The young mill-Wright and miller's guide ...

Evans, Oliver

Philadelphia, 1834

Part the fifth. Ellicott's plans for building mills.

PART THE FIFTH.

CHAPTER XIX.

Practical Instructions for building Mills, with all their proportions, suitable to all falls, of from three to thirty-six feet. Received from Thomas Ellicott, Mill-Wright.

PREFATORY REMARKS.

This part, as appears from the heading, written by Mr. Thomas Ellicott; a part of his preface, published in the early editions of this work, it has been thought best to omit. After some remarks upon the defective operation of mills upon the old construction, he proceeds to say—

In the new way, all these inconveniences and disadvantages are completely provided against: (See Plate XXII;) which is a representation of the machinery, as applied in the whole process of the manufacture; taking the grain from the ship or wagon, and passing it through the whole process by water, until it is completely manufactured into superfine flour. This is a mill of my planning and draughting, now in actual practice, built on Occoquam river, in Virginia, with 3 water-wheels, and 6 pair of stones.

If the wheat come by water to the mill, in the ship Z, it is measured and poured into the hopper A, and thence conveyed into the elevator at B, which elevates it, and drops it into the conveyer C D, which conveys it along under the joists of the second floor, and drops it into the hopper garner at D, out of which it is conveyed into the main wheat elevator at E, which carries it up into the peak of the roof, and delivers it into the rolling-screen at F, which (in this plan) is above the collar beams, out of which it falls into the hopper G, thence into the short elevator at H, which conveys it up into the fan I, from whence it runs down slanting, into the middle of the long conveyer at J, that runs towards both ends of the mill, and conveys the grain, as cleaned, into any garner K K K K K K, over all the stones, which is done by shifting a board under the fan, to guide the grain to either side of the cog-wheel j; and although each of these garners should contain 2000 bushels of wheat, over each pair of stones 12000 bushels in 6 garners, yet nearly all may be ground out without handling it, and the feed of the stones will be more even and regular than is possible in the old way. As it is ground by the several pairs of stones, the meal falls into the conveyer at M M M, and is conveyed into the common meal elevator at N, which raises it to O; from thence it runs down the hopper-boy at P, which spreads and cools it over a circle of 10 or 15 feet diameter, and (if thought best) will rise over it, and form a heap two or three feet high, perhaps thirty barrels of flour, or more, at a time, which may be bolted down at pleasure. When it is bolting, the hopper-boy gathers it into the bolting hoppers at Q, and attends them more regularly than is ever done by hand. As it is bolted, the conveyer R, in the bottom of the superfine chest, conveys the superfine flour to a hole through the floor at S, into the packing chest, which mixes it completely. Out of the packing chest it is filled into the barrel at T, weighed in the scale U, packed at W by water, headed at X, and rolled to the door Y, then lowered down by a rope and windlass, into the ship again at Z.

If the wheat come to the mill by land, in the wagon 7, it is emptied from the bags into a spout that is in the wall, and it runs into the scale 8, which is large enough to hold a wagon load; and as it is weighed it is (by drawing a gate at bottom) let run into the garner D, out of which it is conveyed into the elevator at E, and so through the same process as before.

As much of the tail of the superfine reels 37 as we think will not pass inspection, we suffer to pass on into the short elevator, (by shutting the gates at the bottom of the conveyer next the elevator, and opening one farther towards the other end.) The rubblings, which fall at the tail of said reels, are also hoisted into the bolting hoppers of the sifting reel 39, which is covered with a fine cloth, to take out all the fine flour dust, which will stick to the bran in warm, damp weather; and all that passes through it is conveyed by the conveyer 40, into the elevator 41, which elevates it so high that it will run freely into the hopper-boy at O; and is bolted over again with the ground meal. The rubblings, that fall at the tail of the sifting reel 39, fall into the hopper of the middlings' reel 42; and the bran falls at the tail into the lower story. Thus, you have it in your power, either by day or night, without any hand labour, except to shift the sliders, or some such trifle, to make your flour to suit the standard quality; and the greatest possible quantity of superfine is made out of the grain, and finished completely at one operation.

Agreeably to request, I shall now attempt to show the method of making and putting water on the several kinds of water-wheels commonly used, with their dimensions, &c., suited to falls and heads of from 3 to 36 feet. I have also calculated tables for gearing them to millstones; and made draughts* of several water-wheels with their forebays, and manner of putting on the water, &c.

THOMAS ELLICOTT.

*All my draughts are taken from a scale of eight feet to an inch, except Plate XVII., which is four feet to an inch.

ARTICLE 119.

OF UNDERSHOT MILLS.

FIG. 1, Plate XIII., represents an undershot wheel, 18 feet diameter, with 3 feet total head and fall. It should be 2 feet wide for every foot the mill-stones are in diameter; that is, 8 feet between the shrouds for a 4 feet, and 10 feet wide for a 5 feet stone. It should have three sets of arms and shrouds, on account of its great width. Its shaft should be at least 26 inches in diameter. It requires 12 arms, 18 feet long, 3½ inches thick, by 9 wide; and 24 shrouds, 7½ feet long, 10 inches deep, by 3 thick, and 32 floats, 15 inches wide. Note—It may be geared the same as an overshot wheel, of equal diameter. Fig. 2 represents the forebay, with its sills, posts, sluice, and fall: I have, in this case, allowed 1 foot fall and 2 feet head.

Fig. 3 represents an undershot wheel, 18 feet diameter, with 7 feet head and fall. It should be as wide between the shrouds as the stone is in diameter; its shaft should be 2 feet in diameter; requires 8 arms, 18 feet long, 3¼ inches thick, by 9 wide; and 16 shrouds, 7½ feet long, 10 inches deep, by 3 thick. It may be geared the same as an overshot wheel 13 feet in diameter, because their revolutions per minute will be nearly equal.

Fig. 4 represents the forebay, sluice, and fall: the head and fall about equal.

Fig. 5 represents an undershot wheel, 12 feet diameter, with 15 feet total head and fall. It should be 6 inches wide for every foot the stone is in diameter. Its shaft 20 inches in diameter; requires 6 arms, 12 feet long, 3 by 8 inches; and 12 shrouds, 6½ feet long, 2½ inches thick, and 8 deep. It suits well to be geared to a 5 feet stone with single gears, 60 cogs in the cog-wheel, and 16 rounds in the trundle; to a 4½ feet stone, with 62 cogs and 15 rounds; and, to a 4 feet stone, with 64 cogs and 14 rounds. These gears will do well till the fall is reduced to 12 feet, only the wheel must be less, as the falls are less, so as to make the same number of revolutions in a minute; but this wheel requires more water than a breast-mill, with the same fall.

Fig. 6 is the forebay, gate, shute, and fall. Forebays should be wide, in proportion to the quantity of water they are to convey to the wheels, and should stand 8 or 10 feet in the bank, and be firmly joined, to prevent the water from breaking through; which it will certainly do, unless they be well secured.

ARTICLE 120.

DIRECTIONS FOR MAKING FOREBAYS.

The best way with which I am acquainted, for making this kind of forebays, is shown in Plate XVII., fig. 7. Make a number of solid frames, each consisting of a sill, two posts, and a cap; set them cross-wise, (as shown in the figure,) $2\frac{1}{2}$ or 3 feet apart; to these the planks are to be spiked, for there should be no sills lengthwise, as the water is apt to find its way along them. The frame at the head next the water, and one 6 or 8 feet downwards in the bank, should extend 4 or 5 feet on each side of the forebay into the bank, and be planked in front, to prevent the water, and vermin, from working round. Both of the sills of these long frames should be well secured, by driving down plank edge to edge, like piles, along the upper side, from end to end.

The sills being settled on good foundations, the earth or gravel must be rammed well on all sides, full to the top of the sills. Then lay the bottom with good, sound plank, well jointed and spiked to the sills. Lay your shute, extending the upper end a little above the point of the gate when full drawn, to guide the water in a right direction to the wheel. Plank the head to its proper height, minding to leave a suitable sluice, to guide the water smoothly down. Fix the gate in an upright position—hang the wheel, and finish it off, ready for letting on the water.

A rack must be made across the stream, to keep off the floating matter that would break the floats and buckets of undershot, breast, and pitch-back wheels, and injure the gates. (See it at the head of the forebay, fig. 7, Plate XVII.) This is done by setting a frame 3 feet in front of the forebay, and laying a sill 2 feet in front of it, for the bottom of the rack; in it the staves are put, made of laths, set edgewise with the stream, 2 inches apart, their upper ends nailed to the cap of the last frame; which causes them to lean down stream. The bottom of the race must be planked between the forebay and rack, to prevent the water from making a hole by tumbling through the rack when choked; and the sides must be planked outside of the posts to keep up the banks. This rack must be twice as long as the forebay is wide, or else the water will not come fast enough through it to keep the head up; for the head is the spring of motion of an undershot mill.

ARTICLE 121.

OF THE PRINCIPLE OF UNDERSHOT MILLS.

They differ from all others in principle, because the water loses all its force by the first stroke against the floats; and the time this force is spending, is in proportion to the difference of the velocities of the wheel and the water, and the distance of the floats. Other mills have the weight of the water after the force of the head is spent, and will continue to move: but an undershot will stop as soon as the head is spent, as they depend not on the weight. They should be geared so, that when the stone goes with a proper motion, the water-wheel will not run too fast, as they will not, then, receive the full force of the water; nor too slow, so as to lose its power by its rebounding and dashing over the buckets. This matter requires very close attention, and to find it out by theory, has puzzled our mechanical philosophers. They give us for a rule, that the wheel must move just one-third the velocity of the water: perhaps this may suit where the head is not much higher than the float-boards, but I am fully convinced that it will not suit high heads.

Experiments for determining the proper Motion for Undershot Wheels.

I drew a full sluice of water on an undershot wheel with 15 feet head and fall, and counted its revolutions per minute; then geared it to a mill-stone, set it to work properly, and again counted its revolutions, and the difference was not more than one-fourth slower. I believe, that if I had checked the motion of the wheel to be equal to one-third the motion of the water, the water would have rebounded and flown up to the shaft. Hence, I conclude, that the motion of the water must not be checked by the wheel more than one-third, nor less than one-fourth, else it will lose in power; for, although the wheel will carry a greater load with a slow, than with a swift motion, yet it will not produce so great an effect, its motion being too slow. And again, if the motion be too swift, the load or resistance it will overcome will be so much less, that its effect will be lessened also. I conclude, that about two-thirds the velocity of the water is the proper motion for undershot wheels; the water will then spend all its force in the distance of two float-boards. It will be seen that I differ greatly with those learned authors who have concluded that the velocity of the wheel ought to be but one-third of that of the water. To confute them, suppose the floats 12 inches, and the column of water striking them, 8 inches deep; then, if two-thirds of the motion of this column be checked, it must instantly become 24 inches deep, and rebound against the backs of the floats, and the wheel would be wallowing in this dead water; whereas, when only one-third of its motion is checked, it becomes 12 inches deep, and runs off from the wheel in a smooth and lively manner, *Directions for gearing Undershot Wheels,* 18 *feet in diameter, where the head is above* 3 *and under* 8 *feet, with double gears: counting the head from the point where the water strikes the floats.*

1. For 3 feet head and 18 feet wheel, see 18 feet wheel in the overshot table.
2. For 3 feet 8 inches head, see 17 feet wheel in do.
3. For 4 feet 4 inches head, see 16 feet wheel in do.
4. For 5 feet head, see 15 feet wheel in do.
5. For 5 feet 8 inches head, see 14 feet wheel in do.
6. For 6 feet 4 inches head, see 13 feet wheel in do.
7. For 7 feet head, see 12 feet wheel in do.

The revolutions of the wheels will be nearly equal; therefore the gears may be the same.

The following table is calculated to suit for any sized stone, from 4 to 6 feet diameter, different sized water-wheels from 12 to 18 feet diameter, and different heads from 8 to 20 feet above the point it strikes the floats; and to make 5 feet stones revolve 88 times; 4 feet 6 inch stones 97 times; and 4 feet stones 106 times, in a minute, when the water-wheel moves two-thirds the velocity of the striking water.

MILL-WRIGHT'S TABLE FOR UNDERSHOT MILLS, SINGLE GEARED.

Height of the head of water in feet.	Diameter of the water-wheel in feet.	Velocity of the water per minute in feet.	Velocity of the water wheel per minute in feet.	Revolutions of the water-wheel per minute.	Revolutions of the stone per minute.	Number of cogs in the cog-wheel.	Number of rounds in the trundle head.	Revolutions of the mill-stone for one of the water-whs.	Diameter of the stones in feet.
8	12	1360	906	24	88	56	15	$3\frac{3}{4}$	5
9	13	1448	965	$23\frac{1}{2}$	88	58	15	$3\frac{7}{8}$	5
10	14	1521	1014	$23\frac{1}{7}$	88	58	15	$3\frac{6}{7}$	5
11	15	1595	1061	$22\frac{3}{4}$	88	58	15	$3\frac{3}{4}$	5
12	16	1666	1111	$22\frac{1}{4}$	88	58	15	$3\frac{7}{8}$	5
13	16	1735	1157	$23\frac{1}{7}$	88	60	16	$3\frac{3}{4}$	5
14	16	1800	1200	24	88	59	16	$2\frac{2}{3}$	5
15	16	1863	1242	$24\frac{4}{5}$	88	60	17	$3\frac{1}{3}$	5
16	16	1924	1283	$25\frac{2}{3}$	88	59	17	$3\frac{3}{8}$	5
17	17	1983	1322	25	88	62	17	$3\frac{3}{4}$	5
18	17	2041	1361	$25\frac{2}{3}$	88	62	17	$3\frac{3}{8}$	5
19	18	2097	1398	25	88	62	17	$3\frac{3}{4}$	5
20	18	2152	1435	$25\frac{1}{2}$	88	60	17	$3\frac{3}{8}$	5
1	2	3	4	5	6	7	8	9	10

Note that there are nearly 60 cogs in the cog-wheel, in the foregoing table, and 60 inches is the diameter of a 5 feet stone: therefore, it will do, without sensible error, to put 1 cog more in the wheel for every inch that the stone is less than 60 inches diameter, down to 4 feet; the trundle head and water-wheel remaining the same; and for every three inches that the stone is larger than 60 inches in diameter, put 1 round more in the trundle, and the motion of the stone will be nearly right, up to 6 feet diameter.

ARTICLE 122.

OF BREAST WHEELS.

Breast wheels differ but little in their structure or motion from overshots, excepting only, that the water passes under, instead of over them, and they must be wider in proportion as their fall is less.

Fig. 1, Plate XIV., represents a low breast with 8 feet head and fall. It should be 9 inches wide for every foot of the diameter of the stone. Such wheels are generally 18 feet diameter; the number and dimensions of their parts being as follows: 8 arms 18 feet long, $3\frac{1}{4}$ by 9 inches; 16 shrouds 8 feet long, $2\frac{1}{2}$ by 9 inches; 56 buckets; and shaft, 2 feet diameter.

Fig. 2 shows the forebay, water-gate, and fall, and manner of striking on the water.

Fig. 3 is a middling breast wheel, 18 feet diameter, with 12 feet head and fall. It should be 8 inches wide for every foot the stone is in diameter.

Fig. 4 shows the forebay, gate, and fall, and manner of striking on the water.

Fig. 5 and 6, is a high breast wheel, 16 feet diameter, with 3 feet head in the forebay, and 10 feet fall. It should be 7 inches wide for every foot the stone is in diameter. The number and dimensions of its parts are 6 arms, 16 feet long, $3\frac{1}{4}$ by 9 inches; 12 shrouds, 8 feet 6 inches long, $2\frac{1}{2}$ by 8 or 9 inches deep, and 48 buckets.

ARTICLE 123.

OF PITCH-BACK WHEELS.

Pitch-back wheels are constructed exactly similar to breast wheels, only the water is struck on them at a greater height. Fig. 1, Plate XV, is a wheel 18 feet diameter, with 3 feet head in the penstock, and 16 feet fall below it. It should be 6 inches wide for every foot of the diameter of the stone.

Fig. 2 shows the trunk, penstock, gate, and fall; the gate sliding on the bottom of the penstock, and drawn by the lever A, turning on a roller. This wheel is much recommended by some mechanical philosophers, for the saving of water; but I do not join them in opinion, but think that an overshot with an equal head and fall, is fully equal to it in power; besides the saving of the expense in building so high a wheel, and the greater difficulty of keeping it in order.*

ARTICLE 124.

OF OVERSHOT WHEELS.

Overshot wheels receive their water on the top, being moved by its weight; and are much to be recommended where there is fall enough for them. Fig. 3 represents one 18 feet diameter, which should be about 6 inches wide for every foot the stone is in diameter. It should hang 8 or 9 inches clear of the tail water, otherwise the water will be drawn back under it. The head in the penstock should be generally about 3 feet, which will spout the water about one-third faster than the wheel moves. Let the shute have about 3 inches fall, and direct the water into the wheel at the centre of its top.

I have calculated a table for gearing overshot wheels, which will suit equally well any of the others of equal diameter, that have equal heads above the point where the water strikes the wheel.

* On this subject see the Appendix.—EDITOR.

Dimensions of this wheel, 8 arms 18 feet long, 3 by 9 inches; 16 shrouds 7 feet 9 inches long, 2½ by 7 or 8 inches; 56 buckets; and shaft 24 inches diameter.

Fig. 4 represents the penstock and trunk, &c., the water being let on the wheel by drawing the gate G.

Fig. 1 and 2, Plate XVI., represents a low overshot, 12 feet diameter, which should be in width equal to the diameter of the stone. Its parts and dimensions are, 6 arms 12 feet long, 3½ by 9 inches; 12 shrouds 6½ feet long, 2½ by 8 inches; shaft 22 inches diameter, and 30 buckets.

Fig. 3 represents a very high overshot 30 feet diameter, which should be 3½ inches wide for every foot of the diameter of the stone. Its parts and dimensions are, 6 main arms, 30 feet long, 3¼ inches thick, 10 inches wide at the shaft, and 6 at the end; 12 short arms 14 feet long, of equal dimensions; which are framed into the main arms near the shaft, as in the figure, for if they were all put through the shaft, they would make it too weak. The shaft should be 27 inches diameter, the whole being very heavy and bearing a great load. Such high wheels require but little water.

