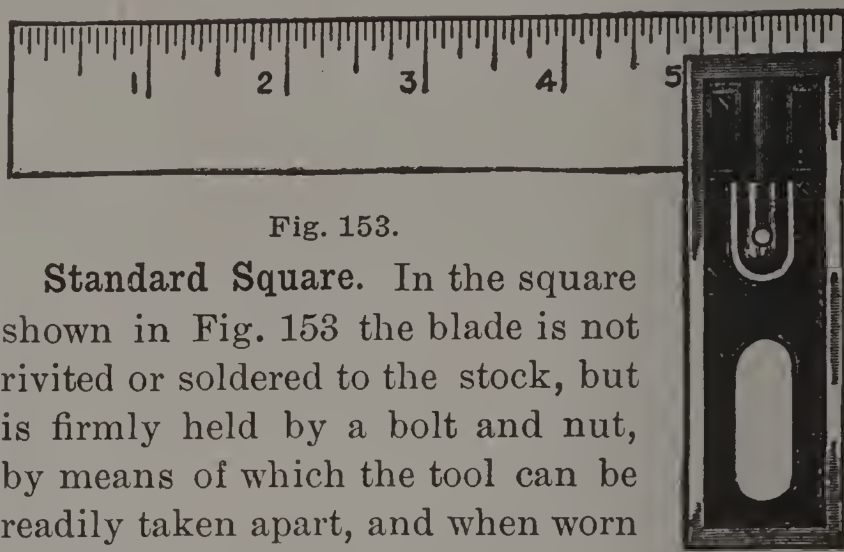


Fig. 153.

Standard Square. In the square shown in Fig. 153 the blade is not rivited or soldered to the stock, but is firmly held by a bolt and nut, by means of which the tool can be readily taken apart, and when worn the blade and stock can be reground or lapped, and put together again as good as new.

Thread-Gauge. The gauge illustrated in Fig. 154 is used for setting screw-cutting tools and testing lathe-centers.

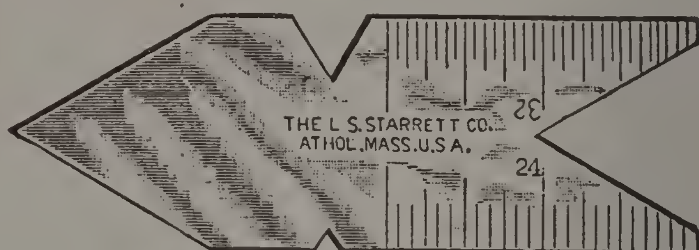


Fig. 154.

Tram-points. The tram-points shown in Fig 155 are made of bronze metal, with forged anc hardened steel points.

Either point can be removed, and the pencil socket accompanying each pair put in its place. The tram-points are adjustable like spring dividers.

Try Square. The square shown in Fig. 156 has concave depressions in each side of the stock, which not only reduce its weight but make it more convenient to hold be-

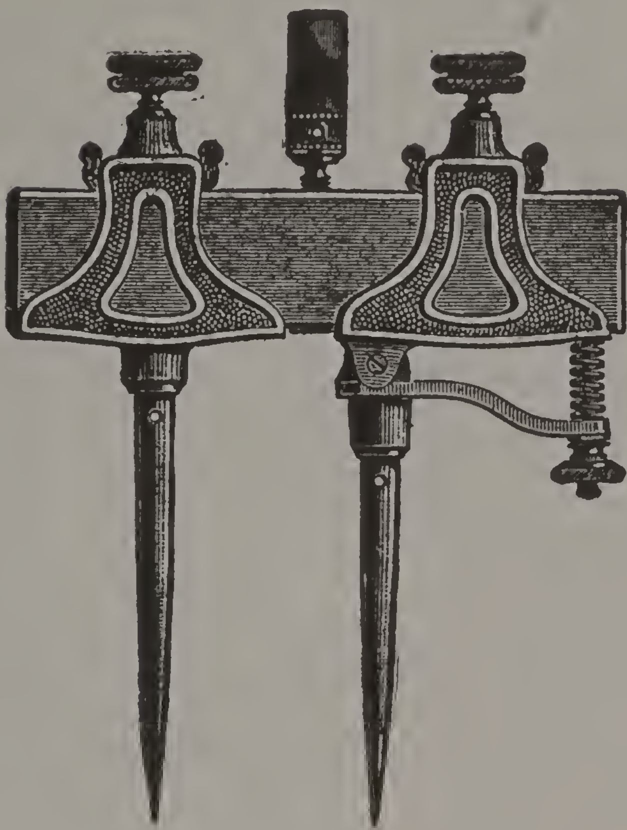


Fig. 155.

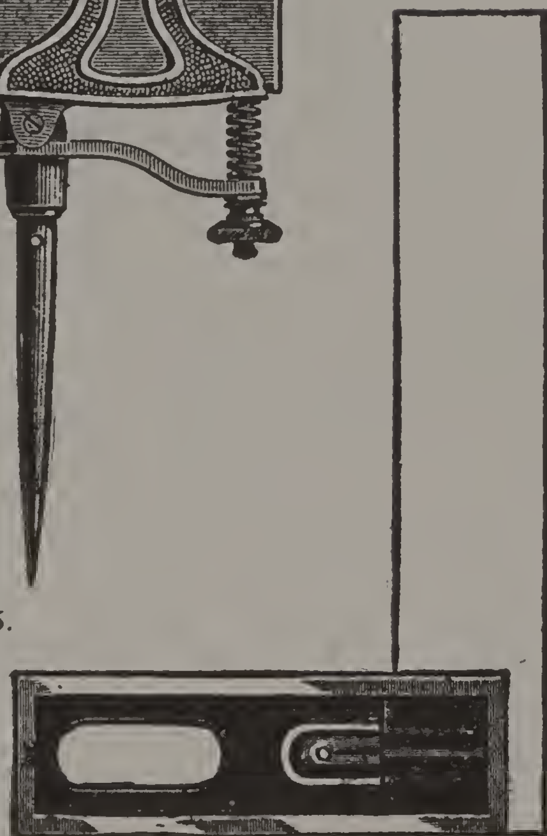


Fig. 156.

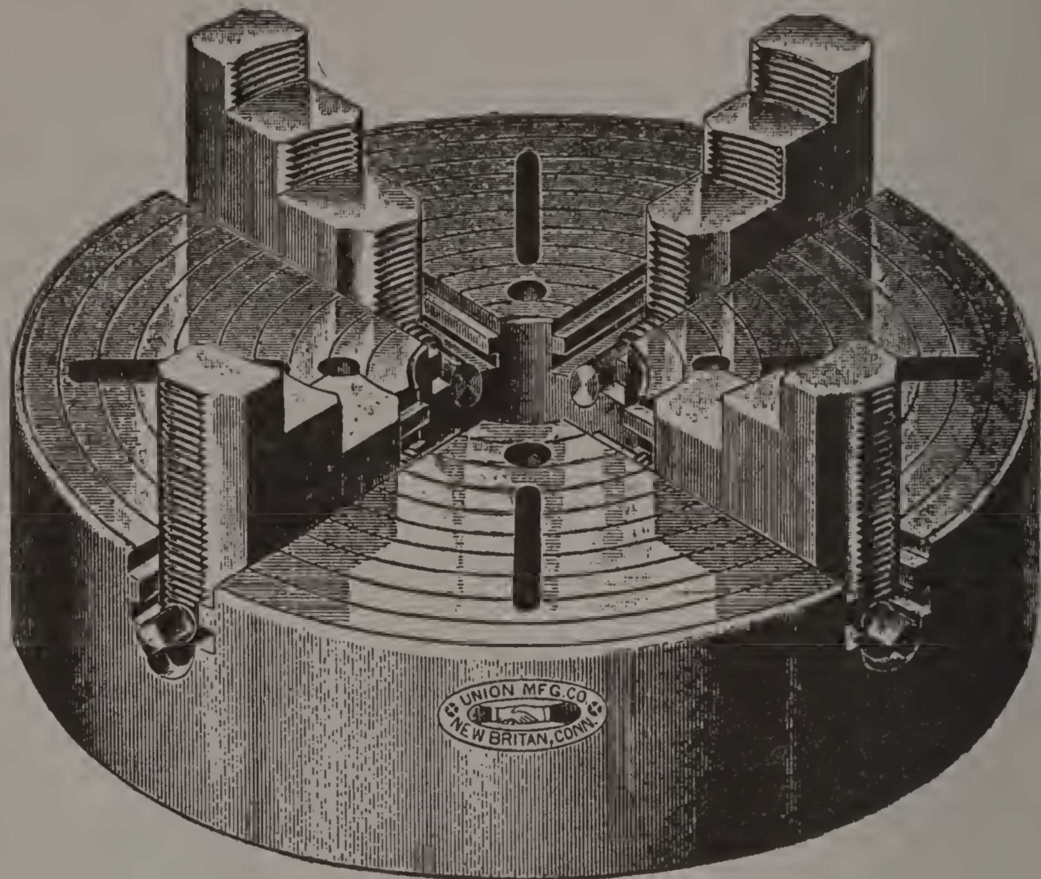
tween the thumb and finger while being used. The stock is casehardened and the blade hardened to a spring temper.

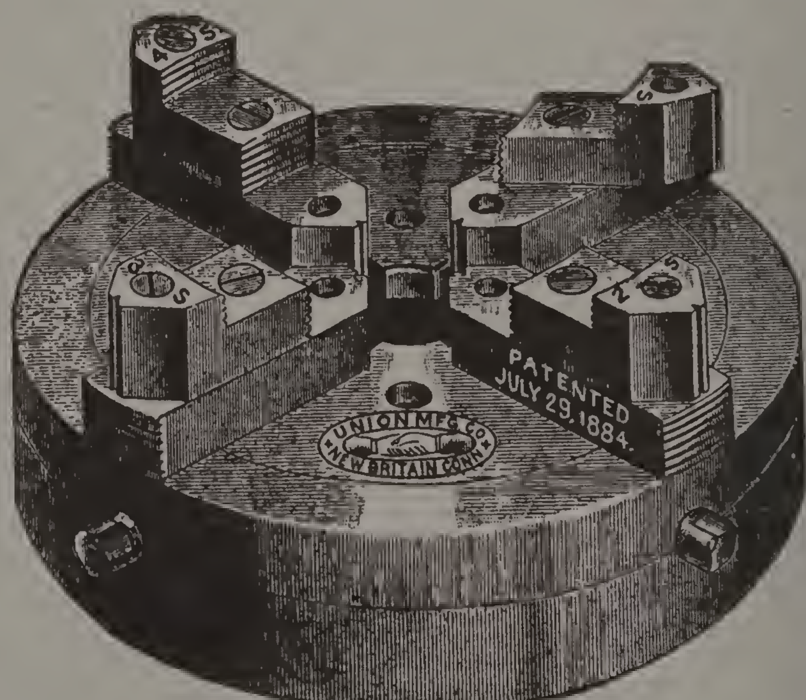
Wrenches. In jobbing shops and on repair work a monkey-wrench is a very necessary tool, but in large factories

Fig. 157.

who manufacture specialties sets of standard spanner wrenches are provided for each workman. A standard type of monkey-wrench is illustrated in Fig. 157.

SHOP TOOLS


UNION MFG. CO.
NEW BRITAN, CONN.


PATENTED
JULY 29, 1884.
UNION MFG. CO.
NEW BRITAIN CONN.

Angular Bit-Stock. The universal angular bit-stock shown in Fig. 158 is to be used in connection with a brace and bit for boring holes in places where the brace and bit alone could not be used. It can be varied in any position

Fig. 158.

from a straight line parallel with the brace chuck to the angle shown in the cut. The ability to vary the angles, either at the commencement or during the operation of boring a hole, is an important feature of this tool.

Arbors. Mandrils or arbors should have their centers so formed as to leave a recess or counterbore about the countersink in their ends, the object being to prevent the blows given to drive the mandril into the work from injuring the centers and thereby causing the work to run out of true.

Belt Clamp. The belt clamp shown in Fig. 159 has corrugated and beveled jaws which insures a strong grip to belting.

The frame is made of Rock Maple, and the screws of the best wrought iron with square head and quick pitch.

These clamps are used for tightening and putting together large belts, and is one of the best clamps made, combining strength, simplicity and convenience. No shop should be without them, as once taking up a belt will frequently save its cost.

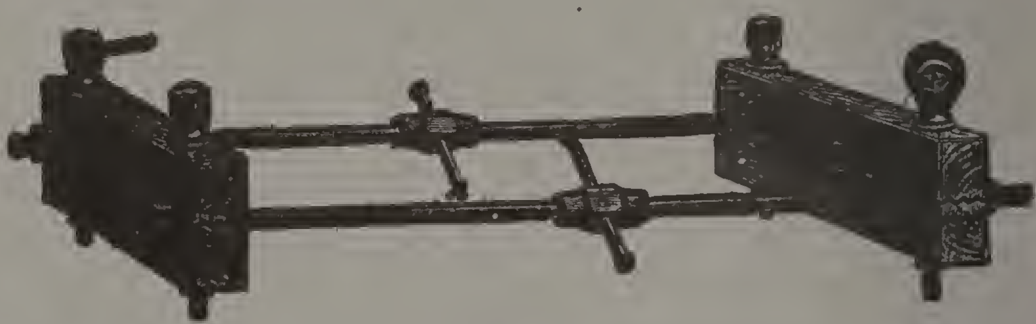


Fig. 159.

All the clamps are made with iron screws. They are rapid working and durable.

Belt and Lace Cutters. These are an indispensable article in the shop. Fig. 160 shows two forms of such tools.

Bench Shears. The shear illustrated in Fig. 161 has the capacity of cutting any length or width, and 3-16 inch in thickness. A prominent feature is in the adjustment of the shear arm by means of an eccentric at the back. With this arrangement a greater or less degree of angle can be quickly given to the blades, so that in cutting thin stock it will not curl the metal. The length of the blades used are three inches. It has a gauge on the table for cutting angles, and one on the arm for gauging the width to be cut, with the standard divisions marked on the bar. Also a clamp for holding down the metal.

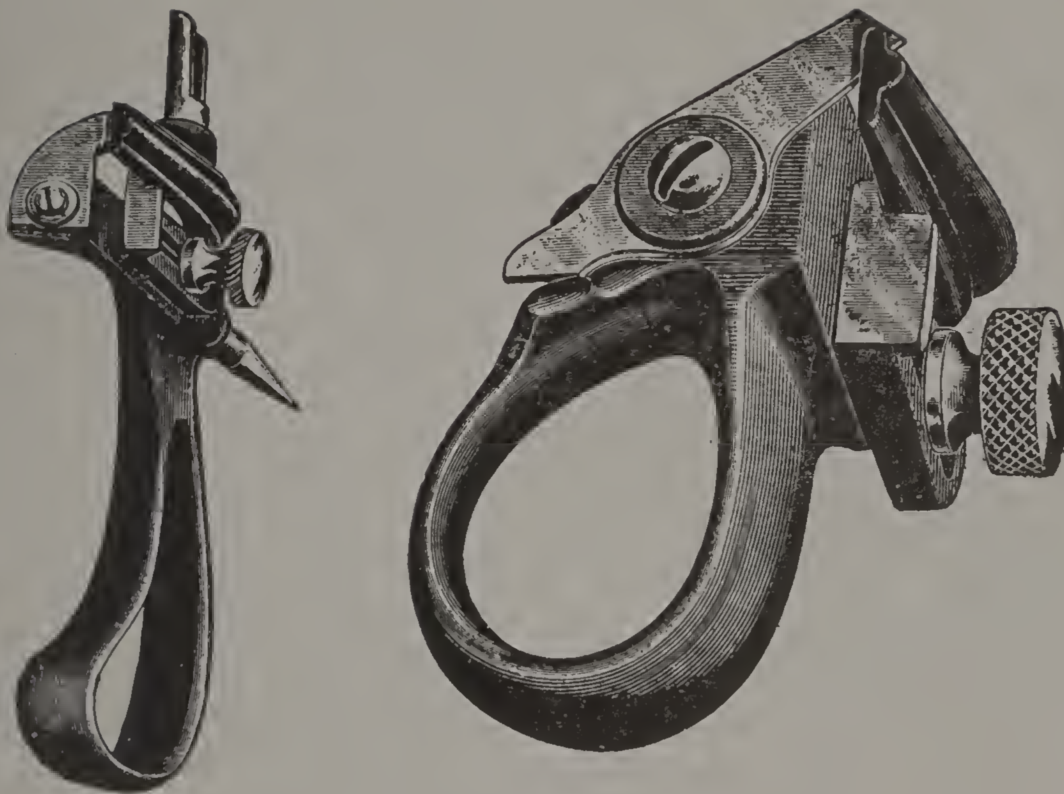


Fig. 160.

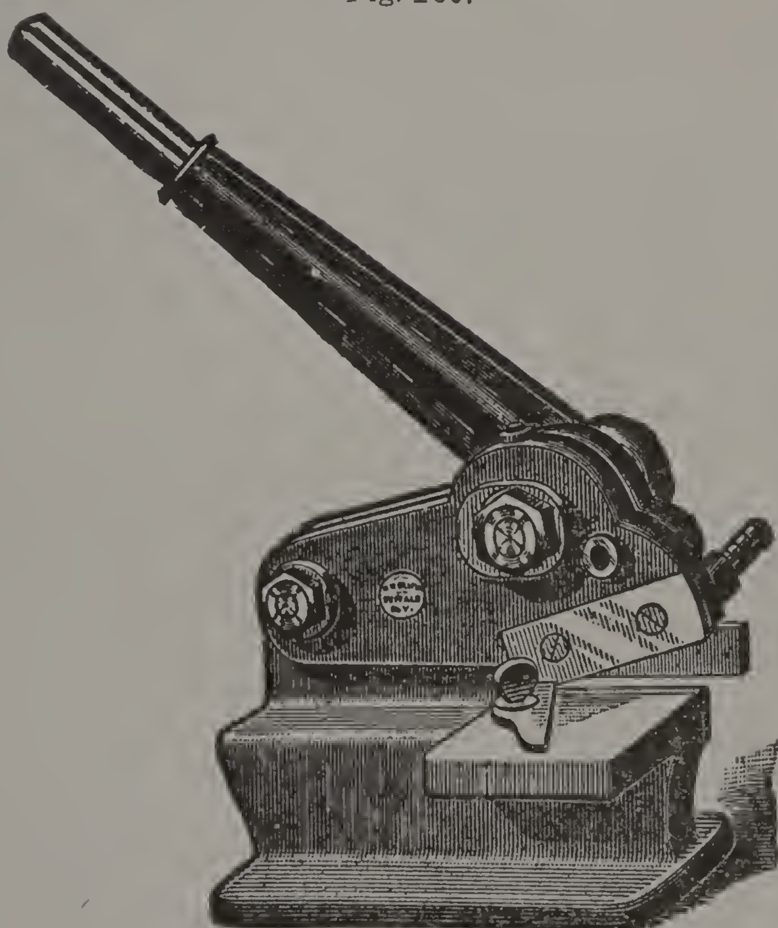


Fig. 161.

Blacksmith's Drill. This machine, shown in Fig. 162, is designed for carriage makers and heavier blacksmith work. It is built heavy and has a large capacity.

Fig. 162.

It will drill a 1½-inch hole to the center of a 16-inch circle. 4½ inches deep.

The greatest distance from the spindle to the table is 22 inches.

The drill-socket screws on to the spindle, and takes a drill with 41-64 inch round shank. It can be removed and a Universal Chuck put on in its place.

The drill has an automatic feed, a swing-table 11 inches in diameter, and grinding attachment.

The drill has two speeds which are obtained without changing the crank. This gives high speed on the balance wheel all the time. The change is made in an instant by turning the small lever to the right or left.

Blacksmith's Forge. The forge illustrated in Fig. 163 is an ingenious invention as regards the three-piece construction for producing a regular and continuous positive blast with great ease. The forge is constructed from structural steel, making it strong, stiff and light. The machinery is all inclosed in an oil-tight casing, and entirely noiseless. It has no belts or friction. It is fitted throughout with ball bearings. It can be taken apart for trans-

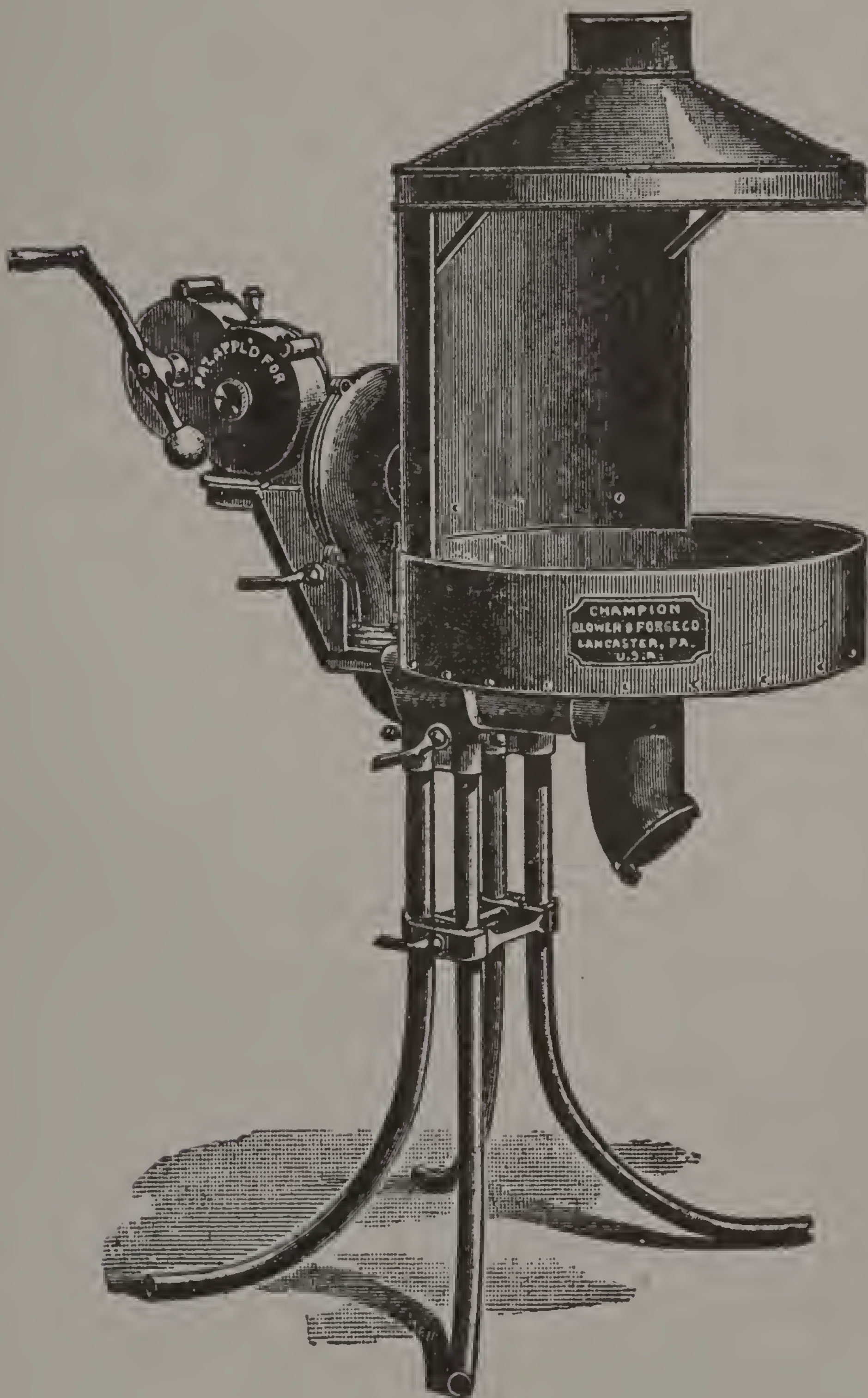


Fig. 163.

portation and again set up for use in several moments. The forge is adapted for government use, elevated and steam railroads, bridge and tank builders, miners and prospectors, boiler repairers, or any portable work requiring compactness and lightness, with a strong blast. If necessary, it will produce a blast to weld 3½ to 4-inch iron in ten minutes. The crank to produce the blast can be turned either way.

Blacksmith's Tools. The effect of blows delivered upon forged work by the blacksmith's tools is not only greater upon the exterior than upon the interior of the metal, but is greatest upon that part of the forging which receives the most working, and upon that part which is at the lowest temperature during the finishing process: because the blows delivered during the finishing process are lighter than those during the earlier stages of the forging, and hence their effects do not penetrate so deeply into the body of the metal. Then again, on that part of the metal which is coolest, the effects of the light hammering do not penetrate so deeply; and from these combined causes, the

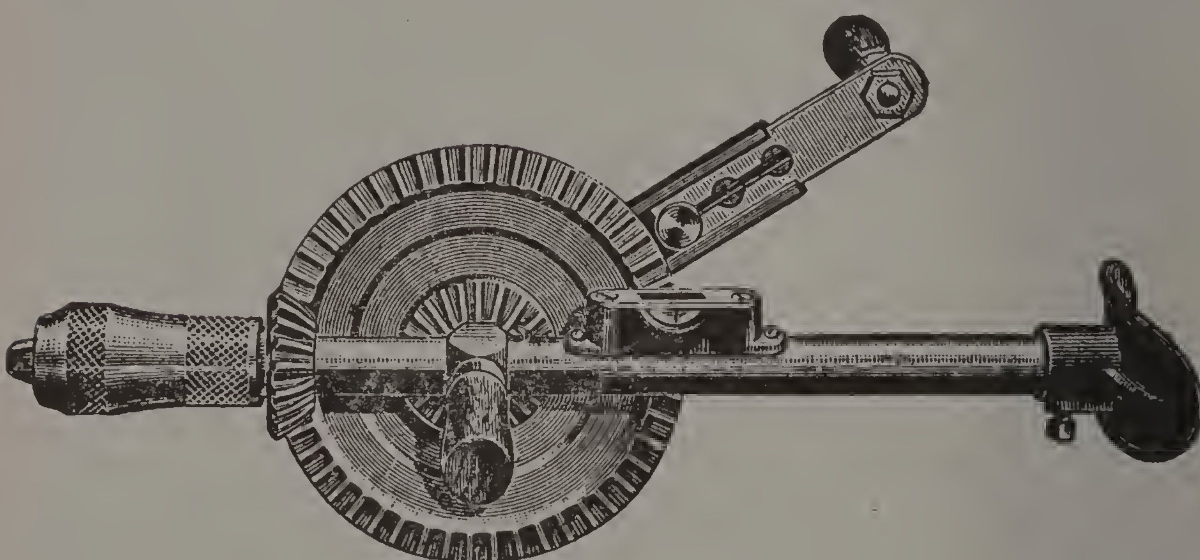


Fig. 164.

tension is not equally distributed over the whole surface of the forging, and hence its removal, by cutting away the outer surface of any one part, and thus releasing the tension of that part, alters the form of the whole body, which does not, therefore, assume its normal shape until the outer skin of its whole surface has been removed.

Breast Drills. The drill shown in Fig. 164 has ball bearings, nickel plated stock and chuck, cocobola handles, extension crank, alligator jaws, which hold both round and square shanks, and a level attachment to enable the op-

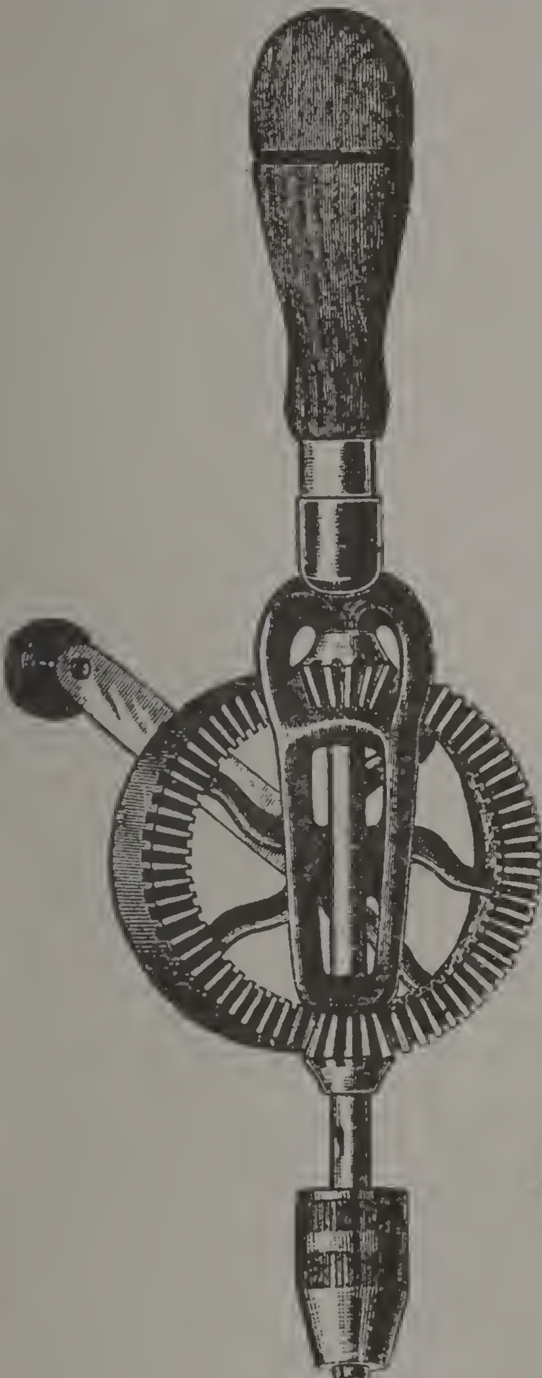


Fig. 165.

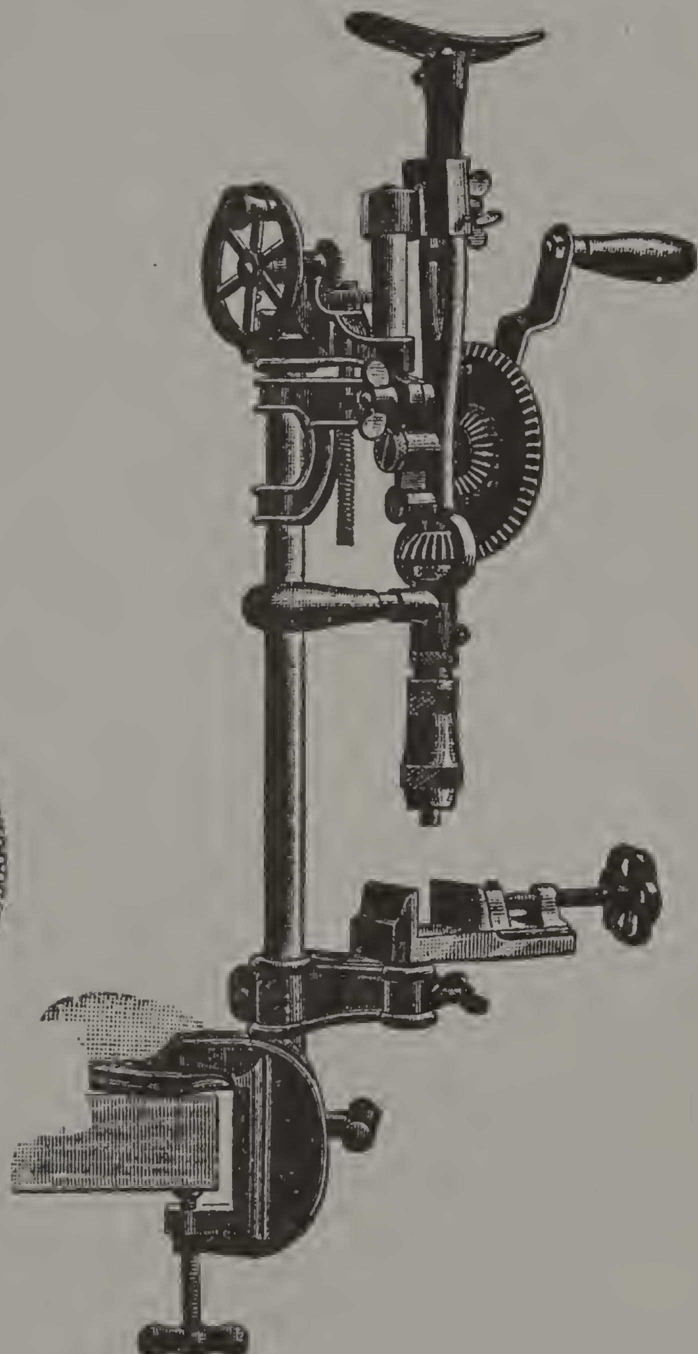


Fig. 166.

erator to see when the tool is held true. The gears are cut and are changeable from 1 to 1 to 3 to 1.

The breast drill illustrated in Fig. 165 has all the advantages of the one shown in Fig. 166, and in addition has a wide rimmed gear to be grasped between the thumb and fingers when the drill is used for delicate work. In this manner it can be run without liability of breaking the drill points. It is double-geared and 11½ inches in length.

Breast Drill Attachment. The drill shown in Fig. 166 is designed to apply to a breast drill, so as to convert it into a drill press or bench drill. The illustration shows a breast drill thus converted.

The bench clamp, vise rest and frame are all clamped to the main standard, and can be moved up and down, or swung to the right or left, and by means of the thumb screws provided, clamped or secured at any desired point.

The vise is hung on a pin which is off the center, so as to give the operator the advantage of a variety of positions.

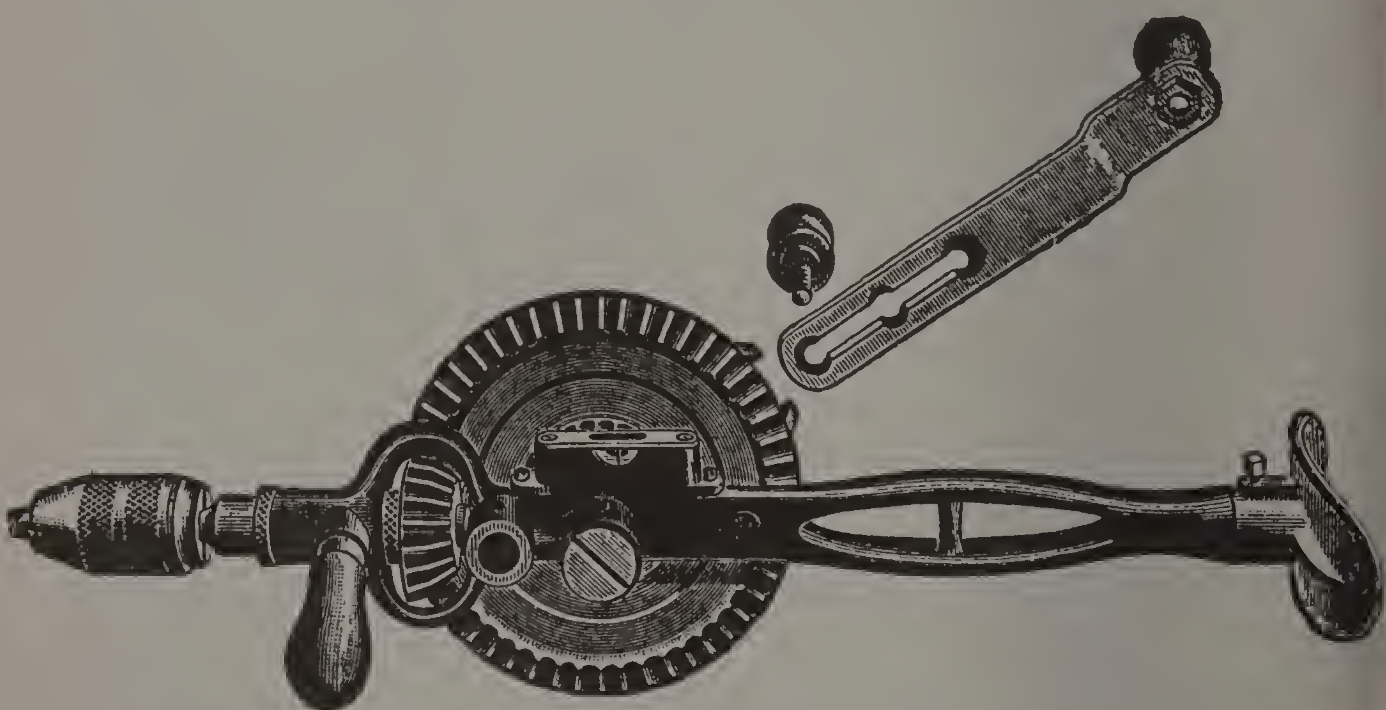


Fig. 167.

The operator may, if desirable, work below the bench by dropping the frame and fixtures down on the standard, and securing the upper end of the same in the bench clamp. This is very convenient in bicycle repairing. The number of positions, heights and adjustments that will suggest themselves as necessity demands, with this tool, is numberless.

Fig. 167 shows the breast drill designed for use with this attachment.

Center Drill and Countersink. Fig. 168 represents a combined drill and countersink for center drilling, the drill and countersink being in one piece. When very true work is required it is preferable to so shape the countersink that the lathe center will first bear at the smallest part of the cone. This will cause the countersink to wear and keep true with the hole.

Fig. 168.

If the center drilling is to be done by hand it is very important to relax every few seconds the hold upon the work sufficiently to permit it to make about a third of a revolution, which may be done while the other hand is supplying oil to the drill. The object and effect of this is to cause the center drilling to be true, which otherwise it would not be, especially if the work is comparatively heavy, or heavier on one side than on another.

Chucks. Fig. 169 shows a new form of lathe chuck, in which the jaws are operated by a rack and a key pinion.

This construction has many advantages over the old style, in that the jaws are stronger and move in that part of the chuck which is attached to the driving spindle. Great firmness is gained to the chuck by this arrangement. The threaded and working parts are covered and thereby secured from injury or dirt.

The chuck shown in Fig. 170 has projecting jaws and the combination prevents larger work than the chuck is

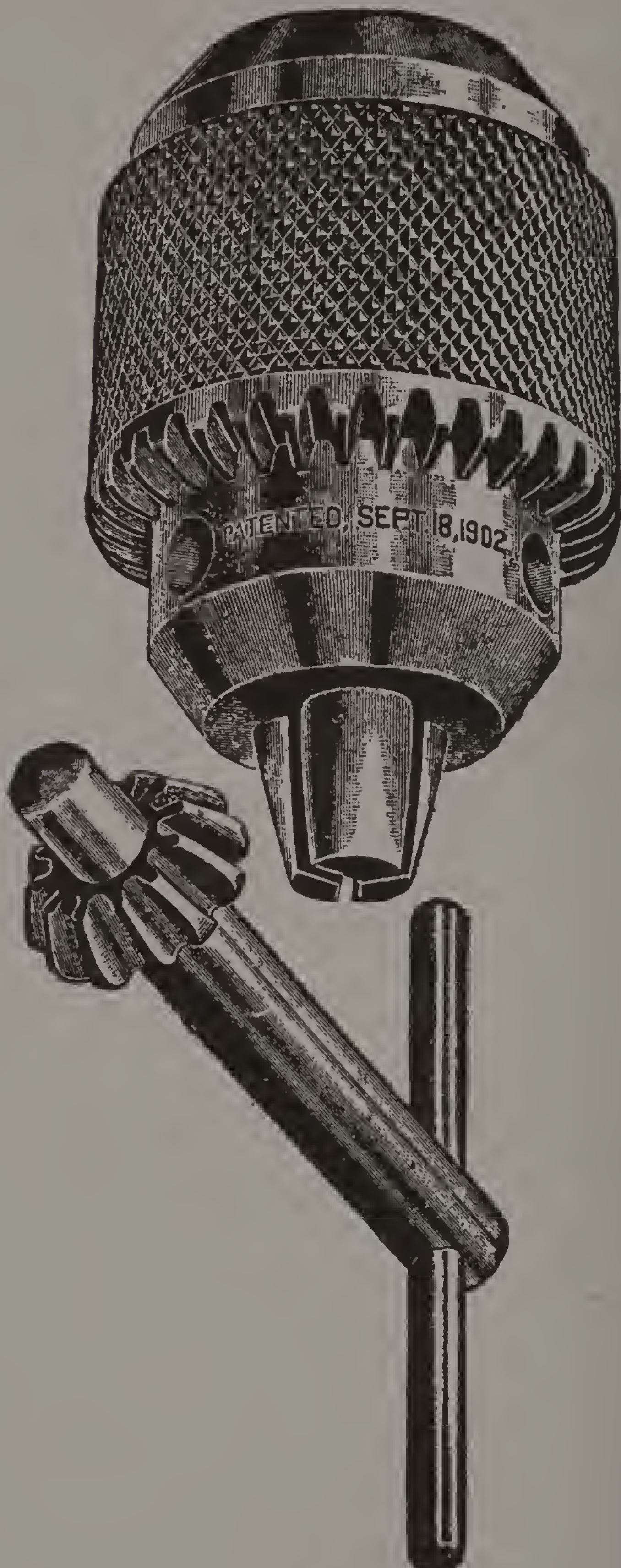


Fig. 169.

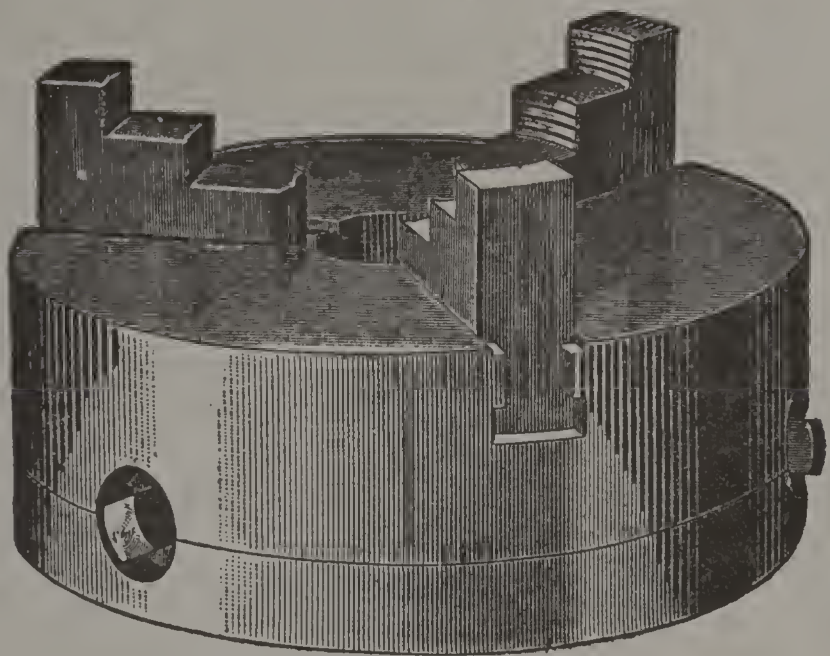


Fig. 170.

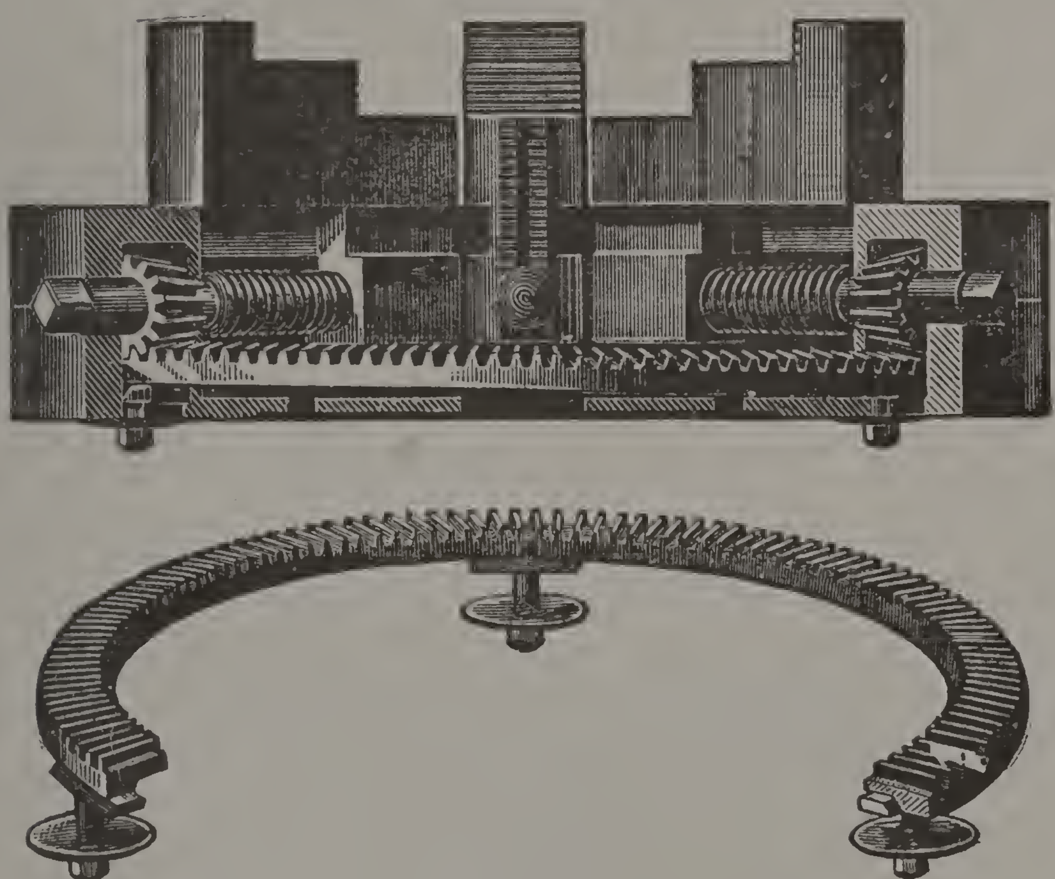


Fig. 171.

designed for being used. It is very powerful and guaranteed to hold true and not injure the shank of the drills. It holds round and square work. The jaws are guided by three strong gibs, and the screws are larger than in any chuck of this description. The jaws and screws are made from cast steel.

Fig. 171 represents a form of chuck, which may be used as an independent or as a universal chuck. Each of the screws for operating the jaws is provided with a bevel pinion, and behind these pinions is a ring provided with teeth, and which may be caused to engage with or disengage from the pinions as follows: The width of the rack has a beveled step, the outer being thicker than the inner diameter. Between this ring or rack and the face of the chuck is placed, beneath each jaw, a cam block beveled to correspond with the beveled edge of the circular step.

Each cam block stem passes through radial slots in the face of the chuck, so that it may be moved towards or away from the center of the chuck. When it is moved in, its cam-head passes into the recess or thin part of the circular rack which then falls back out of gear with the jaw-screw pinion. But when it is moved outward the cam-head slides under the circular rack and places it in gear with the jaw-screw pinion. To change the chuck from an independent one to a universal one, all that is necessary to do is to push the heads of the cam-blocks outwards.

Clamps. Steel clamps for holding work on drill-press tables or surface plates are a very handy tool in a shop. Fig. 172 illustrates a form of clamp much used for this purpose.

Cold Chisels. Chisels are made from two shapes of bar steel, one of which is octagonal, and the other of flat-oval section. With the latter shape the cutting edge and the flat are parallel, and the broad flat is the best guide in holding the chisel level with the surface to be chipped. Either of these chisels is of a proper width for wrought-iron or steel, because chisels used on these metals take all the power to drive that can be given with a hammer of the usual proportions for heavy chipping, which is: Weight

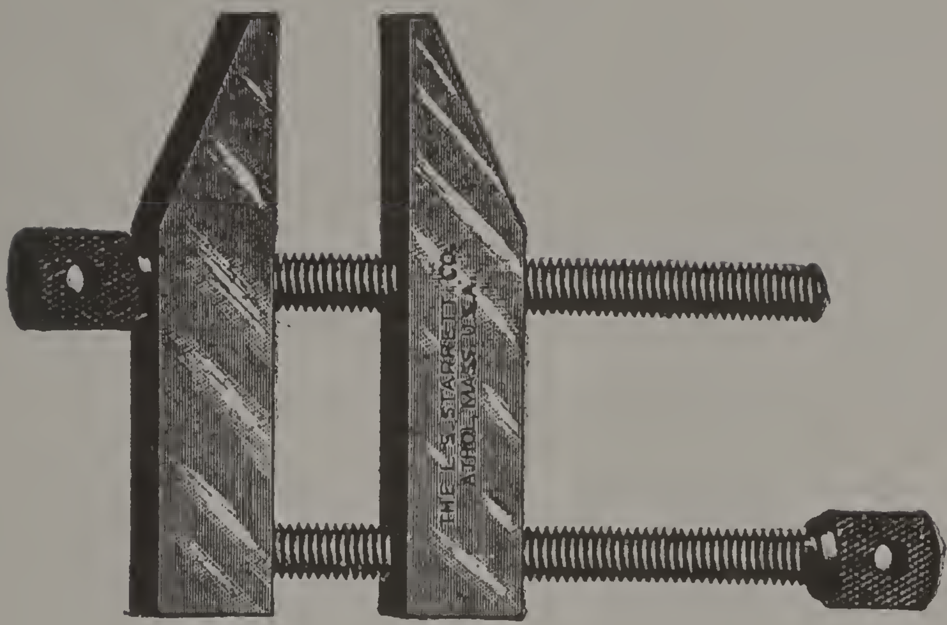


Fig. 172.

of hammer 1¾ pounds, length of hammer handle 15 inches, the handle to be held at its end and swung back about vertically over the shoulder. If so narrow a chisel be used on cast-iron or brass and given full-force hammer-blows, it will break out the metal instead of cutting it and the break may come below the proper depth and leave ugly cavities. For these metals the chisel should be made wider so that the force of the blow will be spread over a greater length of chisel edge and will not move forward so much at each blow, and therefore it will not break the metal out. Another advantage is, that the broader the chisel the easier it is to hold its edge fair with the work surface, and make smooth chipping.

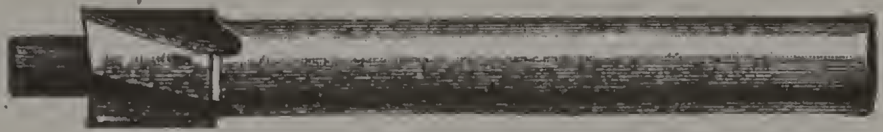


Fig. 173.

Counterbores. Pin drills or counterbores are used to drill the recess for the heads of machine screws. An illustration of a counterbore is shown in Fig. 173.

Fig. 174.

Depth Gauge. Fig. 174 shows the head of the depth gauge together with a portion of the barrel and rod. It will measure to 3 inches in depth.

The base is about 7-16 inch wide and the rod about 1-8 inch in diameter.

A spiral spring in the barrel forces the rod against the bottom of the hole or recess to be measured and by use of the clamp screw the rod is securely locked in position.

Dies. Dies are usually cut of a larger diameter than the size of the bolt the dies are intended to cut. This being done to cause the dies to cut at the cutting edges of the teeth which are at or near the center of each die, so that the threads on each side of each die may act as guides to steady the dies, and prevent them from wabbling as they otherwise would do. The result of this is, that the angle in the thread in the dies is not the correct angle for the thread of the bolt, even when the dies are the closest together, although the dies are nearer the correct angle when in that position than in any other. A very little practice at cutting threads with stocks and dies will demonstrate that the tops of the threads cut on a bolt are larger than the diameter of the bolt, before the thread was commenced to be cut, which arises from the pressure, placed on the sides of the thread of the bolt, by the sides of the thread on the dies, in consequence of the difference in their angles. Which pressure compresses the sides of the bolt thread and causes a corresponding increase in its diameter. It is in consequence of the variation of angle in adjustable dies that a square thread cannot be cut by them, and that they will not cut a good V thread.

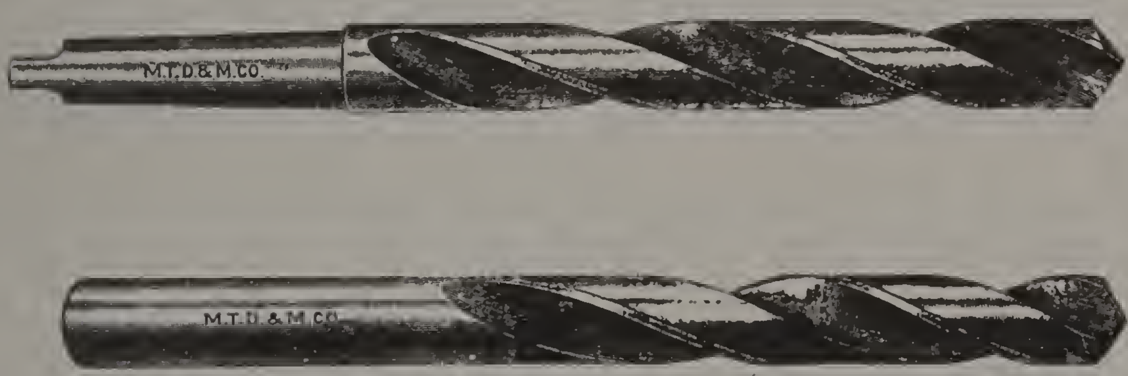


Fig. 175.

Drills and Drill-holders. Twist drills, as shown in Fig. 175, are generally used in machine shops, and vary in size according to the nature of the work. In ordinary shop practice from three-eighths of an inch to $1\frac{1}{2}$ inches in diameter is the range of holes drilled. Therefore, the drills are made in sets, and with each set is a steel socket which fits the drill-press spindle at one end, and at the other end the recess fits all the drills in the set. They are, therefore, interchangeable.

Drill sockets are shown in the illustration in Fig. 176.

To enable the drill to be easily extracted from the socket, the latter is provided with a slot, as shown in the figure; this slot passes entirely through it. The drill end protrudes into the slot, so that if a key or wedge be driven into the opening the drill will be forced out.

Fig. 176.

Drill Grinders. For the accurate grinding of twist drills, the grinders shown in Fig. 177 will be found to be very suitable for the average machine shop.

Emery-wheel Dressing Tools. For the purpose of removing the glazed surface from emery-wheels, dressing tools are used as shown in Fig. 178. These consist of serrated or grooved disks, which are pressed against the face of the emery-wheel, and moved back and forth across it.

Gauges. The gauge shown in Fig. 179 furnishes the correct form for tools used in turning the threads of worms, when the worm wheels are cut with involute cutters. The figures on the gauge correspond to the number of threads per inch of the worm.

The screw pitch gauge shown in Fig. 180 will measure the threads of nuts as well as of screws and contains the pitches 9, 10, 11, 11½, 12, 13, 14, 15, 16, 18, 20 on one

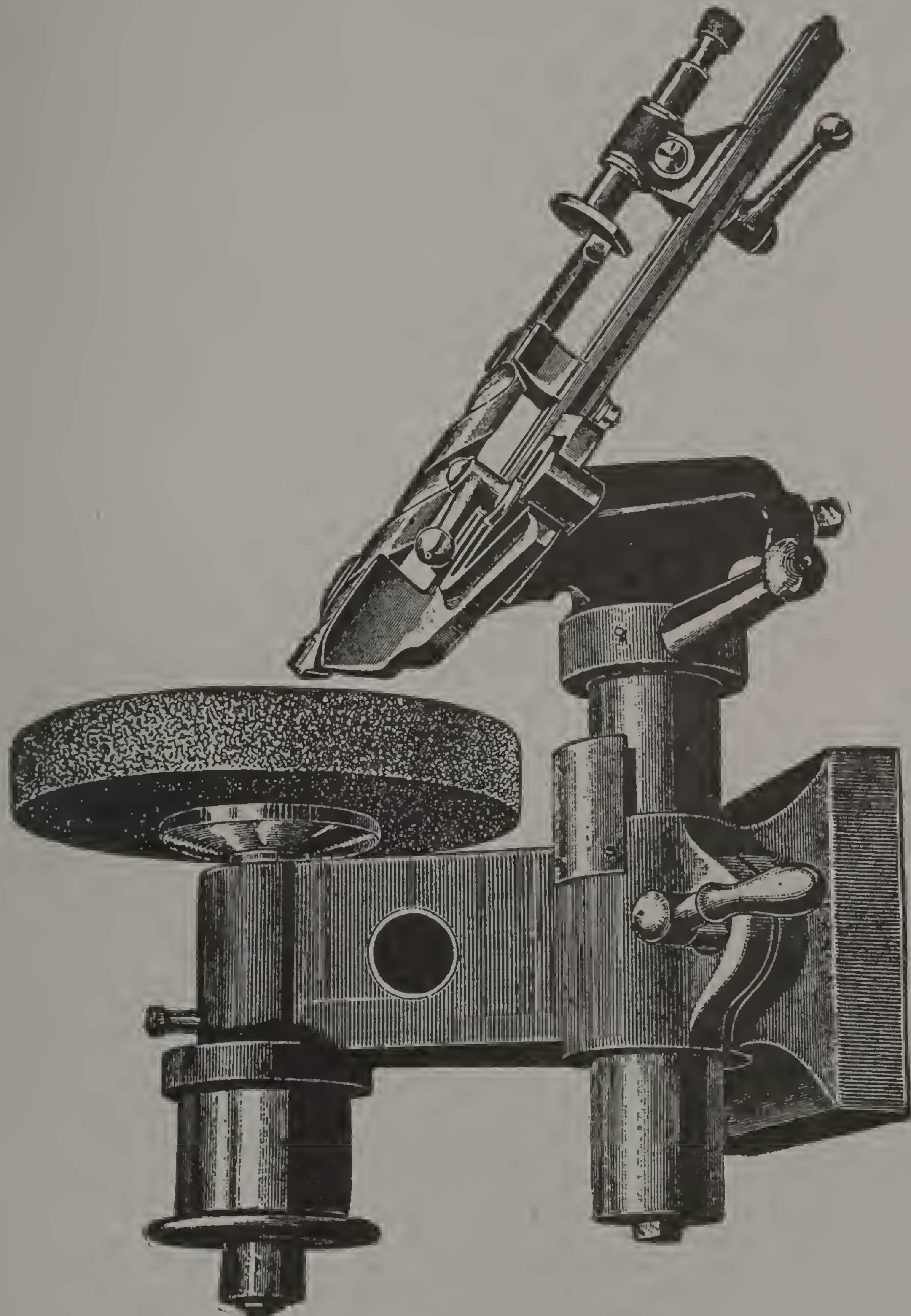


Fig. 177.

Fig. 178.

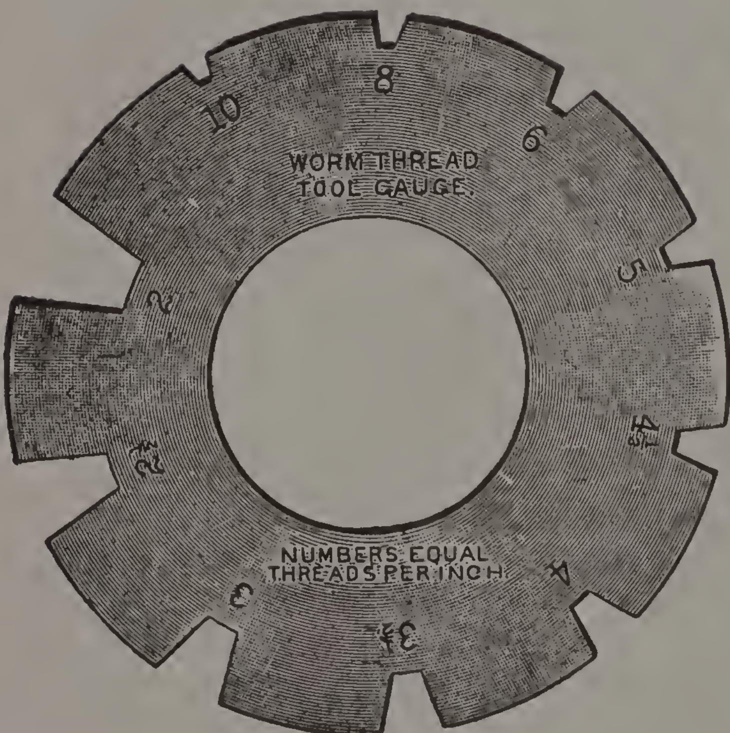


Fig. 179.

Fig. 180.

end and 22, 24, 26, 27, 28, 30, 32, 34, 36, 38 and 40 on the other end.

The arrangement of blades hinged on each end of the case enables any desired number to be quickly placed in position for use.

There are 22 pitches, including pipe thread pitches, 11½ and 27. The 8 pitch may be determined by using the 16 pitch blade.

The 11 smaller pitches are on blades made narrower than the 11 larger ones, so that they have a wider range of use in measuring the threads of nuts than would be the case were they all of one size.

The gauge numbers are stamped on the outside of the frame, as well as on both sides of each blade, allowing the user to determine the position of a desired number at a glance.

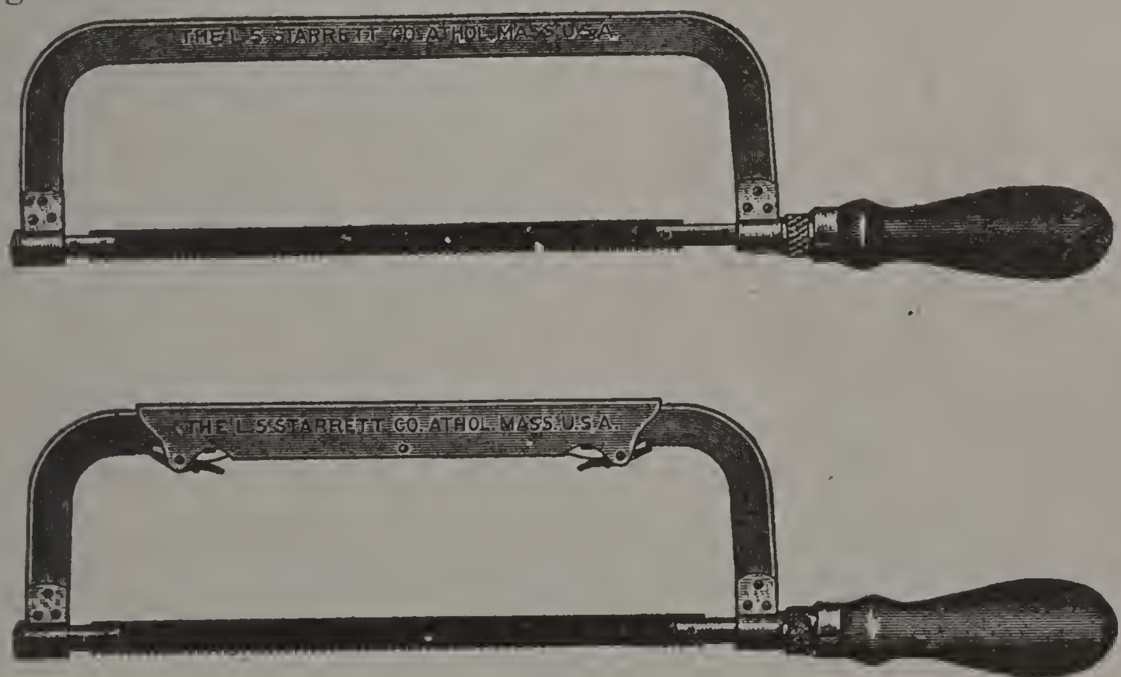


Fig. 181.

Hack Saws. These frames, the frames of the saws shown in Fig. 181, are all made of steel, and as seen in the cut are adjustable so as to face the blade in four different directions. The extension frames will hold different lengths of blades. The solid frames only hold the 8 inch blades, this being the length most in use. They all have staple shaped pins to hold the blades in the frame which are so arranged that they cannot fall out.

Lathe Dogs. Figures 182 and 183 show the ordinary form of lathe-dog or driver, with set-screws to secure them to the work. A screw-clamp lathe dog is illustrated in Fig. 184 which has half-round grooves in the upper and lower clamping pieces so as to hold the work without marring the surface or injuring it in any manner.

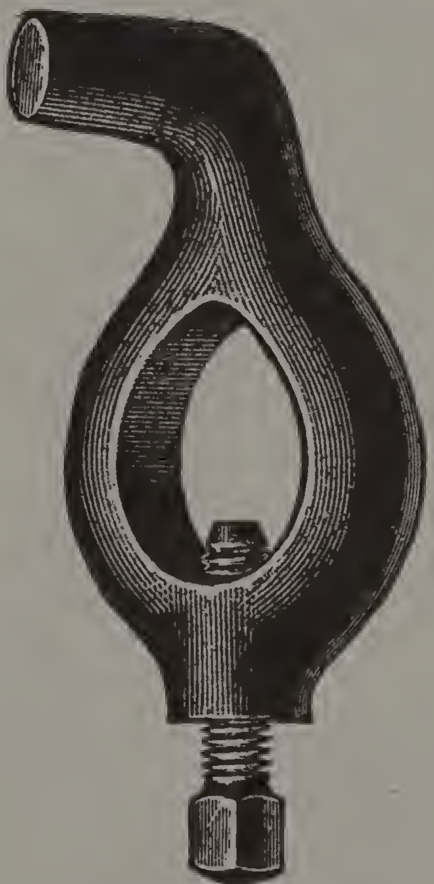


Fig. 182.

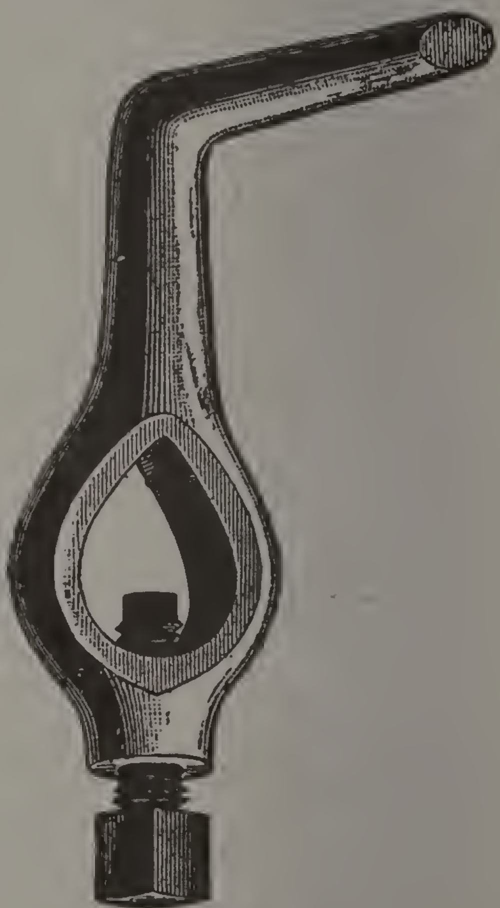


Fig. 183.

Lathe Threading Tool. A new form of lathe threading tool is shown in Fig. 185.

Levels. The level shown in Fig. 186 has, in addition to the regular parallel vial, a cross level which enables one to place or hold the base on a shaft level in its cross section, not canted sidewise, for the shape of a level glass is such that, though true as adjusted on a flat surface, it will not

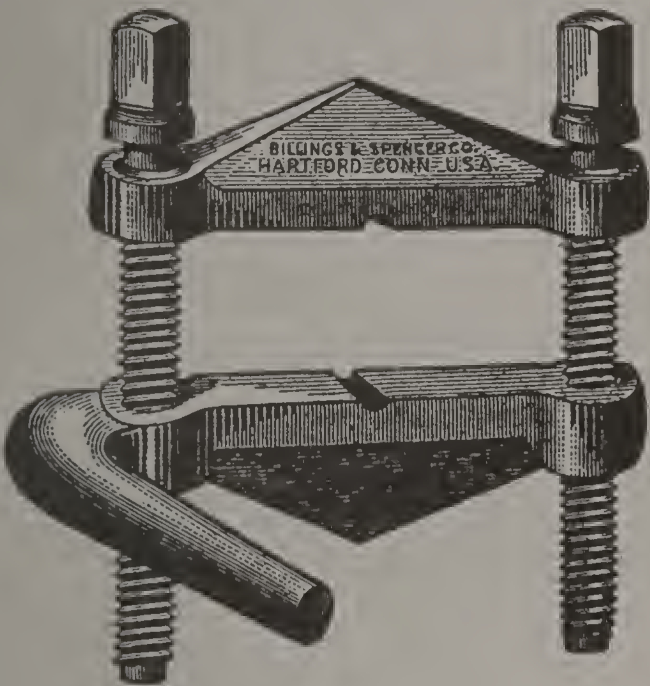


Fig. 184.

Fig. 185.

Fig. 186.

be reliable when canted sidewise. Hence the value of the cross level, not only to test the truth of shafting, but other surfaces which tend to throw the level into a slanting position.

The base of this level has an improved concaved groove running through the length of its base, leaving a flat margin each side, which also improves its seat for flat work, while forming an absolutely true and reliable seat for shafting, and is better than a V groove.

Micrometer. The micrometer shown in Fig. 187 measures all sizes less than one inch by thousandths of an inch. The outer end of the frame is the same size as the measuring spindle, and, as the edges of the measuring surfaces are not beveled, but left square, it is convenient for gauging under a shoulder, or measuring a small projection on a plane surface.

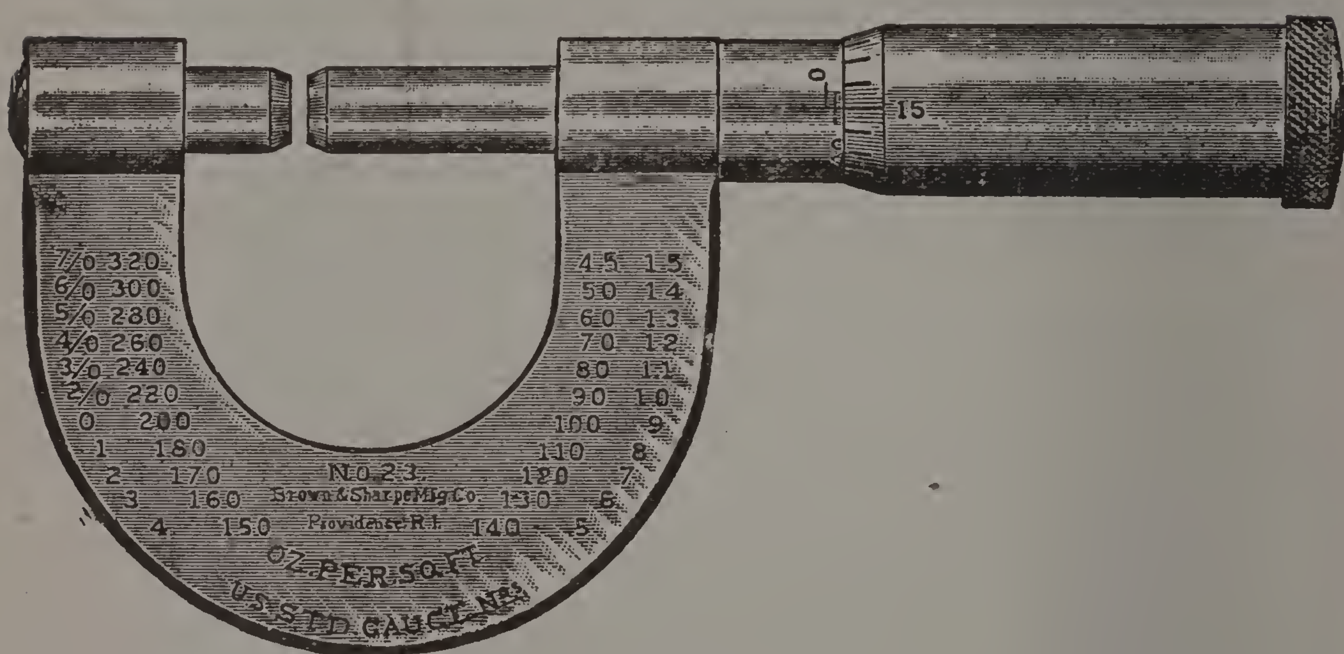


Fig. 187.

The adjustment of the measuring screw is made by an adjustable threaded nut which produces the necessary friction by binding the thread evenly on the angle, thus obviating the use of slots, the points of which are apt to rough the thread if improperly clamped.

Every micrometer is provided with a clamp nut, which clamps the spindle and preserves the setting.

A micrometer sheet metal gauge is shown in Fig. 188.

This gauge has a 2 inch depth of throat to reach over the edge of the sheet metal to gauge its thickness nearer the center. It has one-half an inch movement of the screw. The screw is covered by a shell with its indicator mark, which enables one to take up wear to a nicety and insures a correct reading, the anvil remaining solid. It also has a ratchet friction feed, which insures uniform pressure against the work without springing the frame, as well as a lock nut to lock the spindle firm when desired to make a solid gauge.

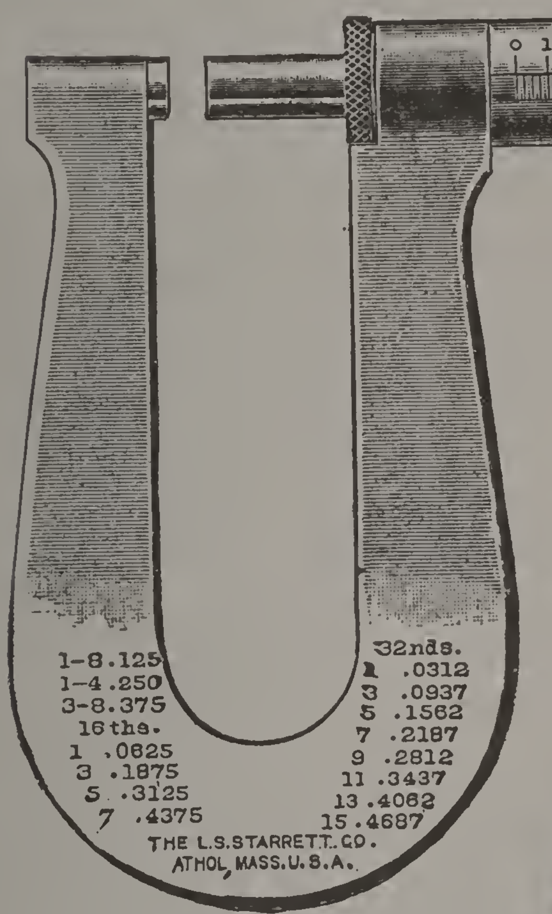


Fig. 188.

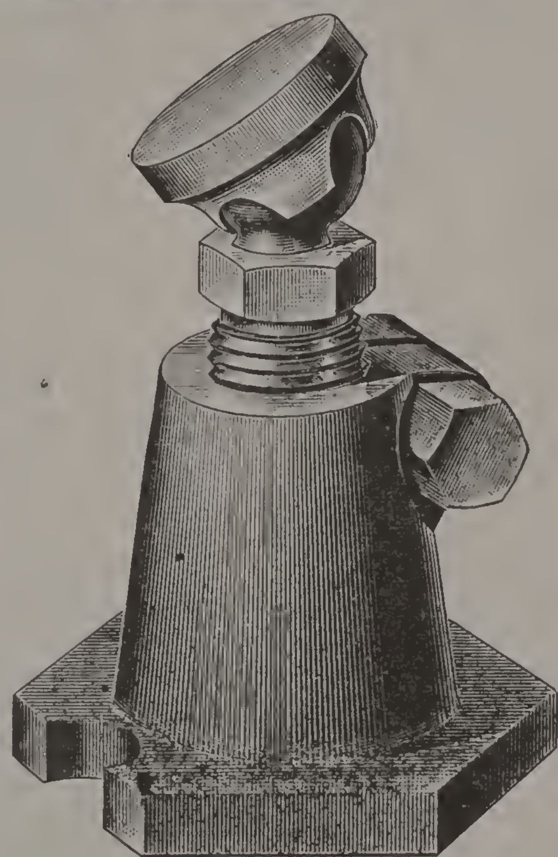


Fig. 189.

