Chapter VII.—DETAILS IN LATHE CONSTRUCTION.

ALTHOUGH in each class of lathe the requirements may be practically the same, yet there is a variety of different details of construction by means of which these requirements may be met or filled, and it may be profitable to enter somewhat into these requirements and the different constructions generally employed to meet them.

The cone spindle or live spindle of a lathe should be a close working fit to its boxes or bearings, so that it will not lift under a

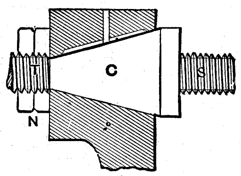

Fig. 553.

heavy cut, or lift and fall under a cut of varying pressure. This lifting and falling may occur even though the work be true, and the cut therefore of even depth all around the work, because of hard seams or spots in the metal.

It is obvious that the bearings should form a guide, compelling the live spindle to revolve in a true circle and in a fixed plane, the axis of revolution being in line with the centre line of the tail spindle and that means should be provided to maintain this alignment while preserving the fit, or in other words taking up the wear. The spindle journals must, to produce truly cylindrical work, be cylindrically true, or otherwise the axis of its revolution will change as it revolves, and this change will be communicated through the live centre to the work, or through the chuck plate to the work, as the case may be.

The construction of the bearings should be such, that end motion to the spindle is prevented in as short a length of the spindle as possible, the thrust in either direction being resisted by the mechanism contained in one bearing.

In Fig. 553 is a form of construction for the front bearing (as that nearest to the live centre is called), in which end motion to the spindle is prevented at the same time as the diametral fit is adjusted. The spindle is provided with a cone at C and is threaded at T to receive two nuts N which draw the spindle cone within the bearing. In this case the journal at the back end may be made parallel, so that if the spindle either expands or contracts more under variations of temperature than the frame or head carrying the bearings or bearing boxes, it will not bind endwise, nor will the fit be impaired save inasmuch as there may be an inequality of expansion in the length of the front journal and its box. In this case, however, the end pressure caused by holding the work between the lathe centres acts to force the spindle into its bearing and increase the tightness of its fit, hence it is not unusual to provide at the back bearing additional means to resist the thrust of the dead centre.

Fig. 554, which is taken from "Mechanics," represents Wohlemberg's patent lathe spindle, in which both journals are coned, fitting into bushes which can be replaced by new ones when worn; the end thrust is here taken by a steel screw, while the end fit is adjusted by means of a ring nut which binds the face of the large cone gear against the inside face of the front bearing and by the face of the gear that drives the change gears. It may be pointed out, however, that in this construction the spindle must be drawn within to adjust the fit of the front bearing, which can only be done by adjusting the pinion that drives the change gears, or by screwing up the nut that is inside the cone, and therefore cannot

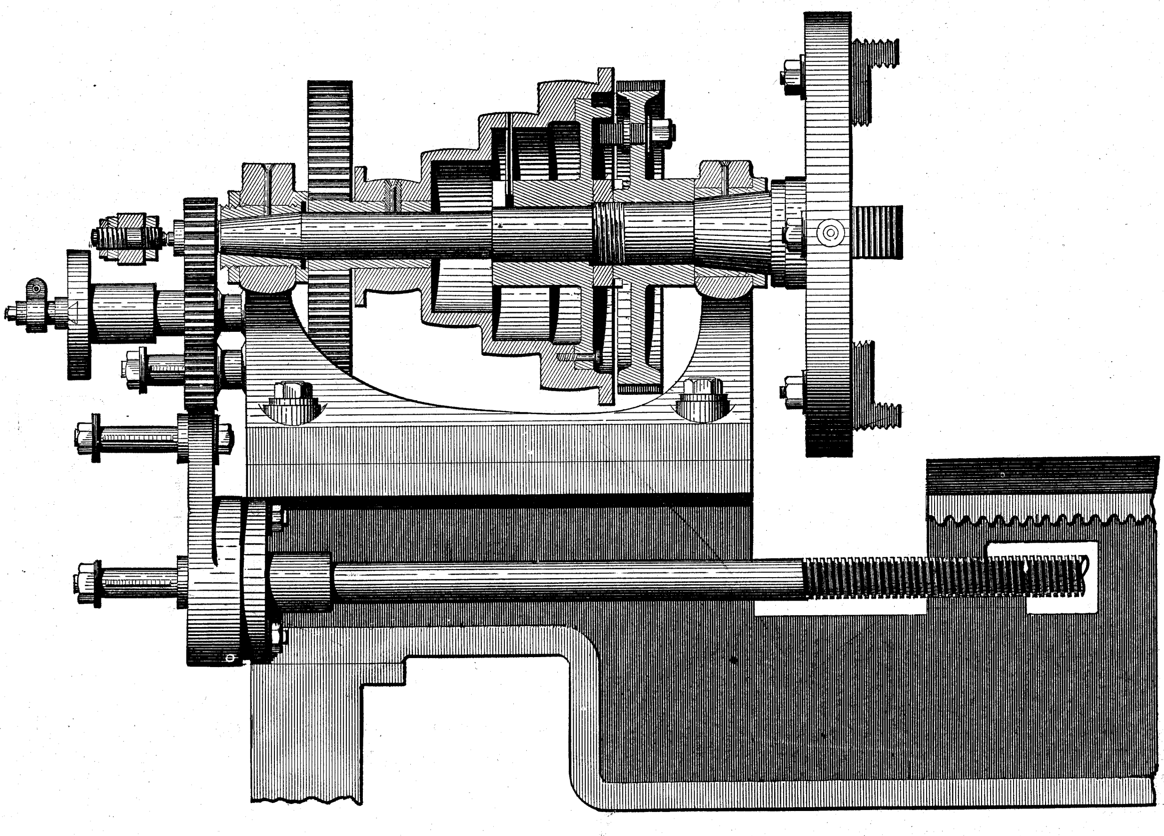

Fig. 554.

be got at. The back bearing can be adjusted by means of the ring nuts provided at each of its ends.

Fig. 555 represents another design of cone bearing, in which the spindle is threaded to receive the nuts A which draw it within the front bearing and thus adjust the fit, and at the same time prevent end motion. The back bearing is provided with a bush parallel outside, and furnished with a nut at B to adjust the fit of the end bearing. To prevent the end pressure of the dead centre from forcing the spindle cones too tightly within their bearings a cross piece P is employed (being supported by two studs provided in the head), and through P passes an adjusting screw D, having

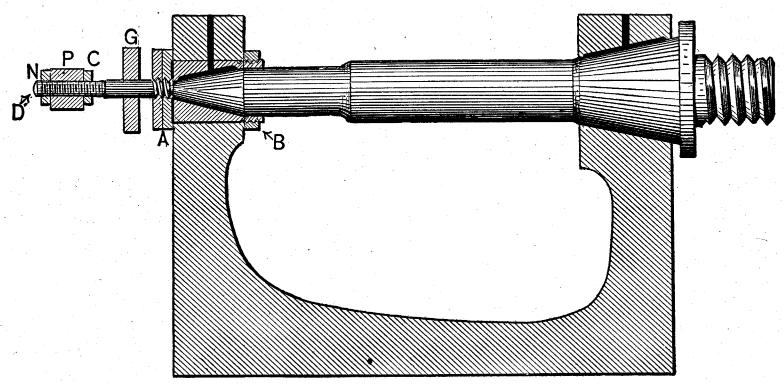

Fig. 555.

nuts N and C, one on each side of P. Between the end of D and of the lathe spindle a washer of leather or of raw hide is placed to prevent the end faces from abrading. A similar device for taking up the end thrust is often provided to lathes in which the journals are both parallel, fitting in ordinary boxes, a top view of the device being illustrated in Fig. 556, in which B is the back bearing box, S S two studs supporting cross-piece P, and N and C are adjusting nuts. G is the gear for driving the change wheels for screw cutting or for ordinary feeding as the case may be. In this design the gear wheel G remains fixed and the combinations of

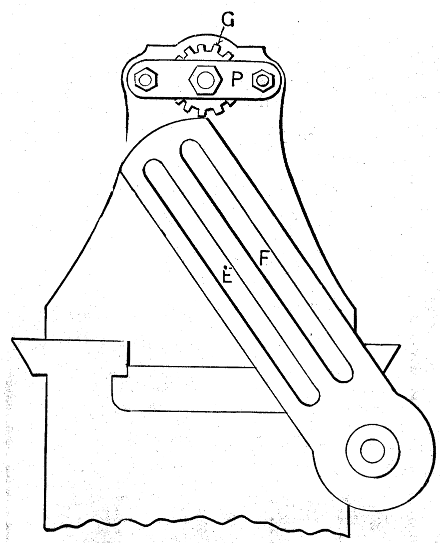

Fig. 557.

gears necessary to cut various pitches of thread must be made on the lead screw and on the swing frame, which must be long enough to permit the change gear stud to pass up to permit the smallest change wheel to gear with wheel G, and which is provided with two grooves E and F, Fig. 557, for two studs to carry two compounded pairs of change wheels. This compounding in two places on the swing frame enables gear G to be comparatively large, and thus saves the teeth from rapid wear, while it facilitates the cutting of left-hand threads, because it affords more convenience for putting in a gear to change the direction of feed screw revolution.

In many lathes of American design the journals are made parallel, and the end play is taken up at the back bearing, an example being given in Fig. 558, in which the back bearing boxes are made in two halves A and B, the latter having a set screw (with check nut) threaded through it and bearing against a washer that meets the end of the spindle.

A simple method of preventing end motion is shown in Fig. 559, a bracket B affording a support for a threaded adjusting screw, which is sometimes made pointed and at others flat. When pointed it acts to support the spindle, but on the other hand it also acts to prevent the journal from bedding fairly in the boxes. In some cases of small lathes the back bearing is dispensed with, and

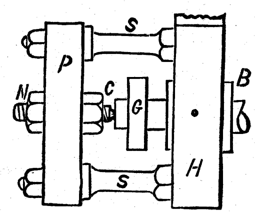

Fig. 556.

a similar pointed adjusting screw takes its place, which answers very well for very small work.

Since the strain of the cut carried by the cutting tool falls mainly upon the live centre end of the cone spindle, it is obvious that the bearing at that end has a greater tendency to wear.

In addition to this the weight of the cone itself is greatest at that end, and furthermore the weight of the face plate or chuck, and of the work, is carried mainly at that end. If, however, one journal and bearing wears more than the other, the spindle is thrown out of line with the lathe shears, and with the tail block spindle. The usual method of obviating this as far as possible is to give that end a larger journal-bearing area.

The direction in which this wear will take place depends in a great measure upon the kind of work done in the lathe; thus in a

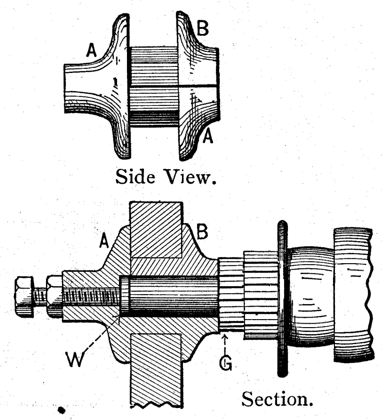

Fig. 558.

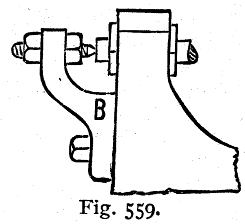

Fig. 559.

lathe running slowly and doing heavy work carried by chucks, or on the face plate, the wear would be downwards and towards the operator, the weight of the chuck, &c., causing the downward, and the resistance or work-lifting tendency of the cut causing the lateral wear. As a general rule the wear will be least in a lateral direction towards the back of the lathe, but the direction of wear is so variable that provision for its special prevention or adjustment is not usually made. In the S. W. Putnam lathe; provision is made that the bearing boxes may be rotated in the head, so that when the lathe is used on a class of work that caused the live spindle to wear the bearing boxes on one side more than on another, the boxes may be periodically partly rotated in the head so that further wear will correct the evil.

The coned hole to receive the live centre should run quite true, so that the live centre will run true without requiring, when inserted, to be placed in exactly the same position it occupied when being turned up at its conical point. But when this hole does not run true a centre punch dot is made on the end of the spindle, and another on the centre, so that by placing the two dots to coincide at all times, the centre will run true.

The taper given to lathe centres varies from $\frac{9}{16}$ per foot to 1 inch per foot. In the practice of Pratt and Whitney a taper of $\frac{9}{16}$ per foot is given to all lathes, the lengths of the tapers for different sizes of lathes being as follows:

Swing of Lathe.	Length of Taper Socket for Live Centre.
13 inches	5 inches.
16 „	$3\frac{3}{4}$ „
18 and 19 inches	$7\frac{11}{16}$ „
„ „ with hollow spindle	5 inches long

and $1\frac{1}{16}$ diameter at the small end.

The less the amount of taper the more firmly the centre is held, but the more difficult it becomes to remove the centre when necessary.

The principal methods of removing live centres are shown in Fig. 560, in which is shown at B a square part to receive a wrench, it being found that if not less than about $\frac{1}{2}$-inch taper per foot of length be given to the live spindle socket, then revolving the

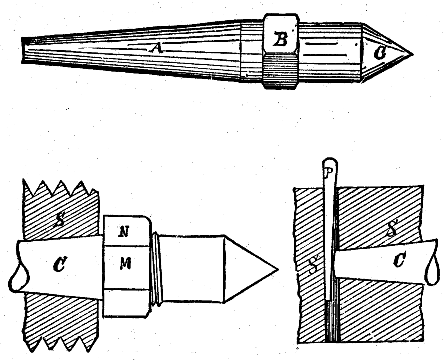

Fig. 560.

centre with a wrench will cause it to release itself, enabling it to be removed by hand. Another method employed on small lathes is to drill a hole through the live spindle to receive a taper pin P, the live centre end being shown at C.

Another and excellent plan for large lathes, is to thread the centre and provide it with a nut M, which on being screwed against the end face of the live spindle will release the centre. The objection to the use of the pin P is that it is apt to become mislaid, and it is not advisable to use a hammer about the parts of the lathe, especially in such an awkward place as between the journal bearing and the cone, which is where the pin hole requires to be located. The square section is, therefore, the best method for small lathes, and the nut for large ones.

In cases where the live spindle is made hollow a bar may be passed through from the rear end to remove the centre; this also enables rods of iron to be passed through the spindle, leaving the end projecting through the chuck for any length necessary for the work to be turned out of its exposed end.

The dead centre may be extracted from the tail spindle by a pin and hole as in Fig. 560, or, what is better, by contact with the end of the tail screw as described when referring to the tail stock of the S. W. Putnam lathe.

The cone pulley should be perfectly balanced, otherwise at high speeds the lathe will shake or tremble from the unbalanced centrifugal motion, and the tremors will be produced to some extent on the work. The steps of the cone should be amply wide, so that it may have sufficient power, without overstraining the belt, to drive the heaviest cut the lathe is supposed to take without the aid of the back gear.

In some cases, as in spinning lathes, the order of the steps is reversed, the smallest step of the cone being nearest to the live centre, the object being to have the largest step on the left, and therefore more out of the way.

The steps of the cone should be so proportioned that the belt will shift from one to the other, and have the same degree of tension, while at the same time they should give a uniform graduation or variation of speed throughout, whether the lathe runs in single gear or with the back gear in. This is not usually quite the case although the graduation is sufficiently accurate for practical purposes. The variation in the diameter of the steps of a lathe cone varies from an inch for lathes of about 12-inch swing, up to 2 inches for lathes of about 30-inch swing, and 3 inches for lathes of 5 or more feet of swing.

To enable the graduation of speed of the cone to be uniform throughout, while the tension of the belt is maintained the same on whatever step the cone may be, the graduation of the steps may be varied, and this graduation may be so proportioned as to answer all practical purposes if the overhead or countershaft cone and that on the lathe are alike.

The following on this subject is from the pen of Professor D. E. Klein, of Yale College.

"The numbers given in the following tables are the differences between the diameters of the adjacent steps on either cone pulley, and are accurate within half a hundredth of an inch, which is a degree of accuracy sufficient for practical purposes.

By simply omitting a step at each end of the cone, the two tables given will be found equally well adapted for determining the diameters of cones having four and three steps respectively.

The following are examples in the use of the tables. Suppose the centres of a pair of pulley shafts to be 60 inches apart, and that the difference of diameter between the adjacent steps is to be as near to $2\frac{1}{2}$ inches as can be, to obtain a uniformity of speed graduation and belt tension, also that each cone is to have six steps, the smallest of which is to be of five inches diameter.

To find the diameters for the remaining steps, we look in Table I. (corresponding to cone pulleys with six steps), under 60 in. and opposite $2\frac{1}{2}$ in. and obtain the differences,

2·37 2·43 2·50 2·57 2.63

Each of these differences is *subtracted* from the *larger* diameter of the two adjacent steps to which it corresponds, thus:

	17·50 =	1st step.
Difference of 1st and 2nd =	2·37	
	15·13 =	2nd „
„ 2nd „ 3rd =	2·43	
	12·70 =	3rd „
„ 3rd „ 4th =	2·50	
	10·20 =	4th „
„ 4th „ 5th =	2·57	
	7·63 =	5th „
„ 5th „ 6th =	2·63	
	5·00 =	6th „

EXAMPLE 2. If we suppose the same conditions as in Example 1, with the exception that each cone is to have four steps instead of six, the largest diameter will, in this case, equal $12\frac{1}{2}$ in. and we may obtain the remaining diameters by omitting the end differences of the above example, and then subtracting the remaining differences as follows:

	12·50 =	2nd step.
Difference of 2nd and 3rd =	2·43	
	10·07 =	3rd „
„ 3rd „ 4th =	2·50	
	7·57 =	4th „
„ 4th „ 5th =	2·57	
	5·00 =	5th „

The 2nd, 3rd, 4th, and 5th steps of the table correspond respectively to the 1st, 2nd, 3rd, and 4th steps of the cone, having but four steps. If the smallest diameter had not been assumed equal to 5 in. we might have dropped a step at each end of the six-step cone of the preceding example, and employed the remaining four diameters, 15·13 in. 12·70 in. 10·20 in. and 7·63 in. for one four-step cone.

The present and the previous examples show that we can assume the size of the smallest step anything that we please,

I.—TABLE FOR FINDING CONE PULLEY DIAMETERS WHEN THE TWO PULLEYS ARE CONNECTED BY AN OPEN BELT, AND ARE EXACTLY ALIKE.

The numbers given in table are the differences between the diameters of the adjacent steps on either cone pulley, and can be employed when there are either six or four steps on a cone. When there are six steps, the largest is the first, and the smallest the sixth step of the table. When there are four steps, the largest is the second, and the smallest the fifth step of the table.

Average difference between the adjacent steps.	Adjacent steps, whose difference is given in table.	Distance between the Centres of Cone Pulleys.											
		10 inches.	20 inches.	30 inches.	40 inches.	50 inches.	60 inches.	70 inches.	80 inches.	90 inches.	100 inches.	120 inches.	240 inches.
1 inch	1st and 2nd	0·87	0·94	0·96	0·97	0·98	0·98	0·98	0·98	0·99	0·99	0·99	1·00
	2nd ,, 3rd	0·94	0·97	0·98	0·98	0·99	0·99	0·99	0·99	0·99	0·99	1·00	1·00
	3rd ,, 4th	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00
	4th ,, 5th	1·06	1·03	1·02	1·02	1·01	1·01	1·01	1·01	1·01	1·01	1·00	1·00
	5th ,, 6th	1·13	1·06	1·04	1·03	1·02	1·02	1·02	1·02	1·01	1·01	1·01	1·00
1½ inch	1st and 2nd	1·21	1·36	1·40	1·43	1·44	1·45	1·46	1·46	1·47	1·47	1·48	1·49
	2nd ,, 3rd	1·36	1·43	1·45	1·46	1·47	1·48	1·48	1·48	1·49	1·49	1·49	1·49
	3rd ,, 4th	1·50	1·50	1·50	1·50	1·50	1·50	1·50	1·50	1·50	1·50	1·50	1·50
	4th ,, 5th	1·64	1·57	1·55	1·54	1·53	1·52	1·52	1·52	1·51	1·51	1·51	1·51
	5th ,, 6th	1·79	1·64	1·60	1·57	1·56	1·55	1·54	1·54	1·53	1·53	1·52	1·51
2 inches	1st and 2nd	1·47	1·74	1·83	1·87	1·90	1·92	1·93	1·93	1·94	1·95	1·96	1·98
	2nd ,, 3rd	1·74	1·87	1·92	1·93	1·95	1·96	1·96	1·97	1·97	1·97	1·98	1·99
	3rd ,, 4th	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·00
	4th ,, 5th	2·26	2·13	2·08	2·07	2·05	2·04	2·04	2·03	2·03	2·03	2·02	2·01
	5th ,, 6th	2·53	2·26	2·17	2·13	2·10	2·08	2·07	2·07	2·06	2·05	2·04	2·02
2½ inches	1st and 2nd	1·66	2·10	2·23	2·30	2·34	2·37	2·39	2·40	2·41	2·42	2·43	2·47
	2nd ,, 3rd	2·10	2·30	2·37	2·40	2·42	2·43	2·44	2·45	2·46	2·46	2·47	2·49
	3rd ,, 4th	2·50	2·50	2·50	2·50	2·50	2·50	2·50	2·50	2·50	2·50	2·50	2·50
	4th ,, 5th	2·90	2·70	2·63	2·60	2·58	2·57	2·56	2·55	2·54	2·54	2·53	2·51
	5th ,, 6th	3·34	2·90	2·77	2·70	2·66	2·63	2·61	2·60	2·59	2·58	2·57	2·53
3 inches	1st and 2nd	1·76	2·42	2·62	2·71	2·77	2·81	2·84	2·86	2·87	2·88	2·90	2·95
	2nd ,, 3rd	2·42	2·71	2·81	2·86	2·88	2·90	2·92	2·93	2·94	2·94	2·95	2·98
	3rd ,, 4th	3·00	3·00	3·00	3·00	3·00	3·00	3·00	3·00	3·00	3·00	3·00	3·00
	4th ,, 5th	3·58	3·29	3·19	3·14	3·12	3·10	3·08	3·07	3·06	2·06	3·05	3·02
	5th ,, 6th	4·24	3·58	3·38	3·29	3·23	3·19	3·16	3·14	3·13	3·12	3·10	3·05
4 inches	1st and 2nd		3·95	3·31	3·49	3·59	3·66	3·71	3·75	3·78	3·80	3·83	3·91
	2nd ,, 3rd	2·94	3·49	3·66	3·75	3·80	3·83	3·85	3·87	3·88	3·89	3·91	3·96
	3rd ,, 4th	4·00	4·00	4·00	4·00	4·00	4·00	4·00	4·00	4·00	4·00	4·00	4·00
	4th ,, 5th	5·06	4·51	4·34	4·25	4·20	4·17	4·15	4·13	4·12	4·11	4·09	4·04
	5th ,, 6th		5·05	4·69	4·51	4·41	4·34	4·29	4·25	4·22	4·20	4·17	4·09
5 inches	1st and 2nd		3·33	3·92	4·20	4·36	4·47	4·55	4·60	4·64	4·68	4·74	4·87
	2nd ,, 3rd	3·31	4·19	4·47	4·60	4·68	4·74	4·77	4·80	4·82	4·84	4·86	4·93
	3rd ,, 4th	5·00	5·00	5·00	5·00	5·00	5·00	5·00	5·00	5·00	5·00	5·00	5·00
	4th ,, 5th	6·69	5·81	5·53	5·40	5·32	5·26	5·23	5·20	5·18	5·16	5·14	5·07
	5th ,, 6th		6·67	6·09	5·80	5·64	5·53	5·45	5·40	5·36	5·32	5·26	5·13
6 inches	1st and 2nd		3·52	4·42	4·83	5·08	5·23	5·34	5·42	5·49	5·55	5·62	5·80
	2nd ,, 3rd		4·83	5·23	5·42	5·54	5·62	5·67	5·71	5·75	5·77	5·81	5·90
	3rd ,, 4th		6·00	6·00	6·00	6·00	6·00	6·00	6·00	6·00	6·00	6·00	6·00
	4th ,, 5th		7·17	6·77	6·58	6·46	6·38	6·33	6·29	6·25	6·23	6·19	6·10
	5th ,, 6th		8·48	7·58	7·17	6·92	6·77	6·66	6·58	6·51	6·45	6·38	6·20

and, other things being equal, can make the required cones large or small.

Example 3. Let distance apart of the centres = 30 in. the average difference between adjacent steps = 2 in. the diameter of the smallest step = 4 in., and the number of steps on each of the cones = 5. The largest step will then equal 12 in., and from Table II., under 30 in. and opposite 2 in., we obtain the differences

1·87   1·96   2·04   2·13

and then subtracting as before we get the required diameters

12 in.   10·30 in.   8·17 in.   6·13 in.   4 in.

Example 4. Let the conditions be as in the preceding example, the cone pulley having, however, three steps instead of five, the largest diameter will then equal 8 in.; and by dropping the end differences and subtracting

	8·00 =	2nd step.
Difference of 2nd and 3rd =	1·96	
	6·04 =	3rd ,,
,, 3rd ,, 4th =	2·04	
	4·00 =	4th ,,

we get the diameters 8 in., 6·04, and 4 in., which correspond respectively to 2nd, 3rd, and 4th steps of the table, and to the 1st, 2nd, and 3rd steps of the three-step cone.

Example 5. Let the distance apart of the centres be 60 in., the average difference between the adjacent steps be $2\frac{1}{8}$ in., the smallest step 7 in. and the number of steps = 5. The largest step will then be 7 in. + $(4 \times 2\frac{1}{8}) = 15\frac{1}{2}$ inches.

Now an inspection of Table II. will show that it contains no horizontal lines corresponding to the average difference $2\frac{1}{8}$ inches, we cannot, therefore, as heretofore, obtain the required differences directly, but must interpolate as follows: since $2\frac{1}{8}$ inches is quarter way between 2 inches and $2\frac{1}{2}$ inches, the numbers corresponding to $2\frac{1}{8}$ inches (for any given distance apart of the centres), will be quarter way between the numbers of the table corresponding to 2 inches and $2\frac{1}{2}$ inches.

Thus, in Table II., we have under 60 inches,

and opposite $2\frac{1}{2}$ in.:	2·40	2·47	2·53	2·60
,, 2	1·93	1·98	2·02	2·07
	·47	·49	·51	·53

Dividing these differences by 4, we get:

·12   ·12   ·13   ·13

to which we add,

1·93   1·98   2·02   2·07

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The numbers given in table are the differences between the diameters of the adjacent steps on either cone pulley, and can be employed when there are either five or three steps on a cone.