CHAPTER XX.

ARTICLE 125.

OF THE MOTION OF OVERSHOT WHEELS.

After trying many experiments, I concluded that the circumference of overshot wheels geared to mill-stones, grinding to the best advantage, should move 550 feet in a minute; and that of the stones 1375 feet in the same time; that is, while the wheel moves 12, the stone moves 30 inches, or in the proportion of 2 to 5.

Then, to find how often the wheel we propose to make, will revolve in a minute, take the following steps: 1st, Find the circumference of the wheel by multiplying the diameter by 22, and dividing by 7, thus:

Suppose the diameter to be 16 feet, then, 16 multiplied by 22, produces 352; which, divided by 7, gives 50 2-7 for the circumference.

```
    16
    22
    --
    32
   32
  ----
 7)352
  ----
  50 2-7
```

By which we divide 550, the distance the wheel moves in a minute, and it gives 11, for the revolutions of the wheel per minute, casting off the fraction 2-7, it being small.

```
5|0)55|0
    --
    11 times.
```

To find the revolutions of the stone per minute, 4 feet 6 inches (or 54 inches) diameter, multiply 54 inches by 22, and divide by 7, and it gives 169 5-7 (say 170) inches, the circumference of the stone.

```
     54
     22
    ---
    108
   108
   ----
 7)1188
   ----
   169 5-7
```

By which divide 1375 feet, or 16500 inches, the distance of the skirt of the stone should move in a minute, and it gives 97; the revolutions of a stone per minute, $4\frac{1}{2}$ feet diameter.

```
       1375
         12
       ----
17|0)1650(0|97
     153
     ---
      120
      119
      ---
        1
```

To find how often the stone revolves for once of the water-wheel, divide 97, the revolutions of the stone, by 11, the revolutions of the wheel, and it gives 8 9-11, (say 9 times.)

```
11)97
   --
   8 9-11
```

ARTICLE 126.

OF GEARING.

If the mill were to be single geared, 99 cogs and 11 rounds would give the stone the right motion, but the cog-wheel would then be too large, and the trundle too small; it must, therefore, be double geared.

Suppose we choose 66 cogs in the big cog-wheel and 48 in the little one, and 25 rounds in the wallower, and 15 in the trundle.

Then, to find the revolutions of the stone for one of the water-wheel, multiply the cog-wheels together, and the wallower and trundle together, and divide one product by the other, and it will give the answer, $8\frac{168}{375}$, not quite $8\frac{1}{2}$ revolutions, instead of 9.

```
     25
     15
    ---
    125
    25
    ---
    375

     66
     48
    ---
    528
   264
   ----
375)3168(8 168-375
    3000
    ----
     168
```

We must, therefore, devise another proportion—Considering which of the wheels we had best alter, and wishing not to alter the big cog-wheel or trundle, we put one round less in the wallower, and two cogs more in the little cog-wheel, and multiplying and dividing as before, we find the stone will turn $9\frac{1}{6}$ times for once of the water-wheel, which is as near as we can get. The mill now stands thus, a 16 feet overshot wheel, that will revolve 11 times in a minute, geared to a stone $4\frac{1}{2}$ feet in diameter; the big cog-wheel 66 cogs, $4\frac{1}{2}$ inches from centre to centre of the cogs; (which we call the pitch of the gear) little cog-wheel 50 cogs, $4\frac{1}{4}$ pitch; wallower 24 rounds, $4\frac{1}{2}$ pitch; and trundle 15 rounds, $4\frac{1}{4}$ inches pitch.

ARTICLE 127.

RULES FOR FINDING THE DIAMETER OF THE PITCH CIRCLES.

To find the diameter of the pitch circle, that the cogs stand in, multiply the number of cogs by the pitch, which gives the circumference; this, multiplied by 7, and divided by 22, gives the diameter in inches; which, divided by 12, reduces it to feet and inches, thus:

```
     66
     4½
    ---
    264
     33
    ---
    297
      7
   ----
22)2079(94½ in.
   198
   ---
    99
    88
    --
    11
```

For the cog-wheel of 66 cogs, and 4½ inches pitch, we find 7 feet 10½ inches to be the diameter of the pitch circle; to which I add 8 inches, for the outside of the cogs, which makes 8 feet 6½ inches, the diameter from out to out.

By the same rules, I find the diameters of the pitch circles of the other wheels to be as follows; namely :—

	feet.	inches.	
Little cog-wheel 50 cogs, 4¼ inches pitch,	5	7½ $\frac{10}{22}$	pitch cir.
I add, for the outside of the circle,		7½	
Total diameter from out to out,	6	3	
Wallower 24 rounds, 4½ inches pitch,	2	11¾ $\frac{4}{22}$	do.
Add, for outsides,	0	3½ $\frac{8}{22}$	
Total diameter from the outsides,	3	3	
Trundle head 15 rounds, 4¼ inches pitch,	1	8¼ $\frac{3}{22}$	do.
Add, for outsides,	0	2½ $\frac{10}{22}$	
Total diameter for the outsides,	1	11	

Thus, we have completed the calculations for one mill, with a 16 feet overshot water-wheel, and stones 4½ feet diameter. By the same rules we may calculate for wheels of all sizes from 12 to 30 feet, and stones from 4 to 6 feet diameter, and may form tables that will be of great use even to master workmen, in despatching of business, in laying out work for their apprentices and other hands, getting out timber, &c.; but more especially to those who are not sufficiently skilled in arithmetic to make the calculations. I have from long experience been sensible of the need of such tables, and have therefore unfore undertaken the task of preparing them.

ARTICLE 128.

MILL-WRIGHTS' TABLES,

Calculated to suit overshot water-wheels with suitable heads above them, of all sizes, from 12 to 30 feet diameter, the velocity of their circumferences being about 550 feet per minute, showing the number of cogs and rounds in all the wheels, double gear, to give the circumference of the stone a velocity of 1375 feet per minute, also the diameter of their pitch circles, the diameter of the outsides, and revolutions of the water-wheel, and stones, per minute.

For particulars, see what is written over the head of each table. Table I. is to suit a 4 feet stone, Table II. a 4½, Table III. a 5 feet, and Table IV. a 5½ feet stone.

N. B. If the stones should be an inch or two larger or less than those above described, make use of the table that comes nearest to it, and likewise for the water-wheels. For farther particulars see "Draughting Mills."

Use of the following Tables.

Having levelled your mill-seat, and found the total fall, after making due allowances for the fall in the races, and below the wheel, suppose there be 21 feet 9 inches, and the mill-stones be 4 feet in diameter, then look in Table I, (which is for 4 feet stones,) column 2, for the fall that is nearest yours, and you find it in the 7th example; and against it in column 8, is 3 feet, the head proper to be above the wheel; in column 4 is 18 feet, for the diameter of the wheel, &c., for all the proportions of the gears to make a steady moving mill; the stones to revolve 106 times in a minute.*

* The following tables are calculated to give the stones the revolution per minute mentioned in them, as near as any suitable number of cogs and rounds would permit, which motion I find is 8 or 10 revolutions per minute slower than proposed by Evans, in his table;—his motion may do best in cases where there is plenty of power, and steady work on one kind of grain; but, in country mills, where they are continually changing from one kind to another, and often starting and stopping, I presume a slow motion will work most regularly. His table being calculated for only one size of mill-stones, and mine for four, any one choosing his motion, may look for the width of the water-wheel, number of cogs, and rounds and size of the wheels to suit them, in the next example following, keeping to my table in other respects, and you will have his motion nearly.

TABLE I. For Overshot Mills, with Stones 4 feet diameter, to revolve 106 times in a minute, pitch of the gear of the great cog-wheel and wallowers $4\frac{1}{2}$ inches, and of lesser cog-wheel and trundle $4\frac{1}{4}$ inches.

No. of Examples.	Total falls of water from the top of that in the penstock to that in the tail-race.	Different heads of water above the water-wheel.	Diameters of water-wheels from out to out.	Widths of water-wheels in the clear.	No. of cogs in the great and lesser cog-wheels.	Diameters of pitch circles of great and lesser wheels.	Diameters of cog-wheels, from out to out.	No. of rounds in the wallowers and trundles.	Diameters of pitch circles in wallowers and trundles.	Total diameters of wallowers and trundles.	Revolutions of great wheel per minute, nearly.
	ft. in.	ft. in.	feet.	ft. in.		ft. in.	ft. in.		ft. in.	ft. in.	
1	15 3	2 6	12	3 0	66	7 10. 5	8 6. 5	25	2 11.75	3 3	13
					48	5 4.87	6 0. 5	15	1 8.33	1 11.33	
2	16 4	2 7	13	2 10	69	8 2.33	8 10.33	25	2 11.73	3 3	12.5
					48	5 4.87	6 0. 5	15	1 8.33	1 11.33	
3	17 5	2 8	14	2 8	69	8 2.33	8 10.33	26	3 1.25	3 5.25	12
					48	5 4.87	6 0. 5	15	1 8.33	1 11.33	
4	18 6	2 9	15	2 6	69	8 2.33	8 10.33	25	2 11.75	3 3	11.5
					50	5 7. 5	6 3	15	1 8.33	1 11.33	
5	19 7	2 10	16	2 4	72	8 7.25	9 3	26	3 1.25	3 5.25	11
					52	5 10.33	6 6	15	1 8.33	1 11.33	
6	20 8	2 11	17	2 3	72	8 7.25	9 3	25	2 11.75	3 3	10.5
					52	5 10.33	6 6	14	1 7	1 10	
7	21 9	3 0	18	2 2	72	8 7.25	9 3	24	2 10.33	3 1. 5	10
					52	5 10.33	6 6	14	1 7	1 10	
8	22 10	3 1	19	2 1	75	8 11.33	9 7.33	24	2 10.33	3 1. 5	9.66
					52	5 10.33	6 6	14	1 7	1 10	
9	23 11	3 2	20	2 0	75	8 11.33	9 7.33	23	2 9	3 0	9.25
					52	5 10.33	6 6	14	1 7	1 10	
10	25 1	3 4	21	1 11	78	9 3. 5	9 11. 5	24	2 10.33	3 1. 5	8.87
					52	5 10.33	6 6	14	1 7	1 10	
11	26 3	3 6	22	1 10	78	9 3. 5	9 11. 5	23	2 9	3 0	8.5
					52	5 10.33	6 6	14	1 7	1 10	
12	27 5	3 8	23	1 9	78	9 3. 5	9 11. 5	23	2 9	3 0	8.25
					54	6 1	6 8. 5	14	1 7	1 10	
13	28 7	3 10	24	1 8	81	9 8	10 4	23	2 9	3 0	8
					54	6 1	6 8. 5	14	1 7	1 10	
14	29 9	4 0	25	1 7	81	9 8	10 4	23	2 9	3 0	7.75
					56	6 3.75	6 11.25	14	1 7	1 10	
15	30 11	4 2	26	1 6	84	10 0.25	10 8.25	23	2 9	3 0	7.5
					56	6 3.75	6 11.25	14	1 7	1 10	
16	32 1	4 4	27	1 5	84	10 0.25	10 8.25	23	2 9	3 0	6.75
					58	6 6.25	7 1.75	14	1 7	1 10	
17	33 3	4 6	28	1 4	84	10 0.25	10 8.25	23	2 9	3 0	6.66
					56	6 3.75	6 11.25	13	1 5.25	1 8.25	
18	34 6	4 9	29	1 3	84	10 0.25	10 8.25	22	2 7. 5	2 10. 5	6. 5
					56	6 3.75	6 11.25	13	1 5.25	1 8.25	
19	35 9	5 0	30	1 2	87	10 5	11 1	22	2 7. 5	2 10. 5	6.25
					56	6 3.75	6 11.25	13	1 6.25	1 8.25	

TABLE II. For Overshot Mills, with Stones 4 feet 6 inches Diameter, to revolve 99 times in a minute, pitch of the gears $4\frac{1}{2}$ and $4\frac{1}{4}$ inches.

No. of Examples.	Total falls of water from the top of that in the penstock to that in the tail-race.		Different heads of water above the water-wheel.		Diameters of water-wheels from out to out.	Widths of water-wheels in the clear.		No. of cogs in the great and lesser cog-wheel.	Diameters of pitch circles of great and lesser cog-wheels.		Diameters of cog-wheels from out to out.		No. of rounds in wallowers and trundles.	Diameters of pitch circles in wallowers and trundles.		Total diameters of wallowers and trundles.		Revolutions of the great wheel per minute, nearly.
	ft.	in.	ft.	in.	feet.	ft.	in.		ft.	in.	ft.	in.		ft.	in.	ft.	in.	
1	15	3	2	6	12	3	6	66	7	10. 5	8	6. 5	26	3	1.25	3	4.25	13
								48	5	4.87	6	0. 5	15	1	8.33	1	11.33	
2	16	4	2	7	13	3	4	66	7	10. 5	8	6. 5	25	2	11.75	3	3	12.5
								48	5	4.87	6	0. 5	15	1	8.33	1	11.33	
3	17	5	2	8	14	3	2	69	8	2.33	8	10.33	26	3	1.25	3	4.25	12
								48	5	4.87	6	0. 5	15	1	8.33	1	11.33	
4	18	6	2	9	15	3	0	69	8	2.33	8	10.33	25	2	11.75	3	3	11.5
								48	5	4.87	6	0. 5	15	1	8.33	1	11. 5	
5	19	7	2	10	16	2	10	69	8	2.33	8	10.33	25	2	11.75	3	3	11
								50	5	7.87	6	3	15	1	8.33	1	11. 5	
6	20	8	2	11	17	2	8	72	8	7.12	9	3	26	3	1.25	3	4.25	10.5
								52	5	10.33	6	6	15	1	8.33	1	11. 5	
7	21	9	3	0	18	2	6	72	8	7.25	9	3	25	2	11.75	3	3	10
								52	5	10.33	6	6	14	1	7	1	11. 5	
8	22	10	3	1	19	2	4	72	8	7.25	9	3	24	2	10.33	3	2. 5	9.5
								52	5	10.33	6	6	14	1	7	1	11. 5	
9	23	11	3	2	20	2	3	75	8	11.33	9	7.33	24	2	10.33	3	2. 5	9
								52	5	10.33	6	6	14	1	7	1	11. 5	
10	25	1	3	4	21	2	2	75	8	11.33	9	7.33	23	2	9	3	0	8.75
								52	5	10.33	6	6	14	1	7	1	11. 5	
11	26	3	3	6	22	2	1	78	9	3. 5	9	11. 5	24	2	10.33	3	2. 5	8.5
								52	5	10.33	6	6	14	1	7	1	11. 5	
12	27	5	3	8	23	2	0	78	9	3. 5	9	11. 5	23	2	9	3	0	8.25
								52	5	10.33	6	6	14	1	7	1	11. 5	
13	28	7	3	10	24	1	11	78	9	3. 5	9	11. 5	23	2	9	3	0	8
								54	6	1	6	8. 5	14	1	7	1	11. 5	
14	29	9	4	0	25	1	10	81	9	8	10	4	23	2	9	3	0	7.75
								54	6	1	6	8. 5	14	1	7	1	11. 5	
15	30	11	4	2	26	1	9	81	9	8	10	4	23	2	9	3	0	7.5
								56	6	3.25	6	11.25	14	1	7	1	11. 5	
16	32	1	4	4	27	1	8	84	10	0.25	10	8.25	23	2	9	3	0	6.75
								56	6	3.25	6	11.25	14	1	7	1	11. 5	
17	33	3	4	6	28	1	6	84	10	0.25	10	8.25	23	2	9	3	0	6.66
								58	6	6.25	7	1.25	14	1	7	1	11. 5	
18	34	6	4	9	29	1	5	84	10	0.75	10	8.25	23	2	9	3	0	6.5
								56	6	3.25	6	11.25	13	1	5.25	1	8.25	
19	35	9	5	0	30	1	4	84	10	0.75	10	8.25	22	2	7. 5	2	10. 5	6.25
								56	6	3.25	6	11.25	13	1	5.25	1	8.25	

TABLE III. Stones 5 feet Diameter, to revolve 86 times in a minute, the pitch of the gears 4½ and 4¼ inches.