Planer Jacks. This jack is very useful article for raising and levelling heavy castings on a planer. An illustration of the jack is shown in Fig. 189.

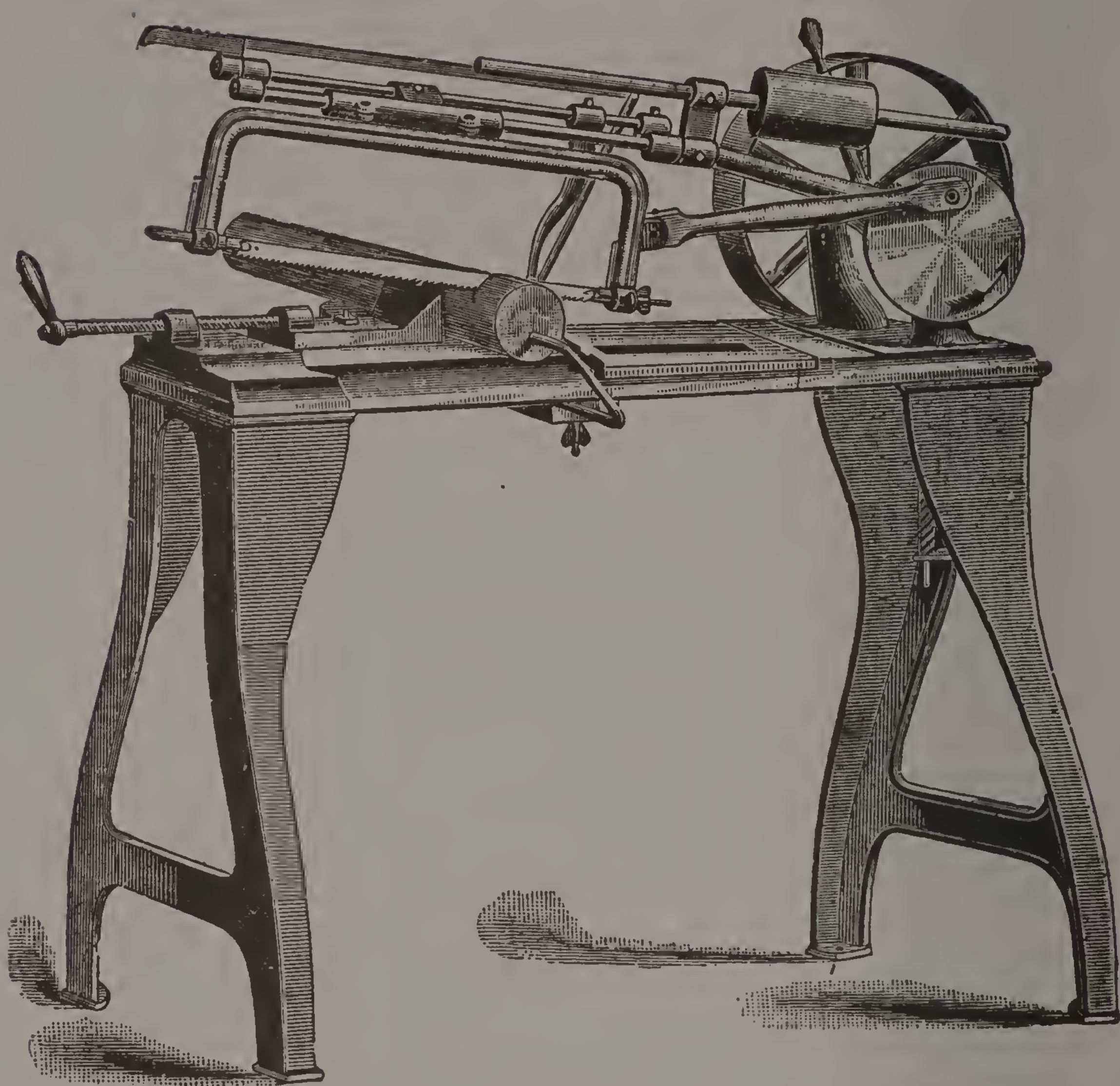


Fig. 190.

Power Hack Saw. The machine illustrated in Fig. 190 is designed for cutting brass, iron and steel. It will cut any size up to 4½ inches in diameter, and any shape that can be held in the vise. Great speed is not claimed in cutting, but metal can be cut more rapidly in this machine than in a lathe or planer, or heating and cutting by a blacksmith. By its use a good percentage of metal is saved, as the pieces cut are left smooth, and no labor or metal is lost in squaring up. This saving in high-priced steel is quite an item in stock to say nothing of the labor. The blades used are Star hack saws, 10, 11 or 12 inches in length. The machine should run from 40 to 45 revolutions per minute.

Taps. Machinists' hand taps are made in three styles: Taper, Plug and Bottoming Taps, as shown in Fig. 191.

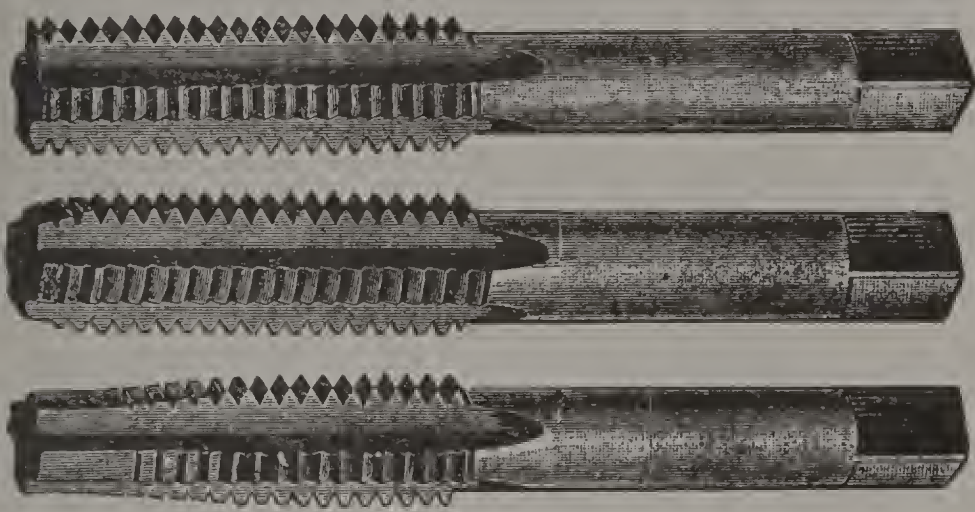


Fig. 191.

Taps for use in holes to be tapped deeply should be of slightly larger diameter than those used to tap shallow ones, because in deep holes the tap is held steady by its depth in the hole, and whatever variation there may be in the pitch of the threads in the hole and those on the bolt, is experienced to an extent as much greater as the length of the thread increases.

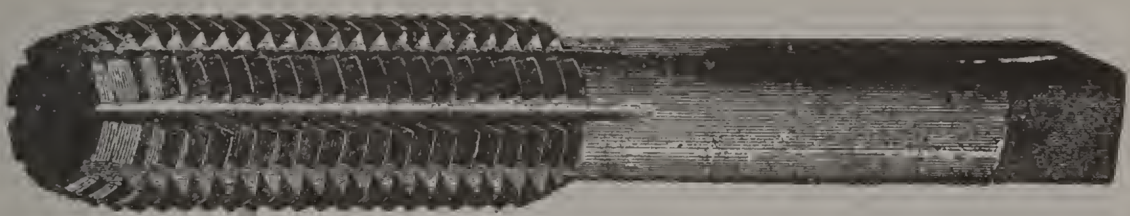


Fig. 192.

Fig. 193.

A short Hob or master tap is illustrated in Fig. 192 and a Machine or Nut Tap in Fig. 193.

Vises. The vise shown in Fig. 194 is designed for jewelers, tool makers, and machinists' use. All parts are drop-

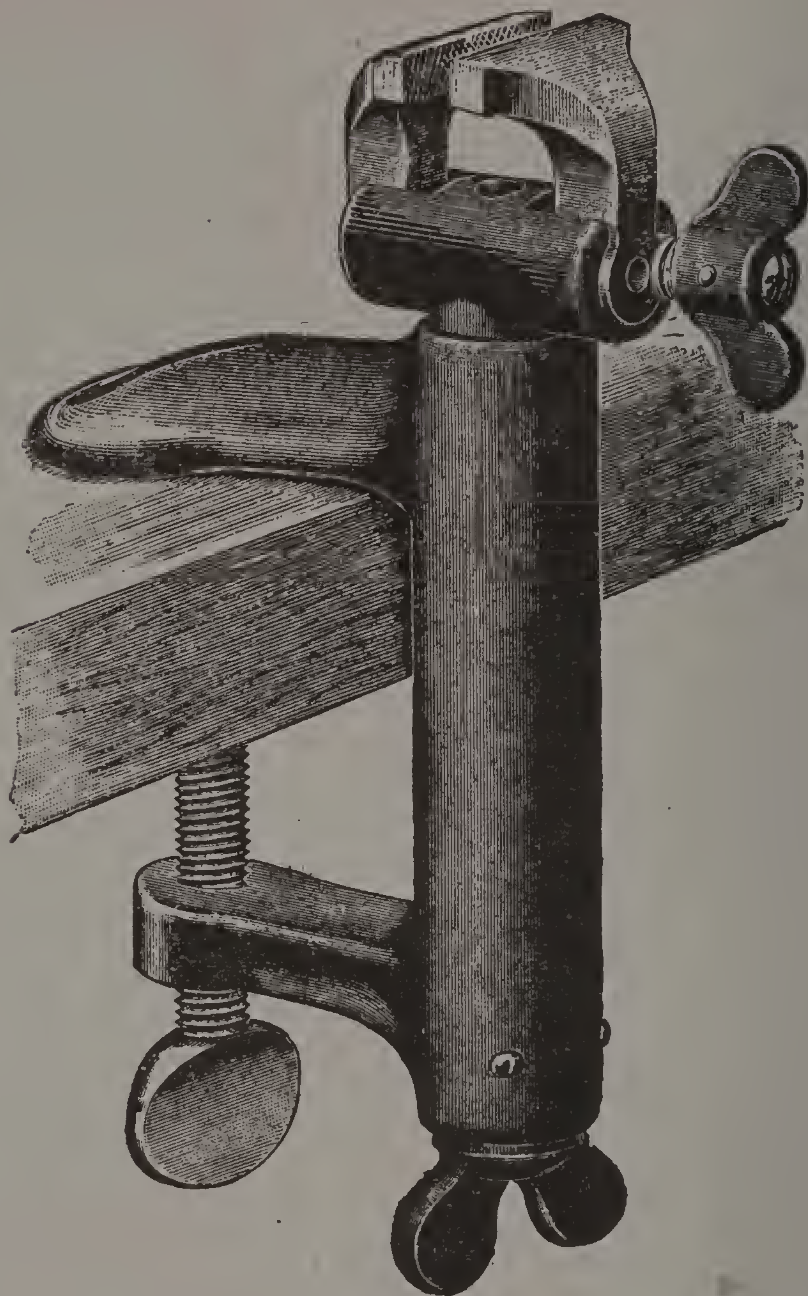


Fig. 194.

forged of best steel for the purpose. The jaws have a positive opening and closing movement in parallel lines, actuated by a right and left hand screw, moving the jaws simultaneously towards or from each other. A hole is entirely through the handle and the jaws will grasp and hold central, round wire from one-sixteenth of an inch up to and including one-quarter of an inch in diameter. The jaws open three-quarters of an inch.

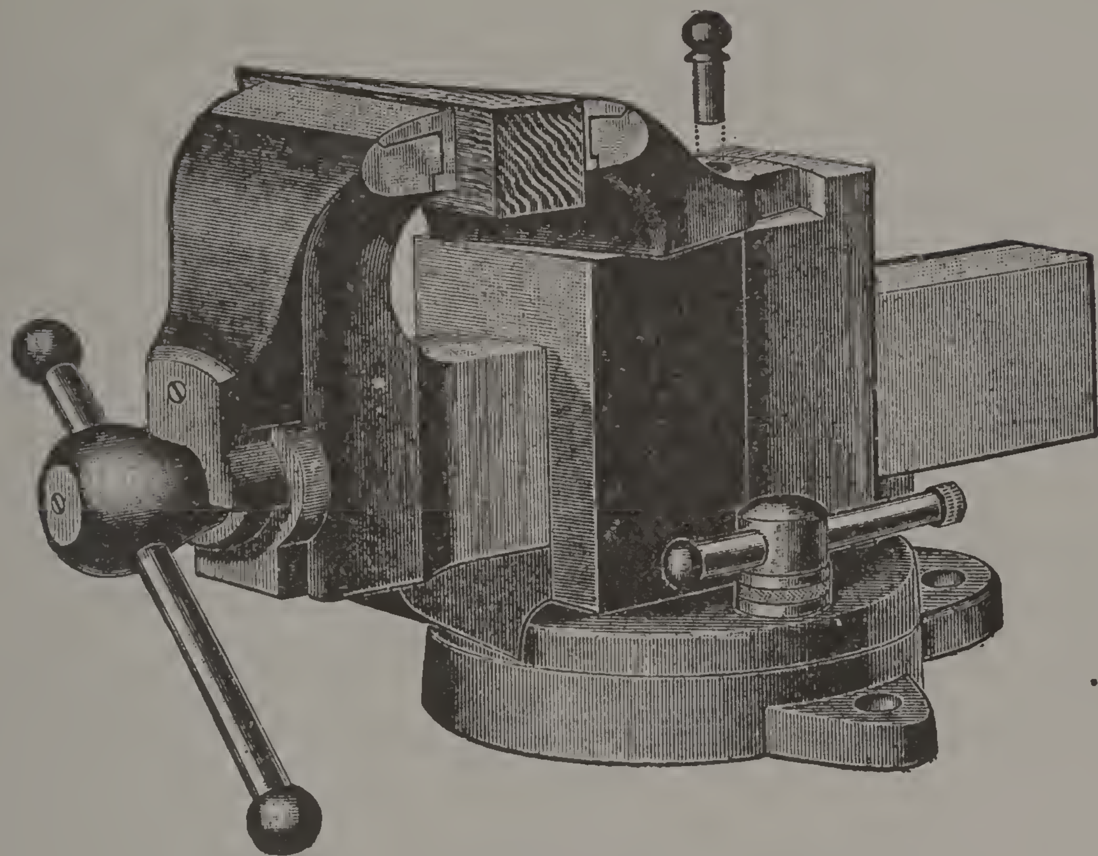


Fig. 195.

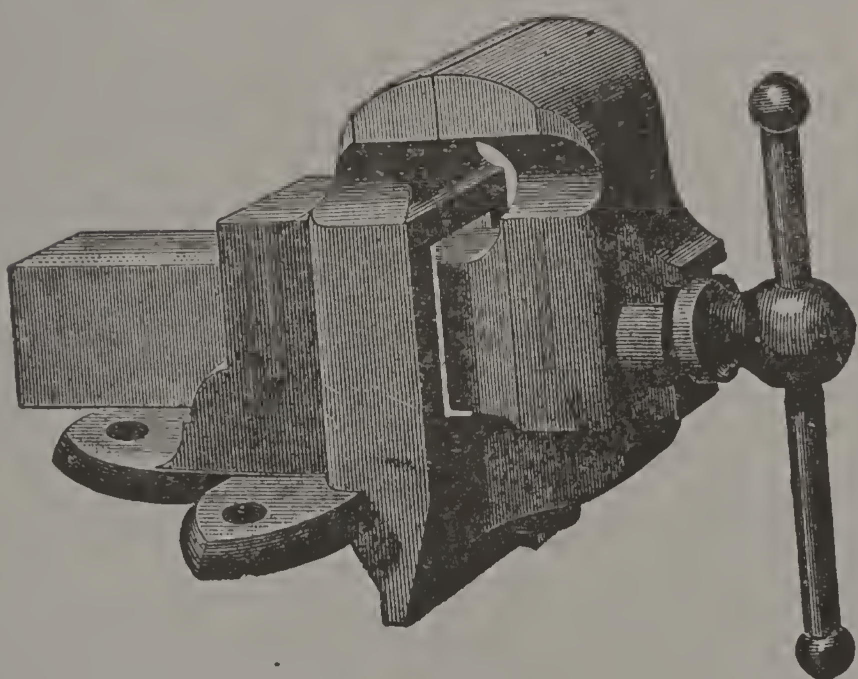


Fig. 196.

Several forms of standard plain and swivel vises are shown in Figs. 195 to 199.

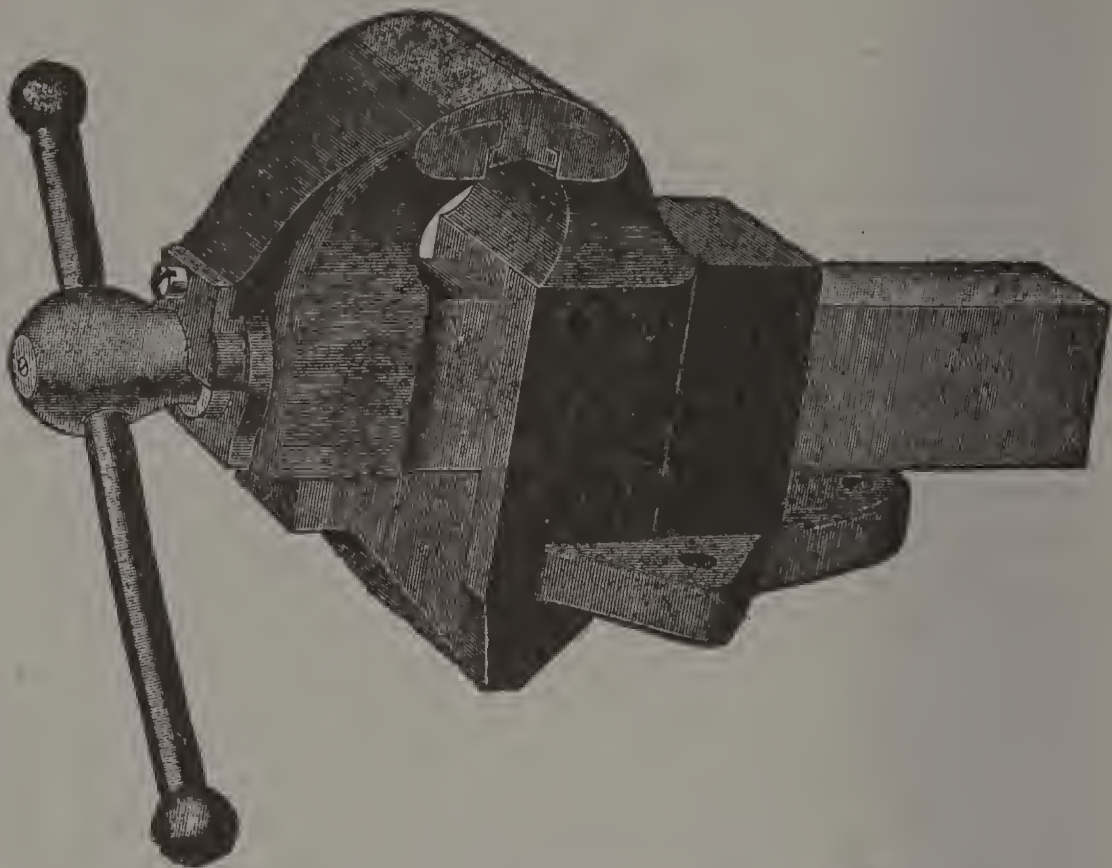


Fig. 197.

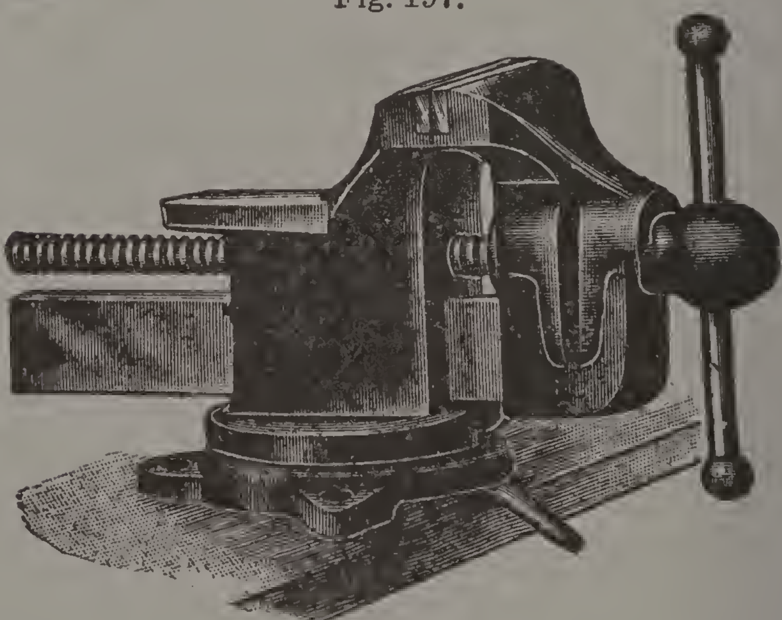


Fig. 198.

A drilling attachment which may be adapted to use with almost any ordinary vise is shown in Fig. 200.

A quick opening form of pawl and ratchet vise is shown in Fig. 201. It also has a swivel base.

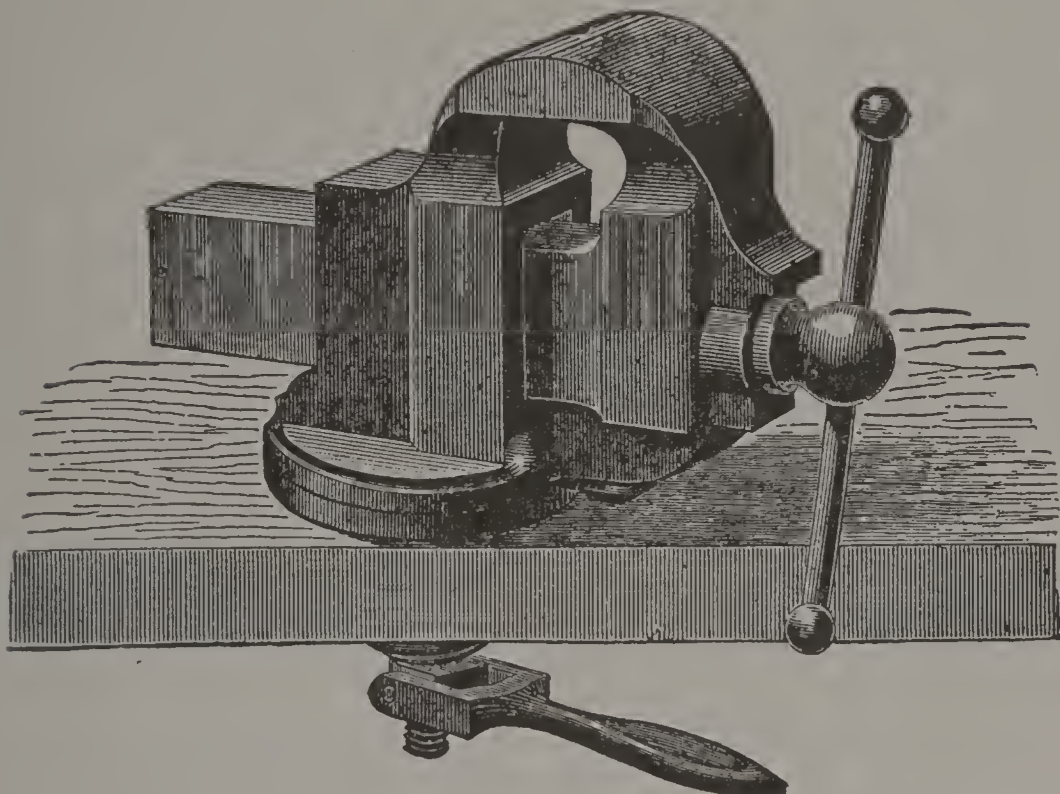


Fig. 199.

Wrenches. For shops engaged in the manufacture of standard or duplicate work, a set of wrenches as shown in Fig. 202 is an almost indispensable necessity. These are

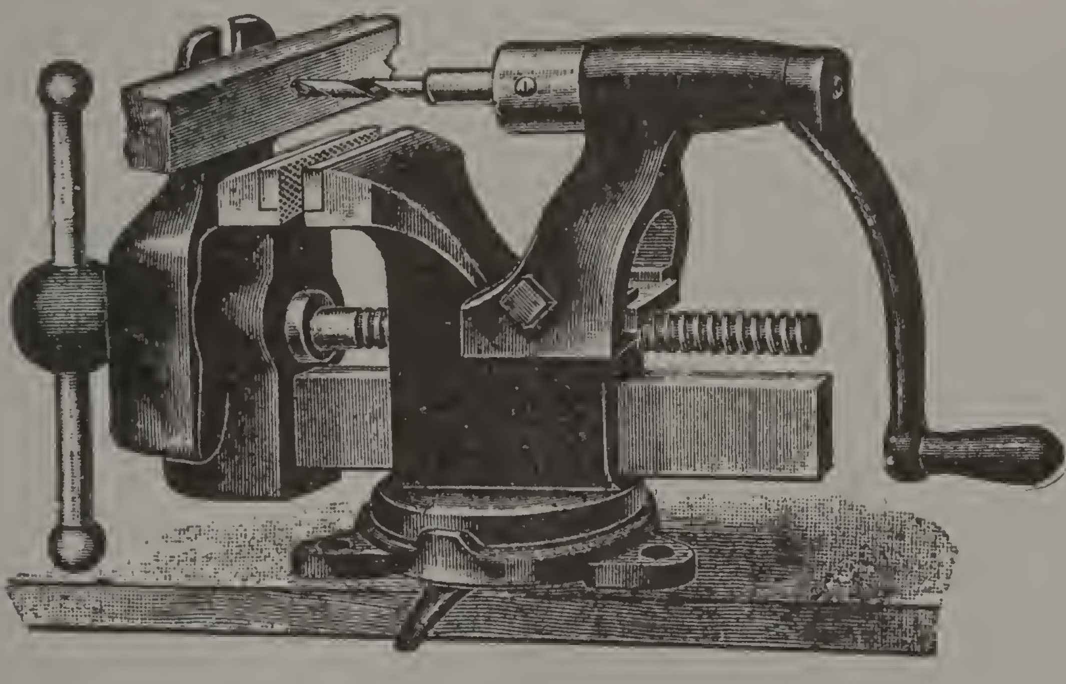


Fig. 200.

made in all sizes from 1/4 of an inch to 1 1/2 inches, and in the styles shown in the drawing.

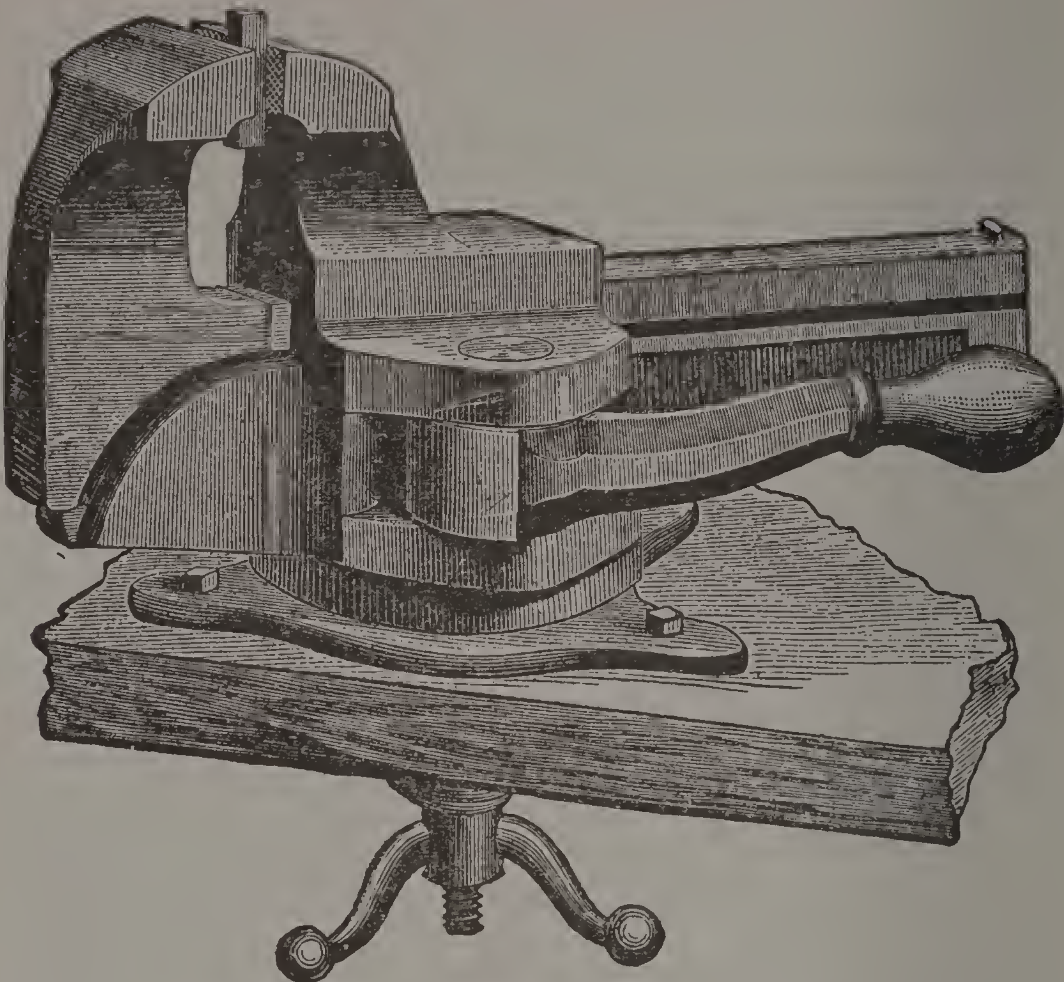


Fig. 201.

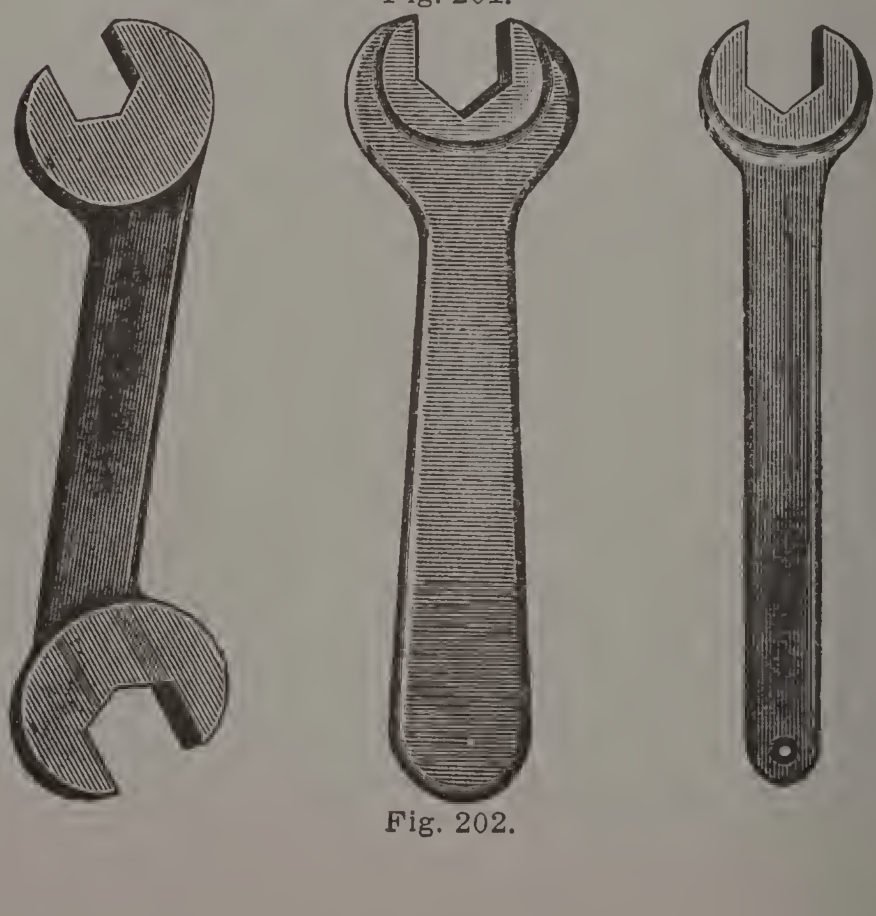
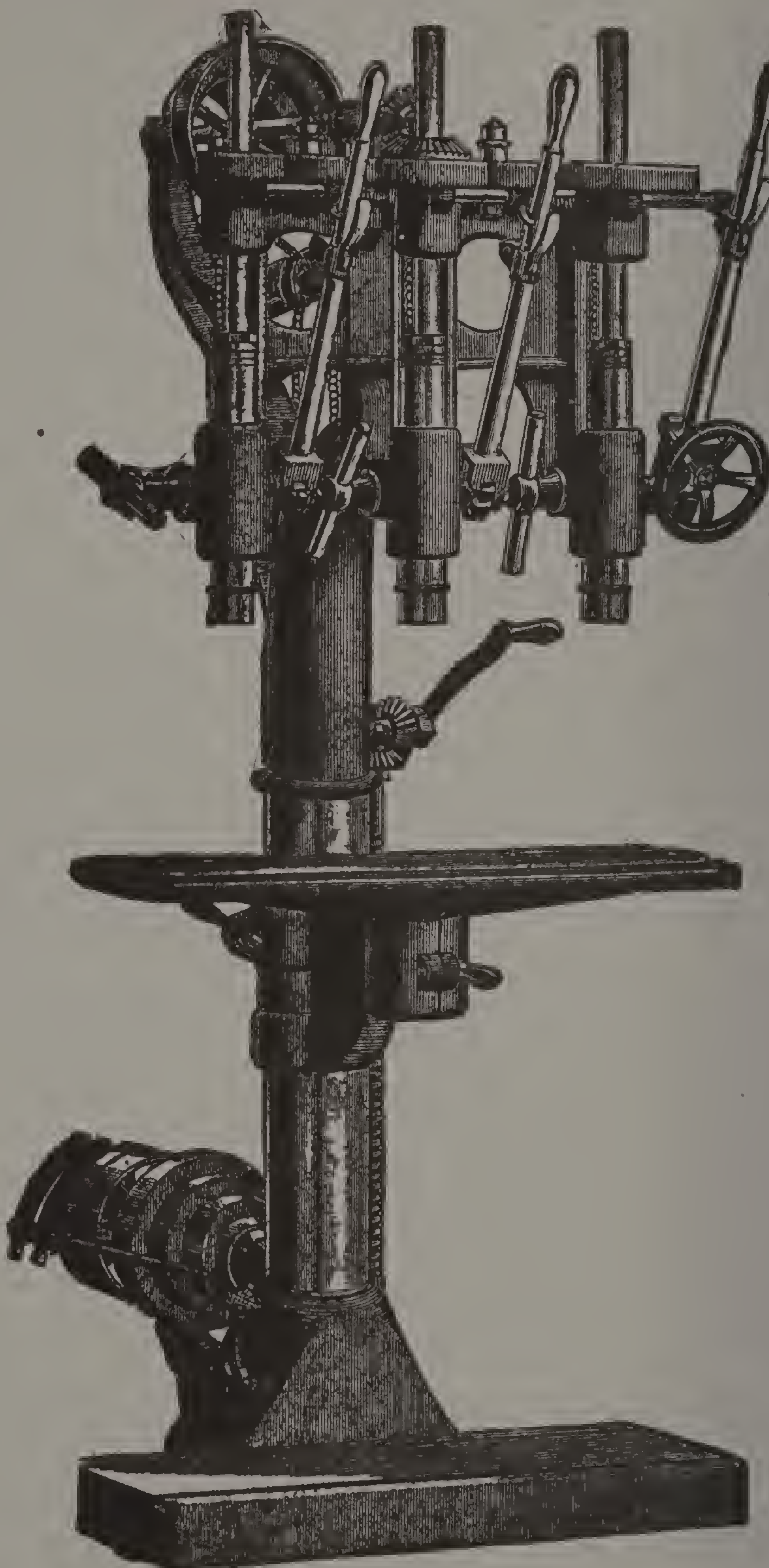


Fig. 202.

MACHINE TOOLS



Erecting Machine Tools. When machine tools are first received, if they have been shipped any distance in an open or box car, a large amount of dirt and grit will have accumulated in transit. In order to thoroughly remove these, the tools should be taken carefully apart and thoroughly cleaned.

The next thing to be considered is the foundation, and if on the ground floor, when possible, so that the tools be placed on a stone foundation. The advantages obtained by so doing will well repay the extra cost. Careful leveling of the machine after it has been placed in position is imperative. Be sure the level is accurate and sensitive, and in addition to this always use a true straight edge. With these the machine can be tested until known to be correct.

The countershaft should also be level, and in strict alignment with the main line.

One of the most important things in starting a new machine, and the one which is most often neglected, is to see that the machine is well lubricated, and with a good quality of oil. The very best oil is the cheapest, and should be used in generous quantities, particularly for the first few weeks the machine is running. Convenient places are provided for oiling all bearings, and careful attention should be given to see that all bearings and sliding surfaces are well lubricated.

If these directions are carefully followed there will be little trouble about the machine running properly.

Bolt Cutters.

Bolt-Cutting Machines or Bolt Cutters are employed to cut the threads upon bolts. These machines are made both single and double, that is, with a single or a double head. Each head contains dies, which are provided with means to close them to cut the thread to the required diameter, and in the cases of simple machines to run backward to withdraw the dies from the bolt, while in the more improved machines the dies are opened automatically so that the bolt can be withdrawn as soon as the thread is cut upon it. The bolts are held in jaws or chucks that are moved by hand-wheels operating right- and left-hand screws so that the jaws open and close equally, and the bolts will be held in line with the thread-cutting dies. The bolts are usually moved up to the dies by levers and sometimes by a rack and pinion motion.

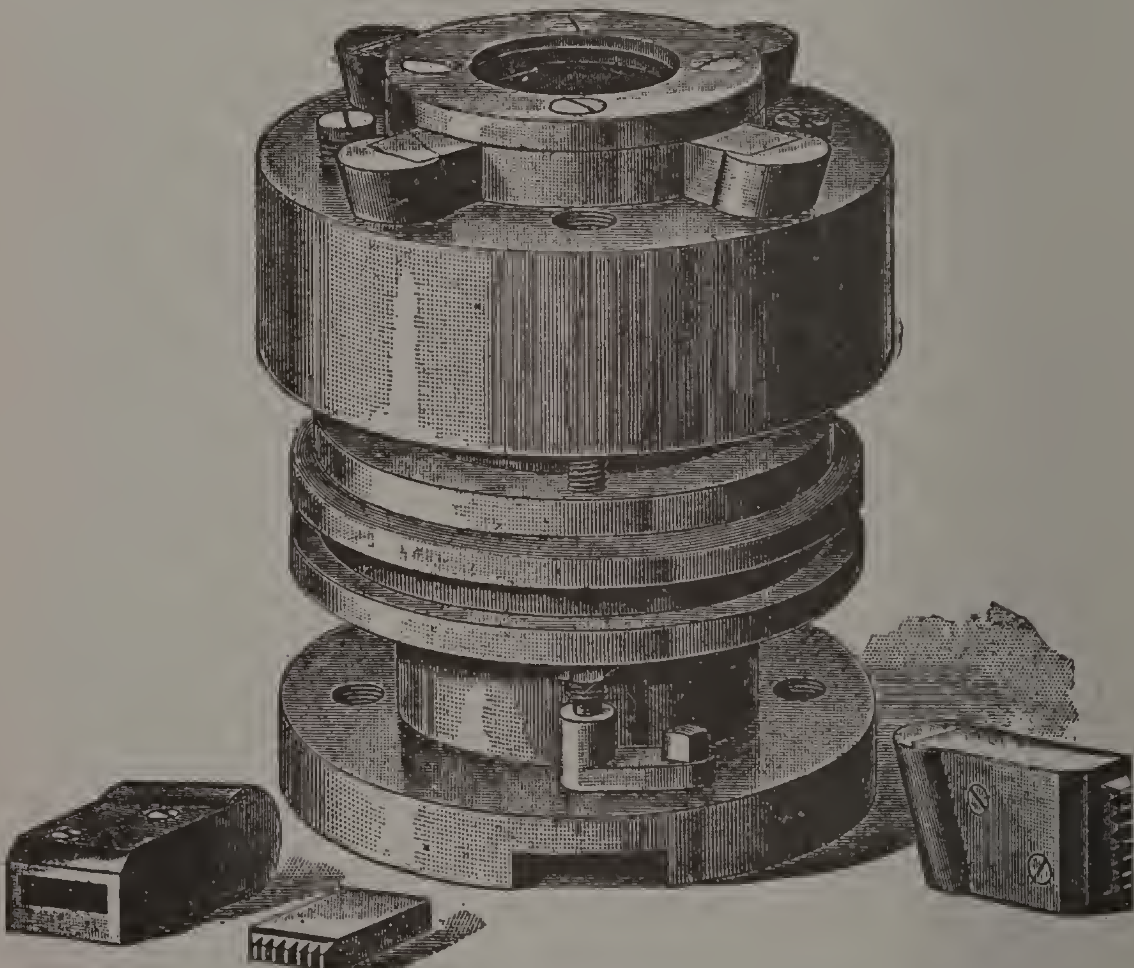


Fig. 203.

Bolt-Cutter Head. The head shown in Fig. 203 is specially designed to receive detachable dies, to hold them rigidly at any desired diameter, and to open or draw dies away from the thread when the cutting is completed. In addition to the time saved, which is practically equal to the time of cutting, the quality of the work performed is fully equal to that cut in the lathe. The barrel or die holder is coupled to the main spindle of the machine, at its outer end are four slots through which the dies are moved to and from its axis. These dies are plain flat pieces of steel, held in a die case, at the upper end of the case is a large cylindrical head, which receives all the outward thrusts of the dies. Special attention is drawn to this construction, which is far superior to any tongue or groove form. The adjustment of the dies is secured by stopping the travel of die ring at different points on the inclined head of the die cases.

Bolt-Cutter. The lead screw in the machine illustrated in Fig. 204 is located directly beneath the head stock and carriage, and is driven by direct gearing from the main spindle. It is of ample size and with a sufficiently coarse thread to insure long life, and need never be removed from the machine in order to change for the pitch of thread to be cut. Change gears to cut the standard pitches within the capacity of the machine are provided. The lead screw is engaged by a split nut, contained within the carriage. This nut is operated by a hand lever conveniently placed. An automatic safety device, which should be used as such only, disengages the nut from the lead screw at the end of the forward travel of the carriage and prevents any injury to the machine which would result if, through carelessness of the operator, the lead screw were allowed to force the carriage against the die head. This attachment automatically opens and closes the die head by the forward and backward travel of the carriage, and can be adjusted so as to operate for any length of thread to be cut on bolts of any length within the capacity of the machine.

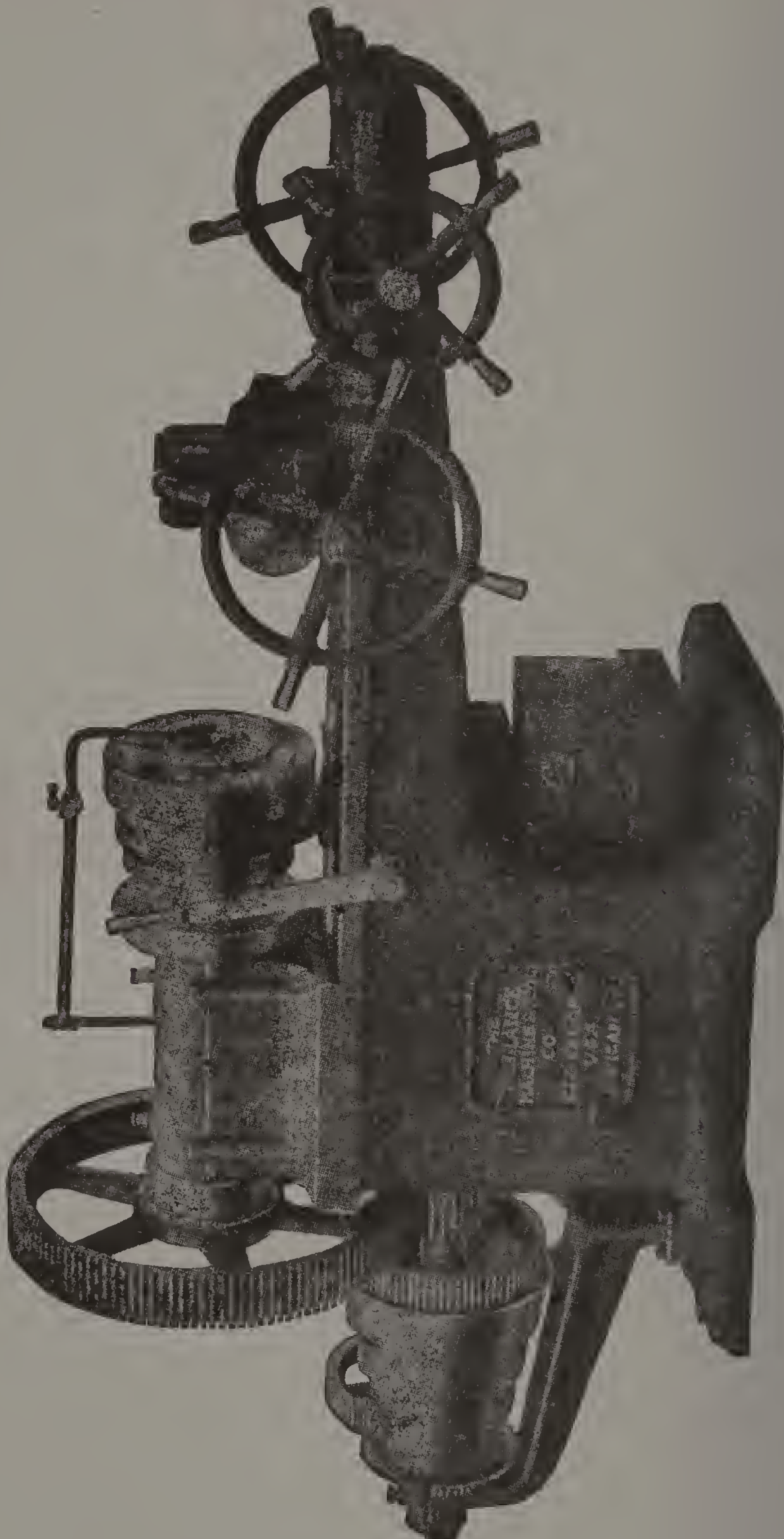


Fig. 204.

The vise jaws are opened and closed by means of a right and left hand screw, which on the smaller sizes of the single and double head machines is operated by a hand wheel directly. On the larger sizes the screw is operated by the hand wheel through reduction gears. The vise screws of triple and quadruple machines are operated by adjustable levers. The carriages of the single and double head bolt cutters are operated by a pilot wheel and rack and pinion. The rack pinion of the larger machines is operated through reduction gears. All gears are cut from the solid metal and provided with covers to prevent injury to them and to the operator.

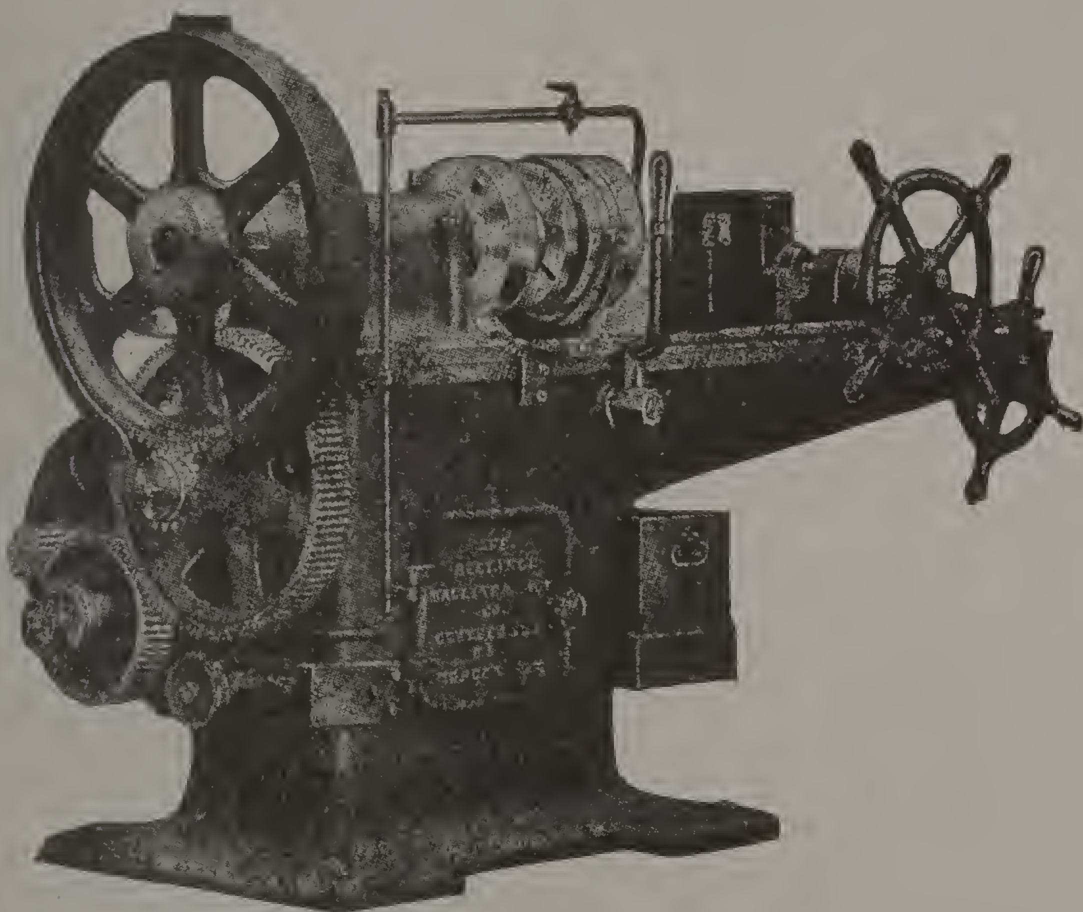


Fig. 205.

One and One-half Inch Motor-Driven Bolt Cutter. The illustration in Fig. 205 shows the rear view of a $1\frac{1}{2}$-inch gear connected single motor-driven bolt cutter. The motor is of the direct current, variable speed, reversible type, bolted vertically to the rear side of the machine column, where it is free from oil and chips. A train of gears transmits the power from the motor to the main spindle of the machine.

This arrangement gives, with the field control only, nine spindle speeds, for cutting either right or left hand, varying from 33 to 66 revolutions per minute.

Three-inch Motor-Driven Bolt Cutter. The design of the machine shown in Fig. 206 embodies several new and improved features. The main spindle is driven by a gear midway between the bearings, and all gearing is placed on the back side of the machine, instead of projecting from the end. The locking bolt and hand lever of the back gears are rendered more accessible. All the gears are covered.

A direct current, variable speed, reversible motor gives, with field control only, in connection with the back gearing, 18 separate spindle speeds, varying from 6 to 75 r. p. m.

Boring Machines.

Figure 207 illustrates a vertical boring-mill in which the horizontal table A is driven by means of bevel-gears. The bed is cast in one piece and well ribbed and braced. The housings B are of hollow section and have wide flanges where they are connected with the bed, to which they are attached by means of bolts passing through seamed holes. The cross-rail C is of box-girder form and has a wide slide surface for the saddles D. The saddles are made right and left so as to allow the tool-bars E to come close together. The tool-holders F are made from solid steel forgings and are held in the tool-bars by steel keys. The tool-bars are held in adjustable capped bearings and may be swung to angle, being counter weighted by weights attached to the chain shown at G. Power-feed screws H are used for elevating the cross rail. The tool-bars E are adjusted vertically by means of the hand-wheels K and

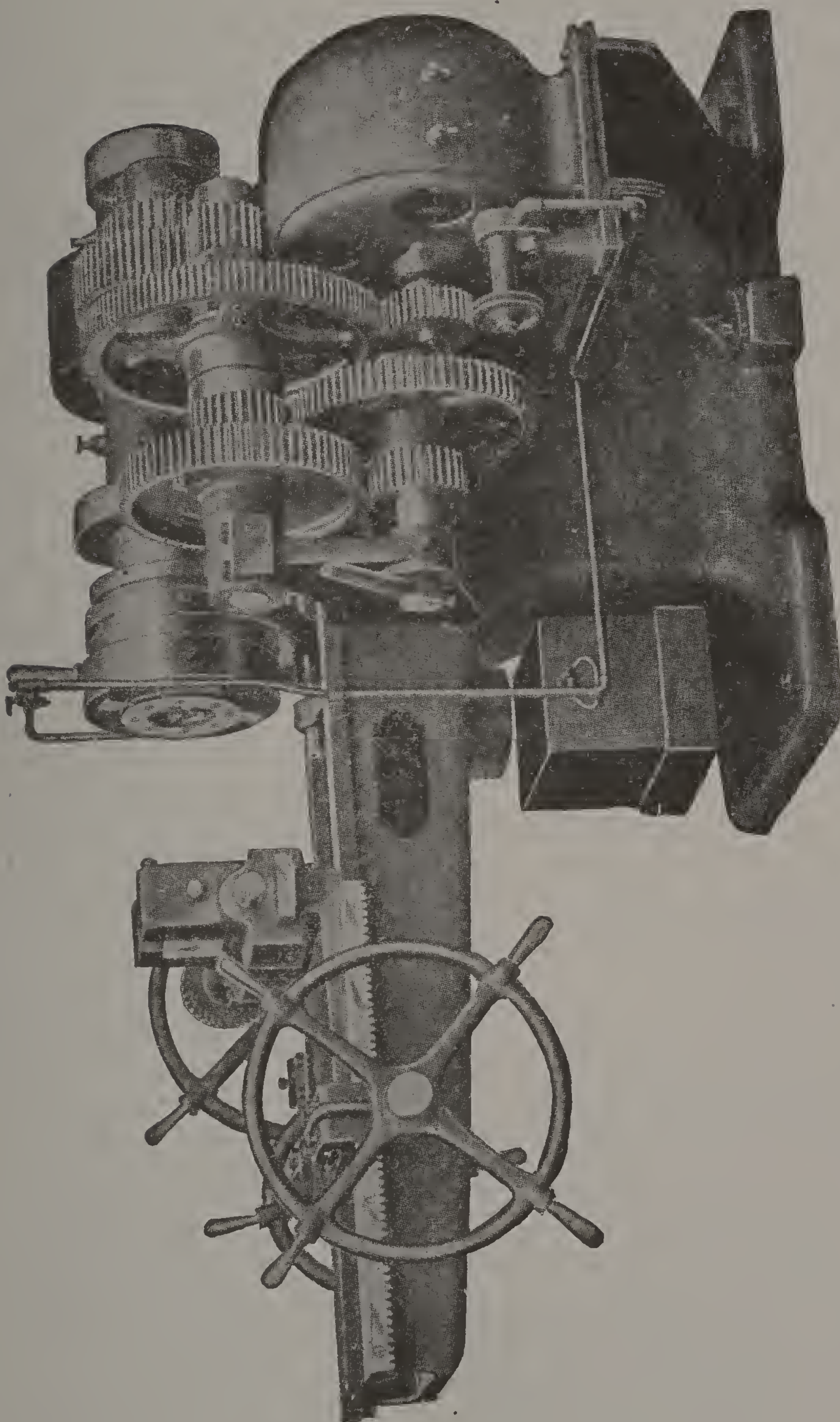


Fig. 206.

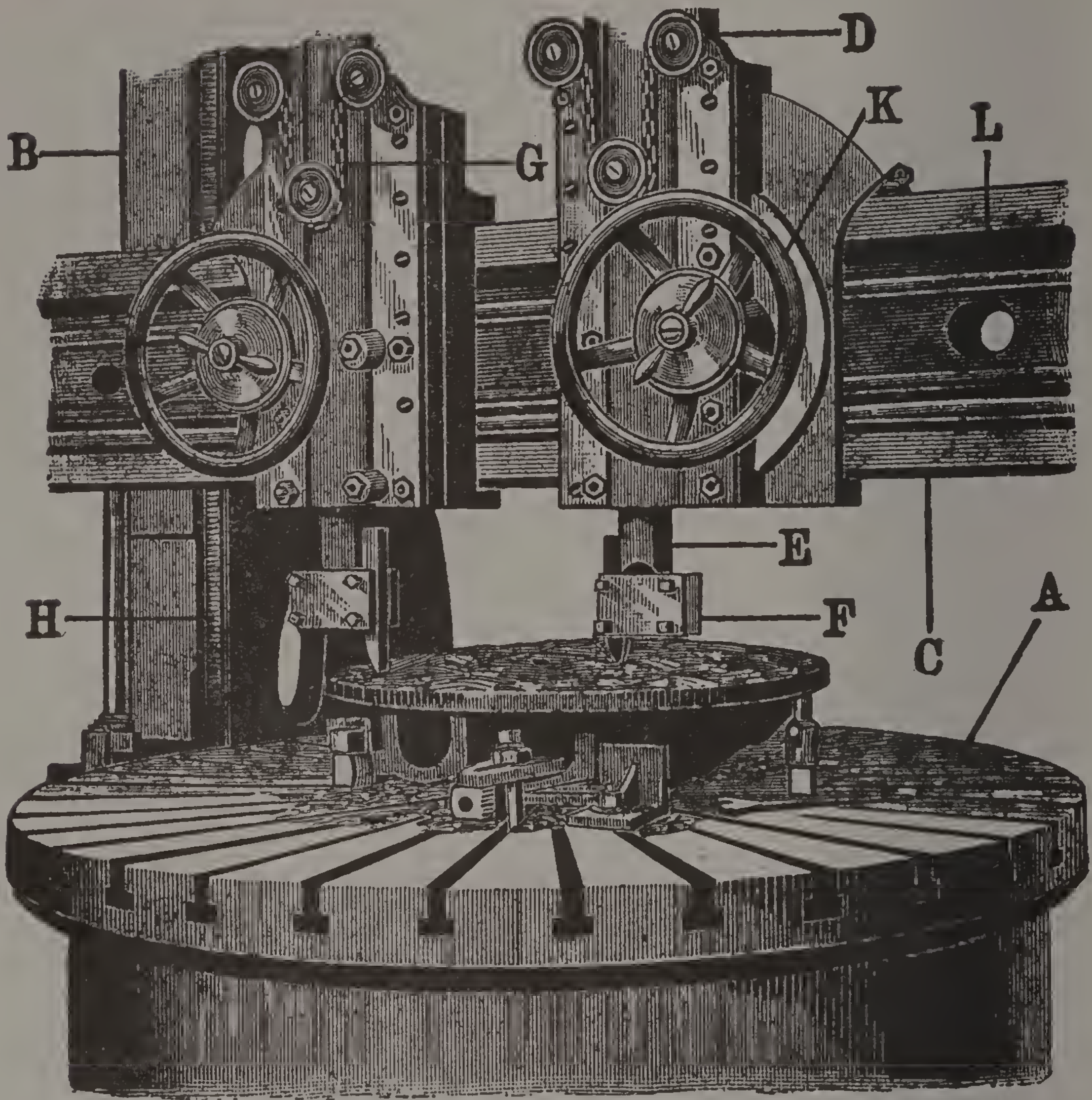


Fig. 207.

have a transverse or cross movement through the shaft L. The tool-holders F will grip the tools in any position, and are easily removable for the insertion of cutter-bars or special tools. The counterweight acts at all angles through the wide bearing surface and in addition, the table has an annular, angular bearing which increases the bearing surface and gives steadiness of motion. It has also a self-centering tendency, so that the combined weight of the table and spindle, as well as that of the work upon the table, tends to preserve and not destroy the alignment.

The advantages in the boring mill are that the work lies upon a horizontal table, and the weight of the table and the work is distributed on a large bearing provided for that purpose, which gives rigidity and smooth-cutting qualities, thereby avoiding all jar or trembling, which usually occur in overhung lathes.

Cylinder Boring Machine. A cylinder-boring machine is shown in Fig. 208, which is suitable for boring small pump, steam and gas engine cylinders.

The boring bar is provided with four power feeds, which are changed from one to another by means of a sliding key. It also has a quick and a slow hand motion, and is fitted with ball thrust-bearings.

A long bar running clear through the tail bearing can be furnished, or a short one with a taper hole in the end for the use of smaller bars. A simple form of facing head is readily attached to the boring bar.

The drive is accomplished from a single pulley by means of a variable speed transmission, which gives any speed from 10 to 50 revolutions per minute.

This machine was designed to do a large variety of accurate boring and drilling, such as is done in machine tool shops or in the tool rooms of manufacturing establishments.

It has been built with special view to accuracy and permanence of alignment, and is accurately fitted to surface plates and straight-edges and carefully lined up, to be true throughout the range of its various adjustments.

Automobile manufacturers will find them especially applicable to their work in boring cylinders, milling facets, drilling frames, etc.

Horizontal Boring Machine. This machine shown in Fig. 209 is designed for all kinds of boring, drilling and milling, for the latter it is particularly valuable, doing work that ordinarily would require a large planer.

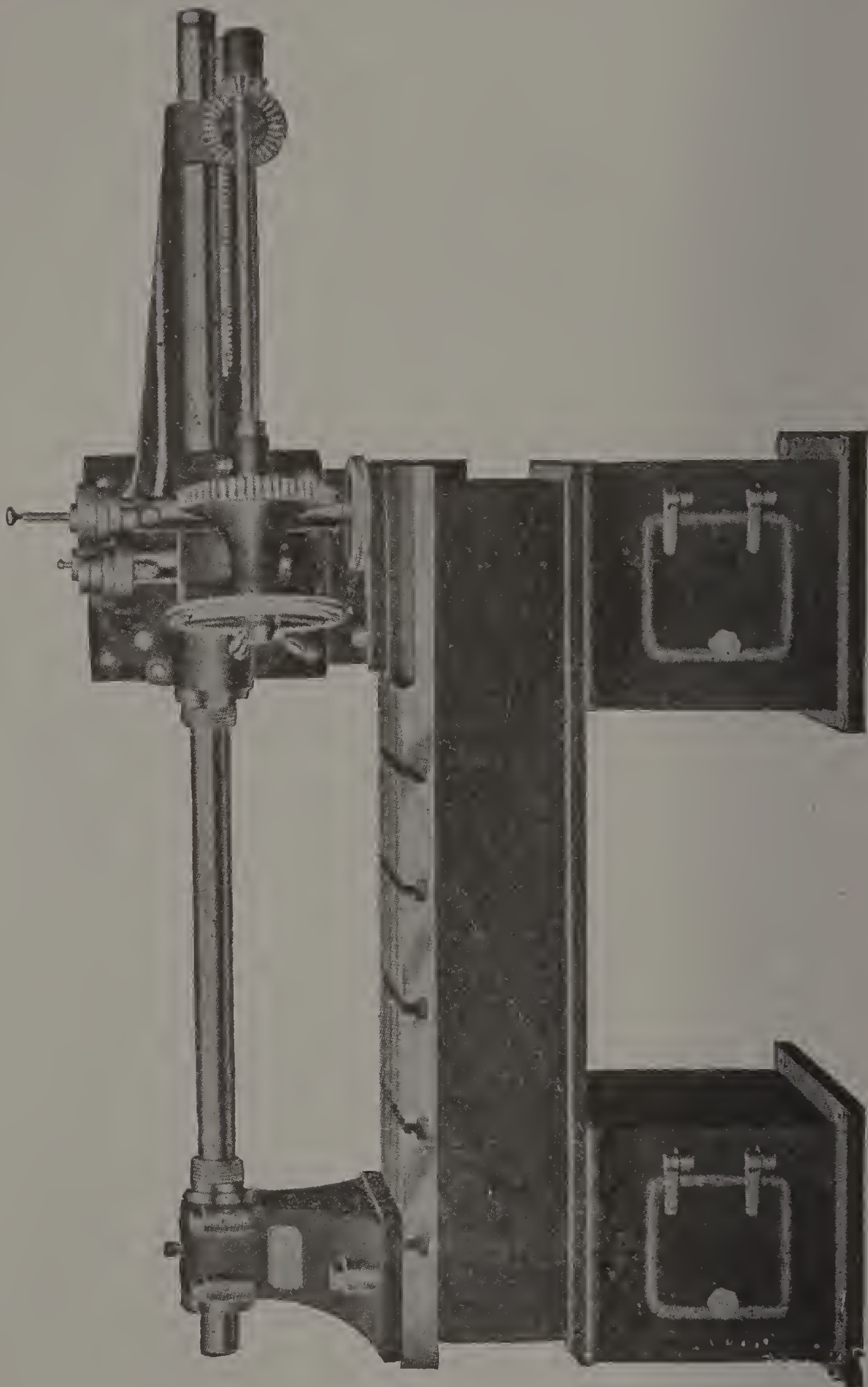


Fig. 208.

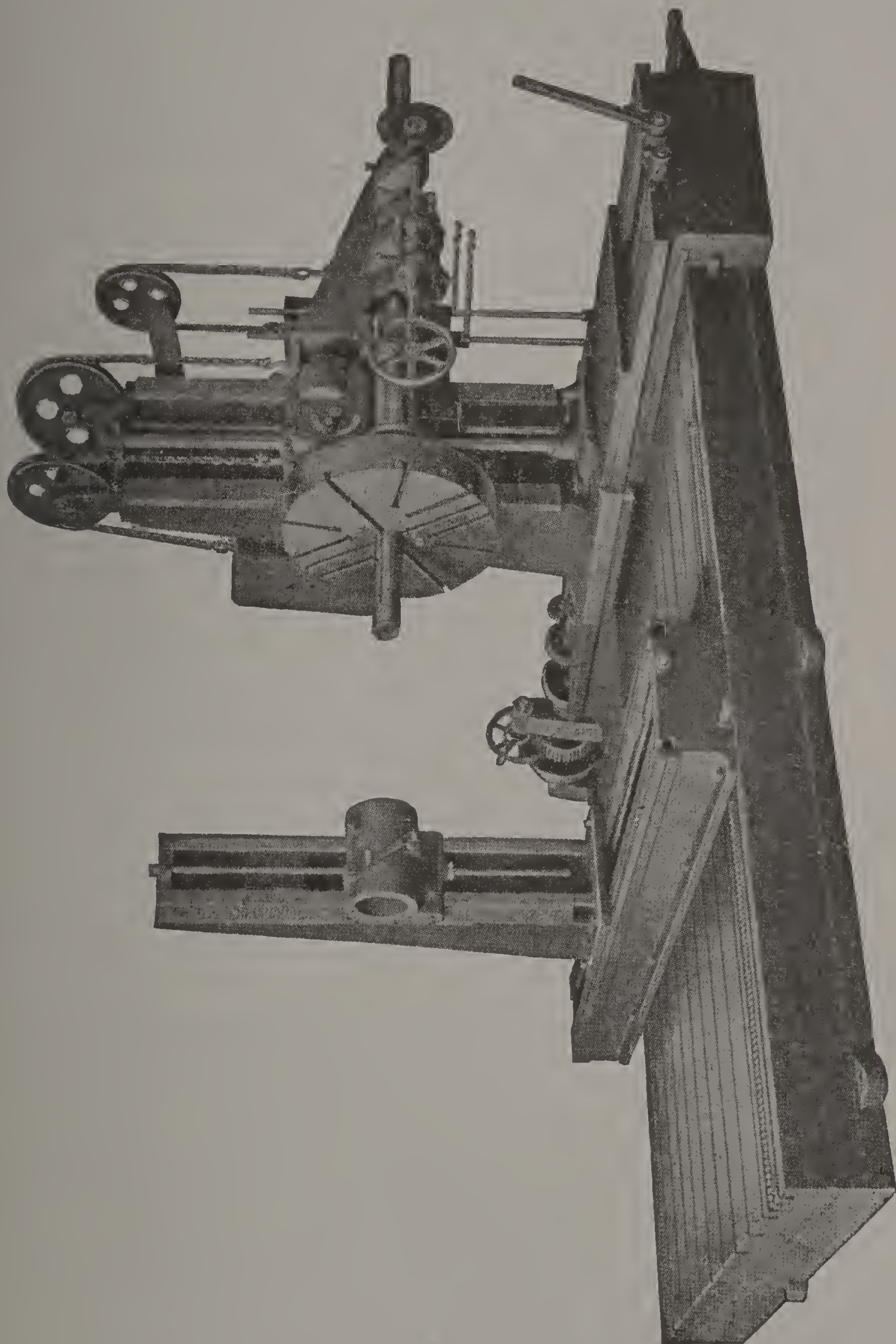


Fig. 209.

The spindle is steel, 5 inches in diameter and powerfully geared, giving 10 changes of speed and can be driven in either direction, it has 31 inches of movement by hand or power feed, with a full bearing at all times in the cast iron sleeve.

The feeds are positive, and six in number, thus permitting the spindle to be moved in either direction without reversing its motion.

The maximum distance from the top of the table to the centre of the spindle is 74 inches, the minimum distance is 25 inches.

The column has a horizontal movement on the bed of 73 inches, the spindle carriage has a vertical movement on the column of 49 inches.

The milling feeds are five in number, horizontal, vertical and in either direction.

Quick traverse, by power, is provided to the column and spindle carriage, which are also graduated with steel rules for accurate adjustment. The table, upon which to place the work, is heavy and well ribbed and arranged with suitable Tee-slots.

The support for the boring bars is mounted upon a carriage, which has a rapid hand adjustment on the table, by means of racks and pinions, and can be securely held in any position.

Horizontal Drilling Machine. The cone pulleys on the machine illustrated in Fig. 210 have 5 speeds for a 4-inch belt, it is strongly back-geared, giving 10 changes on the spindle, which is of cast steel 4 inches diameter, and has a 30-inch movement through the cone with provision for a 60-inch traverse when required. The steel spindle can be driven in either direction, it has a full bearing through the cast iron spindle at all times, and does not lose any of its bearing surface as it runs out, and has a quick movement by hand through a rack and pinion; there are six changes

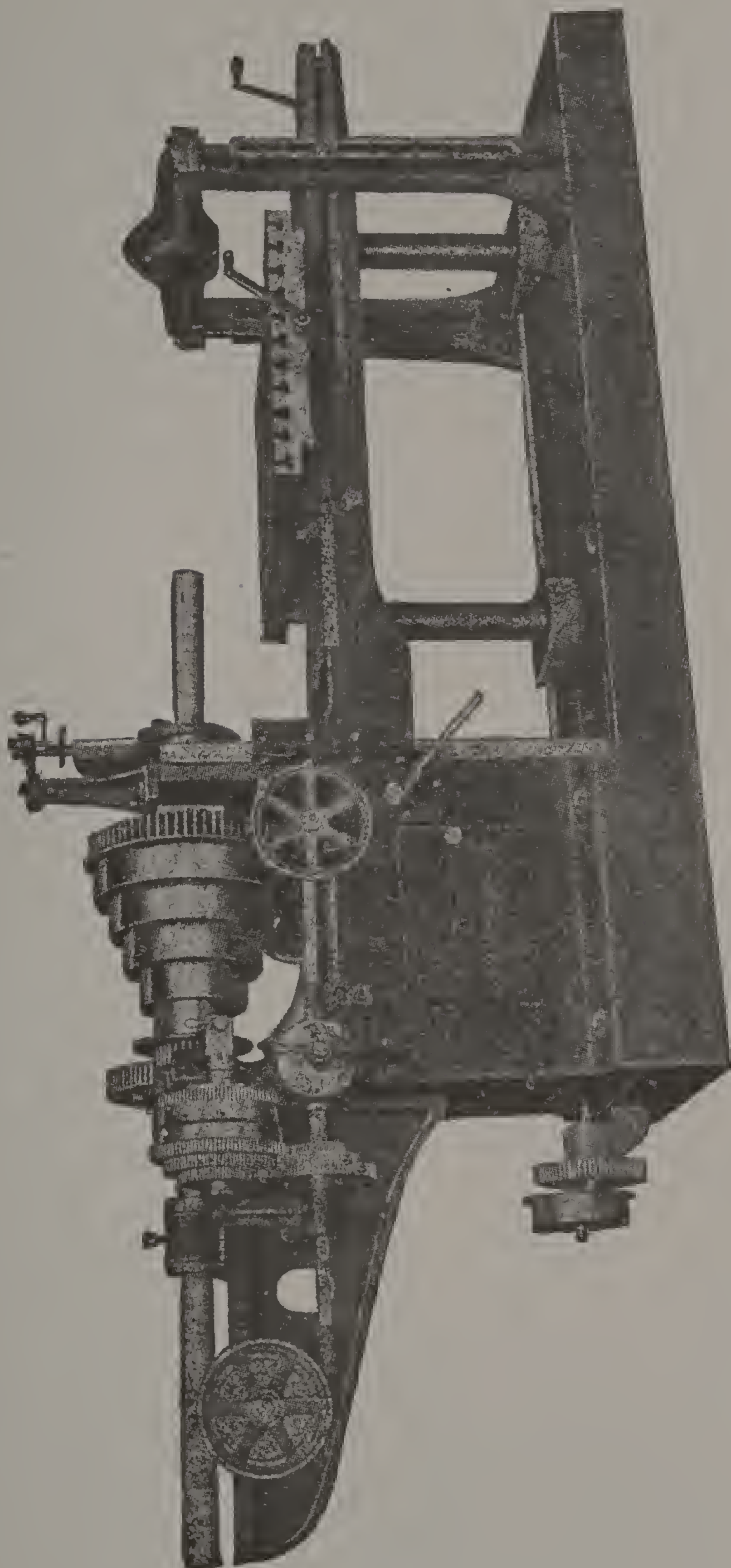


Fig. 210.

of automatic feed, three suitable for drilling and three for boring, by cut cone gearing, and the spindle can be fed in either direction without reversing its motion.

The table is 8 feet long, elevated by screws, worm wheels and worms which are driven by power. The table carries a saddle which has a movement parallel with the main spindle. On this saddle is a cross table 36 inches by 48 inches, which can be lowered until its top is 33 inches from the centre of the spindle, and which has a horizontal movement at right angles to it. This saddle and cross table can be removed to increase the capacity of the machine when necessary.

Vertical Boring Mill. The capacity of the machine shown in Fig. 211 is 44 inches in diameter and 37 inches in height under the cross-rail or 31 inches under the tool holders.

The table is 42 inches in diameter, is powerfully geared, and has ten changes of speed, 5 with back gears and 5 without. The maximum speed of the table is 20 r. p. m. and the minimum speed 6 r. p. m.

The teeth of both the table and pinion are of steel, and are accurately planned.

On the under side of the table there is an outer bearing nearly equal to the diameter of the base.

The table spindle is 10 inches in diameter and 20 1-2 inches in length.

The table spindle has a straight bearing which acts in conjunction with an angular bearing to receive the side strains. There is also a thrust ball bearing on the lower step of the spindle which acts as a preventative against any lifting tendency, and which relieves the friction of table when a heavy cut is being taken.

The turret slide can be set to bore, turn and cut 8 and 11 1-2 threads per inch, and has a vertical movement of 24 inches.