Average difference between the adjacent steps	Adjacent steps, whose difference is given in table.	DISTANCE BETWEEN THE CENTRES OF THE CONE PULLEYS.											
		10 inches.	20 inches.	30 inches.	40 inches.	50 inches.	60 inches.	70 inches.	80 inches.	90 inches.	100 inches.	120 inches.	140 inches.
1 inch	1st and 2nd	0·90	0·95	0·97	0·98	0·98	0·98	0·99	0·99	0·99	0·99	0·99	1·00
	2nd „ 3rd	0·97	0·98	0·99	0·99	0·99	0·99	0·99	1·00	1·00	1·00	1·00	1·00
	3rd „ 4th	1·03	1·02	1·01	1·01	1·01	1·01	1·01	1·00	1·00	1·00	1·00	1·00
	4th „ 5th	1·10	1·05	1·03	1·02	1·02	1·02	1·01	1·01	1·01	1·01	1·01	1·00
$1\frac{1}{2}$ inch	1st and 2nd	1·28	1·39	1·43	1·45	1·46	1·46	1·47	1·47	1·48	1·48	1·48	1·49
	2nd „ 3rd	1·43	1·46	1·48	1·48	1·48	1·49	1·49	1·49	1·49	1·49	1·49	1·49
	3rd „ 4th	1·57	1·54	1·52	1·52	1·52	1·51	1·51	1·51	1·51	1·51	1·51	1·51
	4th „ 5th	1·72	1·61	1·57	1·55	1·54	1·54	1·53	1·53	1·52	1·52	1·52	1·51
2 inches	1st and 2nd	1·61	1·81	1·87	1·90	1·92	1·93	1·94	1·95	1·96	1·96	1·97	1·98
	2nd „ 3rd	1·87	1·94	1·96	1·97	1·97	1·98	1·98	1·98	1·99	1·99	1·99	1·99
	3rd „ 4th	2·13	2·06	2·04	2·03	2·03	2·02	2·02	2·02	2·01	2·01	2·01	2·01
	4th „ 5th	2·39	2·19	2·13	2·10	2·08	2·07	2·06	2·05	2·04	2·04	2·03	2·02
$2\frac{1}{2}$ inches	1st and 2nd	1·89	2·20	2·30	2·35	1·38	2·40	2·41	2·42	2·43	2·44	2·45	2·47
	2nd „ 3rd	2·30	2·40	2·43	2·45	2·46	2·47	2·47	2·47	2·48	2·48	2·48	2·49
	3rd „ 4th	2·70	2·60	2·57	2·55	2·54	2·53	2·53	2·53	2·52	2·52	2·52	2·51
	4th „ 5th	3·11	2·80	2·70	2·65	2·62	2·60	2·59	2·58	2·57	2·56	2·55	2·53
3 inches	1st and 2nd	2·10	2·57	2·71	2·78	2·83	2·86	2·87	2·89	2·90	2·91	2·93	2·96
	2nd „ 3rd	2·71	2·86	2·90	2·93	2·94	2·95	2·96	2·96	2·97	2·97	2·98	2·99
	3rd „ 4th	3·29	3·14	3·10	3·07	3·06	3·05	3·04	3·04	3·03	3·03	3·02	3·01
	4th „ 5th	3·90	3·43	3·29	3·22	3·17	3·14	3·13	3·11	3·10	3·09	3·07	3·04
4 inches	1st and 2nd		3·22	3·49	3·62	3·69	3·75	3·78	3·81	3·83	3·84	3·87	3·94
	2nd „ 3rd	3·48	3·74	3·83	3·87	3·90	3·91	3·92	3·94	3·94	3·95	3·96	3·98
	3rd „ 4th	4·52	4·26	4·17	4·13	4·10	4·09	4·08	4·06	4·06	4·05	4·04	4·02
	4th „ 5th		4·78	4·51	4·38	4·31	4·25	4·22	4·19	4·17	4·16	4·13	4·06
5 inches	1st and 2nd		3·77	4·20	4·40	4·52	4·60	4·66	4·71	4·73	4·76	4·80	4·90
	2nd „ 3rd	4·19	4·60	4·73	4·80	4·84	4·87	4·89	4·90	4·91	4·92	4·93	4·96
	3rd „ 4th	5·81	5·40	5·27	5·20	5·16	5·13	5·11	5·10	5·09	5·08	5·07	5·04
	4th „ 5th		6·23	5·80	5·60	5·48	5·40	5·34	5·29	5·27	5·24	5·20	5·10
6 inches	1st and 2nd		4·21	4·83	5·13	5·31	5·42	5·51	5·57	5·62	5·66	5·71	5·86
	2nd „ 3rd	4·82	5·42	5·62	5·71	5·77	5·81	5·83	5·86	5·87	5·88	5·90	5·95
	3rd „ 4th	7·18	6·58	6·38	6·29	6·23	6·19	6·17	6·14	6·13	6·12	6·10	6·05
	4th „ 5th		7·79	7·17	6·87	6·69	6·58	6·49	6·43	6·38	6·34	6·29	6·14

and get for the differences corresponding to $2\frac{1}{8}$ inches

2·05   2·10   2·15   2·20

and subtracting as before,

	15·5	1st step.
difference of 1st and 2nd =	2·05	
	13·45 =	2nd „
„ 2nd „ 3rd =	2·10	
	11·35 =	3rd „
„ 3rd „ 4th =	2·15	
	9·20 =	4th „
„ 4th „ 5th =	2·20	
	7·00 =	5th „

Thus far, however, we have considered only the case where the two cone pulleys were exactly alike. Now although this case occurs much more frequently than the case in which the cone pulleys are unlike, it is nevertheless true that unlike cone pulleys occur with sufficient frequency to make it desirable that convenient means be established for obtaining the diameters of their steps rapidly and accurately, and Table III. was calculated by the writer for this purpose; its accuracy is more than sufficient for the requirements of practice, the numbers in the table being correct to within a unit of the fourth decimal place (*i.e.* within ·0001). It should be noticed that the tabular quantities are not the diameters of the steps, but these diameters divided by the distance between the centres of the cone pulleys; in other words, the tabular quantities are the effective diameters of the steps only when the centres of the pulleys are a unit's distance apart. By thus expressing the tabular quantities in terms of the distance apart of the axis, the table becomes applicable to all cone pulleys whatever their distance from each other, the effective diameters of the steps being obtained by multiplying the proper tabular quantities by the distance between the centres of the pulleys.

Before describing and applying the table, we will call attention to the term "effective" diameter. The effective radius—as is well known—extends from the centre of the pulley to the centre of the belt; the effective diameter, being twice this effective radius, must also equal the actual diameter plus thickness of belt.

The table is so arranged that the diameter (divided by distance between centres) of one step of a belted pair will always be found in the extreme right-hand column; while its companion step will be found on the same horizontal line, and in that vertical column of the table corresponding to the length of belt employed. For example, if column 14 of the table corresponded to the length of belt employed, some of the possible pairs of diameters would be as follows:

·7118	·5813	·42	·2164	·0474
·06	·24	·42	·60	·72

The upper row of this series of pairs being taken from column 14, and the lower row from the extreme right-hand column, the numbers in each pair being on the same horizontal line. If the distance between the centers of the pulleys were 60 ins. the effective diameters of the steps corresponding to the above pairs would be:

42·71	34·88	25·2	12·98	2·84 ins.
3·6	14·4	25·2	36·0	43 20

being obtained by multiplying the first series of pairs by 60; the length of belt which would be equally tight on each of these pairs would be 3·3195 × 60 ins. = 199·17 ins.

III.—TABLE FOR FINDING THE EFFECTIVE DIAMETERS OF THE STEPS OF CONE PULLEYS, WHEN THE PULLEYS ARE CONNECTED BY AN OPEN BELT AND ARE UNLIKE.

Each vertical cone of the table corresponds to a given length of belt, and the numbers in these columns are the required effective diameters of the steps when the centres of the pulleys are a Unit's distance apart.

LENGTH OF BELT WHEN THE CENTRES OF THE CONE PULLEYS ARE A UNIT'S DISTANCE APART.																	Assumed diameter of steps, divided by distance between the centres of Cone Pulleys
2·0942	2·2827	2·3770	2·4712	2·5655	2·6597	2·7540	2·8482	2·9425	3·0367	3·1310	3·2252	3·3195	3·4137	3·5080	3·6022	3·6965	
1	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
·0534	·1750	·2313	·2867	·3413	·3950	·4479	·5000	·5514	·6020	·6518	·7010	·7495	·7974	·8447	·8913	·9373	0·00
·03	·1477	·2050	·2613	·3167	·3713	·4250	·4779	·5300	·5814	·6320	·6818	·7310	·7795	·8274	·8747	·9213	0·03
	·1194	·1777	·2350	·2913	·3467	·4013	·4550	·5079	·5600	·6114	·6620	·7118	·7610	·8095	·8574	·9047	0·06
	·09	·1494	·2077	·2650	·3213	·3767	·4313	·4850	·5379	·5900	·6414	·6920	·7418	·7910	·8395	·8874	0 09
	·0594	·12	·1794	·2377	·2950	·3513	·4067	·4613	·5150	·5679	·6200	·6714	·7220	·7718	·8210	·8695	0 12
2·1885	·0275	·0894	·15	·2094	·2677	·3250	·3813	·4367	·4913	·5450	·5979	·6500	·7014	·7520	·8018	·8510	0 15
2		·0575	·1194	·18	·2394	·2977	·3550	·4113	·4667	·5213	·5750	·6279	·6800	·7314	·7820	·8318	0·18
		·0244	·0875	·1494	·21	·2694	·3277	·3850	·4413	·4967	·5513	·6050	·6579	·7100	·7614	·8120	0·21
·1177			·0544	·1175	·1794	·24	·2994	·3577	·4150	·4713	·5267	·5813	·6350	·6879	·7400	·7914	0·24
·0894			·0200	·0844	·1475	·2094	·27	·3294	·3877	·4450	·5013	·5567	·6113	·6650	·7179	·7700	0·27
·06				·0500	·1144	·1775	·2394	·30	·3594	·4177	·4750	·5313	·5867	·6413	·6950	·7479	0·30
·0294				·0140	·0800	·1444	·2075	·2694	·33	·3894	·4477	·5050	·5613	·6167	·6713	·7250	0·33
					·0440	·1100	·1744	·2375	·2994	·36	·4194	·4777	·5350	·5913	·6467	·7013	0·36
					·0064	·0740	·1400	·2044	·2675	·3294	·39	·4494	·5077	·5650	·6213	·6767	0·39
						·0364	·1040	·1700	·2344	·2975	·3594	·42	·4794	·5377	·5950	·6513	0·42
							·0664	·1340	·2000	·2644	·3275	·3894	·45	·5094	·5677	·6250	0·45
							·0271	·0964	·1640	·2300	·2944	·3575	·4194	·48	·5394	·5977	0·48
								·0571	·1264	·1940	·2600	·3244	·3875	·4494	·51	·5694	0·51
								·0160	·0871	·1564	·2240	·2900	·3544	·4175	·4794	·54	0·54
									·0460	·1171	·1864	·2540	·3200	·3844	·4475	·5094	0·57
									·0029	·0760	·1471	·2164	·2840	·3500	·4144	·4775	0·60
										·0329	·1060	·1771	·2464	·3140	·3800	·4444	0·63
											·0629	·1360	·2071	·2764	·3440	·4100	0·66
											·0174	·0929	·1660	·2371	·3064	·3740	0·69
												·0474	·1229	·1960	·2671	·3364	0·72
													·0774	·1529	·2260	·2971	0·75
													·0292	·1074	·1829	·2560	0·78
														·0592	·1374	·2129	0·81
														·0081	·0892	·1674	0·84
															·0381	·1192	0·87
																·0681	0·90
																·0138	0·93

3·7907	3·8850	3·9792	4·0735	4·1677	4.2620	4·3562	4·4504	4·5447	4·6389	4·7332	4·8274	4·9217	5·0159	5·1102	Assumed diameter of steps, &c.
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	
·9828	1·0277	1·0721	1·1159	1·1593	1·2021	1 2444	1·2861	1·3274	1·3682	1·4085	1·4484	1·4877	1·5266	1·5650	0·00
·9673	1·0128	1·0577	1·1021	1·1459	1·1893	1·2321	1·2744	1·3161	1·3574	1·3982	1·4385	1·4784	1·5177	1·5566	0·03
·9513	·9973	1·0428	1·0877	1·1321	1·1759	1·2193	1·2621	1·3044	1·3461	1·3874	1·4282	1·4685	1·5084	1·5477	0·06
·9347	·9813	1·0273	1·0728	1·1177	1·1621	1·2059	1·2493	1·2921	1·3344	1·3761	1·4174	1·4582	1·4985	1·5384	0·09
·9174	·9647	1·0113	1·0573	1·1028	1·1477	1·1921	1·2359	1·2793	1·3221	1·3644	1·4061	1·4474	1·4882	1·5285	0·12
·8995	·9474	·9947	1·0413	1·0873	1·1328	1·1777	1·2221	1·2659	1·3093	1·3521	1·3944	1·4361	1·4774	1·5182	0·15
·8810	·9295	·9774	1·0247	1·0713	1·1173	1·1628	1·2077	1·2521	1·2959	1·3393	1·3821	1·4244	1·4661	1·5074	0·18
·8618	·9110	·9595	1·0074	1·0547	1·1013	1·1473	1·1928	1·2377	1·2821	1·3259	1·3693	1·4121	1·4544	1·4961	0·21
·8420	·8918	·9410	·9895	1·0374	1 0847	1·1313	1·1773	1·2228	1·2677	1·3121	1·3559	1·3993	1·4421	1·4844	0·24
·8214	·8720	·9218	·9710	1·0195	1·0674	1·1147	1·1613	1·2073	1·2528	1·2977	1·3421	1·3859	1·4293	1·4721	0·27
·8000	·8514	·9020	·9518	1·0010	1·0495	1·0974	1·1447	1·1913	1·2373	1·2828	1·3277	1·3721	1·4159	1·4593	0·30
·7779	·8300	·8814	·9320	·9818	1·0310	1·0795	1·1274	1·1747	1·2213	1·2673	1·3128	1·3577	1·4021	1·4459	0·33
·7550	·8079	·8600	·9114	·9620	1·0118	1·0610	1·1095	1·1574	1·2047	1·2513	1·2973	1·3428	1·3877	1·4321	0·36
·7313	·7850	·8379	·8900	·9414	·9920	1·0418	1·0910	1·1395	1·1874	1·2347	1·2813	1·3273	1·3728	1·4177	0·39
·7067	·7613	·8150	·8679	·9200	·9714	1·0220	1·0718	1·1210	1·1695	1·2174	1·2647	1·3113	1·3573	1·4028	0·42
·6813	·7367	·7913	·8450	·8979	·9500	1·0014	1·0520	1·1018	1·1510	1·1995	1·2474	1·2947	1·3413	1·3873	0·45
·6550	·7113	·7667	·8213	·8750	·9279	·9800	1·0314	1·0820	1·1318	1·1810	1·2295	1·2774	1·3247	1·3713	0·48
·6277	·6850	·7413	·7967	·8513	·9050	·9579	1·0100	1·0614	1·1120	1·1618	1·2110	1·2595	1·3074	1·3547	0·51
·5994	·6577	·7150	·7713	·8267	·8813	·9350	·9879	1·0400	1·0914	1·1420	1·1918	1·2410	1·2895	1·3374	0·54
·57	·6294	·6877	·7450	·8013	·8567	·9113	·9650	1·0179	1·0700	1·1214	1·1720	1·2218	1·2710	1·3195	0·57
·5394	·60	·6594	7177	·7750	·8313	·8867	·9413	·9950	1·0479	1·1000	1·1514	1·2020	1·2518	1·3010	0·60
·5075	·5694	·63	·6894	·7477	·8050	·8613	·9167	·9713	1·0250	1·0779	1·1300	1·1814	1·2320	1·2818	0·63
·4744	·5375	·5994	·66	·7194	·7777	·8350	·8913	·9467	1·0013	1·0550	1·1079	1·1600	1·2114	1·2620	0·66
·4400	·5044	·5675	·6294	·69	·7494	·8077	·8650	·9213	·9767	1·0313	1·0850	1·1379	1·1900	1·2414	0·69
·4040	·4700	·5344	·5975	·6594	·72	·7794	·8377	·8950	·9513	1·0067	1·0613	1·1150	1·1679	1·22 0	0·72
·3664	·4340	·5000	·5644	·6275	·6894	·75	·8094	·8677	·9250	·9813	1·0367	1·0913	1·1450	1·1979	0·75
·3271	·3964	·4640	·5300	·5944	·6575	·7194	·78	·8394	·8977	·9550	1·0113	1·0667	1·1213	1·1750	0·78
·2860	·3571	·4264	·4940	·5600	·6244	·6875	·7494	·81	·8694	·9277	·9850	1·0413	1·0967	1·1513	0·81
·2429	·3160	·3871	·4564	·5240	·5900	·6544	·7175	·7794	·84	·8994	·9577	1·0150	1·0713	1·1267	0·84
·1974	·2729	·3460	·4171	·4864	·5540	·6200	·6844	·7475	·8094	·87	·9294	·9877	1·0450	1·1013	0·87
·1492	·2274	·3029	·3760	·4471	·5164	·5840	·6500	·7144	·7775	·8394	·90	·9594	1·0177	1·0750	0·90
·0981	·1792	·2574	·3329	·4060	·4771	·5464	·6140	·6800	·7444	·8075	·8694	·93	·9894	1·0477	0·93
·0438	·1281	·2092	·2874	·3629	·4360	·5071	·5764	·6440	·7100	·7744	·8375	·8 94	·96	1·0194	0·96
	·0738	·1581	·2392	·3174	·3929	·4660	·5371	·6064	·6740	·7400	·8044	·8675	·9294	·99	0·99
	·0157	·1038	·1881	·2692	·3474	·4229	·4960	·5671	·6364	·7040	·7700	·8344	·8975	·9594	1·02
		·0457	·1338	·2181	·2992	·3774	·4529	·5260	·5971	·6664	·7340	·8000	·8644	·9275	1·05
			·0757	·1638	·2481	·3292	·4074	·4829	·5560	·6271	·6964	·7640	·8300	·8944	1·08
			·0131	·1057	·1938	·2781	·3592	·4374	·5129	·5860	·6571	·7264	·7940	·8600	1·11
				·0431	·1357	·2238	·3081	·3892	·4674	·5429	·6160	·6871	·7564	·8240	1·14
					·0731	·1657	·2538	·3381	·4192	·4974	·5729	·6460	·7171	·7864	1·17
					·0050	·1031	·1957	·2838	·3681	·4492	·5274	·6029	·6760	·7471	1·20
						·0350	·1331	·2257	·3138	·3981	·4792	·5574	·6329	·7060	1·23
							·0650	·1631	·2557	·3438	·4281	·5092	·5874	·6629	1·26
								·0950	·1931	·2857	·3738	·4581	·5392	·6174	1 29
								·0200	·1250	·2231	·3157	·4038	·4881	·5692	1·32
									·0500	·1550	·2531	·3457	·4338	·5181	1·35
										·0800	·1850	·2831	·3757	·4638	1·38
											·1100	·2150	·3131	·4057	1·41
											·0255	·1400	·2450	·3431	1·44
												·0555	·1700	·2750	1·47
													·0855	·2000	1·50

To get the actual diameters of these steps when thickness of belt $=\frac{7}{32}=0{\cdot}22$ in., we have simply to subtract 0·22 in. from the effective diameters just given, thus:

42·49	34·66	24·98	12·76	2·62 in.
3·38	14·18	24·98	35·78	42·98

would be the series of pairs of actual diameters.

In solving problems relating to the diameters of cone pulleys by means of the accompanying table, we must have, besides the distance between centres, sufficient data to determine the column representing the length of belt. The length of belt is seldom known because it is of small practical importance to know its exact length; but it may be estimated approximately, and then the determination of suitable diameters of the steps becomes an extremely simple matter, as may be seen from what has already preceded. When the length of the belt is not known, and has not been assumed, we indirectly prescribe the length of belt by assuming the effective diameters of the two steps of a belted pair; thus, in the following Figure (561), the length of belt is prescribed when the distance A B, and any one of the pairs of steps D_1d_1, D_2d_2, D_3d_3 and D_4d_4 are given. We will show in the following

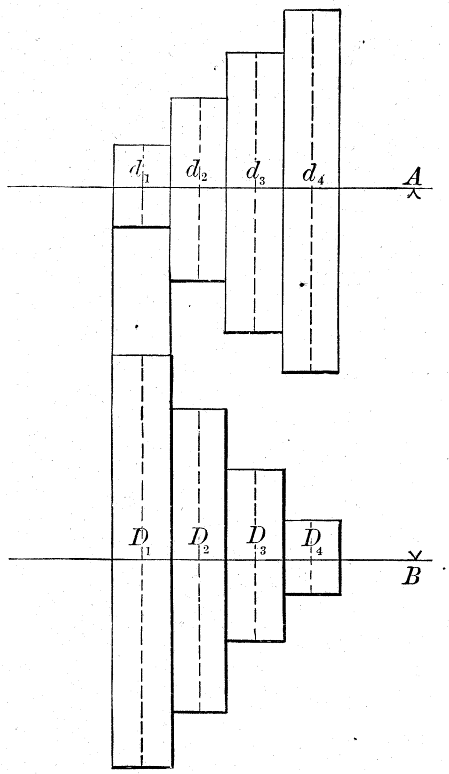

Fig. 561.

examples how the length of belt and its corresponding column of diameter may be found when a pair of steps (like D_1d_1), are given.

EXAMPLE 1. Given the effective diameters

4·5	9 in.	15 in.	21 in.	on cone A,
—	—	15 in.	—	„ B,

and the distance between centres equal to 50 inches.

Required the remaining diameters on cone B.

Since in this example the steps of the given pair are equal, we look for $\frac{15}{50}=0{\cdot}30$, in the extreme right-hand column of table; we will find it in the 11th line from the top; now looking along this line for the diameter of the other step, $=\frac{15}{50}=0{\cdot}30$, we will find it in column 10; consequently the numbers of this column may be taken as the diameters of the steps which are the companions or partners of those in the extreme right-hand column.

We can now easily determine the remaining members of the pairs to which 4 5 in., 9 in., and 21 in. steps respectively belong. To find the partner of the 4·5 step, we find $\frac{4{\cdot}5}{50}=0{\cdot}09$ in the right-hand column, and look along the horizontal line on which 0·09 is placed till we come to column 10, in which we will find the number 0·4850; 0·4850=50 in.=24·25 in. will be the effective diameter of the companion to the 4·5 in. step.

To find the partner to the 9 in. step, we proceed as before, looking for $\frac{9}{50}=0{\cdot}18$ in the right-hand column, and then along the horizontal line of 0·18 to column 10, then will 0·4113 × 50 in.= 20·57 in. be the required companion to the 9 in. step of cone A.

In like manner for the partner of the 21 in. step we get 0·1700 × 50 in.=8·5 in. The effective diameter therefore will be,

4·5 in.	9 in.	15 in.	21 in.	on cone A,
24·25	20·57	15 in.	8·5	„ B.

If the thickness of belt employed were **0·25 in.** the *actual* diameters of steps would be,

4·25	8·75	14·75	20·75	on cone A,
24·00	20·32	14·75	8·25	„ B,

and the length of belt would be 2·9425 × 50=147·125 in.

EXAMPLE 2. Given the effective diameters

6 in.	12 in.	18 in.	24 in.	on cone A,
30 in.	—	—	—	„ B,

and the distance between centres=40 in.

Required the unknown diameters on cone B.

We must, as before, first find the vertical column corresponding to the length of belt which joins the pair of steps $\frac{6 \text{ in}}{30 \text{ in}}$. We find the number $\frac{6}{40}=\cdot15$ in the right-hand column, and then look along its horizontal line for its partner $\frac{30}{40}=0{\cdot}75$. Since we do not find any number exactly equal to ·7500, we must interpolate. For the benefit of those not familiar with the method of interpolation we will give in detail the method of finding intermediate columns of the table. On the aforesaid horizontal line we find in column 16 a number 0·7520, larger than the required 0·7500, and in column 15 a number 0·7014, smaller than 0·7500; evidently the intermediate column, containing the required 0·7500, must lie between columns 16 and 15. To find how far the required column is from column 16, we subtract as follows:

$$\begin{array}{r} 0{\cdot}7520 \\ 0{\cdot}7500 \\ \hline \cdot0020 \end{array} \qquad\qquad \begin{array}{r} 0{\cdot}7520 \\ 0{\cdot}7014 \\ \hline 0{\cdot}0506 \end{array}$$

then the fraction $\frac{\cdot0020}{\cdot00506}=0{\cdot}04$ nearly will represent the position of the required intermediate column; namely, that its distance from column 16 is about $\frac{4}{100}$ of the distance between the adjacent columns, 15 and 16.

To find other numbers in this intermediate column we have only to multiply the difference between the adjacent numbers of columns 16 and 15 by 0·04, and subtract the product from the number in column 16. But it is not necessary to find as many numbers of the intermediate columns as are contained in either of the adjacent columns; it is only necessary to find as many numbers as there are steps in each of the cone pulleys. We will now illustrate what has preceded, by finding the partner to the 12 in. step of cone A. Find, as before, the horizontal line corresponding to $\frac{12}{40}=0{\cdot}30$, then take the difference between the numbers 0·6413 and 0·5867 of columns 16 and 15, and multiply this difference, 0·0546, by 0·04; this product=0·0022 subtracted from 0·6413, will give 0·6391, a number of the intermediate columns corresponding to the length of belt of the present problem. Multiplying by the distance between the axes=40 in. we get 0·6391 × 40=25·56, for the diameter of the step of cone B which is partner to the 12 in. step of cone A.

To find the companion to the 18 in. step, we proceed in the same manner, looking for the horizontal line $\frac{18}{40}=0{\cdot}45$, and interpolating as follows:

$$0{\cdot}5094-(0{\cdot}5094-0{\cdot}4500)\times0{\cdot}04=0{\cdot}5070.$$

Consequently, 0·5070 × 40 in.=20·28 in. will be the required partner of the 18 in. step.

In like manner, for the 24 in. step, we have

$$0{\cdot}3500-(0{\cdot}3500-0\ 2840)\times0{\cdot}04=0{\cdot}3474, \text{ and } 0{\cdot}3474\times40=13{\cdot}90.$$

The effective diameters are therefore

6 in.	12 in.	18 in.	24 in.	on cone A.
30	25·56	20·28	13·9	„ B.

The actual diameters, when thickness of belt = 0·20 in., are :

5·8	11·8	17·8	23·8	on cone A.
29·8	25·36	20·08	13·7	„ B.

And the length of belt will be :

$$[3\cdot5080 - (3\cdot5080 - 3\cdot4137) \times 0\cdot04] \times 40 \text{ in.} = 140\cdot17 \text{ in.}$$

EXAMPLE 3. Given the effective diameters :

12 in.	18 in.	24 in.	30 in.	on cone A,
33 in.	—	—	—	„ B,

and the distance between the centres = 60 in.

Required the remaining diameters on cone B.

The horizontal corresponding to $\frac{12}{60}$ = 0·20 lies $\frac{2}{3}$rd way between the horizontal line, corresponding to 0·18 and 0·21 ; the number $\frac{33}{60}$ = 0·5500, corresponding to the companion of the 12 in. step, will therefore lie $\frac{2}{3}$rd way between the horizontal lines 0·18 and 0·21. We have now to find two numbers on this $\frac{2}{3}$rd line, of which one will be less and the other greater than 0·5500. An inspection of the table will show that these greater and less numbers must lie in columns 13 and 12. The numbers on the $\frac{2}{3}$rd line itself may now be found as follows :

In column 13, 0·5750—$\frac{2}{3}$ (0·5750—0·5513) = 0 5592.

In column 12, 0·5213—$\frac{2}{3}$ (0·5213—c·4967) = 0·5049.