No. of Examples.	Total falls of water from the top of that in the penstock to that in the tail-race. ft.	in.	Different heads of water above the water-wheel. ft.	in.	Diameters of water-wheels from out to out. feet.	Widths of water-wheels in the clear. ft.	in.	No. of cogs in the great and lesser cog wheel.	Diameter of pitch circles of great and lesser cog-wheels. ft.	in.	Diameters of cog-wheels from out to out. ft.	in.	No. of rounds in the wallowers and trundles.	Diameters of pitch circles in wallowers and trundles. ft.	in.	Total diameters of wallowers and trundles. ft.	in.	Revolutions of great wheel per minute, nearly.
1	15	3	2	6	12	4	0	63	7	6.12	8	2.12	26	3	1.25	3	4.25	13
								48	5	4.87	6	0.5	16	1	9.66	2	4.25	
2	16	4	2	7	13	3	10	66	7	10.5	8	6.5	26	3	1.25	3	4.25	12.5
								48	5	4.87	6	0.5	16	1	9.66	2	4.25	
3	17	5	2	8	14	3	8	66	7	10.5	8	6.5	25	2	11.75	3	3	12
								48	5	4.87	6	0.5	15	1	8.33	1	11.33	
4	18	6	2	9	15	3	6	69	8	2.33	8	10.33	26	3	1.25	3	4.25	11.5
								48	5	4.87	6	0.5	15	1	8.33	1	11.33	
5	19	7	2	10	16	3	4	69	8	2.33	8	10.33	25	2	11.75	3	3	11
								48	5	4.87	6	0.5	15	1	8.33	1	11.5	
6	20	8	2	11	17	3	2	69	8	2.33	8	10.33	25	2	11.75	3	3	10.5
								50	5	7.5	6	3	15	1	8.33	1	11.5	
7	21	9	3	0	18	3	0	72	8	7.25	9	3	26	3	1.25	3	4.25	10
								52	5	10.33	6	6	15	1	8.33	1	11.33	
8	22	10	3	1	19	2	10	72	8	7.25	9	3	25	2	11.75	3	3	9.66
								52	5	10.33	6	6	14	1	7	1	11.5	
9	23	11	3	2	20	2	8	72	8	7.25	9	3	24	2	10.33	3	2.5	9.25
								52	5	10.33	6	6	14	1	7	1	11.5	
10	25	1	3	4	21	2	6	75	8	11.33	9	7.33	24	2	10.33	3	2.5	8.87
								52	5	10.33	6	6	14	1	7	1	11.5	
11	26	3	3	6	22	2	5	75	8	11.33	9	7.33	23	2	9	3	0	8.5
								52	5	10.33	6	6	14	1	7	1	11.5	
12	27	5	3	8	23	2	4	78	9	3.5	9	11.5	24	2	10.33	3	2.33	8.25
								52	5	10.33	6	6	14	1	7	1	11.5	
13	28	7	3	10	24	2	3	78	9	3.5	9	11.5	23	2	9	3	0	8
								52	5	10.33	6	6	14	1	7	1	11.5	
14	29	9	4	0	25	2	2	78	9	3.5	9	11.5	23	2	9	3	0	7.75
								54	6	1	6	8.5	14	1	7	1	11.5	
15	30	11	4	2	26	2	0	81	9	8	10	4	23	2	9	3	0	7.5
								54	6	1	6	8.5	14	1	7	1	11.5	
16	32	1	4	4	27	1	11	81	9	8	10	4	23	2	9	3	0	6.33
								56	6	3.25	6	11.25	14	1	7	1	11.5	
17	33	3	4	6	28	1	9	84	10	0.25	10	8.25	23	2	9	3	0	6.66
								56	6	3.25	6	11.25	14	1	7	1	11.5	
18	34	6	4	9	29	1	7	84	10	0.25	10	8.25	23	2	9	3	0	6.25
								58	6	6.25	7	1.25	14	1	7	1	11.5	
19	35	9	5	0	30	1	6	84	10	0.25	10	8.25	23	2	9	3	0	6.25
								56	6	3.25	6	11.25	13	1	5.25	1	8.5	

TABLE IV. For Overshot Mills with Stones 5 feet 6 inches Diameter, to revolve 80 times in a minute, pitch of the gears $4\frac{3}{4}$ inches and $4\frac{1}{2}$ inches.

No. of Examples.	Total fall of water from the top of that in the penstock to that in the tail-race. ft. in.	Different heads of water above the water-wheels. ft. in.	Diameters of water-wheels from out to out. feet.	Widths of water-wheels in the clear. ft. in.	No. of cogs in the great and lesser cog-wheels.	Diameters of pitch circles of great and lesser cog-wheels. ft. in.	Diameters of cog-wheels from out to out. ft. in.	No. of rounds in wallowers and trundles.	Diameters of pitch circles in wallowers and trundles. ft. in.	Total diameters of wallowers and trundles. ft. in.	Revolutions of the great wheel per minute, nearly.
1	15 3	2 6	12	4 6	60	7 6.75	8 2.75	26	3 3.25	3 6.25	13
					48	5 8.75	6 4.25	16	1 11	2 2	
2	16 4	2 7	13	4 4	63	7 11.12	8 7.12	26	3 3.25	3 6.25	12.5
					48	5 8.75	6 4.25	16	1 11	2 2	
3	17 5	2 8	14	4 2	66	8 3.75	8 11.75	26	3 3.25	3 6.25	12
					48	5 8.75	6 4.25	16	1 11	2 2	
4	18 6	2 9	15	4 0	66	8 3.75	8 11.75	26	3 3.25	3 6.25	11.5
					48	5 8.75	6 4.25	15	1 9. 5	2 0. 5	
5	19 7	2 10	16	3 10	69	8 8.33	9 4.33	26	3 3.25	3 6.25	11
					48	5 8.75	6 4.25	15	1 9. 5	2 0. 5	
6	20 8	2 11	17	3 8	69	8 8.33	9 4.33	25	3 1.75	3 4.75	10.5
					48	5 8.75	6 4.25	15	1 9. 5	2 0. 5	
7	21 9	3 0	18	3 6	69	8 8.33	9 4.33	25	3 1.75	3 4.75	9
					50	5 11. 5	6 2. 5	15	1 9. 5	2 0. 5	
8	22 10	3 1	19	3 4	72	9 0.75	9 8.75	26	3 3.25	3 6.25	9.66
					52	6 2. 5	6 10	14	1 8	1 11	
9	23 11	3 2	20	3 2	72	9 0.75	9 8.75	25	3 1.75	3 4.75	9.25
					72	6 2. 5	6 10	14	1 8	1 11	
10	25 1	3 4	21	3 0	52	9 0.75	9 8.75	24	3 0.75	3 3.75	8.12
					52	6 2. 5	6 10	14	1 8	1 11	
11	26 3	3 6	22	2 10	75	9 5.33	10 1.33	24	3 0.75	3 3.75	8.5
					52	6 2. 5	6 10	14	1 8	1 11	
12	27 5	3 8	23	2 8	75	9 5.33	10 1.33	23	2 10.75	3 1.75	8.25
					52	6 2. 5	6 10	14	1 8	1 11	
13	28 7	3 10	24	2 6	78	9 10. 5	10 6	24	3 0.75	3 3.75	8
					52	6 2. 5	6 10	14	1 8	1 11	
14	29 9	4 0	25	2 4	78	9 10. 5	10 6	23	2 10.75	3 1.75	7.75
					52	6 2. 5	6 10	14	1 8	1 11	
15	30 11	4 2	26	2 2	78	9 10. 5	10 6	23	2 10.75	3 1.75	7.5
					54	6 5.33	7 1	14	1 8	1 11	
16	32 1	4 4	27	2 0	81	10 2. 5	10 10. 5	23	2 10.75	3 1.75	6.75
					54	6 5.33	7 1	14	1 8	1 11	
17	33 3	4 6	28	1 11	81	10 2. 5	10 10. 5	23	2 10.75	3 1.75	6.66
					56	6 8	7 3. 5	14	1 8	1 11	
18	34 6	4 9	29	1 10	84	10 7	11 3	23	2 10.75	3 1.75	6.5
					56	6 8	7 3. 5	14	1 8	1 11	
19	35 9	5 0	30	1 9	84	10 7	11 3	23	2 10.75	3 1.75	6.25
					58	6 11	7 6. 5	14	1 8	1 11	

CHAPTER XXI.

ARTICLE 129.

DIRECTIONS FOR CONSTRUCTING UNDERSHOT WHEELS, SUCH AS SHOWN IN FIGURE 1, PLATE XIII.

1. Dress the arms straight and square on all sides, and find the centre of each; divide each into 4 equal parts on the side; square, centre, scribe, and gauge them from the upper side across each point, on both sides, 6 inches each way from the centre.

2. Set up a truckle or centre-post, for a centre to frame the wheel on, in a level piece of ground, and set a stake to keep up each end of the arms level with the truckle, of convenient height to work on.

3. Lay the first arm with its centre on the centre of the truckle, and take a square notch out of the upper side 3-4ths of its depth, wide enough to receive the 2d arm.

4. Make a square notch in the lower edge of the 2d arm, 1-4th of its depth, and lay it in the other, and they will joint, standing square across each other.

5. Lay the 3d arm just equi-distant between the others, and scribe the lower arms by the side of the upper, and the lower edge of the upper by the sides of the lower arms. Then take the upper arm off and strike the square scribes, taking out the lower half of the 3d arm, and the upper half of the lower arms, and fit and lay them together.

6. Lay the 4th arm on the others, and scribe as directed before; then take 3-4ths of the lower edge of the 4th arm, and 1-4th out of the upper edge of the others, and lay them together, and they will be locked together in the depth of one.

7. Make a sweep-staff with a gimlet hole for the centre at one end, which must be set by a gimlet in the centre of the arms. Measure from this hole half the diameter of the wheel, making a hole there, and another the depth of the shrouds towards the centre, making each edge of this sweep at the end next the shrouds, straight

towards the centre hole, to scribe the ends of the shrouds by.

8. Circle both edges of the shrouds by the sweep; dress them to the proper width and thickness; lay out the laps 5 inches long; set a gauge to a little more than one-third their thickness; gauge all their ends for the laps from the outsides; cut them all out but the last, that it may be made a little longer, or shorter, as may suit to make the wheel the right diameter; sweep a circle on the arms to lay the shrouds to, while fitting them; put a small draw-pin in the middle of each lap, to draw the joints close; strike true circles both for the inside and outside of the shrouds, and 1½ inches from the inside, where the arms are to be let in.

9. Divide the circle into 8 equal parts, coming as near the middle of each shroud as possible; strike a scribe across each to lay out the notch by, that is to be cut 1½ inches deep, to let in the arm at the bottom, where it is to be forked to take in the remainder of the shroud. Strike a scribe on the arms with the same sweep that the stroke for the notches on the shrouds was struck with.

10. Scribe square down on each side of the arms, at the bottom, where they are to be forked; make a gauge to fit the arms, so wide as just to take in the shrouds, and leave 1½ inches of wood outside of the mortise; bore 1 or 2 holes through each end of the arms to draw-pin the shrouds to the arms when hung; mark all the arms and shrouds to their places, and take them apart.

11. Fork the arms, put them together again, and put the shrouds into the arms; draw-bore them, but not too much, which would be worse than too little; take the shrouds apart again, turn them the other side up, and draw the joints together with the pins, and lay out the notches for 4 floats between each arm, 32 in all, large enough for admitting keys to keep them fast, but allowing them to drive in when any thing gets under the wheel. The ends of the floats must be dove-tailed a little into the shrouds; when one side is framed, frame the other to fellow it. This done, the wheel is ready to hang, but remember to face the shrouds between the arms

with inch boards, nailed on with strong nails, to keep the wheel firmly together.

ARTICLE 130.

DIRECTIONS FOR DRESSING SHAFTS, &c.

The shaft for a water-wheel with 8 arms should be 16 square, or 16 sided, about 2 feet diameter, the tree to make it being 2 feet 3 inches at the top end. When cut down, saw it off square at each end, and roll it on level skids, and if it be not straight, lay the rounding side down and view it, to find the spot for the centre at each end. Set the large compasses to half its diameter, and sweep a circle at each end, plumb a line across each centre, and at each side of the circle, striking chalk lines over the plumb lines at each side from end to end, and dress the sides plumb to these lines; turn it down on one side, setting it level; plumb, line, and dress off the sides to a 4 square; set it exactly on one corner, and plumb, line, and dress off the corner to 8 square. In the same manner dress it to 16 square.

To cut it square off to its exact length, stick a peg in the centre of each end, take a long square, (which may be made of boards,) lay it along the corner, the short end against the end of the peg, mark on the square where the shaft is to be cut, and mark the shaft by it at every corner line, from mark to mark; then cut it off to the lines, and it will be truly square.

ARTICLE 131.

TO LAY OUT THE MORTISES FOR THE ARMS.

Find the centre of the shaft at each end, and strike a circle; plumb a line through the centre at each end to be in the middle of two of the sides; make another scribe square across it; divide the distance equally between them, so as to divide the circle into 8 equal parts, and strike a line from each of them, from end to end, in the middle of the sides; measure from the top end about 3 feet, and mark for the arm of the water-wheel, and the width of the wheel, and make another mark. Take a straight-edged 10 feet pole, and put the end even with the end of the shaft, and mark on it even with the marks on the shaft, and by these marks measure for the arm at every corner, marking and lining all the way round. Then take the uppermost arms of each rim, and by them lay out the mortises, about half an inch longer than they are wide, which is to leave key room; set the compasses a little more than half the thickness of the arms, and set one foot in the centre line at the end of the mortise, striking a scribe each way to lay out the width by; this done, lay out 2 more on the opposite side, to complete the mortises through the shaft. Lay out 2 more, square across the first, one-quarter the width of the arm longer, inwards, towards the middle of the wheel. Take notice which way the locks of the arms wind, whether to right or left, and lay out the third mortises to suit, else it will be a chance whether they suit or not: these must be half the width of the arms longer, inwards.

The 4th set of mortises must be three-fourths longer inwards than the width of the arms; the mortises should be made rather hollowing than rounding, that the arms may slip in easily and stand fair.

If there be 3 (which are called 6) arms to the cog-wheel, but one of them can be put through the sides of the shaft fairly; therefore, to lay out the mortises, divide the end of the shaft anew, into but 6 equal parts, by striking a circle on each end; and without altering the compasses, step from one of the old lines, six steps round the circle, and from these points strike chalk lines, and they will be the middle of the mortises, which may be laid out as before, minding which way the arms lock, and making two of the mortises one-third longer than the width of the arm, extending one on one side, and the other on the other side of the middle arm.

If there be but 2 (called 4) arms in the cog-wheel, (which will do where the number of cogs does not exceed 60) they will pass fairly through the sides, whether the shafts be 12 or 16 sided. One of these must be made one-half longer than the width of the arms, to give room to put the arm in.

ARTICLE 132.

TO PUT IN THE GUDGEONS.

Strike a circle on the ends of the shaft to let on the end bands; make a circle all round, $2\frac{1}{2}$ feet from each end, and saw a notch all round, half an inch deep. Lay out a square, round the centres, the size of the gudgeons, near the neck; lay the gudgeons straight on the shaft, and scribe round them for their mortises; let them down within one-eighth of an inch of being in the centre. Dress off the ends to suit the bands; make 3 keys of good, seasoned white oak, to fill each mortise above the gudgeons, to key them in, those next to the gudgeons to be $3\frac{1}{4}$ inches deep at the inner end, and $1\frac{1}{2}$ inches at their outer end, the wedge or driving key 3 inches at the head, and 6 inches longer than the mortise, that it may be cut off, if it batter in driving; the piece next the band so wide as to rise half an inch above the shaft, when all are laid in. Then take out all the keys and put on the bands, and make 8 or 12 iron wedges about 4 inches long by 2 wide, 1-3d inch thick at the end, not much tapered except half an inch at the small end, on one side next the wood; by means of a set, drive them in on each side the gudgeon extremely hard, at a proper distance apart. Then put in the keys again, and lay a piece of iron under each band, between it and the key, 6 inches long, half an inch thick in the middle, and tapering off at the ends; then grease the keys well with tallow, and drive it well with a heavy sledge: after this, drive an iron wedge, half an inch from the two sides of each gudgeon, 5 inches long, about half an inch thick, and as wide as the gudgeon.

ARTICLE 133.

OF COG-WHEELS.

The great face cog-wheels require 3 (called 6) arms, if the number of cogs exceed 54; if less, 4 will do. We find by the table, example 43, that the cog-wheel must have 69 cogs, with $4\frac{1}{2}$ inches pitch, the diameter of its pitch circle 8 feet $2\frac{1}{3}$ inches, and of its outsides 8 feet $10\frac{1}{3}$ inches. It requires 3 arms, 9 feet long, 14 by $3\frac{3}{4}$ inches; 12 cants, $6\frac{1}{2}$ feet long, 16 by 4 inches. (See it represented, fig. 1, Plate XVII.)

To frame it, dress and lock the arms together, (fig. 6, Pl. XVII.) as directed, Art. 129, only mind to leave one-third of each arm uncut, and to lock them the right way to suit the winding of the mortises in the shaft, which is best found by putting a strip of board in the middle mortise, and supposing it to be the arm, mark which way it should be cut, then apply the board to the arm, and mark it. The arms being laid on a truckle, as directed, Art. 129, make a sweep, the sides directing to the centre, 2 feet from the outer end to scribe by; measure on the sweep, half the diameter of the wheel; and by it circle out the back edges of the cants, all of one width in the middle; dress them, keeping the best faces for the face side of the wheel; make a circle on the arms half an inch larger than the diameter of the wheel, laying 3 of the cants with their ends on the arms, at this circle, at equal distances apart. Lay the other three on the top of them, so as to lap equally; scribe them both under and top, and gauge all for the laps from the face side; dress them out and lay them together, and joint them close; draw-pin them by an inch pin near their inside corners: this makes one-half of the wheel, shown fig. 5. Raise the centre level with that half; strike a circle near the outside, and find the centre of one of the cants; then, with the sweep that described the circle, step on the circle 6 steps, beginning at the middle of the cant, and these steps will show the middle of all the cants, or places for the arms. Make a scribe from the centre across each; strike another circle exactly at the corners, to place the corners of the next half by, and another about 2½ inches farther out than the inside of the widest part of the cant, to let the arms in by; lay on three of the upper cants, the widest part over the narrowest part of the lower half, the inside to be at the point where the corner circle crosses the centre lines. Saw off the ends, at the centre scribes, and fit them down to their places, doing the same with the rest. Lay them all on, and joint their ends together; draw-pin them to the lower half, by inch pins, 2 inches from their inner edges, and 9 inches from their ends. Raise the centre level with the wheel; plane a little of the rough off the face, and strike the pitch circle, and another 4 inches inside, for the width of the face; strike another very near it, in which drive a chisel, half an inch deep, all round, and strike lines, with chalk, in the middle of the edge of the upper cants, and cut out of the solid, half of the upper cants, which raises the face; divide the pitch circle into 69 equal parts, 4½ inches pitch, beginning and ending in a joint; strike two other circles each 2½ inches from the pitch circle, and strike central scribes between the cogs, and where they cross the circles put in pins, as many as there are cogs, half on each circle; find the lowest part on the face, and make the centre level with it; look across in another place, square with the first, and make it level with the centre also; then make the face straight, from these four places, and it will be true.

Strike the pitch circle, and divide it over again, and strike one circle on each side of it, 1 inch distance, for the cog mortises; sweep the outside of the wheel and inside of the face, and two circles ¾ths of an inch from them, to dress off the corners; strike a circle of two inches diameter on the centre of each cog, and with the sweep strike central scribes at each side of these circles for the cog mortises; bore and mortise half through; turn the wheel, dress and mortise the back side, leaving the arms from under it; strike a circle on the face edge of the arms, equal in diameter to that struck on the face of the half wheel, to let them in by; saw in square, and take out 4½ inches, and let them into the back of the wheel 1¼ inches deep, and bore a hole 1½ inches into each arm, to pin it to the wheel.

Strike a circle on the arms one inch less than the diameter of the shaft; make a key 8 inches long, 1½ thick, 3¼ at the butt, and 2½ inches at the top end, and by it lay out the mortises; two on each side of the shaft, in each arm, to hang the wheel by.