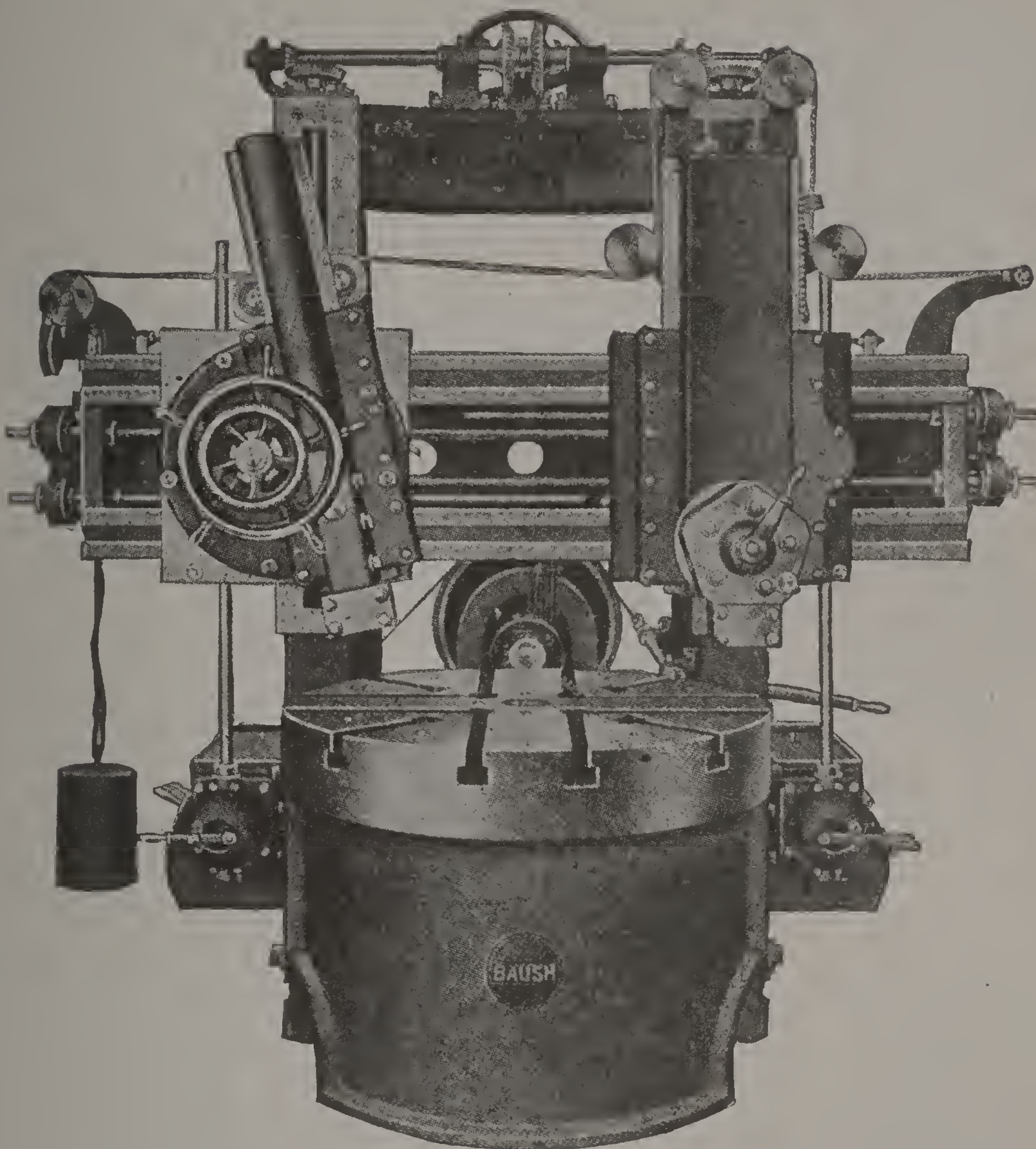


Fig. 211.

The turret slide can be set to bore, turn and cut 8 and has five 2 5-16 inch holes.

The heads are entirely independent in their movement, both as to direction and amount of feed. The left hand head can be set at any angle, and has a movement of 24 inches. Either head can be brought to the center for boring, both heads have a vertical movement of 24 inches.

The heads are attached to steel feed-screws by split nuts, which can be opened, and a rapid movement obtained by ratchet and pinion, engaging a steel rack on the cross-rail.

The feeds are positive and have fifteen changes, ranging from 1-64 inch to 61-64 inches horizontally, and 1-64 inch to 9-16 inches in angular and vertical directions.

The cross-rail is raised and lowered by power, which can be done without removing the table.

The band brake which operates on the main driving cone, by hand, stops the table instantly.

The back gears can be changed by means of a lever, without the use of a lock nut.

Drill Presses.

Figure 212 shows a vertical or upright drill-press, back-geared, with both hand and power-feeds and an adjustable raising and lowering swing-table.

A is a hand-lever for the quick adjustment of the spindle H when using the hand-feed. B is the power-feed device with autotmatic stop, worm-feed and quick return motion for the drill-spindle. C is the step-cone pulley which is driven from the step-cone shown at N. D shows the bevel gears which transmit the motion from the horizontal shaft to the vertical drill-spindle D. E shows the chain to which a weight is attached to balance the weight of the spindle H. F is a hand-wheel for the hand-feed attachment on the worm-gear spindle. G is a quill or sleeve for raising or lowering the drill-spindle D, by means of a rack I attached to the sleeve G, which engages with a pinion upon the worm-gear spindle. J is the upright column or standard which carries the drill-spindle driving mechanism. K shows the crank for raising and lowering the table L by means of the bevel gears and the screw M. L is the circular table or face-plate which is provided with slots for the bolts which hold down the work. R is a bracket which supports the table L and S a foot-lever for actuating the belt-shifter over the tight and loose pulleys P. T is the base-plate which has its upper face planed and is pro-

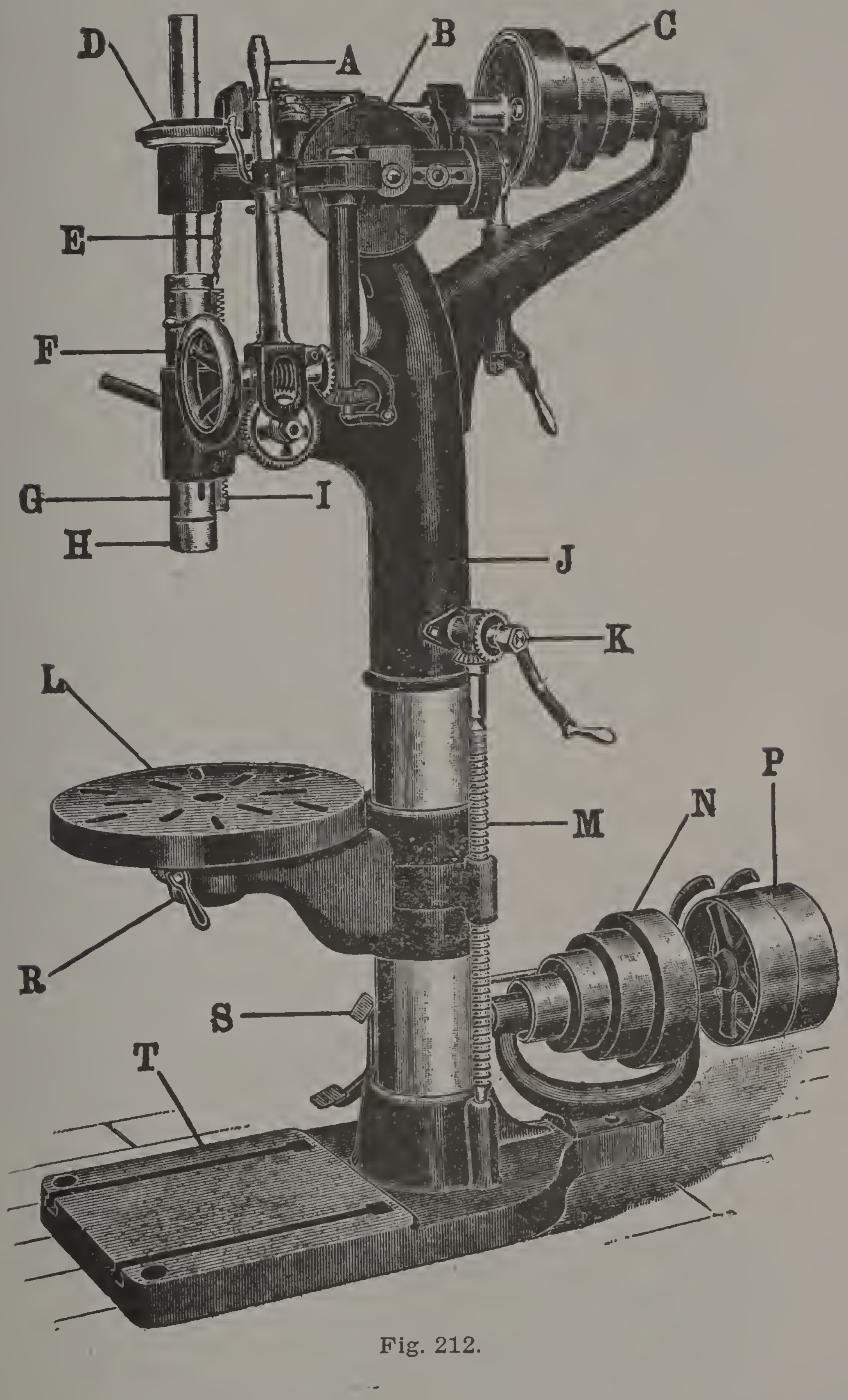


Fig. 212.

Fig. 213.

vided T-slots for bolts to hold large work which cannot be drilled on the table.

A torsional stress is imposed upon drill presses owing to the fact, that a revolving drill does not cut at its central point, even though its outermost circumference may have an excellent cutting effect.

The torsional strain is easily overcome by using a spindle of high carbon steel, accurately cut gearing, and stiff driving shafts. To reach large work the drill head must overhang, and therefore requires a very strong frame to withstand the end pressure.

Friction-Driven Drill-Press.

The drill-press shown in Fig. 213 embodies principles not usually found in other tools of its kind, and is simple in construction and more effective in operation than almost any other drill for light work.

The speed of the drill spindle can be increased or diminished instantly, or the motion reversed, without stopping the machine or shifting the belts.

More or less driving power can be applied to the drill spindle, as the size of the drills or the nature of the work may demand.

The feed lever is provided with a very sensitive adjustment, which with the perfect control of the operator over the speed and power makes it possible to use the smallest drills with the least possible danger of breakage. By a hand screw within convenient reach the platen or table can be moved rapidly on the column and can be clamped firmly at any desired height.

All bearings and wearing surfaces are especially fitted for durability, and ample provision is made for taking up wear.

It is claimed for this drill superiority, both in simplicity of the construction, which renders it less liable to derangement, and in effectiveness of operation on account of the variations of speed and power being so completely under the control of the operator, whereby all the adjustments are made with the least possible loss of time. It is smooth and almost noiseless in operation, and entirely free from the vibratory motion commonly found in drills of this class where the spindle is driven by belt.

Gang Drill Press. Figure 214 illustrates a new pattern of a 3-spindle back-geared Gang Drill press, with an Automatic Approach and Return Feed. It is also made with spindles with or without back gear, spindle with plain lever, spindle with combined lever and worm feed, spindle with self feed and automatic stop, and with spindle with reverse motion for tapping.

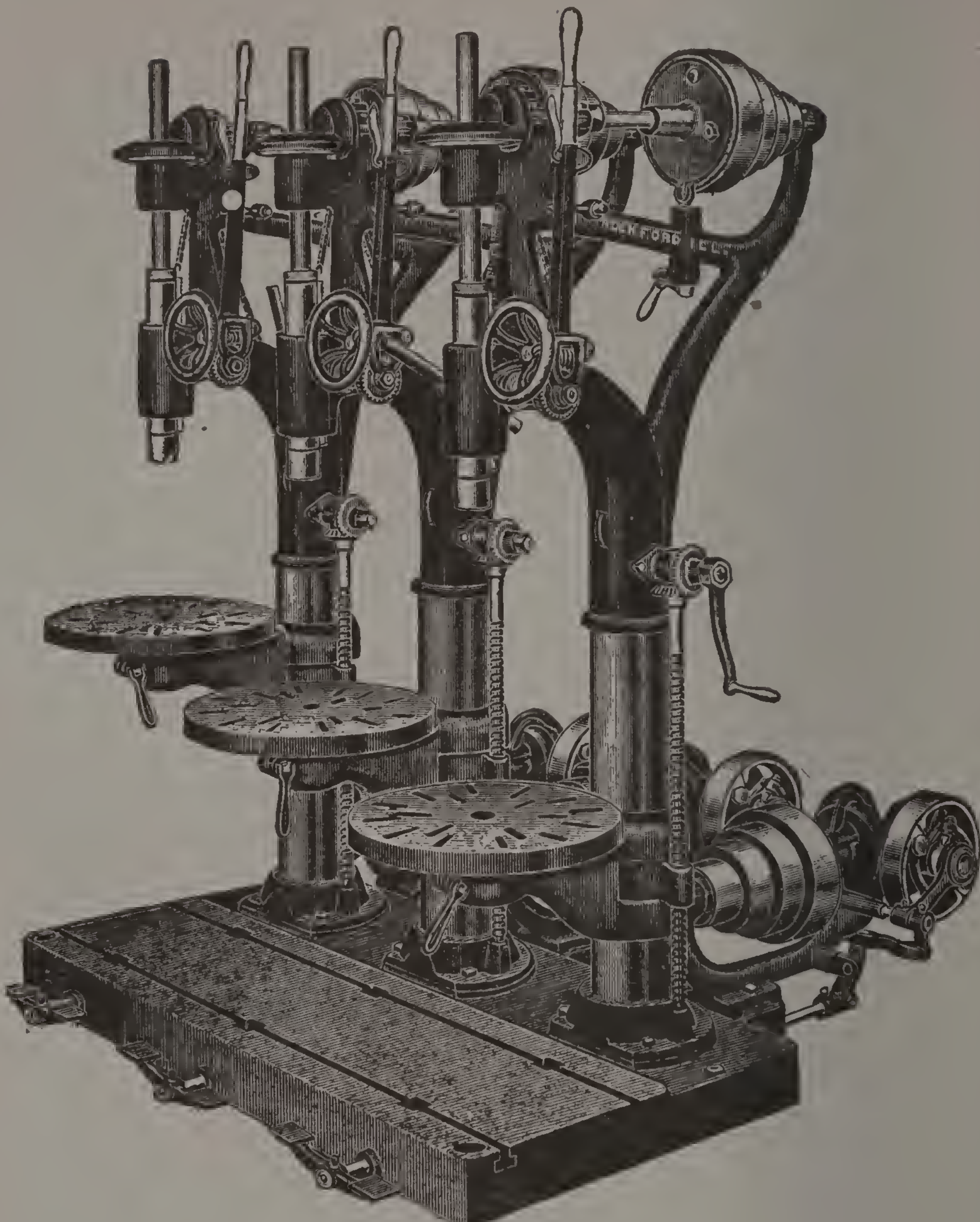


Fig. 214.

Motor-Driven Drill-Presses.

In view of the fact that electricity is becoming so popular as a motive power for driving machinery, two methods or styles of mounting motors to Upright Drill-Presses are shown. Both illustrations (Figs. 215 and 216), show direct-connected electric driven tools. One is called a direct-connected Belt-Driven motor outfit, and the other a direct-

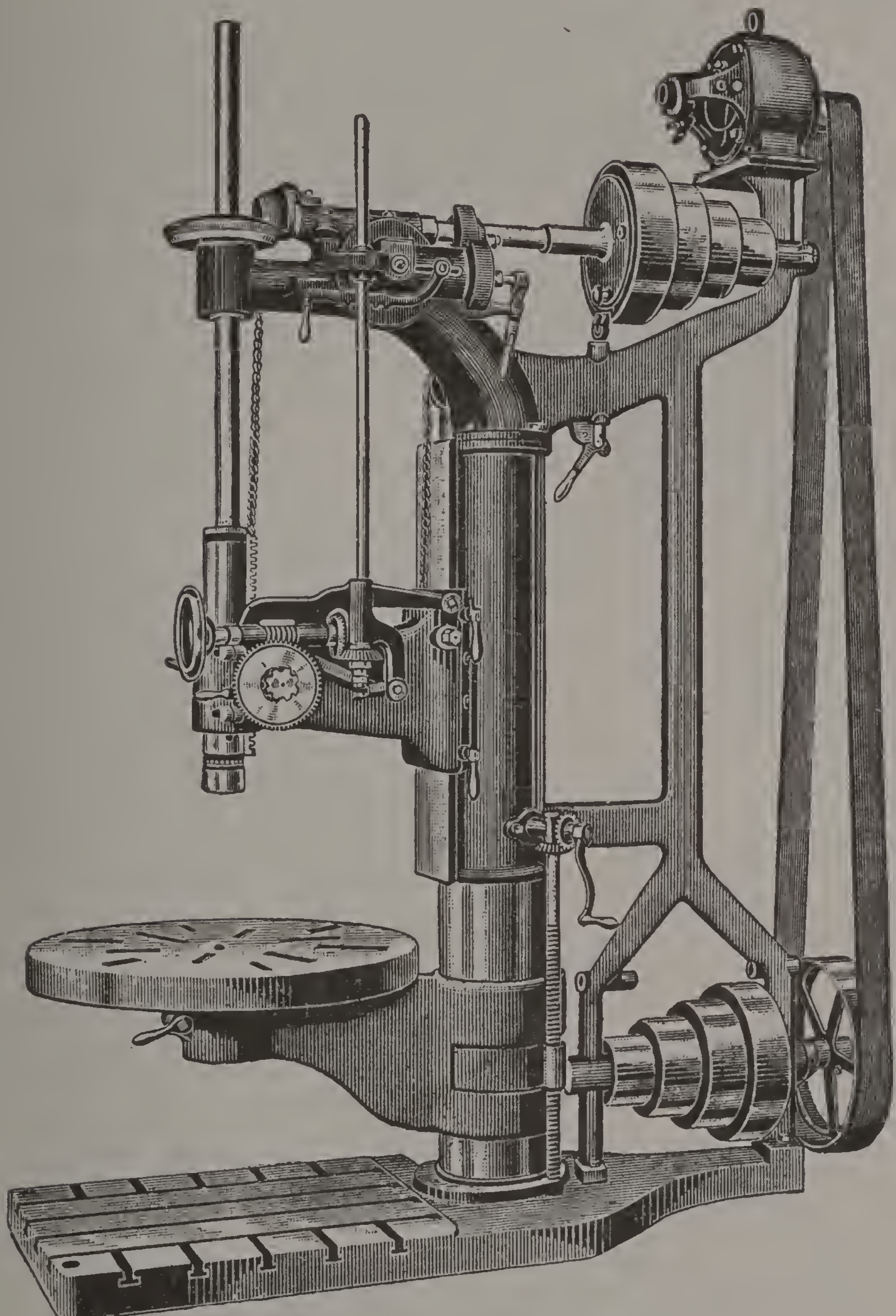


Fig. 215.

connected Gear-Driven motor outfit. The gear-driven outfit has a reverse motion independent of the motor. The belt-driven outfit is the most popular, not only on account of its less cost, but from the fact that the motor is entirely out of the way.

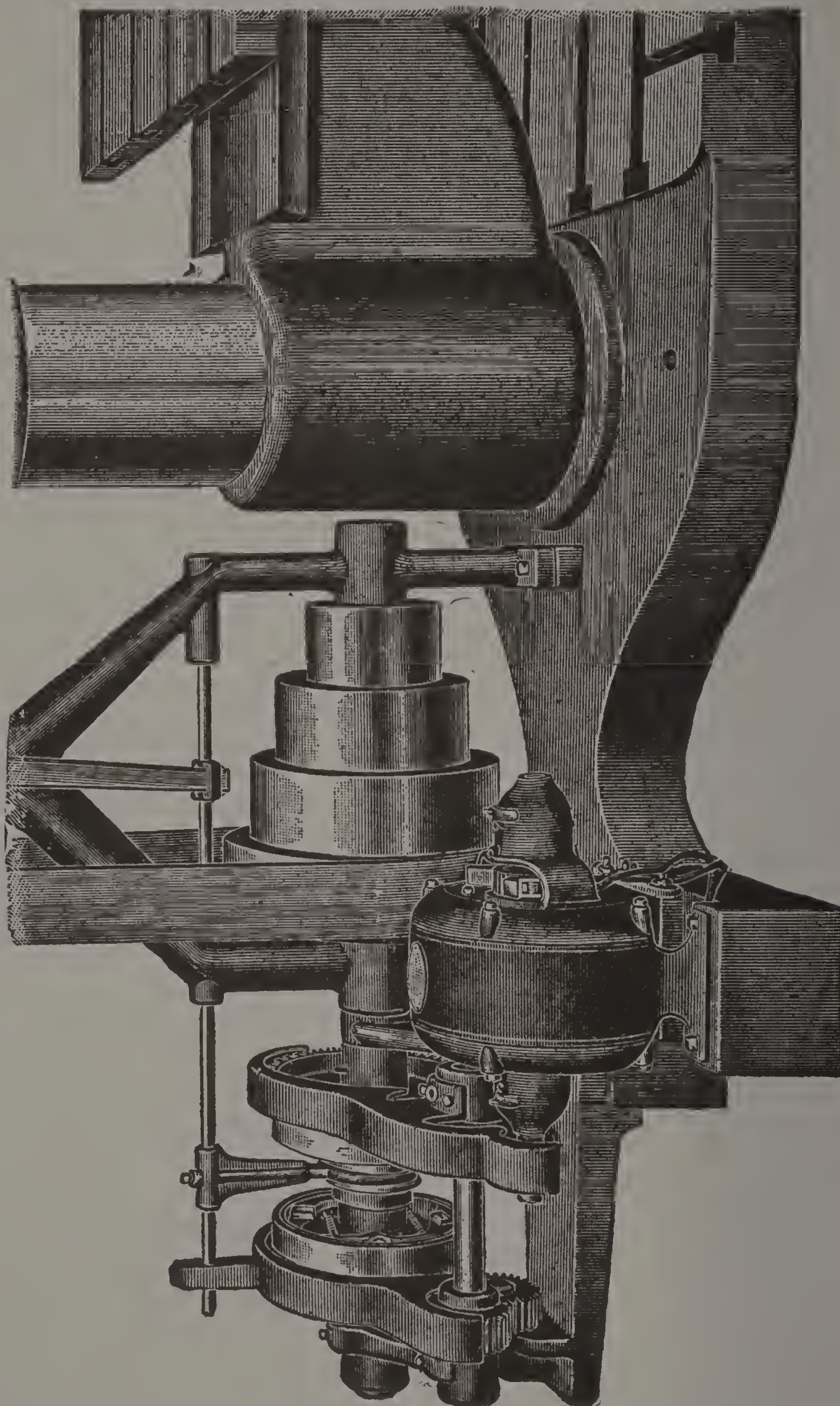


Fig. 216.

Upright Drill. The drill press shown in Fig. 217 is said to be a very strong and stiff tool, thoroughly well made and high grade in every respect. It is made in the following styles:

Without back gear, with hand lever feed.

Without back gear, with combined lever and worm feed.

Without back gear, with self feed, automatic stop, combined lever and worm feed.

Back geared, with hand lever feed.

Back geared, with combined lever and worm feed.

Back geared, with self feed, automatic stop, combined lever and worm feed.

All the drills have a quick return lever for the spindle.

The spindle is fitted with the No. 3 Morse taper.

Radial Drill. The radial drill shown in Fig. 218 embodies in addition to all the useful features of other machines, several decided improvements.

The stationary column is of heavy section throughout, and is made of one piece. It is bolted to the base and does not revolve. There are four webs inside, extending its entire length, which add greatly to the strength of the machine and provide for resisting enormous strains at any height, particularly when the arm and spindle are at their maximum distances.

The arm is made of pipe section, its upper brace being as close to the head as possible, while the lower brace is at the outer edge. This prevents twisting of the arm while resisting the extreme upward pressure of the spindle when drilling. A top cap, resting on roller bearings, supports the arm, both making a full circle about the column, they can be instantly locked by fixed binder levers. The arm is lowered at almost three times the elevating speed by a screw having ball thrust bearings. A bronze plate, attached to the arm, shows the operator the correct speeds for drilling either cast iron or steel.

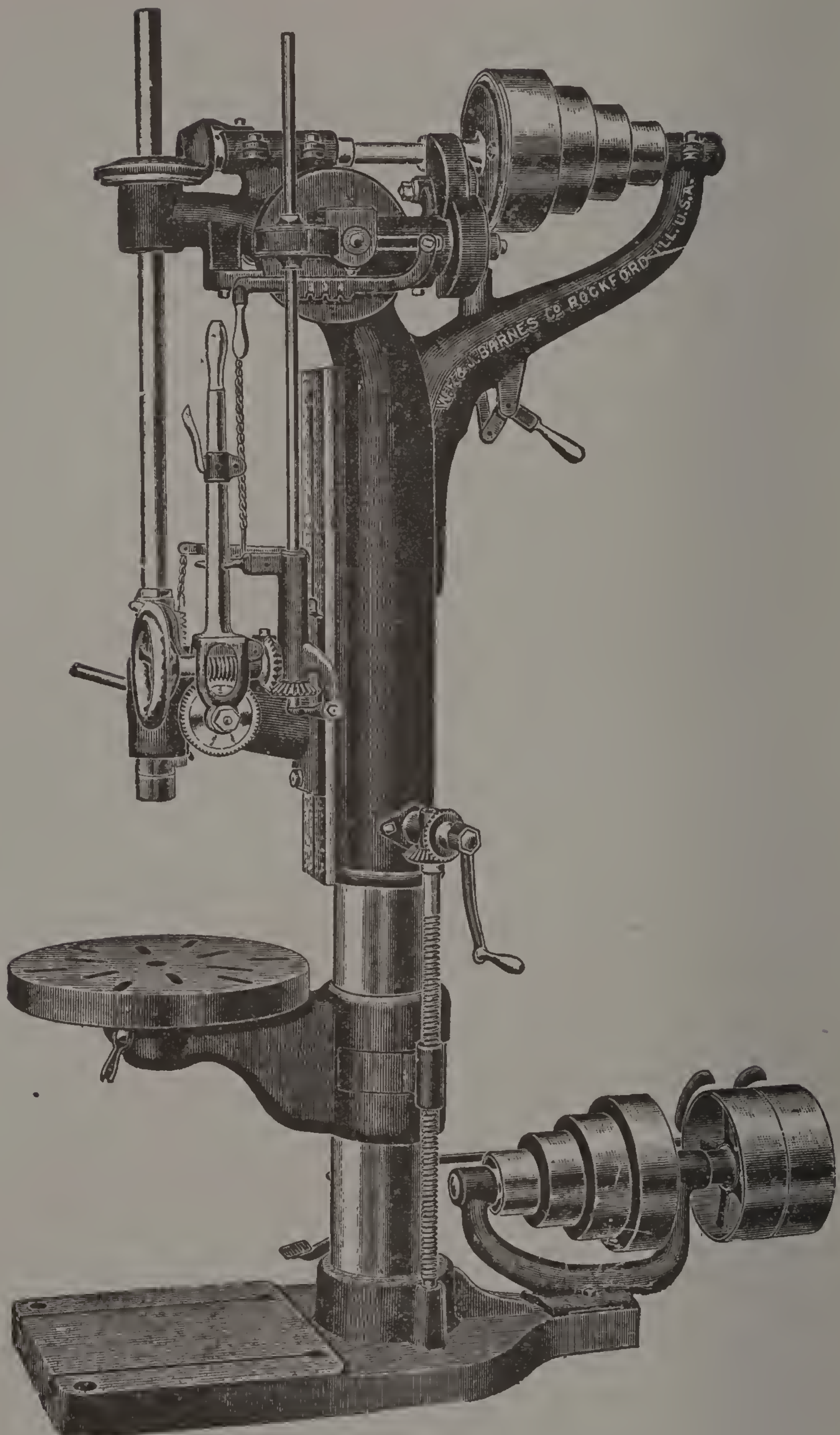


Fig. 217.

A ring, graduated to 360 degrees, turns with the arm, and, in connection with a zero on the column, provides a means for bringing the arm back to a definite position as often as desired. This feature is of special advantage in working on duplicate parts held in fixed jigs or otherwise.

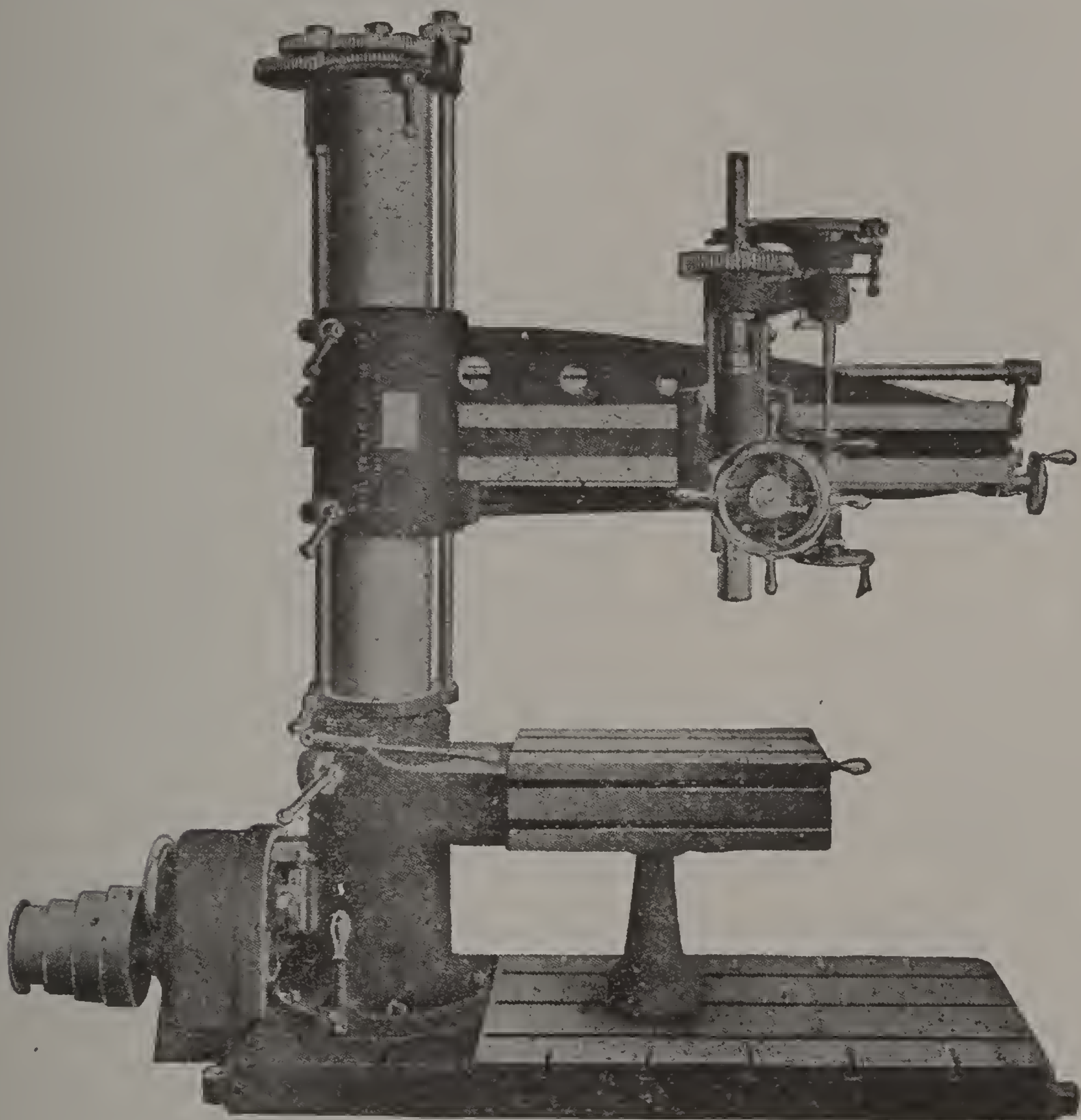


Fig. 218.

The head can be locked to the arm, it is traversed by means of a double pitched screw which engages with the revolving dial on the outer end of the arm. This permits the operator to bring the head to within .001 of an inch of the required place.

The spindle is made of crucible steel, and is ground and counter-balanced, it has a quick advance and return, and has a provision for taking up wear. When used for tapping, it is impossible to accidentally engage either automatic or lever feed, thus avoiding the breaking of taps. An adjustable gauge screw causes the spindle to slip when a tap reaches the bottom of a hole. It requires only four seconds to change the spindle speed from 18 to 370 revolutions per minute, or to any of the 16 available speeds, are arranged in geometric progression, the maximum being more than 20 times the minimum.

The starting lever projects from the loose ring encircling the column and is within easy reach, it can be operated from any position about the machine. It controls the raising and lowering of the arm, also the starting, stopping and reversing of any of the 16 spindle speeds.

The automatic feed is driven by means of a friction plate and by bringing the small friction wheel from the center to the outer diameter of this plate, any feed from .000 to .023 inch per revolution of spindle can be instantly obtained, and while the drill is at work. The amount of friction required for light or heavy drilling is regulated by a knob on the right of the feed shaft.

The automatic trip is provided with a safety stop which prevents the feeding of the spindle after it reaches the limit of its travel. A graduated bar on the counterbalancing weight is set to zero when the drill enters. The bar has several adjustable dogs to trip the feed as often as desired, these do not interfere with the spindle travel. The feed can also be tripped by a lever on the vertical feed rod.

The base of the machine is deep and very heavy, with fan-shaped ribs leading to the center of the column. These ribs insure extreme rigidity, no matter where the pressure of the spindle may come.

The table usually furnished with the drill is plain, but a round or worm-swiveling table can be supplied, if desired. It has a round boss in its center, which can be bored to receive bushings for boring bars passing through the center of the supporting stand on the base.

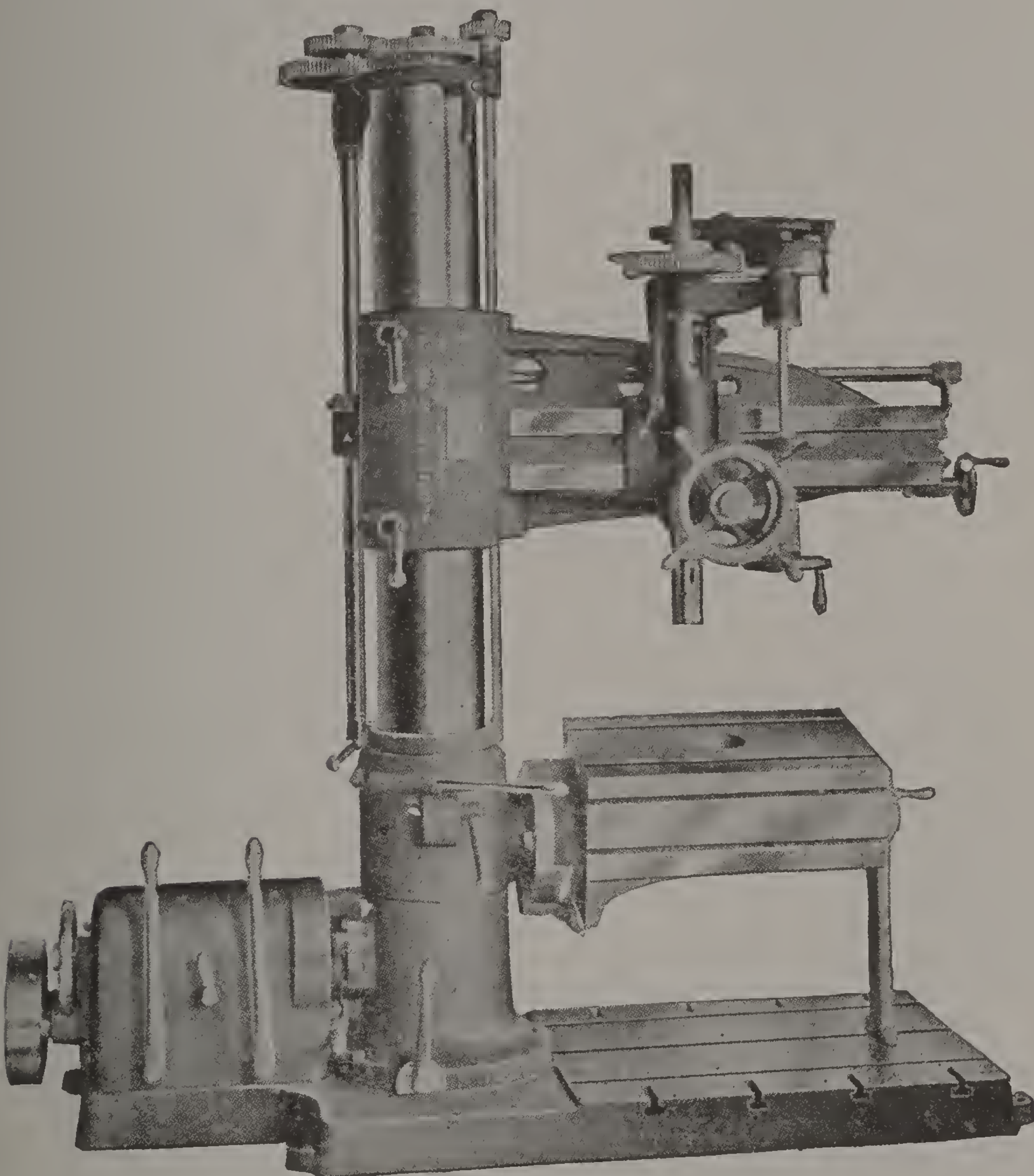


Fig. 219.

Each binder lever is forced by a small nut onto its screw, which has a tapered end, so that, in case of wear, it can be released and changed to suit the operator.

Radial Drill. The drill shown in Fig. 219 has a sliding head, back geared and self-feed and automatic stop and quick return lever for the spindle.

These machines are designed with a view of having all the adjusting parts easy of access, and so arranged that the operator can with the least effort control their action. To stop or start the spindle, to change the speed, to engage the self feed, to change from fast to slow feed, or from hand to self feed, to raise or lower the sliding head on the column, to raise or lower the platen or swing it from under the spindle, to throw in or out the back gearing —all are operated instantly by permanently attached devices for these various purposes. The drills have roller bearing for spindle thrust.

Particular attention is called to the positive self feed with eight changes of feed, gear driven (no belts).

The sliding head and spindle are counterbalanced, all shafts are of steel, and the bearings are extra long.

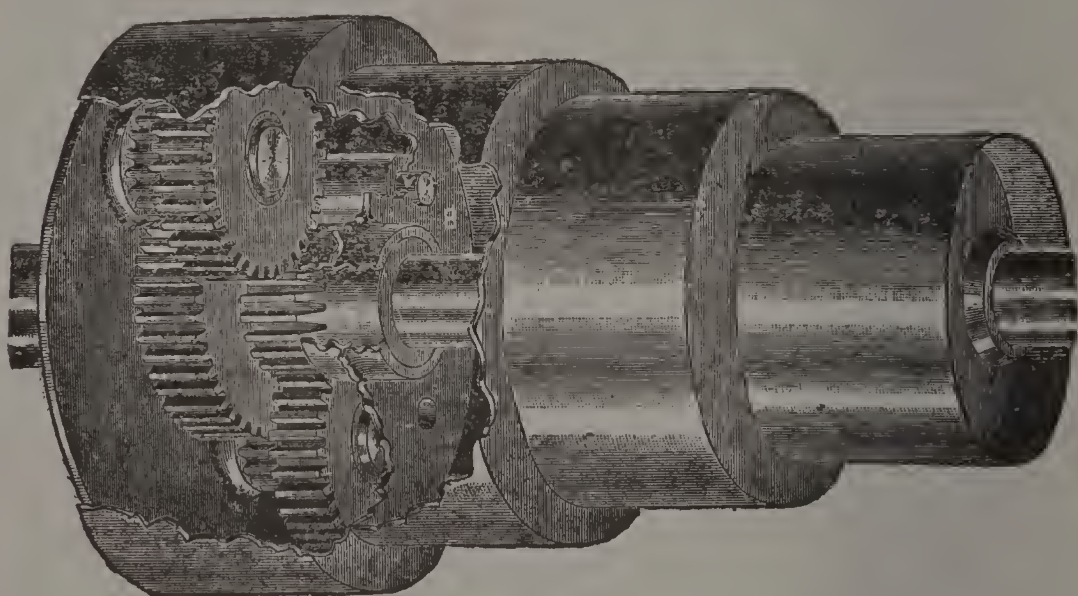


Fig. 220.

Back Gear of Drill Press. The cut in Fig. 220 shows the cone pulley withdrawn from the shaft, and the locking plunger and lever for throwing in and the back gearing exposed to view.

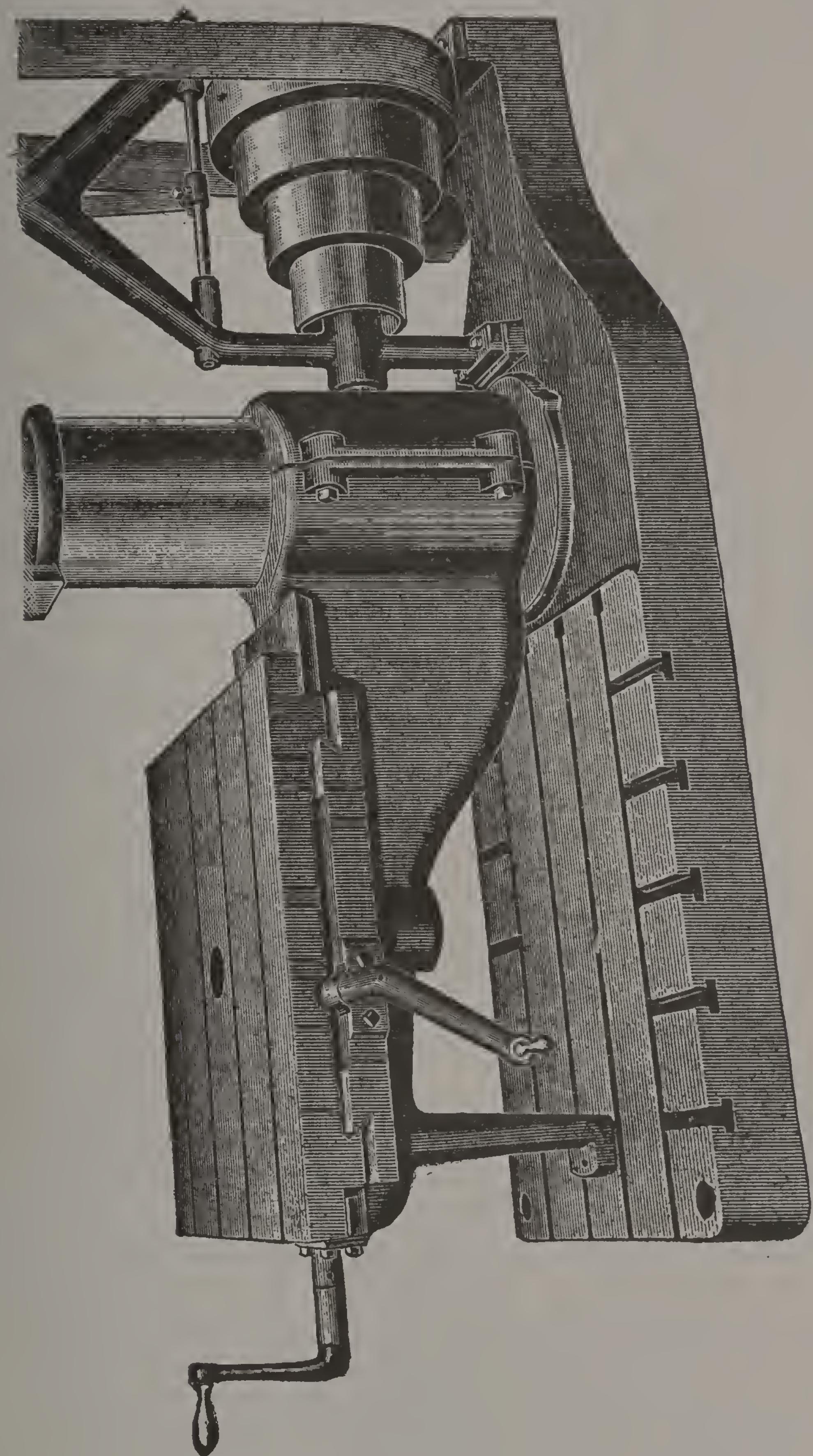


Fig. 221.

This internal back gear is not new and untried, but has been used for fifteen years on drill presses.

This style of back gear throws no oil, accumulates no dirt, is quick acting and always in working order.

Compound Drill Press Table.

The Drill press tables such as are illustrated in Fig. 221 have both transverse and longitudinal feed and may also be swung radially around the column of the press if desired.

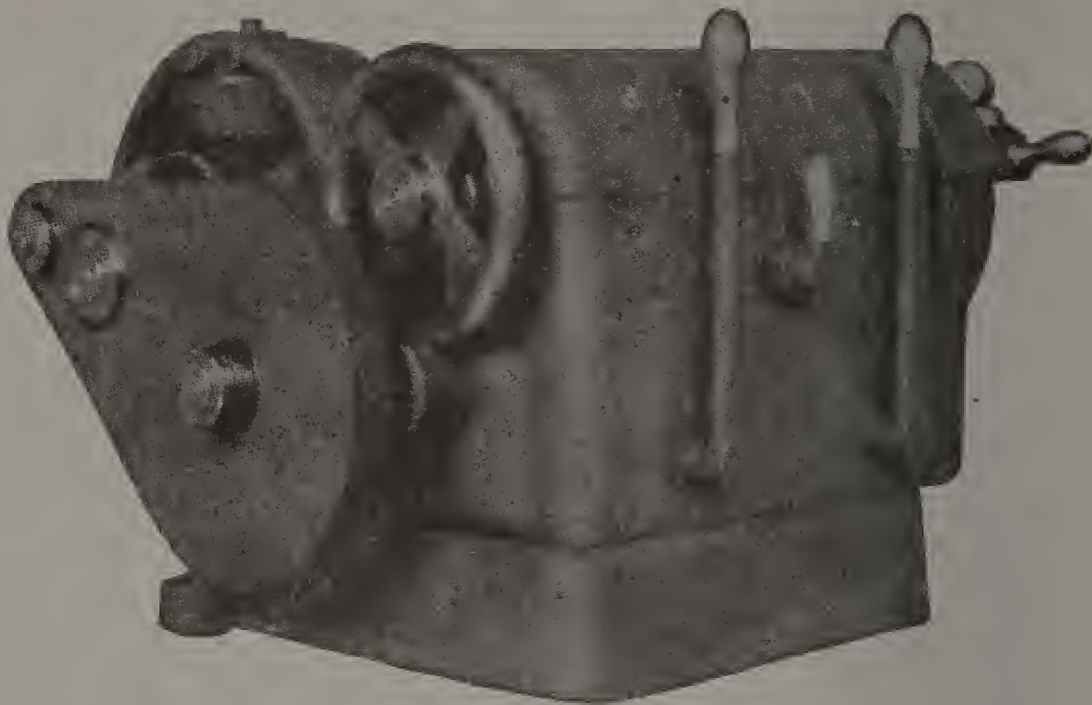


Fig. 222.

Gear change Box. The accompanying illustration Fig. 222 shows a speed box, equipped with a constant speed motor, which can be furnished in place of the plain pulley drive. Either style speed box excels the cone pulley drive, because it is more easily manipulated, does away with the shifting of belts, and can be driven from below the floor or at right angles to the line shaft. The two long levers in front of the box control four changes of speed, the small one between them locks one lever while the other is in use.

The numbers cast on the lid of the box indicate in what direction to push the levers. They correspond with the index plate on the arm, for the proper spindle speed.

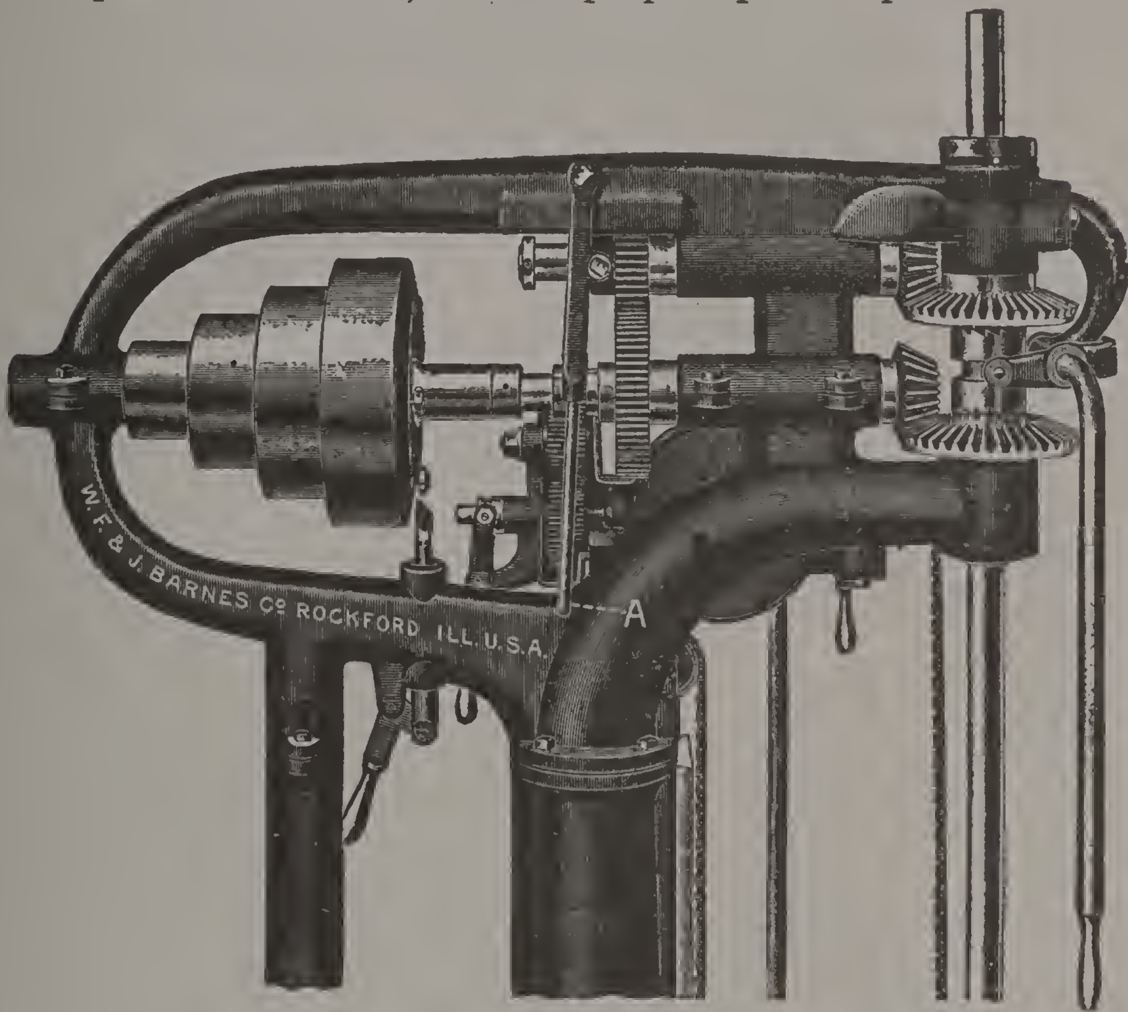


Fig. 223.

Tapping Attachment for Drill Presses.

The geared tapping attachment shown in Fig. 223 works directly on the spindle. It has a positive clutch for engaging the forward and backward motions and gives a reverse speed of 2 to 1. A movement of the conveniently located lever starts, stops, and reverses the spindle instantly without any jar while the machine is in motion. To disengage the tapping attachment throw the lever A and the machine is changed from a tapping machine to an ordinary drill press and vice versa. There is no undue wear as the extra gearing is running only when required.

Fig. 224 shows the change-speed mechanism of the feed of the drill presses described in Figs. 215 and 217.

Tire Drill. The drill shown in Fig. 225 needs very little explanation. For drilling, boring and countersinking tires and rims, it is one of the most rapid and handy tools on

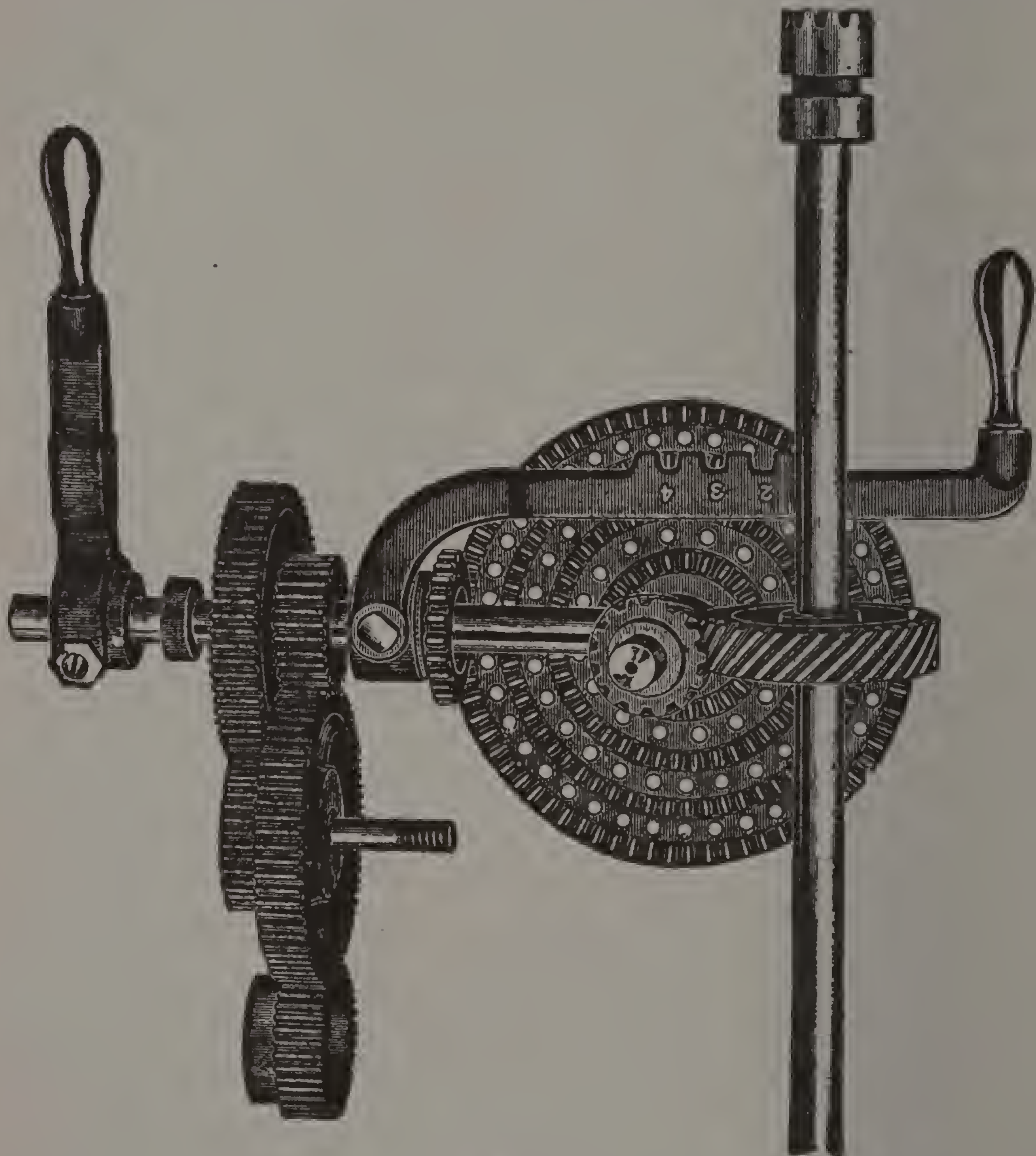


Fig. 224.

the market. By a movement of the lever, each spindle is brought into position and locks itself ready for action, only the spindle in use revolves. The hole in the spindle is No. 2 taper.

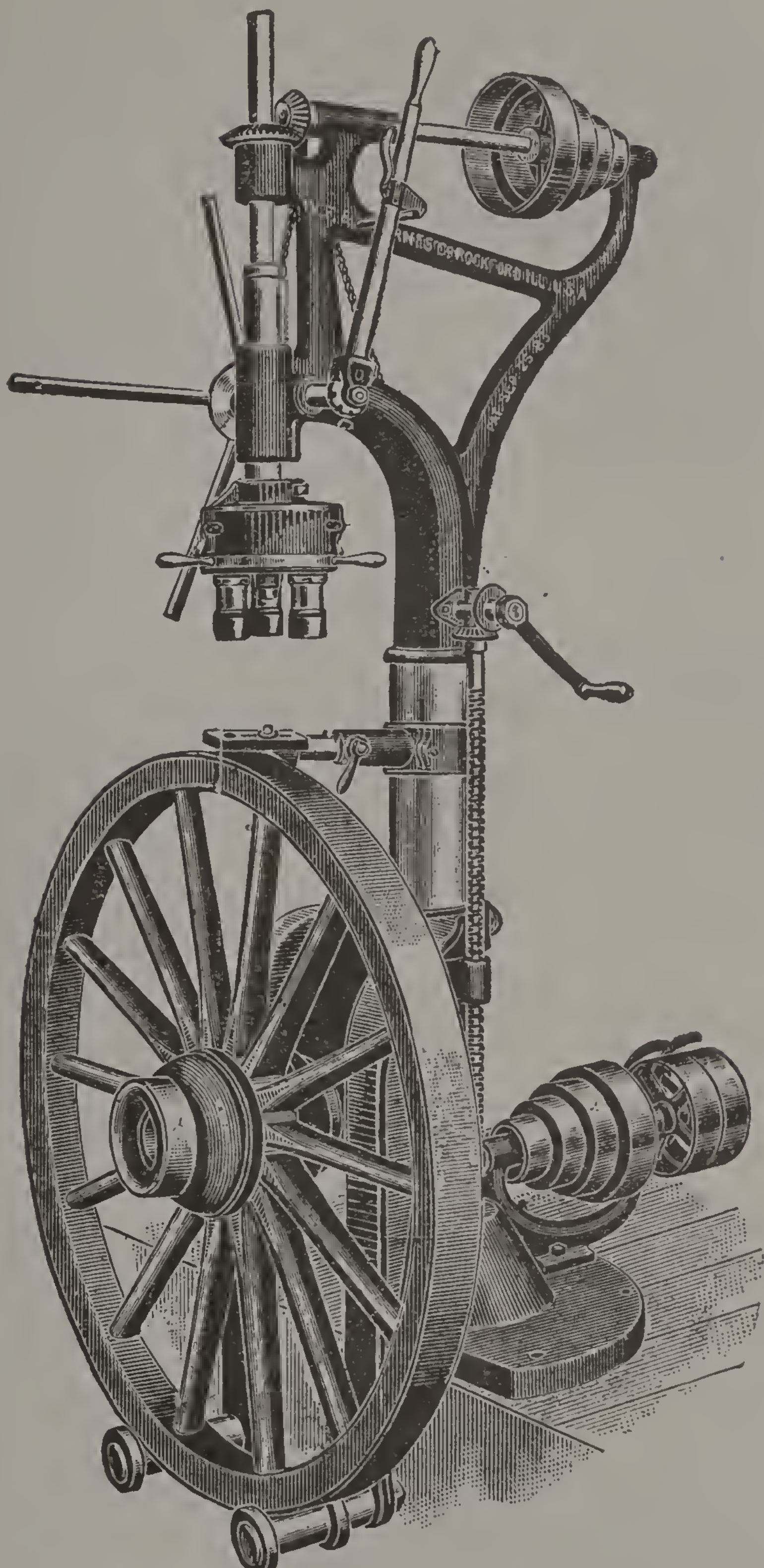


Fig. 225.

The arm on which the wheel rests, has rollers with adjustable collars, the top rim of the wheel rests against an adjustable plunger.

Almond Drill Chuck.

The chuck illustrated in Fig. 226 will center and hold drills with a firm grip, and is said to be one of the best chucks in the market.

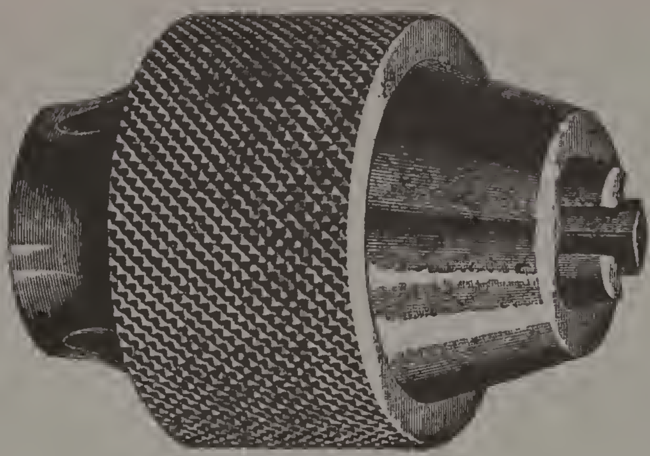


Fig. 226.

Skinner Drill Chuck.

The chuck shown in Fig. 227 is made entirely of steel. It is especially adapted for all light and rapid drilling, such as is done on sensitive drills, and where great accuracy is required.

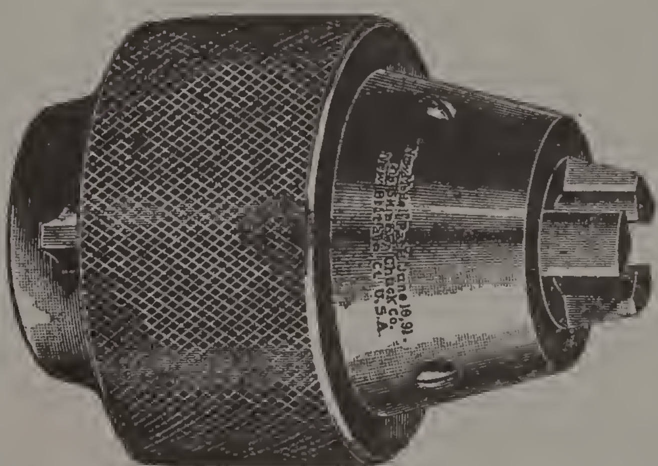


Fig. 227.

Cushman Drill Chuck.

The working parts of the chuck illustrated in Fig. 228 are of steel, and it is made in a most thorough manner. It is a self-tightening chuck, and needs no spanner wrench to make it hold.

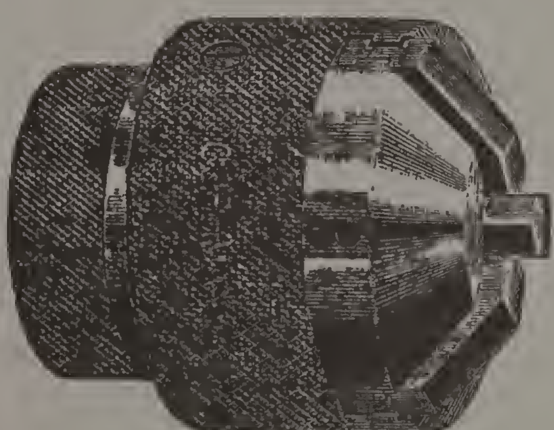


Fig. 228.

Twist Drills.

The advantages of a twist drill over a flat drill are as follows: The cuttings can find free egress more readily through the grooves in the twist drill. In the flat drill the cuttings jamb between the hole and the wedge-

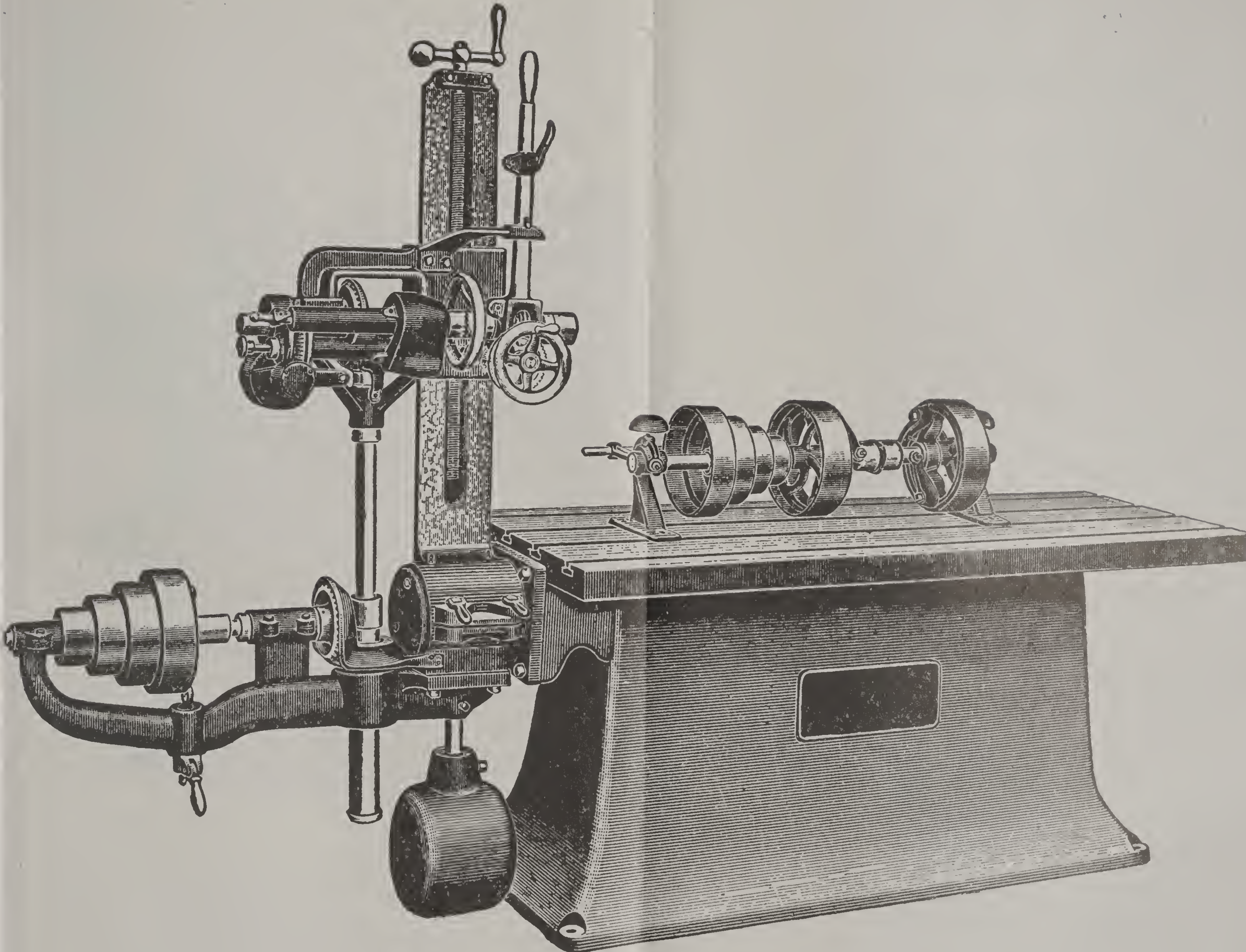


Fig. 229.

shape sides of the drill, requiring frequent removal of the drill to extract the cuttings. In deep holes more time is occupied in this manner than in the actual cutting operation. The twist drill nearly always runs true, and requires no reforging or tempering, and, by reason of its shape, fits

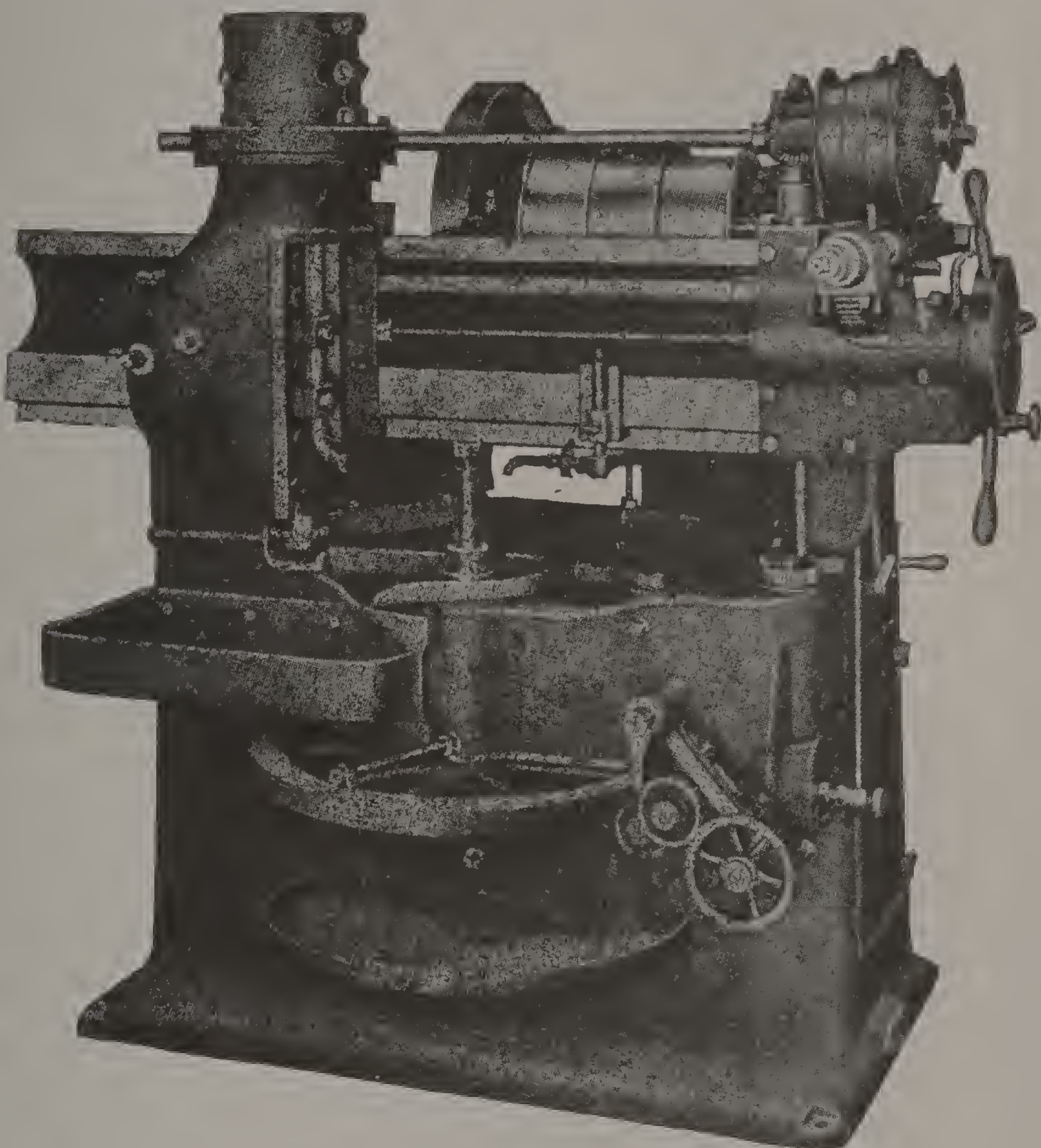


Fig. 230.

closely and produces a straight, parallel hole, provided the point is ground strictly true.

Horizontal Drill Press. A horizontal drill press is illustrated in Fig. 229. This machine is designed especially for large work and the drilling of holes in the end flanges of large cast iron pipes or columns. The head is counterbalanced by a weight as shown and may be swung through a wide angular range.

GEAR CUTTING MACHINES.

Fellow's Gear Shaper. A few of the distinctive features of the machine shown in Fig. 230 are: The gear shaper cuts a theoretically correct gear tooth. Only one cutter for each pitch is necessary. An error in spacing is an

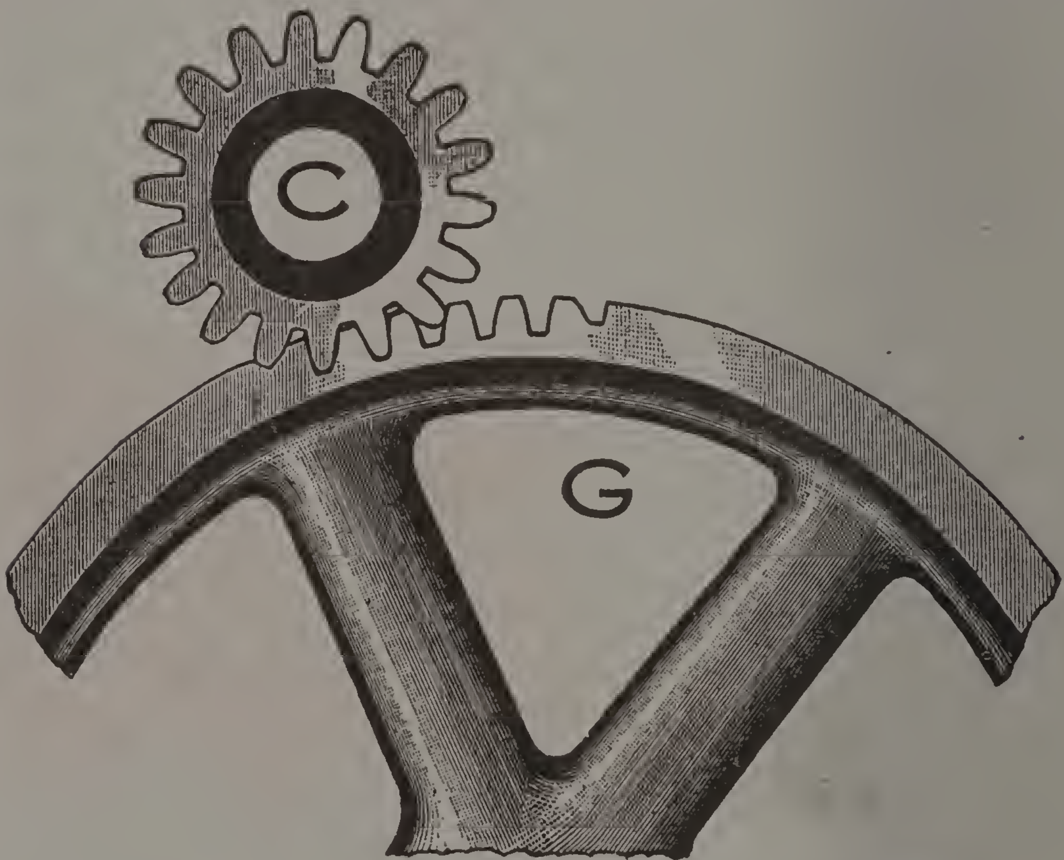


Fig. 231.

impossibility. No depth gauge is required, as the machine attends to that automatically. It cannot produce an incorrect tooth by setting the cutter "off center." The cutter travels the exact face of the blank only. The gear shaper is furnished with an equipment covering all of the ordinary needs of a machine of this kind, including an automatic cutter grinder, a set of six cutters, change gears, oil pump and countershaft.

An example of the work produced is shown in Fig. 231. This is done as follows: The blank to be cut is securely fastened on the work arbor and the machine being started, the cutter reciprocating vertically on its center line is fed towards the blank A, and cuts its way to the proper depth. At this point both the cutter C and the blank G begin to revolve, the cutter C maintaining its reciprocating motion.

