THE

YOUNG MILL-WRIGHT'S GUIDE.

PART THE SECOND.

INTRODUCTION.

WHAT has been said in the first part, was meant to establish theories, and to furnish easy rules. In this part I mean to show their practical application, in as concise a manner as possible, referring only to the articles in the first part, where the reasons and demonstrations are given.

This part is particularly intended for the help of young and practical mill-wrights, whose time will not admit of a full investigation of those principles and theories, which have been laid down; I shall, therefore, endeavour to reduce the substance of all that has been said, to a few tables, rules, and short directions, which, if found to agree with experience, will be sufficient for the practitioner.

CHAPTER IV.

OF THE DIFFERENT KINDS OF MILLS.

ARTICLE 70.

OF UNDERSHOT MILLS.

UNDERSHOT wheels move by the percussion or stroke of the water, and are only half as powerful as other wheels that are moved by the gravity of the water. See Art. 9. Therefore, this construction ought not to be adopted, except where there is but little fall, or great plenty of water. The undershot wheel, and all others that move by percussion, should move with a velocity nearly equal to two-thirds of the velocity of the water. See Art. 42, Fig. 28, Plate IV., represents this construction.

For a rule for finding the velocity of the water, under any given head, see Art. 51. Upon the principles, and by the rule, given in that article, is formed the following table of the velocity of spouting water, under different heads, from one to twenty-five feet high above the centre of the issue; to which is added the velocity of the wheel suitable thereto, and the number of revolutions a wheel of fifteen feet diameter (which I esteem a good size) will revolve in a minute; also, the number of cogs and rounds in the wheels, both for double and single gears, so as to produce about ninety-seven or one hundred revolutions per minute, for a five feet stone, which I think a good motion and size for a mill-stone, grinding for merchantable flour.

That the reader may fully understand how the following table is calculated, let him observe,

1. That, by Art. 42, the velocity of the wheel must be just 577 thousandth parts of the velocity of the water; therefore, if the velocity of the water, per second, be multiplied by ,577, the product will be the maximum velocity of the wheel, or velocity that will produce the greatest effect, which is the third column in the table.

2. The velocity of the wheel per second, multiplied by 60, produces the distance the circumference moves per minute, which, divided by 47,1 feet, the circumference of a 15 feet wheel, gives the number of revolutions of the wheel per minute, which is the fourth column.

3. That, by Art. 20 and 74, the number of revolutions of the wheel per minute, multiplied by the number of cogs in all the driving wheels, successively, and that product, divided by the product of the number of cogs in all the leading wheels, multiplied successively, the quotient is the number of revolutions of the stones per

minute, which is found in the ninth and twelfth columns.

4. The cubochs of power required to drive the stone being, by Art. 61, equal to 111,78, cubochs per second, which, divided by half the head of water, added to all the fall, (if any,) being the virtual or effective head by Art. 61, gives the quantity of water, in cubic feet, required per second, which is found in the thirteenth column.

5. The quantity required, divided by the velocity with which it is to issue, gives the area of the aperture of the gate, and is shown in the fourteenth column.

6. The quantity required, divided by the velocity proper for the water to move along the canal, gives the area of the section of the canal; as in the fifteenth column.

7. Having obtained their areas, it is easy, by Art. 65, to determine the width and depth, which may be varied to suit other circumstances.

THE MILL-WRIGHT'S TABLE

FOR

UNDERSHOT MILLS,

CALCULATED FOR A WATER-WHEEL OF FIFTEEN FEET, AND STONES OF FIVE FEET DIAMETER.