ARTICLE 134.

OF SILLS, SPUR-BLOCKS, AND HEAD-BLOCKS.

See a side view of them in Plates XIII., XIV., XV., and XVI., and a top view of them, with their keys, at the end of the shaft, Plate XVIII. The sills are generally 12 inches square. Lay them on the wall as firmly as possible, and one 3 feet farther out; on these lay the spurs, which are 5 feet long, 7 by 7 inches, 3 feet apart, notched and pinned to the sills: on these are set the head-blocks, 14 by 12 inches, 5 feet long, let down with a dove-tail shoulder between the spurs, to support keys to move it endwise, and let 2 inches into the spurs with room for keys, to move it sidewise, and hold it to its place; see fig. 33 and 34, Plate XVIII. The ends of the shaft are let 2 inches into the head-blocks, to throw the weight more on the centre.

Provide two stones 5 or 6 inches square, very hard and clear of grit, for the gudgeons to run on, let them into the head-blocks, put the cog-wheel into its place, and then put in the shaft on the head-blocks in its place.

Put in the cog-wheel arm, lock them together, and pin the wheel to them; then hang the wheel, first by the keys to make it truly round, and then by side wedges, to make it true in face; turn the wheel, and make two circles, one on each side of the cog mortises, half an inch from them, so that the head of the cogs may stand between them equally.

ARTICLE 135.

OF COGS; THE BEST TIME FOR CUTTING, AND MANNER OF SEASONING THEM.

Cogs should be cut 14 inches long, and 3¼ inches square; this should be done when the sap runs at its fullest, at least a year before they are used, that they may dry without cracking. If either hickory or white oak be cut when the bark is set, they will worm-eat, and, if dried hastily, will crack; to prevent which, boil them and dry them slowly, or soak them in water, a year, (20 years in mud and fresh water would not hurt them;) when they are taken out they should be put in a hay-mow, under the hay, where, while foddered away, they will dry without cracking; but this often takes too long a time. I have discovered the following method of drying them, in a few days, without cracking. I have a malt kiln with a floor of laths two inches apart; I shank the cogs, hang them shank downwards, between the laths, cover them with a hair cloth, make a wood fire, and the smoke prevents them from cracking. Some dry them in an oven, which ruins them. Boards, planks, or scantling, are best dried in a kiln, covered so as to keep the smoke amongst them. Instead of a malt kiln, dig a cave in the side of a hill, 6 feet deep, 5 or 6 feet wide, with a post in each corner with plates on them, on which lay laths on edge, and pile the cogs on end, nearly perpendicular, so that the smoke can pass freely through, or amongst them. Cover them slightly with boards and earth, make a slow fire, and close up the sides, and renew the fire once a day, for 12 or 15 days they will then dry without cracking.

ARTICLE 136.

OF SHANKING, PUTTING IN, AND DRESSING OFF COGS.

Straighten one of the heart sides for the shank, make a pattern, the head 4 and shank 10 inches long, and 2 inches wide at the head, 1¾ at the point; lay it on the cog, scribe the shank and shoulders, for the head, saw in and dress off the sides; make another pattern of the shank, without the head, to scribe the sides and dress off the backs by, laying it even with the face, which is to have no shoulder; take care in dressing them off, that the axe do not strike the shoulder; if it do, it will crack there in drying, (if they be green;) fit and drive them in the mortises exceedingly tight, with their shoulders foremost, when at work. When the cogs are all in, fix two pieces of scantling, for rests, to scribe the cogs by, one across the cog-pit, near the cogs, another in front of them; fix them firmly. Hold a pointed tool on the rest, and scribe for the length of the cogs, by turning the wheel, and saw them off $3\frac{1}{2}$ inches long; then move the rest close to them, and fix it firmly; find the pitch circle on the end of the cogs, and, by turning the wheel, describe it there.

Describe another line $\frac{1}{4}$th of an inch outside thereof, to set the compasses in to describe the face of the cogs by, and another at each side of the cogs to dress them to their width; then pitch the cogs by dividing them equally, so that, in stepping round, the compasses may end in the point where they began; describe a circle, in some particular place, with the pitch, that it may not be lost; these points must be as nearly as possible of a proper distance for the centre from the back of the cogs; find the cog to the back of which this point comes nearest, and set the compasses from that point to the back of the cog; with this distance set off the backs of all the cogs equally, on the circle, $\frac{1}{4}$th of an inch outside of the pitch circle, and from these points, last made, set off the thickness of the cogs, which should, in this case, be $1\frac{1}{8}$ inches.

Then describe the face and back of the cogs by setting the compasses in the hindmost point of one cog, and sweeping over the foremost point of another, for the face, and in the foremost point of one, sweeping over the hindmost of the other, for the back part; dress them off on all sides, tapering about $\frac{1}{8}$th of an inch, in an inch distance; try them by a gauge, to make them all alike; take a little off the corners, and they are finished.

ARTICLE 137.

OF THE LITTLE COG-WHEEL AND SHAFT.

The process of making this is similar to that of the big cog-wheel. Its dimensions we find by the table, and the same example (43,) to be 52 cogs, $4\frac{1}{4}$ pitch; diameter of pitch circle 5 feet $10\frac{1}{3}$ inches, and from out to out, 6 feet 6 inches.

It requires 2 arms, 6 feet 6 inches long, 11 by $3\frac{1}{4}$ inches; 8 cants, 5 feet 6 inches, 17 by $3\frac{1}{2}$ inches. (See it, fig. 4, Plate XVII.)

Of the Shaft.

Dress it 8 feet long, 14 by 14 inches square, and describe a circle on each end 14 inches diameter; strike two lines through the centre, parallel to the sides, and divide the quarters into 4 equal parts, each; strike lines across the centre at each part at the end of these lines; strike chalk lines from end to end, to hew off the corners by, and it will be 8 square; lay out the mortises for the arms, put on the bands, and put in the gudgeons, as with the big shaft.

ARTICLE 138.

DIRECTIONS FOR MAKING WALLOWERS AND TRUNDLES.

By example 43, in the table, the wallower is to have 26 rounds $4\frac{1}{2}$ pitch: the diameter of its pitch circle is 3 feet $1\frac{1}{4}$ inches, and 3 feet $4\frac{1}{4}$ inches from outsides: (see fig. 3, Plate XVII.) Its head should be $3\frac{1}{2}$ inches thick, doweled truly together, or made with double plank, crossing each other. Make the bands 3 inches wide, $\frac{1}{8}$th of an inch thick, evenly drawn; the heads must be made to suit the bands, by setting the compasses so that they will step round the inside of the band in 6 steps; with this distance sweep the head, allowing about $\frac{1}{16}$th of an inch outside, in dressing, to make such a large band tight. Make them hot alike all around with a chip fire, which swells the iron; put them on the head while hot, and cool them with water, to keep them from burning the wood too much, but not too fast, lest they snap; the same mode serves for hooping all kinds of heads.

Dress the head fair after banding, and strike the pitch circle and divide it by the same pitch with the cogs; bore the holes for the rounds with an auger of at least $1\frac{1}{2}$ inches; make the rounds of the best wood, $2\frac{3}{8}$ inches diameter, and 11 inches between the shoulders, the tenons 4 inches, to fit the holes loosely, until within 1 inch of the shoulder, then drive it tight. Make the mortises for the shaft in the heads, with notches for the keys to hang it by. When the rounds are all driven into the shoulders, observe whether they stand straight; if not, they may be set fair by putting the wedges nearest to one side of the tenon, so that the strongest part may incline to draw them straight: this should be done with both heads.

ARTICLE 139.

OF FIXING THE HEAD-BLOCKS AND HANGING THE WHEELS.

The head-blocks, for the wallower shaft, are shown in Plate XVIII. Number 19 is one called a spur, 6 feet long and 15 inches deep, one end of which, at 19, is let 1 inch into the top of the husk-sill, which sill is $1\frac{1}{2}$ inches above the floor, the other end tenoned strongly into a strong post, 14 by 14 inches, 12 or 14 feet long, standing near the cog-wheel, on a sill in the bottom of the cog-pit; the top is tenoned into the husk-plank; these are called the tomkin posts. The other head-blocks appear at 20 and 28. In these large head-blocks there are small ones let in, that are 2 feet long, and 6 inches square, with a stone in each for the gudgeons to run on. That one in the spur 19 is made to slide, to put the wallower in and out of gear, by a lever screwed to its side.

Lay the centre of the little shaft level with the big one, so as to put the wallower to gear $\frac{2}{3}$ the thickness of the rounds deep, into the cog-wheel; put the shaft into its place, hang the wallower, and gauge the rounds to equal distance where the cogs take. Hang the cog-wheel, put in the cogs, make the trundle as directed for the wallower. (See fig. 4, Plate XVII.)

ARTICLE 140.

DIRECTIONS FOR PUTTING IN THE BALANCE-RYNE.

Lay it in the eye of the stone, and fix it truly in the centre; to do which, make a sweep by putting a long pin through the end, to reach into, and fit, the pivot hole in the balance-ryne; by repeated trials on the opposite side, fix it in the centre; then make a particular mark on the sweep, and others to suit it on the stone, scribe round the horns, and with picks and chisels sink the mortises to their proper depth, trying, by the particular marks made for the purpose, by the sweep, if it be in the centre. Put in the spindle with the foot upwards, and the driver on its place, while one holds it plumb. Set the driver over two of the horns, if it has four, but between them if it has but two. When the neck is exactly in the centre of the stone, scribe round the horns of the driver, and let it into the stone, nearly to the balance, if it has four horns. Put the top of the spindle in the pivot-hole, to try whether the mortises let it down freely on both sides.

Make a tram, to set the spindle square by, as follows: take a piece of board, cut a notch in one side, at one end, and hang it on the top of the spindle, by a little peg in the shoulder of the notch, to go into the hole in the foot, to keep it on; let the other end reach down to the edge of the stone; take another piece, circle out one end to fit the spindle neck, and make the other end fast to the lower end of the hanging piece near the stone, so as to play round level with the face of the stone, resting on the centre-hole in the foot, and against the neck; put a bit of quill through the end of the level piece, that will touch the edge of the stone as it plays round. Make little wedges, and drive them in behind the horns of the driver, to keep both ends, at once, close to the sides of the mortises they bear against when at work, keeping the pivot or cock-head in its hole in the balance; try the tram gently round, and mark where the quill touches the stone first, and dress off the bearing sides of the mortises for the driver, until it will touch equally all round, giving the driver liberty to move endwise, and sidewise, so that the stone may rock an inch either way. The ryne and driver must be sunk $\frac{3}{4}$ths of an inch below the face of the stone. Then hang the trundle firmly and truly on the spindle; put it in its place, to gear in the little cog-wheel.

ARTICLE 141.

TO BRIDGE THE SPINDLE.

Make a little tram of a piece of lath, 3 inches wide at one end, and 1 inch at the other, make a mortise in the wide end, and put it on the cock-head, and a piece of quill in the small end, to play round the face of the stone: then, while one turns the trundle, another observes where the quill touches first, and alters the keys of the bridge-tree, driving the spindle-foot toward the part the quill touches, until it does so equally all round. Case the stone neatly round, within 2 inches of the face.

ARTICLE 142.

OF THE CRANE AND LIGHTER STAFF.

Make a crane, with a screw and bale, for taking up and putting down the stone. (See it represented in Plate XI., fig. 2 and 3.) Set the post out of the way as much as possible, let it be 9 by 6 inches in the middle, the arm 9 by 6, the brace 6 by 4; make a hole plumb over the spindle, for the screw; put an iron washer on the arm under the female screw, nail it fast; the length of the screw in the worm part should exceed half the diameter of the stone, and it should reach 10 inches below it; the bale must touch only at the ends to give the stone liberty to turn, the pins to be 7 inches long, $1\frac{1}{8}$ thick, the bale to be $2\frac{1}{2}$ inches wide in the middle, and $1\frac{3}{4}$ inches wide at the end; the whole should be made of the best iron, for if either of them break, the danger would be great: the holes in the stone should be nearest to the upper side of it. Raise the runner by the crane, screw, and bale, turn it and lay it down, with the horns of the driving ryne in their right places, as marked, it being down, as it appears in Plate XXI., fig. 9. Make the lighter staff C C, to raise and lower the stone in grinding, about 6 feet long, $3\frac{1}{2}$ by $2\frac{1}{2}$ inches at the large end, and 2 inches square at the small end, with a knob on the upper side. Make a mortise through the but-end, for the bray-iron to pass through, which goes into a mortise 4 inches deep, in the end of the bray at b, and is fastened with a pin; it may be 2 inches wide and half an inch thick, made plain, with 1 hole at the lower, and 5 or 6 at the upper end; it should be set in a staggering position. This lighter is fixed in front of the meal-beam, at such a height as to be handy to raise and lower at pleasure; a weight of 4lbs. is hung to the end of it by a strap, which laps two or three times round, and the other end is fastened to the post below, that keeps it in its place. Play the lighter up and down, and observe whether the stone rises and falls flat on the bed-stone; if it do, draw a little water, and let the stone move gently round; then see that all things be right, and draw a little more water, let the stone run at a moderate rate, and grind the faces a few minutes.

ARTICLE 143.

DIRECTIONS FOR MAKING A HOOP FOR THE MILL-STONE.

Take a white pine or poplar board, 8 inches longer than will go round the stone, and 2 inches wider than the top of the stone is high, dress it smooth, and gauge it one inch thick, run a gauge mark $\frac{1}{6}$th of an inch from the outside, divide the length into 52 parts, and saw as many saw-gates square across the inside to the gauge-line. Take a board of equal width, 1 foot long, nail one-half of it on the outside at one end of the hoop, lay it in water a day or two to soak, or frequently sprinkle the outside with hot water, during an hour or two. Bend it round so that the ends meet, and nail the other end to the short board, put sticks across inside, in various directions, to press out the parts that bend least, and make it truly round. Make a cover for the hoop, (such as is represented in Plate XIX., fig. 23;) 8 square inside, and 1 inch outside the hoop. It consists of 8 pieces lapped one over another, the black lines showing the joints, as they appear when made, the dotted lines the under parts of the laps. Describe it on the floor, and make a pattern to make all the rest by; dress all the laps, fit and nail them together by the circle on the floor, and then nail it on the hoop; put the hoop over the stone and scribe it to fit the floor.

ARTICLE 144.

OF GRINDING SAND TO FACE THE STONES.

Lay boards over the hoop to keep the dust from flying, and take a bushel or two of dry, clean, sharp sand, teem it gently into the eye, while the stone moves at a moderate rate, continuing to grind for an hour or two; then take up the stones, sweep them clean, and pick the smoothest, hardest places, and lay the stone down again, and grind more sand as before, turning off the back, (if it be a burr,) taking great care that the chisel do not catch; take up the stone again, and make a red staff, equal, in length, to the diameter of the stone, and 3 by $2\frac{1}{2}$ inches; paint it with red paint and water, and rub it over the face of the stone in all directions, the red will be left on the highest and hardest parts, which must be picked down, making the bed-stone perfectly plain, and the runner a little concave, about $\frac{1}{6}$th of an inch at the eye, and lessening gradually to about 8 inches from the skirt. If they be close, and have much face, they need not touch, or flour, so far as if they be open, and have but little face; those things are necessarily left to the judgment of the mill-wright and miller.

ARTICLE 145.

DIRECTIONS FOR LAYING OUT THE FURROWS IN THE STONES, &c.

If they be five feet in diameter, divide the skirt into 16 equal parts, called quarters; if 6 feet, into 18; if 7 feet, into 20 quarters. Make two strips of board, one an inch, and the other 2 inches wide; stand with your face to the eye, and if the stone turn to the right when at work, lay the strip at one of the quarter divisions, and the other at the left hand side close to the eye, and mark with a flat pointed spike for a master furrow; they are all to be laid out the same way in both stones, for when their faces are together, the furrows should cross each other, like shears in the best position for cutting cloth. Then, having not fewer than 6 good picks, proceed to pick out all the master furrows, making the edge next the skirt and the end next the eye, the deepest, and the feather edge not half so deep as the back.

When all the master furrows are picked out, lay the broad strip next to the feather edges of all the furrows, and mark the head lands of the short furrows, then lay the same strip next the back edges, and mark for the lands, and lay the narrow strip, and mark for the furrows, and so mark out all the lands and furrows, minding not to cross the head lands, but leaving it between the master furrows and the short ones of each quarter. But if they be close country stones, lay out both furrows and lands with the narrow strip.

The neck of the spindle must not be wedged too tight, else it will burn loose; bridge the spindle again; put a collar round the spindle neck, but under it put a piece of an old stocking, with tallow rolled up in it, about a finger thick; tack it closely round the neck; put a piece of stiff leather about 6 inches diameter on the cock-head under the driver, to turn with the spindle and drive off the grain, &c., from the neck; grease the neck with tallow every time the stone is up.

Lay the stone down and turn off the back smooth, and grind more sand. Stop the mill, raise the stone a little, and balance it truly with a weight laid on the lightest side. Take lead equal to this weight, melt it, and run it into a hole made in the same place in the plaster; this hole should be largest at bottom to keep it in; fill the hole with the plaster, take up the runner again, try the staff over the stones, and if in good face, give them a nice dressing, and lay them down to grind wheat.

ARTICLE 146.

DIRECTIONS FOR MAKING A HOPPER, SHOE, AND FEEDER.

The dimensions of the hopper of a common mill is 4 feet at the top, and 2 feet deep, the hole in the bottom 3 inches square, with a sliding gate in the bottom of the front to lessen it at pleasure: the shoe 10 inches long, and 5 wide in the bottom, of good sound oak. The side 7 or 8 inches deep at the hinder end, 3 inches at the foremost end, 6 longer than the bottom of the fore end, slanting more than the hopper behind, so that it may have liberty to hang down 3 or 4 inches at the fore end, which is hung by a strap called the feeding-string, passing over the fore end of the hopper-frame, and lapping round a pin in front of the meal-beam, which pin will turn by the hand, and which is called the feeding-screw.