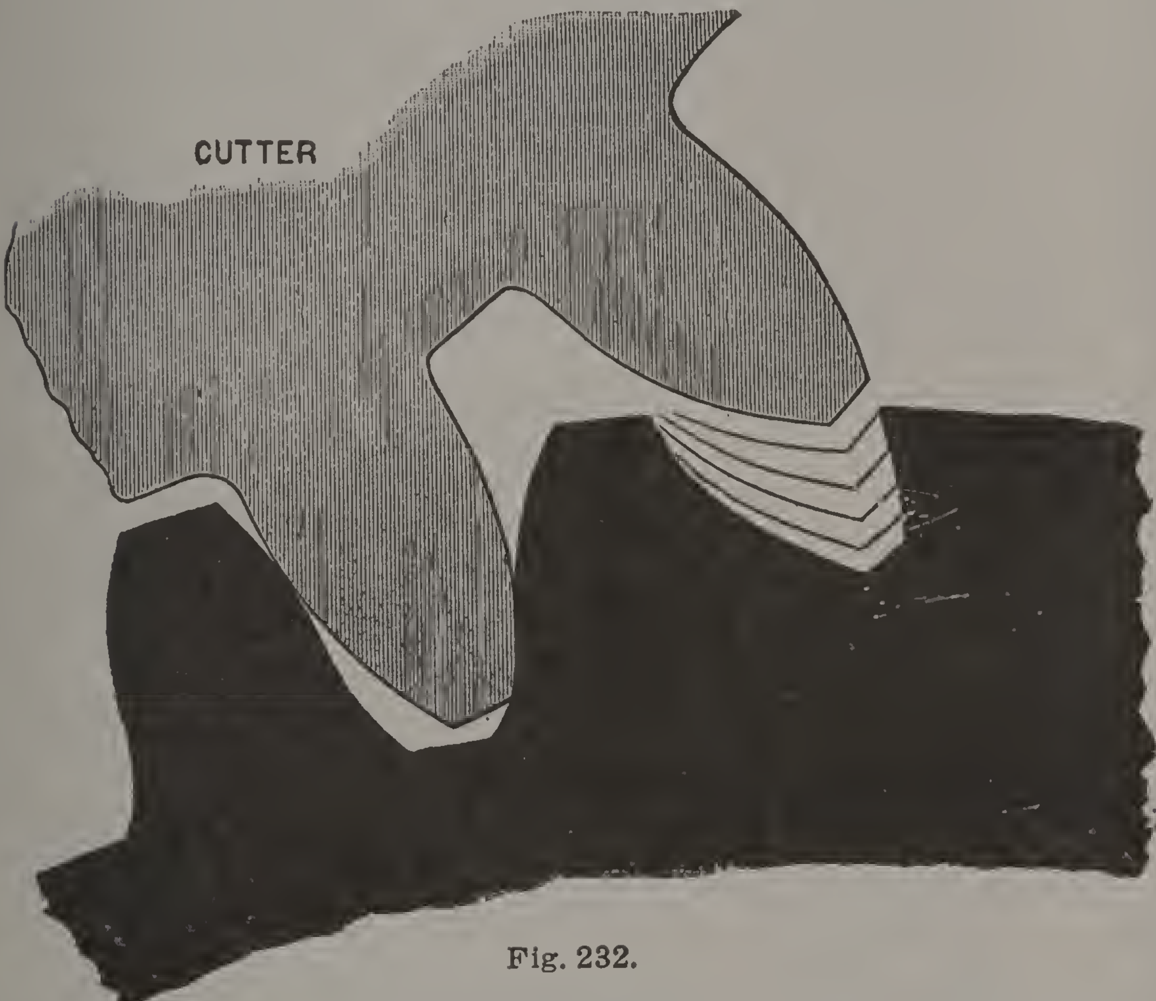


Fig. 232.

This revolution of the cutter C and the blank G is obtained by an external mechanism, which insures that the movement shall be as though the cutter and blank were two complete gears in correct mesh. Fig. 232 is a section through the blank and cutter which shows the process of cutting spur-toothed gear wheel.

It also shows the action of the gear cutter, each cut and the wedge form of the gear shaper chips.

The combined result of the rotary and reciprocating motion is that the cutter teeth generate conjugate teeth in the blanks which mesh correctly with the cutter teeth and with each other.

Whiton Gear Cutter. The tool shown in Fig. 233 is a universal milling machine, which is adapted for cutting

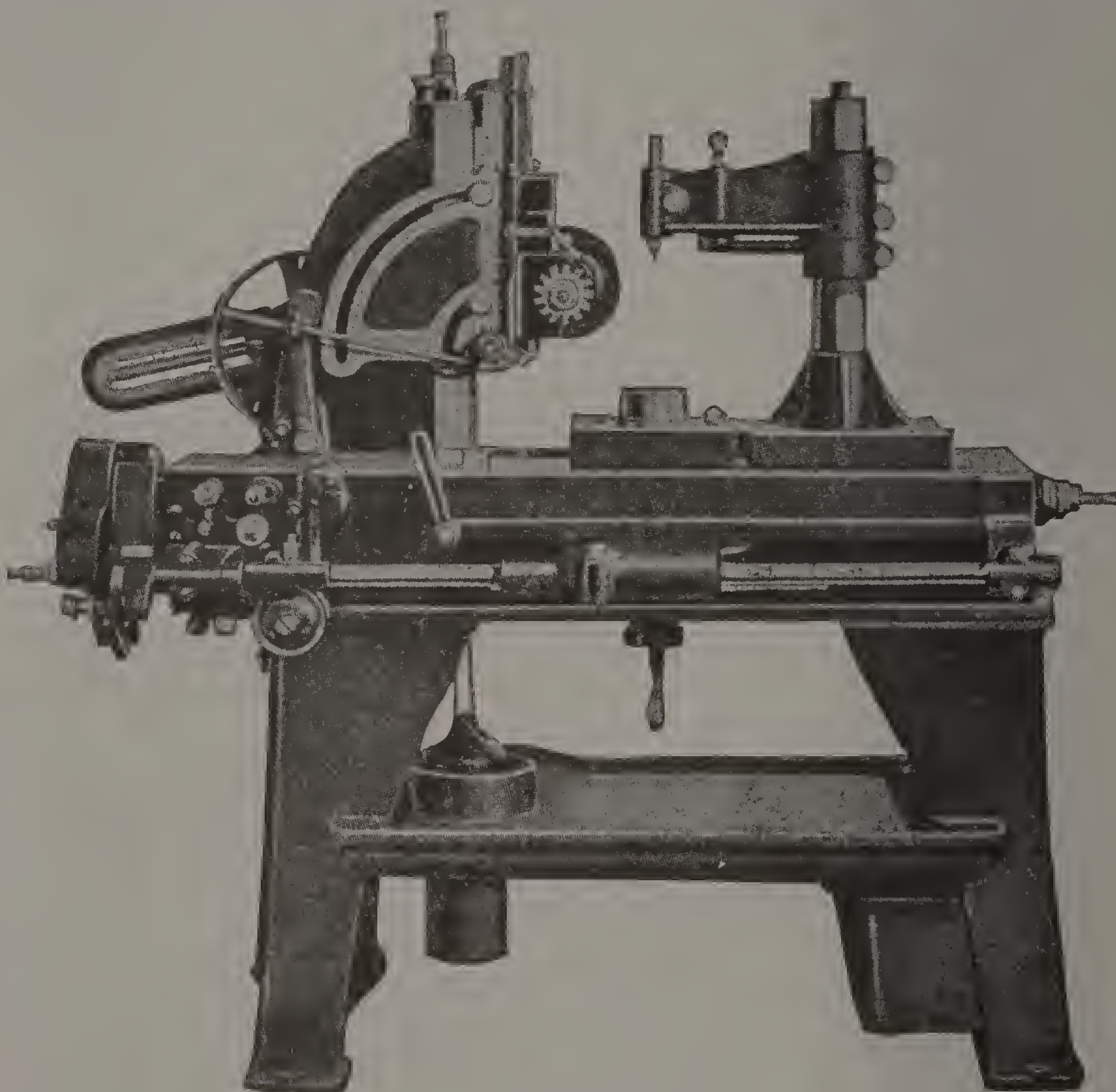


Fig. 233.

spur and bevel gears, and worm gears by the hobbing process, from blanks not previously nicked.

Every movement depends for its action upon the completion of all previous movements, so that the possibility of error is reduced to a minimum.

The feed depends upon the completion of the spacing, and the cutter cannot advance into an imperfectly spaced blank. The feed mechanism is disengaged during the spacing, and the cutter carriage remains at rest. The spacing movement is very rapid, and its completion re-engages the feed. Only one stop adjustment is required.

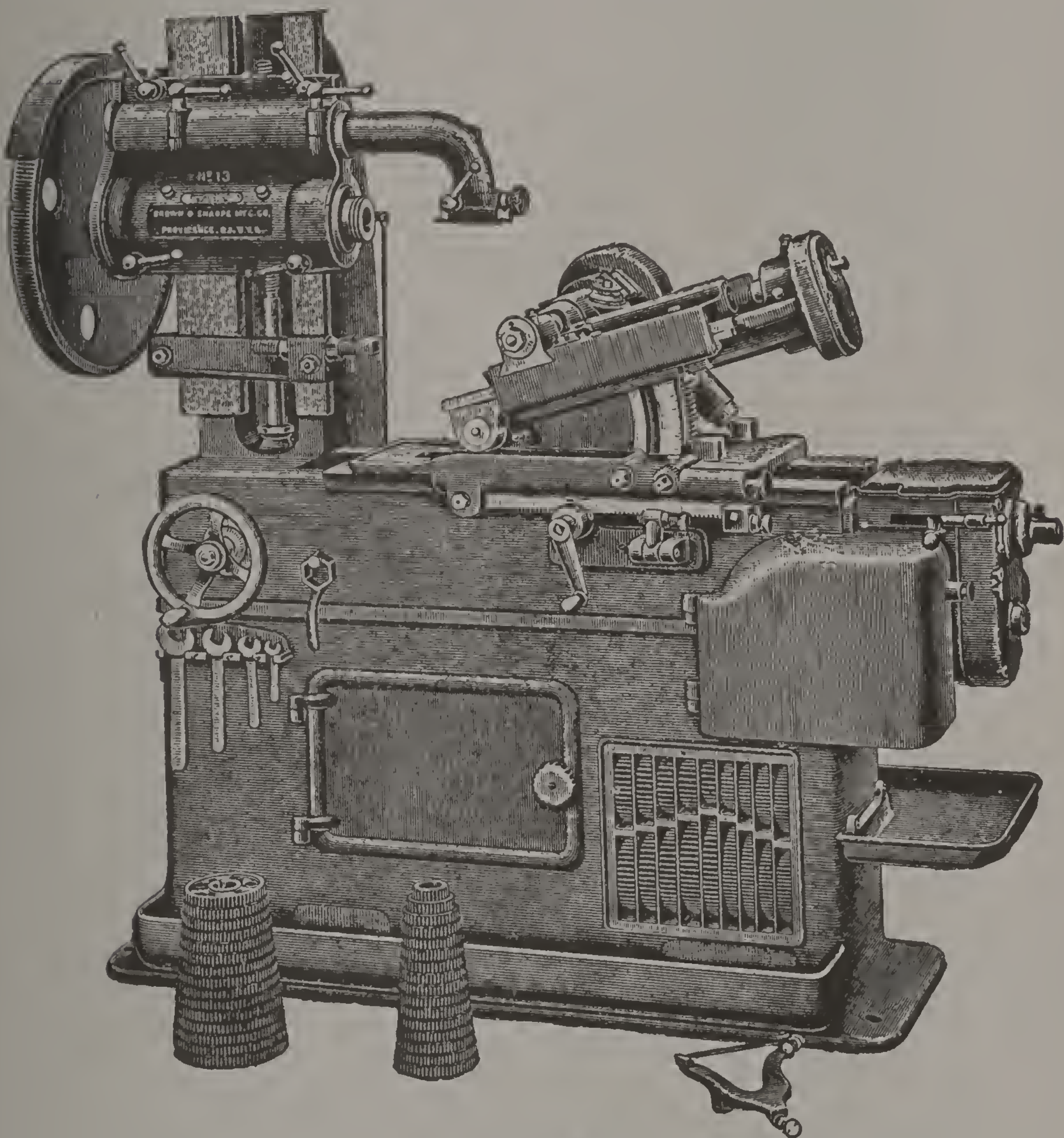


Fig. 234.

There are no frictional devices which consume power when not in action.

Automatic Gear Cutter. The machine shown in Fig. 234 cuts spur gears to 26 inches in diameter; 8 inches face and 4 diametral pitch in cast iron and 5 in steel. The cutter spindle is hardened and ground and provided with means of compensation for wear. It has 6 changes of speed from 20 to 80 revolutions per minute. The speed changes are in geometrical progression and are obtained by change gears. The outer bearing on the cutter slide gives an additional support to the cutter arbor.

The cutter arbor is 1½ inches in diameter, it can be removed in a few moments and smaller ones substituted. The return of the cutter slide is rapid and at a constant speed which is independent of the speed and feed of the cutter. The cutter has 15 changes of feed from .037 to .620 inches per revolution and is obtained by change gears. The feed changes is geometrical progression. The work spindle head is adjusted by means of a screw operated by a crank. The thrust of the elevating screw is taken by ball-bearings. A dial graduated to thousandths of an inch indicates the amount of this adjustment. Provision is also made for raising and lowering the head by power. The indexing mechanism is extremely accurate and entirely independent of the feed and speed of the cutter, so that the indexing is as rapid when the feed and speed are slow as when they are fast. The index change-gear provide for the cutting of all numbers from 12 to 50 and all numbers from 50 to 400 excepting prime numbers and their multiples.

The Sizing and Cutting of Gears. The word **diameter** when applied to gears is always understood to mean **pitch diameter.**

The diametral pitch of a gear is the number of teeth to each inch of its pitch diameter.

If a gear has 40 teeth and the pitch diameter is 4 inches, there are ten teeth to each inch of the pitch diameter, and the diametral pitch is 10, or, in other words, the gear is 10 diametral pitch.

The circular pitch is the distance from the center of one tooth to the center of the next tooth, measured along the pitch circle.

If the distance from the center of one tooth to the center of the next tooth, measured along the pitch circle, is ½ inch, the gear is ½ inch circular pitch.

Having the diametral pitch, to obtain the circular pitch, divide 3.1416 by the diametral pitch.

If the diametral pitch is 4, divide 3.1416 by 4, and the quotient, 7854, is the circular pitch.

Having the circular, to obtain the diametral pitch, divide 3.1416 by the circular pitch.

If the circular pitch is 2 inches, divide 3.1416 by 2 and the quotient 1.5708, is the diametral pitch.

Having the number of teeth and the diametral pitch, to obtain the pitch diameter, divide the number of teeth by the diametral pitch.

If the number of teeth is 40 and the diametral pitch is 4, divide 40 by 4, and the quotient 10, is the pitch diameter.

Having the number of the teeth and the diametral pitch, to obtain the whole diameter or size of blank of the gear, add 2 to the number of teeth, and divide by the diametral pitch.

If the number of teeth is 40 and the diametral pitch is 4, add 2 to the 40, making 42, and divide by 4; the quotient, 10½, is the whole diameter of the gear or blank.

Having the number of the teeth and the diameter of the blank, to obtain the diametral pitch add 2 to the number of the teeth, and divide by the diameter of the blank.

If the number of teeth is 40, and the diameter of the blank is 10½ inches, add 2 to the number of teeth making 42, and divide by 10½. The quotient, 4, is the diametral pitch.

Having the pitch diameter and the diametral pitch, to obtain the number of teeth, multiply the pitch diameter by the diametral pitch.

If the diameter of the pitch circle is 10 inches, and the diametral pitch is 4, multiply 10 by 4, and the product, 40, will be the number of teeth in the gear.

Having whole diameter of the blank and the diametral pitch, to obtain the number of teeth in the gear, multiply the diameter by the diametral pitch and substract 2.

If the whole diameter is 10½, and the diametral pitch is 4, multiply 10½ by 4 and the product, 42 less 2, or 40, is the number of teeth.

To obtain the thickness of a tooth at the pitch line, divide the circular pitch by 2, or divide 1.57 by the diametral pitch.

If the circular pitch is 1.047 inches or the diametral pitch is 3, divide 1.047 by 2, or 1.57 by 3, and the quotient, .523 inch, is the thickness of the tooth.

To obtain the whole depth of a tooth, divide 2.157 by the diametral pitch.

If the diametral pitch of a gear is 6, the whole depth is 2.157 divided by 6, equals .3595.

The whole depth of a tooth is about 11-16, or exactly .6866 of the circular pitch.

If the circular pitch is 2, the whole depth of the tooth is about 11-16 of 2 inches, or 1 3-8 inches nearly.

To obtain the distance between the centres of two gears, add the number of teeth together, and divide half the sum by the diametral pitch.

If two gears have 50 and 30 teeth, respectively, and are 5 pitch, add 50 and 30, making 80, divide by 2, and then divide this quotient, 40, by the diametral pitch, 5, and the result, 8 inches, is the centre distance.

To divide the sum of the pitch diameters of the gears by 2.

No. 13 table shows the diametral pitches with the corresponding circular pitches.

No. 14 table shows the circular pitches with the corresponding diametral pitches.

TABLE NO. 13.

Diametral Pitch.	Circular Pitch, in inches.
1¼	2.5133
1½	1.0944
1¾	1.7952
2	1.571
2¼	1.396
2½	1.257
2¾	1.142
3	1.047
3½	.898
4	.785
5	.628
6	.524
7	.449
8	.393
9	.349
10	.314
11	.286
12	.262
14	.224
16	.196
18	.175
20	.157
22	.143
24	.131
26	.121
28	.112
30	.105
32	.098
36	.087
40	.079
48	.065

TABLE NO. 14.

Circular Pitch, in inches.	Diametral Pitch, in inches.
2	1.571
1⅞	1.676
1¾	1.795
1⅝	1.933
1½	2.094
1 7/16	2.185
1⅜	2.285
1 5/16	2.394
1¼	2.513
1 3/16	2.646
1⅛	2.793
1 1/16	2.957
1	3.142
15/16	3.351
⅞	3.590
13/16	3.867
¾	4.189
11/16	4.570
⅝	5.027
9/16	5.585
½	6.283
7/16	7.181
⅜	8.378
5/16	10.053
¼	12.566
3/16	16.755
⅛	25.133
1/16	50.266

According to the system adopted by the Brown & Sharpe Mfg. Co., and known as the Diametral Pitch System, any gear of one pitch will gear into any other gear or into a rack of the same pitch. **Eight cutters are required for each pitch.** These eight cutters are adapted to cut from a pinion of twelve teeth to a rack, and are numbered respectively, 1, 2, 3, &c.

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

If a cutter is wanted for a wheel of 40 teeth of 8 pitch, then the cutter required, would be No. 3 of 8 pitch, inasmuch as a No. 3 cutter will cut all wheels containing from 35 to 54 teeth, inclusive, and 40 occurring between those numbers, it is the one desired. It should be borne in mind that eight different cutters are required in order to cut all the wheels of any given pitch.

As these cutters allow of being ground when dull, it is important that they be kept sharp. By paying particular attention to this the cutting will be greatly facilitated beside being much better done.

It is desirable in applying gearing of any kind, to avoid having wheels or pinions with a small number of teeth. Pinions of twelve teeth will work very well but a less number of teeth should not be used.

Few mechanics are familiar with the minutiae of gearing and the necessity of exact sizing of wheels, as to diameter, is often overlooked. Special care is required also to know what the distance of the centers of two wheels running together is correct relative to the diameters.

TABLE No. 15—DEPTH OF SPACE AND THICKNESS OF TOOTH IN SPUR WHEELS, WHEN CUT WITH INVOLUTE CUTTERS.

Pitch of Cutter.	Depth to be cut in Gear, in inches.	Thickness of Tooth at Pitch Line, in inches.	Pitch of Cutter,	Depth to be cut in Gear, in inches.	Thickness of Tooth at Pitch Line, in inches.
1¼	1.726	1.257	11	.196	.143
1½	1.438	1.047	12	.180	.131
1¾	1.233	.898	14	.154	.112
2	1.078	.785	16	.135	.098
2¼	.958	.697	18	.120	.087
2½	.863	.628	20	.108	.079
2¾	.784	.570	22	.098	.071
3	.719	.523	24	.090	.065
3½	.616	.448	26	.083	.060
4	.539	.393	28	.077	.056
5	.431	.314	30	.072	.052
6	.359	.262	32	.067	.049
7	.308	.224	36	.060	.044
8	.270	.196	40	.054	.039
9	.240	.175	48	.045	.033
10	.216	.157			

Cutting Gears. When cutting gears care must be taken to have the cutter central with the index centers, and to have the cut exactly the depth required. A good method of testing the setting is to cut a groove in a piece on the centers, then shift the piece end for end and try the groove upon the cutter. A good method of holding the gear blanks is on an arbor with a taper shank which fits in the index spindle, the outer end of the arbor being supported by the foot stock center. Frequently in cutting gears a shank arbor is used with an expanding bushing and a nut on the arbor at each end of the bushing, one nut forcing the bushing up on the arbor and holding the gear blank, while the other pushes the bushing off the taper and releases the gear when finished. If the ordinary arbor and dog are used, care must be taken that the dog does not spring the arbor. The depth of the cut can be gauged from the outside of the blank, or, if so desired, marked on the side by a gear tooth depth gauge. In cutting gears, when the blank has been placed in position it is raised by the elevating screw until it just touches the cutter. The graduated collar on the vertical feed shaft is placed on the zero line and the blank moved horizontally away from the cutter. Then the work is raised the number of thousandths of an inch required for the depth of tooth.

Table No. 15 gives the depth of the gear teeth of pitches from 1¼ to 48 diametral pitch. Directions regarding the sizing and cutting of gear wheels, formulae for determining the dimensions of small gears by diametral pitch, also directions for selecting involute gear cutters for any given pitch are also given in connection with the table.

Tooth Flanks Undercut. It is well known that involute gears can be made of different systems or of different angles of obliquity or pressure. In the system proposed

Fig. 235A

by Professor Willis about fifty years ago, the angle of pressure, or obliquity, is fourteen and a half degrees. Twice this angle is the familiar angle of a worm thread tool. Gears made upon this system are thought to crowd less upon their shafts than those having a greater angle of pressure. If, however, a gear or pinion has fewer than twelve teeth, this angle may cause their flanks to be undercut and in consequence weak in order to clear the faces of the teeth of the engaging gear. The drawing of a segment of a gear of ten teeth, four diametral pitch, in Fig. 235A, illustrates this undercutting which is greater as the teeth are fewer.

Gears or pinions, having fewer than twelve teeth might be unavailable if undercut as much as at A, B and C, in Fig. 235B. Gears that are to do heavy work may require a greater angle of pressure than fourteen and a half degrees, if they are to run with a pinion of fewer than twelve teeth.

Fig. 235B

In the choice of an angle of pressure some idea may be obtained from the lower view in which is taken from a gear 10 teeth, 4 diametral pitch. The angle of pressure in these teeth is 22½ degrees. The greater strength of the tooth flanks in this figure is readily seen. The angle cannot be much more than thirty-two degrees and have the addendum of the teeth or that part of the tooth above pitch line of the ordinary height, which is equal to one part of the diametral pitch.

Bevel Gears. The curve of the teeth in **bevel gears,** when correctly formed, changes constantly from one end of the tooth to the other. Consequently bevel gears, whose teeth are produced with a cutter of fixed curve, are not theoretically correct, the cutter usually being of a curve that will make the correct form at the outer part of the face of the gear, and of necessity will leave the curves too large at the inside ends of the teeth. Small bevel gearing is almost universally produced in this manner, which practically answers the purpose, except when the teeth are very coarse or the gears very small, in which cases their operation is not satisfactory. In place of cutting by changing the position of the cutter, the teeth are often filed slightly, in order to round them off to the curve required for their free running. On all bevel gears cut with a cutter of fixed curve, it is necessary to cut through **twice**, owing to the necessity of making the thickness of the cutter on the pitch line equal to about .005 inches thinner than the space between the teeth at the smallest **Pitch** diameter. As the width of space between the teeth on the largest pitch diameter should be greater than the thickness of the cutter, it must be made so by passing that cutter through the second time. Fig. 236 will explain the forms of spur, bevel and mitre gears, also the terms **pitch diameter, outside diameter, largest pitch diameter, length of face,** etc. When a pair of bevel gears are of same size and number of teeth, with their lines of centers at right angles, they are called **mitre gears**, and one cutter will answer for both, but where one gear has a greater number of teeth, or differs in bevel from the one running into it, then each of the pair of gears may require a different cutter.

When giving the dimension for bevel gears always give the following information as shown in Fig. 237.

The pitch, or if preferred, give the diameter of pitch circle.

The number of teeth in the gear. The number of teeth in the pinion.

A, or diameter of hole in the gear, a, or the diameter of the hole in the pinion.

The backing for both the gear and pinion.
C, or width of the face.

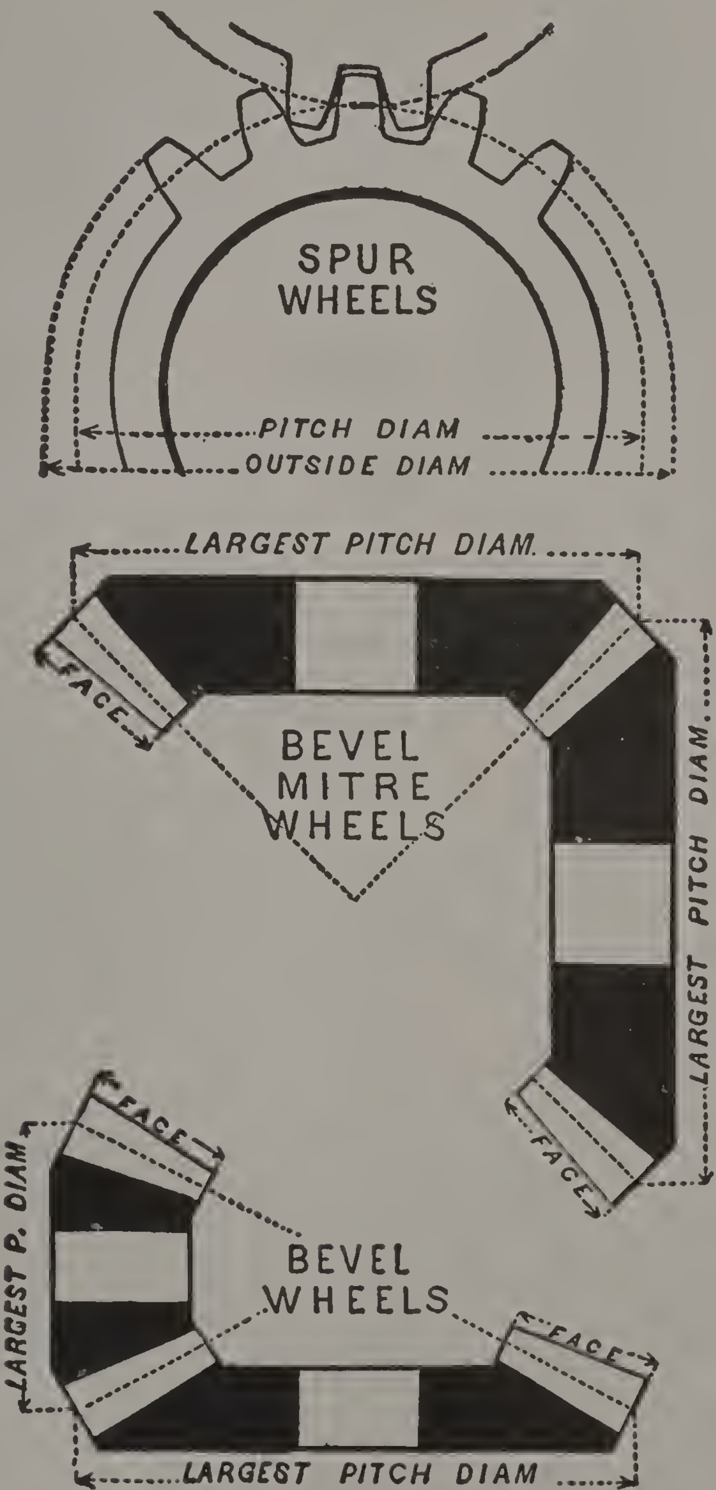


Fig. 236.

D, or diameter of the gear hub, or the diameter of the pinion hub, if these dimensions are of importance.

E, or the distance from center of pinion shaft to end of gear hub; or distance from center of gear shaft to end of pinion hub.

Key way, or set screw, and what size.

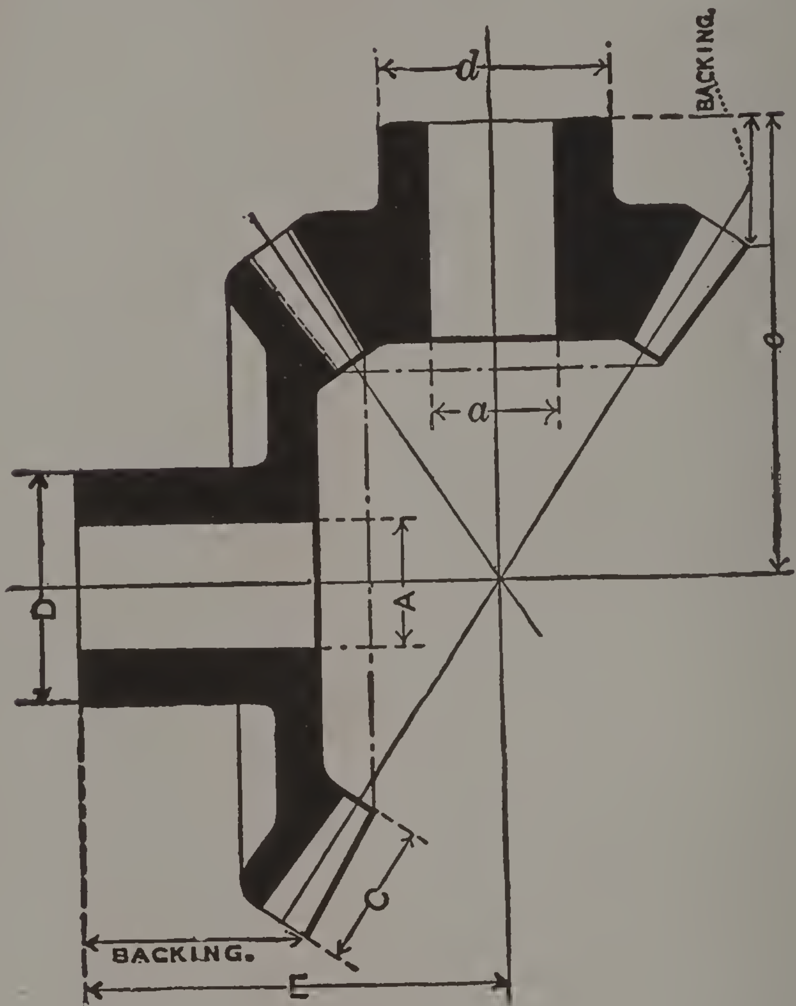


Fig. 237.

Whether to be used for pattern or not.

Does the pinion drive or is it driven.

Comparative sizes of gear teeth. The illustration in Fig. 238 show the comparative size of the teeth of involute gears from 20 to 3 diametral pitch. The teeth shown in the drawing are the full or actual size.

Gear Tooth Caliper. The double vernier caliper shown in Fig. 239, is for the purpose of accurately measuring the distance from the top of the teeth to the pitch line, and

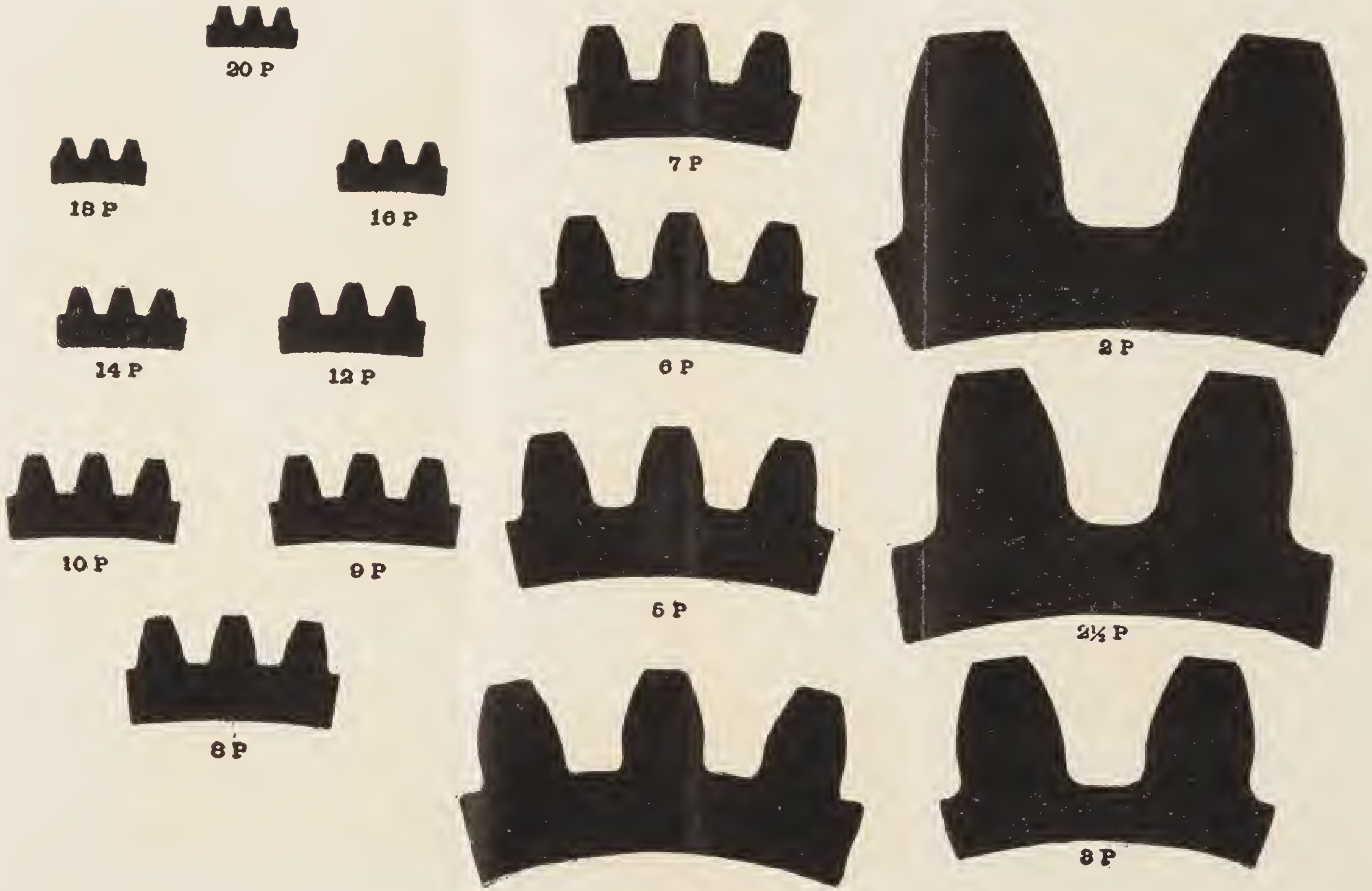


Fig. 238.

the thickness at the pitch line of gear teeth. I will measure all pitches.

The sliding jaw moves upon a bar graduated to read by

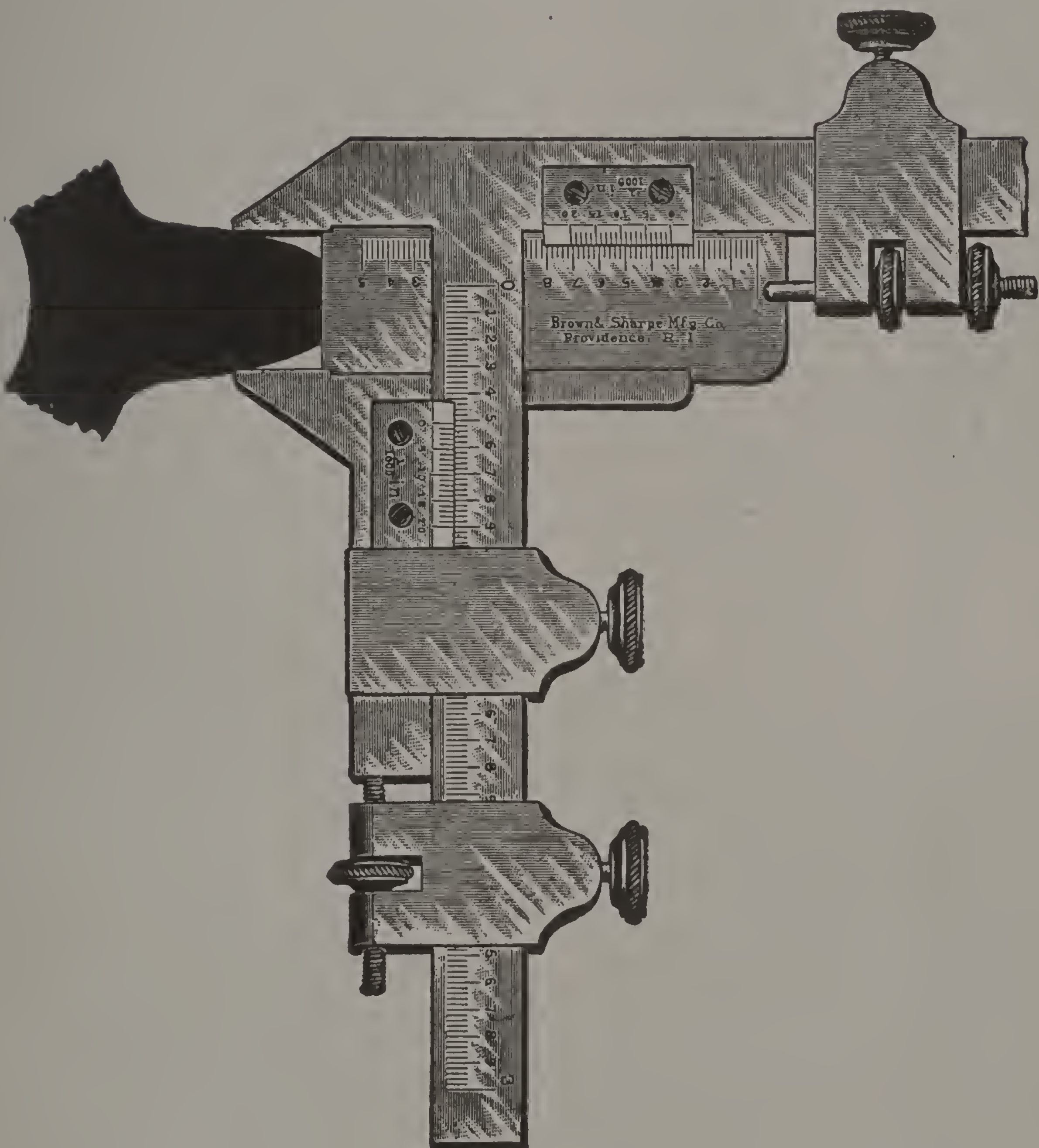


Fig. 239.

means of the vernier to thousandths of an inch. A tongue, moving at right angles with the jaws, is graduated in the same manner. Both the sliding jaw and tongue are provided with suitable adjusting screws.

GRINDING MACHINES.

Grinding Machines have proved to be well adapted for producing accurate work. Not only have they proved economical in the manufacture of machinery and tools, both

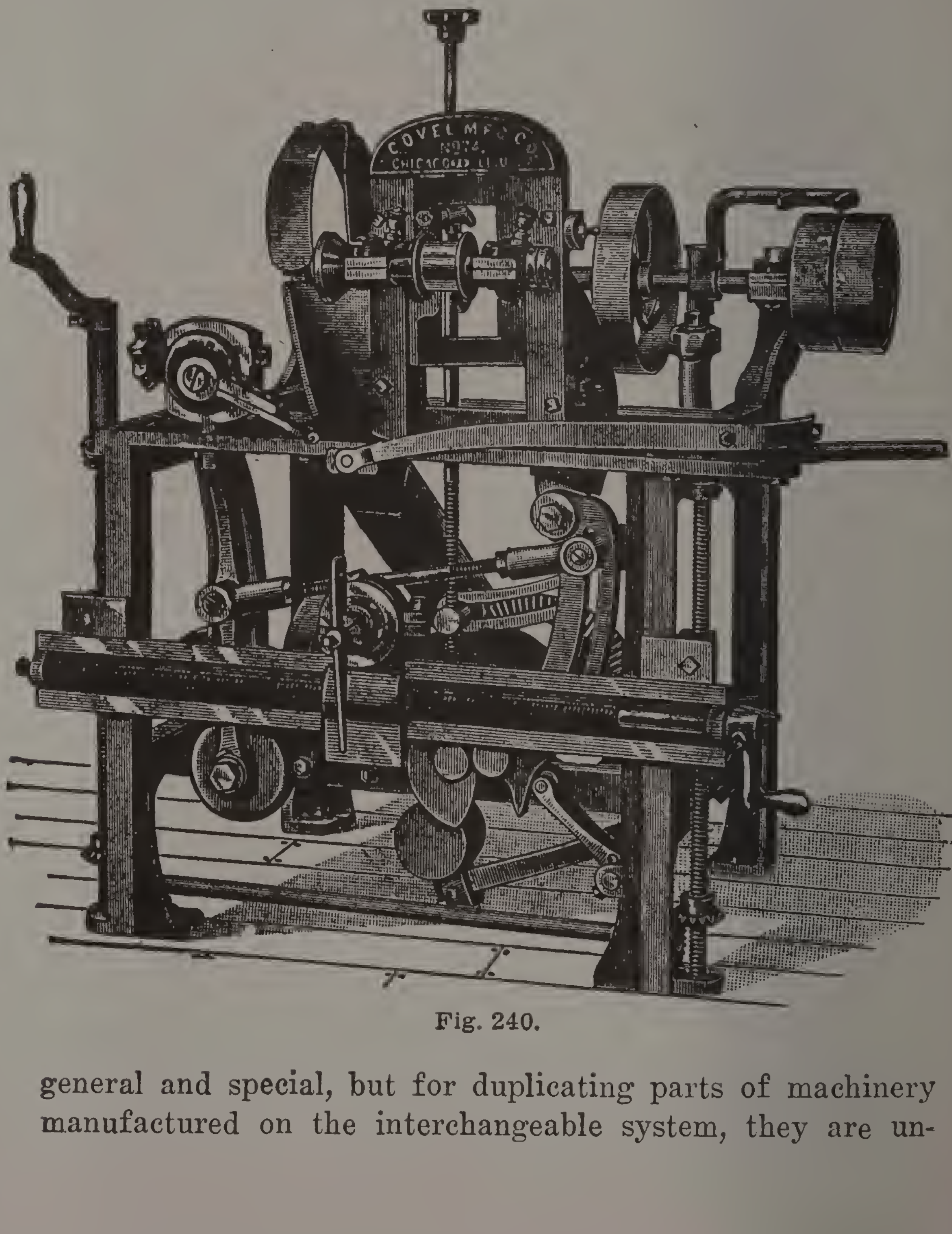


Fig. 240.

general and special, but for duplicating parts of machinery manufactured on the interchangeable system, they are unexcelled. They produce the same degree of accuracy, excellence, and economy when used on either hardened or soft work.

Fig. 241.

That it costs much less to finish and fit work by grinding with emery wheels than by the old method on the lathe, has been repeatedly proven by experience. As emery wheels, for a given amount of work, cost less than files, and emery cloth, it may be seen that this saving, together with the reduction in the time required to do the work, is a material one, whether the grinding is done for making accurate fits, or rough sizing. In many instances, actual practice shows that soft steel can be worked to much better advantage on the grinding machine than in the lathe or the milling machine.

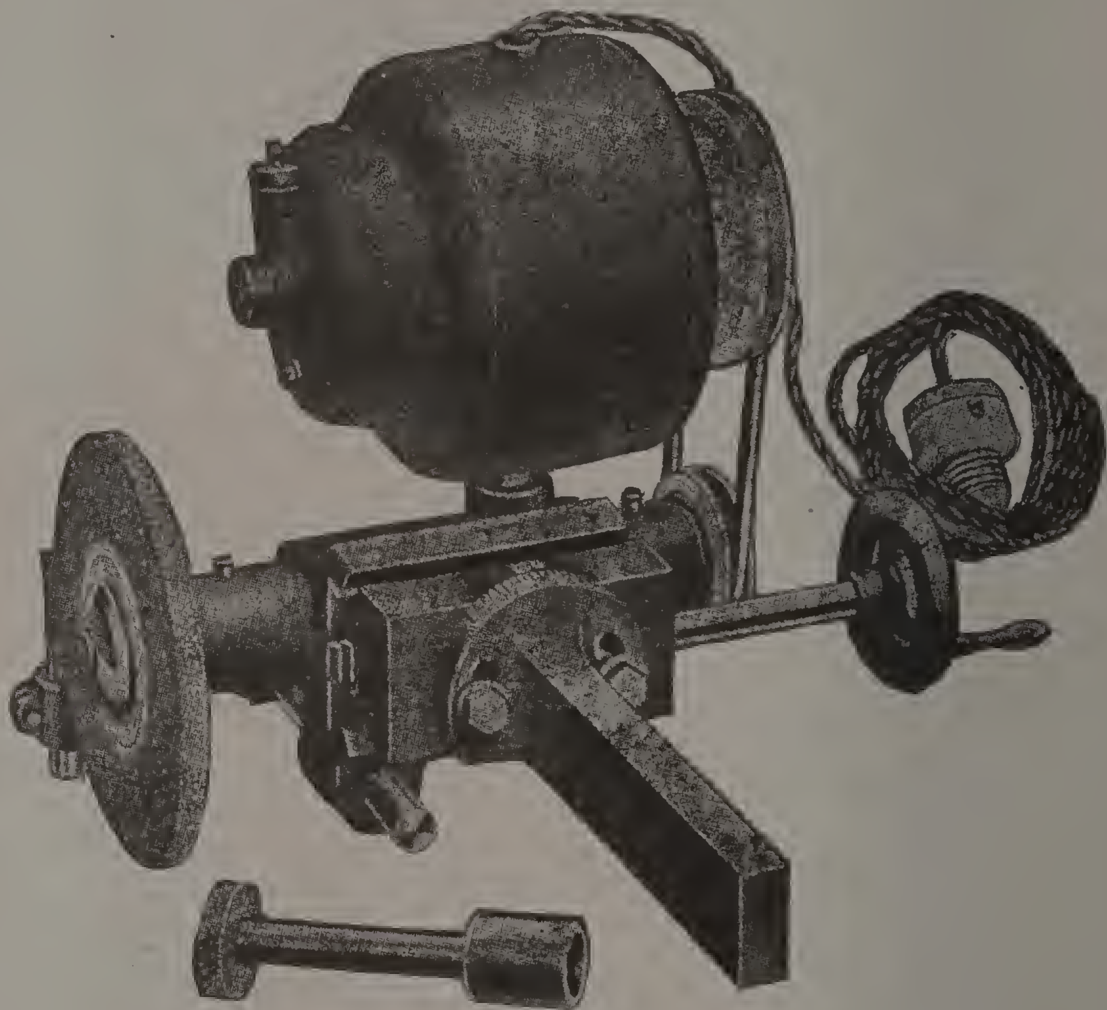


Fig. 242.

Automatic Saw Grinder. The machine shown in Fig. 240 will automatically grind the teeth of saws from 16 to 54 inches diameter.

Bench Grinder. The machine illustrated in Fig. 241 will be found one of the most useful and convenient tools in the shop. The emery wheel head is adjustable to any desired position for throwing light on the work while being ground. By filling the basin with water, it keeps the emery from flying and also provides a convenient place to dip the tools in while grinding.

Grinding Attachment. Figure 242 illustrates a new motor, driver, lathe, planer or shaper grinding attachment to be placed in the tool post of the lathe. The efficiency of this machine can be readily seen by anyone requiring grinding to be done in the lathe. An attachment goes with each machine for internal grinding, as well as external.

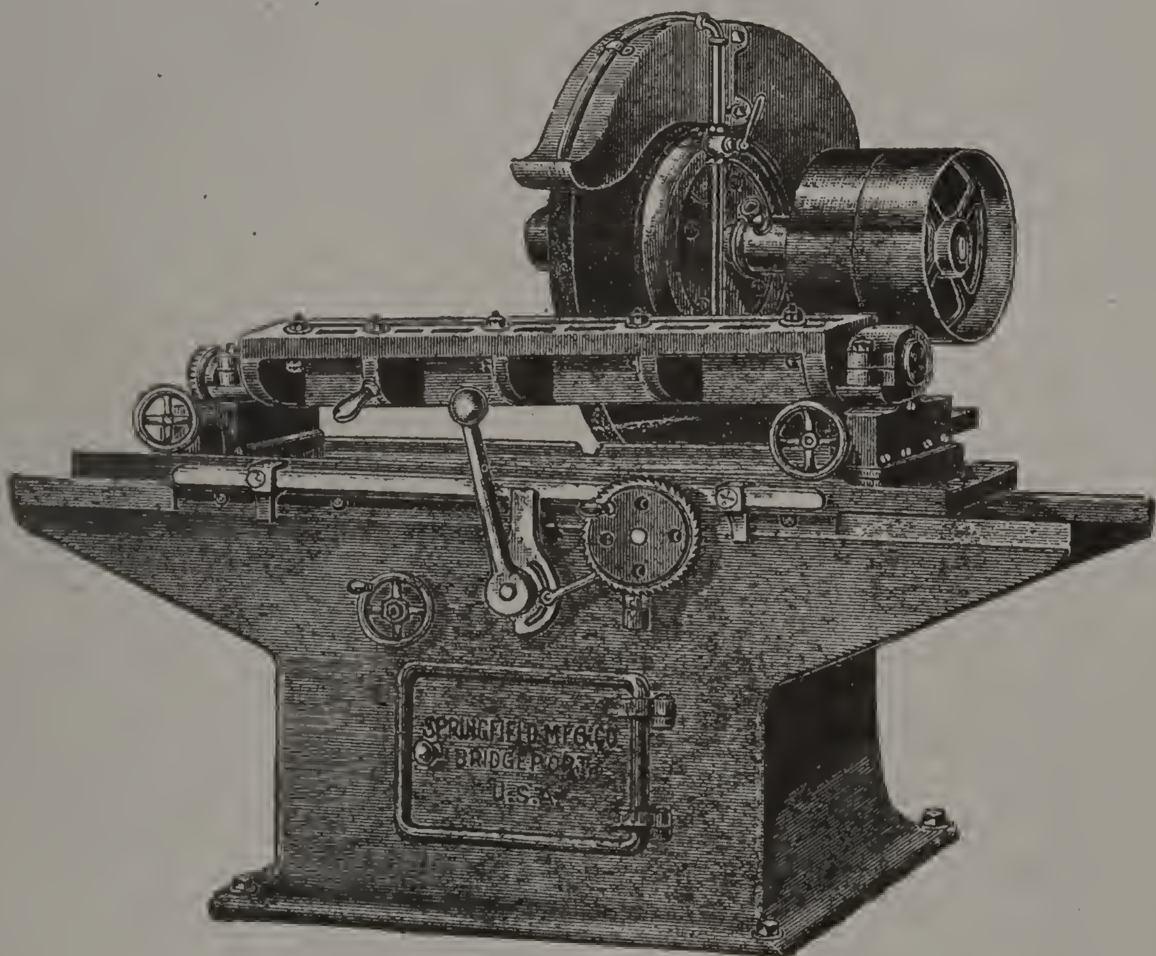


Fig. 243.

Knife Grinding Machine. The machine illustrated in Fig. 243 is particularly adapted for any size and style of straight knives. It is provided with a friction clutch, which admits of starting and stopping the carriage quickly without stopping the belts. The bed and base are cast in one piece, thereby making a very rigid machine, where rigidity and cleanliness are particularly required.

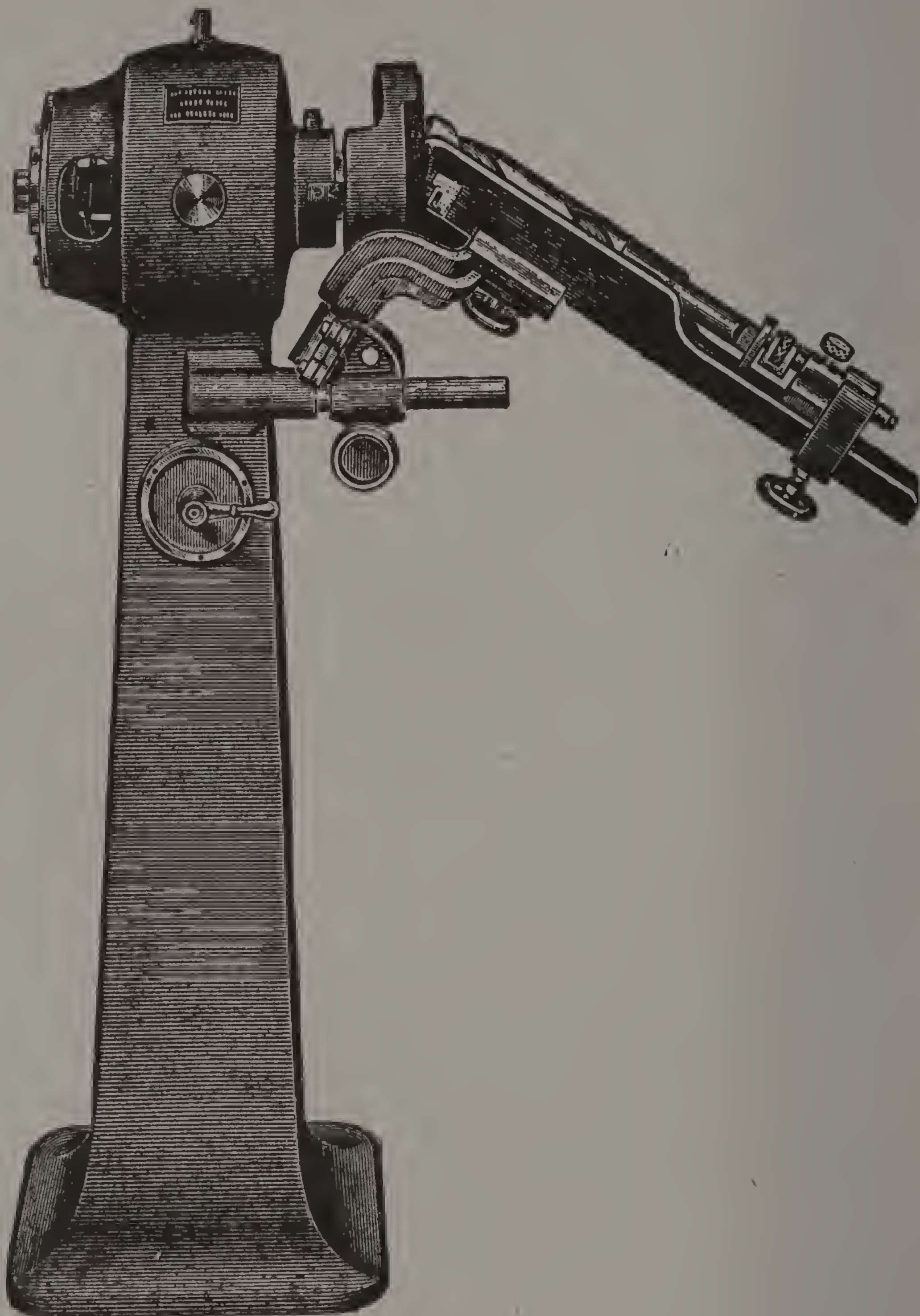


Fig. 244.

Size of the emery wheel, 26x1½ inches. The size of the emery wheel pulleys, tight and loose, 10½x4½ inches. The size of the carriage gang pulleys, 9x2½ inches. The speed of the emery wheel per minute is 356 revolutions. The speed of the carriage per minute is 10½ feet.

Motor Driven Drill Grinder. This machine shown in Fig. 244 is desirable wherever an electrical plant has been installed. It is made both for 110 and 220 volts.

This machine, as is clearly shown, has the motor frame and stand cast in one piece, the controlling switch being located within the hollow column, and is operated by the handle shown on the side. The motor is very solidly made, and will stand rough usage. The bearings are self oiling and are extra large to insure long life. The bushings are made of gun metal and are easily renewed.

One advantage possessed by an electrically driven drill-grinder is that it may be located at any place desired, and quickly connected with the power circuit by wires which can be led in any direction. It needs no pulleys, counter-shaft or belting, and when once installed, the cost of maintenance is reduced to a minimum.

Motor Driven Water Grinders. The motor-driven grinder shown in Fig. 245 is very neat and compact. Every machine is set up and tested for several hours before shipping. They can be furnished to operate with direct or alternating current.

PLAIN GRINDING MACHINES.

The grinding machine shown in Fig. 246 is unusually heavy, and the metal is so disposed as to obtain a maximum strength, and reduce the vibration, which is so common in this class of machines, to a minimum.

The Spindle is of the best machinery steel, turned and ground to size. The ends are provided with threads of 29 degree angle, of the same depth as, but stronger than the square thread generally used.

The Bearings are unusually large and are placed as near the wheels as practicable, thus reducing the liability of vibration. They are dust proof. The larger size grinders are provided with renewable, inter-changeable boxes. The

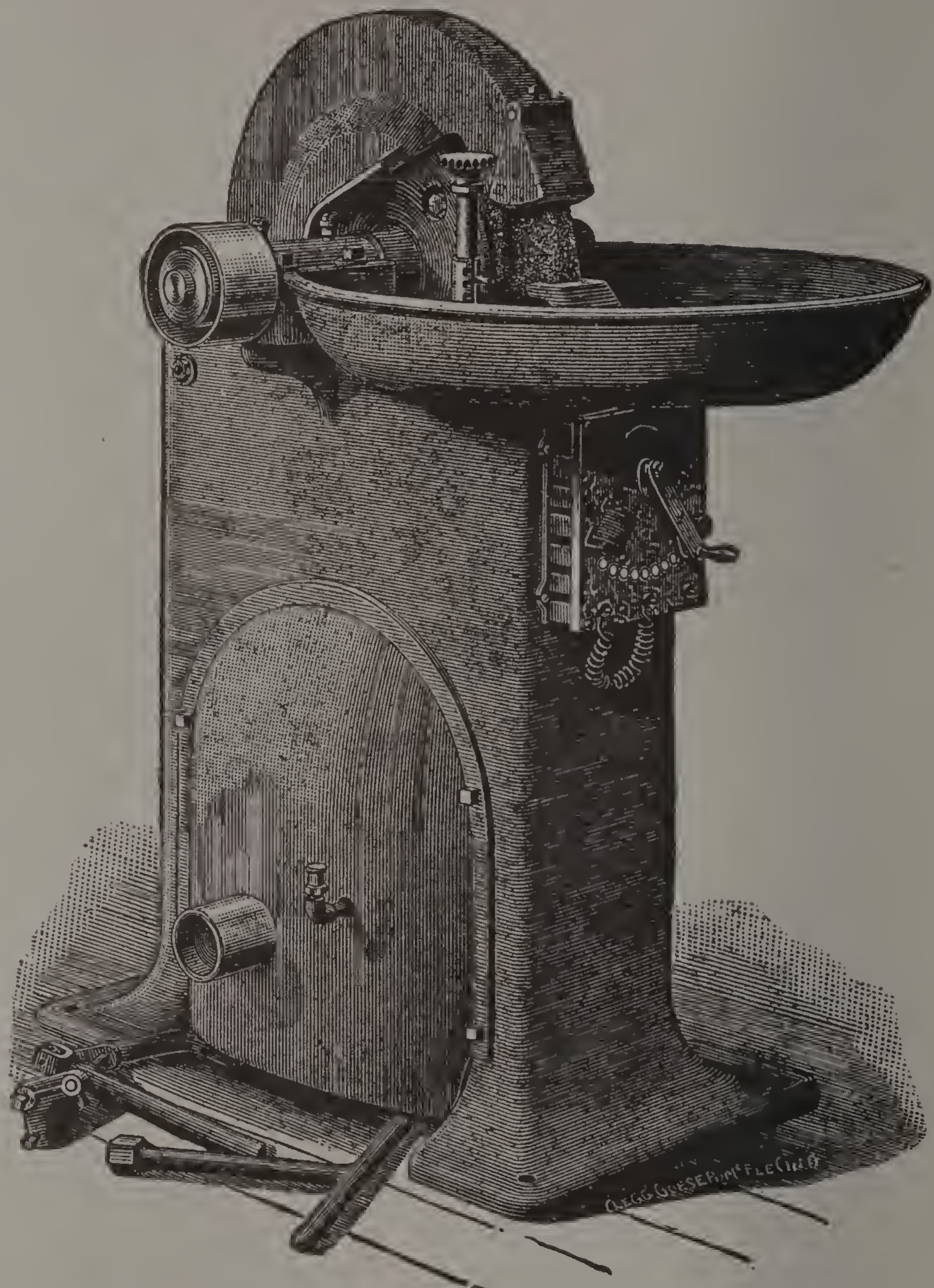


Fig. 245.

caps are tongued and grooved, making them rigid and not liable to work loose.

The Flanges are heavy and of large diameter. The tight flanges are forced on the spindle, and provided with grooves arranged to prevent the entrance of dust or dirt to the bearings from the outer ends of the boxes.

The Self-Oiling Arrangement insures a plentiful supply of oil, and is of such construction that it is impossible for any dust, grit or sediment to reach the bearings. Reservoirs are provided underneath the spindles for holding oil,

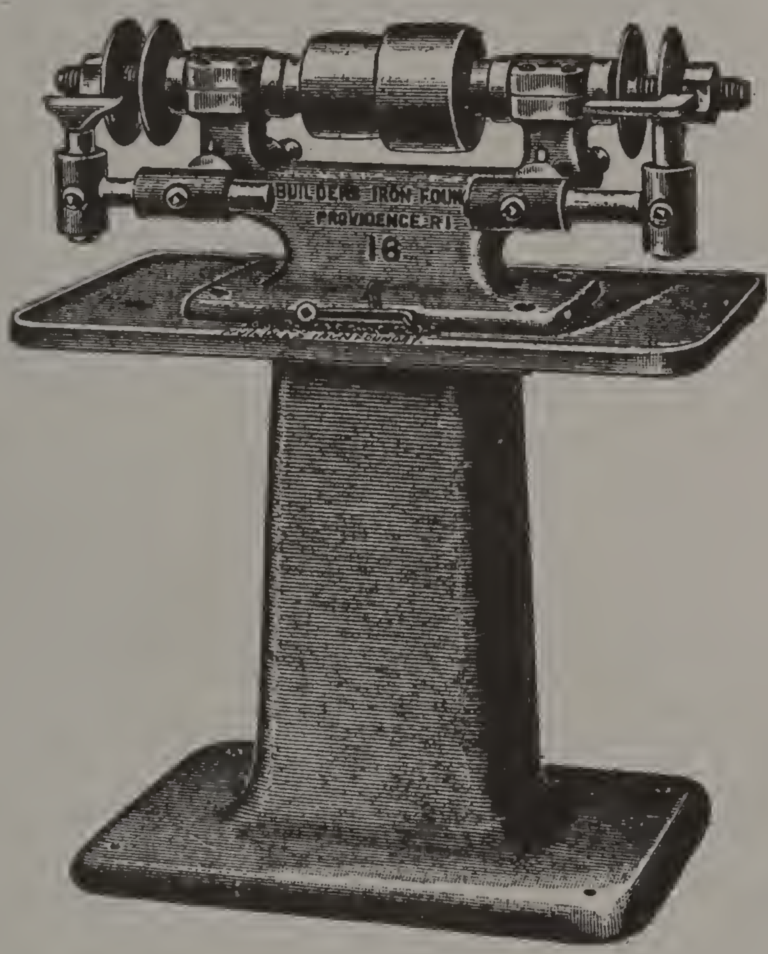


Fig. 246.

which is fed to the bearings by means of a "wiper." The wiper is pressed up by a brass spring, and kept constantly in contact with the spindle.

Polishing or Grinding Machine. The machine illustrated in Fig. 247 is so constructed that emery or polishing wheels, even though out of balance, will revolve on their center of gravity and will run smoothly, and will not pound.

Polishing wheels do not require balancing when run on this machine, and will retain their coating of emery much longer than on the ordinary machine. The work will not bump or stutter on the wheel, but passes over smoothly, and any wavy appearance of work is entirely obviated.

The bearings are so constructed that they can be made

Fig. 247.

pliable and elastic, or rigid, according to the demands of the operator, and the machine can be run at double the speed of the ordinary machine without heating.

Saw Grinder. The machine illustrated in Fig. 248 will grind circular or rip saws from 14 inches to 73 inches, and any shape or size of tooth. It has an adjustable stop screw to regulate the depth of the teeth. Size of the wheel, 12 inches, any thickness to fit the tooth.

Surface Grinder. The hand surface grinder shown in the drawing at Fig. 249 is an extremely useful tool for grinding small work.

Universal Grinding Machines. The grinder shown in Fig. 250 is an **electrically driven tool** in every detail, as both the motor and machine are designed to work together and are built and tested in the same shop. Universal grinders, from the peculiar nature of their work, are better adapted to this mode of driving than most other machine tools, having as they usually do from eight to ten belts, some of which have to be removed for almost every operation. The belts not in use hang in the way and are always giving more or less trouble when running at a high speed. The work of a universal grinder requires that either the wheel or the piece being operated on should occupy almost every conceivable position. This is much easier and more quickly done where the wheel is made to move. Practically all work is held between a pair of plain centers, or in a vise, and the wheel moved instead of the work, thereby making a large saving in time.

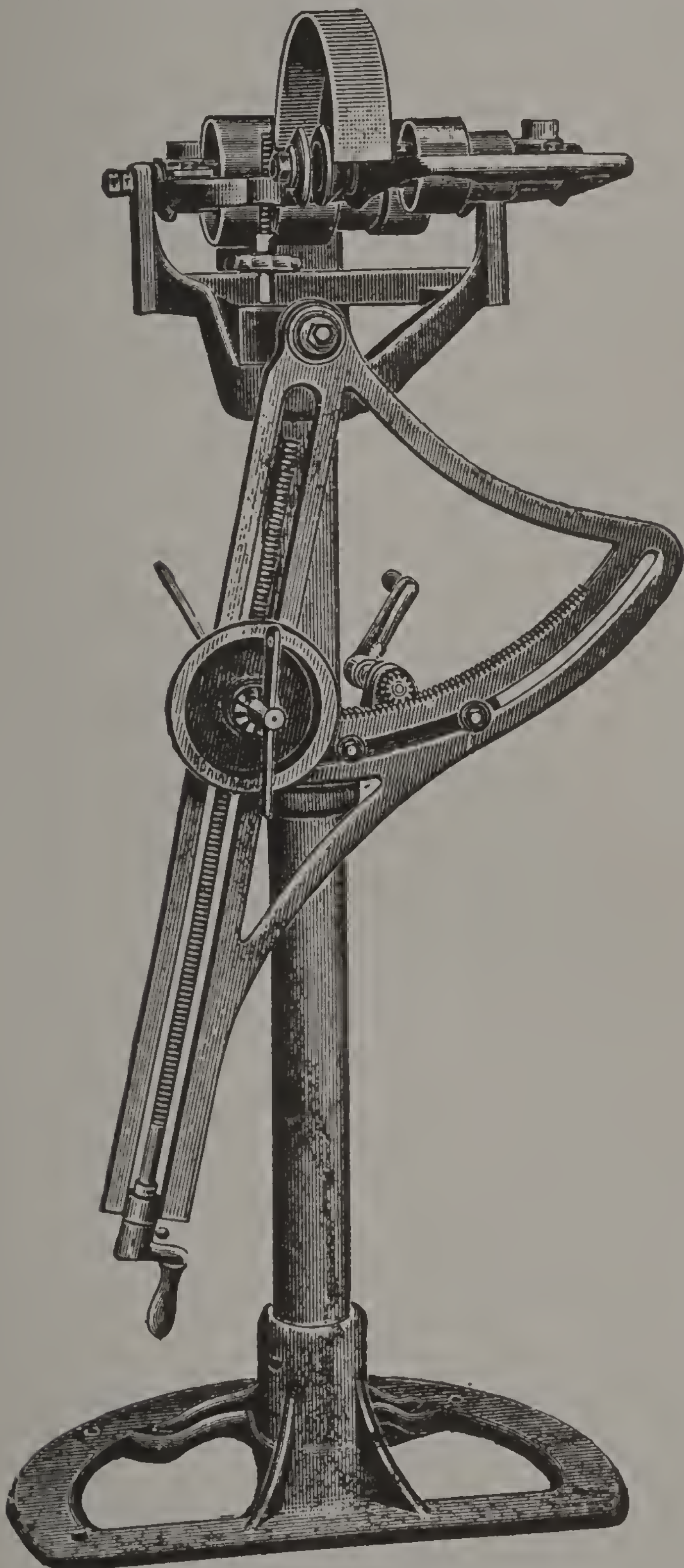


Fig. 248.

The machine shown in Fig. 251 is a universal surface grinding machine with hand instead of power feeds. The longitudinal feed is by a lever as shown and the cross or transverse feed by means of a hand-wheel. A taper grind-

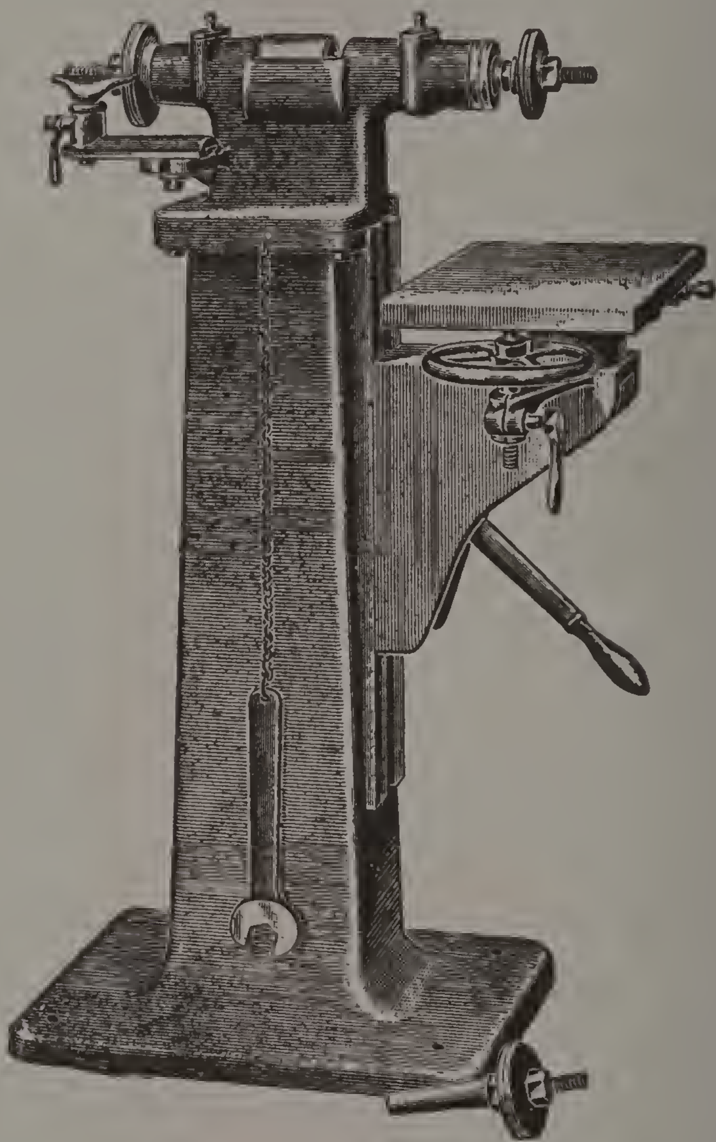


Fig. 249.

ing attachment is provided which is operated by a hand-wheel and screw at the left of the hinged table.

Water Grinding Attachment. The **Water Attachment** as shown in Fig. 252 is arranged for use on the grinder heads. It is so constructed that the outside covering plates can be easily removed, and access quickly had to the wheels. The tool rests and the plates for deflecting the water are adjustable to the wear of the wheel.

Water Grinding Machine. The water attachment on the machine illustrated in Fig. 253 consists of a chain and

Fig. 250.

pulley, entirely clear of the water in the tank, and is operated by simply lowering the lever on the side when a flow of water is desired, and raising it to turn it off. There is no pump to get out of order, nor pan to rust fast. The entire attachment can be reached in a minute's time. The flow is even and constant and the operator is not deluged.

Water Tool Grinder. A water tool grinder is shown in Fig. 254 has an outside attached centrifugal pump to furnish a supply of water to the wheel. The water is collected in the base of the grinder and is used over again.

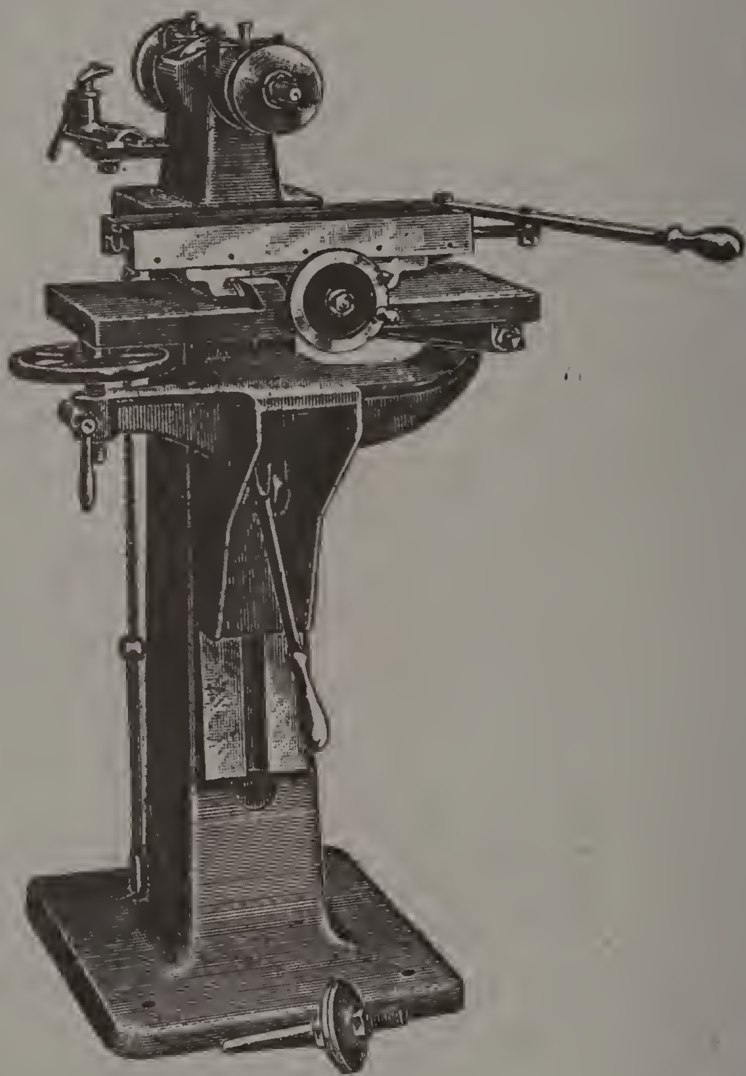


Fig. 251.

Care and Use of Grinding Machines. As the durability of a machine very largely depends upon the care of the operator, it will soon become unreliable if not properly cared for, however well it may have been constructed. All wearing surfaces should be carefully guarded and kept well supplied with oil. The use of a good quality of any machine oil is recommended in preference to one of a low grade. Oil holes which are closed with screws usually have the words oil hole stamped around them, and care should be used when oiling to keep them free from dirt and emery grit.