0·5592 will be the number on the $\frac{2}{3}$rd line, which is greater than 0·5500, and 0·5049 will be the one which is less than 0·5500. The position of the intermediate column, corresponding to the length of belt of the present example, may now be found, as before, briefly. It is :

$$\frac{0\cdot5592 - 0\cdot5500 = 0\cdot0092}{0\cdot5592 - 0\cdot5049 = 0\cdot0543} = 0\cdot17.$$

Consequently the required column lies nearest column 13, $\frac{17}{100}$th way between columns 13 and 12. To find any other number in the required column, we have only to multiply the difference between two adjacent numbers of columns 13 and 12 by $\frac{17}{100}$, and subtract the product from the number in column 13. For example, to find the diameter of the partner to the 18 in. step of cone A, we find the numbers 0·4750 and 0·4177 of columns 13 and 12, which lie on the horizontal line corresponding to $\frac{18}{60}$ = 0·30 ; the difference, 0·0573, between the two numbers is multiplied by 0·17, and the product, 0·0573 × 0·17 = 0·0097, subtracted from 0·4750. This last difference will equal 0·4653, and will be the number sought. If we now multiply by 60, we will get 27·92 in. as the effective diameter of that step on cone B which is the partner to the 18 in. step of cone A.

To find the companion of the 24 in. step, we proceed after the same fashion ; the horizontal line $\frac{24}{60}$ = 0·40 lies $\frac{1}{3}$rd way between 0·39 and 0·42 ; hence,

In column 13, 0·3900—$\frac{1}{3}$ (0·3900—0·3594) = 0·3798 ;

In column 12, 0·3294—$\frac{1}{3}$ (0·3294—0·2975) = 0·3188 ;

And 0·3798—(0·3798—0·3188) × 0·17 = 0·3694.

The required effective diameter of the step, which is partner to the 24 in. step, will therefore be 0·3694 × 60 = 22·16 in.

In like manner we obtain partner for the 30 in. step, thus :

In column 13, 0·2944—$\frac{2}{3}$ (0·2944—0·2600) = 0·2715.

In column 12, 0·2300—$\frac{2}{3}$ (0·2300—0·1940) = 0·2060.

Also 0·2715—(0·2715—0·2060) × 0·17 = 0·2604, and 0·2604 × 60 in. = 15·62 in. = diam. of step belonging to the same belted pair as the 30 in. step of cone A.

The effective diameters will be :

12 in.	18 in.	24 in.	30 in.	on cone A,
33	27·92	22·16	15·62	„ B,

and the actual diameters when belt is 0·22″ thick :

11·78	17·78	23·78	29.78 in.
32·78	27·70	21·94	15·40

and the length of belt is found to be :

$$[3\cdot2252 - (3\cdot2252 - 3\cdot1310) \times 0\cdot17] \times 60 \text{ in.} = 192\cdot55 \text{ in.}$$

In all the preceding problems it should be noticed that we arbitrarily assumed *all* the steps on one cone, and *one* of the steps on the other cone. It will be found that all of the practical problems relating to cone-pulley diameters can finally be reduced to this form, and can consequently be solved according to the methods just given.

For those who find difficulty in interpolating, the following procedure will be found convenient : Estimate approximately the necessary length of belt, then divide this length by the distance between the centres of the cone pulleys ; now find which one of the 33 lengths of belt (per unit's distance apart of the centres) given in the table is most nearly equal to the quotient just obtained, and then take the vertical column, at the head of which it stands, for the companion to the right-hand column. Those numbers of these companion columns which are on the same horizontal line will be the companion steps of a belted pair. The table is so large, that in the great majority of cases not only exact, but otherwise satisfactory values can be obtained by this method, without any interpolation whatever."

The teeth of the back gear should be accurately cut so that there is no lost motion between the teeth of one wheel, and the spaces of the other, because on account of the work being of large diameter or of hard metal (so as to require the slow speed), the strain of the cut is nearly always heavy when the back gear is in use, and the strain on the teeth is correspondingly great, causing a certain amount of spring or deflection in the live spindle and back gear spindle. Suppose then, that at certain parts of the work there is no cut, then when the tool again meets the cut the work will meet the tool and stand still until the lost motion in the gear teeth and the spring of the spindles is taken up, when the cut will proceed with a jump that will leave a mark on the work and very often break the tool. When the cut again leaves the tool a second jump also leaving a mark on the work will be

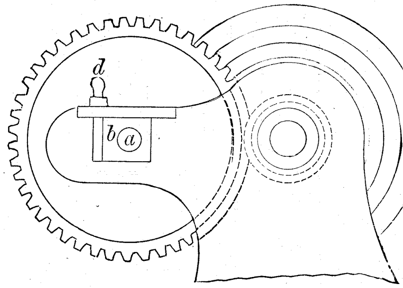

Fig. 562.

made. If the teeth of the gears are cut at an angle to the axial line of the spindle, as is sometimes the case, this jumping from the play between the teeth will be magnified on account of a given amount of play, affording more back lash in such gears.

The teeth of the wheels should always be of involute and not of epicycloidal form, for the following reasons. The transmission of motion by epicycloidal teeth is exactly uniform only when their pitch circles exactly coincide, and this may not be the case in time because of wear in the parts as in the live spindle journals and the bearings, and the back gear spindle and its bearings, and *every variation of speed* in the cut, however slight it may be, produces a corresponding mark upon the work. In involute teeth the motion transmitted will be smooth and equal whether the pitch lines of the wheels coincide or not, hence the wear of the journals and bearings does not impair their action.

The object of cutting the teeth at an angle is to have the point of contact move or roll as it were from one end to the other of the teeth, and thus preserve a more conterminous contact on the line of centres of the two wheels, the supposition being that this would remove the marks on the work produced by the tremor of the back gear. But such tremor is due to errors in the form of the teeth, and also in the case of epicycloidal teeth from the pitch lines of the teeth not exactly coinciding when in gear.

The pitch of the teeth should be as fine as the requisite strength, with the usual allowance of margin for wear and safety will allow, so as to have as many teeth in continuous contact as possible.

Various methods of moving the back gear into and out of gear with the cone spindle gears are employed. The object is to place the back gears into gear to the exact proper depth to hold them securely in position, and to enable the operator to operate the gears without passing to the back of the lathe. Sometimes a sliding bearing box, such as shown in Fig. 562, is employed; *a* is the back gear spindle, *b* its bearing box, and *d* a pin which when on the side shown holds *b* in position, when the back gear is in action. To throw it out of action *d* is removed, *b* pushed back, and *d* inserted in a hole on the right hand of *b;* the objection is that there is no means of taking up the wear of *b*, and it is necessary to pass to the back of the lathe to operate the device.

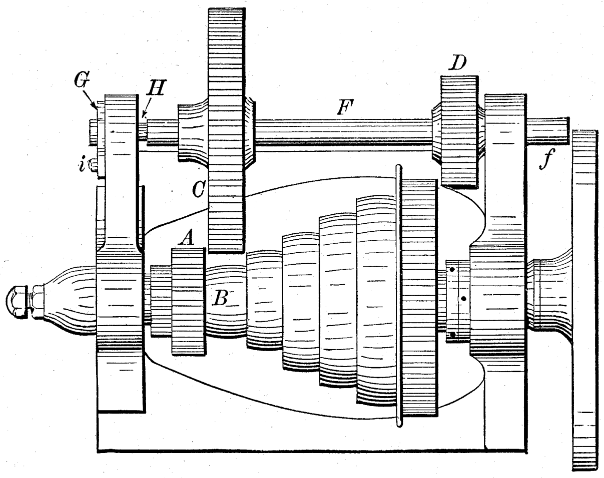

Fig. 563.

Another plan is to let the back gear move endwise and bush its bearing holes with hardened steel bushes. This possesses the advantage that the gear is sure, if made right, to keep so, but it has some decided disadvantages: first, the pinion A, Fig. 563, must be enough larger than the smallest cone-step B to give room

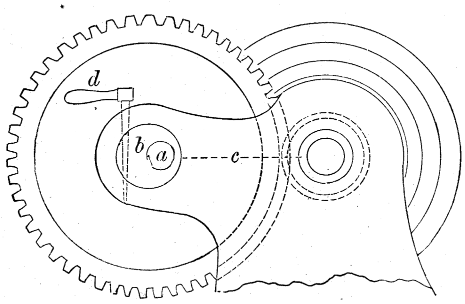

Fig. 564.

between B and C for the belt, and this necessitates that D also be larger than otherwise; secondly, the gear-spindle F projects through the bearing at *f*, and this often comes in the way of the bolt-heads used for chucking work to the face plate. The method of securing the spindle from end motion is as follows: On the back

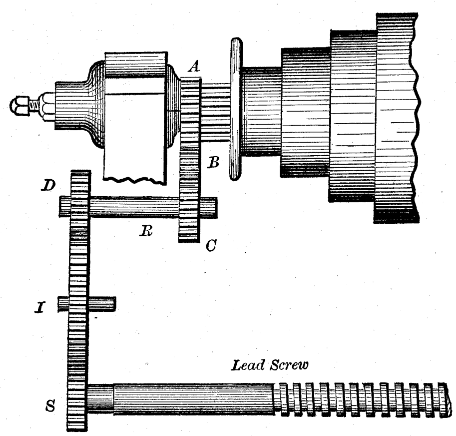

Fig. 565.

of the head is pivoted at *i*, a catch G, and on the gear shaft F are two grooves. As shown in the sketch, G is in one of these grooves while H is the other, but when the back gear is in, G would be in H.

Sometimes a simple eccentric bush and pin is used as in Fig. 564, in which *a* is the spindle journal, *b* a bush having bearing in the lathe head, and *d* a taper pin to secure *b* in its adjusted position.

In large heavy lathes having many changes of speed, there are various other constructions, as will be seen upon the lathes themselves in the various illustrations concerning the methods of throwing the back gear in and out. The eccentric motion shown in Fig. 573 of the Putnam lathe, is far preferable to any means in which the back-gear spindle moves endways, because, as before stated, the end of the back-gear spindle often comes in the way of the bolts used to fasten work to the large face plate. This occurs mainly in chucked work of the largest diameter within the capacity of the lathe.

In many American lathes the construction of the gearing that

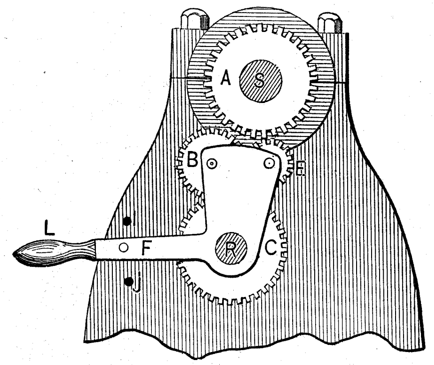

Fig. 566.

conveys motion from the live spindle is such that facility is afforded to throw the change gears out of action when the lathe is running fast, as for polishing purposes, so as to save the teeth from wear. Means are also provided to reverse the direction of lead screw or feed screw revolution. An example of a common construction of this kind is shown in Fig. 565, in which the driving wheel A is on the inner side of the back bearing as shown. It drives (when in gear) a pair of gears, one only of which is seen in the figure at B, which drives C, and through R, D, I, and S, the lead screw. A side view of the wheel A and the mechanism in connection therewith is shown in Fig. 566, in which S represents the live spindle and R is a spindle or shaft corresponding to R in Fig. 565. L is a lever pivoted upon R and carrying two pinions B and E; pinion B is of larger diameter than E, so that B gears with both C

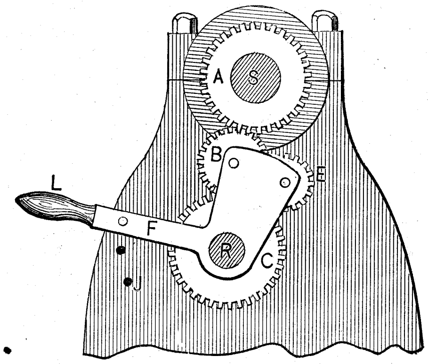

Fig. 567.

and E (C corresponding to wheel C in Fig. 565), while E gears with B only.

With the lever L in the position shown, neither B nor E engages with A, hence they are at rest; but if lever L be raised as in Fig. 567, B will gear with wheels A and C, and motion will be conveyed from A to C, wheel E running as an idle wheel, thus C will revolve in the same direction as the lathe spindle.

But if lever L be lowered as in Fig. 568, then wheel E will gear with and receive motion from A, which it will convey to B, and C will revolve in the opposite direction to that in which the lathe spindle runs. To secure lever L in position, a pin F passes through it and into holes as I, J, provided in the lathe head. Lever L is sometimes placed inside the head, and sometimes outside as in

Fig. 569, and it will be obvious that it may be used to cut left-hand threads without the use of an extra intermediate change gear, which is necessary in the construction shown in Fig. 570, in order to reverse the direction of lead screw revolution.

Sometimes the pin F is operated by a small spring lever attached to L, so that the hand grasps the end of L and the spring lever simultaneously, removing F from the hole in H, and therefore freeing L, so as to permit its operation. By relaxing the pressure on the small spring lever pin F finds its own way into the necessary hole in H, when opposite to it, without requiring any hand manipulation.

In larger lathes the lever L is generally attached to its stud outside the end bearing of the head H.

It is preferable, however, that the device for changing the direction of feed traverse be operative from the lathe carriage as

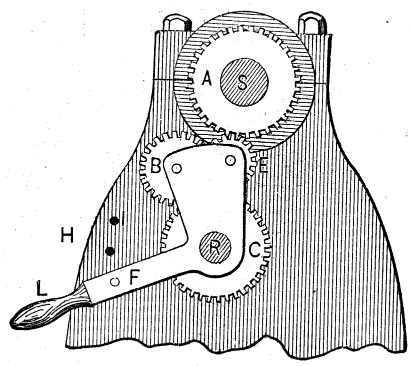

Fig. 568.

in the Sellers lathe, so that the operator need not leave it when it is necessary to reverse the direction of traverse.

The swing frame, when the driving gear D is outside of the back bearing (as it is in Fig. 570), is swung from the axis of the lead screw as a centre of motion, and has two slots for receiving studs for change wheels. But when the driving gear is inside the back bearing as in Fig. 571, the swing frame may be suspended from the spindle (R, Fig. 565) that passes through the lathe head, which may also carry the cone for the independent feed as shown in Fig. 571, no matter on which side of the lathe the lead screw and feed rod are. This affords the convenience that when both lead screw and feed rod are in front of the lathe, the feed may be changed from the screw cutting to the rod feed, or *vice versâ*, by

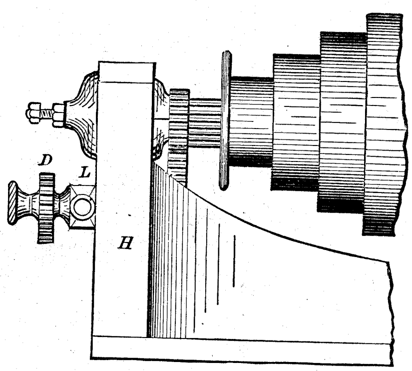

Fig. 569.

suitable mechanism in the apron, without requiring any change to be made in the driving gears.

In the lathe shown in Fig. 572, which is from the design of S. W. Putnam, of the Putnam Tool Company of Fitchburg, Massachusetts, the cone pinion for the back gear, and that for driving the feed motion, are of the same diameter and pitch, so that the gear-wheel L in Fig. 573 may (by means of a lever shown dotted in) be caused to engage with either of them. When the latter is used in single gear it would obviously make no difference which wheel drives L, but when the back gear is put in and L is engaged with the cone pinion, its speed corresponds to that of the cone, which being nine times faster than the live spindle, enables the cutting of threads nine times as coarse as if the back gear was not in use. This affords very great advantages for cutting worms and threads of coarse pitches.

An excellent method of changing the direction of feed motion, and of starting or stopping the same, is shown in Fig. 574, which represents the design of the Ames Manufacturing Company's lathe.

In the figure A, is the small step of the lathe cone, B the pinion to drive the back gear, C a pinion to drive the feed gear,

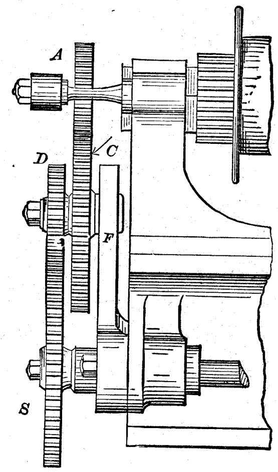

Fig. 570.

giving motion to D, which drives E, the latter being fast to G and rotating freely upon the shaft F, G drives H, which in turn drives I. The clutch J has a featherway into which fits the feather *c*, on the shaft F, so that when the clutch rotates it rotates J through the medium of *c*; K is a circular fork in a groove in J, and operated by a lever operated by a rod running along the front of the lathe bed. This rod is splined so that a lever carried by the apron or feed-table, having a hub and enveloping the rod, may by means of a feather filling into the spline operate the rod by partly rotating it,

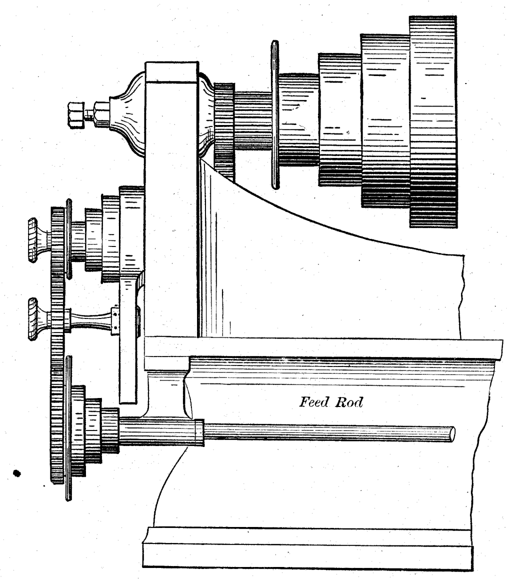

Fig. 571.

and hence operate K. Suppose now that this lever stands horizontal, then the clutch J would stand in the position shown in the cut, and D, E, G, H, and I, would rotate, while F would remain stationary. By lifting the lever, however, J would be moved laterally on F (by means of K) and the lug *a* on J would engage with lug *b* on G, and G would drive J, which through *c* would drive F, on which is placed a change gear at L, thus traversing the carriage forward. To traverse it backward the lever would be lowered or depressed below the horizontal level moving K, and therefore J, to the right, so that lug *a* would engage with lug *b* on I, hence F would be driven by I, whose motion is in an opposite direction to G, as is denoted by the respective arrows.

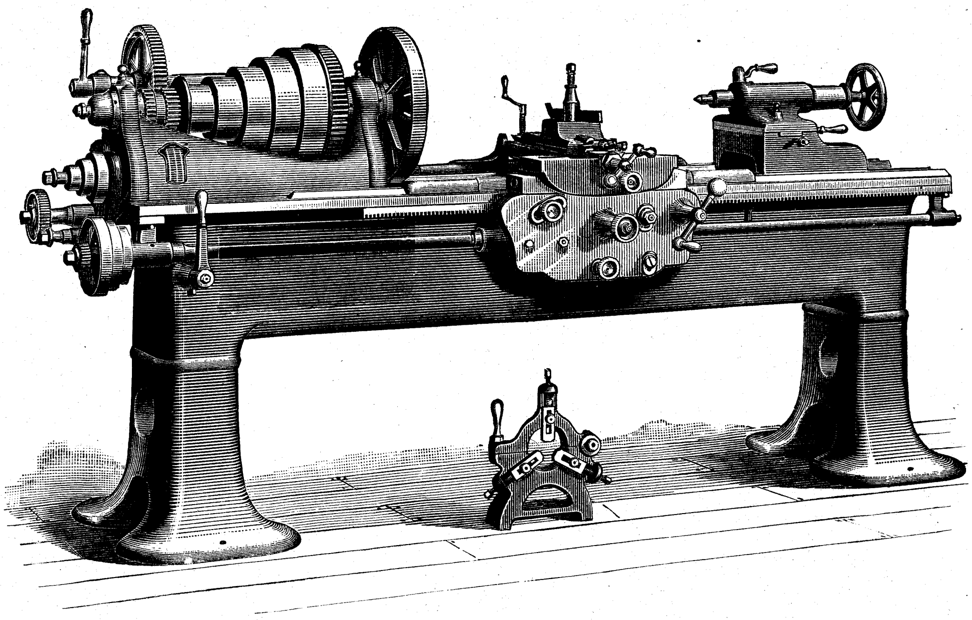

Fig. 572.

To throw all the feed motion out of gear, to run the lathe at its quickest for polishing, &c., the operation is as follows.

M is tubular and fast in N and affords journal bearing to wheel D. Through M passes stud O, having a knob handle at P. At the end

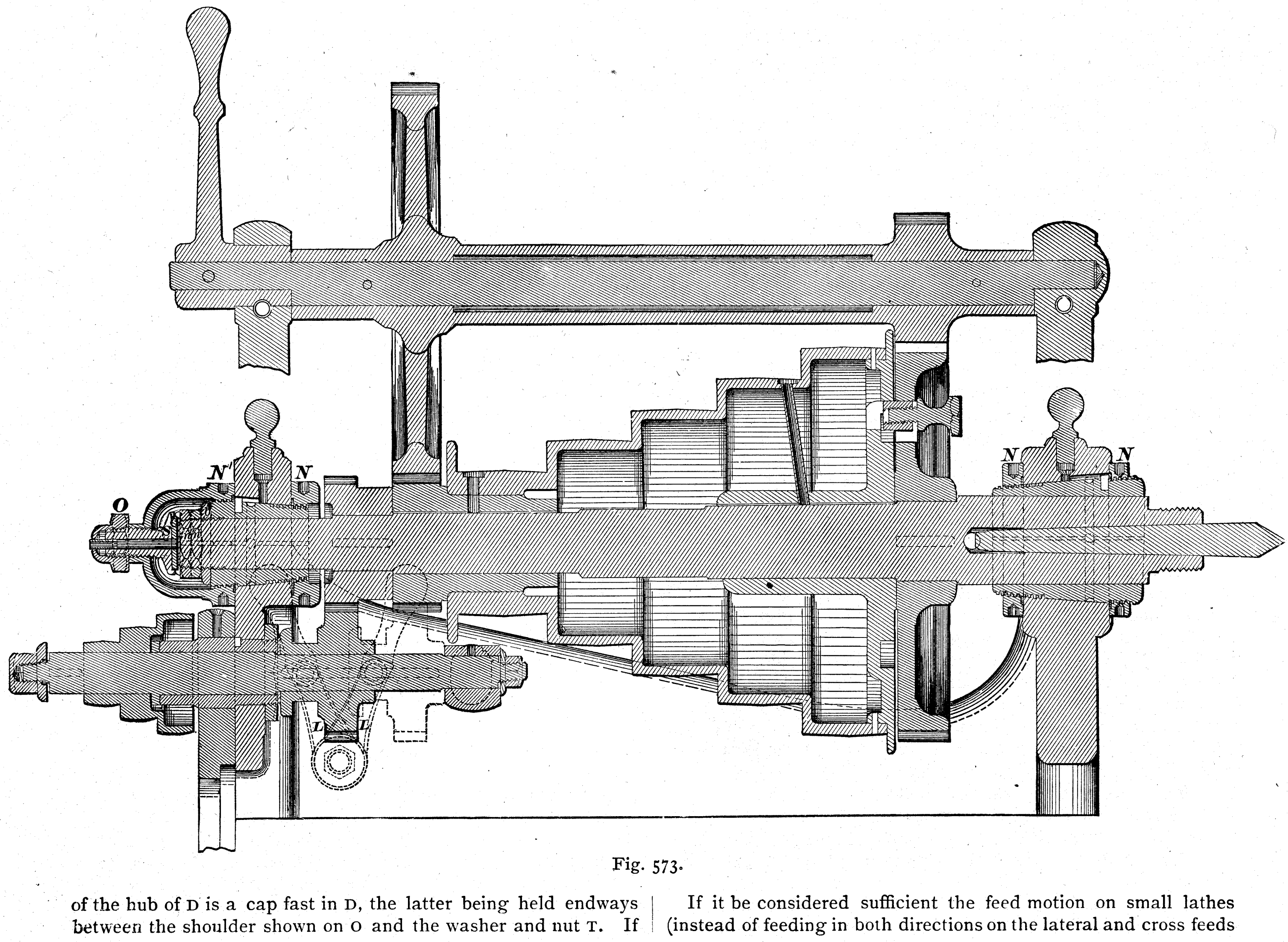

Fig. 573.

of the hub of D is a cap fast in D, the latter being held endways between the shoulder shown on O and the washer and nut T. If then P be pulled outwards O will slide through M, and through the medium of T will cause D to slide over M, in the direction of the arrow, and pass out of gear from C, motion therefore ceasing at C.

Q is the swing frame for the studs to carry the change wheels, and R a bolt for securing Q in its adjusted position. S is a journal and bearing for H.

If it be considered sufficient the feed motion on small lathes (instead of feeding in both directions on the lateral and cross feeds as in the Putnam Lathe), may feed in the direction from the dead to the live centre, and in one direction only on the cross slide.

An example of a feed motion of this kind is shown in Figs. 575 and 576; *f f* is the feed spindle splined and through the medium of a feather driving the bevel pinion A having journal bearing in B. Pinion A drives the bevel gear C, which is in one piece with pinion D. The latter drives gear F, which drives pinion K, which means are provided on the lathe headstock for reversing the direction of motion of the feed spindle *f* so as to reverse the direction of the feeds. It will be observed that so long as *f* rotates, A, C, D, and F rotate, the remaining motions only operating when S is screwed up.

In order to obtain a delicate tool motion from the handle Q it is necessary to reduce the motion between J and I as much as

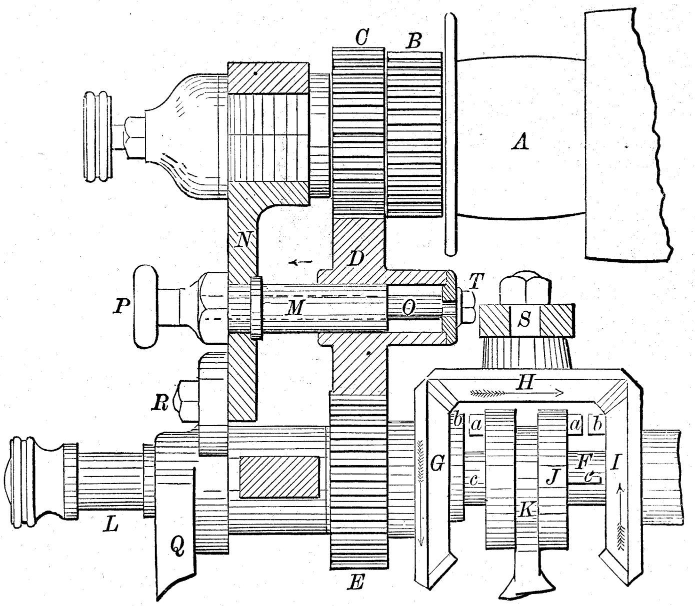

Fig. 574.