The feeder is a piece of wood turned in a lathe, about 20 inches long, 3 inches diameter in the middle, against the shoe, tapered off to 1½ inches at the top; the lower end is banded, and a forked iron driven in it, that spans over the ryne, fitting into notches made on each side, to receive it, directly above the spindle, with which it turns, the upper end running in a hole in a piece across the hopper-frame. In the large part, next the shoe, 6 iron knockers are set, 7 inches long, half an inch diameter, with a tang at each end, turned square to drive into the wood, these knock against and shake the shoe, and thereby shake in the grain regularly.

You may now put the grain into the hopper, draw water on the mill, and regulate the feed by turning the feed screw, until the stream falling into the eye of the stone, be proportioned to the size thereof, or the power of the mill. Here ends the mill-wright's work, with respect to grinding, and the miller takes the charge thereof.

ARTICLE 147.

OF BOLTING CHESTS AND REELS.

Bolting chests and reels are of different lengths, according to the use for which they are intended. Common country chests (a top view of one of which is shown in Plate XIX., fig. 9,) are usually about 10 feet long, 3 feet wide, and 7 feet 4 inches high, with a post in each corner; the bottom 2 feet from the floor, with a board 18 inches wide, set slanting in the back side, to cast the meal forward in the chest, that it may be easily taken up; the door is of the whole length of the chest, and two feet wide, the bottom board below the door sixteen inches wide.

The shaft of the reel is equal in length with the chest, 4 inches diameter, 6 square, two bands on each end, $3\frac{1}{4}$ and $3\frac{3}{4}$ inches diameter; gudgeons 13 inches long, $\frac{7}{8}$ of an inch diameter, 8 inches in the shaft, rounded at the neck $2\frac{1}{2}$ inches, with a tenon for a socket, or handle; there are six ribs $1\frac{1}{2}$ inch deep, $1\frac{1}{8}$ inch thick, $\frac{1}{2}$ an inch at the tail, and $1\frac{1}{2}$ inch at the head, shorter than the shaft, to leave room for the meal to be spouted in at the head, and the bran to fall out at the tail; there are four sets of arms, that is, 12 of them, $1\frac{1}{2}$ inches wide, and $\frac{5}{8}$ thick. The diameter of the reel from out to out of the ribs, is one-third part of the double width of the cloth. A round wheel, made of inch boards, in diameter equal to the outside of the ribs, and $4\frac{1}{2}$ inches wide, measuring from the outside towards the centre, (which is taken out,) is to be framed to the head of the reel, to keep the meal from falling out at the head, unbolted. Put a hoop $4\frac{1}{4}$ inches wide, and $\frac{1}{4}$ thick, round the tail, to fasten the cloth to. The cloth is sewed, two widths of it together, to reach round the reel, putting a strip of strong linen, 7 inches wide at the head, and 5 inches at the tail of the cloth, by which to fasten it to the reel. Paste on each rib a strip of linen, soft paper, or chamois leather (which is the best) $1\frac{1}{2}$ inches wide, to keep the cloth from fretting. Then put the cloth on the reel tight, sew or nail it to the tail, and stretch it lengthwise as hard as it will bear, nailing it to the head.—Six yards of cloth cover a ten feet reel.

Bolting reels for merchant mills are generally longer than for country work, and every part should be stronger in proportion. They are best when made to suit the wide cloths. The socket gudgeons at the head should be much stronger, they being apt to wear out, and troublesome to repair.

The bolting-hopper is made to pass through the floor above the chest, is 12 inches square at the upper, and 10 inches at the lower end; the foremost side 5 inches, and the back side 7 inches from the top of the chest.

The shoe 2 feet long at the bottom of the side pieces, slanting to suit the hopper at the hinder end, set 4 inches higher at the hinder than the fore end, the bottom 17 inches long, and 10 inches wide. There should be a bow of iron riveted to the fore end, to rest on the top of the knocking wheel, which is fixed on the socket gudgeon at the head of the chest, and is 10 inches diameter, 2 inches thick, with 6 half rounds, cut out of its circumference, forming knockers to strike against the bow, and lift the shoe $\frac{3}{4}$ of an inch every stroke, to shake in the meal.

ARTICLE 148.

OF SETTING BOLTS TO GO BY WATER.

The bolting reels are set to go by water as follows:—

Make a bridge 6 by 4 inches, and 4 inches longer than the distance of the tomkin post, described Art. 139; set it between them, on rests fastened into them 10 inches below the cogs of the cog-wheel, and the centre of it half the diameter of the spur-wheel in front of them; on this bridge is set the step gudgeon of an upright shaft, with a spur-wheel of 16 or 18 cogs to gear into the cog-wheel. Fix a head-block to the joists of the 3d floor for the upper end of this shaft; put the wheel 28, (Pl. XIX.) on it; hang another head-block to the joists of the 2d floor, near the corner of the mill at 6, for the step of the short upright shaft that is to be fixed there, to turn the reels 1 and 9. Hang another head-block to the joists of the 3d floor, for the upper end of the said short upright, and fix also head-blocks for the short shaft at the head of the reels, so that the centres of all these shafts will meet. Then fix a hanging post in the corner 5, for the gudgeon of the long horizontal shaft 27—5 to run in. After the head-blocks are all fixed, then measure the length of each shaft, and make them as follows; namely:—

The upright shaft 5½ inches for common mills, but if for merchant-work, with Evans' elevators, &c., added, make it larger, say 6 or 7 inches; the horizontal shaft 27—5, and all the others 5 inches diameter. Put a socket-gudgeon in the middle of the long shafts, to keep them steady; make them 8, or 16, square, except at the end where the wheels are hung, where they must be 4 square. Band their ends, put in the gudgeons, and put them in their proper places in the head-blocks, to mark where the wheels are to be put on them.

ARTICLE 149.

OF MAKING BOLTING WHEELS.

Make the spur wheel for the first upright, with a 4½ inch plank; the pitch of the cogs, the same as the cog-wheel, into which it is to work; put two bands ¾ of an inch wide, one on each side of the cogs, and a rivet between each cog, to keep the wheel from splitting.

To proportion the cogs in the wheels, to give the bolts the right motion, the common way is—

Hang the spur-wheel, and set the stones to grind with a proper motion, and count the revolutions of the upright shaft in a minute; compare its revolutions with the revolutions that a bolt should have, which is about 36 revolutions in a minute. If the upright go $\frac{1}{6}$ more, put $\frac{1}{6}$ less in the first driving-wheel than in the leader, suppose 15 in the driver, then 18 in the leader: but if their difference be more, (say one-half,) there must be a difference in the next two wheels; observing that if the motion of the upright shaft be greater than that of the bolt should be, the driving-wheel must be proportionably less than the leader; but if it be slower, then the driver must be greater in proportion. The common size of bolting wheels is from 14 to 20 cogs; if less than 14, the head-blocks will be too near the shafts.

Common bolting wheels should be made of plank, at least 3 inches thick, well seasoned, and they are best when as wide as the diameter of the wheel, and banded with bands nearly as wide as the thickness of the wheel; the bands may be made of rolled iron, about $\frac{1}{8}$ of an inch thick. Some make the wheels of 2 inch plank, crossed, and no bands; but this proves no saving, as they are apt to go to pieces in a few years. (For hooping wheels, see Art. 136, and for finding the diameter of the pitch circle, see Art. 126.) The wheels, if banded, are generally two inches more in diameter than the pitch circle; but if not, they should be larger. The pitch or distances of the cogs are different; if to turn 1 or 2 bolts, $2\frac{1}{2}$ inches; but if more $2\frac{3}{4}$; if they are to do much heavy work, they should not be less than 3 inches. Their cogs, in thickness, are half the pitch; the shank must drive tightly in an inch auger hole.

When the mortises are made for the shafts in the head, and notches for the keys to hang them, drive the cogs in and pin their shanks at the back side, and cut them off half an inch from the wheel.

Hang the wheels on the shafts so that they will gear a proper depth, about $\frac{2}{3}$ the thickness of the cogs; dress all the cogs to equal distances by a gauge; then put the shafts in their places, the wheels gearing properly, and the head-blocks all secure; set them in motion by water. Bolting reels should turn so as to drop the meal on the back side of the chest, as it will then hold more, and will not cast out the meal when the door is opened.

ARTICLE 150.

OF ROLLING-SCREENS.

These are circular sieves moved by water, and are particularly useful in cleaning wheat for merchant-work. They are of different constructions.

1st. Those of one coat of wire with a screw in them.

2dly. Those of two coats, the inner one nailed to six ribs, the outer one having a screw between it and the inner one.

3dly. Those of a single coat, and no screw.

The first kind answers well in some, but not in all cases, because they must turn a certain number of times before the wheat can get out, and the grain has not so good an opportunity of separating; there being nothing to change its position, it floats a considerable distance with the same grains uppermost.

The double kinds are better, because they may be shorter, and take up less room; but they are more difficult to keep clean.

The 3d kind has this advantage; we can keep the grain in them a longer or shorter time, at pleasure, by raising or lowering the tail end, and it is also tossed about more; but they must be longer. They are generally 9 or 10 feet long, 2 feet 4 inches diameter, if to clean for two or three pairs of stones; but if for more, they should be larger accordingly: they will clean for, from one, to six pairs of stones. They are made 6 square, with 6 ribs, which lie flatwise, the outer corners taken off to leave the edges $\frac{1}{4}$ of an inch thick; the inner corners are brought nearly to sharp edges; the wire work is nailed on with 14 ounce tacks.

The screens are generally moved by the same upright shaft that moves the bolts, which has a wheel on its upper end, with two sets of cogs: those that strike downwards, gear into a wheel striking upwards, which turns a laying shaft, having two pulleys on the other end, one of 24 inches diameter, to turn a fan with a quick motion, the other of 8 inches, which conducts a strap to a pulley

24 inches diameter, on the gudgeon of the rolling screen, to reduce its motion to about 15 revolutions in a minute. (See fig. 19, Plate XIX.) This strap gearing may do for mills in a small way, but where they are in perfection for merchant-work, with elevators, &c., and have to clean wheat for 2, 3, or 4 pairs of stones, they should be moved by cogs.

ARTICLE 151.

OF FANS.

The Dutch fan is a machine of great use, for blowing the dust and other light stuff from among the wheat; there are various sorts of them; those that are only for blowing the wheat, as it falls from the rolling-screen, are generally about 15 inches long, and 14 inches wide, in the wings, and have no riddle or screen in them.

To give motion to a fan of this kind, put a pulley 7 inches diameter, on its axle, to receive a band from a pulley on the shaft that moves the screen, which pulley may be of 24 inches diameter, to give a swift motion; when the band is slack it slips a little on the small pulley, and the motion is retarded, but when tight the motion is quicker; by this the blast is regulated.

Some use Dutch fans complete, with riddle and screen under the rolling screen, for merchant-work; and again use the fan alone for country-work.

The wings of those which are the common farmers' wind-mills, or fans, are 18 inches long, and 20 inches wide; but in mills they are set in motion with a pulley instead of a cog-wheel and wallower.

ARTICLE 152.

OF THE SHAKING SIEVE.

Shaking sieves are of considerable use in country mills, to sift Indian meal, separating it, if required, into several degrees of fineness; and to take the hulls out of buckwheat meal, which are apt to cut the bolting cloth; also, to take the dust out of the grain, if rubbed before ground; they are sometimes used to clean wheat, or screenings, instead of rolling screens.

If they are for sifting meal, they are 3 feet 6 inches long, 9 inches wide, $3\frac{1}{2}$ inches deep; (see it fig. 16, Plate XVIII.) The wire-work is 3 feet long and 8 inches wide : across the bottom of the tail end is a board 6 inches wide, to the top of which the wire is tacked, and then this board and wire are tacked to the bottom of the frame, leaving an opening at the tail end for the bran to fall into the box 17, the meal falling into the meal-trough 15; the head piece should be strong, to hold the iron bow at 15, through which the lever passes that shakes the sieve, which is effected in the following manner. Take two pieces of hard wood, 15 inches long, and as wide as the spindle, and so thick that when one is put on each side just above the trundle, it will make it $1\frac{1}{2}$ inches thicker than the spindle is wide. The corners of these are taken off to a half round, and they are tied to the spindle with a small, strong cord. These are to strike against the lever that works on a pin near its centre, which is fastened to the sieve, and shakes it as the trundle goes round; (see it represented Plate XVIII.) This lever must always be put to the side of the spindle, contrary to that of the meal-spout; otherwise, it will draw the meal to the upper end of the sieve : there must be a spring fixed to the sieve to draw it forward as often as it is driven back. It must hang on straps and be fixed so as to be easily set to any descent required, by means of a roller in the form of a feeding screw, only longer; round this roller the strap winds.

I have now given directions for making, and putting to work, all the machinery of one of the most complete of the old-fashioned grist-mills, that may do merchant-work in the small way; these are represented by Plates XVIII., XIX., XX., XXI.; but they are far inferior to those with the improvements, which are shown by Plate XXII.

CHAPTER XXII.

ARTICLE 153.

OF THE USE OF DRAUGHTING TO BUILD MILLS BY, &c.

Perhaps some are of opinion that draughts are useless pictures of things, serving only to please the fancy. This is not what is intended by them; but to give true ideas of the machine, &c., described, or to be made. Those represented in the plates are all drawn on a scale of $\frac{1}{8}$th of an inch to a foot, in order to suit the size of the book, except Plate XVII., which is a quarter of an inch to a foot; and this scale I recommend, as most buildings will then come on a sheet of common paper.

N. B. Plate XXIV. was made after the above directions, and has explanations to suit it.

The great use of draughting mills, &c., to build by, is to convey our ideas more plainly, than is possible by writing, or by words alone; these may be misconstrued or forgotten; but a draught, well drawn, speaks for itself, when once understood by the artist; who by applying his dividers to the draught and to the scale, finds the length, breadth, and height of the building; or the dimensions of any piece of timber, and its proper place.

By the draught the bills of scantling, boards, rafters, laths, shingles, &c. &c., are known and made out; it should show every wheel, shaft, and machine, and their places. By it we can find whether the house be sufficient to contain all the works that are necessary to carry on the business; the builder or owner understands what he is about, and proceeds cheerfully and without error: it directs the mason where to put the windows, doors, navel-holes, the inner walls, &c., whereas, if there be no draught, every thing goes on, as it were, in the dark; much time is lost and errors are committed to the loss of many pounds. I have heard a man say, that he believed his mill was 500*l.* better from having employed an experienced artist, to draw him a draught to build it by; and I know, by experience, the great utility of them. Every master builder, at least, ought to understand them.

ARTICLE 154.

DIRECTIONS FOR PLANNING AND DRAUGHTING MILLS.

1st. If it be a new seat, view the ground where the dam is to be, and where the mill-house is to stand, and determine on the height of the top of the water in the head race, where it is taken out of the stream; and level from it for the lower side of the race, down to the seat of the mill-house, and mark the level of the water in the dam there.

2ndly. Begin where the tail-race is to empty into the stream, and level from the top of the water up to the mill seat, noticing the depth thereof, in places, as you pass along, which will be of use in digging it out.

Then find the total fall, allowing one inch to a rod for fall in the races; but if they be very wide and long, less will do.

Then, supposing the fall to be 21 feet 9 inches, which is sufficient for an overshot mill, and the stream too light for an undershot; consider well what size stone will suit; for I do not recommend a large stone to a weak, nor a small one to a strong stream. I have proposed stones 4 feet diameter for light, 4,6 for middling, and 5 or 5 feet 6 inches diameter, for heavy streams. Suppose you determine on stones 4 feet, then look in table I., (which is for stones of that size,) column 2, for the fall that is nearest 21 feet 9 inches, your fall, and you find it in the 7th example. Column 3d contains the head of water over the wheel, 3 feet; 4th, the diameter of the wheel, 18 feet; 5th, its width 2 feet 2 inches, &c., for all the proportions to make the stone revolve 106 times in a minute.

Having determined on the size of the wheels, and also of the house; the heights of the stories, to suit the wheels, and machinery it is to contain, and the business to be carried on therein, proceed to draw a ground plan of the house, such as Plate XVIII., which is 32 by 55 feet. (See the description of the plate.) And for the second story, as plate XIX., &c., and for the 3d, 4th, and 5th floors, if required; taking care to plan every thing, so that one shall not clash with another.

Draw an end view, as Plate XX., and a side view, as Plate XXI. Take the draught to the ground, and stake out the seat of the house. It is, in general, best to set that corner of an overshot mill, at which the water enters, farthest in the bank; but great care should be taken to reconsider and examine every thing, more than once, to see whether it be planned for the best; because, much labour is often lost for want of due consideration, and by setting buildings in, and laying foundations on, wrong places. The arrangements being completed, the bills of scantling and iron work may be made out from the draught.

ARTICLE 155.

BILLS OF SCANTLING FOR A MILL, 32 BY 55 FEET, 3 STORIES HIGH; THE WALLS OF MASON WORK, SUCH AS IS REPRESENTED IN PLATES XVIII., XIX., XX., AND XXI.

For the first Floor.

2 sills, 29 feet long, 8 by 12 inches, to lay on the walls for the joists to lie on.

48 joists, 10 feet long, 4 by 9 inches; all of timber that will last well in damp places.

For the second Floor.

2 posts, 9 feet long, 12 by 12 inches.
2 girders, 30 feet long, 14 by 16 do.
48 joists, 10 feet long, 4 by 9 do.

For the Floor over the Water-House.

1 cross girder, 30 feet long, 12 by 14 inches, for one end of the joists to lie on.

2 posts to support the girder, 12 feet long, 12 by 12 inches.

16 joists, 13 feet long, 4 by 9 inches; all of good white-oak, or other timber, that will last in damp places.

For the third Floor.

4 posts, 9 feet long, 12 by 12 inches, to support the girders.
2 girder posts, 7 feet long, 12 by 12 inches, to stand on the water-house.
2 girders, 53 feet long, 14 by 16 inches.
90 joists, 10 feet long, 4 by 9 inches.

For the fourth Floor.

6 posts, 8 feet long, 10 by 10 inches, to support the girders.
2 girders, 53 feet long, 13 by 15 inches.
30 joists, 10 feet long, 4 by 8 do. for the middle tier of the floor.
60 do. 12 feet do. 4 by 8, for the outside tiers, which extend 12 inches over the walls, for the rafters to stand on.
2 plates, 54 feet long, 3 by 10 inches: these lie on the top of the walls, and the joists on them.
2 raising pieces, 55 feet long, 3 by 5 inches; these lie on the ends of the joists for the rafters to stand on.