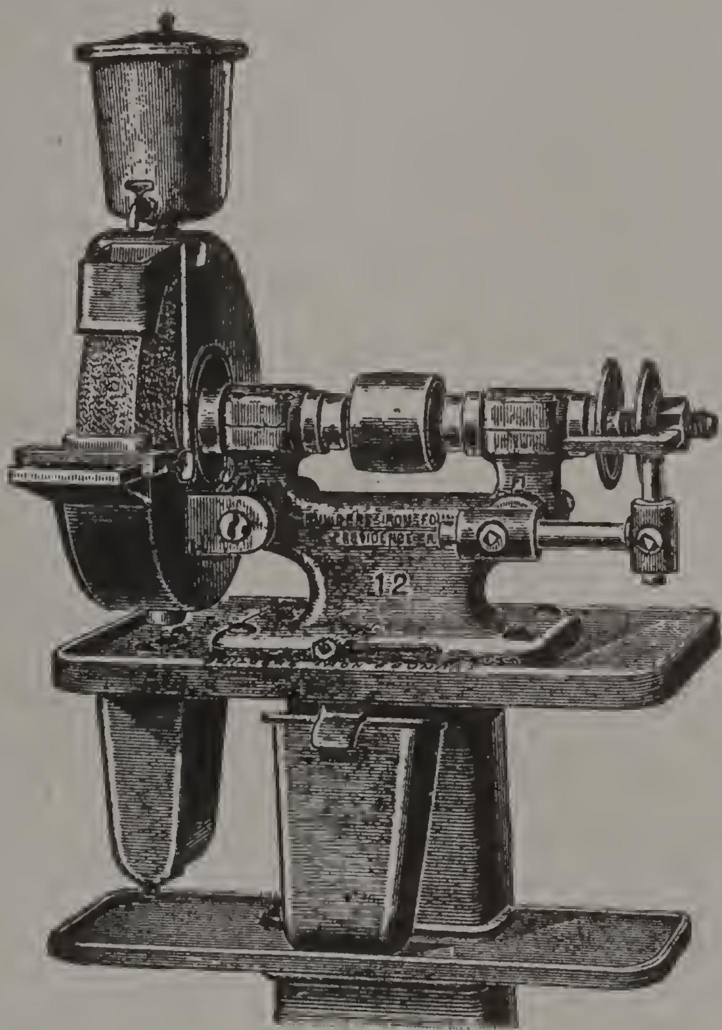


Fig. 252.

The grinding machines should be kept as clean as possible, and in no case should the bearings be allowed to gum up. When the bearings are opened and exposed for any purpose whatever, they should be carefully wiped off before they are closed again to free them from any grit that may have lodged upon the surfaces.

The spindle boxes should be perfectly clean when put together. Before tightening the caps the oil space should be filled with good oil, never lard oil, and the wheel turned slowly while first one cap and then the other is screwed down until quite tight. The felt that supplies the oil to the spindle should be kept clean.

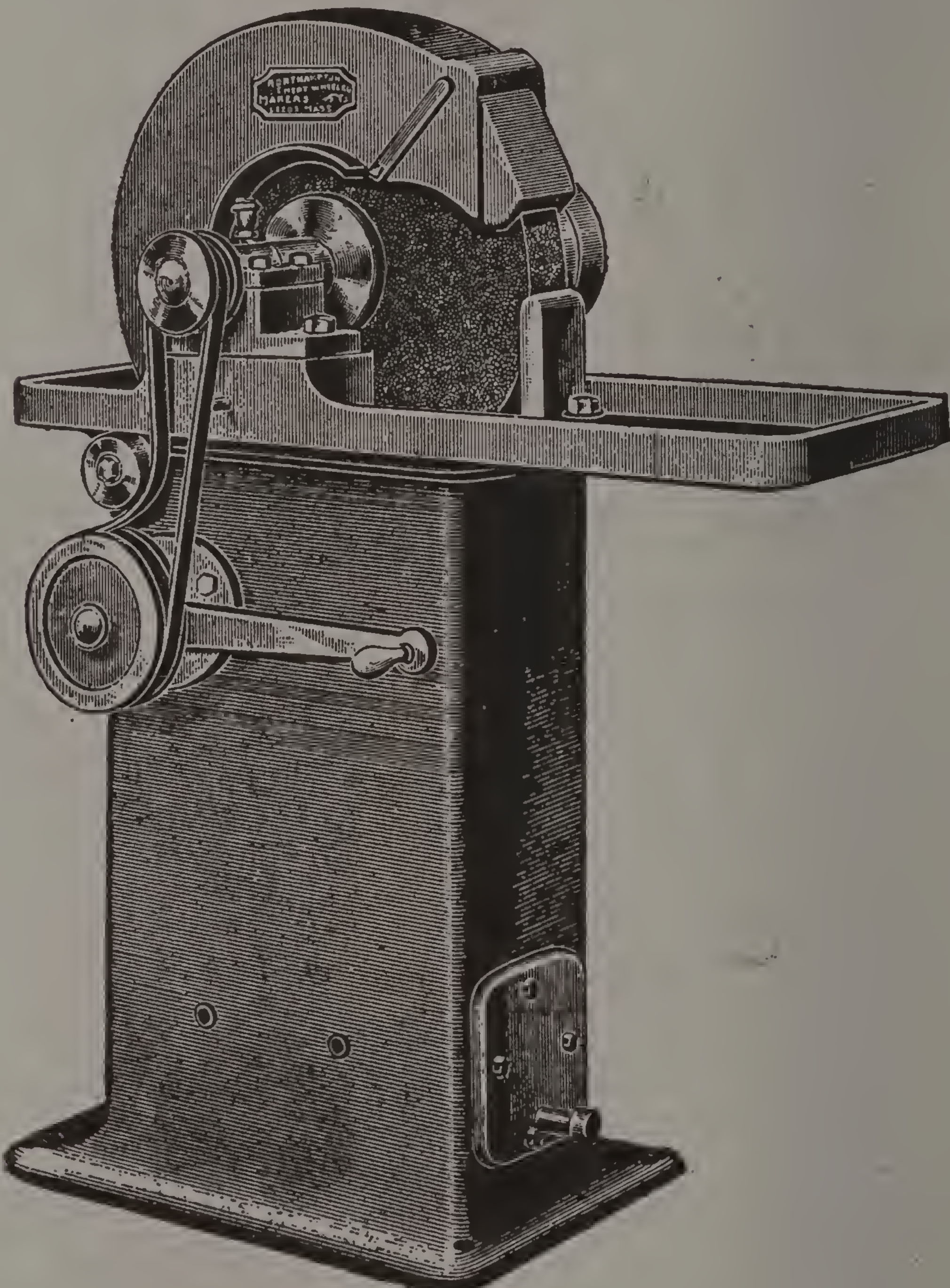


Fig. 253.

Water should always be used on such classes of work as are affected by a change of temperature caused by grinding. It should also be used upon work revolving upon centers, as in this class of work a slight change in temperature will cause the wheel to cut on one side of the piece after it has been ground apparently round.

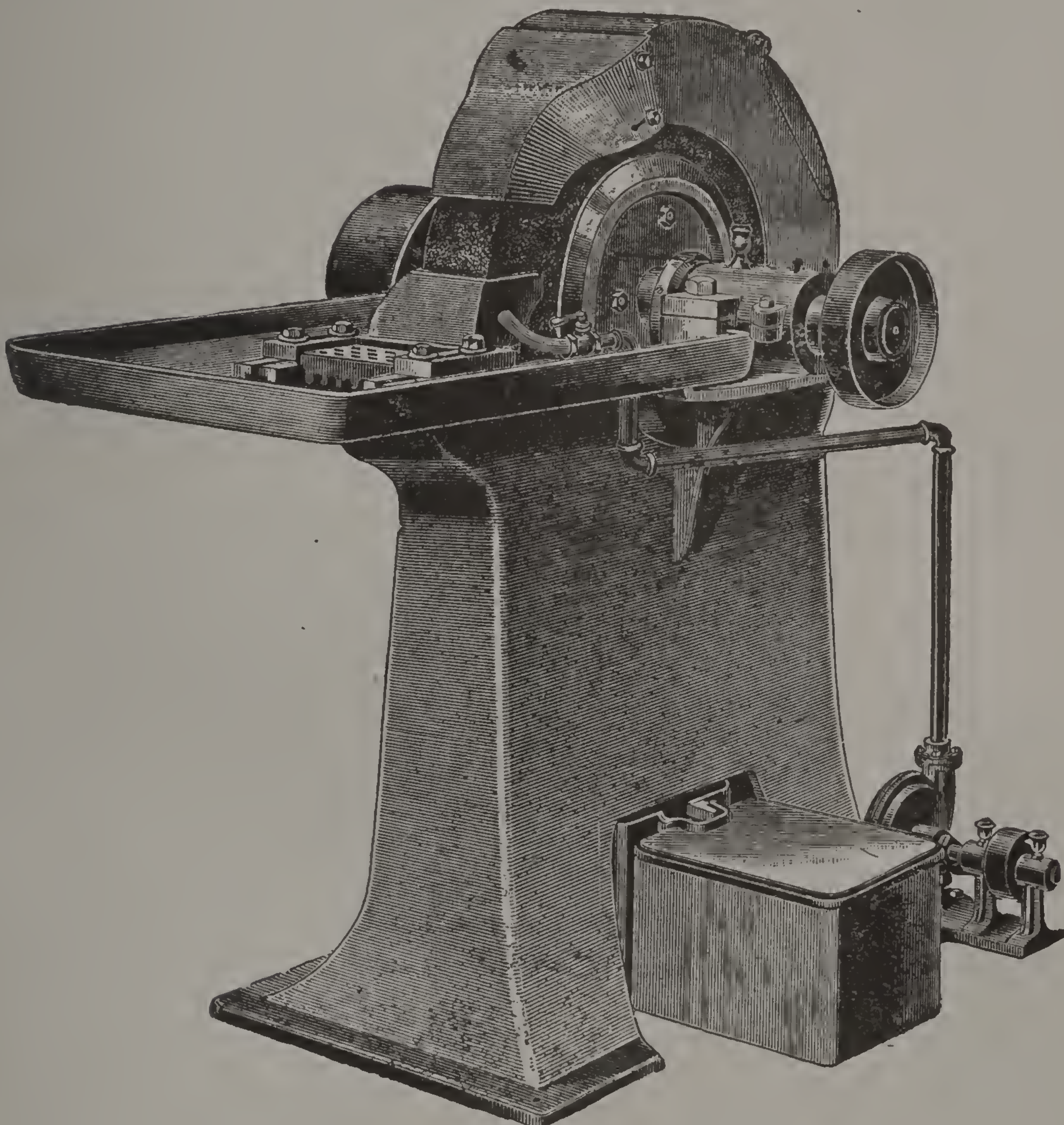


Fig. 254.

In very accurate grinding water is especially useful, for the exactness of the work will be affected by a change in temperature which is not perceptible to the touch. It is well to use the water over and over again, as there is thus less difference between the temperature of the water and the work than if fresh water is used.

Work that will grind smooth with water will often develop minute vibrations when grinding dry. There is, apparently, a rapid fluctuation of temperature, which causes the work to approach and recede from the wheel very rapidly, thus leaving a mottled or rough surface.

Emery Wheels. Wheel should always be kept true. This can be easily done by using a diamond tool, known as the black diamond or carbon point, held in the hand or in the fixture furnished with the machine. A new emery wheel should be started slowly and trued gradually. Fig. 255 shows the method of truing the face and the side of the wheel.

In mounting emery wheels there should always be elastic washers placed between the wheel and the flanges. Sheet rubber is the best for this purpose, but soft leather will answer very well. In some cases manufacturers of emery wheels attach thick, soft paper washers to each side of the wheel, when this is done it is all that is necessary.

A satisfactory emery wheel is an important factor in the production of good work. Too much, however, must not be expected of one wheel. A variety of shapes, sizes, and grades of wheels is necessary for the grinding machine, the same as a variety of shapes and sizes of tools are necessary to obtain the best results from the lathe or milling machine.

Internal Grinding. For internal grinding it is especially important that a wheel should be free cutting, and the work revolved so slowly as to enable the wheel to readily do its work. The wheels should generally be softer than for external grinding, as a much larger portion of the periphery is in contact with the work. In regulating the speed of the work it must always be considered that the small diameters of the wheels make it impossible to obtain the proper periphery speed.

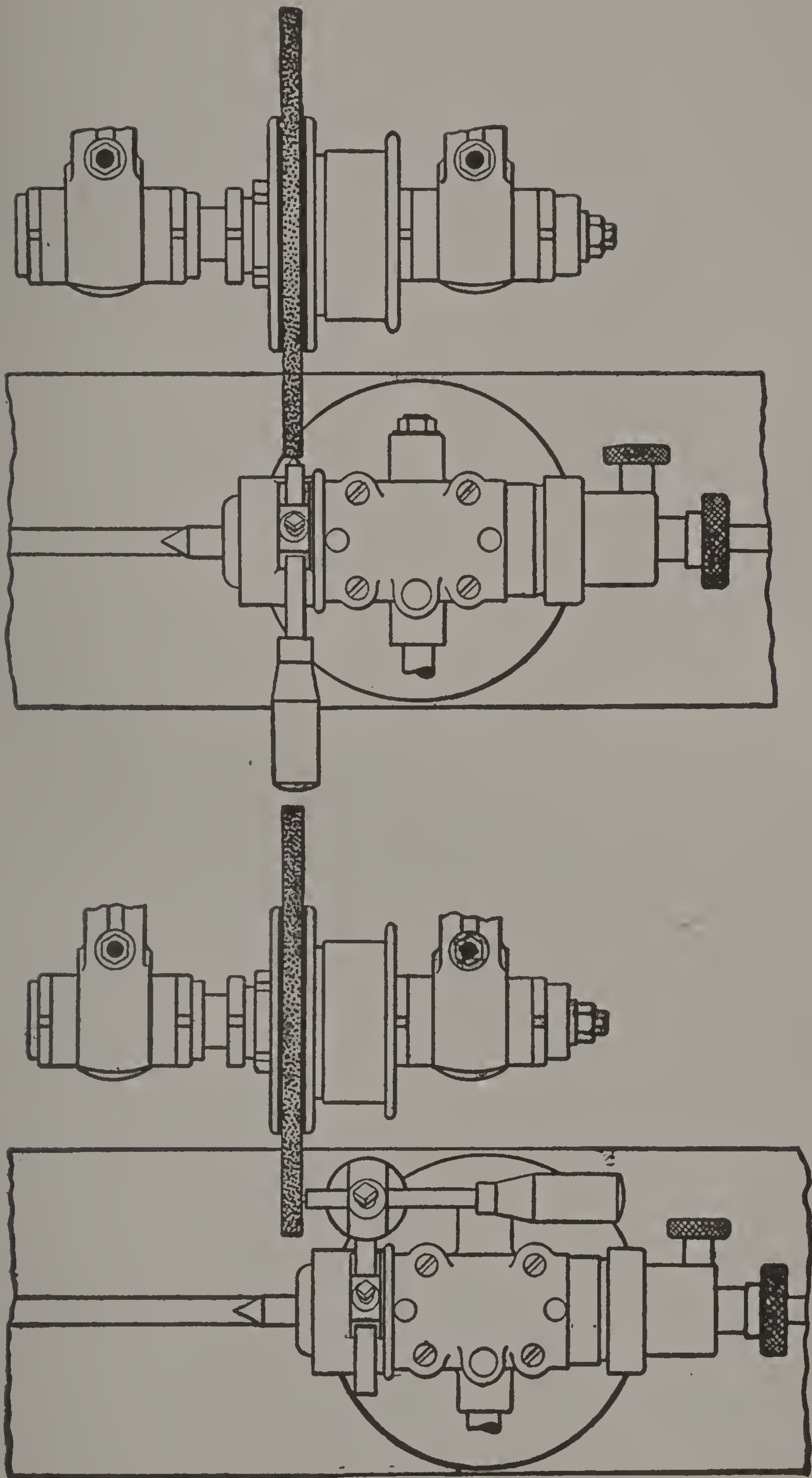


Fig. 255.

The method of driving an internal grinding fixture is illustrated in Fig. 256.

Speed of the Work and Cut of the Wheel. The speed of the work and cut of the wheel bear such close relation to each other that it is best to consider them together. The surface speed of the work should be proportional to the grade and speed of the wheel. For example, if a piece 1 inch in circumference is being ground successfully with a given wheel, and the wheel is sizing accurately in response to the graduations on the cross feed wheel a piece 2 or 3 inches in circumference would, with the same wheel and number of revolutions per minute show a coarser surface, and the wheel would cut larger than shown by the graduations on the cross feed wheel. On the other hand, if the same surface speed was used in both cases the results would be the same.

Should a wheel heat or glaze, more effective work can often be obtained by running it slower. If, on the other hand, it is too soft it can often be made to hold its size, and grind straight, by using a higher speed.

Method of Driving Universal Grinder. The elevation, Fig. 257, shows the location of the overhead works in relation to the grinding machine. The shafts run in the direction indicated by the arrows. The emery wheel is controlled by the main belt shipper and the work is revolved independently of the wheel.

Accuracy of the Work. In order to reduce the diameter of work as little as one-quarter of one-thousandth of an inch, the emery wheel slide must move as little as one-eighth of one-thousandth. If it were possible to split a piece of tissue paper into twelve thicknesses, one of them would represent the movement of the wheel slide required to reduce the diameter of work one-quarter of one-thousandth of an inch, an amount that is scarcely visible to the naked eye. The wheel slide to move such a small

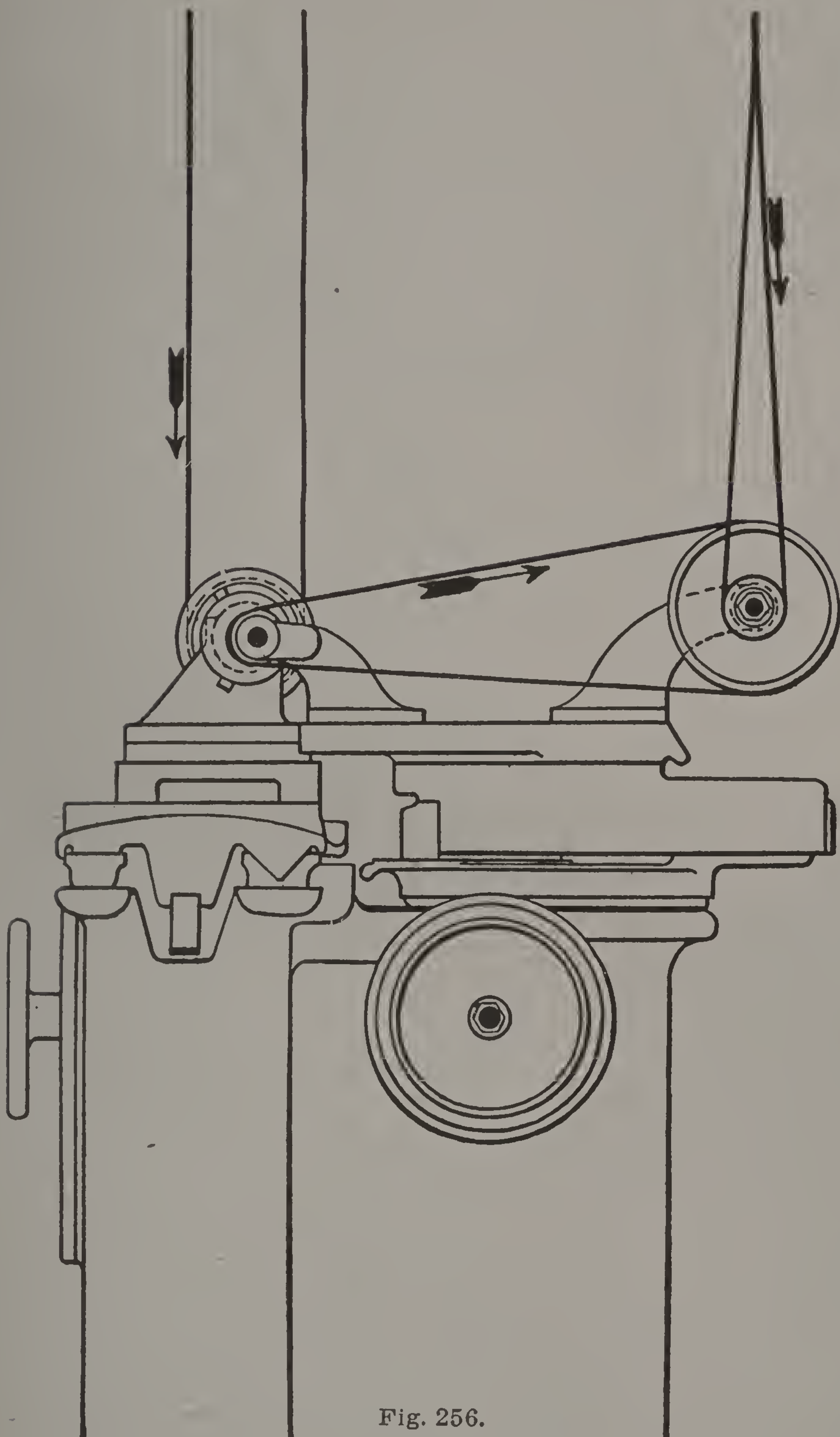


Fig. 256.

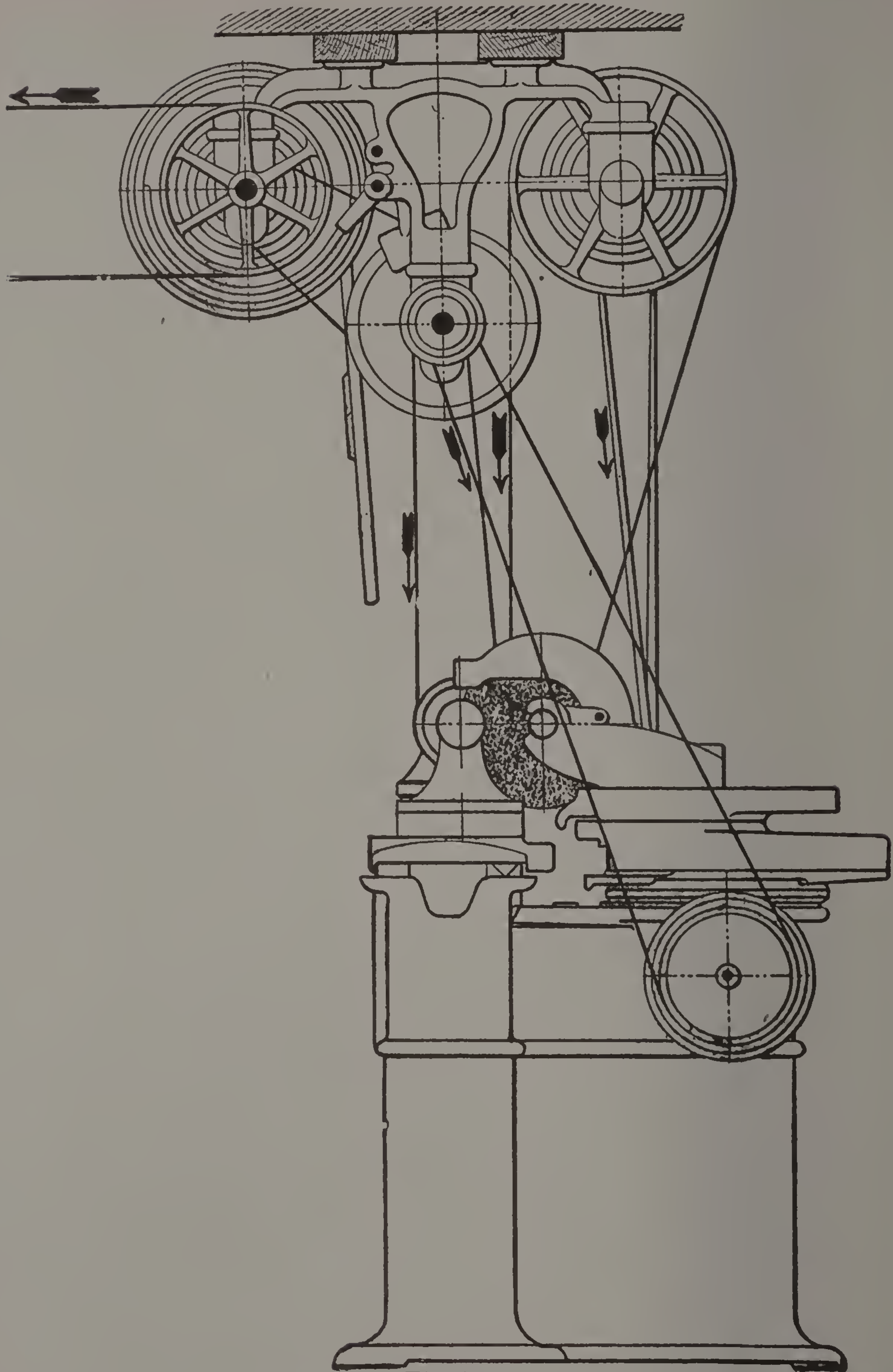


Fig. 257.

amount accurately, must be well oiled each day, and to insure thorough lubrication, it should be moved its entire length while oiling.

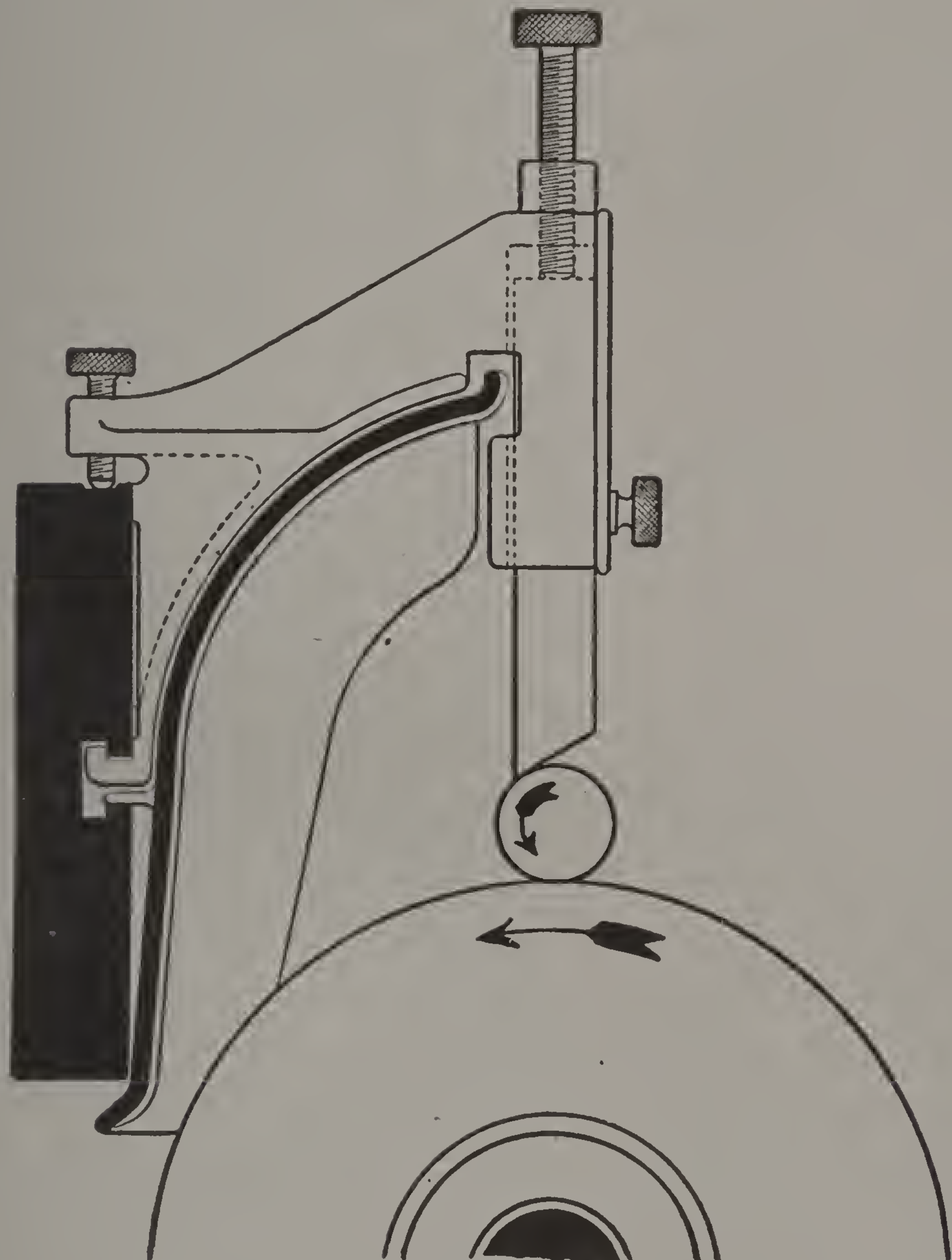


Fig. 258.

Back Rest. A plain back rest as shown in Fig. 258 may be used to advantage on all grinding operations where its use will increase the steadiness of the work.

Soft metal shoes made to fit various diameters, are the best. The shape of these shoes can be varied to suit special work. As a rule, however, back rest shoes must be more or less special and dependent upon the judgment of the operator.

Head Stock. A cross section through the headstock of a grinding machine is shown in Fig. 259. The boxes are usually adjusted before the machine is boxed for shipment, and, ordinarily, no adjustment for wear will be required for several years after the machine has been in operation. When any adjustment for wear is required, remove the caps and scrape a small amount from the seats where they bear upon the head casting when in place. Then re-

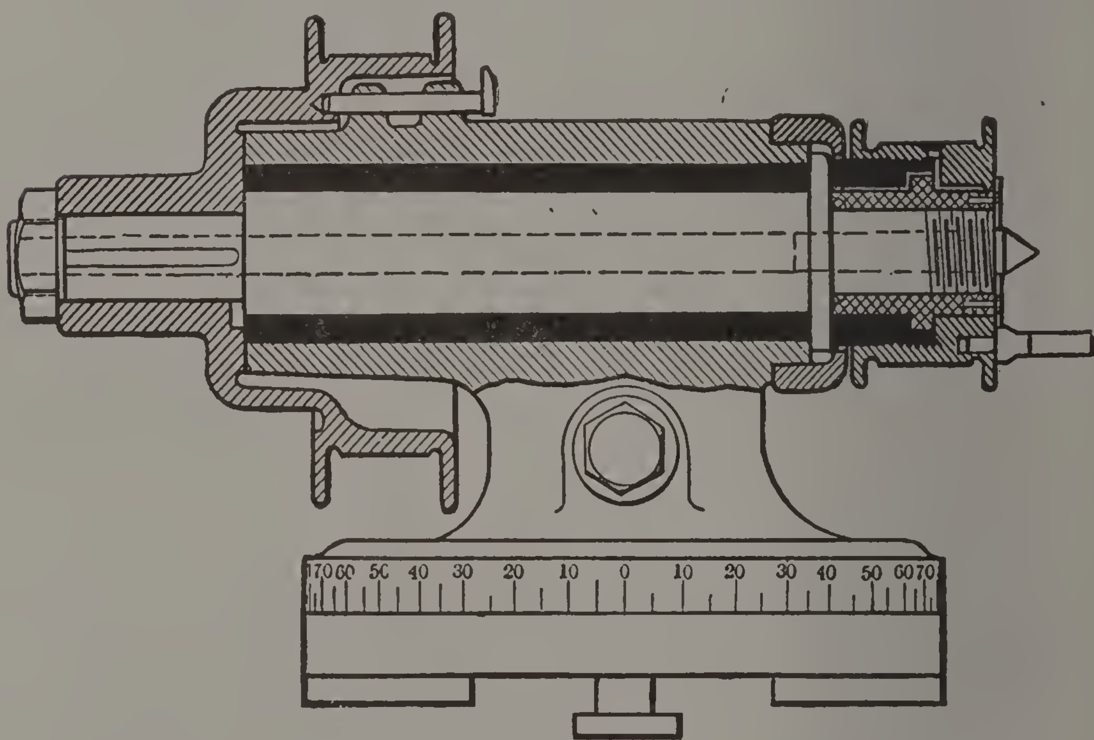


Fig. 259.

place the caps and force them to their seats with the binding screws. When it is desired to grind the work on the dead centers the spindle is held in position by a pin, as shown in Fig. 259.

Vibration of the Work. Vibration or chatter of the work is the cause of much trouble if means of prevention are not understood. In a well designed and constructed machine the vibration of its parts should be reduced to a

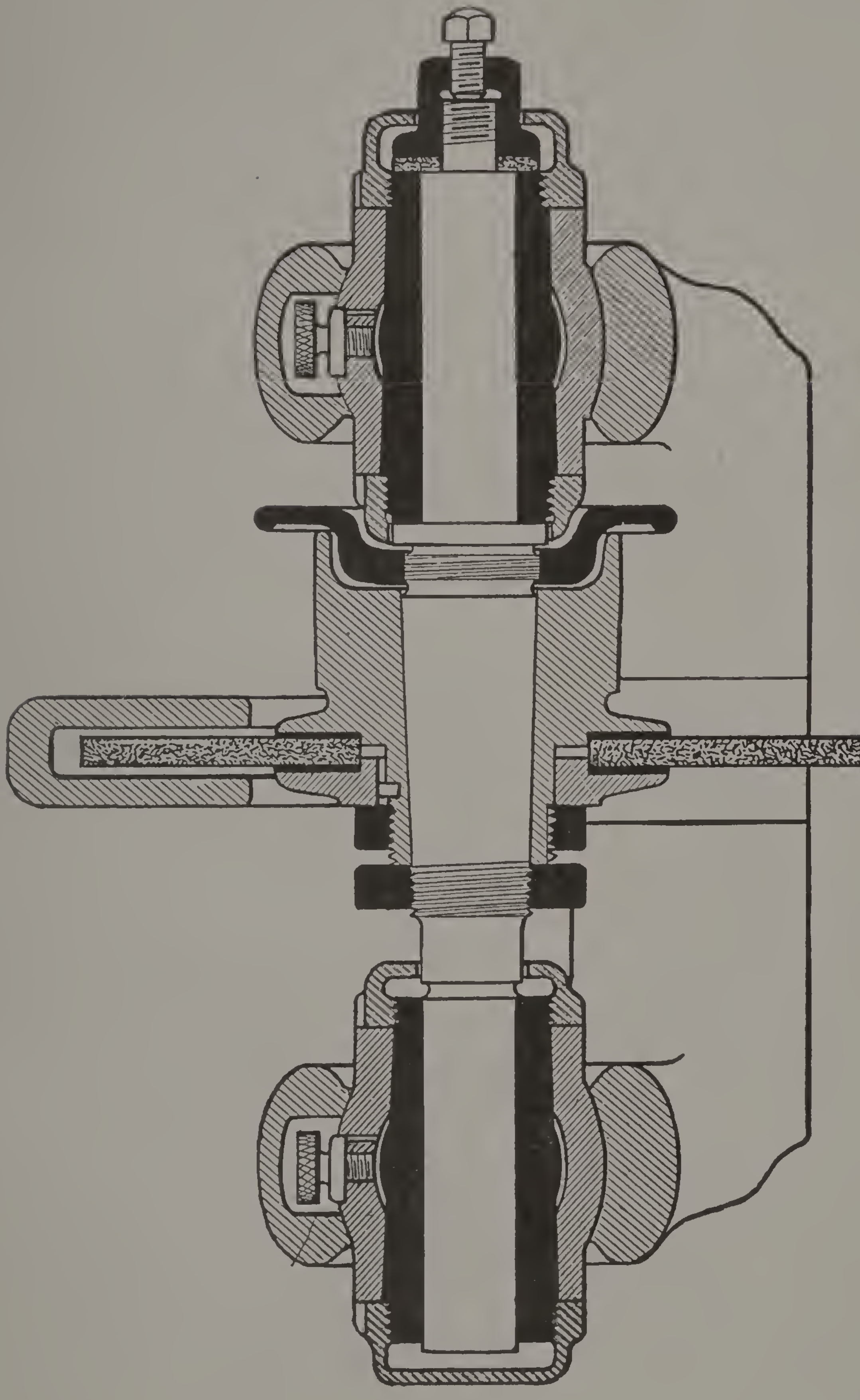


Fig. 260.

minimum, and provision made for changes of speed to help to avoid this difficulty. The wheel journals must also be a very tight fit in the boxes and the wheel belt should be spliced and glued. The use of rivets to fasten the belt should be avoided.

Grinding Work on the Head-Stock. Truing Centers. The accuracy of all work ground on centers is so dependent upon the centers being true that the operation of truing the centers by grinding should be frequently performed. To grind or true a center it is only necessary to set the head-stock to the proper angle by means of the graduations on the base.

Wheel Spindle and Boxes. The wheel spindle and boxes or journal bearings are shown in section in Fig. 260.

Adjustment for the end play of the spindle is made by means of a nut, which is held in position by a check screw.

The boxes are adjusted by two nuts, to compensate for wear both the nuts should be turned toward the back of the machine.

The spindle and boxes can be removed from the wheel stand without disturbing the adjustment of the boxes. Loosen the caps, which are hinged and held in place by bolts.

The driving pulley and flange are made in one piece, and fitted to the spindle and held in place by a lock nut on the spindle.

TABLE NO. 16—EMERY WHEEL SPEEDS.

	For Surface Speed of 5000 feet	For Surface Speed of 6000 feet.	For Surface Speed of 7000 feet.	For Surface Speed of 8000 feet.
Dia. in Inches	Revolutions per minute.	Revolutions per minute.	Revolutions per minute.	Revolutions per minute.
1	19098	22918	26737	30557
2	9549	11459	13368	15278
3	6366	7639	8912	10185
4	4774	5729	6684	7639
5	3819	4583	5347	6111
6	3183	3819	4456	5092
7	2728	3274	3819	4365
8	2387	2864	3342	3819
10	1909	2291	2673	3055
12	1591	1909	2228	2546
14	1364	1637	1909	2182
16	1193	1432	1671	1909
18	1061	1273	1485	1697
20	954	1145	1336	1527
22	868	1041	1215	1388
24	795	954	1114	1273
30	636	763	891	1018
36	530	636	742	848

THE LATHE.

The lathe, as is well known, is the principal machine tool of today. But the lathe has in the last few years undergone many improvements and transformations, thus widening its scope and very greatly extending and expediting its operations. The screw machine and the current lathe are but one form of lathes designed to produce certain classes of work more rapidly and with a minimum amount of skill in the operator.

The simplest form of lathe consists of a bed or shears, carrying a head stock for driving the work and a tailstock or footstock for supporting the work at the other end. The headstock is secured firmly to the shears, while the tailstock is made movable along it so that it may be moved up until the dead center meets the end of the work which is supported at the driving end by the live center.

Erecting Lathes. Erect the lathe on a good floor. It is essential that the floor be free from vibrations, and stiff enough so that it will not give under the weight of the lathe. Where possible a stone or concrete foundation will answer the purpose much better. When levelling use only solid packing under the legs. Level the bed in both directions, using an accurate level. It is most important to have the level show the same when placed across the shears at both the head and tail end of bed. If the level is not long enough to reach across the shears, place it on a good parallel strip. For accurate work it is imperative that the bed should have no twist in it. Attention and care in this regard will increase the life of the lathe fifty per cent, also enabling it to turn out much more accurate and better work.

Place the countershaft over the lathe, when necessary it can vary eighteen inches front or back of the center line. Have the hanger journals in line with the line shaft, and when the hangers are securely tightened, the countershaft should revolve freely. Place the thrust collars so that the shaft has one-eighth of an inch end play. The clutch pulleys should have one-sixteenth of an inch end play on bush. Place the pulley for the slow speed to the left when standing in front of, and facing, the lathe. Both driving pulleys should run in the same direction. This will double the spindle speeds, also give a quick speed change for roughing and finishing work without shifting the belt.

Clean the lathe carefully, and oil both the lathe and the countershaft thorougly. The countershaft pulley bushing can be oiled without throwing off the belt, and should be attended to at least once a month. The lathe should run thirty minutes under careful inspection to see that all parts are oiled and run properly.

Automatic Feed Turret Lathe. The machine shown in Fig. 261 will take bar stock up to 3⅝ inches in diameter which can be fed through the automatic chuck. The travel of the turret slide is 14 inches. The swing over the bed in 20 inches.

The Head and Bed are cast in one piece, insuring the greatest strength and rigidity. The cone has three steps, is geared 1.85 to 1 and back-geared 7.44 to 1, the back gears being engaged and disengaged by friction clutches.

The automatic chuck and the power roller feed handle bar stock of any shape. The chuck is operated by the long lever in front of the head, and the same lever also engages and disengages the roller feed. The chuck jaws are adjustable for any diameter from actual size to 1-16 inch smaller. One set of chuck jaws, and an outer stock support, accompany the machine.

The turret saddle is provided with a supplementary taper base, by means of which the center of the tool-holes

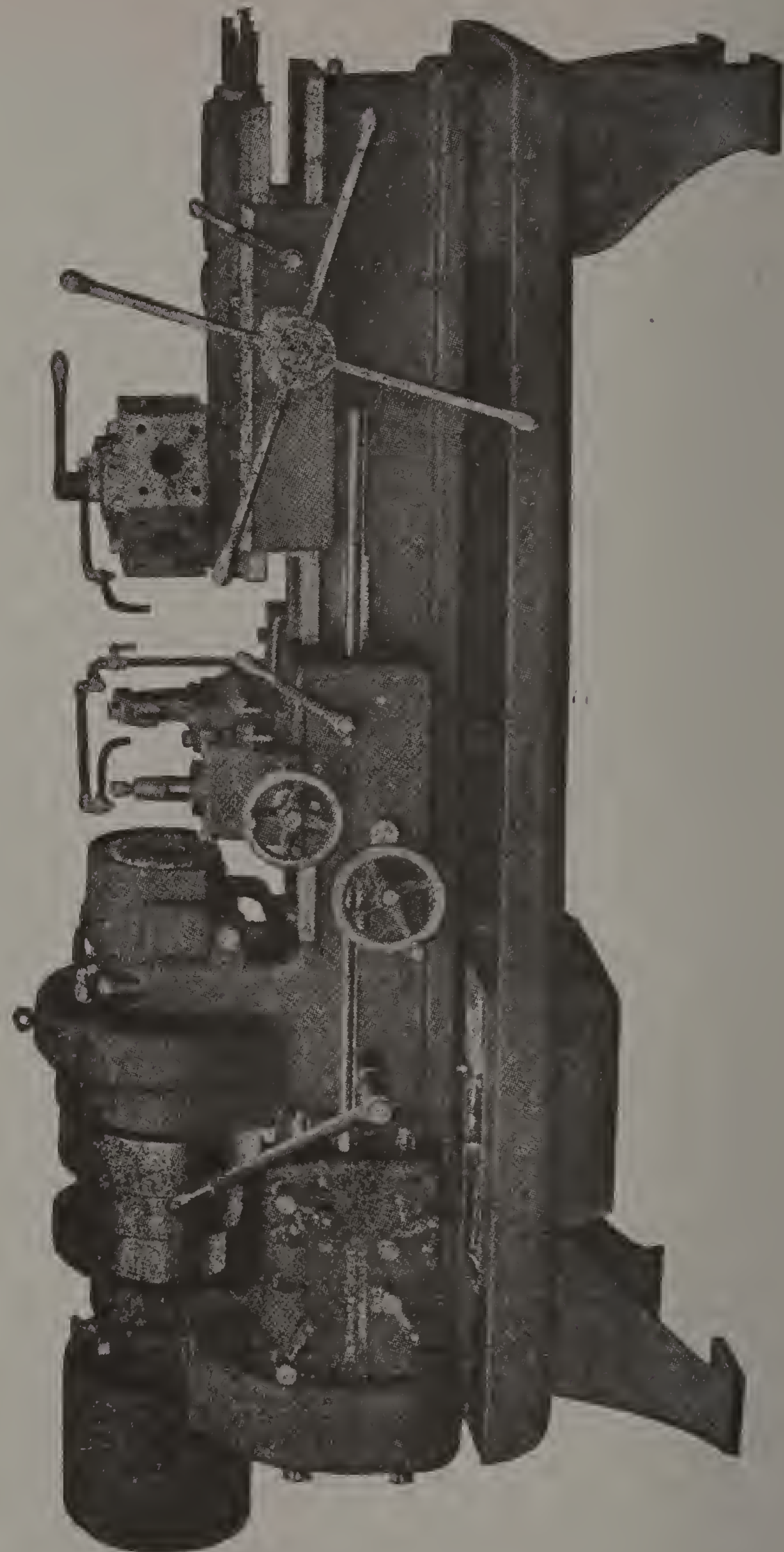


Fig. 261.

in the turret can be adjusted to the exact height of the center of the spindle. Taper gibs, fitted the whole length of the saddle on each side, provide means of adjusting the slide sideways. The turret slide is equipped with a geared automatic feed, with four changes in either direction.

The turret is hexagon in form, has six tool-holes $2\frac{1}{2}$ inches in diameter, and also bolt holes for attaching tools to the faces. It is so arranged that stock of any diameter smaller than the tool-holes can pass entirely through. The index is nearly the full diameter of the turret, and the lock bolt is placed directly under the working tool. Independent adjustable stops are provided for each of the faces.

The carriage has a geared automatic cross feed with four changes in either directions, and hand longitudinal feed. A tool post for holding forming and turning tools, and a cutting-off tool holder are provided.

The geared feeds insure a positive drive, and any one of the changes is instantly available by moving a lever. The turret and carriage feeds are independent of each other and both are provided with adjustable automatic trips.

The geared pump delivers a copious flow of oil to the cutting tools for both the turret and carriage, through two systems of piping. It operates when running in either direction.

Back-Geared Lathe. In the lathe shown in Fig. 262 the spindle is made of 50 point carbon high grade crucible steel and runs in babbitt bearings. The hole in the spindle is 1 15-16 of one inch in diameter. The spindle nose is $3\frac{1}{4}$ inches in diameter, with 4 threads per inch. The front spindle bearing is $3\frac{7}{8}$ by 7 inches. The cone has 5 steps ranging from $5\frac{1}{2}$ to 15 inches, for a 3-inch belt. The back gear ratio is $14\frac{1}{2}$ to 1.

The headstock is massive, double-webbed its entire length, and not weakened to make room for the reverse plate. Am-

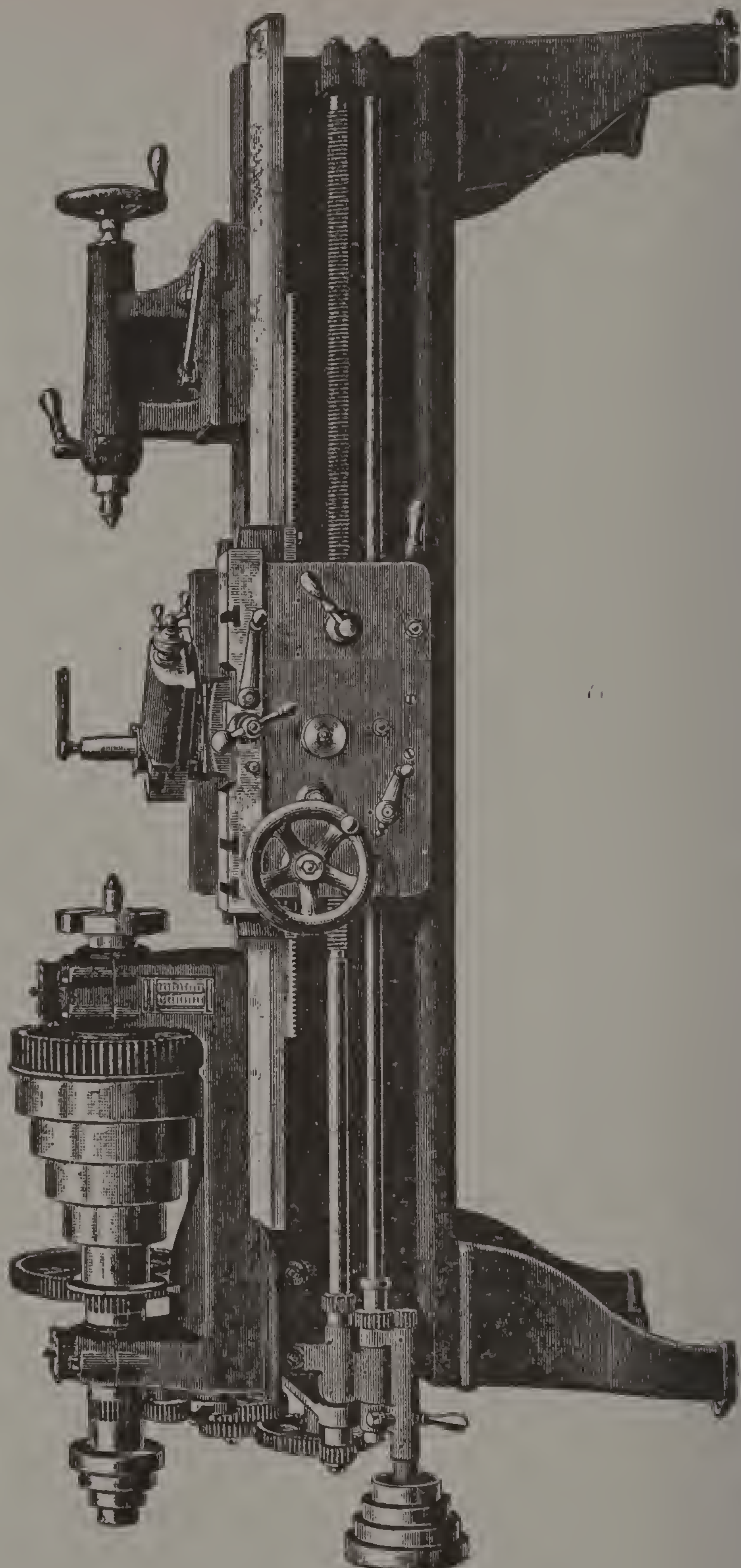


Fig. 262.

ple oiling facilities are provided and oil-holes have dust-proof covers. The front end of the tailstock barrel is re-enforced to withstand heavy strains, it has a No. 4 Morse taper in a spindle, and the set-over is graduated.

The apron is arranged so that it is impossible to throw in the rod and screw-feed at the same time. The rack-pinion can be thrown out of mesh with the rack, so that when chasing there is no resistance or friction of any moving part in the apron. All the feeds are reversed in the apron.

Threads can be cut from 2 to 24 per inch, including 11½ pipe thread. A chasing dial for catching the threads is provided, and threads can be cut without stopping the lathe or reversing the lead screw.

The geared-feed is positive, all the feeds are obtained within the range of modern practice. There are also 3 belt feeds, ranging from .020 to .070 cuts per inch.

The countershaft has double friction pulleys, 14 and 16 in. diameter for a 4½ inch belt. Both belts should run forward as no backing belt is required. Speed of countershaft is 125 and 160 revolutions per minute.

The lathe is made with either plain block or compound rest. A taper attachment, a turret on the shear, or a turret on the carriage can be furnished if desired.

Combination Turret Lathe. Figure 263 shows a 25-inch combination turret lathe. This is said to make an ideal manufacturer's lathe. It possesses all the quick speed and feed changes that are so important for the economical up-to-date production of work. With the triple friction countershaft nine changes of speed are obtained without shifting the belt. The head is geared 16 to 1, so that it has enormous power for facing and scaling cuts.

The cone is arranged for a 4-inch belt, the smallest step is 12 inches diameter, thus securing at all times a good belt speed. This power is increased by a double friction

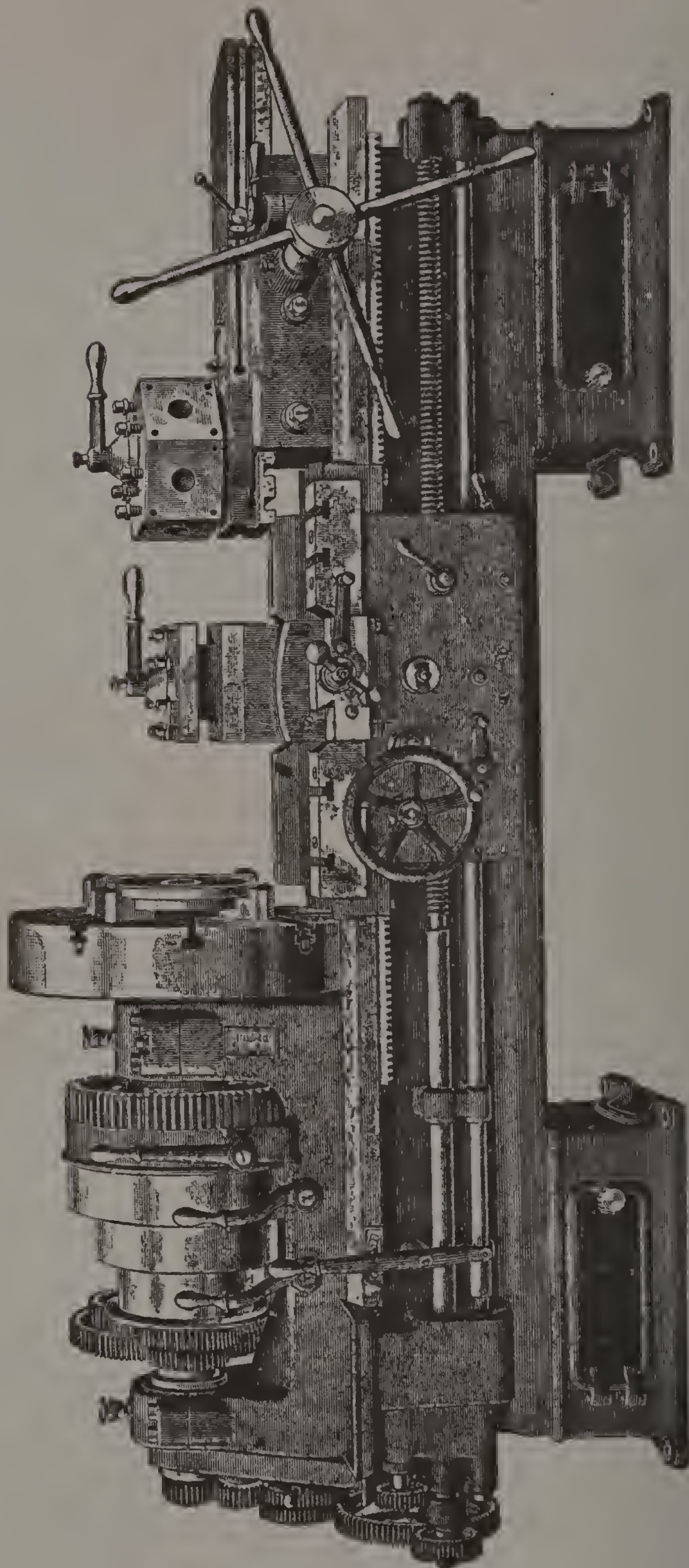


Fig. 263.

back gear. The feeds are positive, four quick changes being made by a lever, these can be varied by change gears to suit all classes of work. The turret and carriage feeds are independent of each other so that the correct feed can be used on a boring and turning operation at the same time. The turret can also be connected to the carriage and a feed obtained with the lead screw for a positive lead in tapping. The carriage is furnished with our turret tool post, carrying four independent tools.

Bench Lathe. For small or fine work the bench lathe

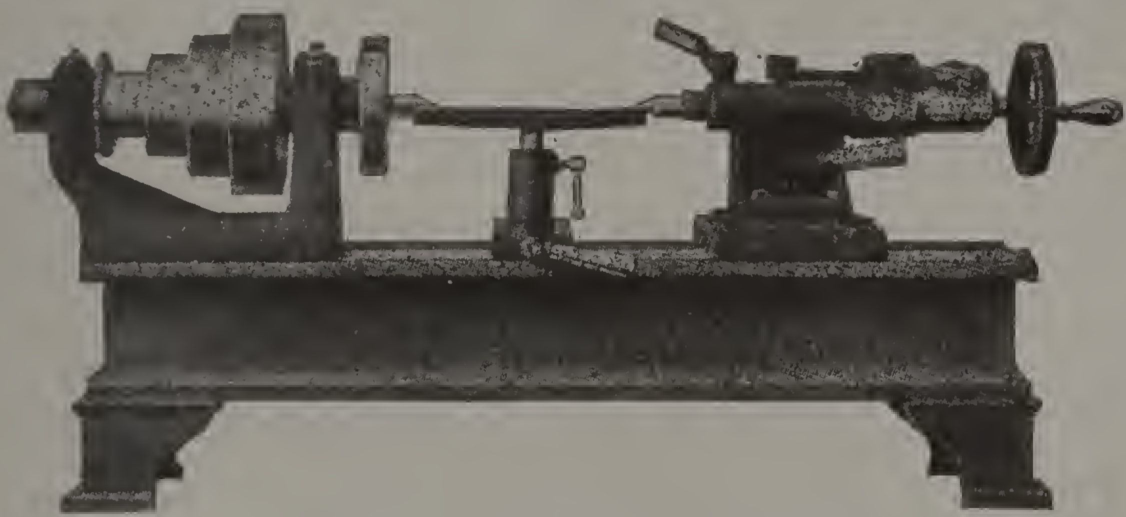


Fig. 264.

shown in Fig. 264 will be found a very useful adjunct even to a well equipped machine shop.

Double Headed Manufacturer's Lathe. The lathe shown in Fig. 265 was designed for finishing work held by a face plate or chuck. Tail stocks can be furnished for work which requires centers. It is especially adapted for manufacturing a large number of duplicate parts as it enables one operator to run two spindles. It is furnished with an automatic longitudinal and cross feed, the speeds and feeds for each head being independent. All feeds are reversed in the apron and are driven by a belt, the belt being kept at proper tension by belt tighteners.

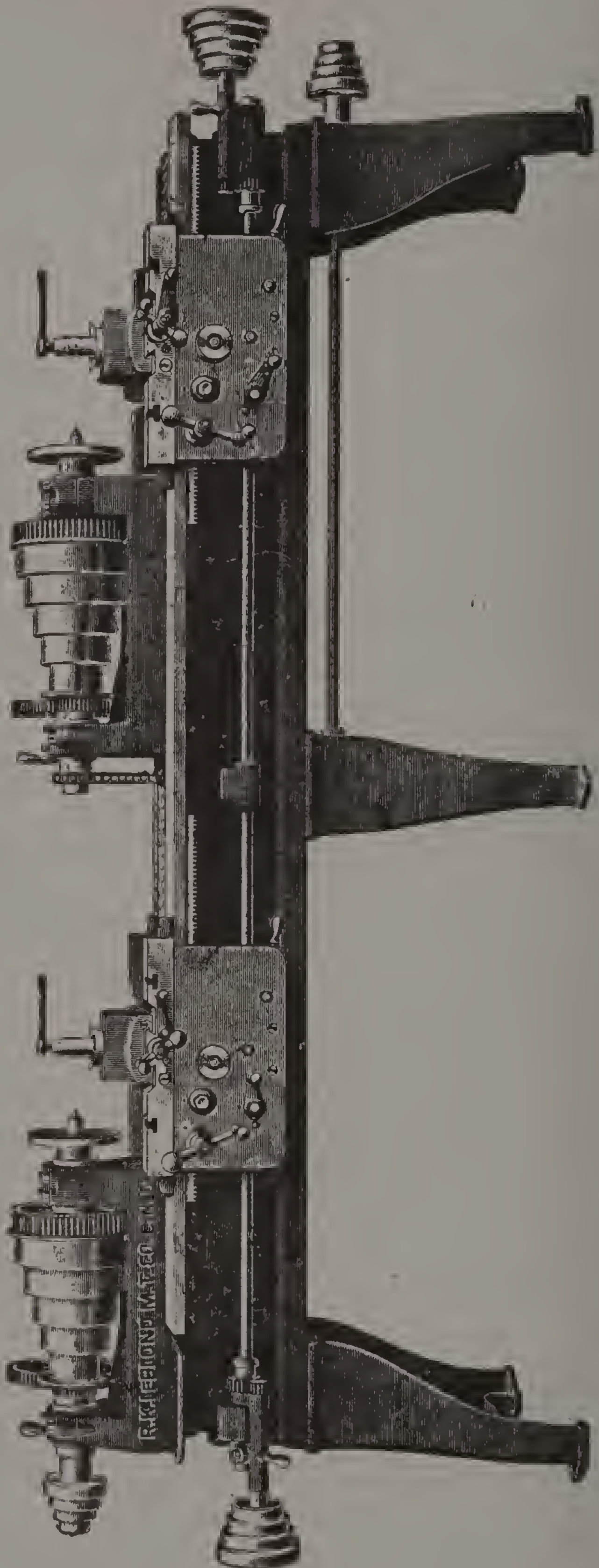


Fig. 265.

Fourteen-Inch Lathe. A fourteen-inch lathe is shown in Fig. 266. The spindle is made from a crucible steel forging and has a 15-16 inch hole through it. The cone pulley has five sections, the largest of which is 9¼ inches diameter for a 2 inch belt. The spindle bearings in the head stock are of cast iron lined with genuine babbitt metal.

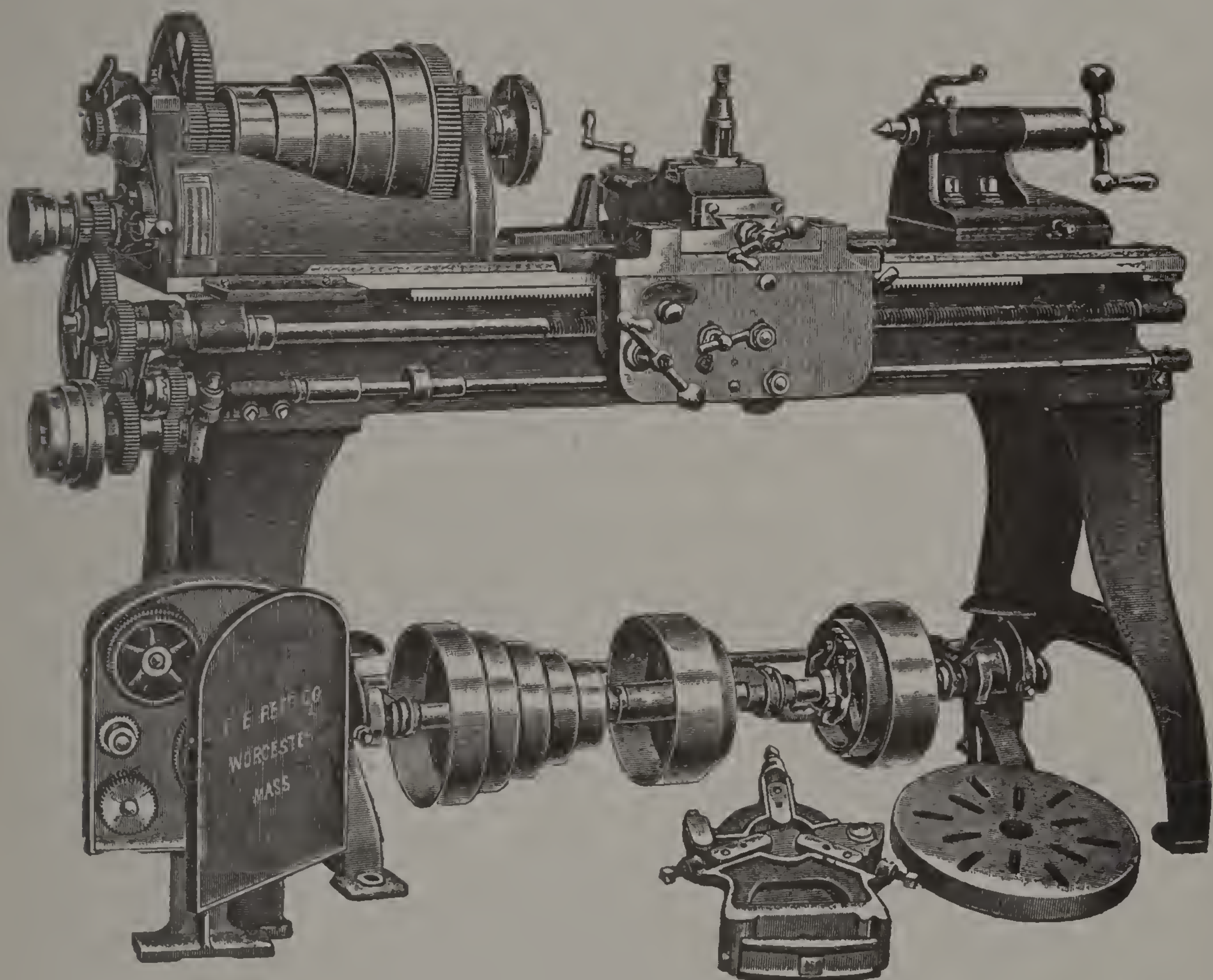


Fig. 266.

It is furnished with an elevating rest, or with a plain rest. It can be furnished with a compound rest also taper attachment is furnished when wanted with either style of rest.

Power cross feed is furnished with either style of rest. Independent rod and patent friction feed. Combined gear and belt feeds are furnished, also automatic stop motion in connection with either gear or belt feed. The lathe is so arranged that the lower feed cone can be swung around to tighten the feed belt, at the convenience of the operator. There are six belt feeds ranging from 40 to 140 inclusive. When the geared feed is wanted the belt can be removed and the feed rod connected with the intermediate gear, then by changing the gears on the feed stud of the head stock, feeds can be obtained from 13 to 150, inclusive.

It has a steel rack and pinion for moving the carriage. The back gear can be drawn out of the rack, thus preventing wear on these parts when not required in screw cutting and other similar work. The steel leading screw is of 5 pitch, with open and shut nut. It cuts threads 3, 4, 5, 6, 7, 8, 9, 10, 11, 11½, 12, 13, 14, 15, 16, 18, 20, 22, 24, 26, 28, 30, 32 and 36 per inch.

The countershaft is furnished with friction pulleys 10 inches diameter for 2½ inch belt, and should make 150 revolutions per minute. The pulleys can be oiled while running, thereby saving loss of time, danger and annoyance in running off the belts, which is an important item where a number of lathes are in use. The countershaft has self oiling hangers.

Motor-Driven Lathe. The claims made for a direct electric motor drive are: Greater efficiency of the tool owing to a more powerful drive and correct cutting speed—doing away with the line shaft, countershafts, belts, etc., thus avoiding the dirt and grime which always follows the belt and darkens the shop—the facility for placing the tools, not having to depend on any special location for the drive—the elasticity of the whole arrangement for adding new tools, properly grouping them and changing when necessary. Also the fact that when the machine is not in use no power is being consumed, but the tools are always ready for work in case of an emergency or overtime without running a long line of shafting and countershafts.

A variable speed motor, with an electrical speed range of about three to one as shown in Fig. 267 is used. Whether this variable speed is obtained by multiple voltage or field

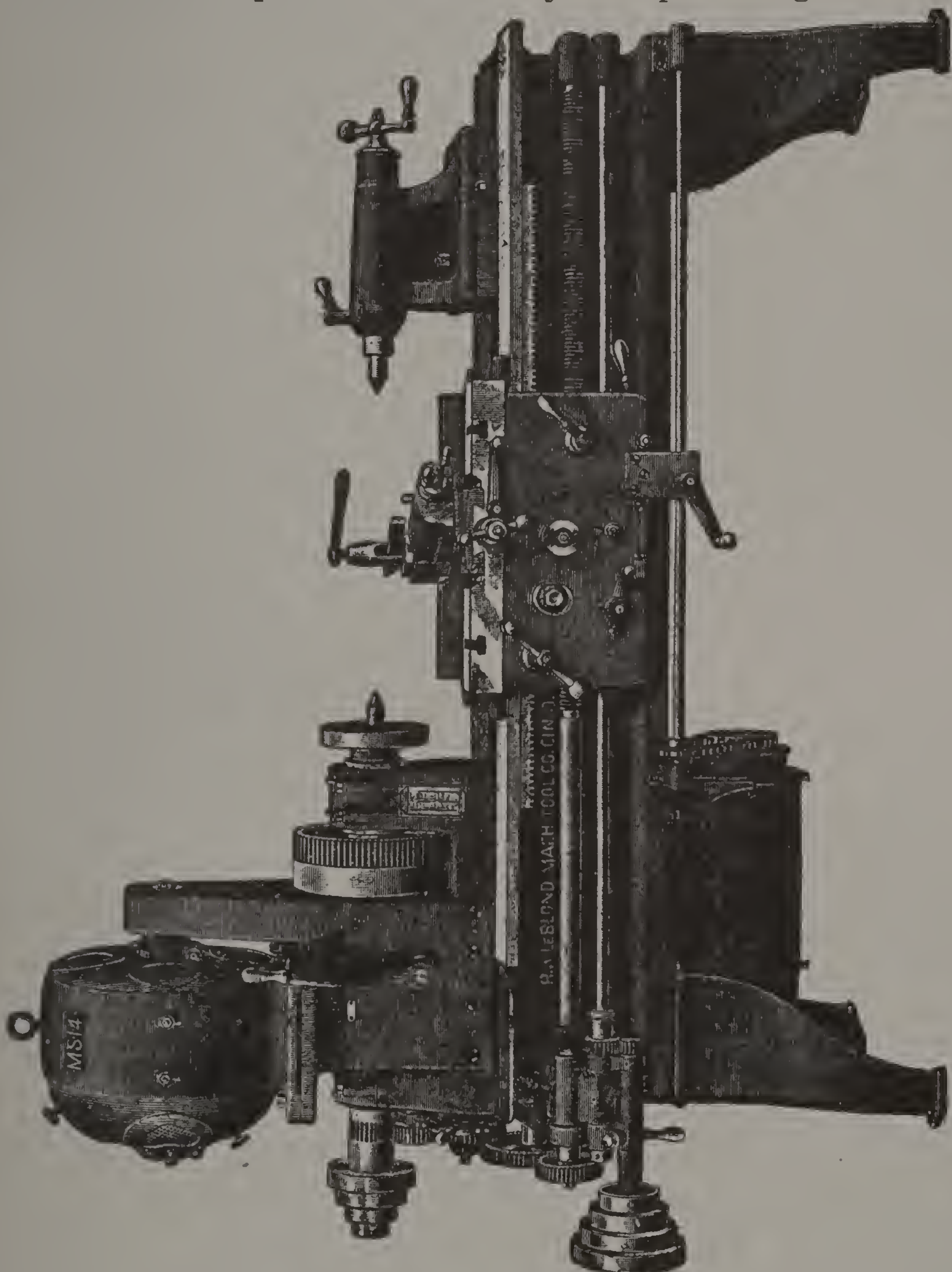


Fig. 267.

control, the results prove satisfactory. This range is then multiplied mechanically to suit the tool.

The multiple voltage is based on well known principles; two or more different voltages are supplied to the armature of the motor from which speeds proportional to these voltages result. These speeds are then divided by field regulation giving the greatest range of any system. With the field control motor one voltage only is required, the entire speed range being obtained by changing the field. This form of control can therefore be used where power is obtained from an outside source, or when only one voltage is available. Where multiple voltage is used special arrangements are necessary in the power plant to obtain two or more voltages.

With the belt drive it has been thoroughly demonstrated that from 45 to 75 per cent of the entire power generated is used by the transmission machinery, in very few instances is there more than 45 per cent used by the machine tool. With direct motor drive, from 70 to 80 per cent of the power generated is delivered at the machine. With any standard make of motor a range of speed changes can be obtained, increasing at a rate of about 10 per cent, while with the cone pulley, as at present used on most lathes, the increase ranges from 30 to 50 per cent. Having the proper speed for the work will therefore greatly increase the capacity of the tool.

Motor-Driven Turret Lathe. The drawing shown in Fig. 268 shows a 21-inch Turret Lathe arranged for a motor drive with field control. The motor has a speed range of 3 to 1, the power being transmitted from the motor spindle to the gear quill with a silent chain, the field control giving 14 speed changes. These speeds can be transferred direct to the spindle by the lever shown on the friction head, or multiplied twice by the second lever which controls the double friction back-gear, giving 3 mechanical changes, and a total number of 42 spindle speeds, ranging from 8 to 382. This lathe can be stopped independently of the motor.

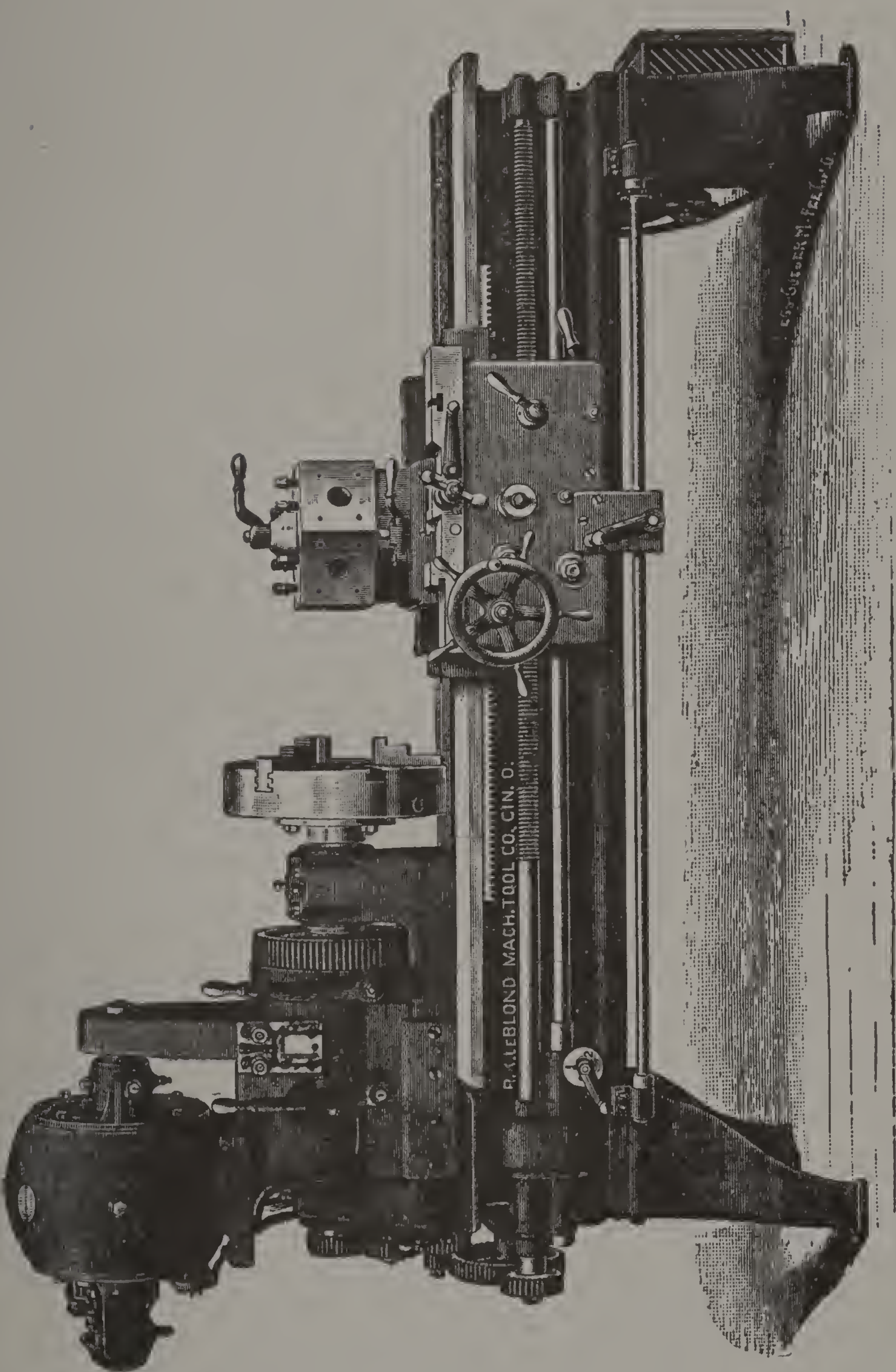


Fig. 268.

Pattern Maker's Lathe. The lathe shown in Fig. 269 is carefully fitted up the same as an iron-working machine. It has adjustable bearings, iron stop cone, carriage with rack and pinion movement, and cross carriage operated by a screw and handle. Automatic feeds can be supplied to the carriage when desired.