Head of water above the point of impact.	Velocity of the water per second at the point of impact.	Velocity of the wheel per second, loaded at the maximum.	Number of revolutions of the wheel of 15 feet diameter, per minute.	No. of cogs in the master cog-wheel.	Rounds in the wallower.	Cogs in the counter cog-wheel.	Rounds in the trundle.	Revolutions of the stone per minute.	Cogs in the cog-wheel for single gear.	Rounds in the trundle.	Revolutions of the stone per minute.	Cubic feet of water required per second to drive a 5 feet stone 97 revolutions per minute.	Area of the gate to vent the water, or rather of a section of the column of water at place of impact.	Area of a section of the canal sufficient to bring on the water with 1.5 feet velocity.
feet.	feet.	feet.										cub. ft.	sup. ft.	sup. ft.
1	8.1	4.67	5.94	112	22	54	16	101.6				223.5	27.5	149.
2	11.4	6.57	8.36	96	23	54	19	99				111.78	9.8	74.5
3	14.	8.07	10.28	88	25	54	19	100.5				74.52	4.6	43.
4	16.2	9.34	11.19	78	23	48	20	97				55.89	3.45	37.26
5	18.	10.38	13.22	66	24	48	18	97	112	15	98.66	44.7	2.48	29.8
6	19.84	11.44	14.6	66	24	48	20	96.2	112	17	96.2	37.26	1.9	24.84
7	21.43	12.36	15.74	66	25	44	19	96.2	104	17	96.2	31.9	1.48	21.26
8	22.8	13.15	16.75	66	25	44	20	97.2	96	16	100.	27.94	1.22	18.6
9	24.3	14.02	17.86	66	26	42	19	100.2	96	17	100.8	24.84	1.02	16.56
10	25.54	14.73	18.78	60	25	44	20	99	96	18	100.	22.89	.9	15.26
11	26.73	15.42	19.7	60	26	44	20	100	96	19	99.5	20.32	.76	13.54
12	28.	16.16	20.5	60	27	44	20	100	96	20	98.4	18.63	.66	12.42
13	29.16	16.82	21.42	60	27	42	20	99.8	96	21	102.6	16.27	.56	10.8
14	30.2	17.42	22.19	60	28	42	20	99	88	20	97.63	15.94	.53	10.6
15	31.34	18.08	23.03	60	29	42	20	99	88	21	96.5	14.9	.47	9.93
16	32.4	18.69	23.8						88	21	99.7	13.97	.43	9.31
17	33.32	19.22	24.48						84	21	97.9	13.14	.39	8.76
18	34.34	19.81	25.23						80	21	96.1	12.42	.36	8.28
19	35.18	20.29	25.82						80	21	98.3	11.76	.33	7.84
20	36.2	20.88	26.6						78	21	98.3	11.17	.3	7.4
21	37.11	21.41	27.26						78	22	97.	10.64	.29	7.1
22	37.98	21.86	27.84						78	22	98.6	10.16	.26	6.77
23	38.79	22.38	28.5						72	21	97.7	9.72	.25	6.48
24	39.69	22.90	29.17						66	20	96.2	9.32	.23	6.21
25	40.5	23.36	29.75						60	18	99.	8.94	.22	5.96
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

It must be observed, that five feet fall is the least that a single gear can be built on, to keep the cog-wheel clear of the water, and give the stone sufficient motion.

Although double gear is calculated to fifteen feet fall, yet I do not recommend them above ten feet, unless for some particular convenience, such as for two pair of stones to one wheel, &c. &c. The number of cogs in the wheels is even, and is thus suited to eight, six, or four arms, so as not to pass through any of them, this being the common practice; but when the motion cannot be obtained without a trundle that will cause the same cogs and rounds to meet too often, such as 16 into 96, which will meet every revolution of the cog-wheel, or 18 to 96, which will meet every third revolution; I advise the putting in either of one more, or one less, as may best suit the motion, which will cause them to change oftener. See Art. 82.

It should be recollected, that the friction at the aperture of the gate will greatly diminish both the velocity and power of the water, where the head is great, if the gate be made of the usual form, that is, wide and shallow. Where the head is great, the friction will be great. See Art. 55: therefore, the wheel must be narrow, and the aperture of the gate of a square form, in order to avoid the friction and loss in a wide wheel, especially if it do not run very closely to the sheeting.

Use of the Table.