For the Roof.

54 rafters, 22 feet long, 3 inches thick, 6½ wide at the bottom, and 4½ at the top end.
25 collar beams, 17 feet long, 3 by 7 inches.
2760 feet of laths, running measure.
7000 shingles.

For Doors and Window-Cases.

12 pieces, 12 feet long, 6 by 6 inches, for door-cases.
36 do. 8 feet long, 5 by 5 inches, for window-cases.

For the Water-House.

2 sills, 27 feet long, 12 by 12 inches.
1 do. 14 feet long, 12 by 12 do.
2 spur-blocks, 4 feet 6 inches long, 7 by 7 do.
2 head-blocks, 5 feet long, 12 by 14 do.
4 posts, 10 feet long, 8 by 8, to bear up the penstock.
2 cap-sails, 9 feet long, 8 by 10, for the penstock to stand on.

4 corner posts, 5 feet long, 4 by 6 inches, for the corners of the penstock.

For the Husk of a Mill of one Water-Wheel and two Pair of Stones.

2 sills, 24 feet long, 12 by 12 inches.
4 corner posts, 7 feet long, 12 by 14 inches.
2 front posts, 8 feet long, 8 by 12 do.
2 back posts, 8 feet do. 10 by 12 inches, to support the back ends of the bridge-trees.
2 other back posts, 8 feet long, 8 by 8 inches.
3 tomkin posts, 12 feet long, 12 by 14 do.
2 interties, 9 feet long, 12 by 12 inches, for the outer ends of the little cog-wheel shafts to rest on.
2 top pieces, 10 feet 6 inches long, 10 by 10 inches.
2 beams, 24 feet long, 16 by 16 inches.
2 bray-trees, 8½ feet long, 6 by 12 inches.
2 bridge-trees, 9 feet long, 10 by 10 inches.
4 planks, 8 feet long, 6 by 14 inches, for the stone-bearers.
20 planks, 9 feet long, 4 by about 15 inches, for the top of the husk.
2 head-blocks, 7 feet long, 12 by 15 inches, for the wallower shafts to run on. They serve as spurs also for the head-block for the water-wheel shaft.

For the Water-Wheel and big Cog-Wheel.

1 shaft, 18 feet long, 2 feet diameter.
8 arms for the water-wheel, 18 feet long, 3 by 9 inches.
16 shrouds, 8½ feet long, 2 inches thick, and 8 deep.
16 face boards, 8 feet long, 1 inch thick, and 9 deep.
56 bucket boards, 2 feet 4 inches long, and 17 inches wide.
140 feet of boards, for soaling the wheel.
3 arms for the cog-wheel, 9 feet long, 4 by 14 inches.
16 cants, 6 feet long, 4 by 17 inches.

For little Cog-Wheels.

2 shafts, 9 feet long, 14 inches diameter.
4 arms, 7 feet long, 3½ by 10 inches.
16 cants, 5 feet long, 4 by 18 inches.

For Wallowers and Trundles.

60 feet of plank, 3½ inches thick.
40 feet do. 3 inches thick, for bolting gears.

Cogs and Rounds.

200 cogs, to be split, 3 by 3, 14 inches long.
80 rounds, do. 3 by 3, 20 inches long.
160 cogs, for bolting works, 7 inches long, and 1¾ square; but if they be for a mill with machinery complete, there must be more in number, accordingly.

Bolting Shafts.

1 upright shaft, 14 feet long, 5½ by 5½ inches.
2 horizontal shafts, 17 feet long, 5 by 5 inches.
1 upright do. 12 feet long, 5 by 5 inches.
6 shafts, 10 feet long, 4 by 4 do.

ARTICLE 156.

BILL OF THE LARGE IRONS FOR A MILL OF TWO PAIR OF STONES.

2 gudgeons, 2 feet 2 inches long in the shaft; neck 4¼ inches long, 3 inches diameter, well steeled and turned. (See fig. 16, Plate XXIV.)
2 bands, 19 inches diameter inside, ¾ thick; and 3 inches wide, for the ends of the shaft.
2 do. 20½ inches inside, ½ an inch thick, and 2½ inches wide, for do.
2 do. 23 inches do. ½ an inch thick, and 2½ inches wide, for do.
4 gudgeons, 16 inches in the shaft, 3½ inches long, and 2½ inches diameter in the neck, for wallower shafts: (See fig. 15, Plate XXIV.)
4 bands, 12 inches diameter inside, ½ an inch thick, and 2 wide, for do.
4 do. 12 inches do. ½ an inch thick, and 2 wide, for do.
4 wallower bands, 3 feet 2 inches diameter inside, 3 inches wide, and ¼ of an inch thick.
4 trundle bands, 2 feet diameter inside, 3 inches wide, and ¼ of an inch thick.

2 spindles and rynes; spindles 5 feet 3 inches long from the foot to the top of the necks; cock-heads 7 or 8 inches long above the necks; the body of the spindles $3\frac{1}{4}$ by 2 inches; the neck 3 inches long, and 3 inches diameter: the balance rynes proportional to the spindles, to suit the eye of the stone, which is 9 inches diameter. (See fig. 1, 2, 3, Plate XXIV.)

2 steps for the spindles, fig. 4.

2 sets of damsel-irons, 6 knockers to each set.

2 bray-irons, 3 feet long, $1\frac{3}{4}$ inches wide, $\frac{1}{2}$ an inch thick: being a plain bar, one hole at the lower, and 5 or 6 at the upper end.

Bill of Iron for the Bolting and Hoisting Works, in the common way.

2 spur-wheel bands, 20 inches diameter from outsides, for the bolting spur-wheel, $\frac{3}{4}$ths of an inch wide, and $\frac{1}{4}$th thick.

2 spur-wheel bands, 12 inches diameter from outsides, for the hoisting spur-wheel.

2 step-gudgeons and steps, 10 inches long, $1\frac{1}{8}$ inches thick in the tang, or square part; neck 3 inches long, for the upright shafts. (See fig. 5 and 6, Plate XXIV.)

2 bands for do. 5 inches diameter inside, $1\frac{1}{4}$ wide, and $1\frac{1}{4}$ thick.

2 gudgeons, 9 inches tang; neck 3 inches long, $1\frac{1}{8}$ square, for the top of the uprights.

8 bands, $4\frac{1}{2}$ inches diameter inside.

1 socket-gudgeon, $1\frac{1}{8}$ of an inch thick; tang 12 inches long; neck 4 inches; tenon to go into the socket $1\frac{1}{2}$ inches, with a key-hole at the end. (See fig. 8 and 9.)

14 gudgeons, neck $2\frac{1}{2}$ inches, tangs 8 inches long, and 1 inch square, for small shafts at one end of the bolting-reels.

10 bands for do. 4 inches diameter inside, and 1 inch wide.

4 socket-gudgeons, for the 4 bolting-reels, $1\frac{1}{4}$ square; tangs 8 inches; necks 3 inches, and tenons $1\frac{1}{2}$ inches, with holes in the ends of the tangs for rivets, to keep them from turning; the sockets 1 inch thick at the mortise, and 3 inches between the prongs. (See fig. 8 and 9.) Prongs 8 inches long and 1 wide.

8 bands, $3\frac{1}{4}$ inches, and 8 do. 4 inches, diameter, for the bolting-reel shafts.

For the Hoisting Wheels.

2 gudgeons, for the jack-wheel, neck $3\frac{1}{2}$ inches, and tang 9 inches long, $1\frac{1}{8}$ square.
2 bands for do. $4\frac{1}{2}$ inches diameter.
2 gudgeons, for the hoisting wheel, neck $3\frac{1}{2}$ inches, tang 9 inches long, and $1\frac{1}{4}$ inches square.
2 bands for do. 7 inches diameter.
6 bands for bolting-heads, 16 inches diameter inside, $2\frac{1}{4}$ wide, and $\frac{1}{6}$th of an inch thick.
6 do. for do. 15 inches do. do.

N. B. All the gudgeons should taper a little, and the sides given are the largest part. The bands for shafts should be widest at the foremost side, to make them drive well; but those for heads should be both sides equal. Six picks for the stones, 8 inches long, and $1\frac{1}{4}$ wide, will be wanted.

ARTICLE 157.

EXPLANATION OF THE PLATES.

PLATE XVII.

Drawn from a scale of a quarter of an inch for a foot.

Fig. 1—a big cog-wheel, 8 feet $2\frac{1}{3}$ inches the diameter of its pitch circle, 8 feet $10\frac{1}{3}$ inches from out to out; 69 cogs, $4\frac{1}{2}$ inches pitch.
2—a little cog-wheel, 5 feet $10\frac{1}{3}$ inches the diameter of its pitch circle, and 6 feet 6 inches from out to out, to have 52 cogs, $4\frac{1}{4}$ pitch.
3—a wallower, 3 feet $1\frac{1}{4}$ inches the diameter of its pitch circle, and 3 feet $4\frac{1}{4}$ inches from out to out; 26 rounds, $4\frac{1}{2}$ pitch.
4—a trundle, 1 foot $8\frac{1}{3}$ inches the diameter of its pitch circle, and 1 foot $11\frac{1}{3}$ inches from out to out; 15 rounds, $4\frac{1}{4}$ inches pitch.
5—the back part of the big cog-wheel.
6—a model of locking 3 arms together.
7—the plan of a forebay, showing the sills, caps, and

where the mortises are made for the posts, with a rack at the upper end to keep off the trash.

PLATE XVIII.—*The Ground-Plan of a Mill.*

Fig. 1 and 8—bolting chests and reels, top view.
2 and 4—cog-wheels that turn the reels.
3—cog-wheel on the lower end of a short upright shaft.
5 and 7—places for the bran to fall into.
6, 6, 6—three garners on the lower floor for bran.
9 and 10—posts to support the girders.
11—the lower door to load wagons, horses, &c., at.
12—the step-ladder, from the lower floor to the husk.
13—the place where the hoisting casks stand when filling.
14 and 15—the two meal-troughs and meal-spouts.
16—meal-shaking sieve for Indian and buckwheat.
17—a box for the bran to fall into from the sieve.
18 and 19—the head-block and long spur-block, for the big shaft.
20—four posts in front of the husks, called bray posts.
21—the water and cog-wheel shaft.
22—the little cog-wheel and shaft, for the lower stones.
23—the trundle for the burr stones.
24—the wallower for do.
25—the spur-wheel that turns the bolts.
26—the cog-wheel.
27—the trundle, head wallower, and bridge-tree, for country stones.
28—the four back posts of the husk.
29—the two posts that support the cross-girder.
30—the two posts that bear up the penstock at one side.
31—the water-wheel, 18 feet diameter.
32—the two posts that bear up the other side of the penstock.
33—the head-blocks and spur-blocks, at water end.
34—a sill to keep up the outer ends.
35—the water-house door.
36—a hole in the wall for the trunk to go through.
37—the four windows of the lower story.

PLATE XIX.—*Second Floor.*

Fig. 1 and 9—a top view of the bolting chests and reels.
2 and 10—places for the bran to fall into.
3 and 8—the shafts that turn the reels.
4 and 7—wheels that turn the reels.
5—a wheel on the long shafts between the uprights.
6—a wheel on the upper end of the upright shaft.
11 and 12—two posts that bear up the girders of the third floor.
13—the long shaft between two uprights.
14—five garners to hold toll, &c.
15—a door in the upper side of the mill-house.
16—a step ladder from 2d to 3d floor.
17—the running burr mill-stone laid off to be dressed.
18—the hatch way.
19—stair way.
20—the running country stone turned up to be dressed.
21—a small step-ladder from the husk to 2d floor.
22—the places where the cranes stand.
24—the pulley-wheel that turns the rolling screen.
25 and 26—the shaft and wheel which turn the rolling screen and fan.
27—the wheel on the horizontal shaft to turn the bolting reels.
28—the wheel on the upper end of the first upright shaft.
29—a large pulley that turns the fan.
30—the pulley at the end of the rolling screen.
31—the fan.
32—the rolling screen.
33—a step ladder from the husk to the floor over the water-house.
34 and 35—two posts that support the girders of the third floor.
36—a small room for the tailings of the rolling screen.
37—a room for the fannings.
38— do. for the screenings.
39—a small room for the dust.
40—the penstock of water.
41—a room for the miller to keep his books in.

42—a fire-place.
43—the upper end door.
44—ten windows in the second story, twelve lights each.

PLATE XX.

Represents a view of the lower side of a stone mill-house, three stories high, which plan will suit tolerably well for a two story house, if the third story be not wanted. Part of the wall is supposed to be open, so that we have a view of the stones, running gears, &c.

Line 1 represents the lower floor, and is nearly level with the top of the sills, of the husk and water-house.
2, 3, and 4—the second, third, and fourth floors.
5 and 6—windows for admitting air under the lower floor.
7—the lower door, with steps to ascend to it, which commonly suits best to load from.
8—the arch over the tail-race for the water to run from the wheel.
9—the water-house door, which sometimes suits better to be at the end of the house, where it makes room to wedge the gudgeon.
10—the end of the water-wheel shaft.
11—the big cog-wheel shaft.
12—the little cog-wheel and wallower, the trundle being seen through the window.
13—the stones with the hopper, shoe, and feeder, as fixed for grinding.
14—the meal-trough.

There is an end view of the husk frame. There are thirteen windows with twelve lights each.

PLATE XXI.

Represents an outside view of the water-end of a mill-house, and is intended to show to the builders, and mill-wrights, the height of the walls, floors, and timbers, with the places of the doors and windows, and a view of the position of the stones and husk timbers, supposing the wall open, so that we could see them.

Fig. 1, 2, 3, and 4, shows the joists of the floors.

5—a weather-cock, turning on an iron rod.

6—the end of the shaft, for hoisting outside of the house, which is fixed above the collar-beams over the doors, to hoist into either of them, or either story, at either end of the house, as may suit best.

7—the dark squares, showing the ends of the girders.

8—the joists over the water-house.

9—the mill-stones, with the spindles they run on, and the ends of the bridge-trees as they rest on the brays a a. b b show the ends of the brays, that are raised and lowered by the levers c c, called the lighter-staffs, for raising and lowering the running stone.

10—the water-wheel and big cog-wheel.

11—the wall between the water and cog-wheel.

12—the end view of the two side walls of the house.

Plate XXII. is explained in the Preface.

CHAPTER XXIII.

ARTICLE 158.

OF SAW-MILLS.

Construction of their Water-Wheels.

The wheels for saw-mills have been variously constructed; the most simple, where water is plenty, and the fall above six feet, is the flutter-wheel; but where water is scarce, or the head insufficient to give flutter-wheels the requisite motion, high wheels, double geared, will be found necessary. Flutter-wheels may be adapted to any head above six feet, by making them low and wide, for low heads, and high and narrow for high ones, so as to have about 120 revolutions, or strokes of the saw in a minute: but rather than double gear, I would be satisfied with 100.

A TABLE

OF THE

DIAMETER OF FLUTTER-WHEELS FROM OUT TO OUT, AND THEIR WIDTH IN THE CLEAR, SUITABLE TO ALL HEADS, FROM SIX TO THIRTY FEET.

Head of water.	Diameter.	Width.
feet.	ft. in.	ft. in.
6	2 : 8	5 : 6
7	2 : 10	5 : 0
8	2 : 11	4 : 8
9	3 : 0	4 : 3
10	3 : 1	4 : 0
11	3 : 2	3 : 9
12	3 : 3	3 : 6
13	3 : 4	3 : 3
14	3 : 5	3 : 0
15	3 : 6	2 : 9
16	3 : 7	2 : 6
17	3 : 8	2 : 4
18	3 : 9	2 : 2
19	3 : 10	2 : 0
20	3 : 11	1 : 10
21	4 : 0	1 : 9
22	4 : 1	1 : 8
23	4 : 2	1 : 7
24	4 : 3	1 : 6
25	4 : 4	1 : 5
26	4 : 5	1 : 4
27	4 : 6	1 : 3
28	4 : 7	1 : 2
29	4 : 8	1 : 1
30	4 : 9	1 : 0

N. B —The above wheels are proposed to be made as narrow as will well do, on account of saving water; but if this be abundant, the wheels may be made wider than directed in the table, and the mill will be the more powerful.

Of Geared Saw-Mills.

Of these I shall say but little, they being expensive and but little used.—They should be geared so as to give the saw 120 strokes in a minute, when at work in a common log. The water-wheel is like that of any other mill, whether of the overshot, undershot, or breast kind; the cog-wheel of the spur kind, and as large as will clear the water. The wallower commonly has 14 or 15 rounds, or such number as will produce the right motion. On the wallower shaft is a balance-wheel, which may be made of stone or wood; this is to regulate the motion. There should be a good head above the water-wheel to give it a lively motion, otherwise the mill will run heavily.

The mechanism of a complete saw-mill is such as to produce the following effects; namely:—

1. To move the saw up and down, with a sufficient motion and power.
2. To move the log to meet the saw.
3. To stop of itself when within 3 inches of being through the log.
4. To draw the carriage with the log back, by the power of the water, so that the log may be ready to enter again.

The mill is stopped as follows; namely :—When the gate is drawn the lever is held by a catch, and there is a trigger, one end of which is within half an inch of the side of the carriage, on which is a piece of wood an inch and a half thick, nailed so that it will catch against the trigger as the carriage moves, which throws the catch off the lever of the gate, and it shuts down at a proper time.

Description of a Saw-Mill.

Plate XXIII. is an elevation and perspective view of a saw-mill, showing the foundation, walls, frame, &c., &c.

Fig. 0, 1—the frame uncovered, 52 feet long, and 12 feet wide.

Fig. 2—The lever for communicating the motion from

the saw-gate to the carriage, to move the log; it is 8 feet long, 3 inches square, tenoned into a roller 6 inches diameter, reaching from plate to plate, and working on gudgeons in them; in its lower side is framed a block, 10 inches long, with a mortise in it two inches wide throughout its whole length, to receive the upper end of the hand pole, having in it several holes for an iron pin, to join the hand pole to it, to regulate the feed; by setting the hand-pole nearer the centre of the roller, less feed is given, and, farther off, gives more.