The head spindle extends through the outer end of the headstock, and is provided with a large face plate for turning work larger than the swing of the lathe. On the larger sizes the head swivels for obtaining the draft on patterns.

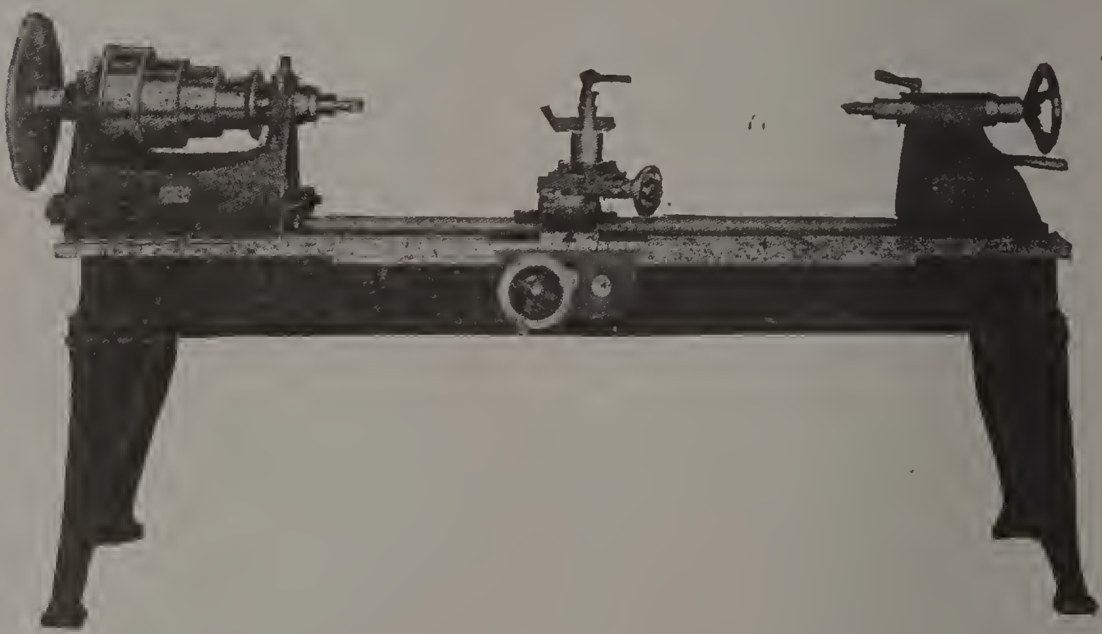


Fig. 269.

The countershaft is equipped with friction clutch pulleys, one large and one quite small, giving a large range of speeds. The lathe is carefully balanced so that it will run at very high speeds without vibration.

Plain Turret Lathe. The 16-inch turret lathe shown in Fig. 270 is designed to perform the simpler operations of chucking. For all work which does not require a carriage or secondary tool on the slide, it will be found very useful. The turret is strong enough to carry heavy facing tools, the spindles are heavy and provided with a large

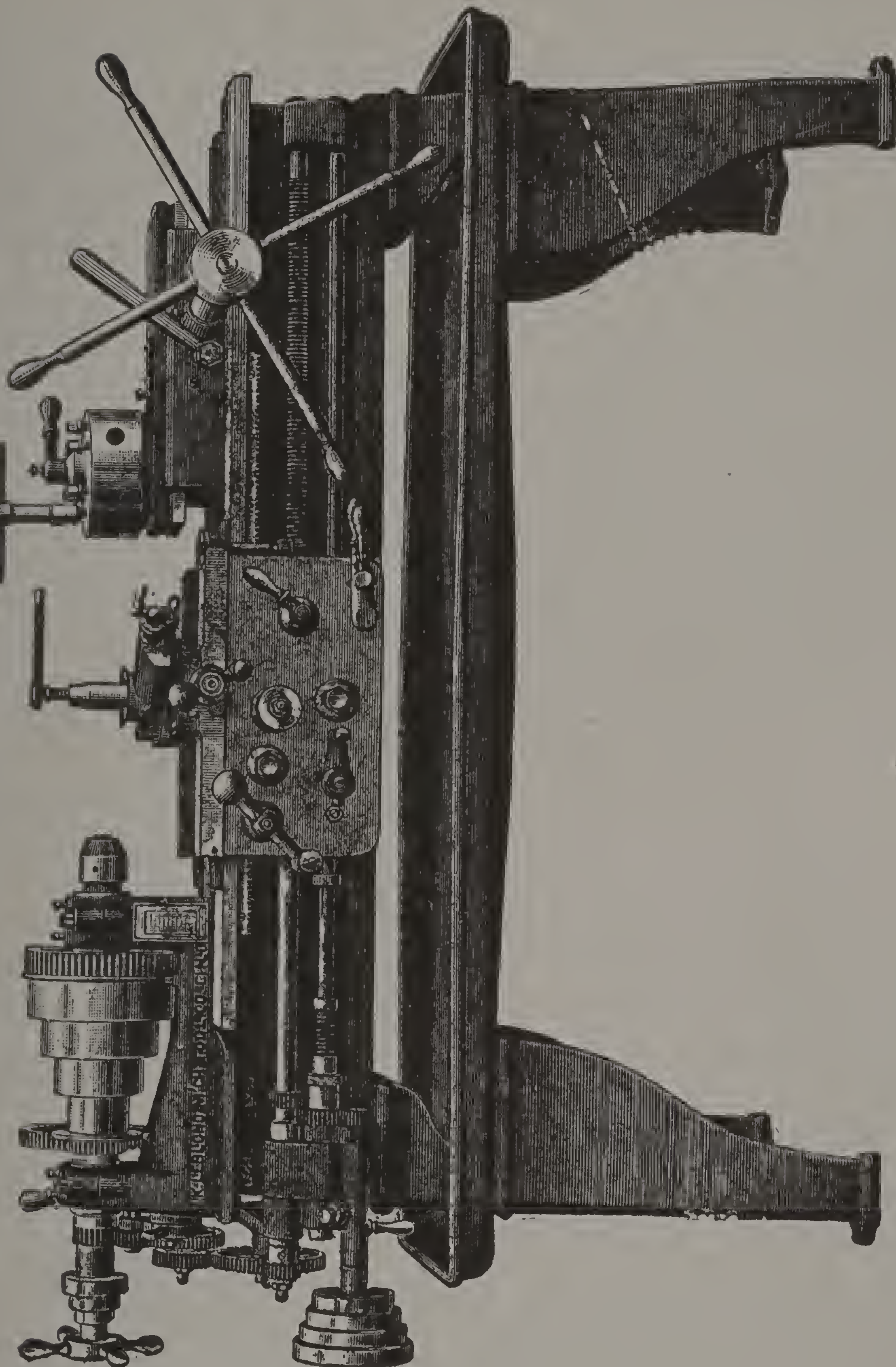


Fig. 270.

hole so that bar work can be conveniently handled, the end thrust is taken with ball bearings. The turrets are automatic and are made with or without power feed. The lathe can be made with back gears, also with double friction back gears and friction head.

The front end of the spindle is bored taper to carry a bushing for supporting boring bars. The turret is of standard make, all parts subject to wear being provided with adjustment to compensate for the same. The turret block is fitted with a taper bushing, so that it can always be kept tight on stem. The locking pin and ring are made of tool steel, hardened and ground, the locking pin has a bearing in the slide on both sides of the ring, the ring is placed at the extreme outside of the turret, so that the tool is rigidly supported.

Quick Change Gear Lathe. The lathe shown in Fig. 271 represents a quick change gear lathe, which are made from 12 to 30-inch swing. These lathes were designed to supply the demand for a tool on which a great variety of work could be done and which required continual changing. The quick feed changes are obtained in the simplest possible manner and so that there will be no undue friction. The device contains the minimum amount of parts, thus requiring the least amount of care and assures long life to the lathe.

The gear change feed box is provided with ample oiling facilities, the bearings are of proportions, and the entire range of feeds can be obtained without stopping the lathe or removing a single gear.

The special features of this quick change lathe are:

There are no splined shafts, nor gears with key-ways, sliding or running on the shaft.

Neither the hear nor bed is weakened by slots cast or cut in them.

There are no shafts in torsion, the power being trans-

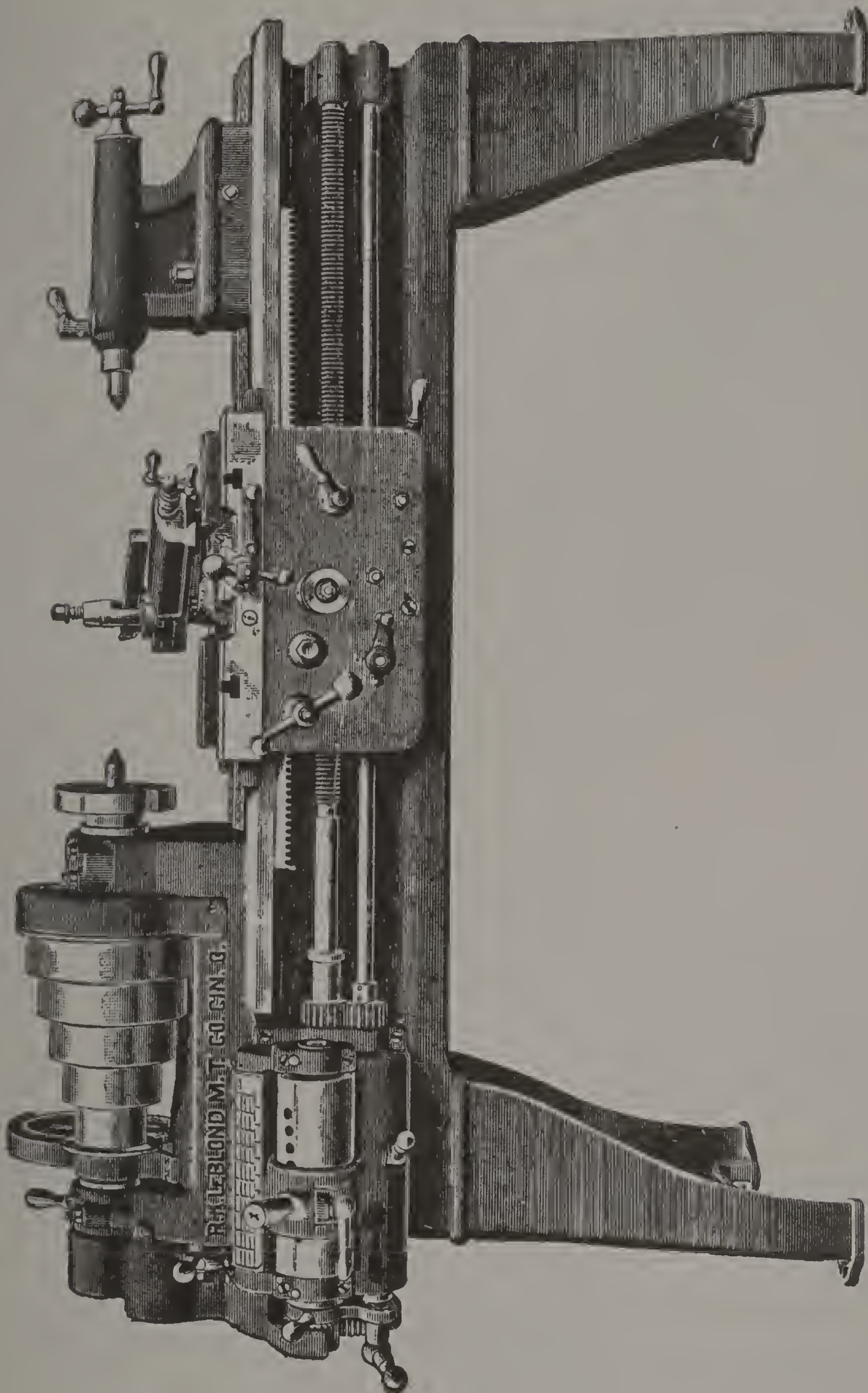


Fig. 271.

mitted entirely by the gears, the shafts simply act as bearings and are not used for transmission.

The locking pin is arranged so it does not over-hang but connects the sleeve directly to the case, and when additional friction is necessary, the whole can be locked together.

The gear box is made so that it is impossible to mesh the gears on the corners, in other words the gears cannot be thrown into mesh until exactly in the proper position longitudinally.

The handle at the bottom which, when placed in a central position, allows the feed works from that point to remain idle, so the gears can be changed at the highest speed without injury, the lower handle can then be thrown which connect the feed works to the gear box.

The box is designed so that the speed of the feed gears is inversely proportioned to the threads to be cut, it being no harder on the gear box to chase four than forty threads per inch.

No compound gearing used between the spindle and the feed box, loss of power, excessive strain and friction generated by compound gears used in other devices of this kind is thus avoided.

The gears are exceedingly strong with wide face and heavy pitch, and those which mesh by throwing them in on the teeth, are of steel.

This lathe is made with an independent feed rod, so that splining the screw is not necessary and when the lathe is used for turning, the lead screw remains stationary.

The gear box is so arranged that if necessary, any thread not on the index plate can be chased by using a change gear as on an ordinary lathe.

All the feed works are easily accessible, no other part of the lathe has to be removed to get at them.

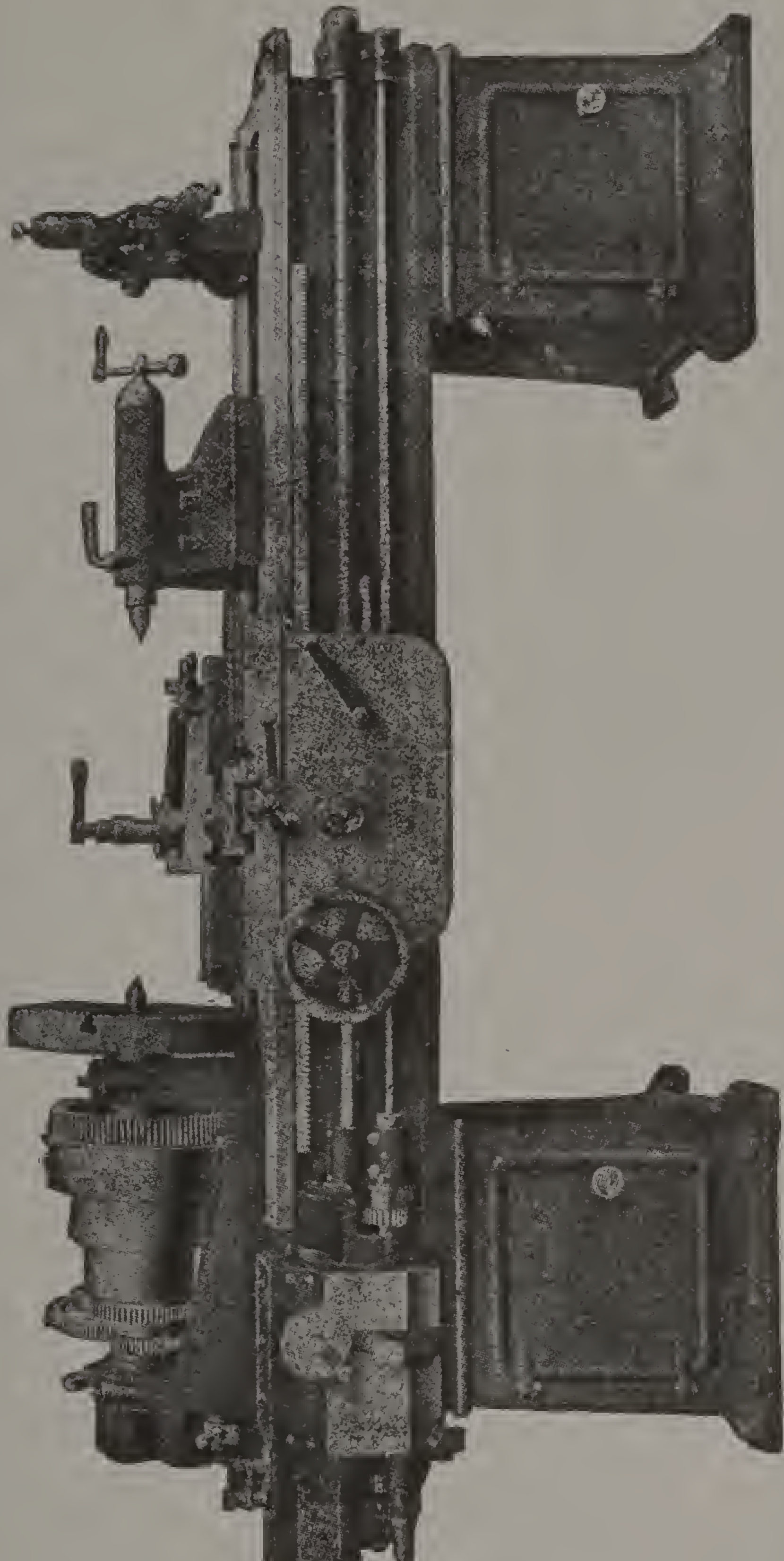


Fig. 272.

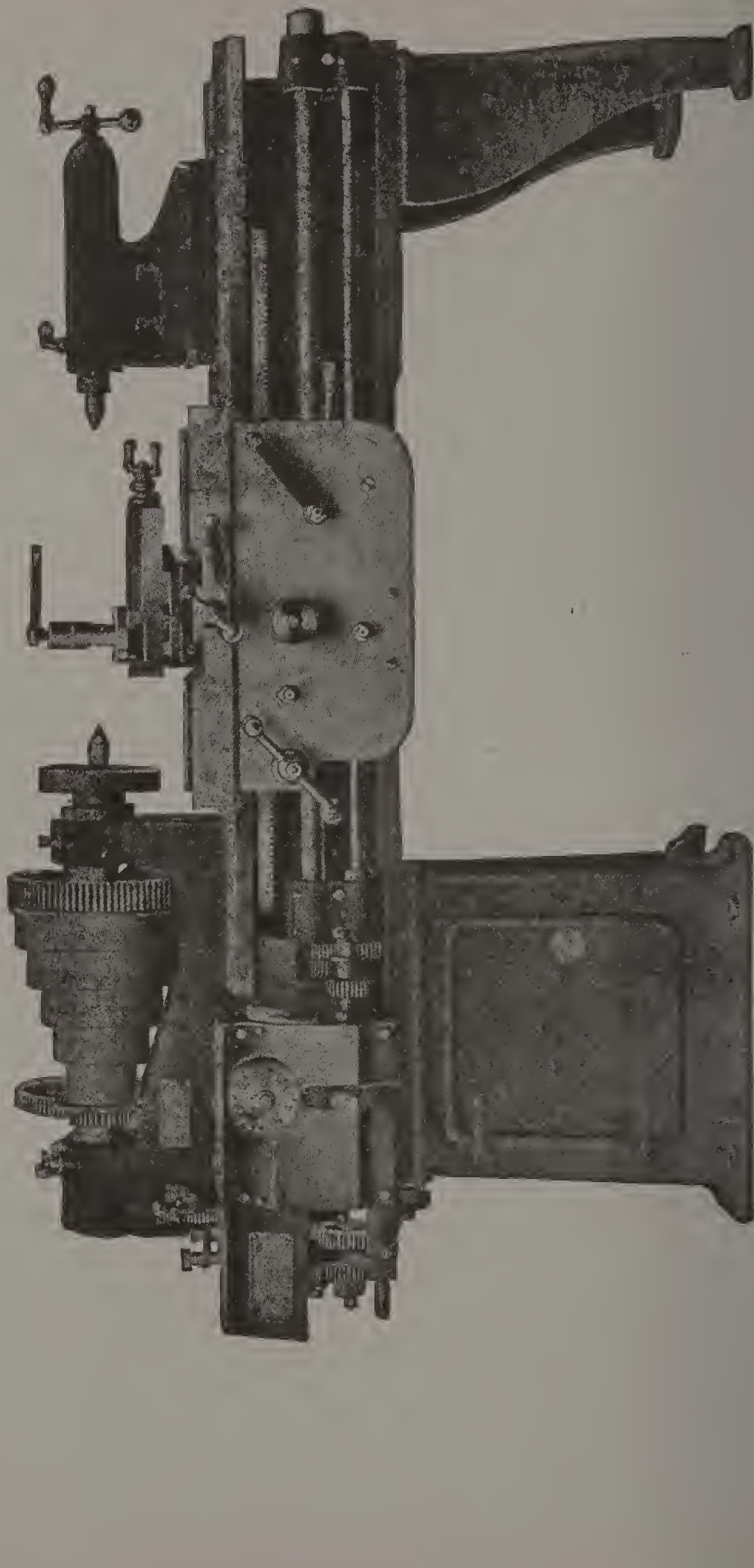


Fig. 273.

Quick Change Gear Engine Lathe. Fig. 272 shows an Instantaneous Change Gear Engine Lathe, with three step cone and double back gear, upon which forty changes of feeds and screw cutting may be obtained, without duplication, as shown in the index. This lathe has reverse feed in the head for both feeds and screw cutting, also a reverse in the apron for feed and power cross feed. The mechanism is so arranged that the longitudinal and cross feed cannot be engaged when cutting screws.

Quick Change Gear 18-inch Lathe. Fig. 273 shows an 18-inch Lathe, with instantaneous change gear device, with which forty changes of feeds and screw cutting may be obtained, without duplication. This lathe embodies all the well known features of standard lathes, having a reverse feed in the head for both feeds and screw cutting, also a reverse in the apron for feeds, the power cross feed is so arranged that cross feed and length feed may be operated at the same time. Provisions have been made so that longitudinal and cross feed cannot be engaged when cutting screws.

Speed Lathe. The lathe shown in Fig. 274 is just the thing for manual training and technical schools, and is a simple, strong machine with many advantages.

The bearings are self-oiling and dirt-proof. Dirt cannot possibly get to the spindle, even in the act of oiling every three months or so, as oil is put in below it.

The advantage of this occasional oiling, and the assurance that lubrication is sufficient at all times, will be appreciated by those especially to whose care the machines are intrusted.

The tailstock and tool-rest clamp rigidly by means of the levers on the front of the machine.

Tool Maker's Lathe. The tool maker's lathe illustrated in Fig. 275 has the spindle made of 50 point carbon high grade crucible steel, and runs in boxes of lumen bronze.

Fig. 274.

The hole in the spindle is eleven-sixteenths of an inch diameter. The spindle nose is $1\frac{1}{4}$ inches in diameter, with 8 threads per inch. The front spindle bearing is 1 7-16 by $2\frac{1}{2}$ inches. The cone has 3 steps ranging from 3 to 6 inches in diameter for $1\frac{1}{2}$ inch belt. The back gear ratio is $7\frac{1}{2}$ to 1.

The headstock is massive, double-webbed its entire length, and not weakened to make room for the reverse plate. Ample oiling facilities are provided, and oil-holes have dust-proof covers.

The front end of the tailstock barrel is re-enforced to withstand heavy strains, and has a No. 2 Morse taper in spindle, and the set-over is graduated.

The apron is arranged for screw and friction feed. The friction feed is through a worm and worm gear which run in oil. A power cross feed is provided.

Threads can be cut from 6 to 40 per inch, including $11\frac{1}{2}$ pipe thread.

The feed is positive and is reversed in the head.

The countershaft has double friction pulleys, 6 inches in diameter for a 2-inch belt, and should run 160 and 220 revolutions per minute. Foot power can be furnished if desired.

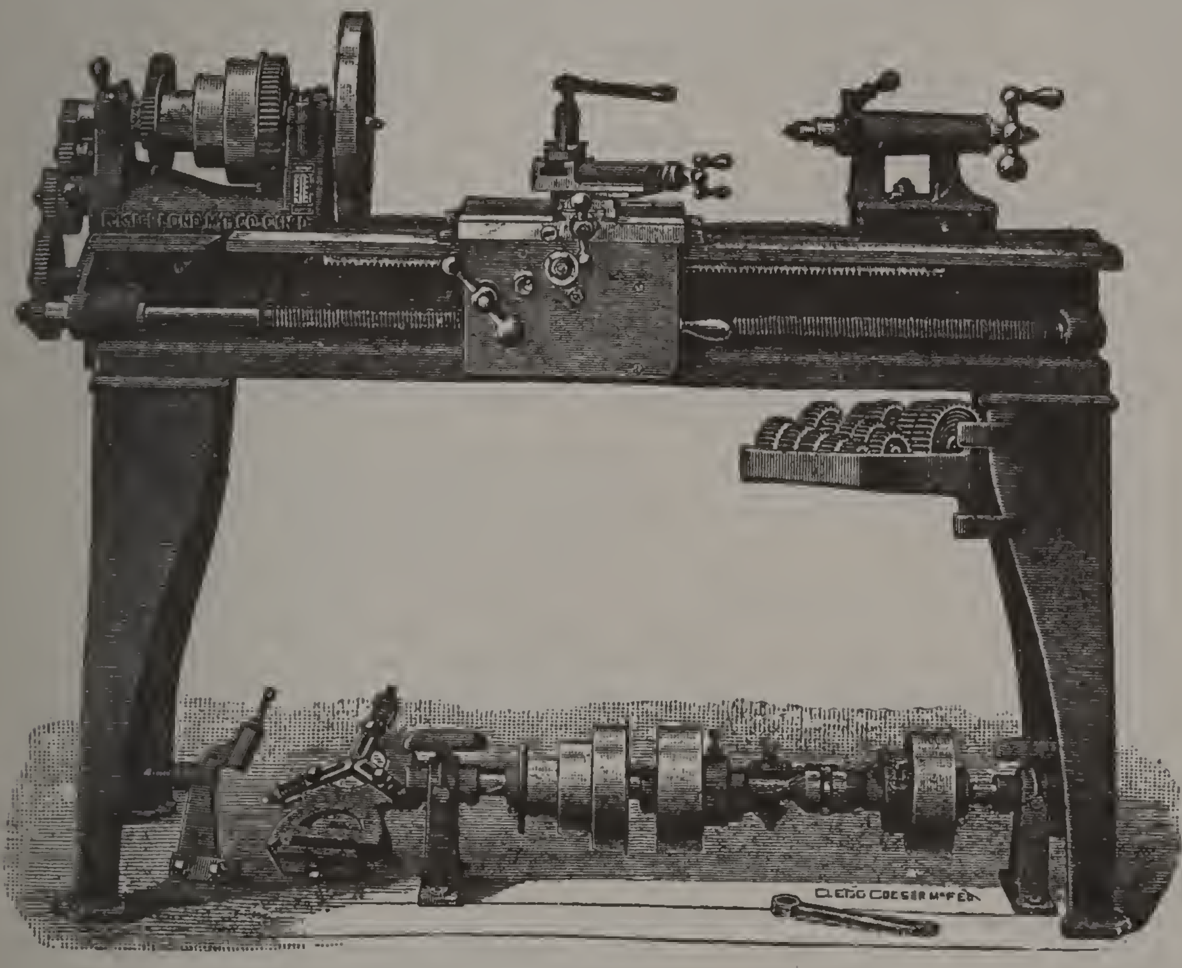


Fig. 275.

The lathe is made with either plain block, compound, or rise and fall rest.

Universal Turret Lathe. In all sizes of the machine shown in Fig. 276 the bed, pan and headstock are made in a single casting, thus greatly increasing rigidity, without corresponding increase of weight, and through this feature alone making greater accuracy possible by preventing any

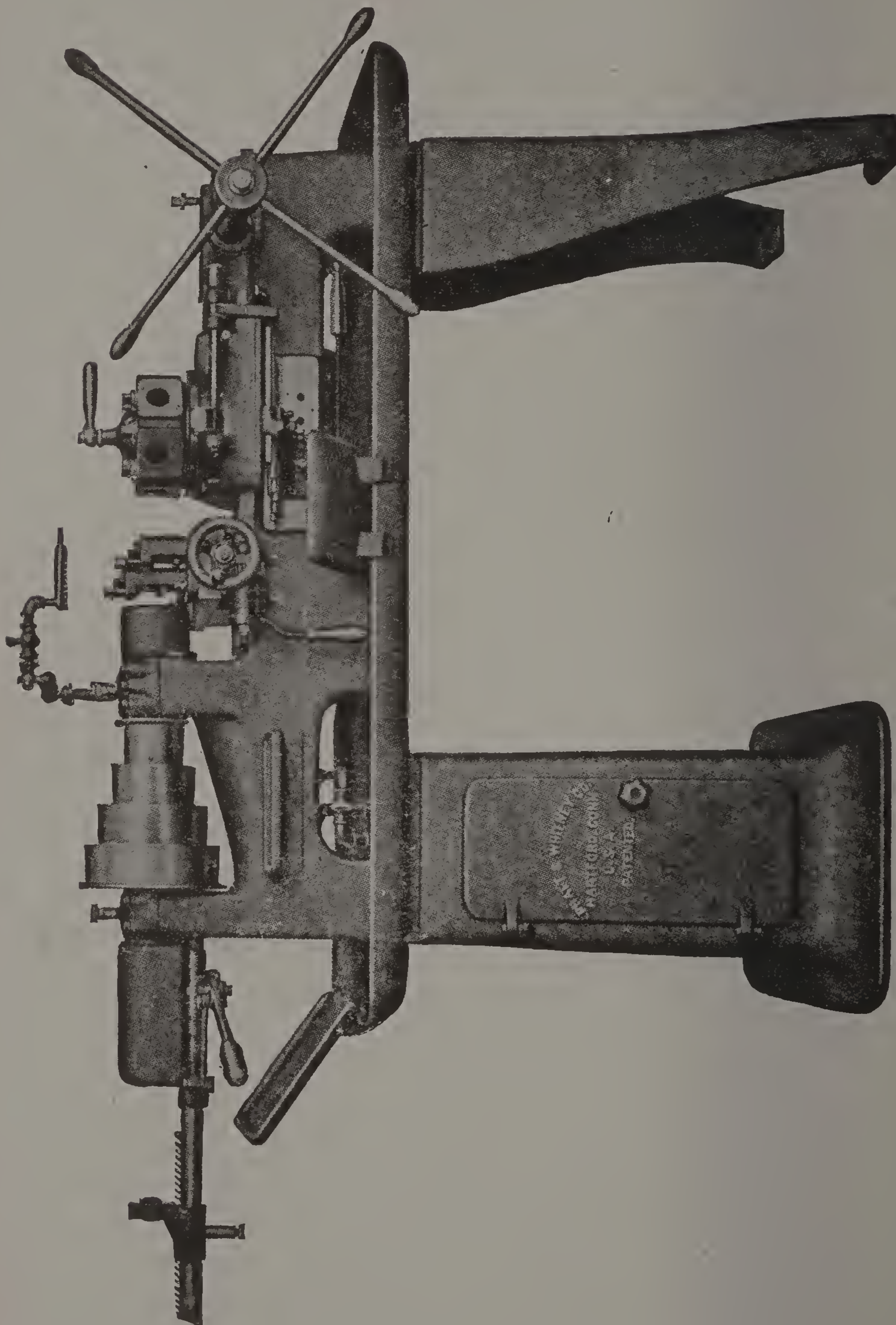


Fig. 276.

spring and movement of parts upon each other under strain.

In these lathes the spindle construction has received special consideration, and in it have been incorporated refinements in the direction of accuracy heretofore used only in the highest grade of toolmakers' lathes and precision tools. The spindle is not only ground externally where it runs in bearings, but in the end of it is a hardened tool-steel liner forced into place, and after the spindle is mounted in its bearings, the nosepiece is ground internally and externally, the closer for the chuck jaws is also hardened and ground, as likewise are the chuck jaws or collets themselves, thus ensuring perfect concentricity of spindle and all parts carried by same. The removal of the nosepiece for the purpose of mounting a large chuck on the spindle does not in any way disturb the adjustment of the regular automatic chuck as it does in some other turret lathes.

In the closing operation the immovability of the chuck is another characteristic and particularly valuable feature where second operations are required, as the stock is not moved lengthwise. This feature makes possible the advantageous use of split step chucks, and these are the only turret lathes on which such attachments can be employed, aside from the bench or watchmakers' lathes on which turrets are sometimes employed where extreme accuracy in a turret machine is required.

A very efficient power rod feed is used on these Turret Lathes, while on smaller machines an improved type of lever rod feed is employed.

The power rod feed has many advantages. It does not mar the rod, as it handles squares and hexagons as easily as rounds, and has no delicate parts to get out of adjustment.

The illustration in Fig. 276 above shows the rod feed mechanism for the Turret Lathe. The carrier is not shown, but one end of the steep pitch screw which traverses it can be seen at the left of the illustration. This screw is attached to a clutch placed between two gears which run in opposite directions.

When the chuck-jaws are opened, the clutch is thrown in and the stock is traversed up to the stock-stop. The clutch is automatically thrown out by a very simple device: When the stock touches the stock-stop the carrier tends to pull the steep pitch screw away from the lathe and as this screw is attached to the clutch it pulls the clutch out of contact. A handle is provided for reversing the screw when it becomes necessary to run the carrier back for a new grip.

The improved lever rod feed used on the turret lathes gives about double the feed of rod to a given movement of the lever than was formerly possible with this type of rod feed.

The machines are furnished with a follower bar which enables short pieces of stock to be as conveniently handled as long bars and at the same time serves to keep such pieces concentric with the spindle. This arrangement is much preferable to tubes placed within the spindle for roughly centering small and short pieces of bar, and feeding this crop end through by hand, or pushing it with a long bar.

For gauging the length of stock delivered by the rod feed on the machines, an auxiliary stop is provided on the headstock. This stop when not in use is swung upwards out the way of the operator and the turret tools. It is stiff and allows no chance for variation when once set to a given length. Fine adjustment for position of stop is made by a fitting at the outer end.

On these machines the cross-slide is operated by lever with pinion and rack, and by screw with hand-wheel, the change from one to the other method being made in a moment by the operator.

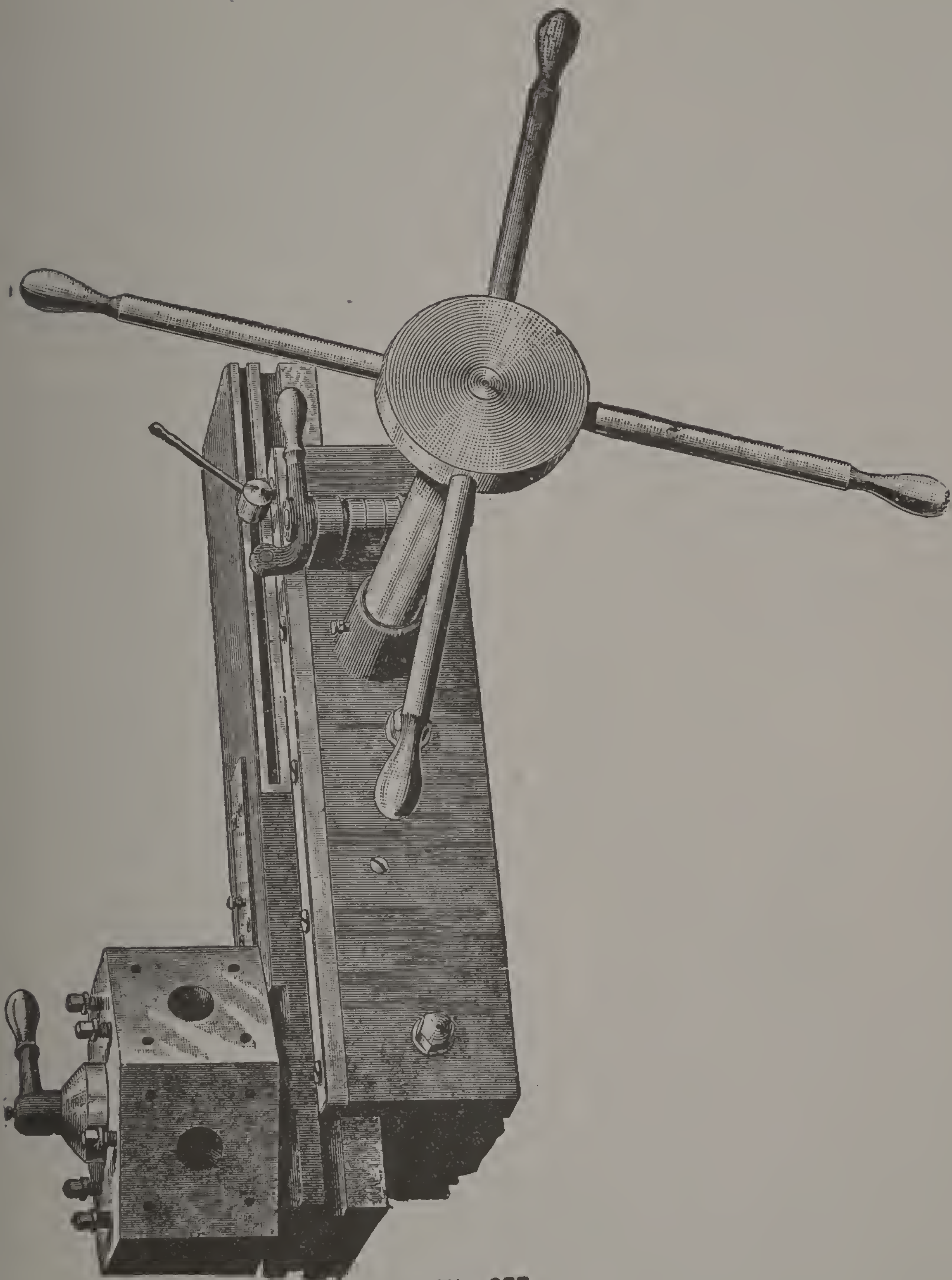


Fig. 277.

The Automatic Turret. The automatic Turret shown in Fig. 277 has as few parts as possible in its construction and can be fitted to any make of lathe from 12 inch to 30 inch swing.

The turret block revolves automatically, and when the top slide is flush with the bottom it can be revolved by hand, and any tool can be rapidly brought in position for work. Wear between the turret block and stem is taken up by an adjustable taper bush. The indexing ring is of large diameter, made of tool steel hardened and ground, as is also the locking plunger, which takes a bearing on both sides of the locking ring. The locking plunger automatically adjusts itself for wear. The top slide is square-gibbed, and is adjusted with a taper gib. The turret is firmly clamped in any position on the bed by two eccentric clamps operated by a wrench from the front.

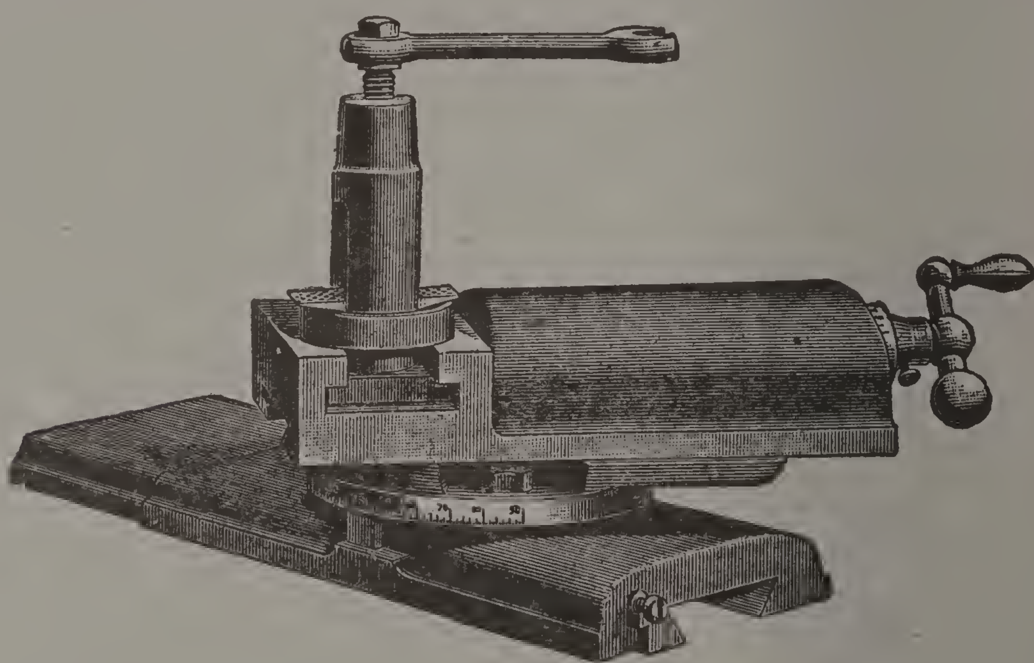


Fig. 278.

The power feed is positive, and is engaged by a lever at the front of the turret, and can be tripped to a line in any position by an adjustable stop. The feed belt on the smaller sizes can be made endless, as it is always kept at the proper tension by a swinging belt-tightener. The larger sizes are driven by a silent chain, and means are provided for obtaining quick changes of feed through gears by a lever at the front of the lathe.

Block Rest with Chasing Stop.

Fig. 278 shows one of the plainest and most solid forms of rest, and for plain hard work there is nothing better. The tool post, rings and wedges are made of machinery steel and case-hardened. Adjustable taper gibs are used for taking up the wear on all sliding surfaces.

Compound Rest.

Fig. 279 shows a compound rest. The swivel is graduated to 180 degrees and is invaluable for turning angular work or boring taper holes. The top slide screw is gradu-

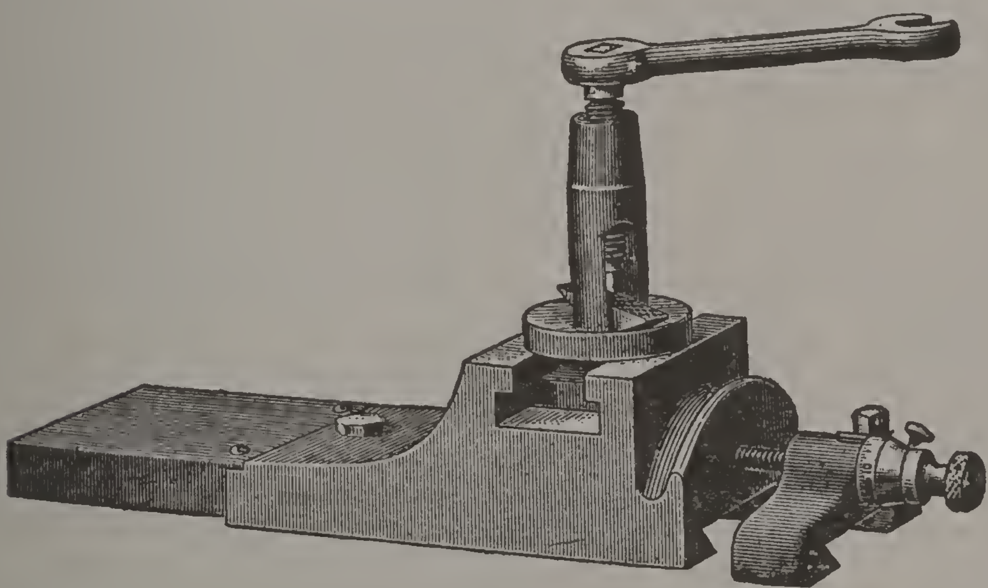


Fig 279.

ated to thousandths of one inch for chasing. The tool post, rings and wedges are made of machinery steel and case-hardened. Adjustable taper gibs are used for taking up the wear on all sliding surfaces.

Full Swing Rest. The rest shown in Fig. 280 is to be clamped on the carriage, and, as the name implies, it can be used for turning the full swing of the lathe. It is also invaluable when used in connection with the regular rest. For instance, two steps of a cone pulley can be turned at

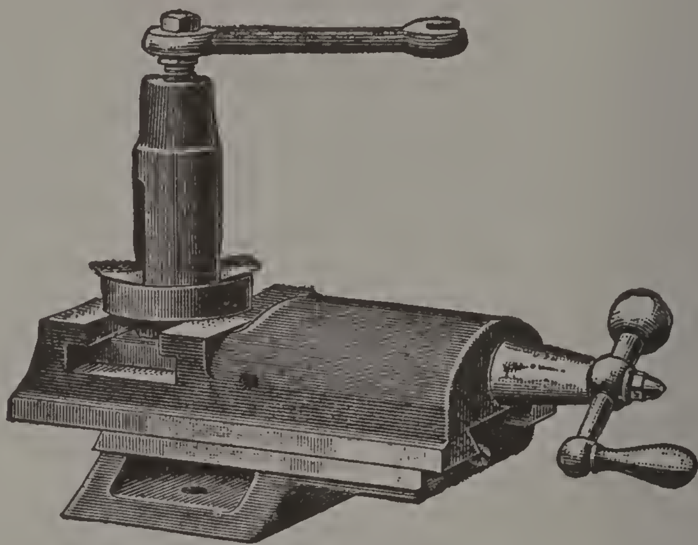


Fig. 280.

once by using both rests at the same time. Two tools can also be used in roughing.

Interchangeable Turret. Figure 281 shows an engine lathe fitted with a Turret on the Carriage. The combination produces an excellent chucking lathe. They are accu-

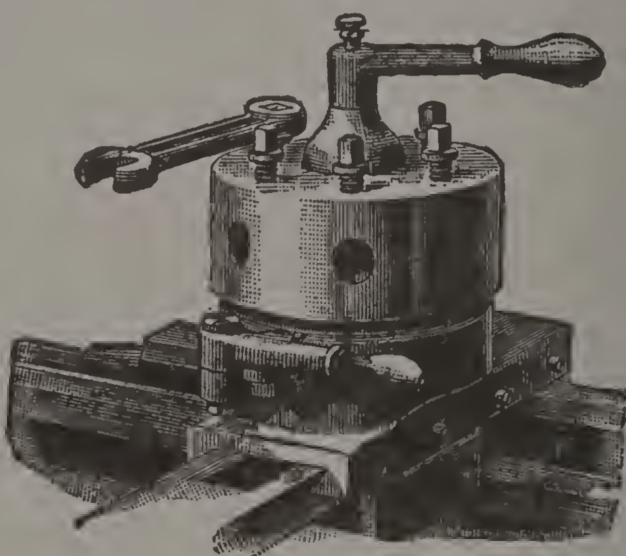


Fig. 281.

rately and substantially made and will index to the one-thousandth part of an inch. The locking ring and pin are made of tool steel, hardened and ground. The locking pin has a bearing on both sides of the locking ring. The center stud is tapering and fitted with a bushing so that all wear between the stud and taper can be adjusted. Turrets arranged in this way have all the feeds of the engine lathe, such as the power cross feed for scaling off work, the length and screw feeds for boring, reaming and tapping. They can be used for facing, and the larger sizes will handle box or forming tools to advantage.

There is a substantial stop at the rear of the turret to always bring it to the correct central position. This can be turned out of the way when using the compound rest.

Lathe Apron. The apron shown in Fig. 282 is of a geared type, doing away with worm and worm wheels. All the feeds are reversed in the apron, and arrangements are

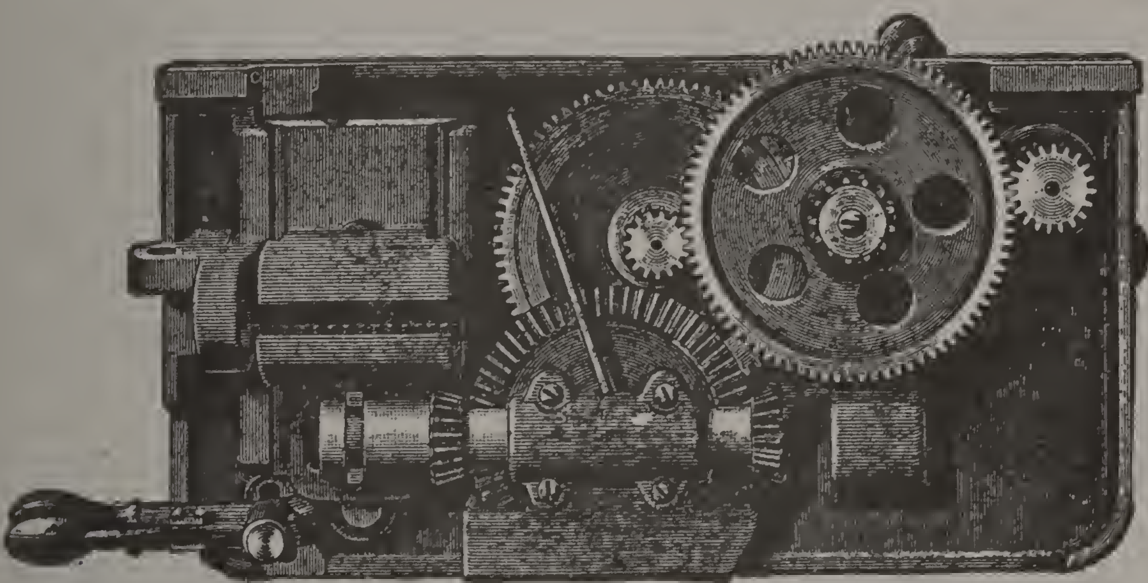


Fig. 282.

made for dropping the rack pinion when chasing long screws. There is also a device for preventing the simultaneous engagement of the rod and screw feeds. All gears in the apron are cut from the solid, the bevel gears and pinions are cut from steel. All the studs are hardened and ground. On the larger sizes a special bracket is used to support the rack pinion stud at its outer end. The longitudinal and cross feeds are both automatic. The cross feeds are graduated to the one-thousandth part of an inch.

Reverse Plate. The reverse plate on the lathe shown in Fig. 283 is located on the outside so that the head does not have to be cored. The gears can be easily oiled, and are always in position when required for cutting left hand threads. The change gears on both the stud and the lead

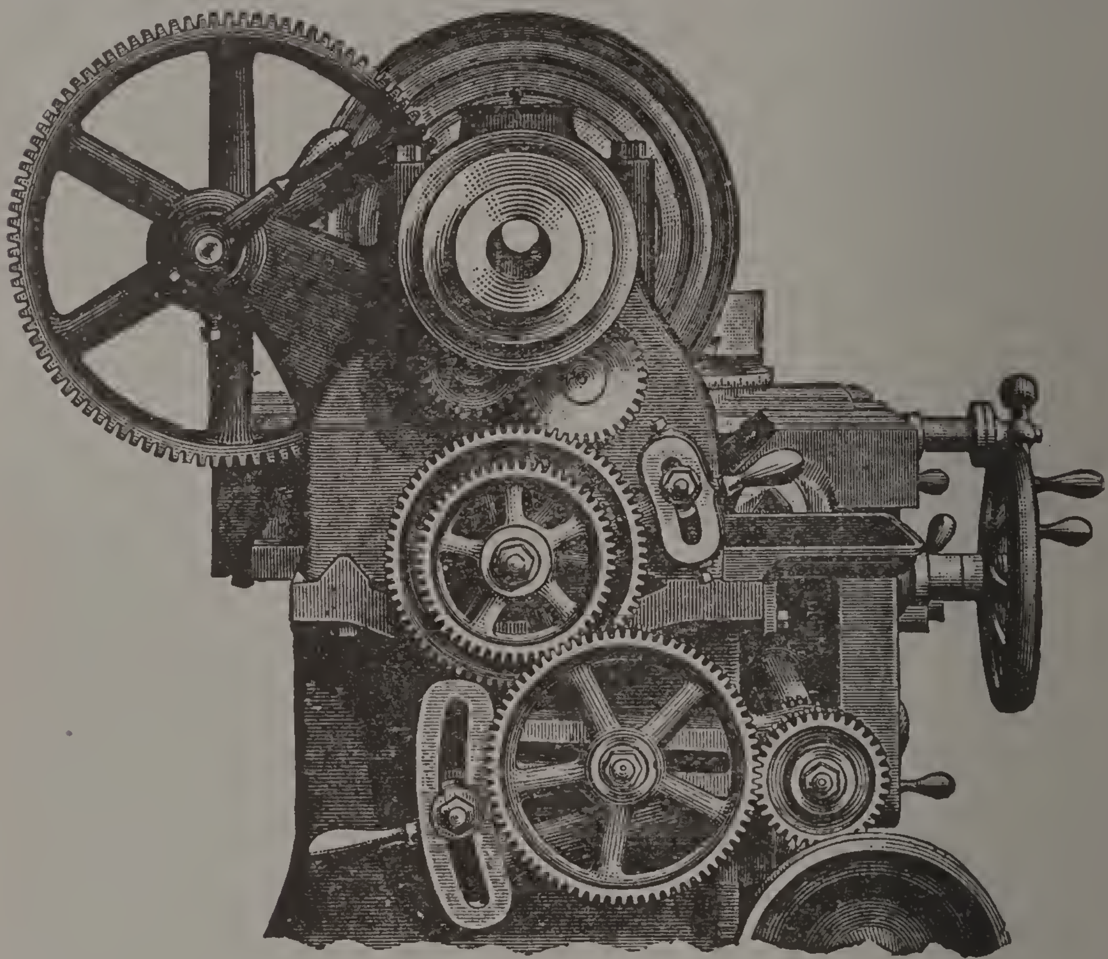


Fig. 283.

screw can be changed, and are so arranged that very few changes are required on the stud. On these lathes most threads can be chased by simply changing the gear on the lead screw.

Taper Attachment. Figure 284 shows a taper turning attachment with a compound rest.

This taper attachment is strong and stiff, and attached to the rest complete in itself. It can be used at any desired place on the lathe, and is secured in position by simply tightening the screw shown on the arm attached to the bed.

Boring or turning to any desired taper can be accomplished with this taper attachment, up to 3 inches to the foot, and it does not admit of lost motion.

This taper attachment can be furnished with a lathe as

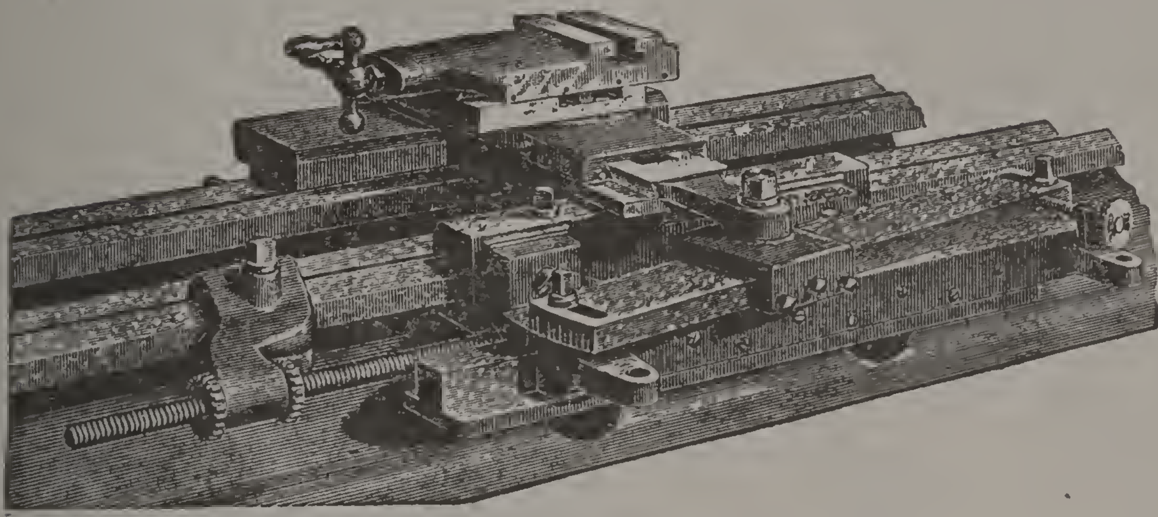


Fig. 284.

follows, with plain rest and power cross feed on any engine lathes from 12 to 30 inch swing, inclusive.

With compound rest and power cross feed on any engine lathes from 12 to 30 inch swing, inclusive.

With elevating rest and power cross feed on 14 and 15 inch swing engine lathes.

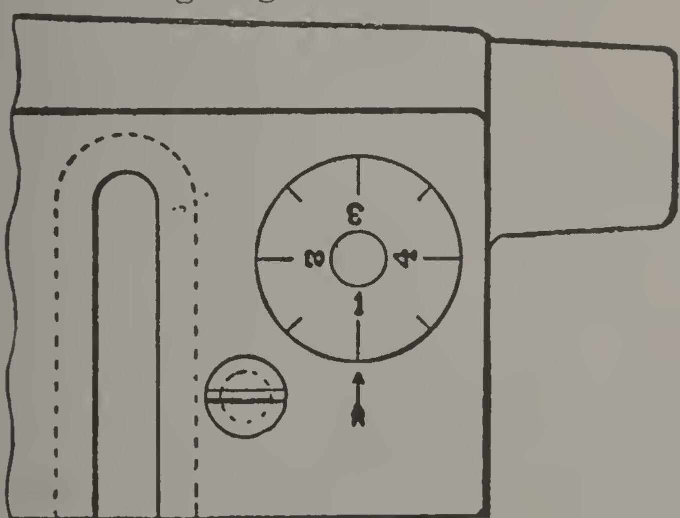


Fig. 285.

With elevating rest, but without power cross feed, on 12 inch swing engine lathes.

With either plain rest or elevating rest on 14 or 16 inch stud and bolt lathes.

Thread Chasing Dial.

Some lathes are furnished with a chasing dial as shown in Fig. 285 with which all threads can be cut without stopping the lathe or reversing the lead screw. No backing belt is required with this device, both belts can be run forward, giving a greater number of spindle speeds. With this chasing dial all even threads can be cut by engaging the lead screw with any line on the dial, all odd threads, such as 7, 9, 11, etc., on the long lines only. This little device is said to effect a saving of 33 per cent in the time of chasing screws.

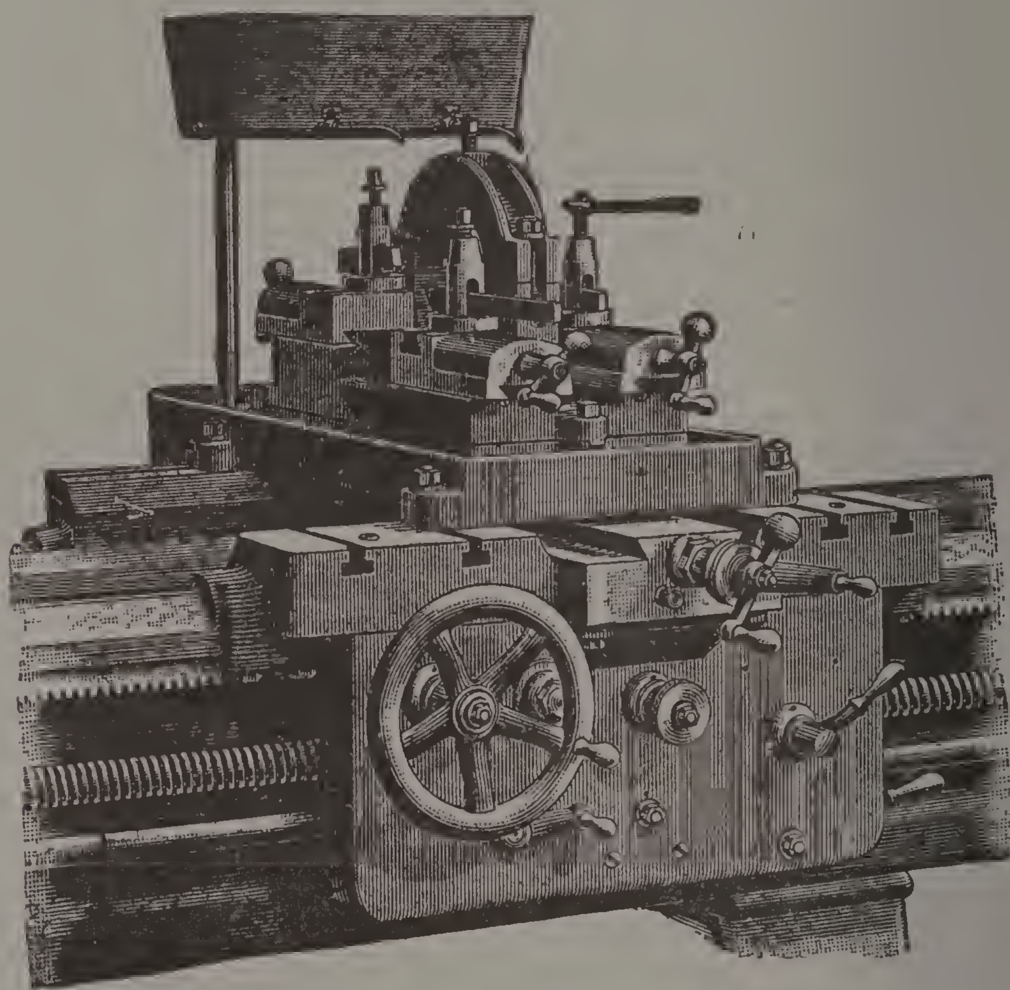


Fig. 286.

Three Tool Shafting Rest. The Three Tool Shafting Rest shown in Fig. 286 is made in two sizes for 24-inch and 30-inch lathes. It is arranged for flooding the work with water, and can be furnished with a pump if desired.

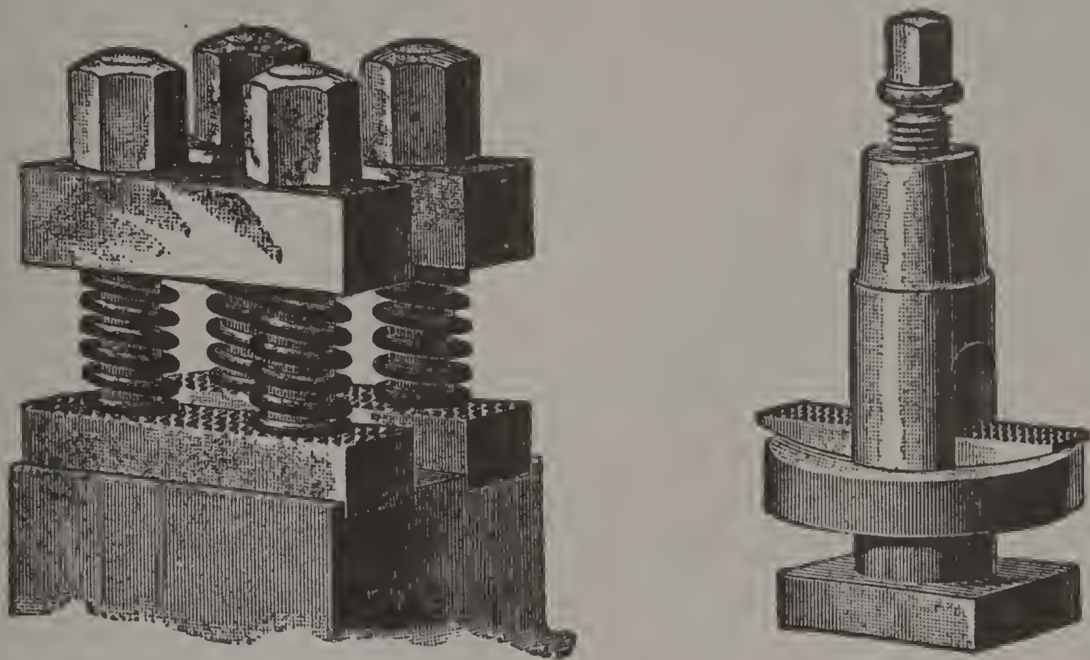


Fig. 287.

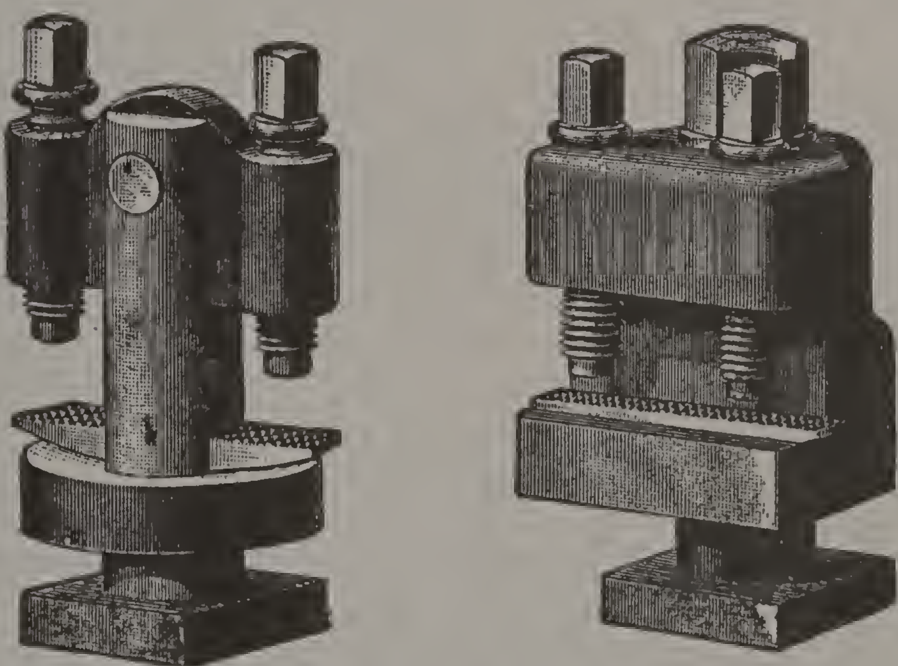


Fig. 288.

Tool-Posts. Four styles of tool-posts are shown in Figs. 287 and 288. The drawings show so clearly the construction that no further explanation is deemed necessary.

Cutting Speed and Feed of Lathe Tools.

It will be observed that the cutting speed given in Table No. 17 for work of 1½ inches diameter, is double that given as the most advantageous for work of 3 inches diam-

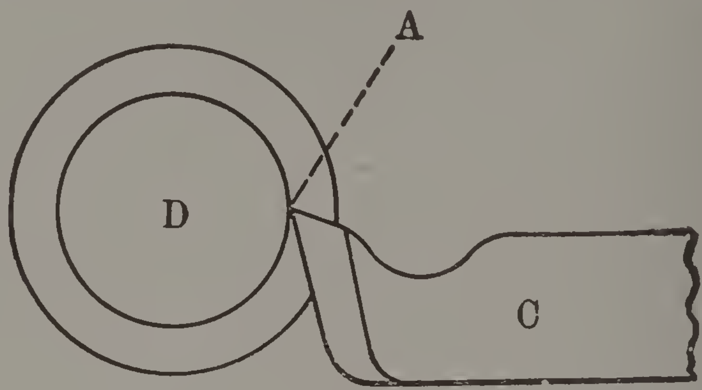


Fig. 289.

eter, while the feed or tool travel can be nearly the same in both cases. The reason of this is that the tool can be ground much keener for the smaller size work than it could be for the larger size work, and because the metal, being

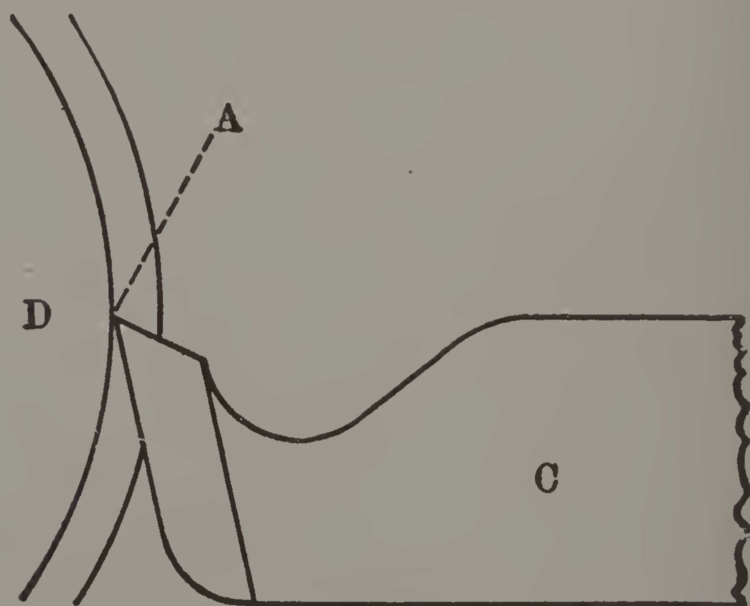


Fig. 290.

cut off the smaller work, is not so well supported by the metal behind it as is the metal being cut off the larger work, and, in consequence, places less strain upon the tool point, as illustrated in Figs. 289 and 290.

TABLE No. 17—CUTTING SPEEDS AND FEEDS.

Diameter of work in inches.	Roughing cuts. Speed in Revs. per minute.	Roughing cuts. Feed.	Finishing cuts. Speed in Revs. per minute.	Finishing cuts. Feed.
STEEL.				
1 and less	63	25	63	30
1 to 2	57	25	57	30
2 to 3	57	25	48	30
3 to 6	48	20	48	30
WROUGHT-IRON.				
1 and less	112	25	121	30
1 to 2	80	20	96	30
2 to 4	80	20	80	25
4 to 6	72	20	72	25
6 to 12	63	15	72	20
12 to 20	57	12	58	16
CAST-IRON.				
1 and less	121	20	121	20
1 to 2	112	20	112	16
2 to 4	96	20	96	10
4 to 6	80	16	80	6
6 to 12	63	14	63	6
12 to 20	63	10	63	4
BRASS.				
1 and less	380	25	380	25
1 to 2	318	25	318	25
2 to 4	255	25	255	25
4 to 6	229	25	229	25
6 to 12	191	25	191	25
COPPER.				
1 and less	1114	25	1273	25
2 to 5	796	25	954	25
5 to 12	637	25	637	25
12 to 20	477	25	477	30

Cutting Tools for the Lathe. The angle of deflection of the point of a lathe tool will vary in its direction with relation to the work, according to the vertical distance of

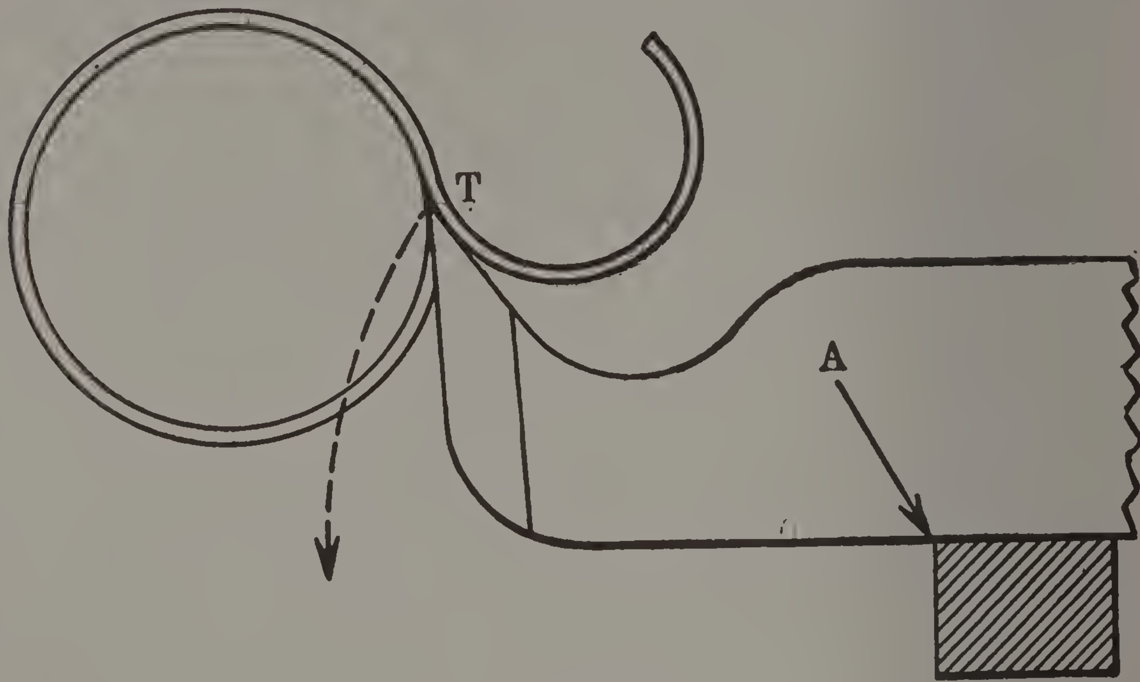


Fig. 291.

the top of the tool-post from the horizontal center of the work. By reference to Figs. 291 and 292 it will be obvious that to produce work as nearly cylindrical as possible it is absolutely necessary, either to have the tool-post A as near

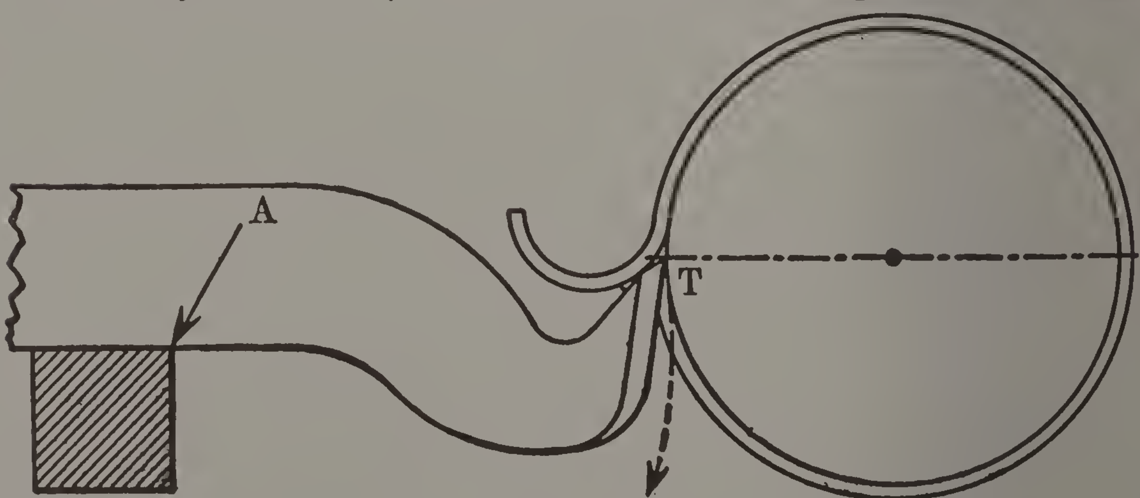


Fig. 292.

the work as possible, or else to have the top of the tool-post as short a vertical distance from the horizontal center line T of the work as can be had. The facing or side tool shown in Fig. 293 mainly used for squaring up the ends of shafting or the sides of collars and washers. The point A of the cutting edge should be level with the cen-

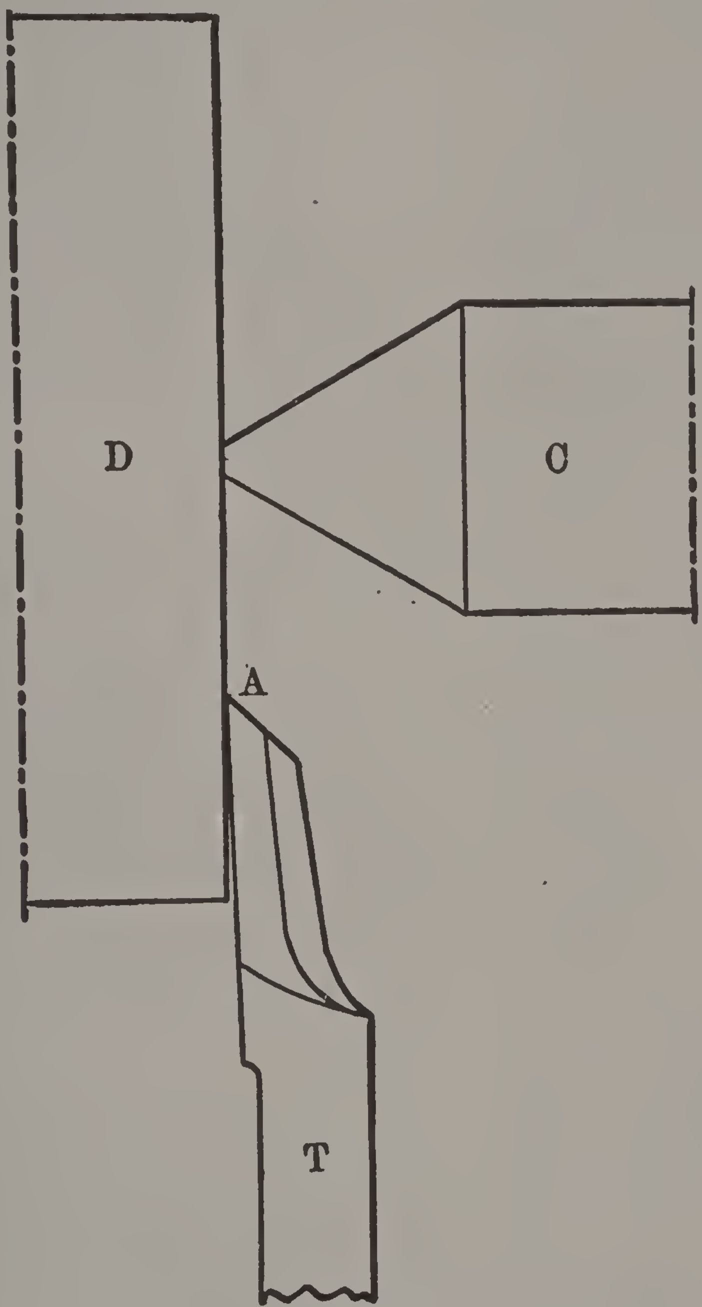


Fig. 293.

ter C which supports the work D and be set at an angle of about 30 degrees with the horizontal center line for wrought iron and steel and level if used for brass or cast iron.