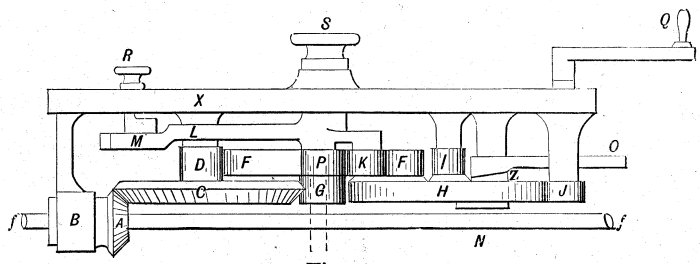

Fig. 575.

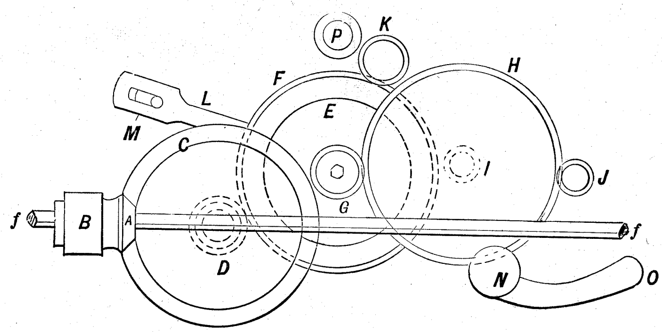

Fig. 576.

is carried on a lever L, pivoted on the stud which carries F, so that by operating L, pinion K is brought into gear with pinion P, which is fast upon the cross-feed screw, and therefore rotates it to effect the automatic cross feed.

As shown in the cut, the lever L is in such a position as to throw K out of gear with P, and the cross feed screw is free to be operated by the handle by hand. At M is a slot in L in which operates a cam or eccentric, one end of which projects into L, while at the other end is the round handle R, Fig. 575, which is rotated to raise or lower that end of L so as to operate K. To operate the saddle or carriage the motion is continued as follows:—at the centre of F is a pinion gear G which operates a gear H, which is in one piece with the pinion I, and the latter is in gear with the rack running along the lathe bed.

If the motion from A to I was continuous, the carriage feed or traverse would be continuous, but means are provided whereby motion from F to I may be discontinued, as follows:—A hand traverse or feed is provided. J, Figs. 575 and 576, is carried by a stud having journal bearing in a hub on X and receiving the handle Q; hence by operating Q, J is rotated, operating the gear H, upon which is the pinion I, which is in gear with the rack running along the lathe bed.

To lock the carriage in a fixed position, as is necessary when operating the cross feed on large radial surfaces, the following device is provided:—N is a stud fixed in a hub on X, and having a head which overlaps the rim of H, as shown in figure. On the other side of that rim is a washer Z on the same stud having a radial face also overlapping the rim of H, but its back face is bevelled to a corresponding bevel on the radial face on the hub of lever O (the hub of O being pivoted on the same stud). When therefore O is depressed the two-bevel face of the hub of O forces the washer Z against the face of the wheel H, whose radial faces at the rim are therefore gripped between the face of the collar N and that of the washer Z, hence H is locked fast. By raising the end of lever O, Z is released and H is free to rotate.

Both the carriage feed and cross feed can only be traversed in one direction so far as these gears and levers are concerned, but

possible, a point in which a great many lathes as at present constructed are deficient, because Q, although used to simply traverse the carriage along the bed, in which case rapid motion of the latter is desirable, is also used to feed the tool into corners when the lathe has no compound rest to put on light cuts on radial faces, hence it should be capable of giving a delicate tool motion.

On account of the deficiency referred to it is often necessary to

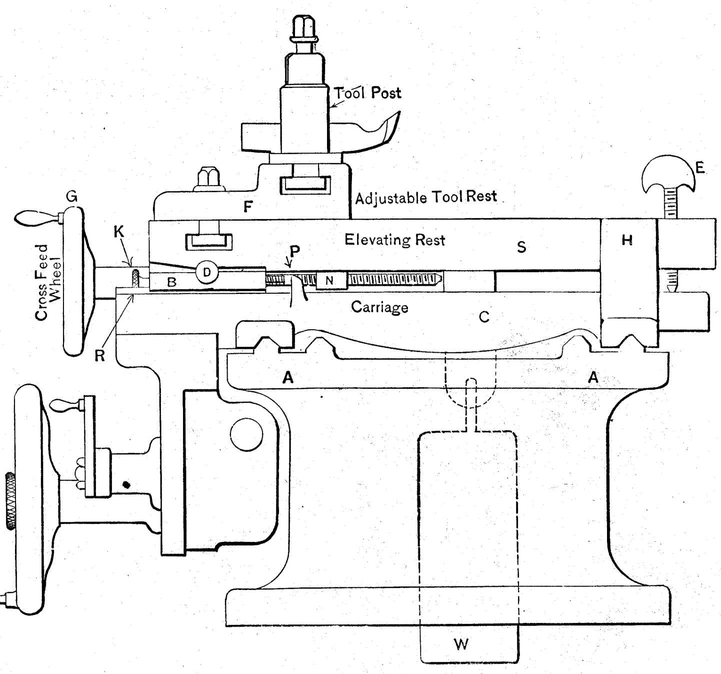

Fig. 577.

put on a fine radial cut by putting the feed traverse in gear, and, throwing the feed screw gear out of contact with the other change wheels, pull it around by hand to put on the cut. In compound slide rests these remarks do not apply, because the upper part of the rest may be used instead of the handle Q.

Many small lathes are provided with a tool rest known as the *elevating rest*, or weighted lathe.

An excellent example of an elevating rest for a weighted lathe is shown in Figs. 577 and 578, which represent the construction in the Pratt and Whitney lathe. A is the lathe shears upon which slides the carriage provided with V slideways R for the sliding piece B, and provided at the other end with the guides H. The cross slide S is pivoted upon B at D, and fits at the other end between the guides H. At E is the elevating screw which when operated raises or lowers that end of the elevating rest to adjust the tool height. This also affords an excellent means of making a minute adjustment for depth of tool cut. The tool rest F is bolted to S.

The weight W is suspended from S and, therefore, holds one

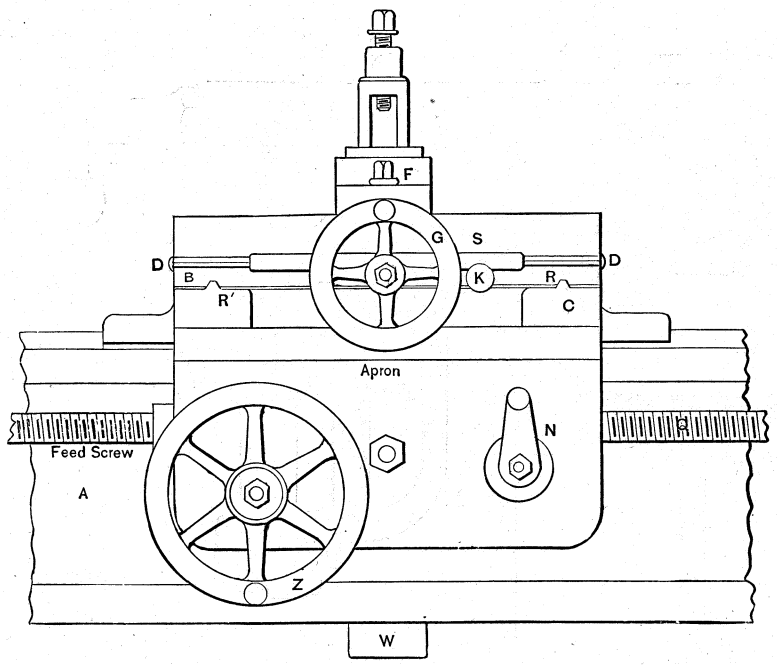

Fig. 578.

end of S to B, the lathe to C, and C to A; at the other end the weight holds S to C (through the medium of the elevating screw E) and C to A. The cross feed nut N is fast to S, the cross feed screw being operated by hand wheel G. B is provided with the V slideways R, which slide upon corresponding V slides R′ upon C; P is a lug cast upon C, and K is a screw threaded in B. When

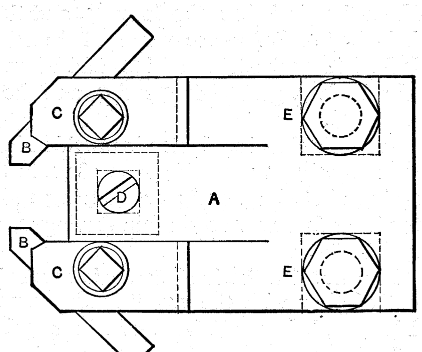

Fig. 579.

the end of screw K abuts against P the motion of S, and, therefore, of the cutting tool T, towards the work is arrested, hence when the tool is adjusted to the proper depth of cut, K is operated to abut firmly against P, and successive pieces may be turned to the same diameter without requiring each piece to be measured for diameter. N is the handle for opening and closing the nut for the feed screw Q, and Z is the wheel for the hand feed traverse. The length of cross feed motion is determined by the length of the cross V slides R′.

This class of rest possesses the advantage that no lost motion in the slides occurs by reason of the wear, because the weight keeps the parts in constant contact notwithstanding such wear; on the other hand, however, the slide Vs sustain the extra wear due to the weight W in addition to the weight of the carriage. Lathes of this class are intended for light work, and are less suited for boring than for plain turning; they are, however, very convenient, and are preferred by many to any other kind of lathe for short and light work.

The tool rest being removable may be supplanted by other special forms of rest. Thus Figs. 579 and 580 represent a special rest for carrying two tools to cut pieces of work to the exact same length. Bolts D and E are to secure the rest A to the elevating rest, and C C are the clamps for the two tools B.

Fig. 581 represents a cross sectional view of the Putnam Tool Company's gibbed elevating rest, there being a gib on the underneath side of the front shear. The elevating screw is pivoted by a ball joint. By employing a gib instead of a weight, the bed may be provided with cross girts or ribs joining the two sides of the shear, thus giving much greater stiffness to it.

Figs. 582, 583, and 584 represent a lathe feed motion by William Munzer, of New York. The object in this motion is to insure that no two feeds can be put into operation simultaneously, because putting the feed in motion in one direction throws it out of gear for either of the others. Another object is to have the transmitting motion as direct as possible so as to avoid the rotation of any wheels not actually necessary for the transmission of the motion; and a third object is to enable the throwing out of gear of all wheels (when no feed motion at all is required) without leaving the apron.

The means employed to effect these objects are as follows:—

In Fig. 582 *f* represents the independent feed spindle and S the lead-screw: *f* is splined to drive A, A′ and A″, which is a sleeve in one piece, and consists of a circular rack at A, a bevel pinion at A′, and a second bevel pinion at A″. This sleeve may be operated in either direction along *f* by rotating the pinion B. As shown in the cut A′ and A″ are both out of gear with the bevel-wheel C, but if B be rotated to the right then A′ will be in gear with C, or if it be operated to the left then A″ will be in gear with C. Now the direction of rotation of C will be governed by which pinion, A′ or A″, drives it, and these are the means by which the direction of the feed traverse and also of the cross feed is determined.

If none of the feeds are required to operate, the sleeve occupies the position shown in the cut, and the circular rack at A simply rotates while B and all other parts remain at rest. On the same central pin as C is the pinion D driving a spur gear E″. On the same centre pin as E is the gear F driving G, which is on the same central pin as C and D. The gear H is fixed to and rotates

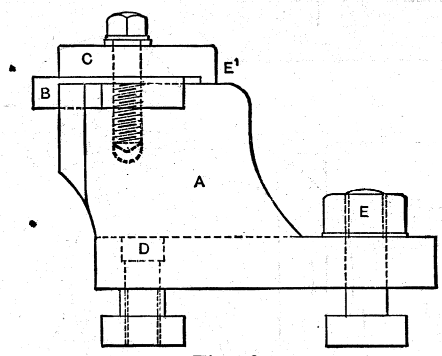

Fig. 580.

with G and drives I; all these gears serving to reduce the speed of motion when operating to feed the carriage traverse in either direction.

A gear J is carried on the end of a lever K, being pivoted at L. In the position shown J is out of gear with all gears, but it may be swung to the right so as to engage with wheel I and wheel M, and convey the motion of I to M. Upon the same spindle as M is the pinion N, engaging with the rack O, which is fast on the lathe bed. This completes the automatic feed traverse.

For a hand feed traverse, pinion P is employed to drive M, which is fast to N. The cross feed is self-acted by moving lever K to the left, causing it to engage with pinion Q as well as with T, Q being fast on the cross feed screw. To lock J in either of its three positions there is provided on lever K a spring locking pin R, shown clearly in Fig. 584, which represents an irregular section of the gearing viewed from the headstock of the lathe.

The pin R is pressed inward by the spiral spring shown, and has a conical end fitting into holes provided in the apron to receive it. There are three of these holes, shown in dotted lines at *a b c* in Fig. 582. When the pin is in *a* the lever K, and therefore wheel J, Fig. 582, is locked out of gear; when it is in hole *b* wheel J is locked in gear with I and M, and when it is in *c* the wheel J is in gear with T and Q, and the cross feed is actuated.

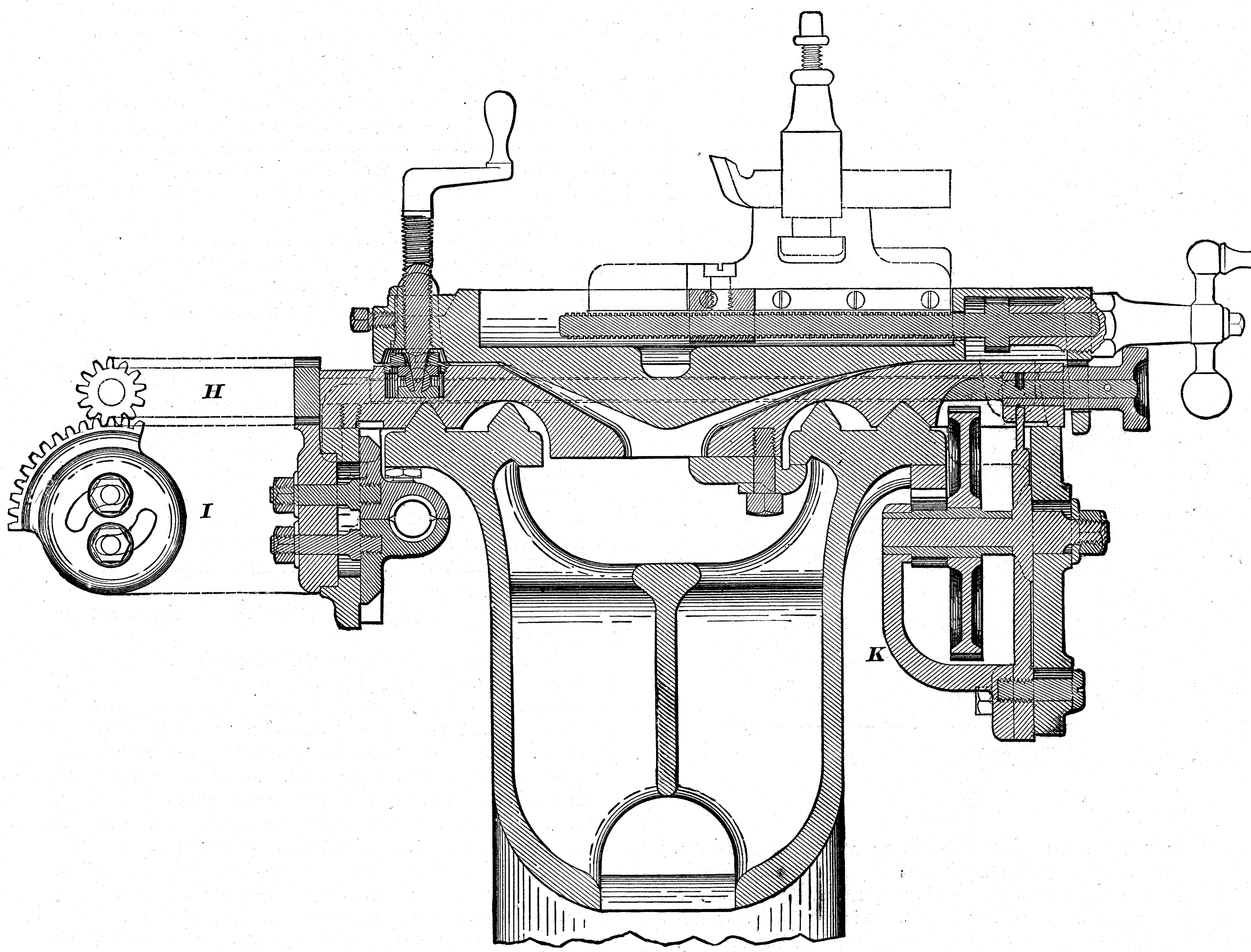

Fig. 581.

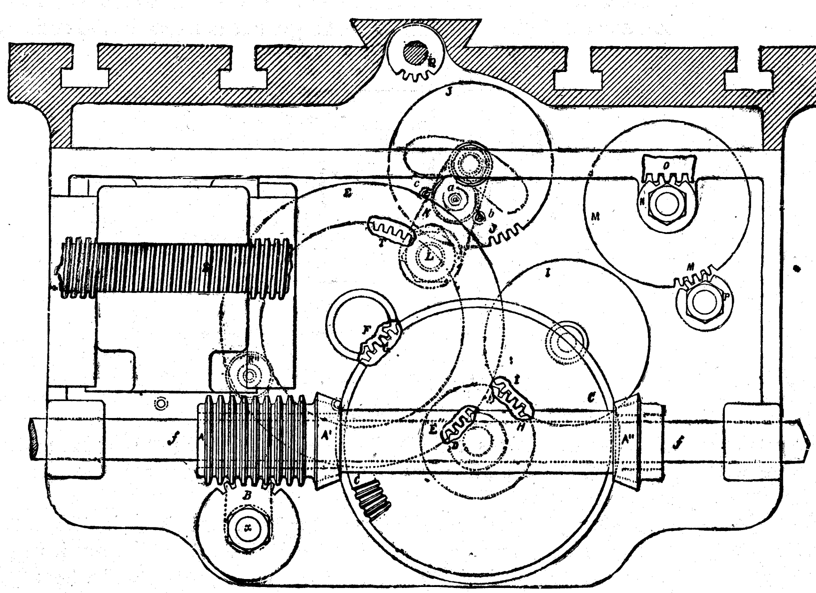

Fig. 582.

A similar locking device is provided for the pinion B for actuating A; thus in Fig. 582 B is the lever, the spring pin being at R″; or referring to Fig. 584, X is the lever fast at *x* on the pin driving B, and R″ is the spring pin.

The nut for the lead screw is secured either in or out of gear with the screw in the same manner, *x*′, Fig. 583, being the lever and R′ the spring pin.

In screw cutting the cutting tool requires to be withdrawn from the thread while the carriage traverses back, and it is somewhat difficult to know just how far to move the tool in again in order to put on a proper depth of cut. To facilitate this the device shown in Fig. 585 (which is taken from the "American Machinist,") is sometimes employed.

It consists of a ring C inserted between the cross slide D and the handle hub B having journal bearing on and rotating with the latter. When the first cut is put on, the mark on C is coincident with that on D, and the ring is then, while the first cut is traversing, moved (supposing the cross feed screw to have a right-hand thread) to the left, as shown in the figure, to the amount the handle will be required to move to the right to put on the next cut, and when the next cut is put on the handle will be moved the distance it was moved to withdraw the tool for the back traverse, and in addition enough to make the marks coincide, then while the second cut is being taken the ring is again moved to the left, G. When the cut is carried along the work to the required distance the tool is withdrawn by moving D over until it rests upon stud or stop H. While the slide rest is traversing back E is lifted and B rotated so that E will fall into the next notch, and

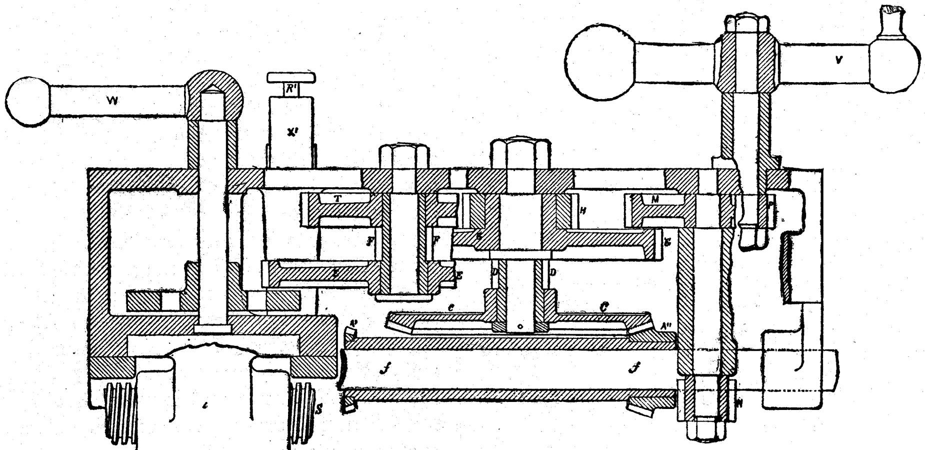

Fig. 583.

as in the cut, to give the depth of cut for the next traverse, and so on.

If the cross feed screw has a left-hand thread, the mark on the ring would require to be moved to the right instead of to the left of the mark on D. It is obvious that this answers the same purpose, but is more exact than the chalk mark before referred to, and, indeed, that chalk mark could be used in the same way, leaving the chalk mark D and rubbing out that on C while the cut is proceeding and making a new one for the next cut.

Another device for use on lathes specially designed for screw-cutting is shown in Fig. 586, in which A represents the cross feed

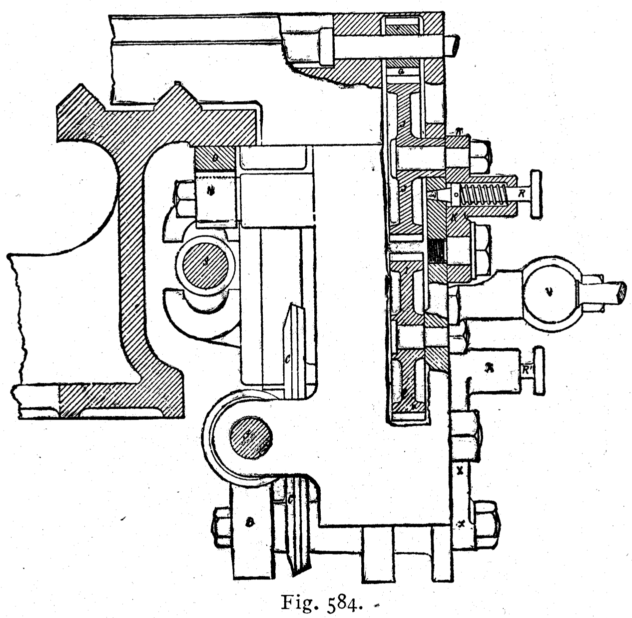

Fig. 584.

screw. It is fast to the notched wheel B, and is operated by it in the usual way. C is a short screw which provides journal bearing for the screw A by a plain hole. It is screwed on the outside, and the plate in which it fits acts as its nut. It is fast to the handle D, and is in fact operated by it. The handle or lever is provided with a catch E, pivoted in the enclosed box F, which also contains a means of detaining the catch in the notches of the wheel, or of holding it free from the same when it is placed clear. If, then, the lever D be moved back and forth the feed screw A, and hence the slide rest, will be operated; while, if the catch be placed in one of the notches on the wheel B, both the screws, A and C, will act to operate the rests. When, therefore, the tool is set to touch the diameter of the work, the catch E is lifted and the feed wheel B rotated, putting on the cut until the catch E will fall into the next notch in B, the lever D resting in the meantime on the stud when the tool starts forward again D is moved over from H to G, as shown in the figure, and the tool cut is put on.

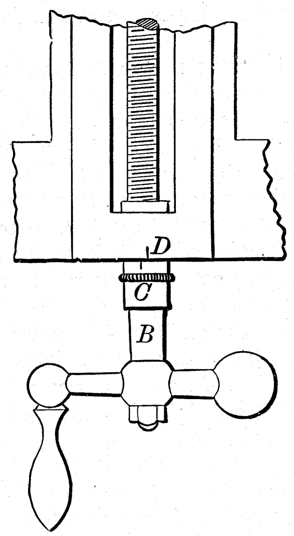

Fig. 585.

When the device is not required to be used E is thrown out, D rests on E, and the feed is operated in the ordinary manner.

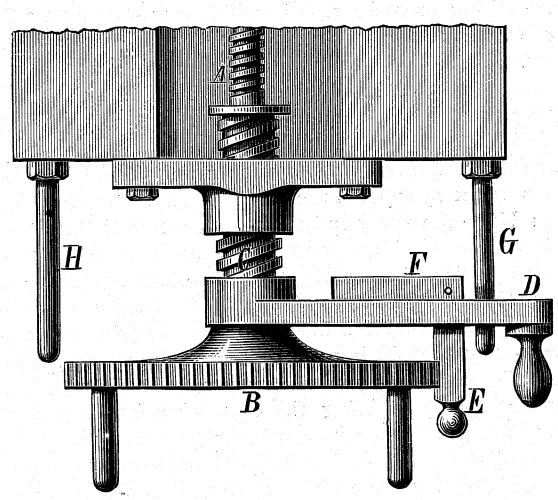

Fig. 586.

A simple attachment for regulating on a slide rest the depth of tool cut in screw cutting or for adjusting the cut to a requisite diameter when a number of pieces are to be turned to diameter by a finishing cut, is shown in Fig. 587, in which B represents the slide rest carriage, and E the cross slide on which the slide rest A is traversed by means of the cross feed screw *f*. A screw is screwed into the rest, as shown, carrying the two circular milled edge nuts R P; the screw passes an easy fit through the piece C, which is capable of being fixed in any position along the slide E by means of the set screw S; the nut R is set in such a position on the screw that it will abut against C when the tool is clear of the work surface (for the back traverse) while P may be

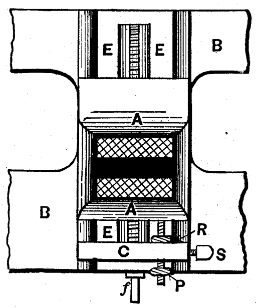

Fig. 587.

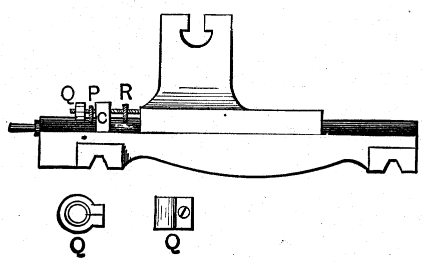

Fig. 588.

used in two ways:—First it may be set so that when it comes against C the thread is cut to the required depth, and thus act as stop to give the thread depth without trying the gauge: or it may be used to answer the same purpose and in the same way as the ring C in Fig. 585.

The use of this device as a stop to gauge the thread depth is confined to such lengths of work as enable the tool to cut several pieces without requiring regrinding, because when the tool is removed to grind it, it is impracticable to set it exactly the same distance out from the tool post, hence the adjustment of P becomes destroyed. It is better, therefore, in most cases where a number of threads of equal pitch and diameter are to be cut, to rough them all out, cutting the threads a little above the gauge diameter so as to leave a finishing cut to be taken. In roughing out, however, the nut P may still be used to regulate the depth.