Having levelled your mill-seat carefully, and finding such fall and quantity of water as determines you to make choice of an undershot wheel; for instance, suppose 6 feet fall, and about 45 cubic feet of water per second, which you may find in the way directed in Art. 53; cast off about one foot for fall in the tail-race below the bottom of the wheel, if subject to back-water, which leaves you 5 feet head; then look for 5 feet head in the first column of the table, and against it are all the calculations for a 15 feet water-wheel and 5 feet stones; in the thirteenth column you have 44,7 cubic feet of water, which shows you have enough for a pair of five feet stones; and the velocity of the water will be 18 feet per second, the velocity of the wheel 10,38 feet per second, and it will revolve 13,22 times per minute. If you choose double gear, then 66 cogs in the master cog-wheel, 24 rounds in the wallower, 48 cogs in the counter cog-wheel, and 18 rounds in the trundle, will give the stone 97 revolutions in a minute; if single gear, 112 cogs and 15 rounds give 98,66 revolutions in a minute; it will require 44,7 cubic feet of water per second; the size of the gate must be 2,48 feet, which will be about 4 feet wide, and ,62 feet, or about 7¼ inches deep; the size of the canal must be 29,8 feet; that is, about 3 feet deep and 9,93 or nearly 10 feet wide. If you choose single gear, you must make your water-wheel much smaller, say 7½, the half of 15 feet, then the cog-wheel must have half the number of cogs, the trundle-head the same, the spindle will be longer, and the husk lower; the mill will then be full as good as with double gear: in the case supposed, however, a cog-wheel of 66 cogs would not answer, because it would reach the water; but where the head is 10 or 12 feet, it will do very well.

If you choose stones, or water-wheels, of other sizes, it will be easy, by similar rules, to proportion the whole to suit, seeing you have the velocity of the periphery of a wheel of any size.*

* One advantage large wheels have over small ones is, that they cast off the back water much better. The buckets of the low wheel will lift the water much more than those of the high wheel; because the nearer the water rises to the centre of the wheel, the nearer the buckets approach the horizontal or lifting position.

To make a wheel cast off back-water, some mill-wrights fix the sheeting below the wheel, with joints and hinges, so that the end down stream can be raised so as to shoot the water, as it leaves the wheel, on to the surface of the back-water, and thus roll it from the wheel, it is thought that it will drive off the back-water much better.

Plate IV. fig. 28, shows an undershot wheel. Some mill-wrights prefer to slant the forebay under the wheel, as in the figure, that the gate may be drawn near the floats; because they think that the water acts with more power near the gate, than at a distance; which appears to be the case, when we consider, that the nearer we approach the gate, the nearer the column of water approaches to what is called a perfectly definite quantity. See Art. 59.

Others, again, say, that it acquires equal power of descending the shute. (It will certainly acquire equal velocity abating only for the friction of the shute and the air.) When the shute has a considerable descent, the greater the distance from the gate, the greater the velocity and power of the water; but where the descent of the shute is not sufficient to overcome the friction of the air, &c., then

Observations on the Table.

1. The table is calculated for an undershot wheel constructed, and the water shot on, as in Plate IV. fig. 28. The head is counted from the point of impact I., and the motion of the wheel at a maximum, about ,58 of the velocity of the water; but when there is plenty of water, and great head, the wheel will run best at about ,66 or two-thirds of the velocity of the water; therefore, the stones will incline to run faster than in the table, in the ratio of 58 to 66, nearly; for which reason, I have set the motion of 5 feet stones under 100 revolutions in a minute, which is slower than common practice; they will incline to run between 96 and 110 revolutions.

2. I have taken half of the whole head above the point of impact, for the virtual or effective head, by Art. 53, which I apprehend will be too little in very low heads, and, perhaps, too much in high ones. As the principle of non-elasticity does not seem to operate against the power so much in low as in high heads; therefore, if the head be only 1 foot, it may not require 223,5 cubic feet of water per second, and if 20 feet, may require more than 11,17 cubic feet of water per second, the quantities given in the table.

ARTICLE 71.

OF TUB MILLS.