If a lathe tool be supposed to be turning down or reducing the diameter of a piece of work in the direction of its length, the angle of clearance of the tool would be maintained under all conditions of work and rate of feed. But at each successive cut the angle of clearance of the

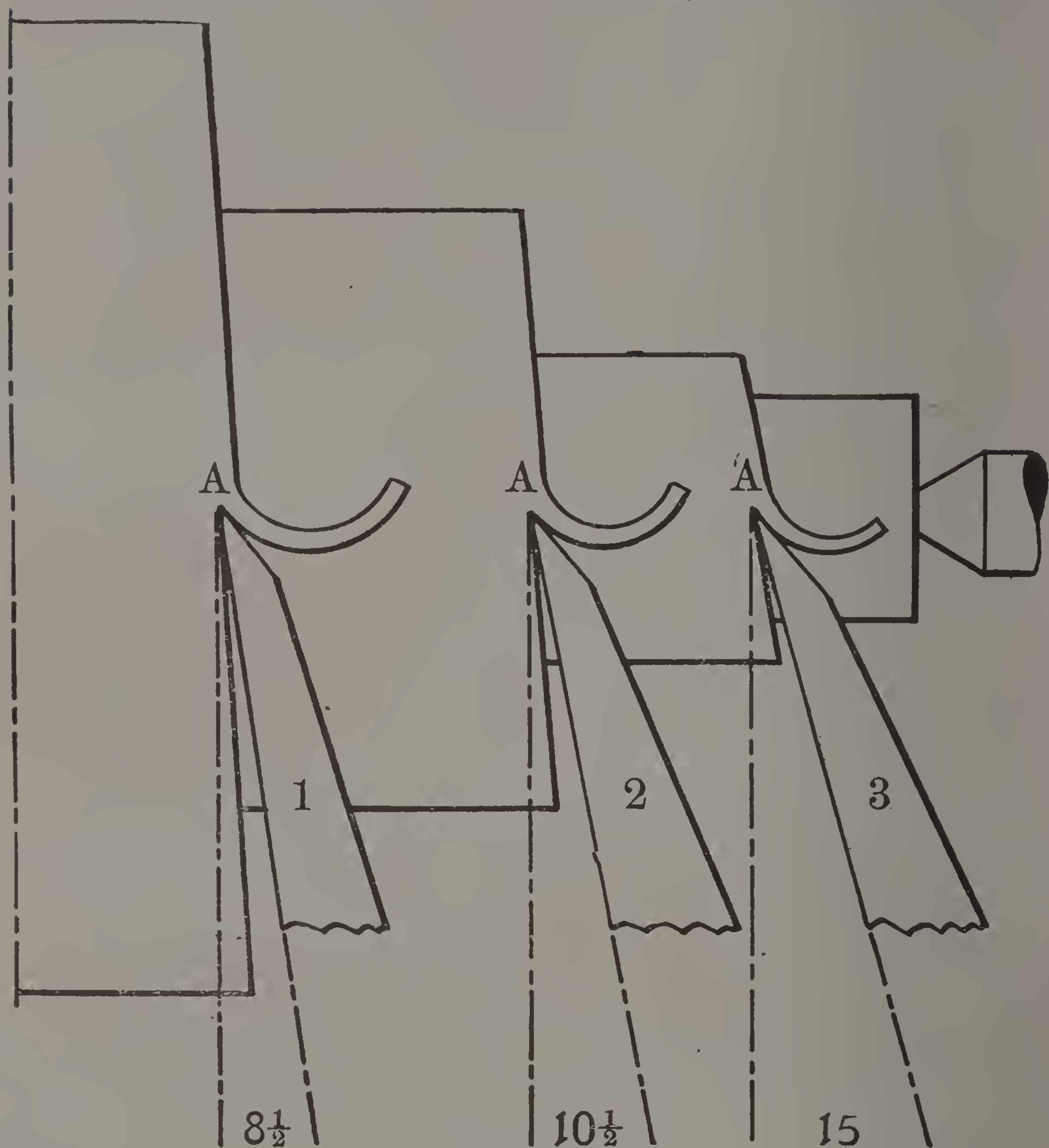


Fig. 294.

tool will be changed and will continue to change as long as the work is being reduced in diameter. The only way therefore to obtain an equal clearance from the cut, would be to give the tool a different angle for each variation in diameter. Fig. 294 shows how much the shape of the tool

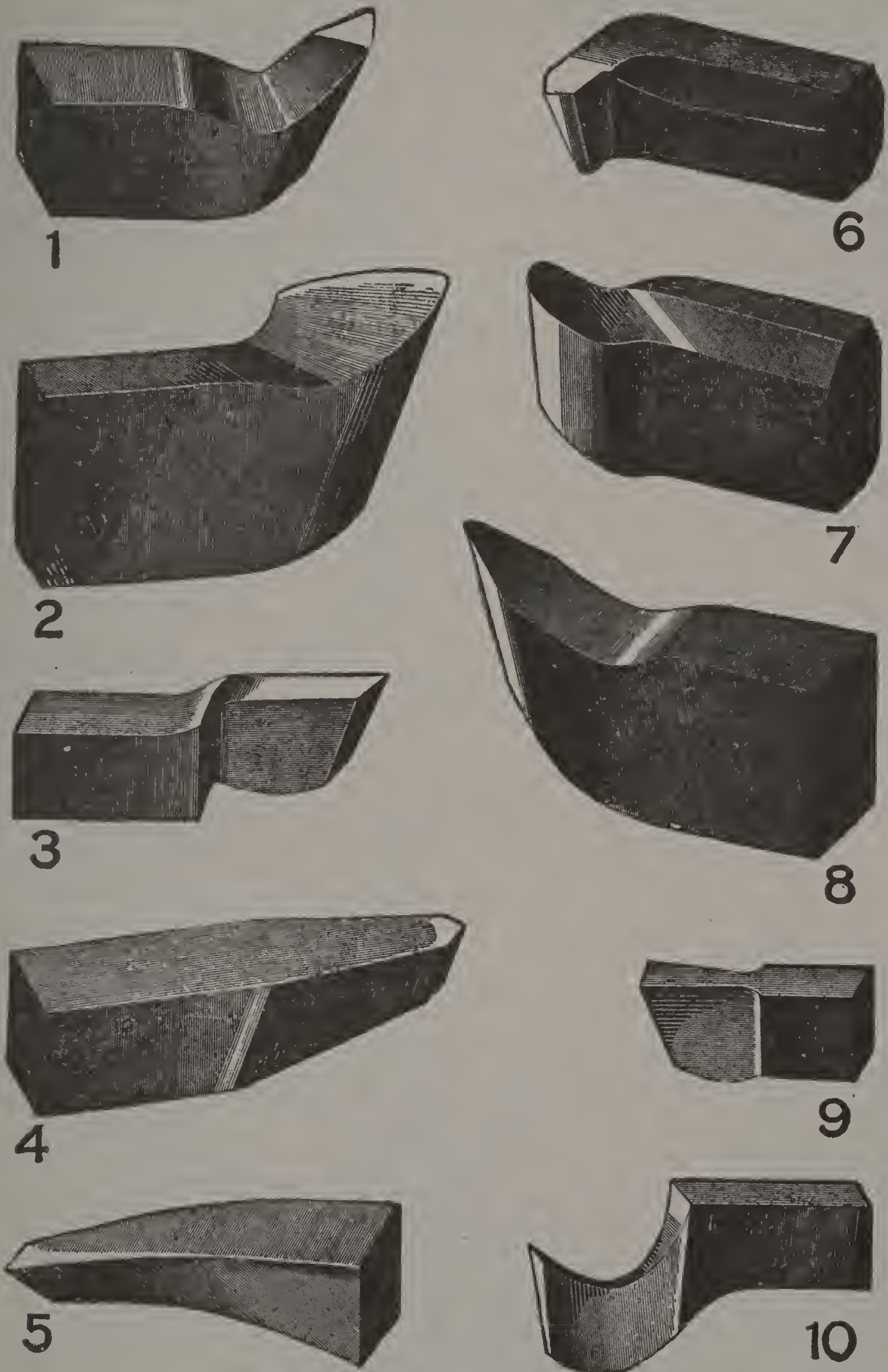


Fig. 295.

would be affected by each variation in diameter. The tool in each position has a clearance of 5 degrees from the face of the work at the point A. In position 1 the tool

Fig. 296.

stands at 8½ degrees with a right angle line drawn from the point A. In position 2 it stands at 10½ degrees and in position 3 at 15 degrees from the point A. A special set of lathe tools are illustrated in Fig. 295 and their respective uses designated below:

1—Left hand side cutting tool.
2—Side tool for heavy roughing.
3—Left hand side facing tool.
4—Front cutting tool for brass.
5—Right hand side tool for brass.
6—Right hand tool for boring.
7—Right hand tool for heavy boring.
8—Round nosed tool for iron or steel.
9—Cutting-off tool for small work.
10—Deep cutting-off tool for large work.

A standard or regular set of lathe tools is shown in Fig. 296, the drawing is self explanatory.

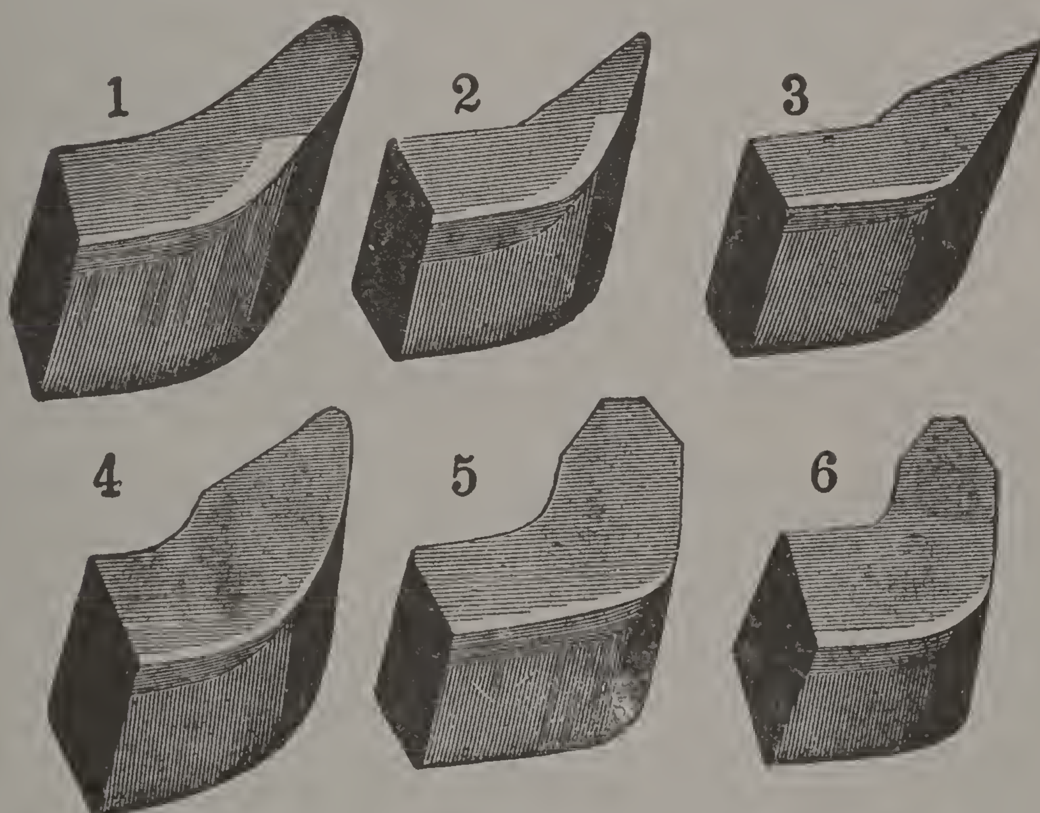


Fig. 297.

A set of boring tools for lathe use are illustrated in Fig. 297, No. 1 is for taking a heavy cut in wrought iron. No. 2 for use on wrought iron when the work is some distance from the tool-post. No. 3 is to cut a square corner at the bottom of a hole. No. 4 is to take a heavy cut in cast iron, while Nos. 5 and 6 are for boring in brass.

Screw-Cutting.

To determine the proper number of teeth in the change gears for screw-cutting in a Lathe.

In a properly designed lathe, screws to any degree of pitch, or number of threads in a given length, may be cut by means of a leading screw of any given pitch, accompanied with change gears and pinions as follows:

Divide the number of threads in a given length of the screw which is to be cut, by the number of threads in the same length of the leading screw of the lathe. The quotient is the ratio that the gear on the end of the screw must bear to that on the end of the lathe spindle.

Example: It is required to cut a screw with 5 threads in one inch, the leading screw being of ½ inch pitch, or containing two threads in one inch. What must be the ratio of the gears to be used?

Answer: $5 \div 2 = 2.5$, the ratio they must bear to each other.

Then if a pinion of 40 teeth be upon the lathe spindle, $40 \times 2.5 = 100$ teeth or the number required for the gear on the end of the lead screw.

Screws of a greater degree of fineness than about 8 threads in one inch, are more conveniently cut by an additional gear and pinion, because the proper degree of velocity is more effectively attained thereby. These additional gears on account of revolving upon a stud, are usually called the stud gear and pinion, but the method of calculation and ratio of screw are the same as in the preceding example, and all that is further necessary is to decide upon any 3 gears, as those for the spindle and stud-gears, then multiply the number of teeth in the spindle-gear by the ratio of the screw, and by the number of teeth in that gear or pinion which is in contact with the gear on the end of the screw. Divide the product by the number of teeth in the stud-gear in contact with the spindle-gear, and the quotient is the number of teeth required in the gear on the end of the leading screw.

Example: A screw is required to be cut with 25 threads in one inch, the leading screw as before, having 2 threads in one inch. A gear of 60 teeth is used upon the end of the lathe spindle 20 teeth for the pinion in contact with the last screw gear, and 100 teeth for the pinion in contact with the gear on the end of the lathe spindle. Required the number of teeth in the gear for the end of the leading screw.

Answer: $25 \div 2 = 12.5$, and $(60 \times 12.5 \times 20) \div 100 = 150$ teeth.

Or if the spindle and lead screw gear to be those fixed upon, or any one of the stud-gears to find the number of teeth in the other gear, then $(60 \times 12.5) \div (150 \times 100) = 20$ teeth, or $(60 \times 12.5 \times 20) \div 100 = 100$ teeth.

TABLE No. 18—CHANGE GEARS FOR SCREW CUTTING. THE LEADING SCREW BEING ½-inch PITCH OR 2 THREADS PER INCH OF SCREW.

Number of threads in one inch of screw.	Number of teeth in		Number of threads in one inch of screw.	Number of teeth in				Number of threads in one inch of screw.	Number of teeth in			
	Lathe-spindle gear.	Leading screw gear		Lathe-spindle gear.	Gear in contact with spindle gear.	Pinion in contact with screw gear.	Leading-screw gear.		Lathe-spindle gear.	Gear in contact with spindle gear.	Pinion in contact with screw gear.	Leading-screw gear.
1	80	40	8¼	40	55	20	60	19	50	95	20	100
1¼	80	50	8½	90	85	20	90	19½	80	120	20	130
1½	80	60	8¾	60	70	20	75	20	60	100	20	120
1¾	80	70	9½	90	90	20	95	20¼	40	90	20	90
2	80	80	9¾	40	60	20	65	21	80	120	20	140
2¼	80	90	10	60	75	20	80	22	60	110	20	120
2½	80	100	10½	50	70	20	75	22½	80	120	20	150
2¾	80	110	11	60	55	20	120	22¾	80	130	20	140
3	80	120	12	90	90	20	120	23¾	40	95	20	100
3¼	80	130	12¾	60	85	20	90	24	65	120	20	130
3½	80	140	13	90	90	20	130	25	60	100	20	150
3¾	80	150	13½	60	90	20	90	25½	30	85	20	90
4	40	80	13¾	80	100	20	110	26	70	130	20	140
4¼	40	85	14	90	90	20	140	27	40	90	20	120
4½	40	90	14¼	60	90	20	95	27½	40	100	20	110
4¾	40	95	15	90	90	20	150	28	75	140	20	150
5	40	100	16	60	80	20	120	28½	30	90	20	95
5½	40	110	16¼	80	100	20	130	30	70	140	20	150
6	40	120	16½	80	110	20	120	32	30	80	20	120
6½	40	130	17	45	85	20	90	33	40	110	20	120
7	40	140	17½	80	100	20	140	34	30	85	20	120
7½	40	150	18	40	60	20	120	35	60	140	20	150
8	30	120	18¾	80	100	20	150	36	30	90	20	120

The above table will suit a lathe with a leading screw of ¼ inch pitch, or 4 threads per inch, by doubling one of the driving gears or halving one of the driven gears.

To find the angle or rate that must be given to the nose of the tool in a screw-cutting lathe, so as to cut a square-thread screw without injury to the sides of the threads.

Draw a right angle triangle the base of which equals half the pitch of the screw to be cut, and the perpendicular equals the diameter of the screw minus the double depth of the thread. The hypothenuse of the triangle, drawn from the end of the base to the end of the perpendicular, gives the angle or rake for the tool from a vertical line with the bed of the lathe.

Using the Center Gauge. The angles used on the gauges shown in Fig. 298 are 60 degrees for the U. S. Standard and Metric Gauges, and 55 degrees for the Whiteworth or

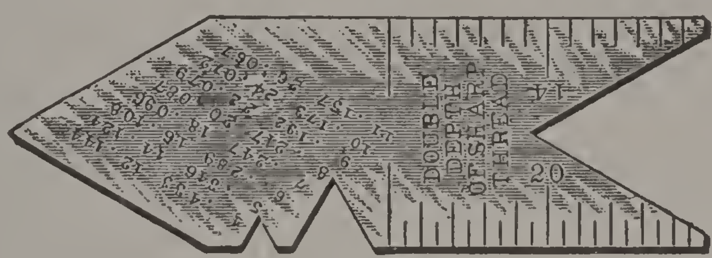


Fig. 298.

English Standard. The four divisions 14, 20, 24 and 32 parts to the inch are useful in measuring the number of threads to the inch. The following parts to the inch can be determined by them, viz.: 2, 3, 4, 5, 6, 7, 8, 10, 12, 14, 16, 20, 24, 28 and 32.

The table on the gauge is used for determining the size of tap drills for sharp 60 degree V threads and shows in thousandths of an inch the double depth of thread of tap and screws of the pitches most commonly used. This table is made up by dividing 1.732, the double depth of thread of a screw that is one pitch, by the number of threads of the various pitches shown. For instance, the decimal .433 represents the double depth of the thread of a screw that is 4 pitch, is obtained by dividing 1.732 by 4. In the same manner the double depth of thread of pitches not shown in the table may be readily obtained. The double depth of thread of a screw that is 2 pitch, is one-half of 1.732.

As the double depth of the thread represents the difference in the diameter of a tap and a tap drill, to obtain the diameter of a tap drill of any desired pitch it is only necessary to subtract the decimal showing the double depth of the thread of that pitch from the diameter of the tap. For example, if the top is 4 pitch, is a sharp V thread, and one inch in diameter, subtract .433, the decimal showing the double depth of the thread of this pitch in the table, from 1 and the result, .567 of an inch, is the size of the tap drill, which would allow of a sharp thread in the hole. Allowance is to be made for the extent to which it is desired the threads should be flattened.

The U. S. Standard Thread is flattened, top and bottom, 1-8 of its depth, so that the sizes of tap drills for this style of thread may be obtained by dividing the constant 1.299, which is 3-4 of the constant 1.732, by the pitch, and subtracting the result from the outside diameter.

By the formulas given below, the results are the actual diameters at the bottoms of the threads. The tap drills used is, in common practice, one that is one or two gauge numbers larger, for the smaller, or numbered sizes, and one that is about .005 inches larger for the larger sizes. The amount allowed for clearance varies in different shops and on different classes of work.

Formula for United States Standard.

$$\text{Diameter of Tap Drill} = \text{Diameter of Tap} - \frac{1.299}{\text{Pitch}}$$

Sharp V Threads.

$$\text{Diameter of Tap Drill} = \text{Diameter of Tap} - \frac{1.732}{\text{Pitch}}$$

In Fig. 299 at A, is shown the manner of gauging the angle to which a lathe centre should be turned. At B, the angle to which a screw thread cutting tool should be ground, and at C, the correctness of the angle of a screw thread already cut.

The shaft with the screw thread on it is supposed to be held between the centres of a lathe. By applying the Gauge as shown at D, or E, the thread tool can be set at

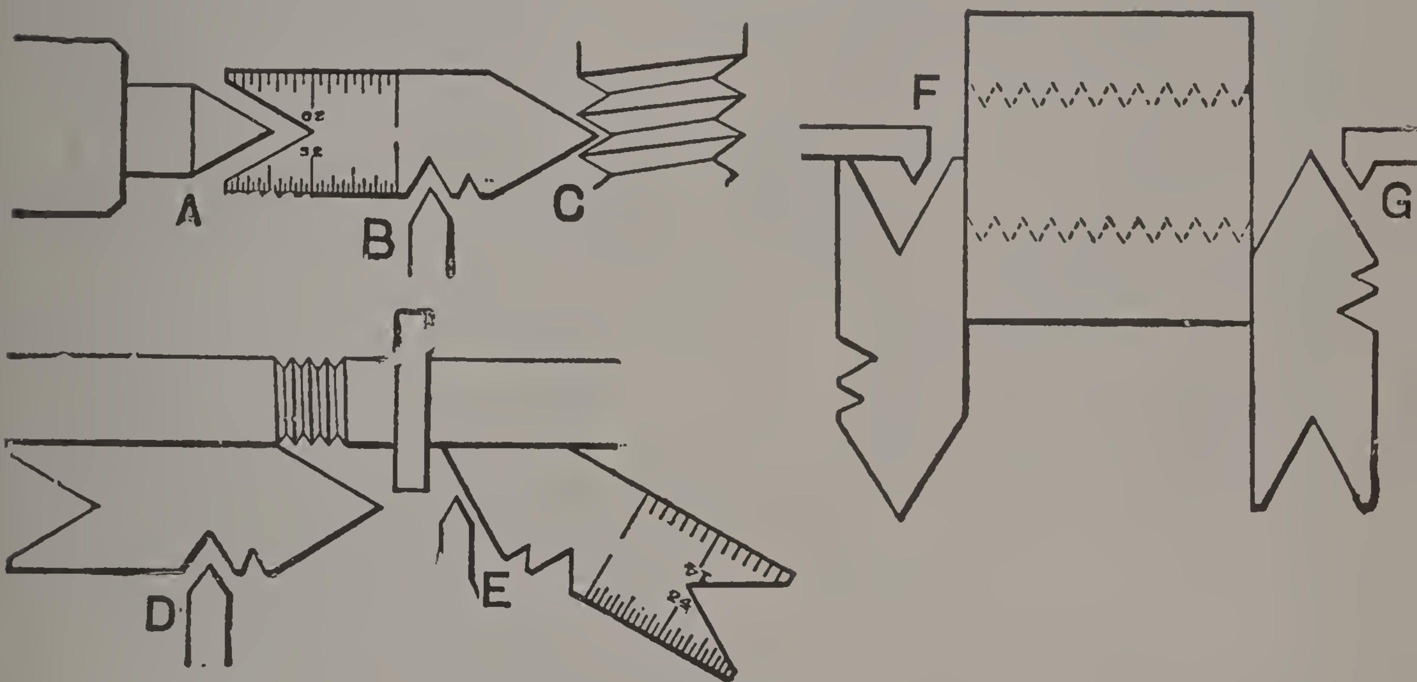


Fig. 299.

right angles to the shaft and then fastened in place by the screw in the tool post, thereby avoiding any imperfect or leaning threads.

At F and G, the manner of setting the tool for cutting inside threads is illustrated.

Work done on the Turret Lathe. The parts shown in Fig. 300 are a few of the many that can be made on an automatic turret lathe, as shown in Fig. 276.

In practice, all pieces are made from a continuous bar and are machined as follows: A long bar of iron or steel is pushed through the spindle, until the piece projects beyond the chuck long enough to make the piece desired. The various tools on the turret are set for the different diameters and cuts, and after each performs its operation, it is turned out of the way to admit the next tool. Since

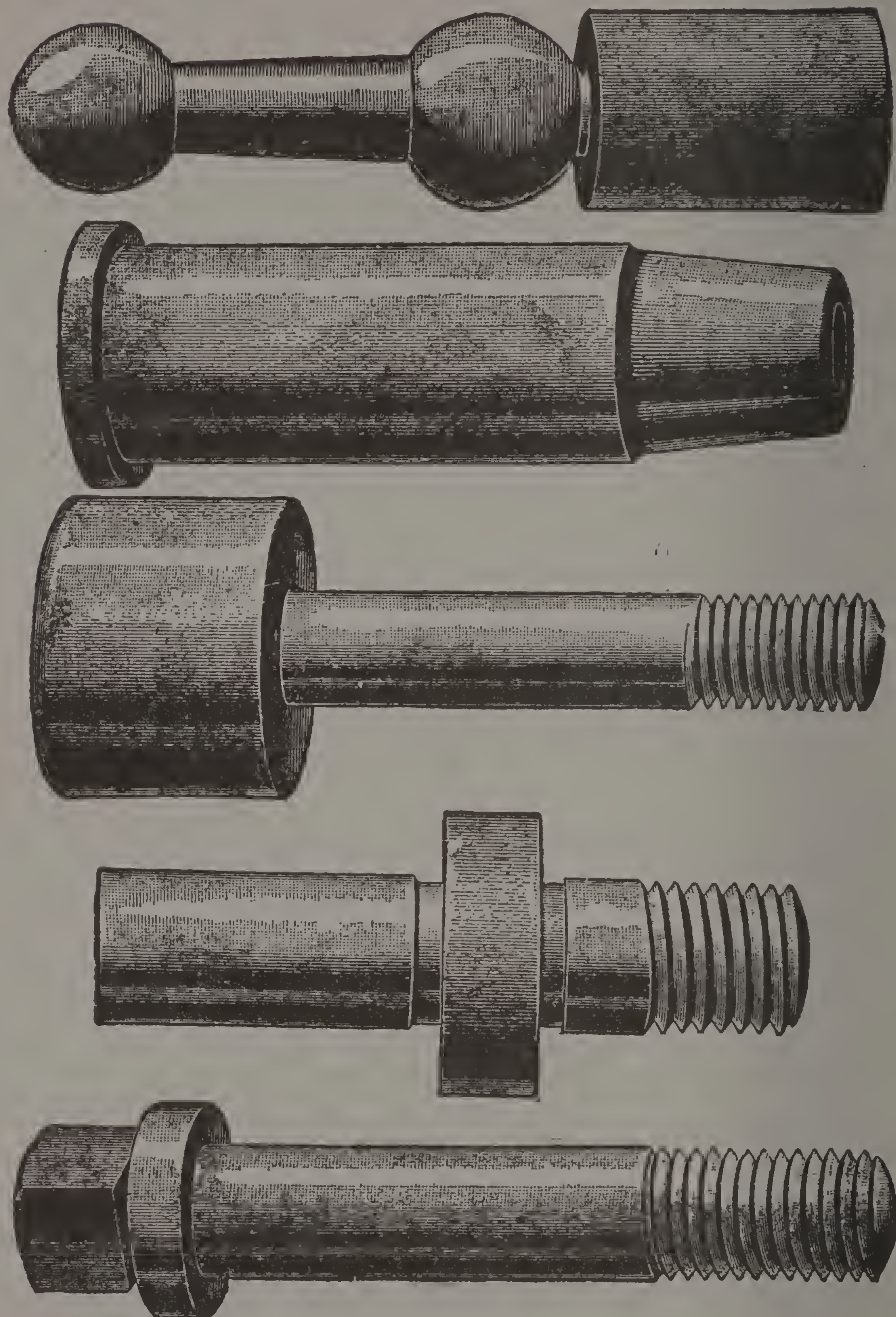


Fig. 300.

a number of tools are set for the various diameters, it gives this machine a great advantage over the lathe where there is but one tool.

MILLING MACHINES.

Erecting Milling Machines. Erect the miller on a good floor. It is essential that the floor be free from vibrations and stiff enough so that it will not give under the weight of the miller. Where possible a 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 overhanging arm support. Have the hanger journals in line with the line shaft. When the hangers are securely tightened the countershaft should revolve freely. Place the thrust collars so that the shaft has one-eighth inch end play. The on the bushing. This end play helps to distribute the oil. pulleys also should have one-sixteenth of an inch end play Place the pulley for the slow speeds next to the driving cone. Both driving cones should run in the same direction, this will double the spindle speeds, it also will give a quick change without shifting the belt.

The countershaft pulleys can be oiled without throwing off the belt, and should be oiled once a month. The hangers have self-oiling journals and the reservoir should be filled to the oil hole. The countershaft should be speeded according to the diagram so that an intermediate change of speed between the cone changes is had. This gives the best and greatest range. Care must be taken that the feed pulley runs in the direction shown by the arrow on feed box.

To oil the machine observe the following rules: Use good mineral oil. Fill the spindle oil chambers from the oilers on the side of the column. All the oil holes are furnished with dust-proof oilers. In oiling the geared feed box place the speed change 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 the saddle are oiled through oil holes at the front of the saddle. Oilers are placed in all parts of the machine, showing very clearly where the oil is required.

The machine and countershaft should be thoroughly cleaned and oiled and be let run thirty minutes under careful inspection to see that all the parts run properly.

Adjusting Milling Machines. Locking the different movements of the machine does not interfere in any way with the gib adjustment, this adjustment being made entirely separate from the lock. All the 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.

The front journal of the spindle is made tapering, and the back journal straight. The thrust is taken at the front end of the spindle by a hardened steel and babbit collar. The wear on these collars 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 the box by tightening the nut. The nut is directly on the spindle and draws the spindle back into the box. There should be a space between the nut and the hub of the gear.

To adjust the rear journal, tighten the nut, this draws the taper bronze bushing back into the column, compressing it on the spindle. The adjustment of the spindle will not interfere with the alignment of the machine.

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. The gib being securely fastened cannot raise or move when the table is at the extreme position. By this method freer table movement is secured, avoiding the cramp occasioned by the movement of the gib. To adjust the knee and saddle gibs tighten the large filister head screws.

Locking the movements is entirely independent of the gib adjustment and is accomplished by the locking handle. 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 usually furnished. If the cutters are used at the extreme end of a long arbor see that both supports are used. The brace can be set at either side of the knee shoe, giving the 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 the inside nut, 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 babbit or some soft metal so that the nut can be removed without forcing. When this nut is clear of the thread the spindle can be withdrawn from the machine. The nut must be raised to clear the spindle key.

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

Generally lard oil is used in milling, but any animal or fish oils may be used. The oil may be separated from the chips by a centrifugal separator, or by the wet process,

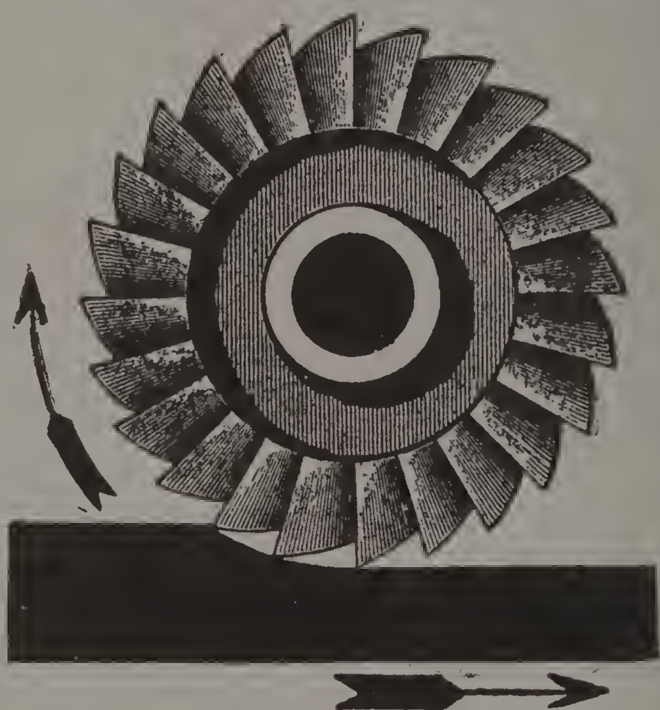


Fig. 301.

so that a large amount may be used with but little waste.

Some manufacturers prefer to mix mineral oil with lard-oil.

There is a difference of opinion as to whether the work should be moved against the milling cutter as in Fig. 301. But in most cases experience shows it is best for the work to move against the milling cutter as shown.

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

Some work, however, is better milled by moving with the cutter. To dress both sides of a thick piece with a pair of large straddle mills as shown in Fig. 302, it is better to

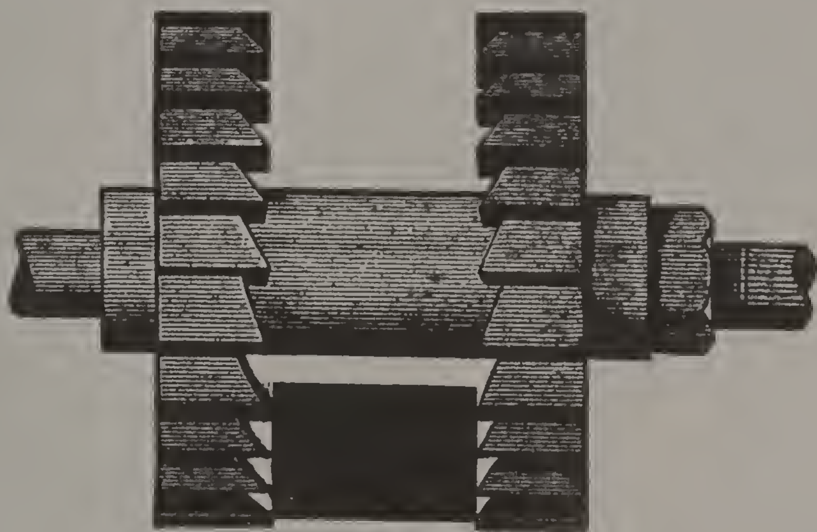


Fig. 302.

move the piece towards the left instead of the right as shown in Fig. 301, as the milling cutters then tend to keep it down in place instead of lifting it.

Milling Machine. The following description in connection with the illustration shown at Fig. 303, will give the names of the prncipal parts of a milling machine and their use:

A is the standard or column on which are attached the principal parts of the machine.

B is the horn and carries the elevating screw which is used to raise and lower the table G.

C is the screw spindle of the transverse or cross feed adjustment for the table G.

D is the screw spindle with a micrometer attachment for raising and lowering the table G.

E is the crank-handle connected with the quick-return longitudinal movemeint of the table.

F is the housing which carries the bearings of the step cone pulleys and the back-gear.

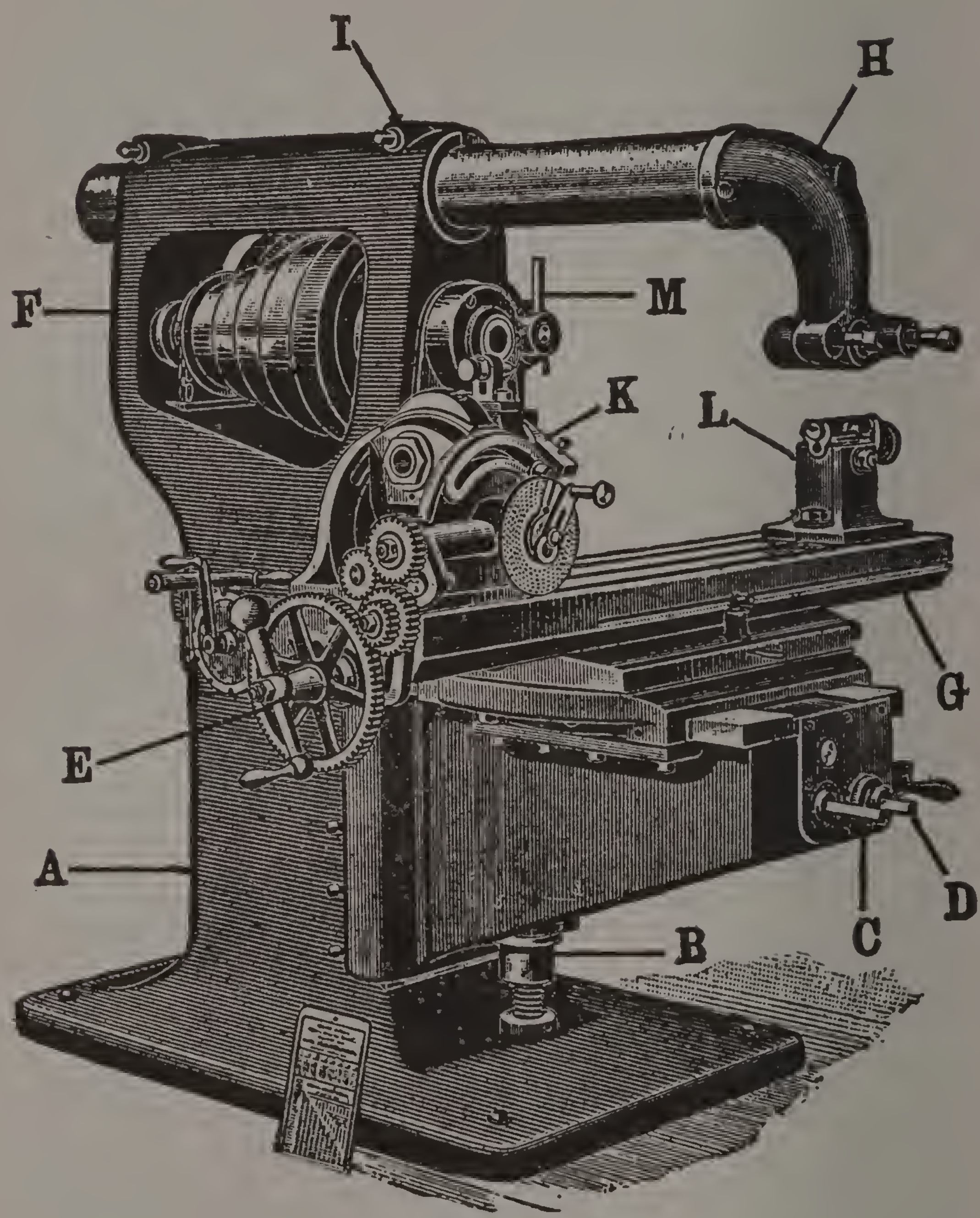


Fig. 303.

G is the table which carries the work.

H is the overhanging arm, which is used to support the outer end of the horizontal spindle.

K is the universal dividing head with power feed.

L is the foot-center or tail-stock.

M is the lever for throwing the back-gears in and out of mesh.

Automatic-feed Milling Machines. The journals of the machine shown in Fig. 304 are taper, self-oiling and self-adjusting, running in annular bearings, and capable of prolonged use without showing perceptible wear or need of alteration, and especially adapted to maintain true alignment of the spindle.

The front journal and thrust collar which runs loosely between the face of the bearing and spindle collar, are so proportioned in their combined bearing surfaces as to compensate each other for what wear may take place, and, as they are properly adjusted and tested before leaving the factory, will call for little or no attention outside of occasional renewal of oil supply in oil pockets.

The rear journal is entirely independent of the spindle, and consists of a steel shell keyed to but sliding on the same. Its adjustments are independent of those of the front journal, and readily allow for contraction and expansion of spindle under changes of temperatures.

Large oil pockets are molded in either housing directly under the bearings, in which the oiling rings are suspended. These rings revolve with the spindle and cause a constant flow of oil to the bearings as long as the spindle revolves. The oil pockets should be filled until the oil shows in the oil hole covers at the side of the bearings.

The driving cone has four steps, and with the back gears provides eight changes of speed to the spindle, which may be doubled with the two-speed countershaft. The back gears are fully covered and protected.

The upper housings carrying the overhanging arm are annular in form, the arm fitting the sleeves properly, clamping being effected by suitably shaped split bushings locked to the arm by means of the binding handles as shown in the cuts. The use of the front binding handle alone is sufficient to hold the arm, as with binders loose there is no possibility of shake in either bearing. This we believe to be an important improvement over the common form of split shell for the housings, which when clamped is liable to disturb the alignment of the arm with the hole in the spindle.

The overhanging arm is amply proportioned in each sized machine so as to rigidly support the outer end of the cutter arbor when under a heavy cut. The machines are all fitted with the straight bar and removable pendant, a desirable feature where frequent changes to the vertical spindle or other attachments are necessary. All machines are furnished with the supporting braces to knee, as shown in cuts.

The means for supporting the cutter arbors are as follows: An adjustable center, small bronze collet, and large shell bushing, furnishing a variety of supports, suitable for each class of milling, whether it be light, medium, or heavy.

All the machines have their center distances located and bored through the back-gear arms, overhead arm and spindle housings in a mill especially designed and constructed for this work. This mill supports and locates the body of the machine from its finished column, and insures accurate right-angled alignment of all holes with the column.

The saddles and swivels are made liberal in size and weight, with long wings, giving extra length of bearing for the table, and increased support even when the table is used in its extreme positions.

The swivel carriage for universal machines, carrying the table, is graduated in degrees through an arc on its front surface, and, the feed of the table being actuated from the center, it can be set and used at any angle up to 45 degrees with the axis of the spindle. The carriage is firmly clamped to the saddle by means of three bolts working in T slots and links, placed well out from the center to afford the greatest rigidity.

The tables are very deep and rigid with bearings on the shoulders of the saddle or carriage instead of the foot of the angles. This method carries the support well out from the center and prevents any tendency of the table to rock when work is machined at or clear of the edge. The tables have oil ways, channels, and suitable T slots, and are fitted with draining cock. The tables furnished with plain machines have a larger working capacity than those of the universals. The saddle and table are fitted with a taper gib having an adjusting screw at either end, making a positive lock for the gib when set.

The elevating screws for knee are made telescope. This double construction greatly strengthens the screw, overcoming any tendency in single screws to buckle when the knee is at its highest elevation. The telescopic screw avoids the necessity of cutting through the floor as in the case of the ordinary type of single screw, to afford a means of escape when the knee is lowered to the capacity of the machine.

Ball thrusts are fitted to the elevating screws, thus reducing the labor of operating the screws to a minimum, at the same time greatly increasing their sensitiveness to adjustments.

The binding handles are in use at all necessary points, superseding the old method of clamping with bolts and wrenches.

Dividing Head and Center. These form part of the regular equipment supplied with all universal machines, as illustrated in Fig. 304. The body of this head consists of a substantial base with parallel, annular housings, a center block carrying the spindle, worm gear and worm, and the trunnion supporting plates for the block. These trunnions have a 360 degree bearing of large diameter in their housings, and are recessed into the block on either side, and permanently held in position when assembled with it by means of dowel. Binding bolts for clamping head when in position pass clear through the trunnion plates, one below, one above and one at the end of the spindle, which operate to bind the head in one compact whole with no deflecting strains of any kind set up in the head. The full circular

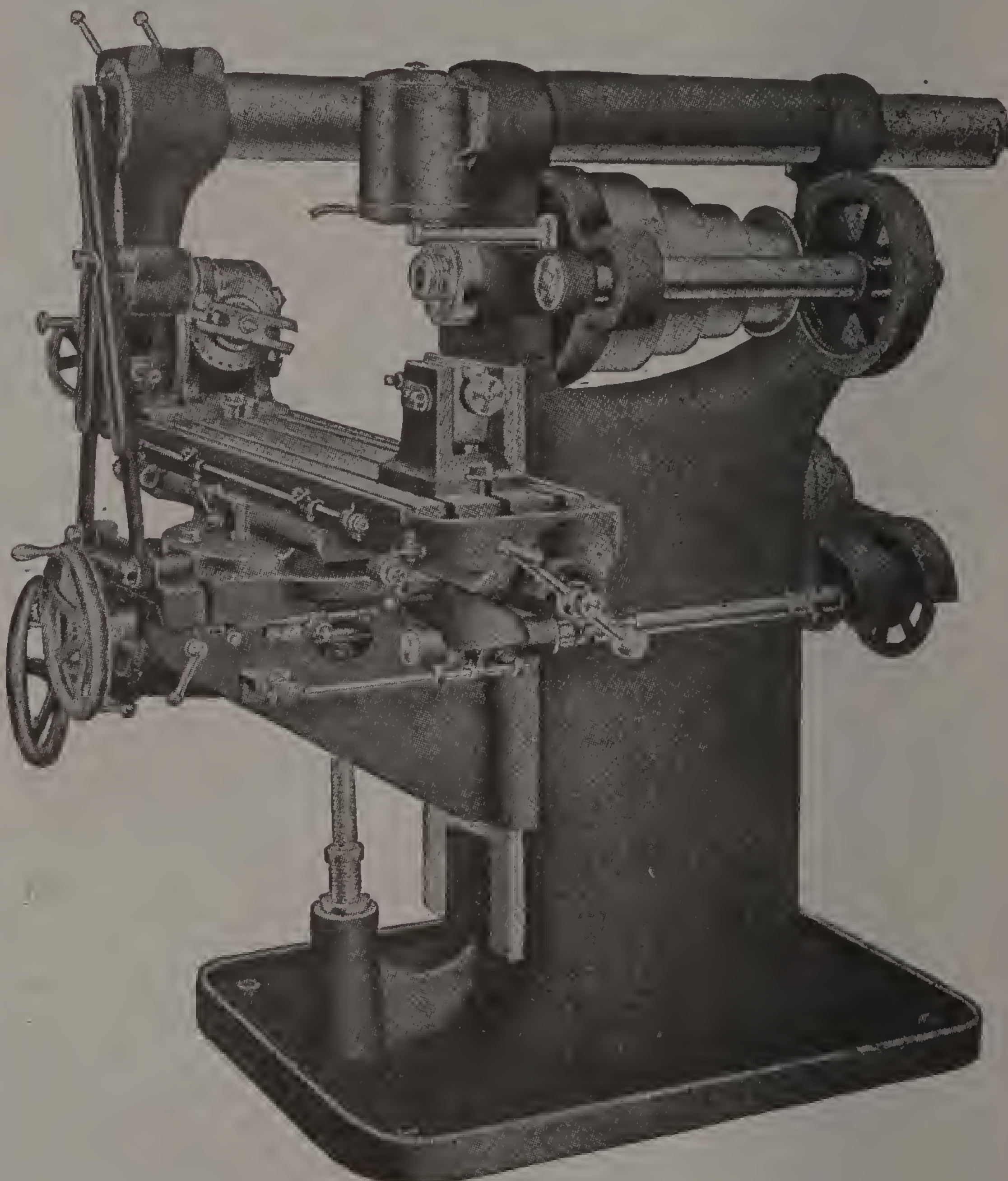


Fig. 304.

shape of the head affords means for a good length of spindle, which has taper journals at either end and an adjusting collar at rear.

Motor-Driven Milling Machines. Fig. 305 represents a Universal Milling Machine. This is a representative machine, showing the general style and design of electrically driven millers.

Experience has demonstrated that the most satisfactory

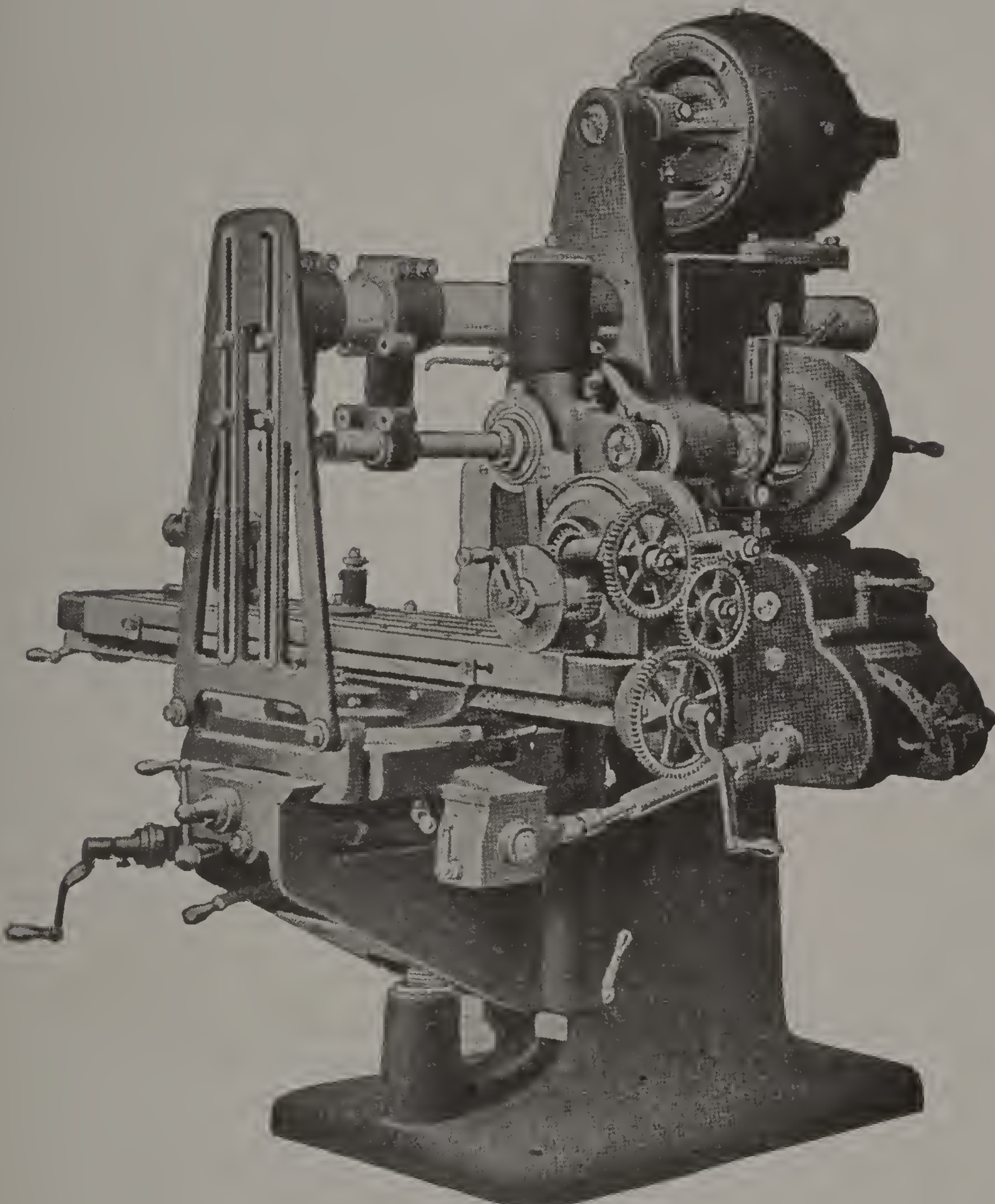


Fig. 305.

motor-driven milling machine is one driven by a variable speed motor with an electrical speed range of about three to one. This range being multiplied mechanically, gives the proper spindle speeds required. Whether the electrical variations are obtained by multiple or single voltage and field control, the results prove equally satisfactory. The multiple voltage is based on well known principles, two or more different voltages are supplied to the armature of the motor from which speeds proportional to these voltages result. These speeds are then divided by field regulation, giving the greatest range of any system. With the field control motor one voltage only is required, the entire speed range being obtained by changing the field. This form of control can therefore be used where power is obtained from an outside source, or when only one voltage is available.

The great advantage of an electrically driven machine is the fact that the speed range can be obtained by much smaller increments than it is possible to obtain a like range mechanically. The machine thus driven by a variable speed motor greatly increases the available number of spindle speeds and also simplifies the mechanical changes, and procures for the operator the proper cutting speeds for all diameters of cutters. It is necessary with a variable speed motor to have mechanical changes in connection with the electrical, the steps or intervals of these mechanical changes are equal to the entire electrical speed range of the motor, thus securing changes of speed in geometric progression.

The three mechanical changes required, are obtained by a quill on the spindle which takes the place of the ordinary cone. This quill being double back geared, gives one change when connected direct to the face gear and two more changes when back-geared. The drive from the motor shaft to the quill is by a noiseless chain through a friction pinion, so that the frequent operations of starting and stopping the machine to test the work or for any other purpose are entirely mechanical and are performed without any interference with the electrical details. With this arrangement all delay in stopping the rapidly running motor and the additional delay in again bringing up the speed is avoided—the operator cannot fail to start the machine again at the previous speed. The mechanical changes are thus covered by the speed range of the motor, a complete range of spindle speeds being obtained in geometrical progression with an average increase of not more than 3 per cent.

Motor-Driven Universal Millers. The machine shown in Figs. 306 and 307 represents the most modern practice in milling machine design. It differs radically from the

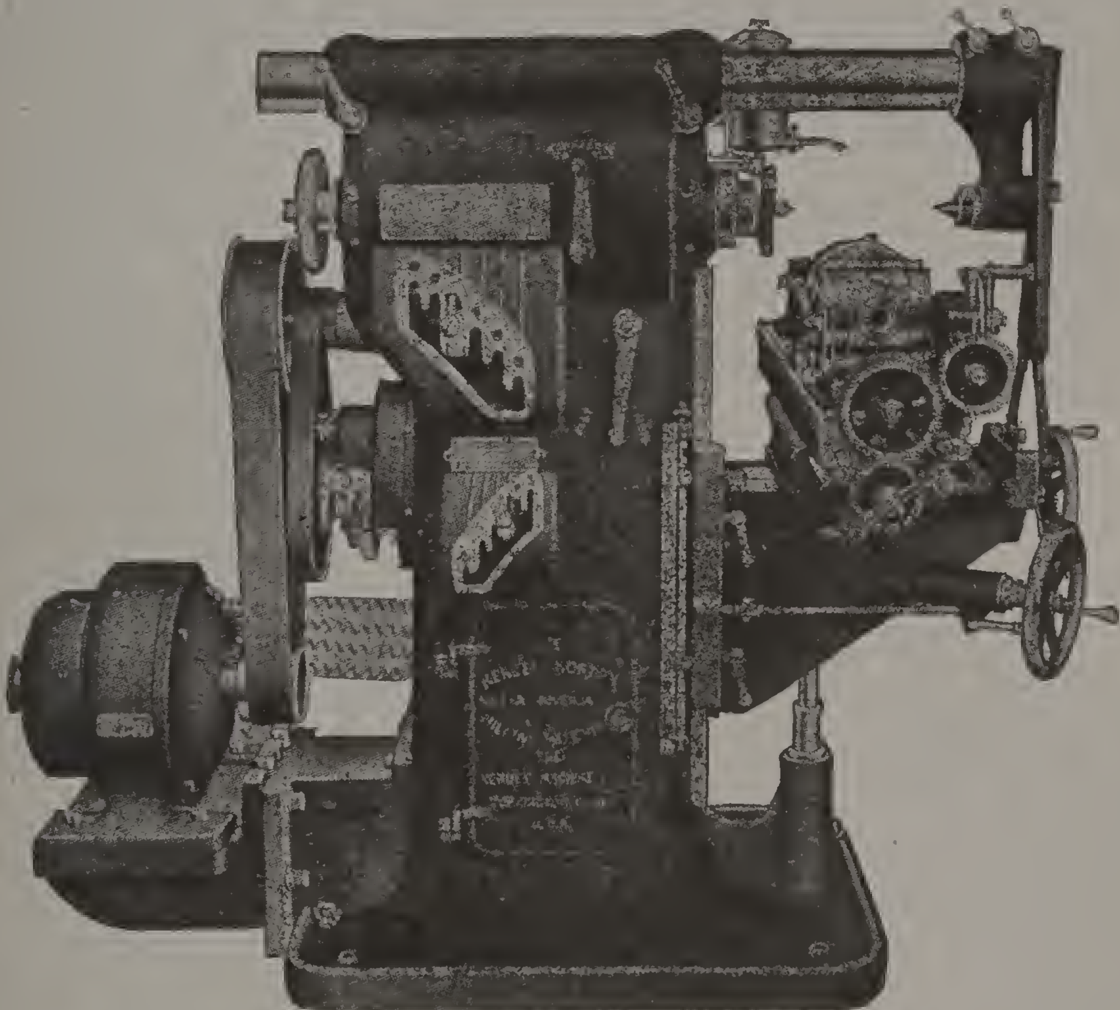


Fig. 306.

standard machine in that it has a gear instead of a belt-cone on the main spindle for speed changes, giving a greater range of spindle speeds, and the full range of feeds is entirely independent of the spindle speeds. In this miller these results are accomplished in the following manner: What may be called the driving shaft carries the large flanged pulley on the outer end, and is driven either from ordinary countershaft or from motor, as shown in the cut. Sliding on this driving shaft, inside the base or column is the regular form of bracket carrying the driving gear and intermediate, which may be meshed into any one of the six gears forming the cone on the spindle, and controlled by the guiding handle fitted with a spring latch, the two

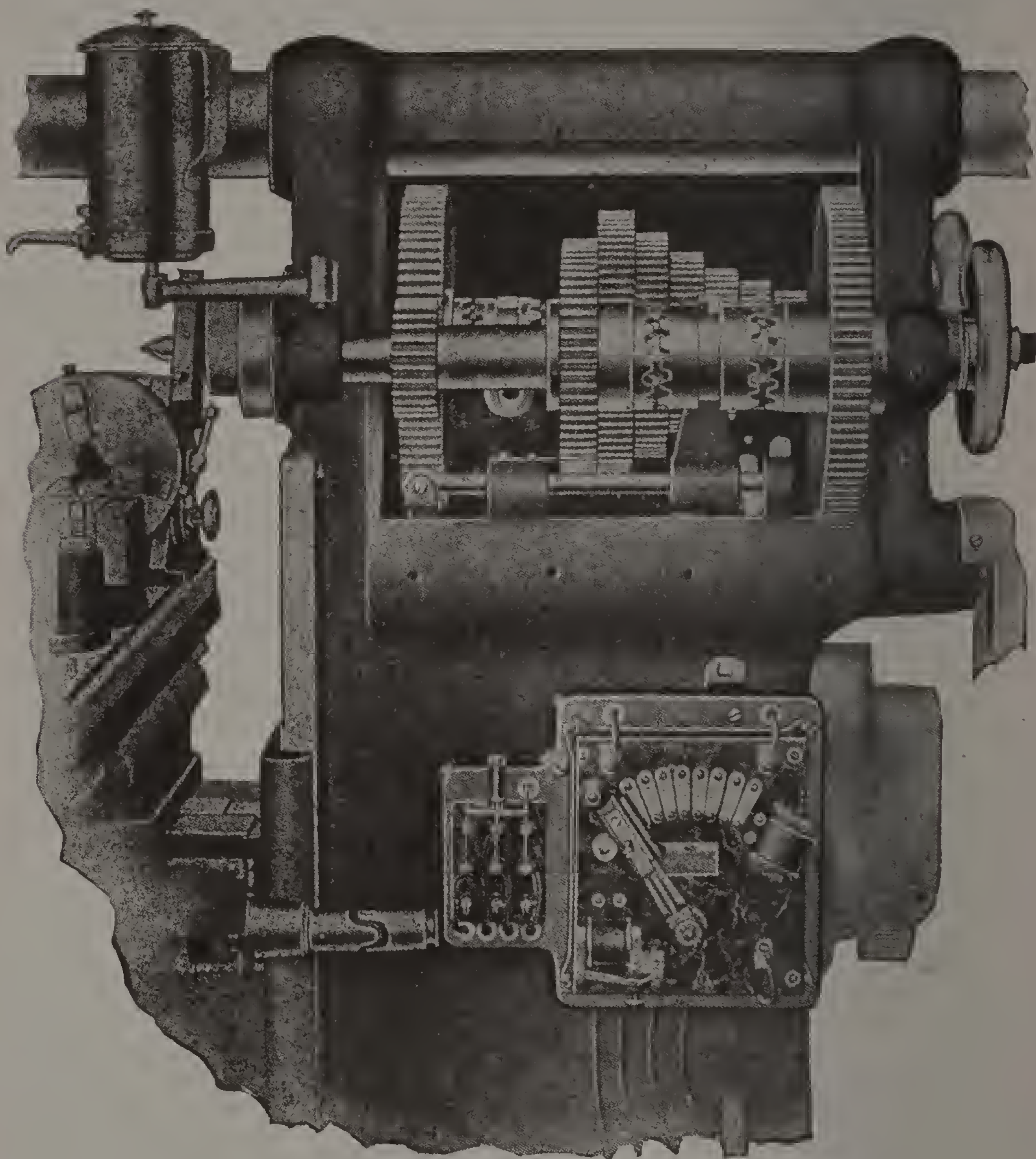


Fig. 307.

engaging in the guiding slots and locking holes in the upper wall of the opening. Six different and progressive direct spindle speeds are thus available, and, as the machine is double back geared, a series of eighteen different and progressive spindle speeds is supplied, having a rang of 16 to 370 revolutions per minute.

The back gearing may be left constantly in mesh if preferred, and when so set up it facilitates handling the entire range of speeds, as by means of the two positive clutches, one of which is mounted direct on the spindle, the other on the back gear shaft, and both controlled by the two levers shown on the left side of the machine, one direct and two back gear speeds are handled for every setting made in the cone of gears on the spindle.

All gearing entering into this combination, excepting the large face gear and large back gear, is made of steel. The clutches are made of crucible steel, and are hardened.

The upper lever shown in Fig. 307, controls the out and in clutch for the back gear or direct drive, while the lower lever controls the fast and slow back gear combination.

The hand wheel attached to the rear end of the spindle furnishes a convenient means for rolling the spindle over by hand, either for entering gears or close setting to work.

The feed shaft is geared from the driving spindle with a chain and sprocket as shown in Fig. 308, and the whole eighteen feed changes are available for each and every spindle speed.

The feed index plate gives the table travel in inches, running from 3/8 to 20 inches per minute. These speeds apply practically to saddle and knee feeds also, as both are automatic.

The simple method of mounting the motor makes it possible to use any standard make of reversible motor in place of a countershaft if so desired.

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

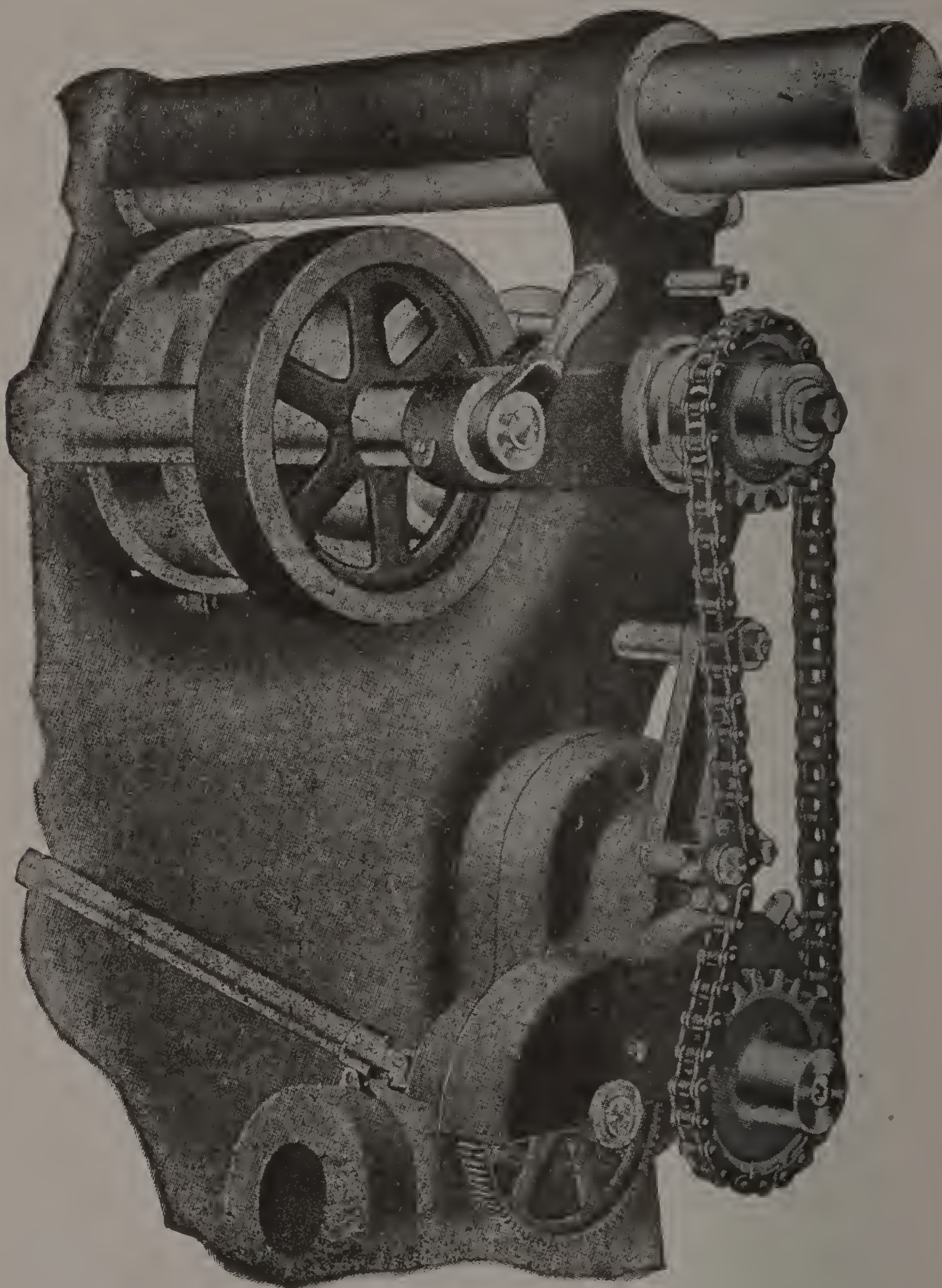


Fig. 308.

As the index spindle may be revolved by the crank, and as in this case forty turns of the crank make one revolution of the spindle, to find how many turns of the crank are necessary for a certain division of the work, or what is the same thing, for a certain division of a revolution of the spindle, forty is divided by the number of the divisions which are desired. The rule then, may be said to be, divide forty by the number of divisions to be made and the quotient will be the number of turns, or the part of a turn, of the crank, which will give each desired division. Applying this rule—to make forty divisions the crank would be turned completely around once to obtain each division, or to obtain twenty divisions it would be turned twice. When, to obtain the necessary divisions, the crank has to be turned only a part of the way around, an index plate, shown in Fig. 309, is used. For example: If the work is to be divided into eighty divisions the crank must be turned one-half way around, and an index plate with an even number of holes in one of the circles would be selected, it being necessary only to have two holes opposite to each other in the plate. If the work is to be divided into three divisions an index plate should be selected which has a circle with a number of holes that can be divided by three, as fifteen is divisible by 3, five times.

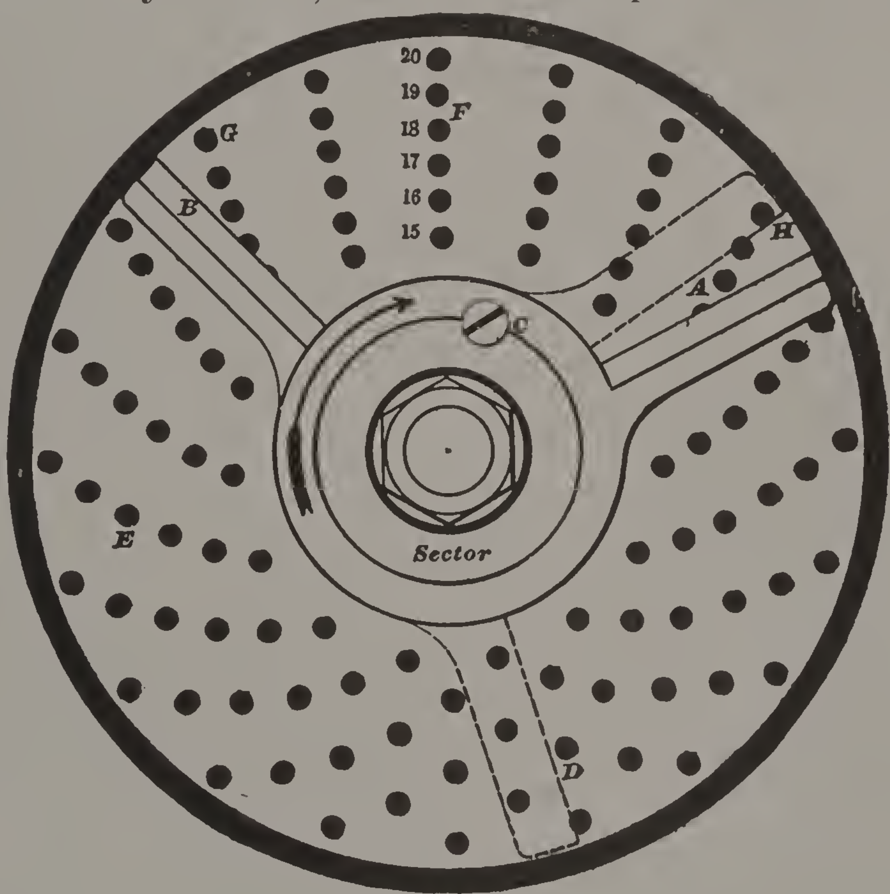


Fig. 309.

TABLE NO. 19—INDEX TABLE.

Number of Divisions.	Number of Holes in the Index Circle.	Number of Turns of the Crank.	Number of Divisions.	Number of Holes in the Index Circle.	Number of Turns of the Crank.
2	ANY	20	35	49	1 7-49
3	39	13 13-39	36	27	1 3-27
4	ANY	10	37	37	1 3-37
5	"	8	38	19	1 1-19
6	39	6 26-39	39	39	1 1-39
7	49	5 35-49	40	ANY	1
8	ANY	5	41	41	40-41
9	27	4 12-27	42	21	20-21
10	ANY	2	43	43	40-43
11	33	3 21-33	44	33	30-33
12	39	3 13-39	45	27	24-27
13	39	3 3-39	46	23	20-23
14	49	2 42-49	47	47	40-47
15	39	2 26-39	48	18	15-18
16	20	2 10-20	49	49	40-49
17	17	2 6-17	50	20	16-20
18	27	2 6-27	52	39	30-39
19	19	2 2-19	54	27	30-27
20	ANY	2	55	33	24-33
21	21	1 19-21	56	49	35-49
22	33	1 27-33	58	29	20-29
23	23	1 17-23	60	39	26-39
24	39	1 26-39	62	31	20-31
25	20	1 12-20	64	16	10-16
26	39	1 21-39	65	39	24-39
27	27	1 13-27	66	33	20-33
28	49	1 21-49	68	17	10-17
29	29	1 11-29	70	49	28-49
30	39	1 13-39	72	27	15-27
31	31	1 9-31	74	37	20-37
32	20	1 5-20	75	15	8-15
33	33	1 7.33	76	19	10-19
34	17	1 3-17	78	39	20-39

TABLE No. 19 (Continued)—INDEX TABLE.

Number of Divisions.	Number of Holes in the Index Circle.	Number of Turns of the Crank.	Number of Divisions.	Number of Holes in the Index Circle.	Number of Turns of the Crank.
80	20	10-20	164	41	10-41
82	41	20-41	165	33	8-33
84	21	10-21	168	21	5-21
85	17	8-17	170	17	4-17
86	43	20-43	172	43	10-43
88	33	15-33	180	27	6-27
90	27	12-27	184	23	5-23
92	23	10-23	185	37	8-37
94	47	20-47	188	47	10-47
95	19	8-19	190	19	4-19
98	49	20-49	195	39	8-39
100	20	8-20	196	49	10-49
104	39	15-39	200	20	4-20
105	21	8-21	205	41	8-41
108	27	10-27	210	21	4-21
110	33	12-33	215	43	8-43
115	23	8-23	216	27	5-27
116	29	10-29	220	33	6-33
120	39	13-39	230	23	4-23
124	31	10-31	232	29	5-29
128	16	5-16	235	47	8-47
130	39	12-39	240	18	3-18
132	33	10-33	245	49	8-49
135	27	8-27	248	31	5-31
136	17	5-17	260	39	6-39
140	49	14-49	264	33	5-33
144	18	5-18	270	27	4-27
145	29	8-29	280	49	7-49
148	37	10-37	290	29	4-29
150	15	4-15	296	37	5-37
152	19	5-19	300	15	2-15
155	31	8-31	310	31	4-31
156	39	10-39	312	39	5-39
160	20	5-20	360	18	2-18

Compound Indexing. To illustrate the manner of using the machine shown in Fig. 310 in compound indexing, suppose that it is desired to divide the work into 69 parts. Reference to Table No. 19 shows that the work is moved through 21 spaces, or holes in the 23 hole circle and then turned in the opposite direction 11 holes in the 33 hole circle of the index plate shown in Fig. 310. The first movement is made in the ordinary manner. The stop or back pin is placed in the 33 hole circle, the index-crank pin is

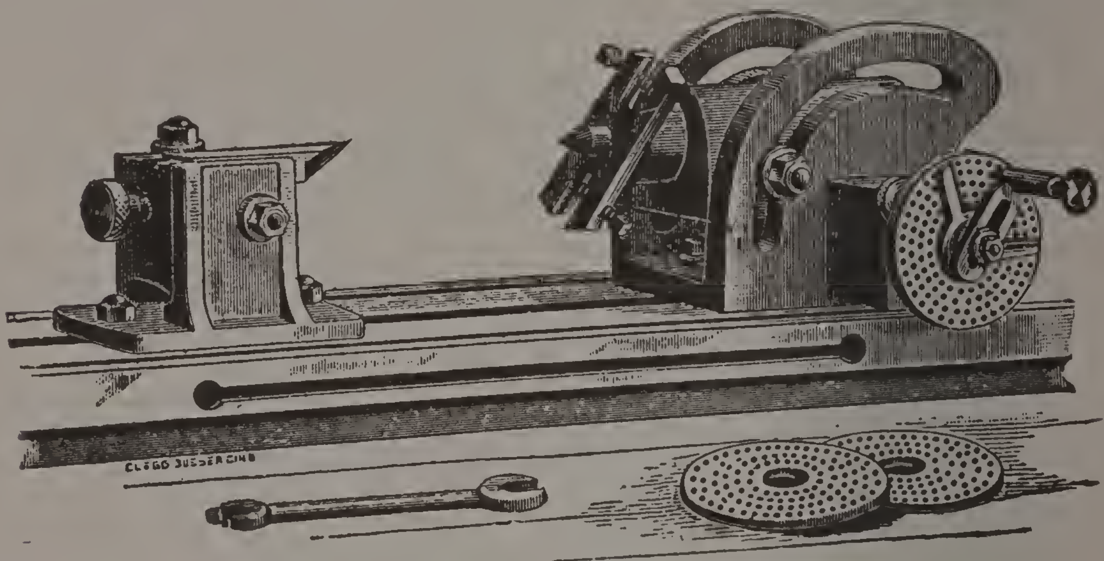


Fig. 310.

pulled out of the 23 hole circle, and the index crank is turned through 21 holes in the desired direction, the holes being measured by the sector. For the second movement, the index crank pin is left in the 23 hole circle, the back pin is pulled back from the plate, and as the minus sign is given in the table, the crank is turned 11 holes in the direction opposite to that of the former movement. In this part of the indexing the index plate and crank turn together, and as there is no sector on the back of the plate, the holes or spaces have to be counted directly in the plate. Had the plus sign been given, as in the indexing to obtain 77 divisions of the work, both movements of the crank would have been in the same direction. Ordinarily the order of the movements is not material and if more convenient for any reason, the back pin could usually be withdrawn first, and the movement described as the second could be made first. In some instances as in dividing the work into 174, 272 or 273 parts, the outer circle is naturally used first.