For the finishing cut the tool may be ground and P adjusted to give the requisite depth of cut, taking a single traverse over each thread to finish it. This, of course, preserves the tool and enables it to finish a larger number of threads without regrinding, and the consequent readjustment of P.

It is obvious that the nut P may be employed in the same manner to turn a number of plain pieces to an equal diameter.

It is preferable in a device of this kind, however, to employ the two adjusting nuts P and Q in Fig. 588, Q being a clamp nut that can be closed by a screw so as to firmly grip the threaded stud. Q is adjusted so that when P abuts against it the tool will cut to the correct diameter when it is moved in as far as nuts P Q will permit. The use of the second nut P is as follows:—Suppose a first cut has been taken and P may be screwed up to just meet the face of clamp C. Then while the carriage is traversing, P may be screwed back towards Q sufficiently to put on the next cut, and so on, so that P is used to adjust the depths of the roughing, and Q that of the finishing cut.

Sometimes a feed motion to a slide rest is improvised by what is known as the *star feed*, the principle of action of which is as follows: Upon the outer end of the feed screw of the boring bar or slide rest, as the case may be, is fastened a piece of iron plate, which, from having the form in which stars are usually represented, is called the star. If the feed is for a slide rest a pin is fastened to the lathe face plate or other revolving part, in such a position that during the portion of the revolution in which it passes the star it will strike one of the star wings, and move it around sufficiently to bring the next wing into position to be struck by the pin during its succeeding revolution. When the feed is applied to a revolving boring bar the construction is the same, but in this case the pin is stationary and the star revolves with the feed screw of the bar.

In Fig. 589 is shown a star feed applied to a slide rest. A is the slide rest, upon the end of the feed screw of which the star, B, is fitted. C is a pin attached to the face plate of the lathe, which, as it revolves, strikes one of the star wings, causing it to partly rotate, and thus move the feed screw. The amount of rotation of the feed screw will depend upon the size of the star and how far the circle described by the pin C intersects the circle described by the extreme points of the star wings. Thus the circles denoted by D E show the path of the pin C; the circle F H the path of the star points, and the distance from F to G the amount which one intersects the other. It follows that at each revolution of C an arm or wing of the star will be carried from the point G to point F, which, in this case, is a sixth of a revolution. If more feed is required, we may move the pin C, so that it may describe a smaller circle than D E, and cause it to intersect F H to a greater extent, in which case it will move the star through a greater portion of its revolution, striking every other wing and doubling the amount of feed.

It will be observed that the points F and G are both below the horizontal level of the slide rest's feed screw, and therefore that the sliding motion of the pin C upon the face of the star wings will be from the centre towards the points. This is better, because the motion is easier and involves less friction than would be the case if the pin contact first approached and then receded from the centre, a remark which applies equally to all forms of gearing, for a star feed is only a form of gearing in which the star represents a tooth wheel, and the pin a tooth in a wheel or a rack, according to whether its line of motion is a circle or a straight line.

It is obvious that in designing a star feed, the pitch of the feed screw is of primary importance. Suppose, for example, that the pitch of a slide rest feed screw is 4 to an inch, and we require to

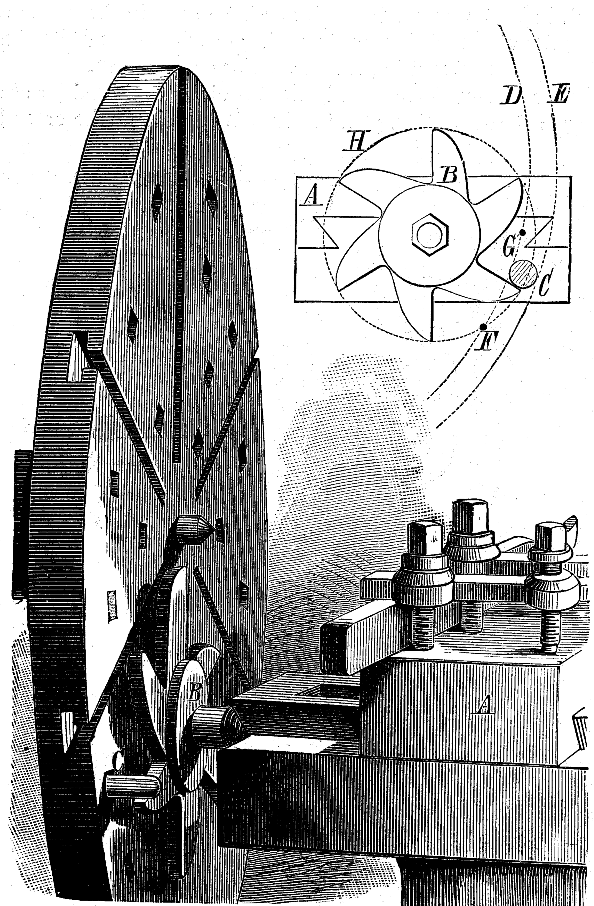

Fig. 589.

feed the tool an inch to every 24 lathe revolutions; then the star must have 6 wings, because each revolution of the screw will move the rest $\frac{1}{6}$ in., while each revolution of the pin C will move the star $\frac{1}{6}$ of a revolution, and $4 \times 6 = 24$. To obtain a very coarse feed the star attachment would require to have two multiplying cogs placed between it and the feed screw, the smaller of the cogs being placed upon the feed screw.

In many lathes of European design, the feeds or some of them, are actuated by ratchet handles, operated by an overhead shaft, having arms which rock back and forth. Thus in Fig. 590 is a lathe on which there is provided at A a crank disc, carrying in a dovetail slot a pin P, for rocking the overhead shaft from whose arms a chain is attached which may be connected to the ratchet handle shown on the cross-feed screw, the weight being for the purpose of carrying that handle down while the chain pulls it up. To regulate the amount of feed the pin P is adjusted in the slot in A, or the chain may be attached in different positions along the length of the ratchet arm, the weight being provided with a set screw so that it may be set in any required position along the ratchet arm.

TOOL-HOLDING DEVICES.—Perhaps no part of a lathe is found in American practice with so many different forms of construction as the device for holding the cutting tool. The requirements for a lathe to be used on light work and where frequent changes in the position of the tool are necessary, are quite different from those for a lathe intended to take as heavy a cut as the lathe will properly drive, and wherein tools having the cutting edge at times standing a long way out from the tool post (as sometimes occurs in the use of boring tools). In the former case a single holding screw will suffice, possessing the advantage that the tool may be quickly inserted, adjusted for height and set to one

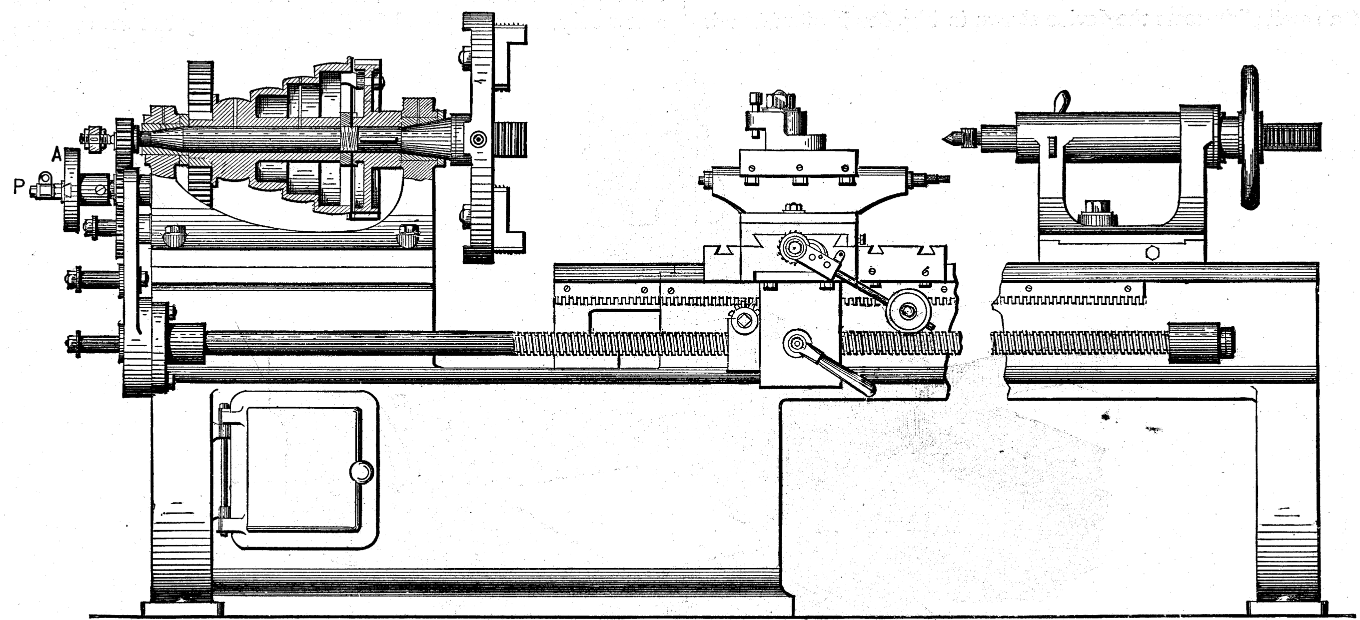

Fig. 590.

side or the other, with a range of motion which often permits of a tool that has taken a parallel cut being moved in position to capacitate it to take a facing one, which would not be the case were its capacity for side adjustment limited.

In the case of the common American lathe having a self-acting feed and no compound rest, the tool post is usually employed, the rest being provided with a T slot such as shown in Fig. 577. This enables the tool post to be moved from side to side of the tool rest, and swing around in any required position. In connection with such tool posts various contrivances are employed to enable the height of the cutting edge of the tool to be readily adjusted. Thus in the Fig. 591, the tool post is surrounded by a cupped washer W, and through the slot in the tool post passes a gib G, which may be moved endways in the slot and thus elevates or depresses the tool point.

The objection to this is that the tool is not lifted parallel, or in other words is caused to stand out of its proper horizontal position which alters the clearance of the tool, and by presenting the angles forming the tool edge in an improper position, with relation to the work, impair its cutting qualification, as will be shown hereafter when treating of lathe cutting tools.

An improvement on this form has been pointed out by Professor John E. Sweet, whose device is shown in Fig. 592. Here the washer or ring is rounded and the bottom surface of the gib is hollowed, so that chips or dirt will to a great extent fall off, and every time the tool post is swung the gib acts to push off whatever dirt may lodge on the washer.

In the design shown in Fig. 593, the tool rests upon two washers W that are tapered, and its height is adjusted by revolving one of these washers, it being obvious that the limit of action to depress the tool point is obtained when the two thin sides of the washers are placed together, and on the same side of the tool post as the cutting edge of the tool, while the limit of action to raise the tool point is obtained when the washers have their thick sides together and nearest to the tool point.

Here again the tool is thrown out of level, and to obviate this difficulty the stepped washer shown in Fig. 594 may be used, the steps on opposite sides of the washer being of an equal height. This enables the tool to be raised or lowered without being set out of the horizontal position; but it has the defect that the adjustment cannot be made any finer than the height of the steps, and if the height is made to vary but slightly, in order to refine, as it were, the adjustment, the range of tool elevation or depression is correspondingly limited. Another form of stepped washer is shown in Fig. 595, in which no two steps are of the same height. This affords a wider range of adjustment, because the same two steps will alter the height of the tool by simply turning the washer one-half revolution. It has two defects, however; first, the least amount of adjustment is that due to the difference in height of the steps; and, second, when the tool is elevated it grips the washer at A, so that the tool is not supported across the full width of face of the washer, as it should be.

A defect common to all devices in which the tool is thrown out of level, is that the binding screw does not bed fair upon the tool, and as a result it is apt, if screwed home very firmly, as is necessary to hold boring tools that stand far out from the tool post, to spread the screw end as in Fig. 596, or to bend it.

A very convenient tool-adjusting device is shown in Fig. 597. It consists of a threaded ring N receiving the threaded bush M, the tool height being adjusted by screwing or unscrewing one within the other.

The objection to this is, that it occupies so much vertical height that there is not always room to admit it, which occurs, for example, in compound slide rests on small lathes.

On these rests, therefore, a single washer is more frequently used, which answers very well when the tool post is in a slot, so that it can be moved from side to side of the rest as occasion may require. When, however, the position of the tool post is fixed it has the disadvantage that the point P, Fig. 598, where the tool takes its leverage, is too far removed, and the tool is therefore liable to bend or spring from the pressure of the cut.

In Fig. 599 is an elevating device sometimes used on the compound rests of large lathes. The top of the rest is provided with a hub H, threaded externally to receive a ring nut R, around whose edge there are numerous holes to receive a pin for operating the nut. The tool-post is situated central in the hub. When the tool is loose the ring nut can be operated by hand or the tool may be gripped lightly and the ring nut operated by a pin. The

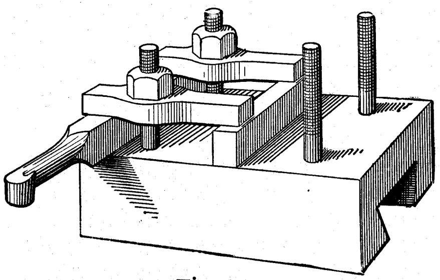

Fig. 607.

level of the tool is here maintained; it is supported to about the edge of the rest on account of the large diameter of the ring nut, and a very delicate adjustment for height can be made, but such a device is only suitable for large lathes on account of the depth of the ring nut and hub.

On small slide-rests the device shown in Fig. 600 is often found. It consists of a holder H, in which is cut a seat for the tool, this seat being inclined to give the piece of steel used as a tool a certain constant degree of angle, and at the same time to permit of the tool being moved endwise in the holder to set it for height; but, as the tool requires to be pushed farther and farther through the holder to raise it, it is not so well supported as is desirable when slight tools are used, unless the holder is made long, so as to pass through the tool post with the tool. Again, it does not support the tool sideways unless the tool steel is dressed up and closely fits the groove in the holder.

In Fig. 601 W W are two inverted wedges which afford an accurate adjustment, but the range is limited, because if the wedges have much taper they are apt to move endways when the tool is fastened.

A convenient device for the compound rests of small lathes is shown in Fig. 602. It consists of a holder pivoted upon a central post and carrying two tool-binding screws, hence it can be revolved to set the tool in any required position. A similar device is shown in Fig. 603, in which the central post is slotted at A to receive the tool, and also carries a plate C, held by the nut N, and provided with tool-holding screws B and B′, which abut against the top of the rest, a top view of the device being shown in Fig. 604. Plate C may thus be swung around to set the tool in any required position on either side of the rest.

In Maudslay's slide rest, the tool clamp shown in Fig. 605 is employed. Screws A are employed to grip the tool moderately firm, and a turn of screws B (whose ends abut against the top of the slide rest) very firmly secures the tool, since it moves the clamp C as a lever, whose fulcrum is the screw A.

Figs. 606 and 607 represent the Whitworth tool clamp, the clamping plates of which change about upon the four studs, and are supported at their inner ends by a block equal in height to the height of the tool steel.

Figs. 608, 609, 610, and 611 represent the "Lipe" tool post, so called from the name of its inventor. The top of the cross slide is cylindrical, and is bored to receive the tool post which has a cylindrical stem. The cylindrical part of the tool post is split vertically, and has two lips, the bolt D passing through one lip and threading into the other, so that by operating bolt D the tool post may be gripped very firmly or released, so that it may be revolved to bring the tool into any required position after it is fastened in the tool post, which is a great advantage because the tool is brought to a solid seating in the post before its height is adjusted, and will not therefore be altered in height by setting up the set screws as often occurs in ordinary tool posts. From the shape of the tool post, the tool may be gripped by one set screw only, when required for light duty, or by two set screws for heavy duty or for boring, while in either case it is supported clear to the edge of the rest.

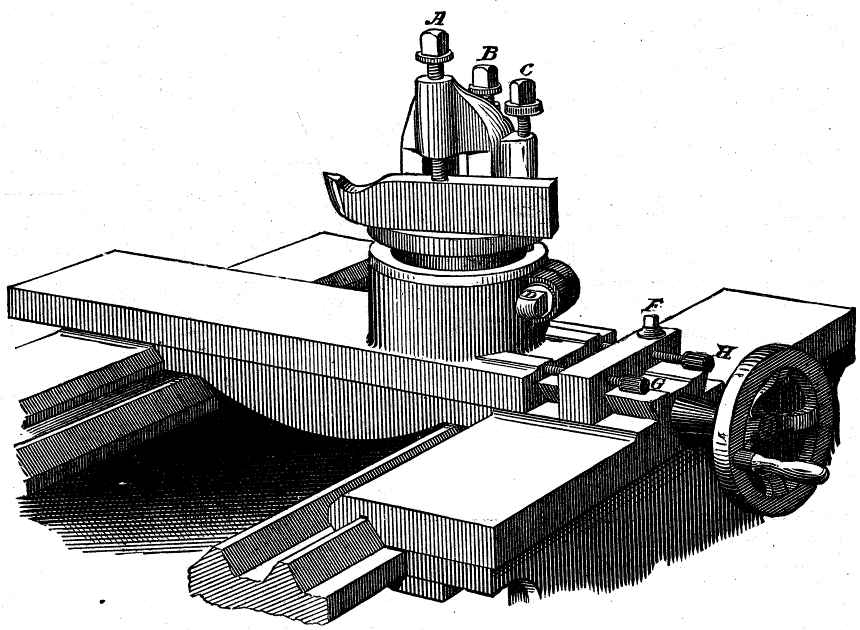

Fig. 608.

Fig. 608 shows the tool in position, held by a single screw, for work requiring the tool to be close up to the work driver. In Fig. 609 a tool is shown held as is required by work between centres, but both set-screws are used. Fig. 610 shows a tool in position for boring, two set-screws being used. Fig. 611 shows a tool being held for the same purpose, but by a single screw, and it will be observed that the advantage of the second set-screw is obtained without in any way sacrificing the handiness of the post, when used with a single screw. Whether one or two set-screws are used, the boring tool may be forged from a single bar of octagon steel, which can be seated in a piece like that shown at E in Fig. 610, which is grooved so as to receive and hold the tool. As is well known, boring tools are the most troublesome both to forge and to adjust in the lathe, and, as the result, a light tool is often used because no other is at hand and it is costly to make a new one. When, however, the tool can be forged from a plain piece of steel, these objections are overcome, and a sufficient number of tools may be had so that one can always be found suitable for any ordinary sized hole, the object being to use as rigid a tool as can be got into the hole bored.

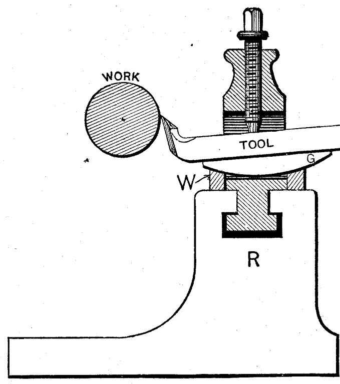

Fig. 591.

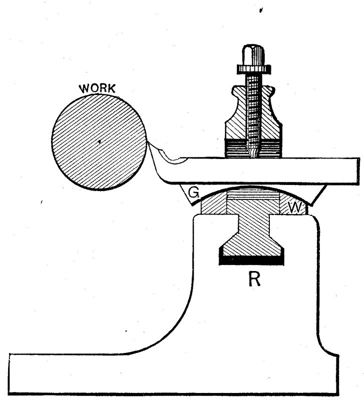

Fig. 592.

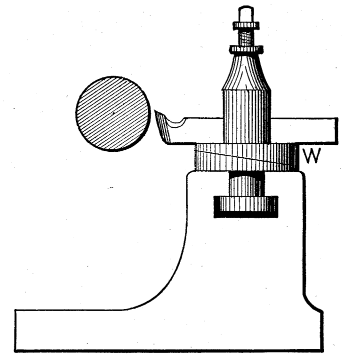

Fig. 593.

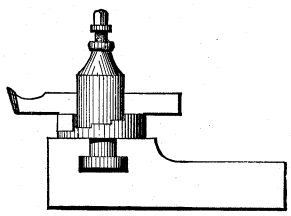
Fig. 594.

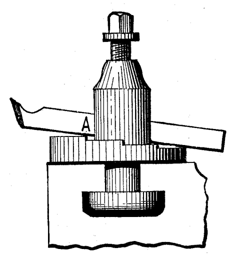

Fig. 595.


Fig. 596.

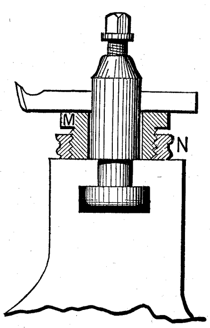

Fig. 597.

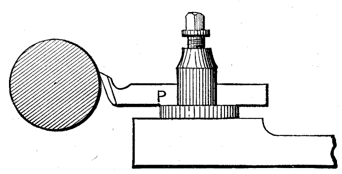

Fig. 598.

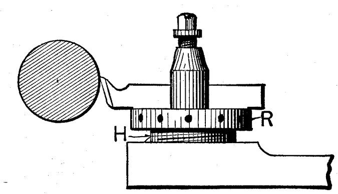

Fig. 599.

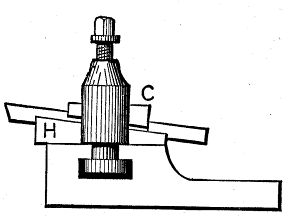

Fig. 600.

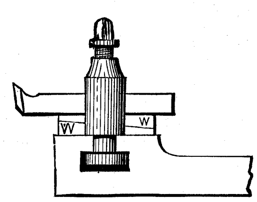

Fig. 601.

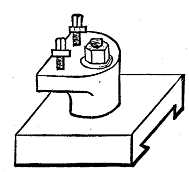
Fig. 602.

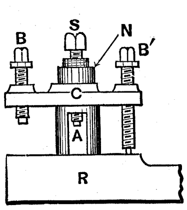

Fig. 603.

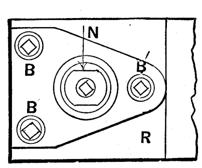

Fig. 604.

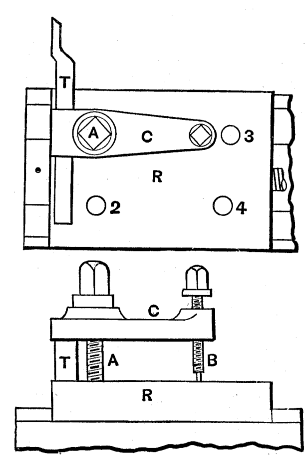

Fig. 605.

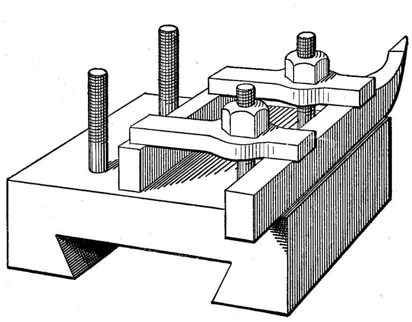
Fig. 606.

The feature of maintaining the tool level is of great importance in boring work, because when the tool requires to be set out of level to adjust its height, it will generally strike against the mouth of the hole if the latter is of much depth. This annoyance is also frequently met with in boring tools which are forged out of rectangular steel, because the rounded stem is generally left taper. The largest end of the taper is generally nearest the tool post. Hence the capacity to use octagon steel and keep it level while adjusting its height, added to the fact that the tool is supported clear to the edge of the tool rest, and the tool post is so blocked as to virtually become a part of the rest, constitute a very important advantage.

A common device on large lathes is shown in Fig. 612, the two clamps being shown in position for outside turning, and being changed (so as to stand at a right angle to the position they occupy in the figure) for holding boring tools. The bolts are enveloped by spiral springs which support the clamps.

Figs. 613 and 614 represent the tool holders employed in the Brown and Sharpe small screw machines. In the front rest, Fig. 613, the piece R receives two adjusting and tool-gripping screws S, upon which sits the gib G, and upon this the tool is placed. The surface E at the top of the tool post slot is curved so that it will bear upon the top of the tool at a point only. The tool is here supported along the full length of the gib, and there is no set-screw at the top of the tool post, which enables a much more unobstructed view of the tool.

Fig. 614 is the tool post used at the back of the rest, the piece B passing through the tool post slot. The tool rests upon the top of screw E and upon the top of B at F, and is secured by set-screw S; its height is therefore adjusted by means of screw E, which is threaded in B. The set-screw S is not in this case objectionable, because it is at the back of the rest, and therefore does not obstruct the view of the work, while it is at the same time convenient to get at.

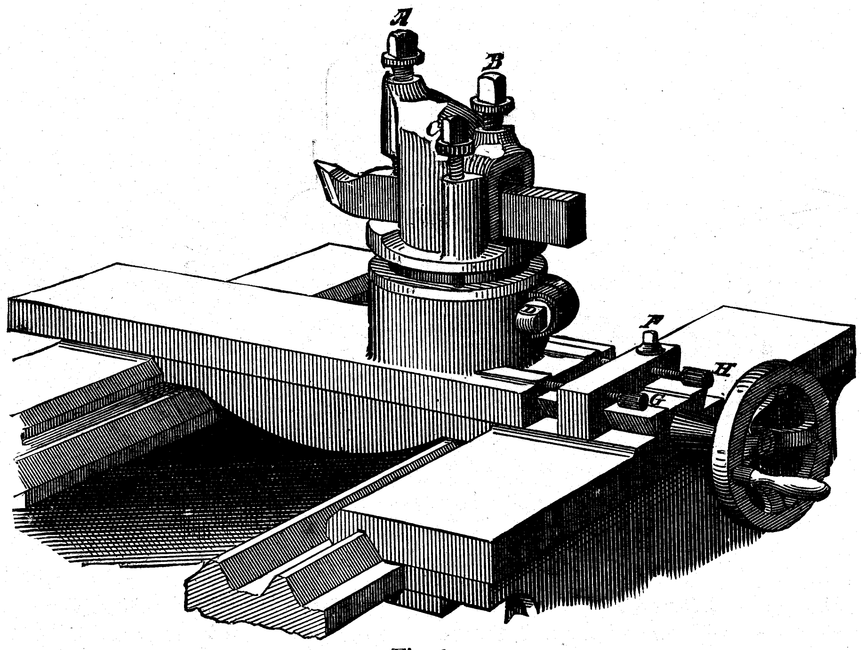

Fig. 609.

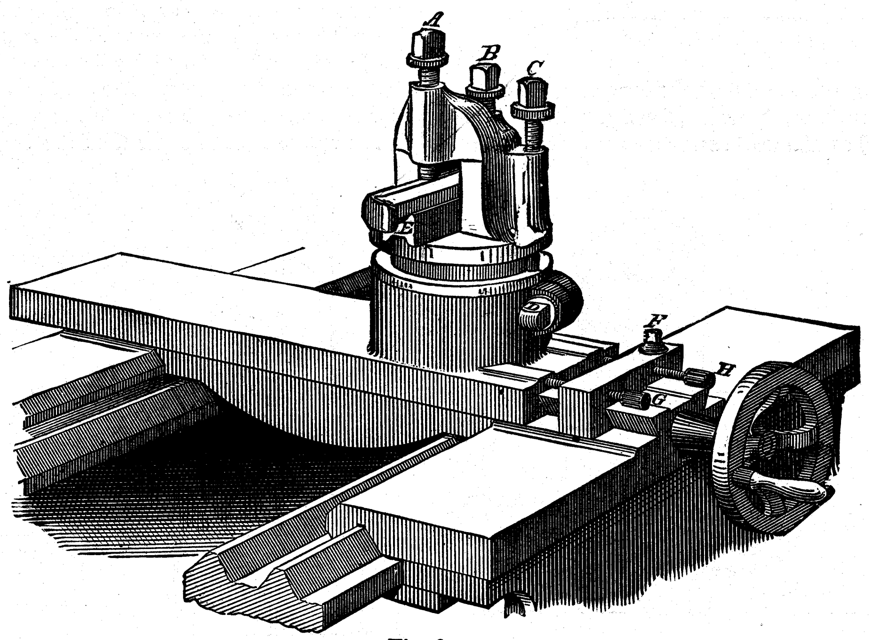

Fig. 610.

