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 mill-stones; 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 cogwheel, 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,) 2½ 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	3¾	5
9	13	1448	965	23½	88	58	15	3⅞	5
10	14	1521	1014	23 1/7	88	58	15	3 6/7	5
11	15	1595	1061	22¾	88	58	15	3¾	5
12	16	1666	1111	22¼	88	58	15	3⅞	5
13	16	1735	1157	23 1/7	88	60	16	3¾	5
14	16	1800	1200	24	88	59	16	2⅔	5
15	16	1863	1242	24⅘	88	60	17	3⅓	5
16	16	1924	1283	25⅔	88	59	17	3⅜	5
17	17	1983	1322	25	88	62	17	3¾	5
18	17	2041	1361	25⅔	88	62	17	3⅜	5
19	18	2097	1398	25	88	62	17	3¾	5
20	18	2152	1435	25½	88	60	17	3⅜	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, 3¼ by 9 inches; 16 shrouds 8 feet long, 2½ 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, 3¼ by 9 inches; 12 shrouds, 8 feet 6 inches long, 2½ 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.