Fig. 3, the hand-pole or feeder, 12 feet long, and 3 inches square, where it joins the block, (Fig. 4,) and tapering 2 inches at the lower end, on which is the iron hand, 1 foot long, with a socket; the end of this is flattened, steeled, and hardened, and turned down half an inch at each side, to keep it on the rag-wheel.

Fig. 5—the rag wheel. This has four cants, 4½ feet long, 17 by 3 inches in the middle, lapped together to make the wheel 5 feet diameter; is faced between the arms with 2 inch plank, to strengthen the laps. The cramp or ratchet iron is put on as a hoop, nearly 1 inch square, with ratchet notches cut on its outer edge, about 3 to an inch. On one side of the wheel are put 12 strong pins, 9 inches long, to tread the carriage back, when the backing works are out of order. On the other side are the cogs, about 56 in number, 3 inches pitch, to gear into the cog-wheel on the top of the tub-wheel shaft, with 15 or 16 cogs. In the shaft of the rag-wheel are 6 or 7 rounds, 11 inches long in the round part, let in nearly their whole thickness, so as to be of a pitch equal to the pitch of the cogs of the carriage, and gear into them easily: the ends are tapered off outside, and a band is driven on them at each end, to keep them in their places.

Fig. 6 is the carriage; a frame 4 feet wide from outsides, one side 29 feet long, 7 by 7 inches; the other 32 feet long, 8 by 7 inches, very straight and true, the interties at each end 15 by 4 inches, strongly tenoned and braced into the sides to keep the frame from racking. In the under side of the largest piece are set two rows of cogs, 2 inches between the rows, and 9 inches from the foreside of one cog to that of another; the cogs of one row between those of the other, so as to make $4\frac{1}{2}$ inches pitch, to gear into the rounds of the rag-wheel. The cogs are about 66 in number; shank 7 inches long, $1\frac{3}{4}$ inches square; head $2\frac{3}{4}$ long, 2 inches thick at the points, and $2\frac{1}{4}$ inches at the shoulder.

Fig. 7—the ways for the carriage to run on. These are strips of plank $4\frac{1}{2}$ inches wide, 2 inches thick, set on edge, let $1\frac{1}{2}$ inches into the top of the cross sills, of the whole length of the mill, keyed fast on one side, made very straight both side and edge, so that one of them will pass easily between the rows of cogs in the carriage, and leave no room for it to move sideways. They should be of hard wood, well seasoned, and hollowed out between the sills to keep the dust from lodging on them.

Fig. 8—the fender posts. The gate with the saw plays in rabbets $2\frac{1}{2}$ deep and 4 inches wide, in the fender posts, which are 12 feet long, and 12 inches square, hung by hooked tenons, to the front side of the two large cross beams in the middle of the frame, in mortises in their upper sides, so that they can be moved by keys to set them plumb. There are 3 mortises, 2 inches square, through each post, within half an inch of the rabbets, through which pass hooks with large heads, to keep the frame in the rabbets: they are keyed at the back of the posts.

Fig. 9—the saw, which is 6 feet long, 7 or 8 inches wide, when new; hung in a frame 6 feet wide from the outsides, 6 feet 3 inches long between the end pieces, the lowermost of which is 14 by 3 inches, the upper one 12 by 3, the side pieces 5 by 3 inches, 10 feet long, all of the best dry, hard wood. The saw is fastened in the frame by two irons, in form of staples; the lower one with two screw pins passing through the lower end, screwing one leg to each side of the end piece: the legs of the upper one are made into screws, one at each side of the end piece, passing through a broad, flat bar, that rests on the top of the end piece, with strong burrs, $1\frac{3}{4}$ inches square, to be turned by an iron spanner, made to fit them.

These straps are made of flat bars, 3 feet 9 inches long, 3 inches wide, $\frac{3}{4}$ths thick before turned; at the turn they are 5 inches wide, square, and split to receive the saw, and tug-pins, then brought near together, so as to fit the gate. The saw is stretched tightly in this frame, by the screws at the top, exactly in the middle, at each end, measuring from the outside; the top end standing about half an inch more forward than the bottom.

Fig. 10—the forebay of water, projecting through the upper foundation wall.

Fig. 11—the flutter-wheel. Its diameter and length according to the head of water, as shown in the table. The floats are fastened in with keys, so that they will drive inward, when any thing gets under them, and not break. These wheels should be very heavy, that they may act as a fly, or balance, to regulate the motion, and work more powerfully.

Fig. 12—the crank, (see it represented by a draught from a scale of 1 foot to an inch, fig. 17, Plate XXIV.) The part in the shaft 2 feet 3 inches long, $3\frac{3}{4}$ by 2 inches, neck 8 inches long, 3 thick, and 12 inches from the centre of the neck to the centre of the wrist or handle, which is 5 inches long to the key hole, and 2 inches thick.

The gudgeon at the other end of the shaft is 18 inches in the shaft, neck $3\frac{1}{2}$ long, $2\frac{3}{4}$ diameter.

The crank is fastened in the same way as gudgeons. (See Art. 132.)

Fig. 12, 13—the pitman, which is $3\frac{1}{2}$ inches square at the upper end, $4\frac{1}{2}$ in the middle, and 4 near the lower end; but 20 inches of the lower end is $4\frac{1}{2}$ by $5\frac{1}{2}$, to hold the boxes and key, to keep the handle of the crank tight.

Pitman Irons of an improved Construction.

(See fig. 10, 11, 12, 13, 14, 18, Plate XXIV.) Fig. 10 is a plate or bar, with a hole in each end, through which the upper ends of the lug-pins 11—11 pass, with a strong burr screwed on each; they are 17 inches long,

$1\frac{1}{8}$ inch square, turned at the lower end to make a round hole $1\frac{1}{8}$ diameter, made strong round the hole.

Fig. 12 is a large, flat link, through a mortise near the lower side of the end of the saw frame. The lug-pins pass one through each end of this link, which keeps them close to the gate sides.

Fig. 14 is a bar of iron 2 feet long, $3\frac{1}{2}$ inches wide, $\frac{1}{2}$ inch thick at the lower, and $1\frac{1}{8}$ at the upper end. It is split at the top and turned as in the figure, to pass through the lug-pins. At fig. 13 there is a notch set in the head of the pitman bar 14, $1\frac{1}{2}$ inch long, nearly as deep as to be in a straight line with the lower side of the side-pins, made a little hollow, steeled and made very hard.

Fig. 18 is an iron plate, $1\frac{1}{2}$ inch wide, half an inch thick in the middle, with 2 large nail-holes in each end, and a round piece of steel welded across the middle and hardened, made to fit the notch in the upper end of the pitman, Plate XXVI., and draw close by the lug-pins, to the under side of the saw-frame, and nailed fast. Now, if the bearing part of this joint be in a straight line, the lower end of the pitman may play without friction in the joint, because both the upper and lower parts will roll without sliding, like the centre of a scale beam, and will not wear.

This is the best plan for pitman irons, with which I am acquainted. The first set, so made, has been in my saw-mill 8 years, doing much hard work, and three minutes have not been required to adjust them.

Fig. 14—the tub-wheel, for running the carriage back. This is a very light wheel, 4 feet diameter, and put in motion by means of the foot or hand, at once throwing it in gear with the rag-wheel, lifting off the hand and clicks from the ratchet, and hoisting a little gate to let water on the wheel. The moment the saw stops, the carriage begins to move gently back again with the log.

Fig. 15—the cog-wheel on the top of the tub-wheel shaft, with 15 or 16 cogs.

Fig. 16—the log on the carriage, sawed. partly through.

Fig. 17—a crank and windlass, to increase power, by

which one man can draw heavy logs on the mill, and turn them, by a rope passing round the log and windlass.

Fig. 18—a cant hook for rolling logs.

Fig. 19—a double dog, fixed into the hindmost head-block, used by some to hold the log.

Fig. 20 are smaller dogs to use occasionally at either end.

Figs. 21, 22, represent the manner of shuting water on a flutter-wheel by a long, open shute, which should not be nearer to a perpendicular than an angle of 45 degrees, lest the water should rise from the shute and take air, which would cause a great loss of power.

Fig. 23 represents a long, perpendicular, tight shute; the gate 23 is always drawn fully, and the quantity of water regulated at the bottom by a little gate r, for the purpose. There must be air let into this shute by a tube entering at a. (See Art. 71.) These shutes are for saving expense where the head is great, and should be much larger at the upper than at the lower end, else there will be a loss of power. They must be very strong, otherwise they will burst. The perpendicular ones suit best where a race passes within 12 feet of the upper side of the mill.

OPERATION.

The sluice drawn from the penstock 10, puts the wheel 11 in motion—the crank 12 moves the saw-gate, and saw 9, up and down; and as they rise they lift up the lever 2, which pushes forward the hand-pole 3, which moves the rag-wheel 5, which gears in the cogs of the carriage 4, and draws forward the log 16 to meet the saw, as much as is proper to cut at a stroke. When it is within 3 inches of being through the log, the cleet C, on the side of the carriage, arrives at a trigger and lets it fly, and the sluice gate shuts down; the miller instantly draws water on the wheel 14, which runs the log gently back, &c.

ARTICLE 159.

DESCRIPTION OF A FULLING-MILL.

Fig. 19, Plate XXIV., is the penstock, water-gate, and spout of an overshot fulling-mill, the whole laid down from a scale of 4 feet to an inch.

Fig. 20—one of the 3 interties, that are framed with one end into the front side of the top of the stock-block; the other ends into the tops of the 3 circular pieces that guide the mallets; they are 6 feet long, 5 inches wide, and 6 deep.

Fig. 21 are two mallets; they are 4 feet 3 inches long, 21 inches wide, and 8 thick, shaped as in the figure.

Fig. 22—their handles, 8 feet long, 20 inches wide, and 3 thick: a roller passes through them, 8 inches from the upper ends, and hangs in the hindermost corner of the stock-post. The other ends go through the mallets, and have each, on their underside, a plate of iron faced with steel and hardened, 2 feet long, 3 inches wide, fastened by screw-bolts, for the tappet-blocks to rub against while lifting the mallets.

Fig. 23—the stock-post, 7 feet long, 2 feet square at the bottom, 15 inches thick at the top, and shaped as in the figure.

Fig. 24—the stock where the cloth is beaten, shaped inside as in the figure, planked inside as high as the dotted line, which planks are put in rabbets in the post, the inside of the stock being 18 inches wide at the bottom, 19 at the top, and 2 feet deep.

Fig. 25—one of the 3 circular guides for the mallets; they are 6 feet long, 7 inches deep, and 5 thick; are framed into a cross sill at bottom, that joins its lower edge to the stock-post. This sill forms a part of the bottom of the stock, and is 4 feet long, 20 inches wide, and 10 thick.

The sill under the stock-post is 6 feet long, 20 inches wide, and 18 thick. The sill before the stock is 6 feet long, and 14 inches square.

Fig. 26—the tappet-arms, 5 feet 6 inches long, 21

inches each side of the shaft, 12 inches wide, and 4 thick. There is a mortise through each of them, 4 inches wide, the length from shaft to tappet, for the ends of the mallet handles to pass through. The tappets are 4 pieces of hard wood, 12 inches long, 5 wide, and 4 thick, made in the form of half circles pinned to the ends of the arms.

Fig. 27—an overshot water-wheel, similar to those in other mills.

Fig. 28—one of the 3 sills, 16 feet long, and 16 inches square, with walls under them, as in the figure.

OPERATION.

The cloth is put in a loose heap in the stock 24; the water being drawn on the wheel, the tappet-arms lift the mallets, alternately, which strike the under part of the heap of cloth, and the upper part is continually falling over, and thereby turning and changing its position under the mallets, which are shaped as in the figure, to produce this effect.

Description of the Drawings of the Iron-work, Plate XXIV.

Fig. 1 is a spindle, 2 the balance ryne, and 3 the driver, for a mill-stone. The length of the spindle from the foot to the top of the neck is about 5 feet 3 inches; cock-head 8 or 9 inches from the top of the neck, which is 3 inches long, and 3 diameter; blade or body $3\frac{1}{2}$ by 2 inches; foot $1\frac{1}{4}$ inch diameter; the neck, foot, and top of the cock-head, steeled, turned, and hardened.

Fig. 2—the balance-ryne is sometimes made with 3 horns, one of which is so short as only to reach to the top of the driver, which is let into the stone directly under it; the other to reach nearly as low as the bottom of the driver: of late, they are mostly made with 2 horns only; this may be made sufficiently fast by making it a little wider than the eye, and letting it into the stone a little on each side, to keep it steady, and prevent its moving sideways. Some choose them with 4 horns, which fill the eye too much.

Fig. 3 is a driver, about 15 inches long.

Fig. 4—the step for the spindle foot to run in. It is a box 6 inches long, 4 inches wide at the top, but less at bottom, and 4 inches deep outside, the sides and bottom half an inch thick. A piece of iron 1 inch thick is fitted to lie tightly in the bottom of this box, but not welded; in the middle of this is welded a plug of steel 1½ inches square, in which is punched a hole a quarter of an inch deep, to fit the spindle-foot. The box must be tight, to hold oil.

Fig. 5—a step-gudgeon for large upright shafts, 16 inches long and 2 square, steeled and turned at the toe.

Fig. 6—the step for it, similar to 4, but proportionably less.

Fig. 7 is a gudgeon for large bolting shafts, 13 inches long, and 1½ square.

Fig. 8—a large joint-gudgeon, tang 14 inches, neck 5, and tenon 2 inches long, 1½ square.

Fig. 9—the socket part to fit the shaft, with 3 rivet-holes in each.

Fig. 10, 14, 18—pitman irons, described Art. 158.

Fig. 15, the wallower gudgeon, tang 16 inches, neck 3½ inches long, and 2½ diameter.

Fig. 16—the water-wheel gudgeon, tang 3 feet 2 inches long, neck 4½ inches long, 3¼ square.

Fig. 17—a saw-mill crank, described Art. 158.

N. B.—The spindle-ryne, &c., is drawn from a scale of 2 feet to an inch, and all the other irons 1 foot to an inch.

ARTICLE 160.

To what has been said of Saw-Mills, by Thomas Ellicott, I add the following:—

Of hanging the Saw.

First, set the fender posts as nearly plumb every way as possible, and the head-blocks on which the log is to lie, level. Put the saw just in the middle of the gate, measuring from the outsides, set it by the gate and not by a plumb line, with the upper teeth about half an inch farther forward than the lower ones;—this is to give the saw liberty to rise without cutting, and the log room to push forward as it rises. Run the carriage forward, so that the saw may strike the block—stick up a nail, &c., there—run it back again its full length, and standing behind the saw, set it to direct exactly to the mark. Stretch the saw in the frame, rather the most at the edge, that it may be stiffest there. Set it in motion, and hold a tool close to one side of it, and observe whether it touch equal-the whole length of the stroke—try if it be square with the top of the head blocks, else it will not make the scantling square.

Of whetting the Saw.

The edge of the teeth ought to be kept straight, and not suffered to wear hollowing—set the teeth a little out, equal at each side, and the outer corners a little longest—they will then clear their way. Some whet the under side of the teeth nearly level, and others a little drooping down; but it then never saws steadily, but is apt to *wood* too much; the teeth should slope up, although but very little. Try a cut through the log, and if it come out at the mark made to set it by, it is shown to be hung right.

Of springing Logs straight.

Some long small logs will spring so much in sawing as to spoil the scantling, unless they can be held straight; to do which make a clamp to bear with one end against the side of the carriage, the other end under the log, with a post up the side thereof—drive a wedge between the post and log, and spring it straight; this will bend the carriage side—but this is no injury.

Of moving the Logs to the Size of the Scantling, &c.

Make a sliding-block to slide in a rabbet in front of the main head-block; fasten the log to this with a little dog on each side, one end of which being round, is driven into a round hole, in the front side of the sliding-block, the other flattened to drive in the log, cutting across the grain, slanting a little out—it will draw the log tight, and stick in it the better. Set a post of hard wood in the middle of the main block close to the sliding one, and to extend with a shoulder over the sliding one, for a wedge to be driven under this shoulder to keep the block tight. Make a mark on each block to measure from—when the log is moved the key is driven out. The other end next the saw is best held by a sliding dog, part on each side of the saw, pointed like a gouge, with two joint dogs, one on each side of the saw.

Remedy for a long Pitman.

Make it in two parts by a joint 10 feet from the crank, and a mortise through a fixed beam, for the lower end of the upper part to play in, the gate will work more steadily, and all may be made lighter.

The feed of a saw-mill ought to be regulated by a screw fixed to move the hand-pole nearer or farther from the centre of the roller that moves it, which may be done, as the saw arrives at a knot, without stopping the mill.

ARTICLE 161.

The following Observations on Saw-Mills, &c., were communicated by William French, *Mill-Wright, New Jersey.*

Saw-Mills, with low heads, have been much improved in this state. Mills with two saws, with not more than 7 feet head and fall, have sawed from five to six hundred thousand feet of boards, plank, and scantling, in one year. If the water be put on the wheel in a proper manner, and the wheel of a proper size, (as by the following table,) the saw will strike between 100 and 130 strokes in a minute, (see fig. 1, Plate XXVI.) The lower edge of the breast-beam B to be $\frac{3}{4}$ths the height of the wheel, and one inch to a foot, slanting up stream, fastened to the pen-stock posts with screw-bolts, (see post A) circled out to suit the wheel C; the fall D circled to suit the wheel and extending to F, 2 inches above the lower edge of the breast-beam, or higher, according to the size of the throat or sluice E, with a shuttle, or gate, sliding on F E, shutting against the breast-beam B : then 4 buckets out of 9 will be acted on by the water. The method of fastening the buckets or floats is, to step them in starts mortised in the shaft—see start G—9 buckets in a wheel 4½ inches wide, see them numbered 1, 2, &c.

Fig. 2, the go back, is a tub wheel. Its common size is from 4½ to 6 feet diameter, with 16 buckets. The water is brought on it by the trunk H. The bucket I, is made with a long tenon, so as to fasten it with a pin at the top of the wheel.

TABLE

Of the Dimensions of Flutter-Wheels.

Head 12 feet.	Bucket 5 feet.	Wheel 3 feet.	Throat 1¾ inches.
11	5½	3	2
10	6	3	2⅛
9	6½	2 10 inches.	2¼
8	7	2 9	2½
7	7½	2 8	3¼
6	8	2 7 p.	3½
5	9	2 6	3¾

N. B.—The crank about 11 inches, but varies to suit the timber.

The Pile Engine.