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

The table gives the movements for absolute divisions of the work of nearly all numbers from 50 to 250.

TABLE NO. 19—COMPOUND INDEX TABLE.

No. of Teeth.	Index Moves.	No. of Teeth.	Index Moves.	No. of Teeth.	Index Moves.
50	16-20	94	20-47	160	5-20
52	30-39	95	8-19	164	10-41
54	20-27	96	3-18 + 1-24	165	8-33
55	24-33	98	20-49	168	5-21
56	35-49	99	15-27 — 5-33	170	4-17
58	20-29	100	8-20	172	10-43
60	26-39	104	15-39	174	11-33 — 3-29
62	20-31	105	8-21	180	6-27
64	10-16	108	10-27	182	3-39 + 7-49
65	24-39	110	12-33	184	5-23
66	20-33	115	8-23	185	8-37
68	10-17	116	10-29	186	17-31 — 11-33
69	21-23 — 11-33	120	13-39	188	10-47
70	28-49	124	10-31	190	4-19
72	15-27	128	5-16	195	8-39
74	20-37	130	12-39	196	10-49
75	8-15	132	10-33	198	3-27 + 3-33
76	10-19	135	8-27	200	4-20
77	9-21 + 3-33	136	5-17	205	8-41
78	20-39	138	11-33 — 1-23	210	4-21
80	10-20	140	14-49	215	8-43
82	20-41	144	5-18	216	5-27
84	10-21	145	8-29	220	6-33
85	8-17	147	13-39 — 3-49	225	5-18 — 2-20
86	20-43	148	10-37	230	4-23
87	23-29 — 11-33	150	4-15	231	3-21 + 1-33
88	15-33	152	5-19	232	5-29
90	12-27	154	8-21 — 4-33	235	8-47
91	6-39 + 1-4	155	8-31	240	3-18
92	10-23	156	10-39	245	8-49
93	3-31 + 1-3			248	5-31

Cam Cutting Attachment. The attachment shown in Fig. 311 is used for cutting either face or cylindrical cams from a flat former cut from a disk.

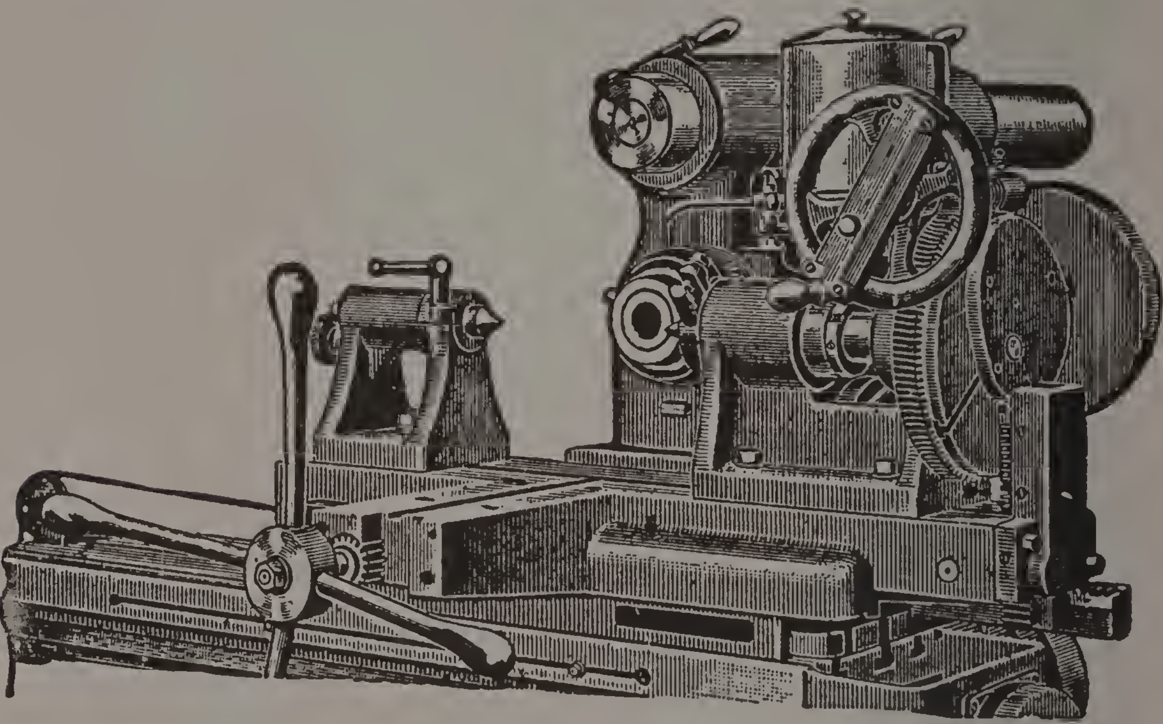


Fig. 311.

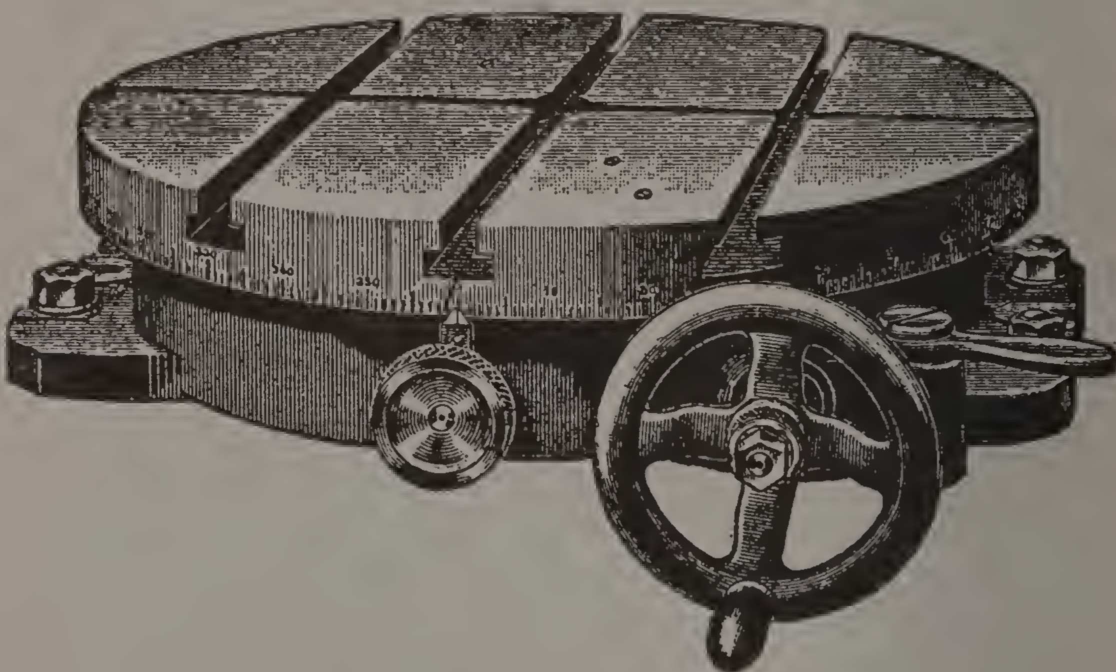


Fig. 312.

All the necessary movements are contained in the attachment itself, thereby allowing the table of the machine to remain clamped in one position during the cutting of the cam.

Cams 12 inches in diameter can be cut with any throw up to 5 inches.

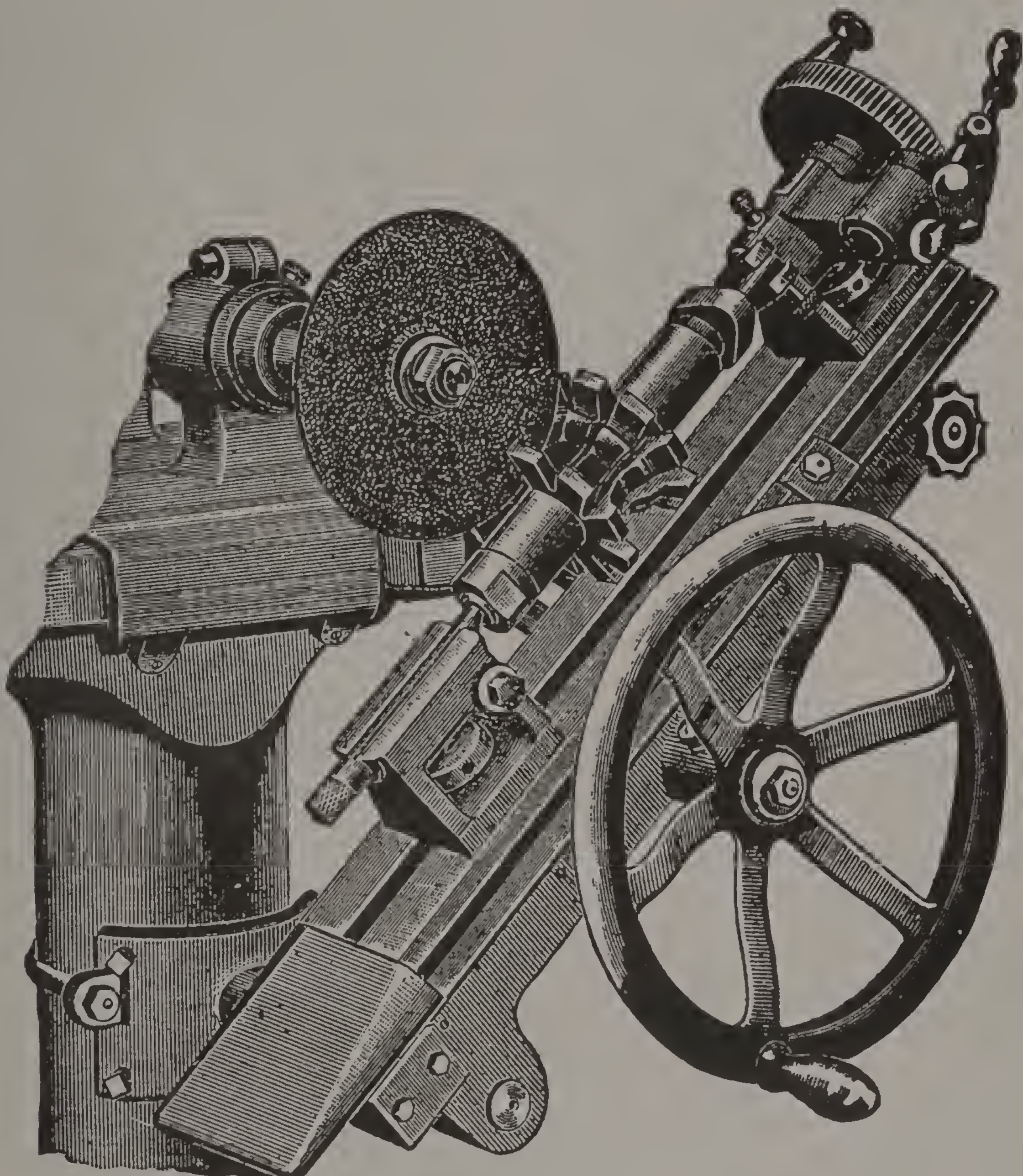


Fig. 313.

Circular Milling Attachment. The attachment shown in Fig. 312 is new in design and is well adapted for use upon milling machines in connection with a vertical spindle milling attachment.

The Table is 18 inches in diameter and has 4 T slots 5/8 inches wide. The circumference of the entire circle is graduated to degrees.

The Feed of the table is operated by the hand wheel shown in the drawing. The worm can be thrown out of mesh and the table easily turned by hand.

A clamp screw is provided for clamping the table in position.

Cutter Grinding Attachment. The attachment illustrated in Fig. 313 is used for grinding the teeth of formed cutters

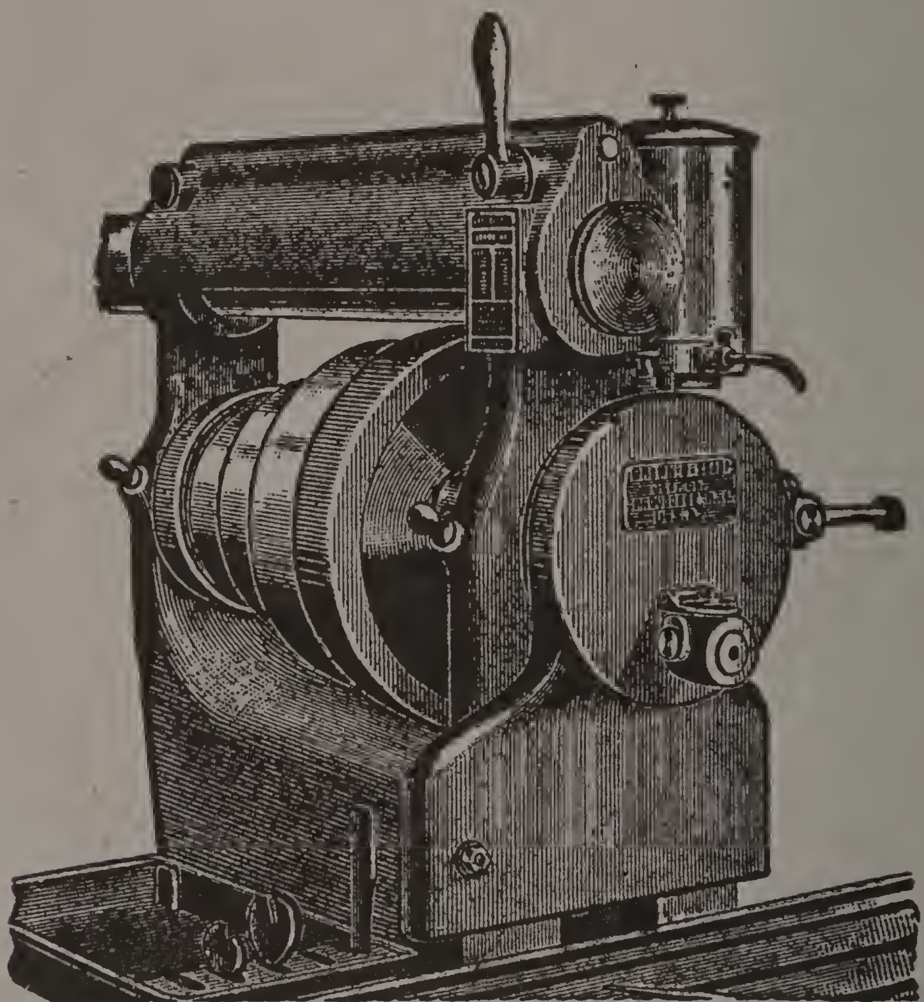


Fig. 314.

radially, this being necessary in order to insure their cutting the correct form. It consists of a bed rigidly attached to the main bar, that carries a sliding table provided with

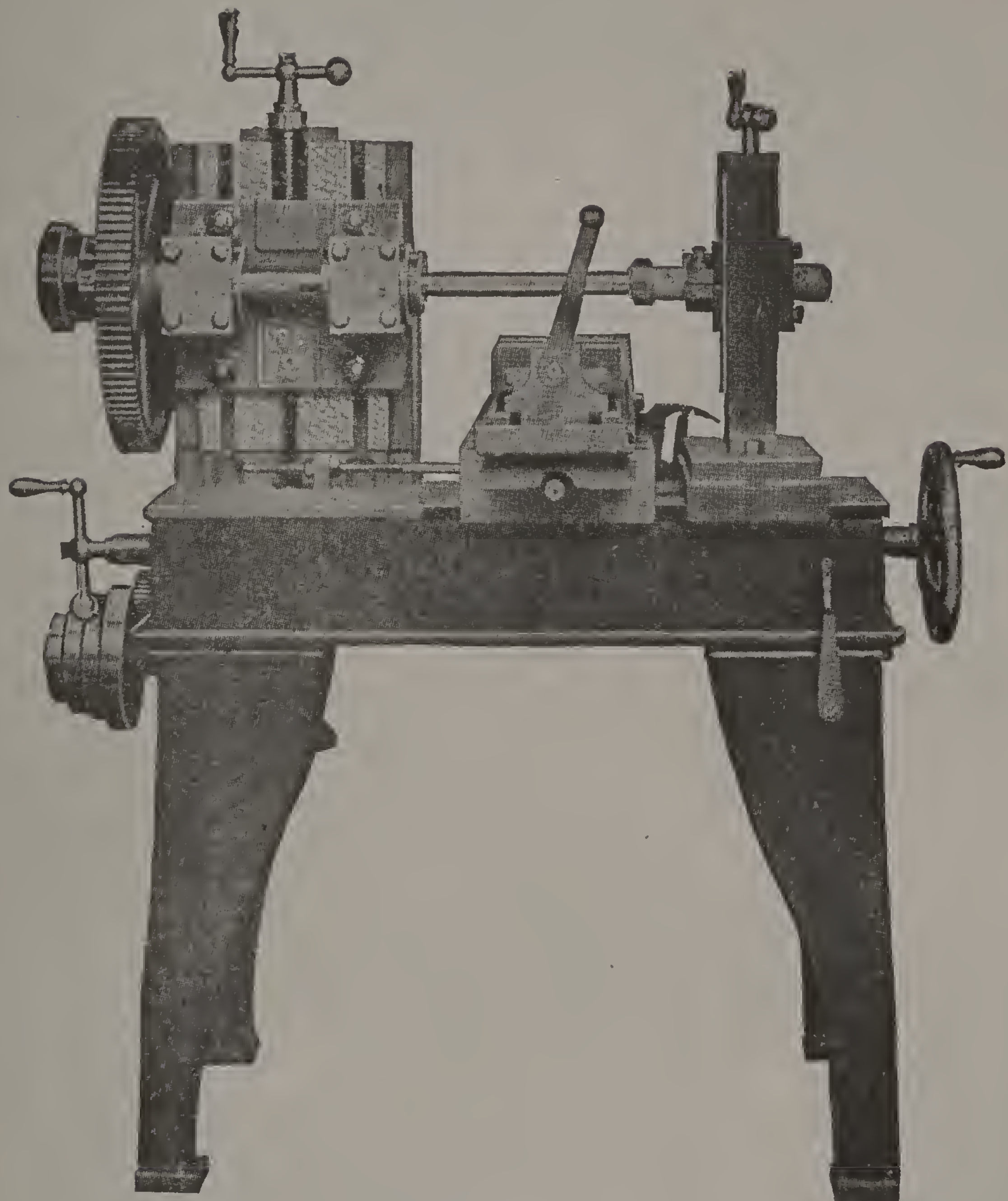


Fig. 315.

a pair of index centers, between which the work to be ground is held.

The Centres swing 4 3-4 inches in diameter and take 10 1-2 inches in length.

The Index Plate has 24 holes and can be turned by a worm or the worm can be disengaged and the plate turned by hand.

Formed Cutters to 8 inches in diameter can be ground by the use of raising blocks.

Hight Speed Milling Attachment. A high speed milling attachment is shown in Fig. 314. By means of an internal gearing and a pinion it is geared up about 3 to 1.

Lincoln Milling Machine. This machine (Fig.315) is radically different in construction to that of those in general use. The spindle is raised and lowered and the carriage has only two movements, longitudinal and transverse.

Geared Pump. The pump shown in Fig. 316 is principally used on machines where the cutting tools operate

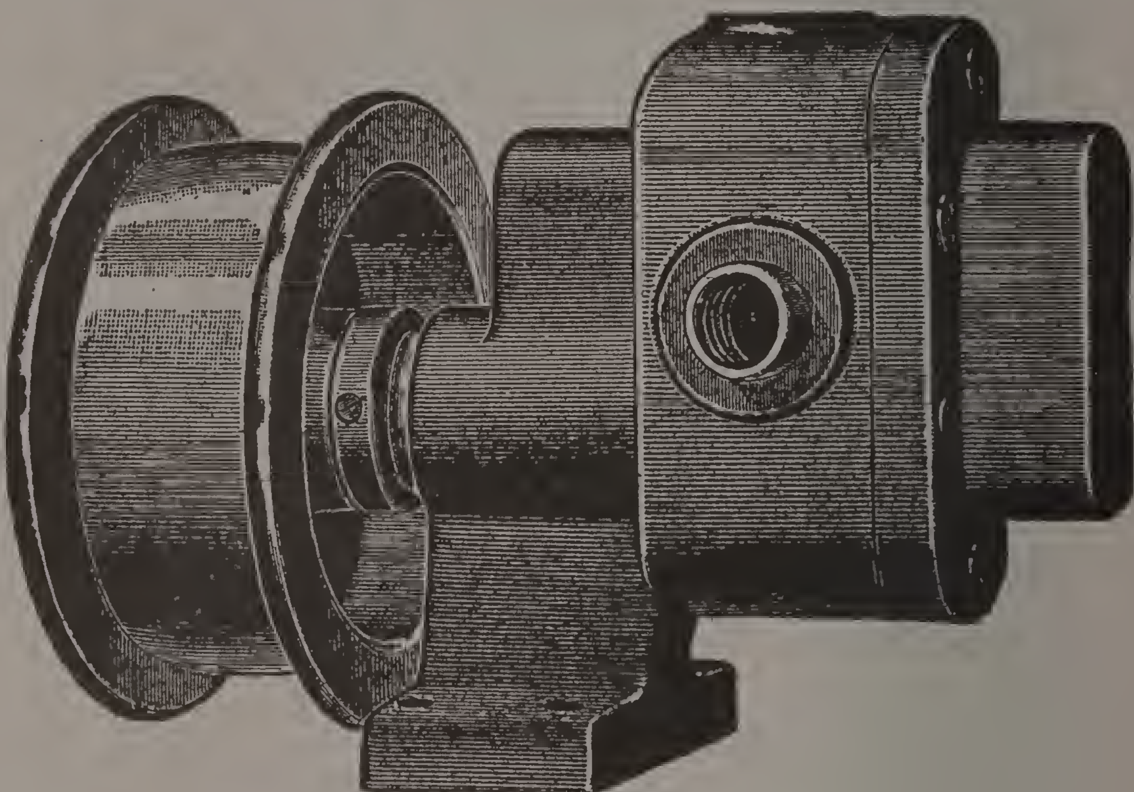


Fig. 316.

only in one direction, as milling machines, gear cutting machines, chucking machines. But, by running the pump independently, it can be used on machines that reverse.

It is simple in construction, the principal mechanism being a pair of gears which run together in a tight case.

To obtain the best results the pump should be placed as near as possible to the level of the liquid in the tank.

Gear Cutting Attachment. The spindle of the machine shown in Fig. 317 is $2\frac{3}{4}$ inches in diameter, and is made tapering to compensate for wear. The master wheel is 7 inches in diameter with 40 divisions. With the small lever on the side the spindle can be securely locked in any position, relieving the index pin from all strain. The worm

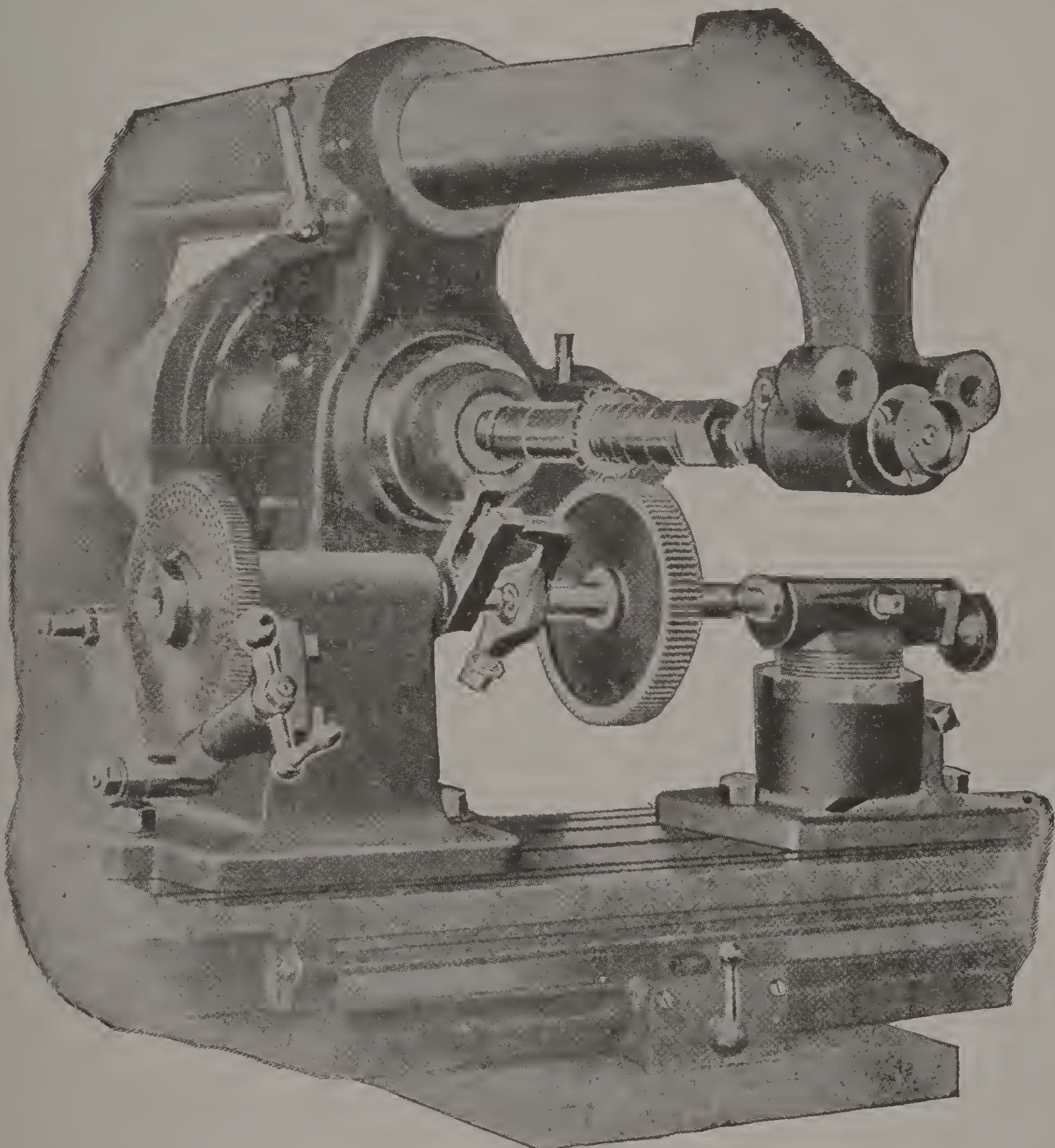


Fig. 317.

shaft can be adjusted to compensate for wear, and when necessary can be instantly thrown out of mesh and the divisions had with the notched wheel at the rear. This is very convenient for quick divisons. The spindle is hollow and bored to No. 10 B. & S. taper. Tail stock is adjustable for taper work. With index plates furnished all numbers to 50, the even numbers to 100, and most numbers to 360, can be divided. The tail stock is adjustable, the adjustments being obtained by a screw so that it can be set accurately and securely clamped in position.

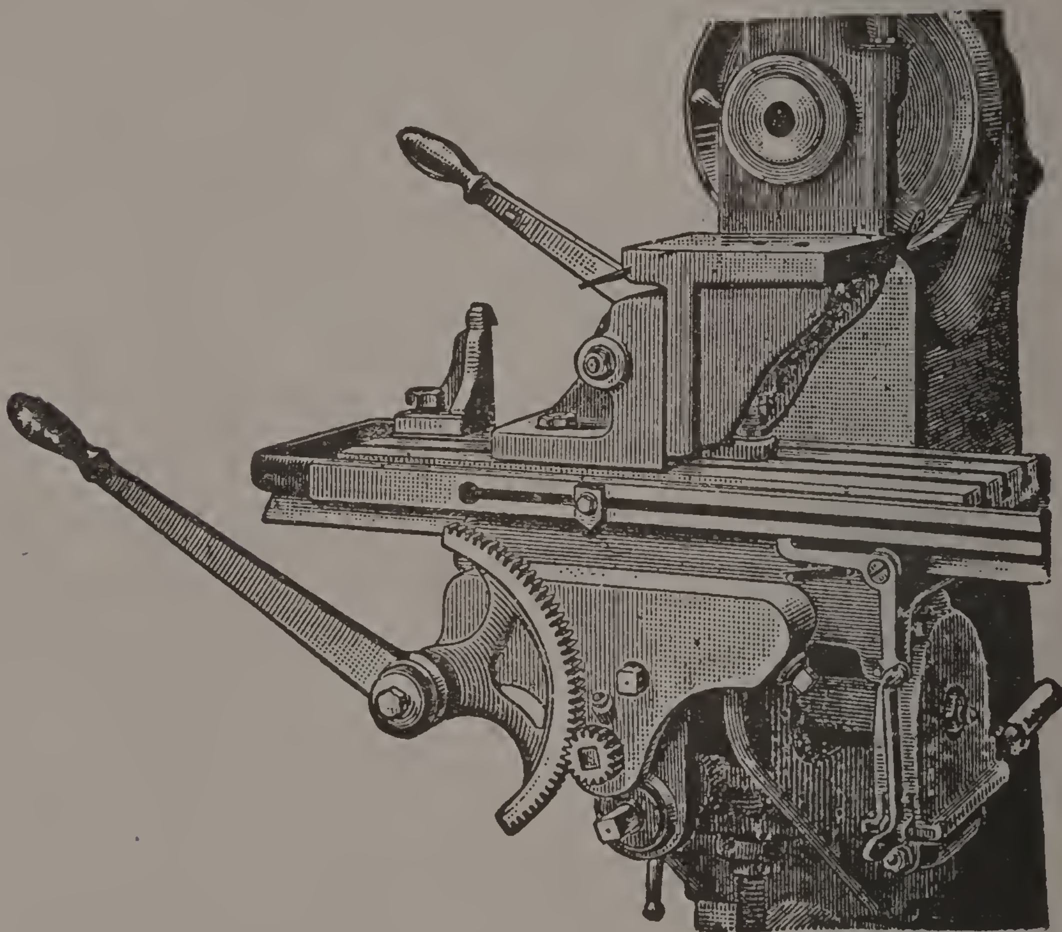


Fig. 318.

Hand Milling Attachment. A plain Milling Machine with a Rack Feed can be quickly changed by means of the attachment shown in Fig. 318 into a hand milling machine with or without an automatic longitudinal feed.

An apron, placed on the outside end of the knee, carries a lever attached to a segment of a gear which runs in a pinion placed over the end of the shaft that moves the table longitudinally, and this lever when moved turns the shaft as the crank would if it were in position.

The attachment, with a knee, is clamped on the table and on this the fixtures for holding the work can be fastened as on a hand milling machine. When brought to position the lever can be held by the clutch in the holder, shown at the left of the drawing, which can be released by a latch on the back of the lever, so that at the same time that the knee is returned to position the catch is released without an extra movement. While the lever is held down, the feed can be thrown in and milling done as on a plain milling machine.

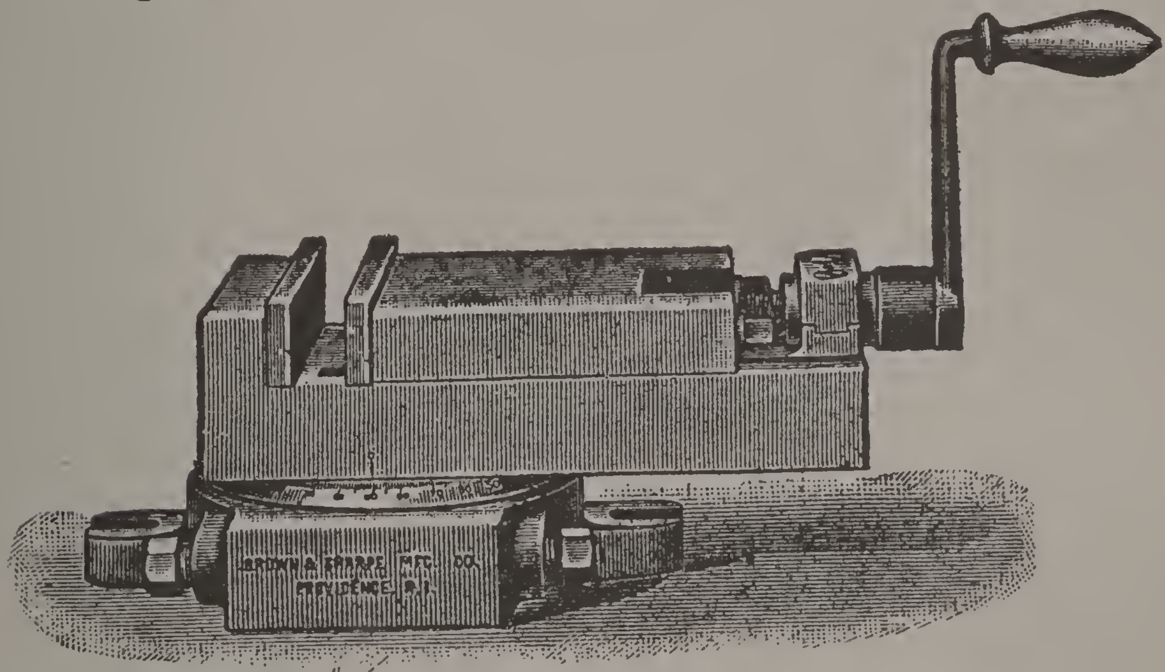


Fig. 319.

Plain Vise. The vise illustrated in Fig. 319 is provided with flanges for clamping them to the table of milling or planing machines, they are a very convenient and extremely useful tool.

Quill Gear Cutting Attachment. The attachment shown in Fig. 320 is for cutting the small members of quill gears, as shown in the drawing, or other gears of similar construction.

They are easily and quickly placed in position or removed.

The cutter spindle is raised above the cutter spindle of the machine and driven by a train or gears.

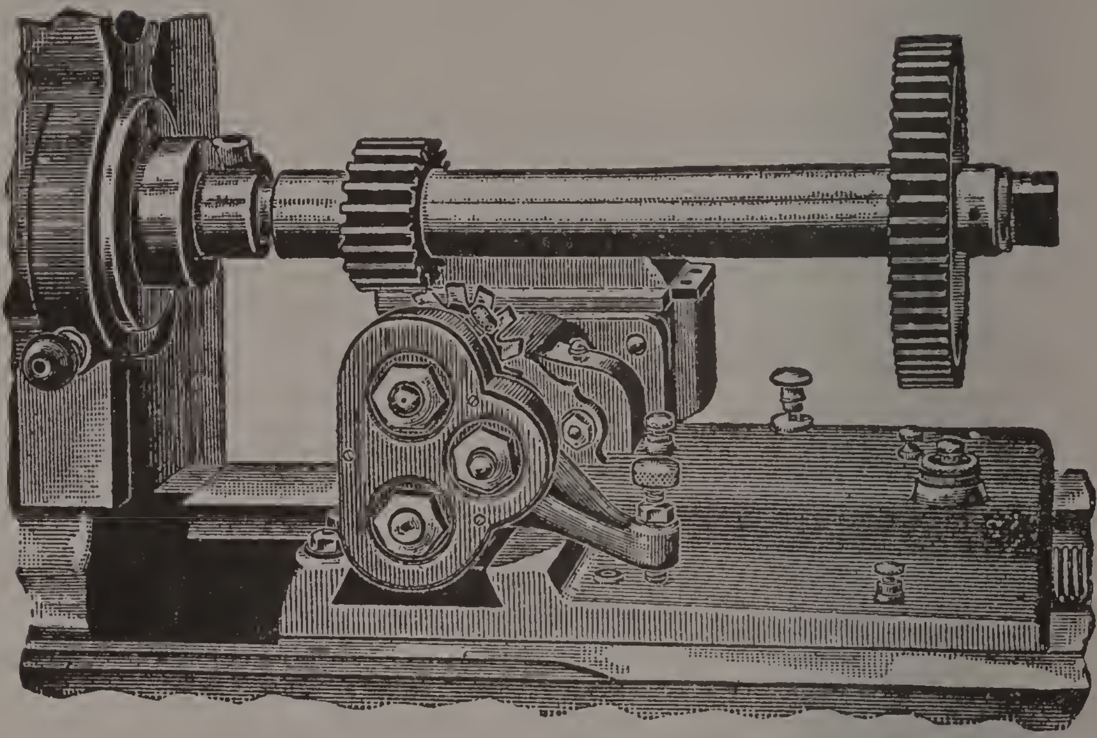


Fig. 320.

Rack Cutting Attachment. The attachment shown in Fig. 321 embodies in its construction many important improvements that greatly enhance its value, making it exceptionally rigid and convenient. All working parts are entirely enclosed, thus protecting them from dirt and chips.

The upper part of the frame is clamped to the overhanging arm, means being provided for vertical adjustment to compensate for any variation in the center distance between arm and spindle. The lower part of the frame is clamped to the front of the knee slide, and provided with means for adjusting the cutter spindle parallel with the table.

The cutter spindle is hardened and ground, and runs in phosphor bronze boxes. The front box is provided with means of compensation for wear. It is smoothly and powerfully driven by the main spindle of the machine, through spiral and herring bone gears.

Rack Cutting Attachment. The body of the attachment shown in Fig. 322 and its supporting bracket which clamps to the column of the machine are formed, of one casting, making it very rigid. The front pendant forms the cap for the head of the attachment to which it is firmly screwed and doweled. All the gearing is made of steel. The

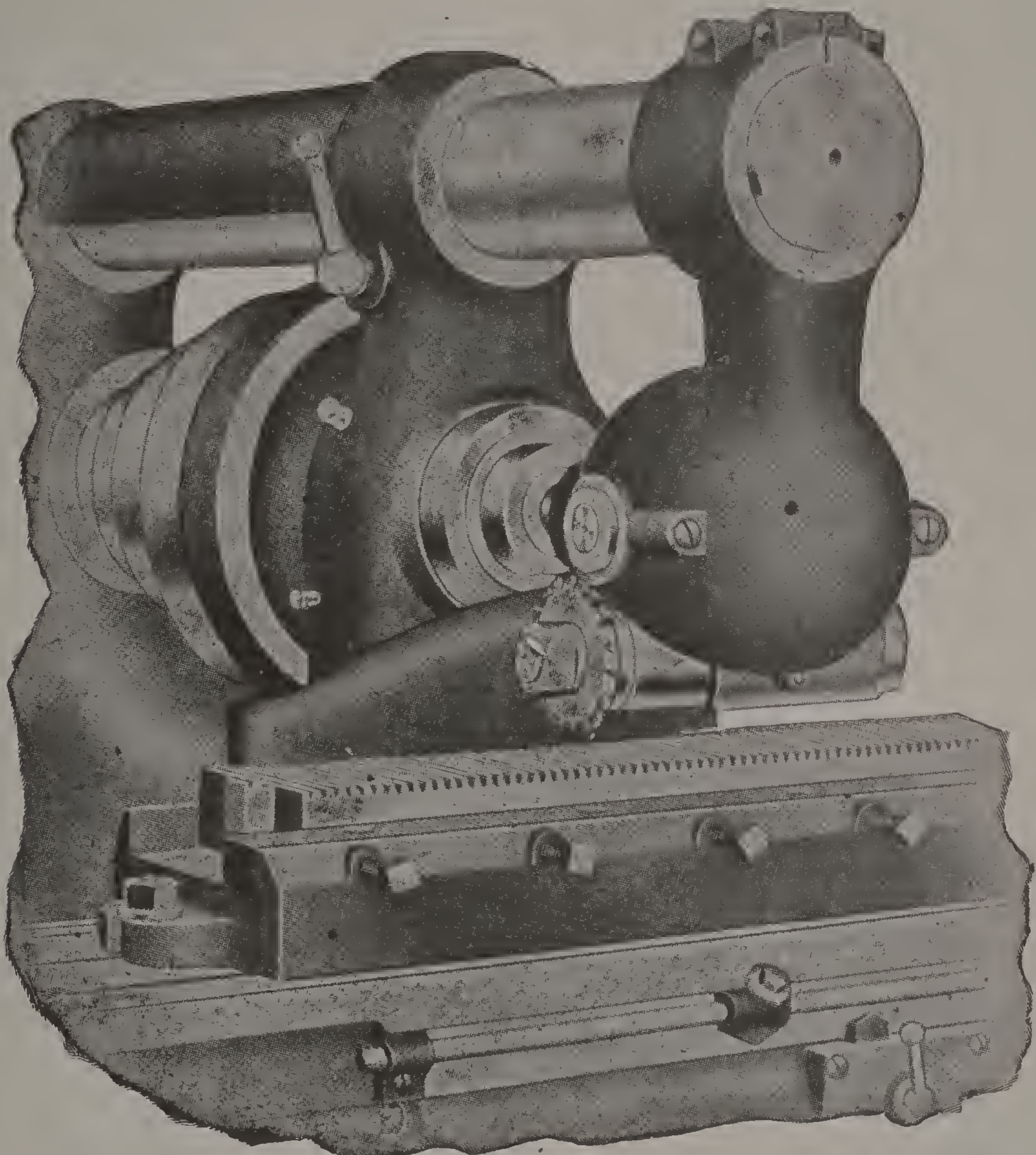


Fig. 321.

shafts run in bronze bearings, and the cutter arbor has taper journal at its head end. The movable jaw of the vise is made of steel.

Universal v Plain Millers. The Universal Miller shown

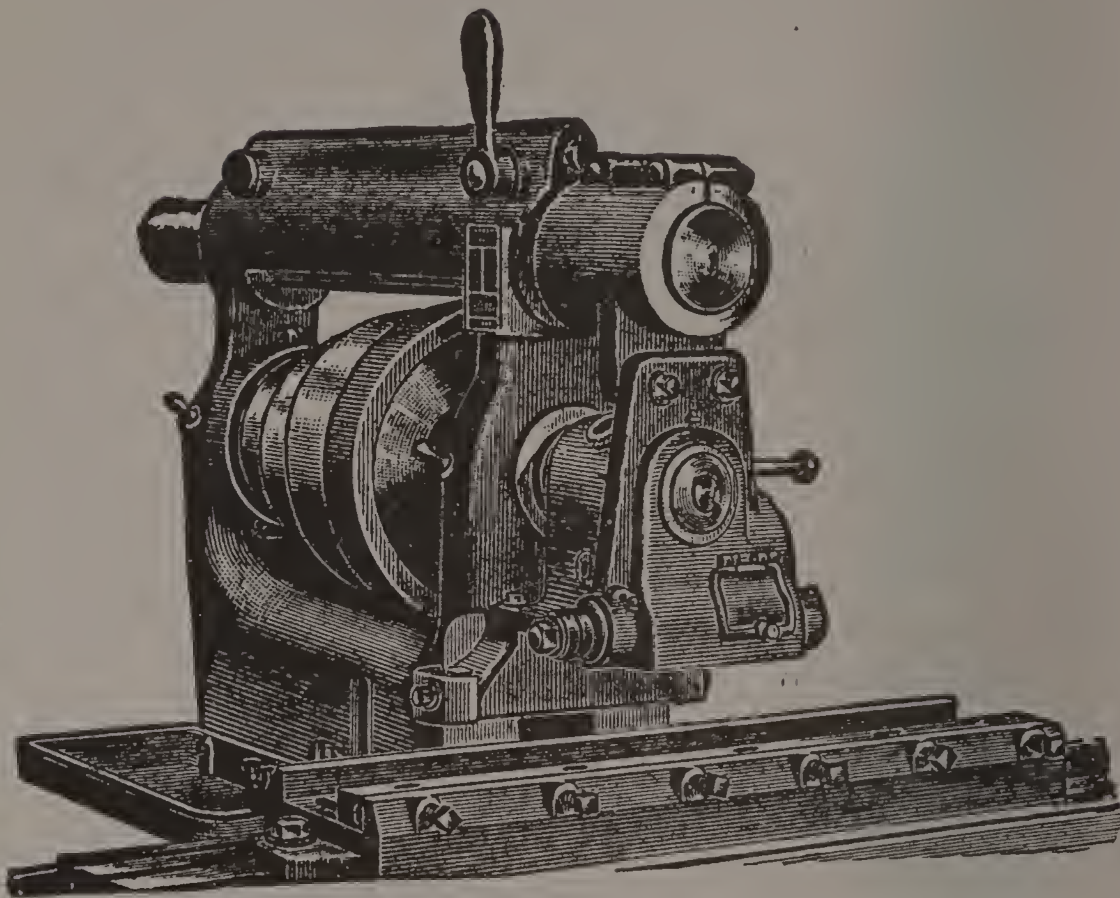


Fig. 322.

in Fig. 323 is exactly the same as the Plain Miller shown in Fig. 324 except that provisions are made for swiveling the table and automatically rotating the universal head. They are especially useful in tool rooms, or where there is a large variety of work. They can perform every operation of which a Plain Miller is capable, having, in addition to the parts of the Plain Miller the swivelling table and universal head with the means for rotating the head, giving facilities for cutting spirals, notching worm wheels, etc.

Universal machines are not as good as Plain Millers for manufacturing purposes. The swiveling feature makes one more joint, and also lessens the vertical range. The feeding mechanism has to be brought up through the center of the swivel, thus restricting the design, and consequently they can not be made as simple and substantial as a Plain Miller. However, these are the faults of the type and not of the machine.

Plain Milling Machine. The spindle of the machine

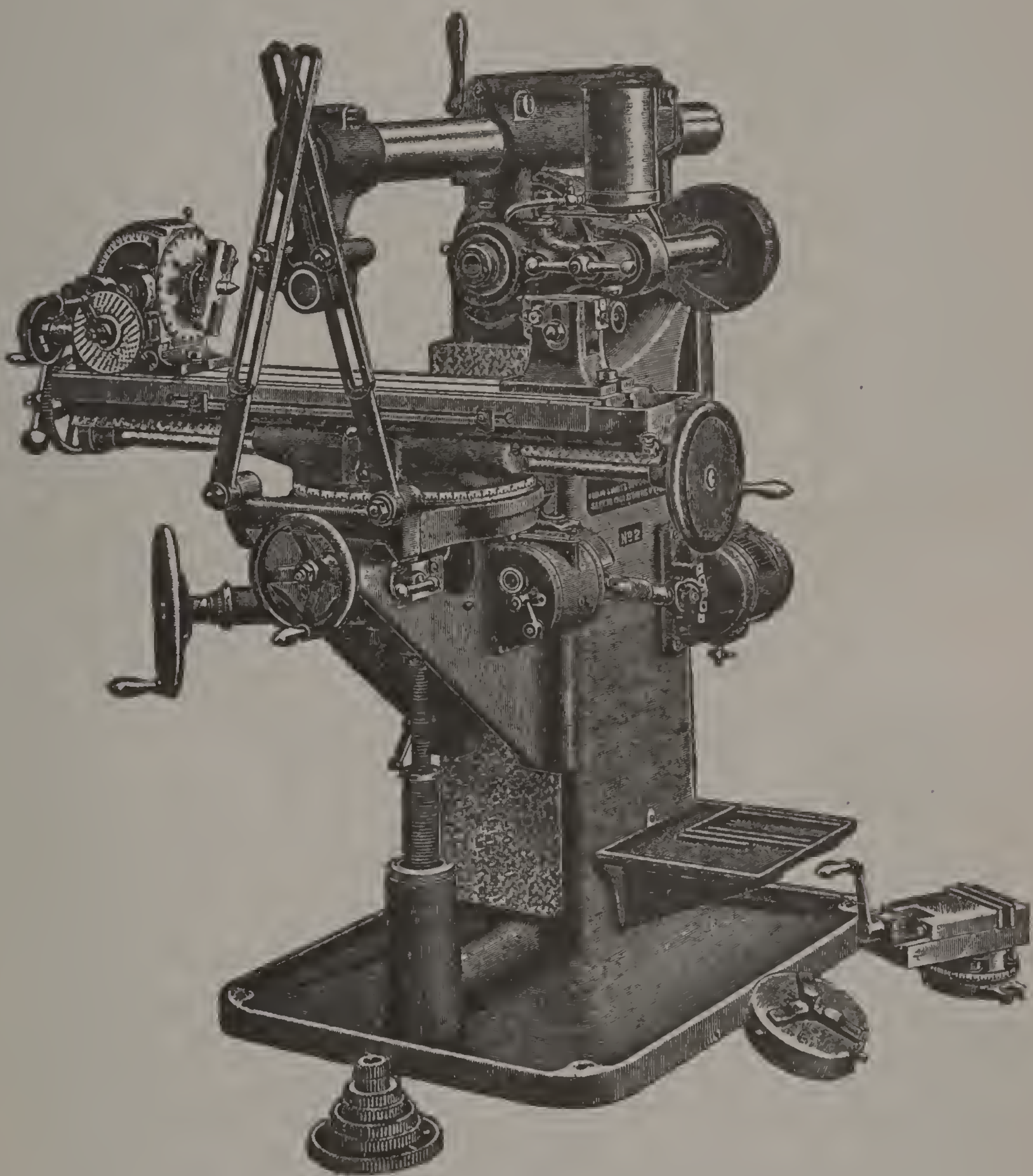


Fig. 323.

shown in Fig. 325 is crucible steel and the bearings ground. The bronze boxes provided with means of compensation for wear. The spindle is driven from the cone by a gear and pinion. The vertical adjustment by means of nuts on a vertical screw.

The overhanging arm is of solid steel.

Feed. Longitudinal, automatic, 15 inches. Can be automatically released at any point. Four changes, varying from .015 inch to .066 inch to one revolution of spindle.

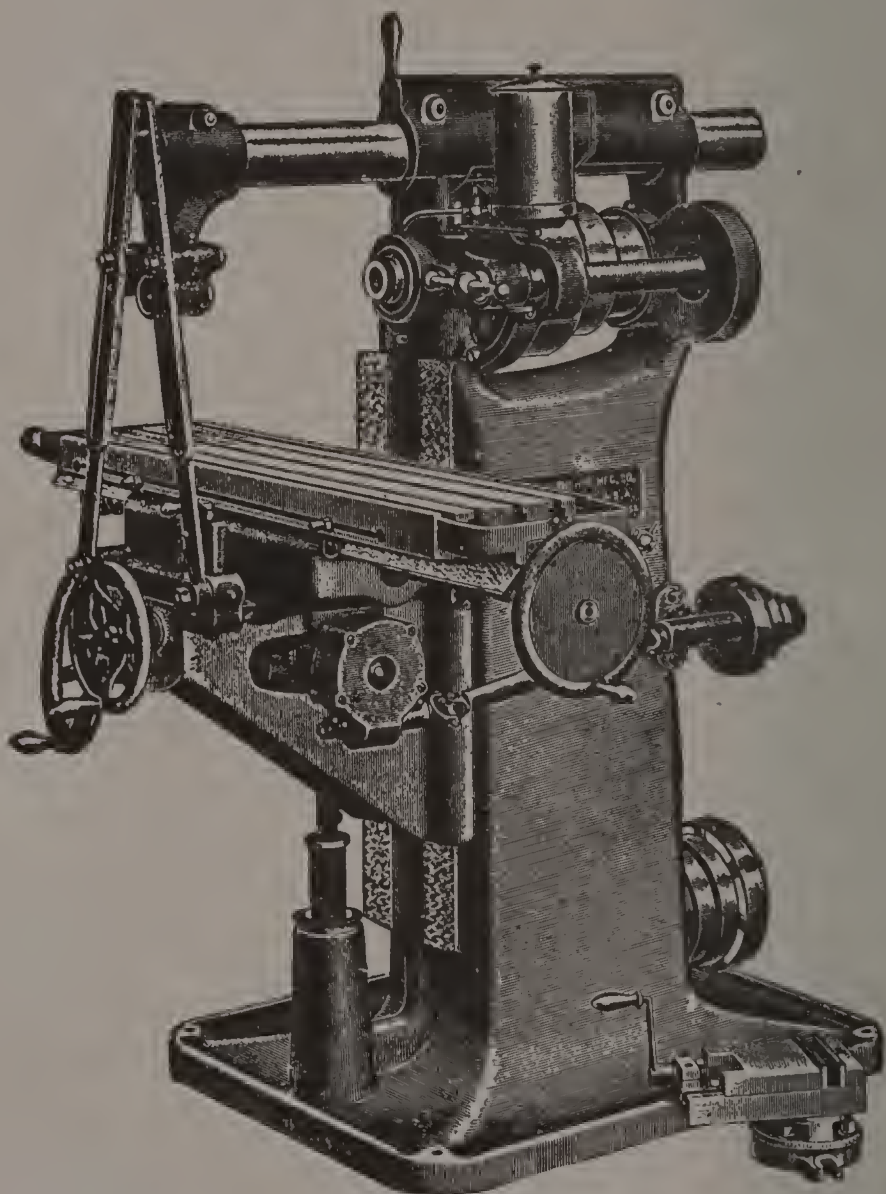


Fig. 324.

Oil Tank. Provides for use of pump.

Vise. Flanged. Jaws hardened, $6\frac{1}{8}$ inches wide, 1 9-16 inch deep, open $3\frac{5}{8}$ inches.

Bench Milling Machine. A small bench hand miller is illustrated at Fig. 326, it has both vertical and horizontal spindles, and raising and lowering table with cross and

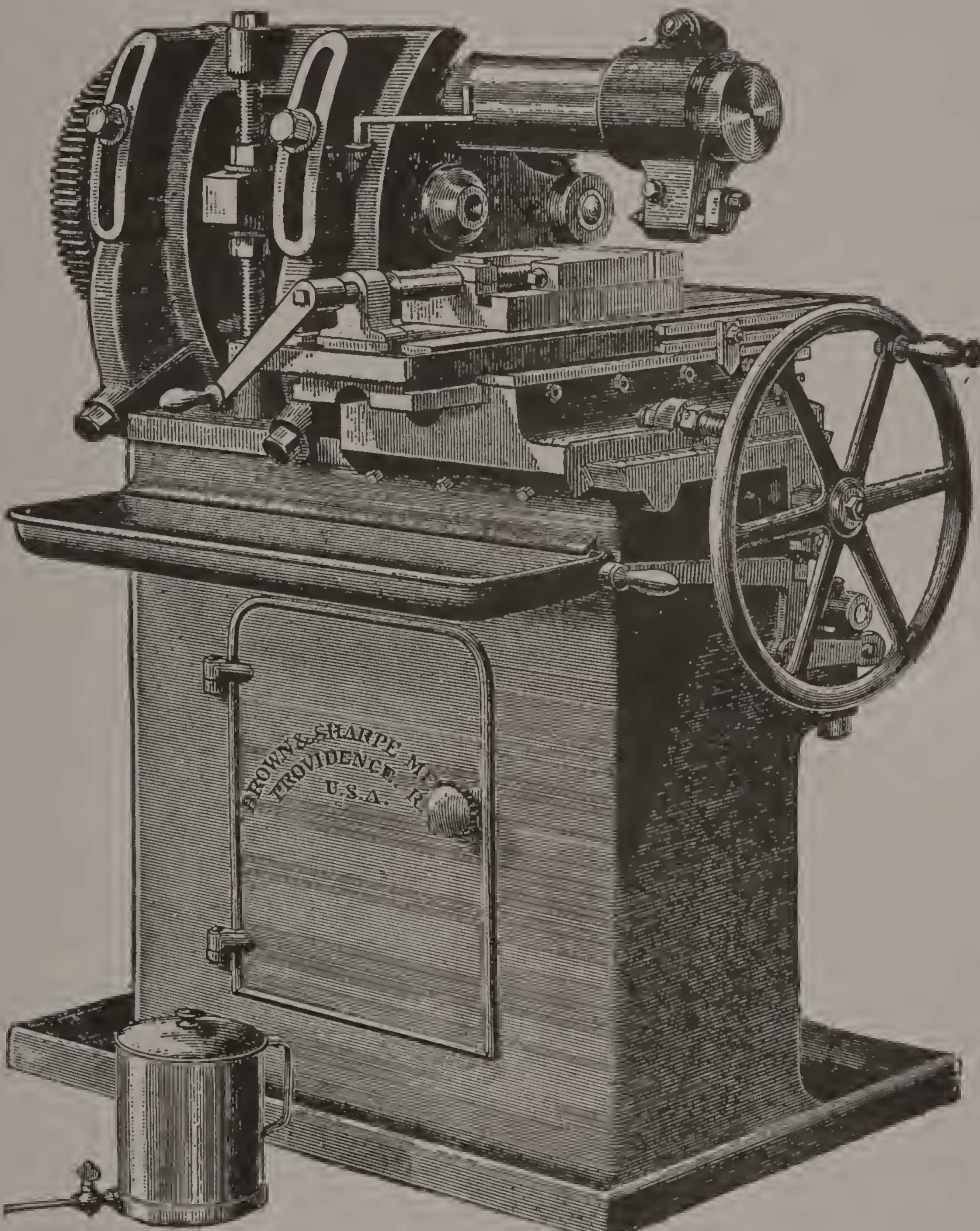


Fig. 325.

longitudinal feeds, operated by hand levers. This will be found an extremely useful tool for milling key-ways, making small tools, etc.

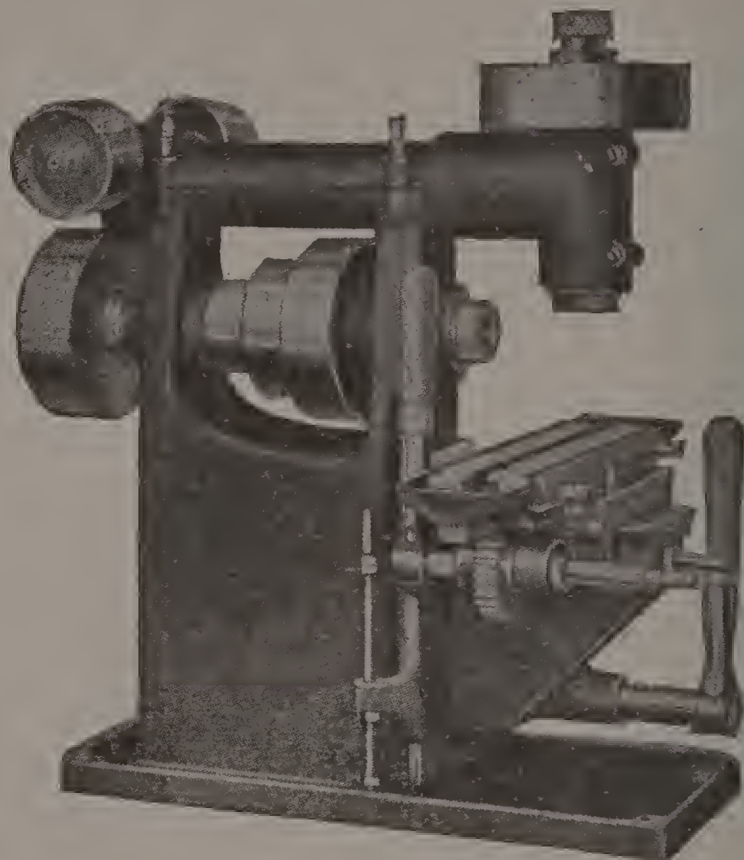


Fig. 326.

Vertical Spindle Milling Machine. The spindle of the machine shown in Fig. 327 is of crucible steel and the bearings ground, and with bronze boxes. The lower box is provided with means of compensation for wear.

The feeds are positive. All the spur gears are driven by chain and have 20 changes, varying in geometrical progression, from .0012 to .060 inches per revolution of the spindle. There are no loose change gears. The changes are made by an adjustment of the index slide and lever.

Slotting Attachment. The attachment illustrated in Fig. 328 is new in design and is particularly well adapted for tool making of all kinds, as in forming box tools for screw machines, making templates and work of a similar character.

It is simple in construction, there being no auxiliary fixtures or belting required for attaching it to the ma-

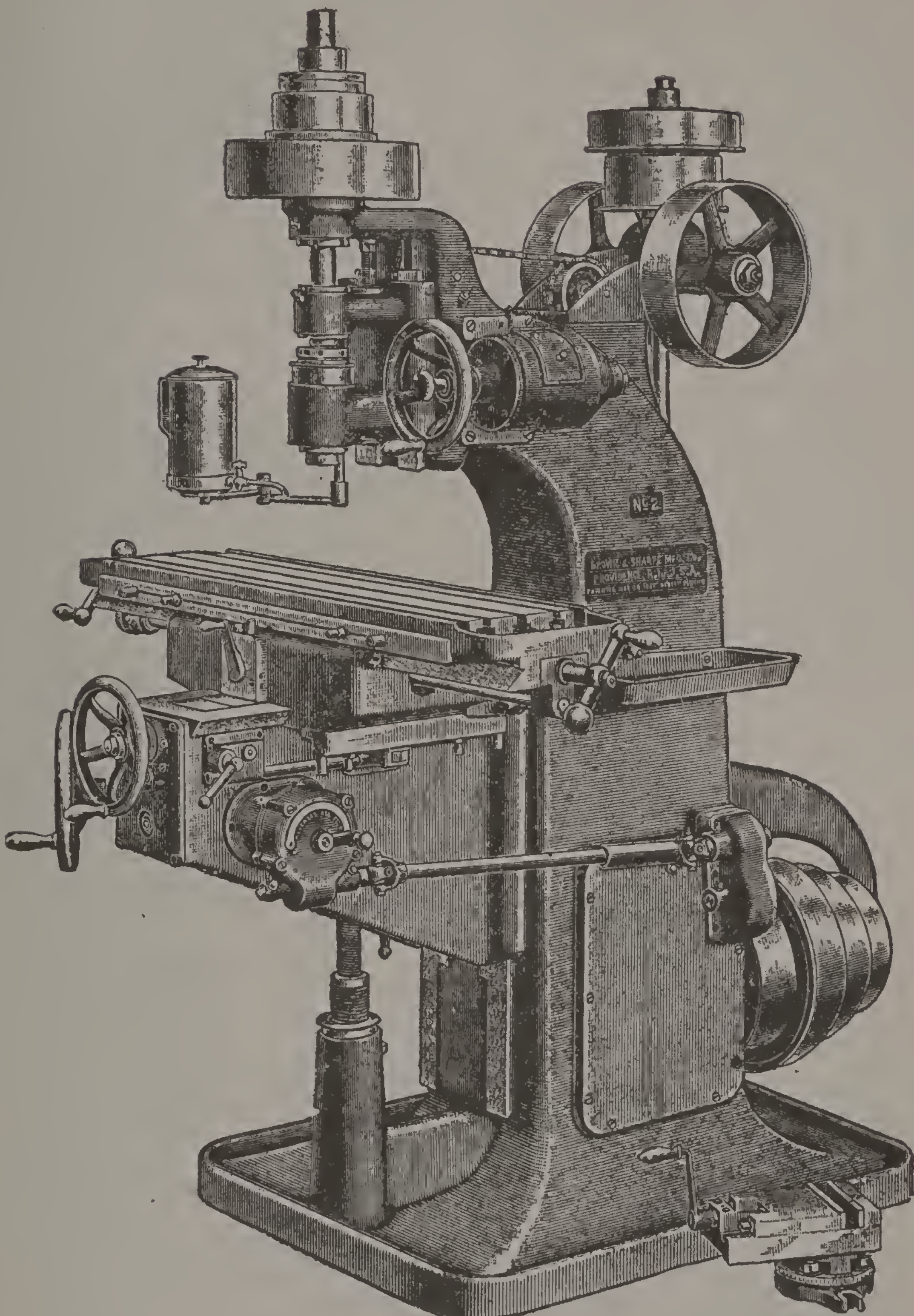


Fig. 327.

chine. It is exceptionally rigid when in position, the upper part of the frame being clamped to the overhanging arm, and the lower part of the top of the knee slide.

The tool slide is driven from the main spindle of the machine by an adjustable crank that allows the stroke to be adjusted. The slide can be set at any angle, between 0 to 10 degrees, on either side of the center line. The position being indicated by a scale on the lower part of the frame.

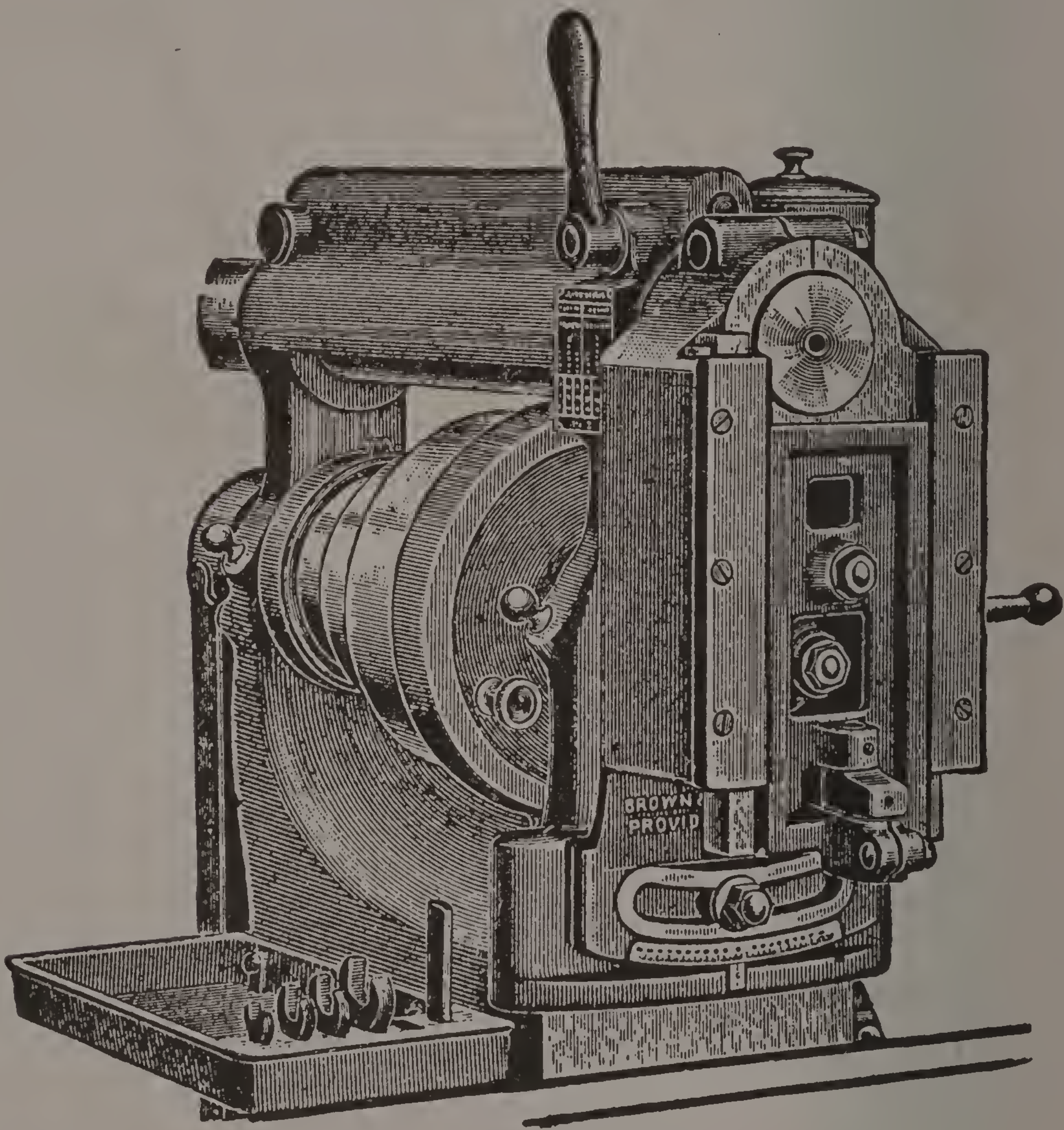


Fig. 328.

The tool holder allows for the use of tools with shanks ½ inch in diameter. The tools are held in place by a clamp bolt and a tool stop that swings over the top of the tool shank and prevents any possibility of the tool being pushed through. The holder is also provided with a key that fits the key-ways in the shanks of the tools and insures their relative positions always being the same.

When the attachment is in position both the longitudinal and transverse feeds of the machine are available and have dials that read to .001 of an inch.

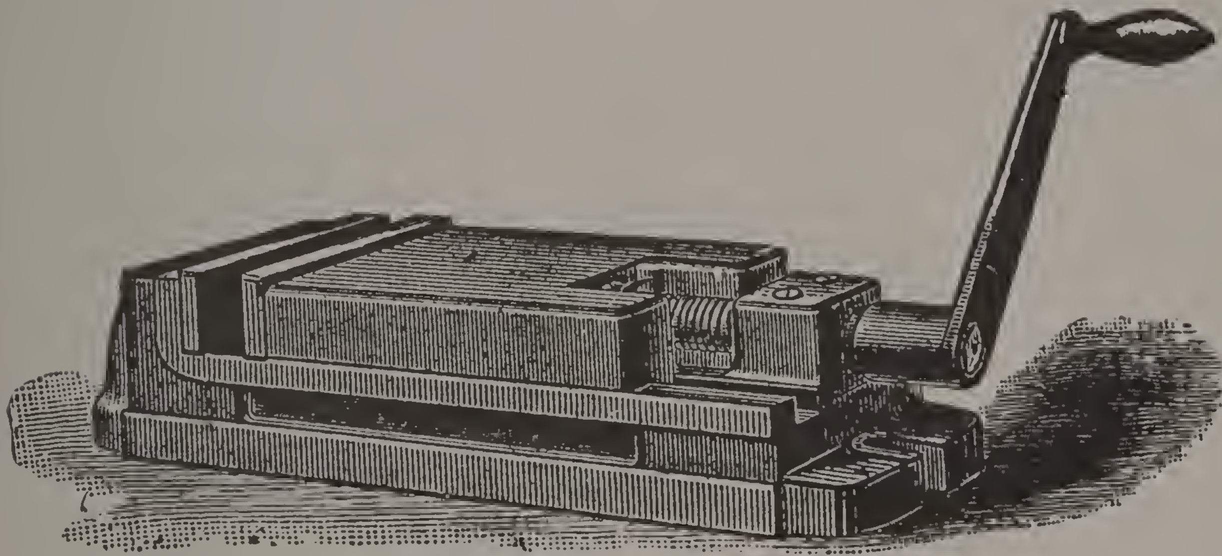


Fig. 329.

Swivel Vise. The vise shown in Fig. 329 is exceptionally rigid and convenient for millng or planing. These vises are exceptionally low and bring the work close to the table, thus insuring rigidity and compactness.

Toolmaker's Universal Vise. The vise illustrated in Fig. 330 is of an entirely new design, for use on milling machines and is so constructed that it can be set at any angle to the surface of the table or to the spindle of the machine, and rigidly clamped in position.

The base is double, the upper portion is graduated, and can be set at any angle in a horizontal plane. On the top of the swivel base is a hinged knee, which can be set at any angle, to 90 degrees, in a vertical plane. The top of the knee is graduated. The knee is clamped rigidly in position by means of the nut on the end of the bolt forming the hinge, and the locking levers shown at the left of the cut. These levers are clamped in position by the bolt shown in the center and the bolts at the ends of the levers.

The vise proper is fastened to the hinged knee in such a manner that it can be set at any angle on a horizontal plane, and can be clamped in position by the bolt which holds the upper locking lever.

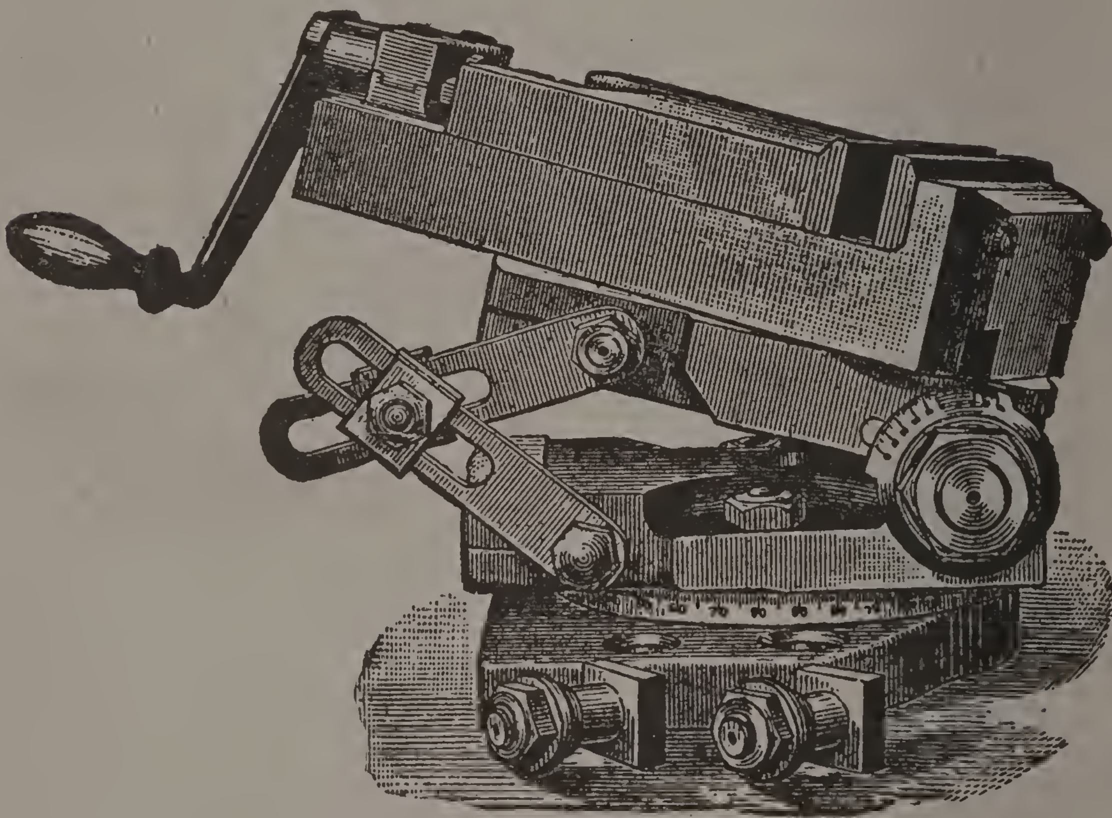


Fig. 330.

The vise base is fastened to the table by means of two bolts fitting into the table T-slot. The base is provided with two sets of holes to allow for moving the vise, when set in a vertical plane, in order to clear the milling machine spindle.

Universal Index Centers. The centers of the universal index shown in Fig. 331 wing 12 and one-half inches in diameter.

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

The spindle is provided with a face plate and adjustable dog carrier. The front end has a No. 12 taper hole. The