When the screw for traversing a lathe carriage is used for plain feeding, it is termed the feed screw, but when it is used to cut threads it is termed the lead screw.

A lead screw should be used for screw cutting only, so that it may be preserved as much as possible from wear. As the greater portion of threads cut in a lathe of a given size are short in comparison with the length of the lathe, it follows that the part of the lead screw that is in operation when the carriage or saddle is traversing over short work is most worn, while the other end is least worn, hence it is not unusual to so construct the screw and its bearings that it may be changed end for end in the lathe, to equalize the wear. By turning a lead screw end for end, therefore, to equalize the wear, the middle of the length of the screw will become the least worn, and, therefore, the most true. Hence it is better to use one end of the lead screw for general work, and to reverse it and use the other end only for screws requiring to be of very correct pitch.

To obviate the wear as much as possible the feed nut should embrace as great a length of the screw as convenient, and should be of a material that will suffer more from wear than the lead screw, or in other words shall relieve the feed screw from wear as much as possible. The wear on the nut being equal from end to end, the wearing away of one side of its thread does not vary its pitch; hence the only consideration as to its wearing qualification are the expense of its renewal and the length of time that may occur between its being engaged with the lead screw and giving motion to the lathe carriage, this time increasing in proportion as the nut thread is worn. Under quick speeds or when the lathe is in single gear, the rotation of the feed screw is so quick that not much time is lost before the carriage feeds, but when the back gear is in operation at the slowest speeds, the loss of time due to a nut much worn is an item of importance.

In some lathes the feed screw is employed for screw cutting and for operating an independent feed also. This is accomplished by cutting a feather way or spline along it, so that a worm having journal bearing in the apron of the rest carriage may envelop the lead screw and be driven by it, through the medium of a feather fast into the worm gear. The motion obtained from the worm gear is transferred through suitable gearing to the rack pinion.

The spline is cut deeper than the thread, so as to prevent the latter as far as possible from wear, by reason of the friction of the spline.

The lead screw if long should be supported, to prevent its sagging of its own weight. In some cases the lead screw is sup-

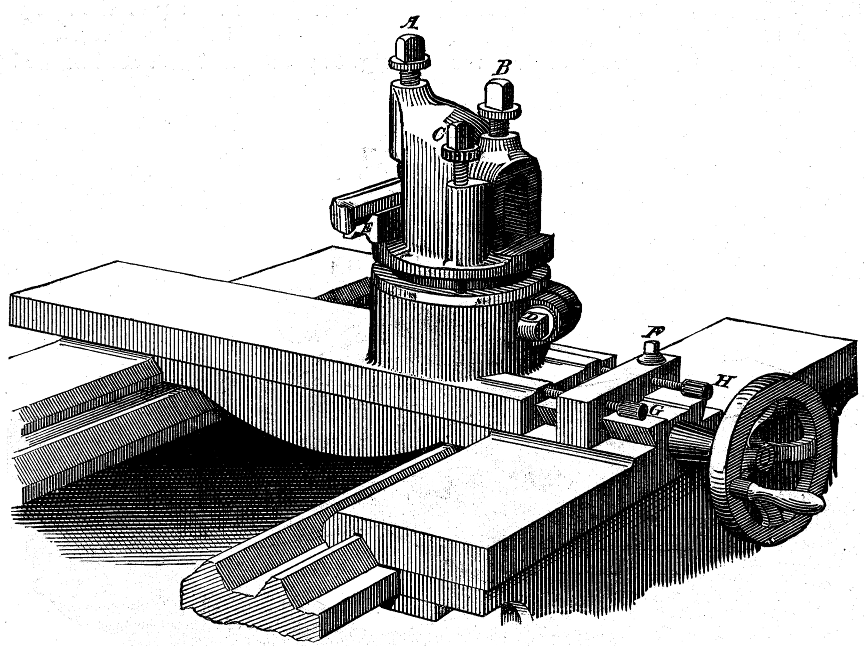

Fig. 611.

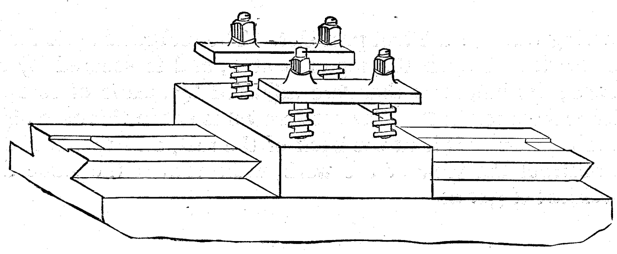

Fig. 612.

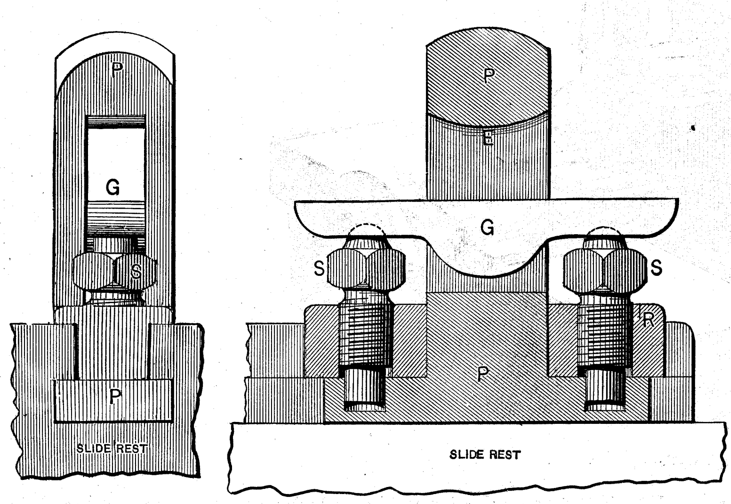

Fig. 613.

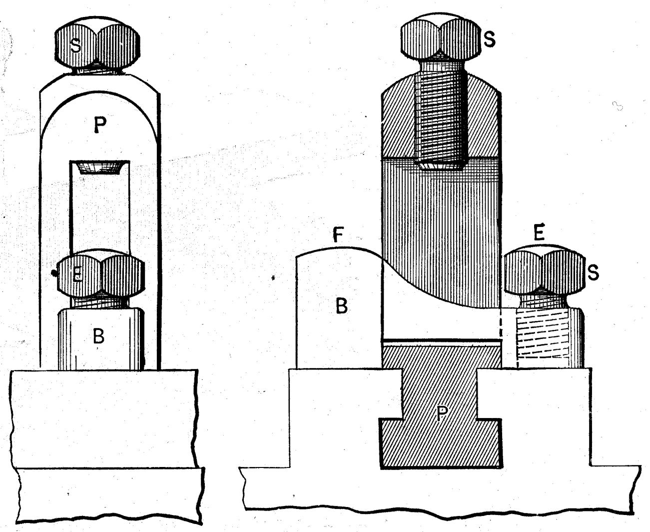

Fig. 614.

ported in a trough along its whole length, as is done in the Sellers lathe. In other cases, bearings hanging from the **V**-slides, and movable along the bed, are employed.

It is desirable that the feed screw and nut be as near the middle of the carriage as possible, so that it shall pull the carriage at as short a leverage as possible, thus avoiding the liability to tilt or twist the carriage; but it is not practicable to place it midway between the lathe shears, because in that case the cuttings, &c., from the work would fall upon it, and cause excessive and rapid wear of the screw and nut.

In general the lead screw is located either in front, or at the back of the lathe, and in considering the more desirable of the two locations, we have as follows:

The feed nut should obviously remain axially true with the lead screw, as by reason of the extra weight of the front of the carriage, both it and the lathe shears wear most at the front, and the carriage, therefore, falls to the amount of its own wear and the wear of the shears. If the lead screw is used to feed with (as usual form, or with threads whose sides have about fifteen degrees of angle, so that the two halves of the feed nut may be let together to take up the wear. It is obvious that in a **V**-thread or in a thread whose sides are at an angle, the feeding strain tends to force the two halves of the feed nut apart, and therefore places a strain on the feed-nut operating mechanism that does not exist in the case of a square thread. Furthermore it can be shown that with a **V**-thread the opportunities to lock the carriage on a wrong place, after traversing it back by hand in screw cutting, are increased, thus augmenting the liability to cut intermediate and improper threads.

In Fig. 615, for example, we have a pitch of lead screw of three threads per inch, and the gears arranged to cut six threads per inch on the work. As the bottom wheel has twice as many teeth as the top one, it is clear that, while the top one makes one, the bottom one will make half revolution, and the lead screw will make half a turn for every turn the work makes. Now, suppose the tool point to stand opposite to space A, and the nut (supposing it to

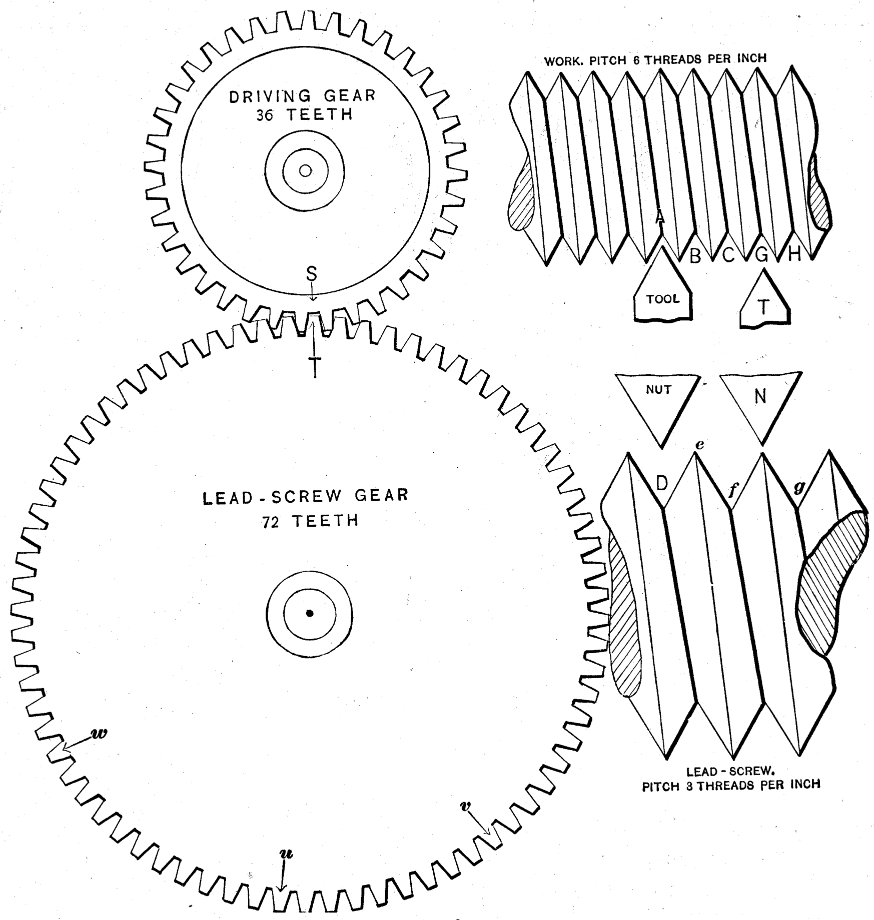

Fig. 615.

it should not be), the nut wears coincidently with the carriage and the shears, and the screw alignment is not impaired; but with an independent feed, only a small portion of the carriage traversing is done with the lead screw, hence the carriage lowers from the wear due to the independent feeding, and when the lead screw comes to be used its nut is not in true alignment with it. It is obviously preferable, then, to place the lead screw at the back, where the carriage and shears wear the least. Furthermore, this relieves the carriage front from the weight of the nut, &c., tending to equalize the back and front wear, while removing the nut-operating device from the front to the back of the shears, and thus reducing the number of handles in front, and thus avoid complication in small lathes.

LATHE LEAD SCREWS.—Lead screws have their pitches in terms of the inch throughout all parts of the world; or, in other words, the lead screws of all lathes contain so many full threads per inch of length.

Lead screws are usually provided with square threads of the have but one thread only, which is all that is required for our purpose), stand opposite to space D. Suppose, further, that the lathe makes one revolution, and space B on the work will have moved to occupy the position occupied by space A, or, rather, there will still be a place at A fully in front of the tool, as should be the case, but the lead screw will have made half revolution, the top *e* of the thread coming opposite to the feed nut, as in the position of tool and nut shown in the figure at T and N; hence the nut would not engage, without moving the lathe carriage sideways, and thus throwing the tool to one side of the thread in the work. When, however, the work had made another revolution, both the feed screw and the work would again come into position for the tool and nut to engage properly, and it follows that in this case the tool will always fall into proper position for the nut to be locked.

It is obvious, however, that had the lead screw thread been a square one, and the nut thread to accurately fit to the lead screw thread, so as to completely fill it, then the nut could not engage with the lead screw until the lathe had made a complete revolution, at which time the work will have made two full or complete revolutions, and the tool would, therefore, fall into proper position to follow in the groove or part of a thread cut at the first tool traverse.

In Fig. 616, we have the same lead screw geared to cut five or an odd number of threads per inch. The tool and the nut are shown in position to properly engage, but suppose, the nut being disengaged, that the work makes one revolution, and during this period the lead screw will have made $\frac{3}{5}$ths of a revolution, hence the nut will not be in position to engage properly, because, although space B will have travelled forward so as to occupy the position of space A in the figure (that is, there will be a space fairly in front of the tool point), yet the nut will not engage properly, because the nut point will not be opposite to the bottom of the lead screw thread. When the work has made its second revolution, and space C moves to the position occupied by A, the lead screw will have made $\frac{6}{5}$ or $1\frac{1}{5}$ revolutions, and the nut cannot engage properly; when the lathe has made its third revolution, the lead screw will have made $1\frac{4}{5}$ revolutions and the nut will still fall to one side of the thread space, and will not lock properly. The work having made its fourth turn, the lead screw will have made $2\frac{2}{5}$ turns, and the nut will not be in position to lock fairly. The work having made its fifth turn, however, the lead screw will have made three turns, and the threads will fall into the same position that they occupy in the figure, and both tool and feed nut will fall into their proper positions in their respective threads. It does not follow, however, that, the lead screw having a V-shaped thread, the nut cannot be forced to engage but once in every five turns of the lead screw, because, were this the case, it would be impossible to lock the nut in an improper position.

Suppose, for example, that we have in Fig. 617, the same piece of work and lead screw as in Fig. 616, and that a first groove, A, has been cut with the tool in the position shown, and the nut engaged in the position marked 1. Now, suppose the nut be disengaged and the work allowed to make one revolution, then the lead screw will, during this revolution, revolve $\frac{3}{5}$ of a revolution, and the position of the nut point with relation to the lead screw will be as at position 2. If, then, the nut was forced into the lead screw thread, it would, acting on the wedge principle, move the carriage to the right sufficiently to permit the nut to engage fully in thread G, and the tool would then cut a second groove on thread B. If the nut then be withdrawn from thread G, and the work allowed to make another revolution, the nut will stand in a precisely similar position with relation to the lead screw thread as it did in position 2, and by forcing it down into thread H the carriage would be again forced to the right, causing a third thread, C, to be cut. By repeating the operation of withdrawing the nut, letting the work make another revolution and then engaging the nut again, it will seat in thread K, and a fourth thread D will be cut. On again repeating the operation, however, the nut will come into position 5, and, on being drawn home into thread, or, rather, into space L, the tool will fall into groove A again. Thus there will be four threads, each having a pitch equal to that of the lead screw. The second (B) of these four will fall to the left of thread A to an amount or distance equal to $\frac{2}{5}$ of the pitch of the lead screw, because, in forcing the nut from position 2 down into the lead screw, the slide rest, and therefore the tool, will be moved to the right $\frac{2}{5}$ of the pitch of the lead screw. The third thread C will fall to the left of thread B also to an amount equal to $\frac{2}{5}$ of the pitch of the lead screw, because, in forcing the thread to seat itself into thread H from position 3, the slide rest was again moved (to that amount) to the right. The fourth thread D will fall to the left of thread C to the same amount and for the same reason.

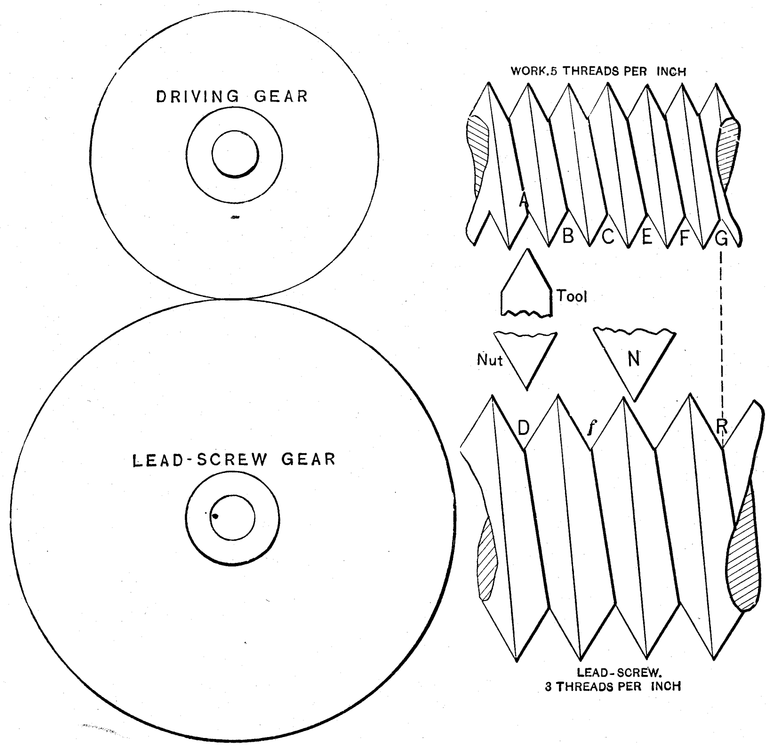

Fig. 616.

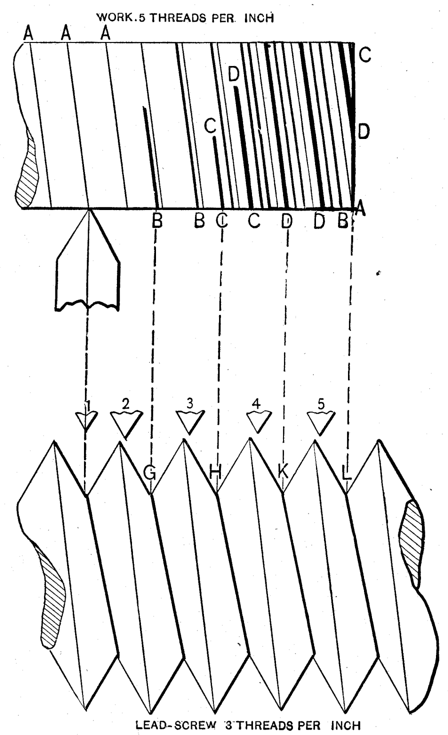

Fig. 617.

But in this case, as before, if the lead screw had a square thread and the nut threads completely filled the spaces between the lead screw threads, then the nut could not engage at the 2nd, 3rd, or 4th work revolution, hence the false threads B, C, and D, could not have been cut, even though the feed nut was disengaged and the lathe carriage was traversed back by hand.

Now, suppose that two threads on the work measure less than the amount the lead screw advances during the time that the work makes a revolution, and if the lead screw has a V-shaped thread, the case is altered. We have, for example, in Fig. 618, a pitch of lead screw of 3 to cut 12 and 13 threads respectively. In the case of the 13 threads it will be seen that, supposing there to have been a first cut taken on the work, and the feed nut to be disengaged while the work makes a revolution, then the lead screw will revolve $\frac{3}{13}$ revolution and the point A on the lead screw will have moved up to point B, and the nut point remaining at N, seating it in the thread, would cause it to engage with the same thread that it did before, and no second thread would be cut. If the nut be then released, the work allowed to make another revolution and the nut again closed, the operation would be the same as before, and no error would be induced, and so on. Suppose, further, that after the nut was disengaged the lathe was permitted to make two revolutions, and the lead screw would make $\frac{6}{13}$, or less than half a turn, and closing it would still cause it to pass back into the same thread on the lead screw and produce correct work. But if after the nut was released the work made three turns, the lead screw would make $\frac{9}{13}$ of a turn, and the nut would fall on the right-

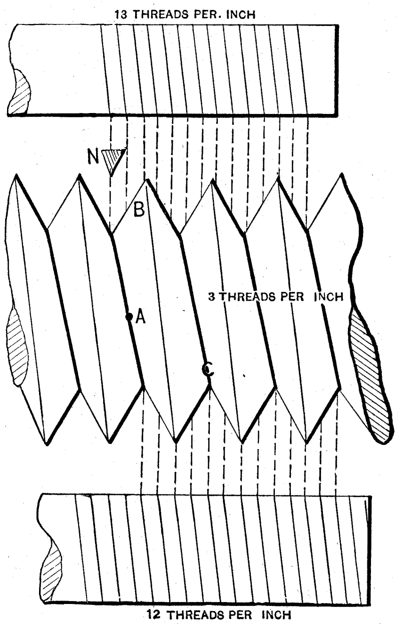

Fig. 618.

hand side of the lead screw thread, and in closing would move the lathe carriage to the right, causing the tool to cut a second thread. Now, the same operation that occurred with the first thread would during the next three trials occur with the second thread, and at the next or seventh trial a third thread would be cut, which would be again operated upon during the next succeeding three trials. At the eleventh trial a fourth thread would be cut, but on the next three trials the tool would again fall into the groove first cut and the work proceed correctly. In the case of the 12 threads, the thread cut at the first and second trials would be correct. At the third trial the nut would seat itself in the groove C of the lead screw, causing the carriage to move to the right to a distance equal to twice the pitch of thread being cut, but the tool would still fall into the same groove in the work, as it also would on the fourth. At the fifth trial the process would be repeated, and so on, so that no second thread would be cut.

It may now be noted that if we draw the lead screw and the thread to be cut as in the figure, and draw the dotted lines shown, then those that meet the bottom of the thread on the lead screw, and also meet the groove cut on the work, at the first trial, represent the cases in which the nut will fall naturally into its proper position for the tool to fall into the correct groove, while whenever the nut is being forced home it seats in a groove in the lead screw, the bottom of which groove meets a line drawn from the first thread cut; the results obtained will be made correct by reason of the movement given to the slide nut when artificially seating the nut. This is shown to be the case in Fig. 619, which represents a lead screw having an even number of threads per inch, and from which it appears that in cutting 12 threads (an even number also) the nut cannot be engaged wrong, whereas in the case of 13 threads it can be engaged right three times in 13 trials, and 10 times wrong, the latter causing the tool to cut three wrong threads.

To prevent end motion of a lead screw it should have collars on both sides of one bearing, and not one at each bearing. By this means the screw will be permitted to expand and contract under variations of atmospheric temperature, without binding against the bearing faces.

When a lead screw is long it requires to be supported, otherwise, either its weight will be supported or lifted by the feed nut in gear, or if that nut does not lift the screw, the thread cut will be finer than that due to the pitch of the lead screw, by reason of its deflection or sag.

A lead screw should preferably be as near as possible to the middle of the lathe shears, and as close to the surface as possible, so as to bring it as nearly in line with the strain on the tool as possible, but on account of the cuttings, which falling upon the screw would cause it to wear rapidly, it is usual to locate it on one side, so as to protect it from the cuttings. It is better to locate it on the front side of the lathe rather than on the back, because the strain of the cut falls mainly on the front side (especially in work of large diameter when this strain is usually greatest) and it is desirable to pull the carriage as near in a line with the resistance of the cut as possible, because the farther off the feed nut from the cutting tool point, the greater the tendency to twist the carriage on the shears.

To preserve the nut from wear, it should be made as long as convenient, as, say, five or six times the diameter of the lead screw; it is usually made, however, three or four diameters,

It is obvious that the pitch of the thread should be as accurate as possible, but it has not as yet been found practicable to produce a screw so accurate that it would not show an error, if sufficient of its length be tested, as, say, several feet.

If the error in a screw be equal, and in the same direction at all parts of its length, various devices may be employed to correct it. Thus Fig. 620 represents a device employed by the Pratt and Whitney Co.

It was first ascertained by testing the lathe that its lead screw was too short by $\frac{7}{100}$ths of a revolution in a length of 2 feet, the pitch of its thread being 6 to an inch. Now in 2 feet of the screw there would be 144 threads, and since $\frac{7}{100}$ths (the part of a revolution the thread was too short) $\times \frac{1}{6}$ (the pitch of the thread) $= \frac{7}{600}$ths (which was called $\frac{1}{85}$th), the error amounted to $\frac{1}{85}$th inch in 144 turns of the screw. The construction of the device employed to correct this error is as follows: In Fig. 620, A represents the bearing of the feed screw of the lathe, and B *b* a sleeve, a sliding fit upon A, prevented from revolving by the pin *h*, while still having liberty to move endways. C represents a casing affording

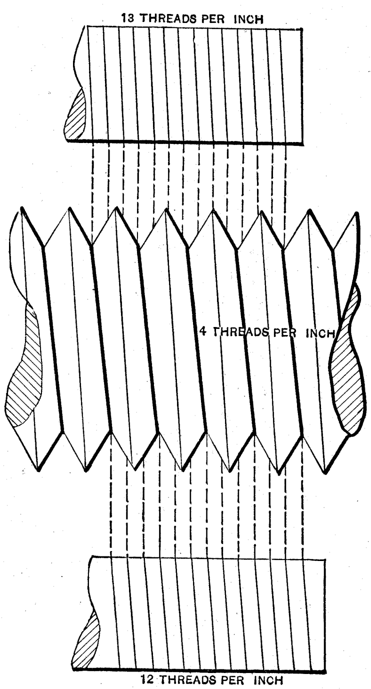

Fig. 619.

journal bearing to B *b*, having a fixed gear-wheel at its end C′, and an external thread upon a hub at that end. D is the flange of C to fasten the device to the shears of the latter, being held by screws. E represents an arm fast upon the collar of the feed screw, and carrying the pinion F, the latter being in gear with the pinion C′, and also with G, which is a pinion containing two internal threads, one fitting to B at *b*, and the other fitting to C at *c*, the former having a pitch of 27 threads to an inch, the latter a pitch of 25 to an inch.