Fig. 3, a simple machine for driving piles in soft bottoms for setting mill-walls or dams on. It consists of a frame 6 or 7 feet square, of scantling, 4 by 5 inches, with 2 upright posts 2 inches apart, 10 or 12 feet high, 3 by 3 inches, braced from top to bottom of the frame, with a cap on top 2 feet long, 6 by 8 inches, with a pulley in its middle, for a rope to bend over, fastened to a block I, called a tup, which has 2 pieces, 4 inches wide between the uprights, with a piece of 2 inch plank T, 6 inches wide, framed on the ends, so as to slide up and down the upright posts S. This machine is worked by 4 or 6 men, who draw the tup up by the sticks fastened to the end of the rope K, and let it fall on the pile L; they can thus strike 30 or 40 strokes in a minute, by the swing of their arms.

Of building Dams on Soft Foundations.

The best method is to lay 3 sills across the stream, and frame cross sills into them up and down stream, setting the main mud sills on round piles, and pile them with 2 inch plank, well jointed, and driven closely together, edge to edge, from one end to the other. Taking one corner off the lower end of the plank will cause it to keep a close joint at bottom, and by driving an iron dog in the mud-sill, and a wooden wedge to keep it close at the top end, it will be held to its place when the tup strikes. It is necessary to pile the outside cross sills also in some bottoms, and to have wings to run 10 or 12 feet into the bank at each side; and the wing-posts 2 or 3 feet higher than the posts of the dam, where the water falls over, planked to the top N N, and filled with dirt to the plate O.

Fig. 4 is a front view of the breast of the tumbling dam.

Fig. 5 is a side view of the frame of the tumbling dam, on its piling a b c d e, and f g h is the end of the mud-sills. The posts k, are framed into the main mud-sills with a hook tenon, leaning down stream 6 inches in 7 feet, supported by the braces 11, framed into the cross sills I; the cross sills I to run 25 feet up and down stream, and to be well planked over, and the breast-posts to be planked to the top, (see P, fig. 4,) and filled with dirt on the upper side, within 12 or 18 inches of the plate O, (see Q, fig. 5;) slanting to cover the up-stream ends of the sills 3 or 4 feet deep: R represents the water.

When the heads are high, it is best to plank the braces for the water to run down; but, if low, it may fall perpendicularly on the sheeting.

CHAPTER XXIV.

RULES FOR DISCOVERING NEW IMPROVEMENTS; EXEMPLIFIED IN IMPROVING THE ART OF CLEANING AND HULLING RICE, WARMING ROOMS, VENTING SMOKE BY CHIMNEYS, &c.*

The true Path to Inventions.

NECESSITY is called the mother of invention, but, upon inquiry, we shall find that Reason and Experiment bring it forth; for almost all inventions have resulted from such steps as the following:—

I. To investigate the fundamental principles of the theory, and process of the art, or manufacture, we wish to improve.

II. To consider what is the best plan, in theory, that can be deduced from, or founded on, those principles, to produce the effect we desire.

III. To inquire whether the theory be already put in practice to the best advantage; and what are the imperfections or disadvantages of the common process, and what plans are likely to succeed better.

IV. To make experiments in practice, upon any plans that these speculative reasonings may suggest, or lead to. Any ingenious artist, taking the foregoing steps, will probably be led to improvement on his own art: for we see, by daily experience, that every art may be improved. It will, however, be in vain to attempt improvements, unless the mind be freed from prejudice in favour of established plans.

EXAMPLE I.

On the Art of cleaning Grain by Wind.

I. What are the principles on which the art is founded? When bodies fall through resisting mediums, their velo-

* The rules and observations, which formed an appendix to the former editions of this work, contain some suggestions which are worthy of attention. Since they were written, many improvements have been made, in the processes to which they refer; but the path is still open, and perhaps the remarks made by Mr. Evans, may yet lead to useful results; with this hope, they have, with some modifications been retained.

cities are as their specific gravities, and the surface they expose to the medium; consequently, when light and heavy articles are mixed together, the farther they fall, the greater will be their distance apart: on this principle a separation can be effected.

II. What is the best plan in theory? First, make a current of air, as deep as possible, for the grain to fall through; the lightest will then be carried farthest, and the separation be more complete at the end of the fall. Secondly, cause the grain, with the chaff, &c., to fall in a narrow line across the current, that the light parts may meet no obstruction from the heavy, in being carried forward. Thirdly, fix a movable board edgewise to separate between the good clean, and the light grain, &c. Fourthly, cause the same blast to blow the grain several times, and thereby effect a complete separation at one operation.

III. Is this theory in practice already? what are the disadvantages of the common process? We find that the farmers' common fans drop the grain in a line 15 inches wide, to fall through a current of air about 8 inches deep, instead of falling in a line half an inch wide, through a current three feet deep; so that it requires a very strong blast even to blow out the chaff; but garlic, light grains, &c., cannot be thus removed, as they meet so much obstruction from the heavy grains; the grain has, therefore, to undergo two or three such operations, so that the practice appears absurd, when tried by the scale of reason.

IV. The fourth step is to construct a fan to put the theory in practice, by experiment. (See Art. 83.)

EXAMPLE II.

The Art of Distillation.

I. The principles on which this art is founded, are evaporation and condensation. When liquid is heated, the spirit it contains, being more volatile than the watery part, evaporates, before it, into steam, which being condensed again into a liquid, by cold, is obtained in a separate state.

II. The best plan, in theory, for effecting this, appears to be as follows: the fire should be applied to the still, so as to spend the greatest possible part of its heat to heat the liquid. Secondly, the steam should be conveyed into a metallic vessel of any suitable form, and this should be immersed in cold water, to condense the steam; in order to keep the condenser cold, there should be a stream of cold water continually entering the bottom and flowing over the top of the condensing tub; the steam should have no free passage out of the condenser, else the strongest part of the liquor will escape.

III. Is this theory already put in practice, and what are the disadvantages of the common process?—1st, A great part of the heat escapes up the chimney. 2dly, It is almost impossible to keep the grounds from burning in the still. 3dly, The fire cannot be regulated to keep the still from boiling over; we are, therefore, obliged to run the spirit off very slowly; how are we to remedy these disadvantages?—First, to lessen the fuel, apply the fire as much to the surface of the still as possible; enclose the fire by a wall of clay that will not convey the heat away so fast as stone; let in no more air than is necessary to keep the fire burning, for the surplus air carries away the heat of the fire. Secondly, to keep the grounds from burning, immerse the still, with the contained liquor, in a vessel of water, joining their tops together; then, by applying the fire to heat the water in the outside vessel, the grounds will not burn, and by regulating the heat of the outside vessel the still may be kept from boiling over.

IV. A still to be heated through the medium of water, was made, some years ago, by Colonel Alexander Anderson, of Philadelphia, and the experiment tried; but the outside vessel being open, the water in it boiled away, and carried off the heat, and the liquor in the still could not be made to boil—this appeared to defeat the scheme. But, by enclosing the water in a tight vessel, so that the steam could not escape, and that the heat might be increased, it now passed to the liquor in the still, which boiled as well as if the fire had been immediately applied to it. By fixing a valve to be loaded so as to let the steam escape, when it has arrived to such a degree of heat as to require it, all danger of explosion is avoided, and all boiling over prevented.

EXAMPLE III.

The Art of venting Smoke from Rooms by Chimneys.

I. The principles are:—Heat, by repelling the particles of air to a greater distance than when cold, renders it lighter than cold air, and it will rise above it, forming a current upwards, with a velocity proportional to the degree of heat, and the size of the tube or funnel of the chimney, through which it ascends, and with a power proportional to its perpendicular height; which power to ascend will always be equal to the difference of the weight of a column of rarefied air of the size of the smallest part of the chimney, and a column of common air of equal size.

II. What is the best plan, in theory, for venting smoke, that can be founded on these principles?

1st. The size of the chimney must be proportioned to the size and closeness of the room and to the fire; because, if the chimney be immensely large, and the fire small, there will be little current upwards. And again, if the fire be large, and the chimney too small, the smoke cannot be all vented by it: more air being necessary to supply the fire, than can find vent up the chimney, it must spread in the room again, which air, after passing through the fire, is rendered deleterious.

2dly. The narrowest place in the chimney must be next the fire, and in front of it, so that the smoke would have to pass under it to get into the room; the current will there be greatest, and will draw up the smoke briskly.

3dly. The chimney must be perfectly tight, so as to admit no air but at the bottom.

III. The errors in chimneys in common practice, are,

1st. In making them widest at bottom.

2dly. Too large for the size and closeness of the room.

3dly. In not building them high enough, so that the wind, whirling over the tops of houses, blows down them.

4thly. By letting in air any where above the breast, or opening, which destroys the current of it at the bottom.

IV. The cures directed by the principles and theory, are,

1st. If the chimney smoke on account of being too large for the size and closeness of the room, make the chimney less at the bottom—its size at the top may not do much injury, but it will weaken the power of ascent, by giving the smoke time to cool before it leave the chimney; the room may be as tight, and the fire as small as you please, if the chimney be in proportion.

2dly. If it be small at the top and large at the bottom, there is no cure but to lessen it at the bottom.

3dly. If it be too small, which is seldom the case, stop up the chimney and use a stove—it will be large enough to vent all the air that can pass through a two inch hole, which is large enough to sustain the fire in a stove. Chimneys built in accordance with these theories, I believe, are every where found to answer the purpose. (See Franklin's letters on smoky chimneys.)

EXAMPLE IV.

The Art of warming Rooms by Fire.

I. Consider in what way fire operates.

1st. The fire heats and rarefies the air in the room, which gives us the sensation of heat or warmth.

2dly. The warmest part of the air being lightest, rises to the uppermost part of the room, and will ascend through holes (if there be any) to the room above, making it warmer than the one in which the fire is.

3dly. If the chimney be too open, the warm air will fly up it, leaving the room empty; the cold air will then rush in at all crevices to supply its place, which keeps the room cold.

II. Considering these principles, what is the best plan, in theory, for warming rooms?

1st. We must contrive to apply the fire to spend all its heat, to warm the air which comes into the room.

2dly. The warm air must be retained in the room as long as possible.

3dly. Make the fire in a lower room, conducting the heat through the floor into the upper one, and leaving another hole for the cold air to descend to the lower room.

4thly. Make the room so tight as to admit no more cold air, than can be warmed as it comes in.

5thly. By closing the chimney so as to let no warm air escape, but that which is absolutely necessary to sustain the fire—a hole of two square inches will be sufficient for a very large room.

6thly. The fire may be supplied by a current of air brought from without, not using any of the air already warmed. If this theory, which is founded on true principles and reason, be compared with common practice, the errors will appear, and may be avoided.

I had a stove constructed in accordance with these principles, and have found all to answer according to theory.

The operation and effects are as follows; namely:—

1st. It applies the fire to warm the air as it enters the room, and admits a full and fresh supply, rendering the room moderately warm throughout.

2dly. It effectually prevents the cold air from pressing in at the chinks or crevices, but causes a small current to pass outwards.

3dly. It conveys the coldest air out of the room first, consequently,

4thly. It is a complete ventilator, thereby rendering the room healthy.

5thly. The fire may be supplied (in very cold weather) by a current of air from without, that does not communicate with the warm air in the room.

6thly. Warm air may be retained in the room any length of time, at pleasure; circulating through the stove, the coldest entering first, to be warmed over again.

7thly. It will bake, roast, and boil equally well with the common ten plate stove, as it has a capacious oven.

8thly. In consequence of these improvements, it requires not more than half the usual quantity of fuel.

Description of the Philosophical and Ventilating Stove.

It consists of three parts, either cylindrical or square, the greatest surrounding the least. (See fig. 1, Plate X.) S F is a perspective view thereof in a square form, supposed open at one side: the fire is put in at F, into the least part, which communicates with the space next the outside, where the smoke passes to the pipe 1—5. The middle part is about two inches less than the outside part, leaving a large space between it, and above the inner part, for an oven, in which the air is warmed, being brought in by a pipe B D between the joists of the floor, from a hole in the wall at B, it rises under the stove at D, into the space surrounding the oven and the fire, which air is again surrounded by the smoke flue, giving the fire a full action to warm it, whence it ascends into the room by the pipe 2. E brings air from the pipe D B to blow the fire. H is a view of the front end plate, showing the fire and oven doors. I is a view of the back end, the plate being off, the dark square shows the space for the fire, and the light part the air-space surrounding the fire, the dark outside space the smoke surrounding the air; these are drawn on a larger scale. The stove consists of fifteen plates, twelve of which join, by one end, against the front plate H.

To apply this stove to the best advantage, suppose fig. 1, Plate X., to represent a three or four story house, two rooms on a floor—set the stove S F in the partition on the lower floor, half in each room; pass the smoke pipe through all the stories; make the room very close; let no air enter but what comes in by the pipes A B or G C through the wall at A and G, that it may be the more pure, and pass through the stove and be warmed. But to convey it to any room, and take as much heat as possible with it, there must be an air-pipe surrounding the smoke pipe, with a valve to open at every floor. Suppose we wish to warm the rooms No. 3—6, we open the valves, and the warm air enters, ascends to the upper part, depresses the cold air, and if we open the holes a—c, it will descend the pipes, and enter the stove to be warmed again: this may be done in very cold weather. The higher the room above the stove, the more powerfully will the warm air ascend and expel the cold air. But if the room require to be ventilated, the air must be prevented from descending, by shutting the little gate 2 or 5, and drawing 1 or 6, and giving it liberty to ascend and escape at A or G—or up the chimney, letting it in close at the hearth. If the warm air be conveyed under the floor, as between 5—6, and let rise in several places, with a valve at each, it will be extremely convenient and pleasant; if above the floor, as at 4, several persons might set their feet on it to warm. The rooms will be moderately warm throughout—a person will not be sensible of the coldness of the weather.

One large stove of this construction may be made to warm a whole house, ventilate the rooms at pleasure, bake bread, meat, &c.

These principles and improvements ought to be considered and provided for in building.

EXAMPLE V.

Art of Hulling and Cleaning Rice.

Step I. The principles on which this art may be founded, will appear, by taking a handful of rough rice, and rubbing it hard between the hands—the hulls will be broken off, and, by continuing the operation, the sharp texture of the outside of the hull (which, through a magnifying glass, appears like a sharp, fine file, and, no doubt, is designed by nature for the purpose) will cut off the inside hull, and the chaff being blown out, will leave the rice perfectly clean, without breaking any of the grains.

II. What is the best plan, in theory, for effecting this? (See the plan proposed, represented in Plate X., fig. 2; explained Art. 103.)

EXAMPLE VI.

To save Ships from sinking at Sea.

STEP I. The principle on which ships float, is the difference of their specific gravities from that of the water,—sinking only to displace a quantity of water equal in weight to that of the ship, and its lading; they sink deeper, therefore, in fresh than in salt water. If we can calculate the weight of the cubic feet of water a ship displaces when empty, it will show her weight, and subtracting that from what she displaces when loaded, shows the weight of her load; each cubic foot of fresh water weighing 62,5 lbs. If an empty rum hogshead weigh 62,5 lbs. and measure 15 cubic feet, it will require 875 lbs. to sink it. A vessel of iron, containing air only, and so large as to make its whole bulk lighter than so much water, will float, but if it be filled with water, it will sink. Hence, we may conclude, that a ship loaded with any thing that will float, will not sink if filled with water; but if loaded with any thing specifically heavier than water, it will sink as soon as filled.

II. This appears to be the true theory:—How is it to be applied in case a ship spring a leak, that gains on the pumps?

III. The mariner, who understands well the above principles and theory, will be led to the following steps:

1st. To cast overboard such things as will not float, and carefully to reserve every thing that will float, for by them the ship may at last be buoyed up.

2dly. To empty every cask or thing that can be made water-tight, to put them in the hold, and fasten them down under the water, filling the vacancies between them with billets of wood; even the spars and masts may, in desperate cases, be cut up for this purpose, which will fill the hold with light matter, and as soon as the water inside is level with that outside, no more will enter. If every hogshead buoy up 875 lbs., they will be a great help to buoy up the ship, (but care must be taken not to put the empty casks too low, which would overset the ship,) and she will float, although half the bottom be torn off. Mariners, for want of this knowledge, often leave their ships too soon, taking to their boats, although the ship be much the safest, and do not sink for a long time after being abandoned—not considering that, although the water gain on their pumps at first, they may be able to hold way with it when risen to a certain height in the hold, because the velocity with which it will enter, will be in proportion to the square root of the difference between the level of the water inside and outside—added to this, the fuller the ship the easier the pumps will work, because the water has to be raised to a less height; therefore, they ought not to be too soon discouraged.

Description of the Thrashing Machine, with elastic Flails; invented by James Wardrop, *of Ampthill, Virginia.**

PLATE XXV.

A—the floor on which the flails are fixed.

B—the part of the floor on which the grain is laid, made of wicker-work, through which the grain falls, and is conveyed to the fan or screen below; the pivot of the fan is seen at P, and is turned by a band from the wheel or wallower.

C C C—a thin board raised round the floor to confine the wheat, and made shelving outwards, to render raking off the straw more easy.

D—the wallower or wheel.

E—Crank handle to turn the wheel.

F F—Flails.

G G G—Lifters, with ropes fixed to the flails.

I I I—Catches or teeth to raise the lifters.

K—Post on which the wallower is fixed.

L—Beam on which the lifters rest and are fixed by an iron rod passing through the lifters, and let into this beam.

M—Check-beam to stop the end of the lifters from rising.

N—Keeps in which the lifters work.

O—Beam in which the ends of the flails are mortised.

Q—Fly-ends loaded with lead, not necessary in a horse machine.

R—Showing the lifters and keeps, how fixed.

The machine, to be worked by two men, was made on a scale of a 12 foot flail, having a spring which required a power of 20 lbs. to raise it three feet high at the point:—A spring of this power, and raised three feet high, being found to get out wheat with great effect.

* The flail thrashing machine has been superseded by that with cylindrical beaters and a concave, variously modified. This is now so generally introduced as not to require any description. The flail machine having been originally engraved for this work, has been retained.