The operation is as follows :—The ordinary change wheels are connected to the feed screw, or lead screw, as it is sometimes termed, at J in the usual manner. The arm E being fast to the feed screw will revolve with it, and cause the pinion F to revolve around the stationary gear-wheel C′. F also gears with G. Now, F is of 12 diametrical pitch and contains 26 teeth, C′ is of 12 diametrical pitch and contains 37 teeth, and G is of 12 diametrical pitch and contains 36 teeth. It follows that the pinion F, while moving around the fixed gear C′, will revolve the pinion G (which acts as a nut), to an amount depending upon the difference in the number of its teeth and those of fixed gear C′ (in this case as 36 is to 37), and upon the difference in the pitches of the two threads, so that at each revolution G will move the feed screw ahead of the speed imparted by the change gears, the end of the sleeve B abutting against the collar of the feed screw to move it forward.

In this case there are 36 turns of the feed screw A for one turn of the nut pinion G, the thread on sleeve B being 27, and that on the hub of C being 25 to the inch ; hence, 36 turns of the feed screw gives an end motion to the sleeve B of $\frac{1}{25}$ minus $\frac{1}{27}=\frac{2}{675}$, and $\frac{1}{36}$ of that$=\frac{1}{12150}$ of an inch = the amount of sliding motion of the sleeve *b*, for each revolution of the lathe feed screw. By varying the proportions between the number of teeth in C′ and G and the pitches of the two threads in a proper and suitable ratio, the device enables the cutting of a true thread from any untrue one in which the variation is regular.

It is usual to fasten to the side of the lathe head stock a brass plate, giving a table of threads, and the wheels that will cut them, and obviously such tables vary according to the pitch of the lead screw, but a universal table may be constructed, such as the following table (prepared by the author) that will serve for any lathe.

At the top of the table is the number of teeth in wheels, advancing by four from 12 to 80 teeth, but it may be carried as

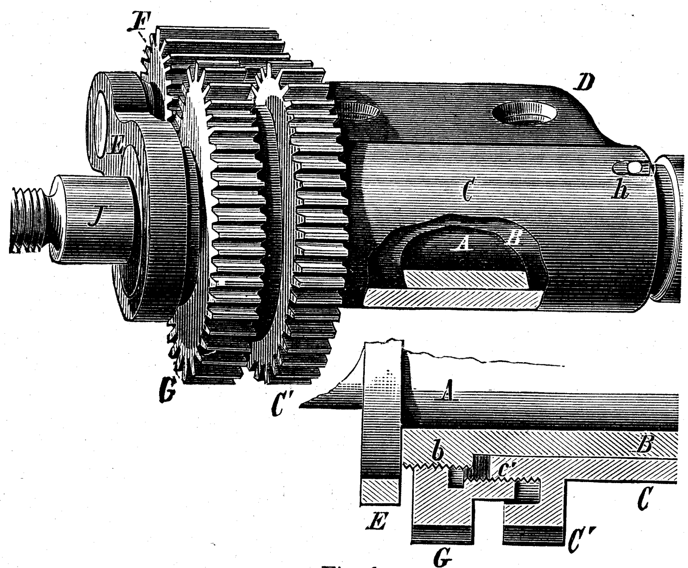

Fig. 620.

much beyond 80 as desired. On the left hand of the table is a column of the same wheels. At the bottom of the scale are pitches of lead screw from 3 up to 20 threads per inch. Over each lead screw pitch are thread pitches, thus on lead screw pitch 4 we have 20, 19, 18, and so on.

The use of the table is as follows :—

Find the pitch of the lead screw, and at the head of that column is the number of teeth for the lathe stud or mandril. Then find in that column the number of threads to be cut, and on the same line, but at the left hand, will be found the number of teeth for the lead screw.

NUMBERS OF TEETH FOR WHEEL TO GO ON LATHE SPINDLE, LATHE STUD, OR MANDRIL.

Lead Screw.	12	*16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80
12	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
16	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
20	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
24	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
28	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
32	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
36	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
40	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
44	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
48	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
*52	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
56	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
60	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
64	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
68	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
72	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
76	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
80	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	Lead Screw Pitch 3.	Lead Screw Pitch 4.	Lead Screw Pitch 5.	Lead Screw Pitch 6.	Lead Screw Pitch 7.	Lead Screw Pitch 8.	Lead Screw Pitch 9.	Lead Screw Pitch 10.	Lead Screw Pitch 11.	Lead Screw Pitch 12.	Lead Screw Pitch 13.	Lead Screw Pitch 14.	Lead Screw Pitch 15.	Lead Screw Pitch 16.	Lead Screw Pitch 17.	Lead Screw Pitch 18.	Lead Screw Pitch 19.	Lead Screw Pitch 20.

EXAMPLE.—The lead screw has a pitch of 4, and I require to cut 13 threads per inch. At the head of the column is 16, and on a line with the 13 of the column, but on the left is 52, each number being marked by a * hence the 16 and 52 are the wheels ; if we have not those wheels, multiply both by 2 and 32, and 104 will answer.

If the pitch of the lead screw is 2 threads per inch, the wheels must advance by 6 teeth, as indicated below :—

NUMBERS OF TEETH FOR WHEEL TO GO ON LATHE STUD, LATHE SPINDLE OR MANDRIL.

Number of Teeth for Wheel to go on Lead Screw.	Lead Screw.	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96
	12	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	18	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	24	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	36	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	42	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	48	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	54	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	60	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	*Pitch of Lead Screw.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

This table may be used for compound lathes by simply dividing the pitch of the lead screw by the ratio of the compounded pair of wheels. For example, for the wheels to cut 8 threads per inch, the pitch of lead screw being 4 and the compounded gears 2 to 1, as the ratio of the compounded pair is 2 to 1, we divide the pitch of lead screw by 2, which gives us 2, and we thus find the wheels in the column of pitch of lead screw 2, getting 12 and 48 as the required wheels, the 12 going on top of the lathe because it is at the top of the table, and the 48 on the lead screw because it is at the left-hand end of the table, and the lead screw gear is at the left-hand end of the lathe.

The table may be made for half threads as well as whole ones by simply advancing the left-hand column by two teeth, instead of by four, thus :—

Teeth for Wheel on Lead Screw.	Teeth for Wheel on Stud.								
	12	16	20	24	28	32	36	40	44
12	3	3	3	3	3	3	3	3	3
14	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$
16	4	4	4	4	4	4	4	4	4
18	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$
20	5	5	5	5	5	5	5	5	5
22	$5\frac{1}{2}$	$5\frac{1}{2}$	$5\frac{1}{2}$	$5\frac{1}{2}$	$5\frac{1}{2}$	$5\frac{1}{2}$	$5\frac{1}{2}$	$5\frac{1}{2}$	$5\frac{1}{2}$
24	6	6	6	6	6	6	6	6	6
26	$6\frac{1}{2}$	$6\frac{1}{2}$	$6\frac{1}{2}$	$6\frac{1}{2}$	$6\frac{1}{2}$	$6\frac{1}{2}$	$6\frac{1}{2}$	$6\frac{1}{2}$	$6\frac{1}{2}$
28	7	7	7	7	7	7	7	7	7
30	$7\frac{1}{2}$	$7\frac{1}{2}$	$7\frac{1}{2}$	$7\frac{1}{2}$	$7\frac{1}{2}$	$7\frac{1}{2}$	$7\frac{1}{2}$	$7\frac{1}{2}$	$7\frac{1}{2}$
32	8	8	8	8	8	8	8	8	8
34	$8\frac{1}{2}$	$8\frac{1}{2}$	$8\frac{1}{2}$	$8\frac{1}{2}$	$8\frac{1}{2}$	$8\frac{1}{2}$	$8\frac{1}{2}$	$8\frac{1}{2}$	$8\frac{1}{2}$
36	9	9	9	9	9	9	9	9	9
38	$9\frac{1}{2}$	$9\frac{1}{2}$	$9\frac{1}{2}$	$9\frac{1}{2}$	$9\frac{1}{2}$	$9\frac{1}{2}$	$9\frac{1}{2}$	$9\frac{1}{2}$	$9\frac{1}{2}$
40	10	10	10	10	10	10	10	10	10
42	$10\frac{1}{2}$	$10\frac{1}{2}$	$10\frac{1}{2}$	$10\frac{1}{2}$	$10\frac{1}{2}$	$10\frac{1}{2}$	$10\frac{1}{2}$	$10\frac{1}{2}$	$10\frac{1}{2}$
Pitch of Lead Screw.	3	4	5	6	7	8	9	10	11

For quarter threads we advance the left-hand column by one tooth, or for thirds of threads by three teeth, and so on.

If we require to find what wheels to provide for a lathe, we take the pitch of the lead screw for the numerator, and the pitch required for the denominator, and multiply them first by 2, then by 3, then by 4, and so on, continuing until the numerator or denominator is as large as it can be to give the required proportion of teeth, and not exceed the greatest number that the largest wheel can contain.

For example: A lathe has single gear, and its lead screw pitch is 8 per inch, what wheels will cut 18, 17, 16, 15, 14, or 13 threads per inch?

			Wheels.			
Pitch of lead screw / Pitch required	$\frac{8}{18}$	$\times\, 2 =$	$\frac{16}{36}$	$\frac{24}{54}$	$\frac{32}{72}$	
Pitch of lead screw / Pitch required	$\frac{8}{17}$	"	$\frac{16}{34}$	$\frac{24}{51}$	$\frac{32}{68}$	
Pitch of lead screw / Pitch required	$\frac{8}{16}$	"	$\frac{16}{32}$	$\frac{24}{48}$	$\frac{32}{64}$	
Pitch of lead screw / Pitch required	$\frac{8}{15}$	"	$\frac{16}{30}$	$\frac{24}{45}$	$\frac{32}{60}$	
Pitch of lead screw / Pitch required	$\frac{8}{14}$	"	$\frac{16}{28}$	$\frac{24}{42}$	$\frac{32}{56}$	
Pitch of lead screw / Pitch required	$\frac{8}{13}$	"	$\frac{16}{26}$	$\frac{24}{39}$	$\frac{32}{52}$	$\frac{40}{65}$

If we suppose that the greatest number of teeth permissible in one wheel is not to exceed 100, then in this table we have all the combinations of wheels that can be used to cut the given pitches; and having made out such a table, comprising all the pitches to be cut, we may select therefrom the least number of wheels that will cut those pitches. The whole table being made out it will be found, of course, that the numerators of the fractions are the same in each case; that is, in this case, 16, 18, 24, 32, and so on as far as we choose to carry the multiplication of the numerator. We shall also find that the denominators diminish in a regular order: thus taking the fractions whose numerators are in each case 16, we find their denominators are, as we pass down the column, 36, 34, 32, 30, 28, and 26, respectively, thus decreasing by 2, which is the number we multiplied the left-hand column by to obtain them. Similarly in the fractions whose numerators are 24, the denominators diminish by 3, being respectively 54, 51, 48, 45, 42, and 39; hence the construction of such a table is a very simple matter so far as whole numbered threads are concerned, as no multiplication is necessary save for the first line representing the finest pitch to be cut.

For fractional threads, however, instead of using the pitch of the lead screw for the numerator, we must reduce it to terms of the fraction it is required to cut. For example, for $5\frac{1}{2}$ threads we proceed as follows. The pitch of the lead screw is 8, and in 8 there are 16 halves, hence we use 16 instead of 8, and as in the $5\frac{1}{2}$ there are 11 halves we use the fraction $\frac{16}{11}$ and multiply it first by 2, then by 3, and then by 4, and so on, obtaining as follows: $\frac{16}{11}$, $\frac{32}{22}$. $\frac{48}{33}$, $\frac{64}{44}$, obtaining as before three sets of wheels either of which will cut the required pitch. In selecting from such a table the wheels to cut any required number of pitches, the set must, in order to cut a thread of the same pitch as the lead screw, contain two wheels having the same number of teeth.

Now, suppose that the pitch of the lead screw was 6 instead of 8 threads per inch, and the table will be as follows :—

$\frac{6}{18}$	$\frac{12}{36}$	$\frac{18}{54}$	$\frac{24}{72}$
$\frac{6}{17}$	$\frac{12}{34}$	$\frac{18}{51}$	$\frac{24}{68}$
$\frac{6}{16}$	$\frac{12}{32}$	$\frac{18}{48}$	$\frac{24}{64}$
$\frac{6}{15}$	$\frac{12}{30}$	$\frac{18}{45}$	$\frac{24}{60}$
$\frac{6}{14}$	$\frac{12}{28}$	$\frac{18}{42}$	$\frac{24}{56}$
$\frac{6}{13}$	$\frac{12}{26}$	$\frac{18}{39}$	$\frac{24}{52}$

Here, again, we find that in the first vertical column the denominators decrease by two for each thread less per inch, in the second column they decrease by three, and in the third by four; this decrease equalling the number the first fraction was multiplied by.

But suppose the lead screw pitch is an odd one, as, say, 3 threads per inch, and we construct the table as before, thus—

Pitch of lead screw / Pitch to be cut	$\frac{3}{18}$	$\frac{6}{32}$	$\frac{9}{54}$	$\frac{12}{72}$	$\frac{15}{90}$

Now it is useless to multiply by 2 or by 3, because they give a less number of teeth than the smallest wheel should have, hence the first multiplier should be 4, giving the following table :—

$\frac{3}{18}$	$\frac{12}{72}$	$\frac{15}{90}$	$\frac{18}{108}$
$\frac{3}{17}$	$\frac{12}{68}$	$\frac{15}{85}$	$\frac{18}{102}$
$\frac{3}{16}$	$\frac{12}{64}$	$\frac{15}{80}$	$\frac{18}{96}$
$\frac{3}{15}$	$\frac{12}{60}$	$\frac{15}{75}$	$\frac{18}{90}$

By continuing the table for other pitches we shall find that in the first vertical column the denominators diminish by 4, the second column by 5, and the third by 6; and it is seen that by diminishing the pitch of the lead screw, we have rendered necessary one of two things, which is, that either larger wheels containing more teeth must be used, or the change gears must be compounded.

Assuming that the pitch of the lead screw was 5 per inch, the table would be as follows :—

$\frac{5}{18}$	$\times\, 3 =$	$\frac{15}{54}$	$\frac{20}{72}$	$\frac{25}{90}$
$\frac{5}{17}$	"	$\frac{15}{51}$	$\frac{20}{68}$	$\frac{25}{85}$
$\frac{5}{16}$	"	$\frac{15}{48}$	$\frac{20}{64}$	$\frac{25}{80}$

The wheels in the first column here decrease by 3, the second by 4, and the third by 5.

In nearly all lathes the advance or decrease is by 4 or by 6. In determining this rate of advance or decrease, there are several elements, among which are the following. Suppose the lathe to be geared without compounding, then the distance between the lathe spindle and the lead screw will determine what shall be the diameters of the largest and of the smallest wheel in the set, it being understood that the smallest wheel must not contain less than 12 teeth. Assume that in a given case the distance is 10 inches, and it is obvious that the pitch of the teeth at once commands consideration, because the finer the pitch the smaller the wheel that will contain 12 teeth, and the larger the wheel on the lead screw may be made. Of course the pitch must be coarse enough to give the required tooth strength.

Let it be supposed that the arc pitch is $\frac{3}{4}$-inch, then the pitch circumference of a 12-toothed wheel would be 9 inches and its radius 1·432 in.; this subtracted from the 10 leaves 8·568 in. as the radius, or 17·136 in. as the largest diameter of wheel that can be used on the lead screw, supposing there to be no intermediate gears. Now a wheel of this diameter would be capable of containing more than 75 teeth, but less than 76. But from the foregoing tables it will be seen that it should contain a number of teeth divisible either by 4 or by 6 without leaving a remainder, and what that number should be is easily determined by means of a table constructed as before explained. Thus from the tables it would be found that 72 teeth would be best for a lead screw having a pitch of either 8, 6, 5, or 3 threads per inch, and the screw-cutting capacity of the lathe would (unless compounded) be confined to such pitches as may be cut with wheels containing between 12 and 72 teeth both inclusive.

But assume that an arc pitch of $\frac{3}{8}$-inch be used for the wheel teeth, and we have as follows: A wheel of this pitch and containing 12 teeth will have a radius of $7\frac{16}{1000}$ inches, leaving 9·284 in. as the radius of the largest wheel, assuming it to gear direct with the 12-tooth pinion. With this radius it would contain 155 teeth and a fraction of a tooth; we must, therefore, take some less number, and from what has been said, it will be obvious that this lesser number should be one divisible by either 4 or 6. If made divisible by 6, the number will be 150, because that is the highest number less than 155 that is divisible by 6 without leaving a remainder. But if made divisible by 4, it may contain 152 teeth, because that number is divisible by 4 without leaving a remainder. With 150 teeth the latter could cut a thread $12\frac{1}{2}$ times as fine as the lead screw, because the largest wheel contains $12\frac{1}{2}$ times as many teeth as the smallest one; or it would cut a thread $12\frac{1}{2}$ times as coarse as the lead screw, if the largest wheel be placed on the mandril and the smallest on the lead screw. With 152 teeth the lathe would be able to cut a thread $12\frac{84}{100}$ times as fine or as coarse as the lead screw. Unless, however, the lathe be required to cut fractional pitches, it is unnecessary that the largest wheel have more teeth than divisible, without leaving a remainder, by the number of teeth in the smallest wheel, which being 12 we have 144 as the number of teeth for the largest wheel. In the United States standard pitches of thread, however, there are several pitches in fractions of an inch, hence it is desirable to have wheels that will cut these pitches.

LATHE SHEARS OR BEDS.—The forms of the shears and beds may be classified as follows.

The term shear is generally applied when the lathe is provided with legs, while the term bed is used when there are no legs; it may be noted, however, that by some workmen the two terms of *shear* and *bed* are used indiscriminately.

The forms of shears in use on common lathes are, in the United States, the raised **V**, the flat shear and the shear, with the edge at an angle of 90° or with parallel edges. In England and on the continent of Europe, the flat shear is almost exclusively employed.

Referring to the raised **V** it possesses an important advantage in that, first, the slide rest does not get loosely guided from the wear; and second, the wear is in the direction that least affects the diameter of the work.

In Fig. 621, for example, is a section of a lathe shear, with a slide rest shown in place, and it will be observed that the wear of the **V** upon the lathe bed, and of the **V**-groove in the slide rest, will cause the rest to fall in the direction of arrow A, and that a given amount of motion in that direction will have less effect in altering the diameter than it would in any other direction. This is shown on the right hand of the figure as follows: Suppose the cutting point of the tool is at *a*, and the work will be of the diameter shown by the full circle in the figure. If we suppose the tool point to drop down to *f*, the work would be turned to the diameter denoted by dotted arc *g*, while if the tool were moved outwards from *a* to *c* the work would be turned to the diameter *e*. Now since *f* and *c* are equidistant from the point *a*, therefore the difference in the diameters of *e* and *g* represents the difference of effect between the wear letting the rest merely fall, or moving it outwards, and it follows that, as already stated, the diameter of the work is less affected by a given amount of wear, when this wear is in the direction of A, than when it is in the direction of B. When the carriage is held down by a weight as is shown in Figs. 577 and 578, there is therefore no lost motion or play in the carriage, which therefore moves steadily upon the shears, unless the pressure of the cut is sufficient in amount, and also in a direction to lift the carriage (as it is in the case of boring with boring tools); but to enable the carriage to remain firm upon the shears under all conditions, it is necessary to provide means to

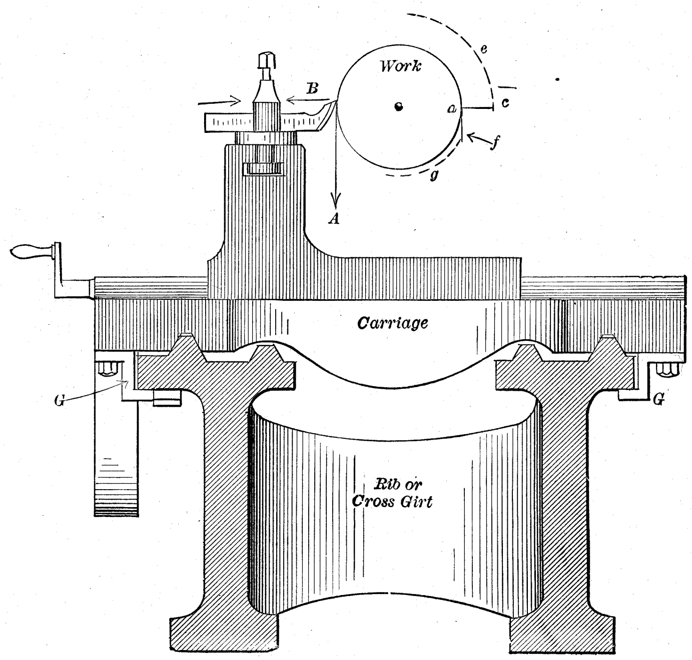

Fig. 621.

hold it down upon the **V**s, which is done by means of gibs G, G, which are secured to the carriage, and fit against the bottom of the bed flange as shown.

Now since lathes are generally used much more frequently on short than on long work, therefore the carriage traverses one part of the shears more than another, and the **V**s wear more at the part most traversed, and it follows that if gibs G are set to slide properly at some parts they will not be properly set at another or other parts of the length of the shears; hence the carriage will in some parts have liberty to move from the bed, there being nothing but the weight of the carriage, &c., to hold it down to the **V**s. Now, the wear in the direction of A acts directly to cause this inequality of gib fit, whereas that in the direction of B does so to a less extent, as will appear hereafter.

Meantime it may be noted that when the carriage is held down by a suspended weight the shears cannot be provided with cross girts, and are therefore less rigid and more subject to torsion under the strain of the cut; furthermore the amount of the weight must be sufficient to hold the carriage down under the maximum of cut, and this weight acts continuously to wear the **V**s, whether the carriage is under cutting duty or not, but the advantage of keeping the carriage firmly down upon the **V**s is sufficiently great to cause many to prefer the weighted carriage for light work driven between the lathe centres.

Fig. 622 represents the flat shear, the edges being at an angle and the fit of the carriage to the shears being adjusted by the gibs at *a a*, which are set up by bolts *c c* and *d d*. In this case there is a large amount of wearing surface at *b b*, to prevent the fall of the carriage *c*, but the amount of end motion (in the direction of B, Fig. 621), permitted to the carriage by reason of the wear of the gibs and shear edges, is greater than the amount of the wear because of the edges being at an angle. It is true that the amount of fall of the carriage on the raised V is also (on account of the angle of the V) greater than the actual amount of the wear, but the effect upon the work diameter is in this case much greater, as will be readily understood from what has already been said. The wearing surface of the raised V may obviously be increased by providing broader Vs, or two Vs instead of having four. This would tend to keep the lathe in line, because the wear due to moving the tailblock would act upon those parts of the shear length that are less acted upon by the carriage, and since the front journal and bearing of the live spindle wear the most, the alignment of the lathe centres would be more nearly preserved.

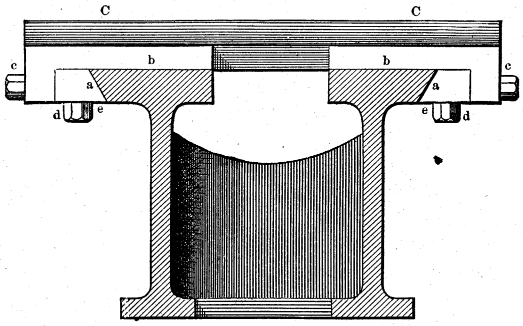

Fig. 622.

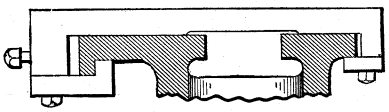
Fig. 623.

Fig. 623 represents another form of parallel edged shears in which the fit of the carriage to the shears is effected at the front end only, the other or back edge being clear of contact with the carriage, but provided with a gib to prevent the carriage from lifting. This allows for any difference in expansion and contraction between the carriage and the shears, while maintaining the fit of the carriage to the bed.

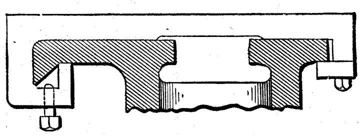
Fig. 624.

A modification of this form (both these forms being taken from "Mechanics") is shown in Fig. 624, in which the underneath side of the front edge is beveled so that but one row of screws is required to effect the adjustment.

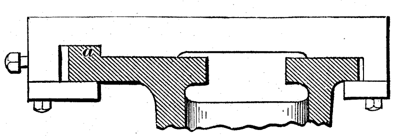

Fig. 625.

Fig. 625 represents a form of bed in which the fit adjustment is also made at the front end only of the bed, and there is a flange or slip at *a*, which receives the thrust outwards of the carriage; and a similar design, but with a bevelled edge, is shown in Fig. 626.

In Fig. 627 is shown a lathe shear with parallel edges, the fit being adjusted by a single gib D, set up by set-screws S. In this case the carriage will fall or move endwise, to an amount equal to whatever the amount of the wear may be, and no more, but it may be observed that in all the forms that admit of wear endways (that is to say in the direction of B in Fig. 621), the straightness of the shears is impaired in proportion as its edges are more worn at one part than at another.

A compromise between the flat and the raised V-shear is shown in Fig. 628, there being a V-guide on one side only, as at J. When the carriage is moved by mechanism on the front side of the lathe, and close to the V, this plan may be used, but if the feed screw or other mechanism for traversing the carriage is within the two shears, the carriage should be guided at each end, or if the operating mechanism is at the back of the lathe, the carriage should be guided at the back end, if not at both ends.

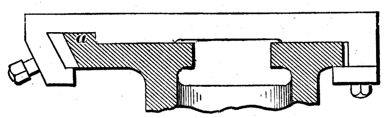
Fig. 626.

In flat shear lathes the tailstock is fitted between the inside edges of the two shears, and the alignment of the tailstock depends upon maintaining a proper fit notwithstanding the wear that will naturally take place in time. The inside edges of the shears are sometimes tapered; this taper makes it much easier to obtain a correct fit of the tailstock to the shears, but at the same time more hard to move the tailstock along the bed. To remedy this difficulty, rollers are sometimes mounted upon eccentrics having journal bearing in the tailstock, so that by operating these eccentrics one half a turn, the rollers will be brought down upon the upper face of the shears, lifting the tailstock and enabling it to be easily moved along the bed to its required position.

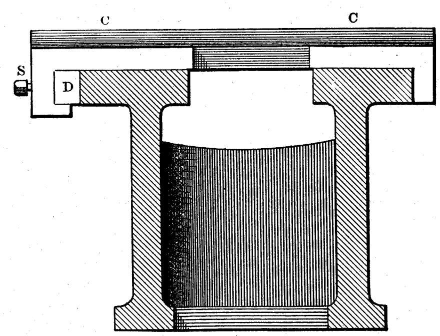

Fig. 627.

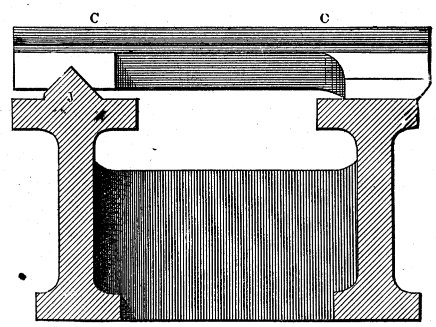

Fig. 628.

In many of the watchmakers' lathes the outer edges are beveled off as in Fig. 629, the bearing surfaces being on the faces *b* as well as on the edges *a*. As a result, edges *a* are relieved of weight, and therefore to some extent of wear also, and whatever wear faces *b* have helps the fit at *a a*.

In the Barnes lathe, as in several other forms in which the lathe is made (as, for example, in screw-making lathes) the form of bed in Fig. 630 is employed. The tailblock may rest on the surfaces A, A′, B, C, D, and E, or as in the Barnes lathe the tailstock may fit to angles A B, but not to E D, while the carriage fits to B E, and C D, but not to A, the intention being to equalize the wear as much as possible.

The shears of lathes require to be as rigid as possible, because

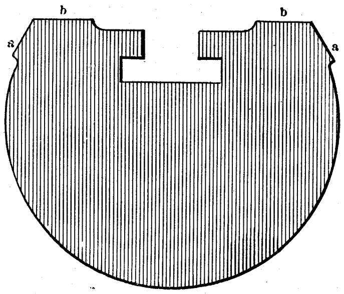

Fig. 629.

the pressure of the cut, as well as the weight of the carriage, slide rest, and tailstock, and of the work, tends to bend and twist them.

The pressure of the dead centre against the end of the work

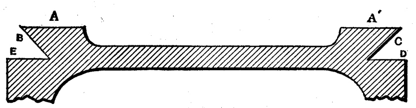

Fig. 630.

considered individually, is in a direction to bend the lathe shears upward, but the weight of the work itself acts in an opposite direction.

The strain due to the cut falls in a direction variable with the shape of the cutting tool, but mainly in a direction towards the operator, and, therefore, tending to twist the shears. To resist these strains, lathe shears are usually given the **I** form shown in the cuts.

Figs. 631 and 632 represent the ribbing in the Putnam Tool Company's lathe; a middle rib running the entire length, which greatly stiffens it.

The legs supporting lathe shears are, in lathes of ordinary length, placed at each end of the bed, so that the weight of the two heads, that of the work, and that of the carriage and slide rest, as well as the downward pressure of the cut, act combined to cause it to deflect or bend. It is necessary, therefore, in long beds to provide intermediate resting or supporting points to prevent this deflection.

Professor Sweet has pointed out that a lathe shears will be more truly supported on three than on four resting points, if the foundation on which the legs rest do not remain permanently level, and in lathes designed by him has given the right-hand end of the shears a single supporting point, as shown at *a* in Fig. 633.

J. Richards in an article in "Engineering," has pointed out also that, when the lathe legs rest upon a floor that is liable from moving loads upon it to move its level, it is preferable that the legs be shaped as in Fig. 634, being narrowest at the foot, whereas when upon a permanent foundation, in which the foundation is intended to impart rigidity to the legs, they should be broader at the base, as in Fig. 635.

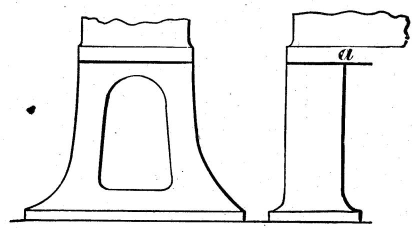

Fig. 635.

The rack on a lathe bed should be a cut one, and not simply a cast one, because when a cutting tool is running up to a corner as against a radial face, the self-acting motion must be stopped and the tool fed into the corner by hand. As a very delicate tool movement is required to cut the corner out just square, it should be capable of easy and steady movement, but in the case of cast racks, the rest will, from defects in the rack teeth, move in little jumps, especially if the pitch of the teeth be coarse. On the other hand it is difficult to cast fine pitches of teeth perfectly, hence the racks as well as the gear teeth should be cut gear and of fine pitch.

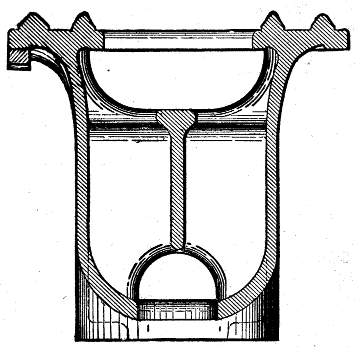

Fig. 631.

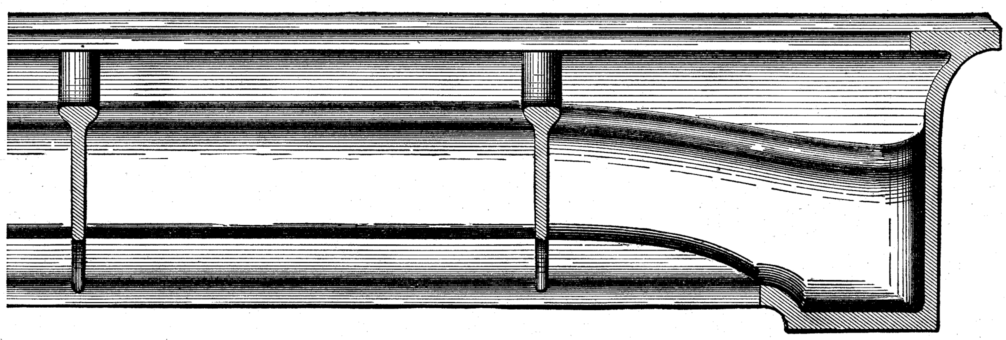

Fig. 632.

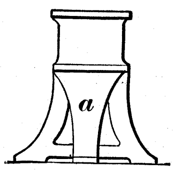

Fig. 633.

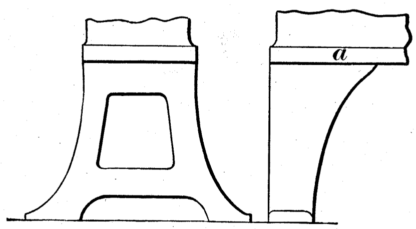

Fig. 634.

The tailblock of a lathe should be capable of easy motion for adjustment along the shears, or bed of the lathe, and readily fixible in its adjusted position. The design should be such as to hold the axial line of its spindle true with the axial line of the live spindle. If the lathe bed has raised **V**s there are usually provided two special **V**s for the tailblock to slide on, the slide rest carriage sliding on two separate ones. In this case the truth of the axial line of the tail spindle depends upon the truth of the **V**s.

If the lathe bed is provided with ways having a flat surface, as was shown in Fig. 622, the surfaces of the edges and of the projection are apt in time to wear, permitting an amount of play which gives room for the tailblock to move out of line. To obviate this, various methods are resorted to, an example being given in the Sellers lathe, Fig. 518.

In wood turners' lathes, where tools are often used in place of the dead centre, and in which a good deal of boring is done by such use of the tail spindle, it is not unusual to provide a device for the rapid motion of that spindle. Such a device is shown in Fig. 636; it consists of an arm A to receive the end C of the lever B, C being pivoted to A. The spindle is provided with an eye at E, the wheel W is removed and a pin passed through D and E, so that by operating the handle the spindle can be traversed in and out without any rotary motion of the screw.

When the tailblock of a lathe fits between the edges of the shears, instead of upon raised **V**s, it is sometimes the practice to give them a slight taper fitting accurately a corresponding taper on the edges of the shears. This enables the obtenance of a very

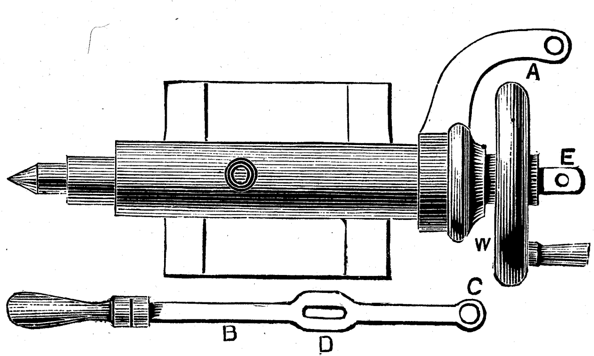

Fig. 636.

good fit between the surfaces, giving an increased area of contact, because the surfaces can be filed on their bearing marks to fit them together; but this taper is apt to cause the tailstock to fit so tightly between the shears as to render it difficult to move it along them, and in any event the friction is apt to cause the fit to be destroyed from the wear. An excellent method of obviating these difficulties is by the employment of rollers, such as shown at R in Figs. 637 and 638, which represent the tailstock of the Putnam Tool Company's lathe. In some cases such rollers are carried on eccentric shafts so that they may be operated to lift the tailstock from the bed when moving it.

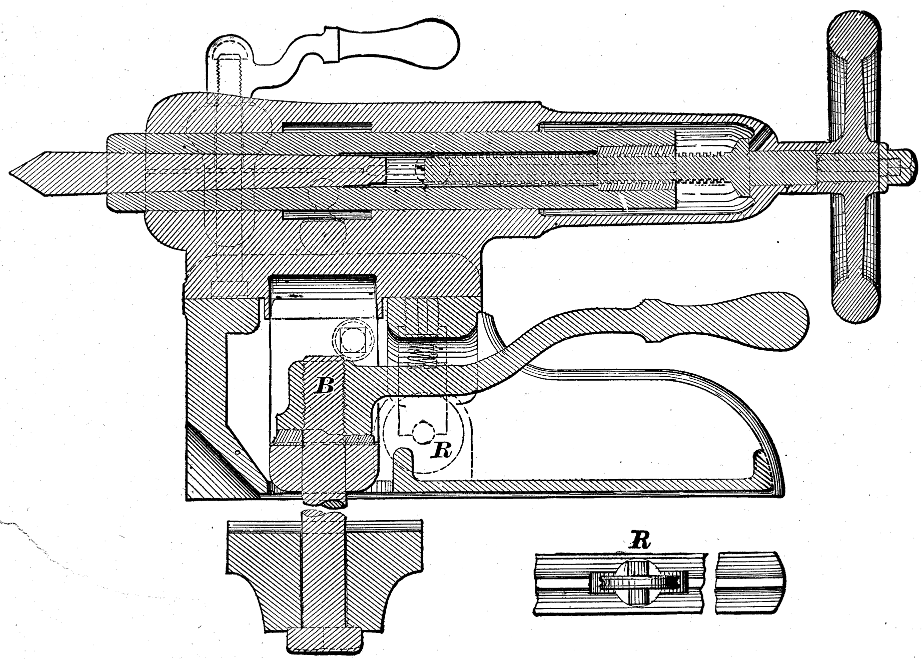

Fig. 637.

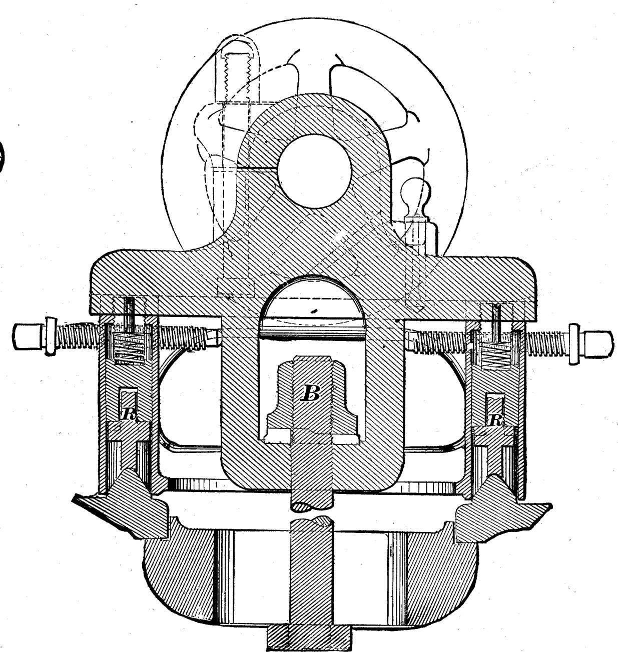

Fig. 638.

A very ready method of securing or releasing a small tailstock to a lathe shears is shown applied to a wood turner's hand rest in Fig. 639, in which A A represents the lathe shears, B the hand rest, C the fastening bolt, D a piece hinged at each end and having through its centre a hole to receive the fastening bolt, and a counter-sink or recess to receive the nut and prevent it unscrewing. E represents a hinged plate, and F a lever, having a cam at its pivoted end. A slot for the fastening bolt to pass through is provided in the plate E. In this arrangement a very moderate amount of force applied to bring up the cam lever will cause the plate D to be pressed down, carrying with it the nut, and binding the tailstock or the tool rest, as the case may be, with sufficient force for a small lathe.

When a piece of work is driven between the lathe centres, the weight of the work tends to deflect or bend down the tail spindle. The pressure of the cut has also to be resisted by the tail spindle, but this pressure is variable in direction, according to the shape of the tool and the direction of the feed; usually it is laterally towards the operator and upwards. In any event, however, the spindle requires locking in its adjusted position, so as to keep it steady. The pressure on the conical point of the dead centre is in a direction to cause the tail screw to unwind, unless it be a left-hand thread, as is sometimes the case.

If the spindle and the bore in which it operates have worn, the resulting looseness affords facility for the spindle to move in the bore as the pressure of the cut varies, especially when the spindle is far out from the tailstock.

Now, in locking the tail spindle to obviate these difficulties, it is desirable that the locking device shall hold that spindle axially true with the live spindle of the lathe, notwithstanding any wear that may have taken place. The spindle is released from the pressure of the locking device whenever it is adjusted to the work, whether the cut be proceeding or not. Hence, the wear takes place on the bottom of the spindle and of the hole, wear only ensuing on the top of the spindle and bore when the spindle is operated under a slight locking pressure, while the cut is proceeding in order to take up the looseness that may have arisen from wear in the work centres.

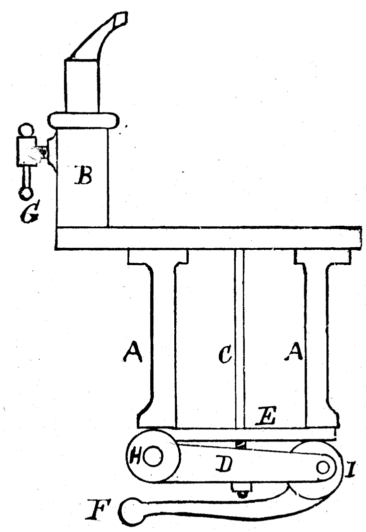

Fig. 639.

In all cases the feed of the cut should be stopped while the centre is adjusted, so as to relieve the spindle and bore from undue wear; but most workmen pay little heed to this; hence the wear ensues, being, as already stated, mainly at the bottom. It is obvious, then, that, if the spindle is to be locked to the side of the bore on which it slides, it will be held most truly in line if it be locked to that side which has suffered least from wear, and this has been shown to be at the top.

The methods usually employed to effect this locking are as follows:—In Fig. 640, S is the tail spindle, B part of the tailblock in section, R a ring-bolt, and H a handled nut. Screwing up the nut H causes R to clamp S to the upper part of the bore of B;

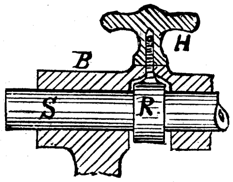

Fig. 640.

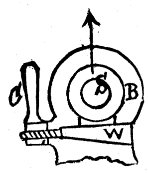

Fig. 641.

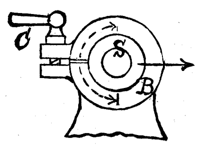

Fig. 642.

while releasing H leaves S free to slide. There are three objections to this plan. The ring R tends to spring or bend S. The weight of R tends to produce wear upon the top of the spindle, and the spindle is not gripped so near to its dead centre end as it might be. If S is a close fit in B the pressure of R could not spring or bend S; but, so soon as wear has taken place, S becomes simply suspended at R, having the pressure of R, and the weight of the work tending to bend it. Another locking device is shown in Fig. 641. It consists of a shoe placed beneath S, and a wedge-bolt beneath it, operated by the handled nut C. Here the pressure is again in a direction to lift S, as denoted by the arrow; but when the wedge W is released the shoe falls away from S, hence the locking device produces no wear upon S. This device may be placed nearer to the end of B, since the wedge may pass through the front leg of the tailstock instead of to the right of it, as in Fig. 640. But S is still suspended from the point of contact of the shoe, and the weight of the work still bends it as much as its play in B will permit.

Another clamping device is shown in Fig. 642. In this the cylindrical part B of the tailblock is split on one side, and is provided with two lugs. A handled screw passes through the upper lug, and is threaded into the lower one, so that by operating the handle C, the bore may be closed, so as to grip S, or opened to relieve it. This possesses the advantages: First, that it will cause S to be gripped most firmly at the end of B, and give a longer length of bearing of B upon S; and, secondly, that it will grip S top and bottom, and, therefore, prevent its springing from the weight of the work. But, on the other hand, B will close mainly on the side of the split, as denoted by the dotted half-circle, and therefore tend to throw S somewhat in the direction of the

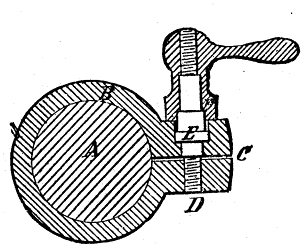

Fig. 643.

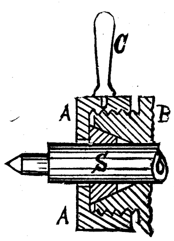

Fig. 644.

arrow, which it will do to an amount answerable to the amount of looseness of S in B. In the Pratt and Whitney lathes this device is somewhat modified, as is shown in Fig. 643. A stud E screws into the lower lug D, having a collar at E let into the upper lug, with a square extending above the upper lug so that the stud may be screwed into D, exerting sufficient pressure to close the bore of B to a neat working fit to the spindle. The handled nut, when screwed up, causes B to grip the spindle firmly; but when released, leaves the spindle a neat working fit and not loose to the amount of the play; hence, the locking device may be released, and the centre adjusted to take up the wear in the work centres while the cut is proceeding, without any movement of the spindle in B, because there is no play between the spindle and B.

In the design shown in Fig. 644, the end B of the tailblock is threaded and is provided with a handled cap nut A A. In the end of the tailblock where the spindle emerges, is provided a cone, and into this cone fits a wedge-shaped ring, as shown. This ring is split quite through on one side, while there are two other slots nearly but not quite splitting the wedge-ring. When the handle C is pulled towards the operator it screws A up on the end B, and forces the wedge-ring up in the conical bore in B. From the split the ring closes upon the spindle S, and grips it. Now, as the ring is weakened by slots in two places besides the split, it closes more nearly cylindrically true than if it had only a split, there being three points where the ring can spring when closing upon S; and from the cone being axially true with the live spindle of the lathe, S is held axially true, notwithstanding any wear of the spindle, because the locking device, being at the extreme end of B, is as near to the dead centre as it is possible to get it; and, furthermore, when C is operated for the release, the wedge-ring opens clear of S, so that S does not touch it when moved laterally. The wear of the bore of B has, therefore, no effect to throw S out of line, nor has the gripping device any tendency to bend or spring S, while the latter is held as close to the work as possible; hence the weight of the work has less influence in bending it. The pitch of the thread and the degree of cone are so proportioned that less than one-quarter rotation of A will suffice to grip or release S, the handle C being so placed on A as to be about vertical when the split ring binds S; hence C is always in a convenient position for the hand to grasp.

In this case, however, the spindle being locked at the extreme end of the hole, there is more liability of the other end moving

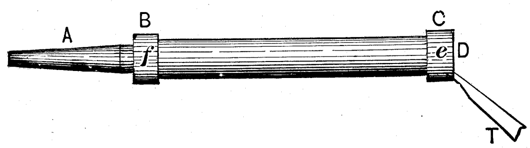

Fig. 645.

from the pressure of the cut, or from the weight of the work; hence it would seem desirable that a tail spindle should be locked in *two* places; one at the dead centre end of the hole, and the other as near the actuating wheel, or handle, as possible, and also that each device should either hold it central to the original bore, notwithstanding the wear, an end that is attained in the Sellers lathes already described.

Slide rests for self-acting or engine lathes are divided into seven kinds, termed respectively as follows: simple, or single, elevating, weighted, gibbed, compound, duplex, and duplex compound. A simple, or single, slide rest contains a carriage and one cross slide, as in Fig. 621. An elevating slide rest is one capable of elevation at one end to adjust the cutting tool height, as in Fig. 499. A weighted slide rest is one held to the shears by a weight, as in Fig. 577. A gibbed slide rest is held to the shears by gibbs, as in Fig. 621. A compound slide rest has above the cross slide, a second slide carrying the tool holder, this second slide pivoting to stand at any required angle, as in Fig. 505. A duplex slide rest has two rests on the same cross slide, and in a compound duplex both these two rests are compound, as in Fig. 511. The rest shown on the Putnam lathe in Figs. 492 and 499, is thus an elevating gibbed single rest.

TESTING A LATHE.—To test a lathe to find if its live and dead spindles are axially in line one with the other and with the guides on the lathe bed, the following methods may be employed in addition to those referred to under the heading of Erecting.

To test if the live spindle is true with the bed or shear guides, a piece such as in Fig. 645 may be turned up between the lathe centres, the end A fitting into the live spindle in place of the live centre, and the collars B C being turned to an equal diameter, and the end face D squared off true. The end A must then be placed in the lathe in place of the live centre, the dead centre being removed from contact with the work; with the lathe at rest a tool point may be set to just touch collar C, and if when the carriage is moved to feed the tool past collar B, the tool draws a line along it of equal depth to that it drew along C, the live head is true; the dead centre may then be moved up to engage the work end D, and the lathe must be revolved so that (the tool not having been moved at all by the cross-feed screw) the tool may be traversed back to draw another line along C, and if all three lines are of equal depth the lathe is true. The tool should be fine pointed and set so as to mark as fine a line as possible.

Another method is to turn up two discs, such as in Fig. 646, their stems A and B fitting in place of the live and dead centres. One of these discs is put in the place of the live, and the other in that of the dead centre, and if then the lathe tailstock be set up so that the face of B meets that of A, their coincidence will denote the truth of the live and dead spindles. The faces of the discs may be recessed to save work and to meet at their edges only, but their diameters must be equal. If the discs come one higher than the other, as in Fig. 647, the centres are of unequal height. If the faces meet at the top and are open at the bottom, as in Fig. 648, it shows that the back bearing of the live spindle is too high, or that the tail spindle is too low at the dead centre end. If the discs, when viewed from above, come as in Fig. 649, it is proof that either the live spindle or the tail spindle does not stand true with the lathe shears. If the disc faces come so nearly fair that it is difficult to see if they are in contact all around, four pieces of thin paper may be placed equidistant between them, and the grip upon them tested by pulling.

If the tailstock has been set over to turn taper and it is required to set it back to turn parallel again, place a long rod (that has been accurately centred and centre-drilled) between the lathe centres, and turn up one end for a distance of an inch or two.

Then turn it end for end in the lathe and let it run a few moments so that the work centre, running on the dead centre of

Any View.

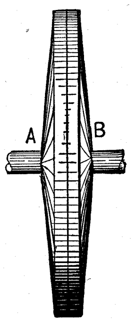

Fig. 646.

Side View.

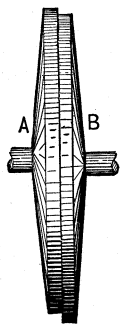

Fig. 647.

Side View.

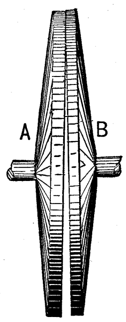

Fig. 648.

Top View.

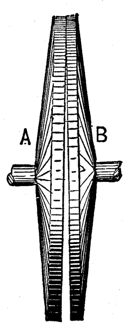

Fig. 649.

the lathe, may wear to a proper bed or fit to the lathe centre, and then turn up a similar length at the dead centre end, taking two cuts, the last a fine finishing cut taken with a sharp tool, and feeding the finishing cut from left to right, so that it will be clear of the work end when the cut is finished. Without moving the cross-feed screw of the lathe after the finishing cut is set, take the bar out of the lathe and wind the slide rest carriage, so that the turning tool will stand close to the live centre. Place the bar of iron again in the lathe, with the turned end next to the live centre, and move the lathe carriage, so that the tool is on the turned end of the bar.

Rotate the bar by hand, and if the tool just touches the work without taking a cut the line of centres is parallel with the ways. If there is space between the tool point and the turned end of the bar, the tailstock requires setting over towards the back of the lathe, while if the tool takes a cut the tailstock requires to be set over towards the operator. If a bar is at hand that is known to be true, a pointed tool may be adjusted to just make a mark on the end of the bar when the slide rest is traversed. On the bar being reversed, the tool should leave, when traversed along the bar, a similar mark on the bar.

To test the workmanship of the back head or tailstock, place the forefinger on the spindle close to the hub whence it emerges, and observe how much the hand wheel can be moved without moving the spindle; this will show how much, if any, lost motion there is between the screw and the nut in the spindle. Next wind the back spindle about three quarters of its length out of the tailstock, take hold of the dead centre and pull it back and forth laterally, when an imperfect fit between the spindle and the hole in which it slides will be shown by the lateral motion of the dead centre. Wind the dead centre in again, and tighten and loosen the spindle clamp, and see if doing so moves the spindle in the socket.

To examine the slide rest, move the screw handles back and forth to find how much they may be moved without giving motion to the slides; this will determine the amount of lost motion between the collars of the screws and between the screws themselves and the nuts in which they operate. To try the fit of the slide rest slides, in the stationary sliding ways or **V**s, remove the feed screws and move the slide so that only about one-half inch is in contact with the **V**s, then move the slide back and forth laterally to see if there is any play. Move the slide to the other end of the **V**s, and make a similar test, adjusting the slide to take up any play at either end. Then clean the bearing surfaces and move the slide back and forth on the **V**s, and the marks will show the fit, while the power required to move the slide will show the parallelism of the **V**s.

If the lathe carriage have a rack feed, operate it slowly by hand, to ascertain if it can be fed slowly and regularly by hand, which is of great importance. Then put the automatic feed in gear, and operate the feed gear back and forth, to determine how much it can be moved without moving the slide rest. To test the fit of the feed screw to the feed nut, put the latter in gear and operate the rack motion back and forth.

To determine whether the cross slide is at a right angle with the ways or shears, take a fine cut over a radial face, such, for example, as the largest face plate, and test the finished plate with a straight edge. If the face plate runs true and shows true with a straight edge, so that it is unnecessary to take a cut over it, grind a piece of steel a little rounding on its end, and fasten it in the tool post or clamp, with the rounded end next to the face plate. Let the rounded end be about $\frac{1}{4}$in. away from the face plate, and then put the feed motion into gear, and, with the steel near the periphery of the face plate, let the carriage feed up until the rounded steel end will just grip a piece of thin paper against the face plate tight enough to cause a slight strain in pulling the paper out, then wind the tool in towards the lathe centre and try the friction of the paper there; if equal, the cross slide is true.

To find the amount of lost motion in the screw feed gear, adjust it ready to feed the saddle, and pull the lathe belt so as to revolve the cone spindle backward, until the slide rest saddle begins to move, then mark a fine line on the lathe bed making the line coincident with the end of the lathe saddle or carriage. Then revolve the cone spindle forward, and note how much the cone spindle rotates before the saddle begins to traverse.

If the lathe has an independent feed motion it may be tested in the same manner as above.

In large lathes this is of great consideration, because the work revolves very slowly, and if there is much lost motion in the feed gear, it may take considerable time after the feed is put in gear before the carriage begins to travel. Suppose, for example, a 14-foot pulley is being turned, and that the tool cuts at 15 feet per minute, it will take nearly three minutes for the work to make a revolution.