A tub mill has a horizontal water-wheel, that is acted on by the percussion of the water altogether; the shaft is

the nearer the gate, the greater the velocity and power of the water; which argues in favour of drawing the gate near the floats. Yet, where the fall is great, or water plenty, and the expense of a deep penstock considerable, the small difference of power is not worth the expense of thus obtaining it. In these cases, it is best to have a shallow penstock, and a long shute to convey the water down to the wheel, drawing the gate at the top of the shute: this is frequently done to save expense in building saw-mills, with flutter-wheels, which are small undershot wheels, fixed on a crank shaft, and made so small as to obtain a sufficient number of strokes of the saw in a minute, say about 120. This wheel is to be of such a size as is calculated to suit the velocity of the water at the point of impact, so as to make that number of revolutions (120) in a minute.

Thomas Ellicott's method of shooting the water on an undershot wheel, where the fall is great, is shown in plate 13, fig. 6.

vertical, carrying the stone on the top of it, and serves in place of a spindle; the lower end of this shaft is set in a step fixed in a bridge-tree, by which the stone is raised and lowered, as by the bridge-tree of other mills; the water is shot on the upper side of the wheel, in the direction of a tangent with its circumference. See fig. 29, Plate IV., which is a top view of the tub-wheel, and fig. 39, which is a side view of it, with the stone on the top of the shaft, bridge-tree, &c. The wheel runs in a hoop, like a mill-stone hoop, projecting so far above the wheel as to prevent the water from shooting over the wheel, and whirls it about until it strikes the buckets, because the water is shot on in a deep narrow column, 9 inches wide and 18 inches deep, to drive a 5 feet stone, with 8 feet head—the whole of this column cannot enter the buckets until a part has passed half way round the wheel, so that there are always nearly half the buckets struck at once: the buckets are set obliquely, that the water may strike them at right angles. See Plate IV., fig. 30. As soon as it strikes, it escapes under the wheel in every direction, as in fig. 29.*

* Note. That in Plate IV. fig. 30, I have allowed the gate to be drawn inside of the penstock, and not in the shute near the wheel, as is the common practice; because the water will leak out much alongside of the gate, if drawn in the shute. But here we must consider that the gate must always be full drawn, and the quantity of water regulated by a regulator in the shute near the wheel; so that the shute will be perfectly full, and pressed with the whole weight of the head, else a great part of the power may be lost.

To show this more plainly, suppose the long shute A, from the high head (shown by dotted lines) of the undershot mill, fig. 28, be made tight by being covered at top, then, if we draw the gate A, but not fully, and if the shute at bottom be large enough to vent all the water that issues through the gate when the shute is full to A, then it cannot fill higher than A; therefore, all that part of the head above A is lost, it being of no other service than to supply the shute, and keep it full to A, and the head from A to the wheel, is all that acts on the wheel.

Again, when we shut the gate, the shute cannot run empty, because it would leave a vacuum in the head of the shute at A; therefore, the pressure of the atmosphere resists the running out of the water from the shute, and whatever head of water is in the shute, when the gate is shut, will balance its weight of the pressure of the atmosphere, and prevent it from acting on the lower side of the gate, which will cause it to be very hard to draw. For, suppose 11 feet head of water to be in the shute when the gate was shut, its pressure is equal to about 5 lbs. per square inch; then, if the gate be 48 by 6 inches, which is equal to 288 inches, this multiplied by 5, is equal to 1440 lbs. the additional pressure on the gate.

Again, if the gate be full drawn, and the shute be not much larger at the up-

The disadvantages of these wheels are,

1. Under the best construction the water does not act to advantage on them; and it is in general necessary to make them so small, in order to give velocity to the stone, that the buckets take up a third part of their diameter.

2. The water acts with less power than on undershot wheels, as it is less confined at the time of striking the wheel, and its non-elastic principle operates more fully.

3. If the head be low, it is with difficulty we can put a sufficient quantity of water to act on them so as to drive them with sufficient power; I, therefore, advise to let the water strike on them in two places; as in Plate IV. fig. 29; the apertures need then only be about 6 by 13 inches each, instead of 9 by 18; they will then operate to more advantage, as nearly all the buckets will be acted on at once.

Their advantages are,

Their exceeding simplicity and cheapness, having no cogs nor rounds to be kept in repair, their wearing parts are few, and have but little friction; the step-gudgeon runs under water, therefore, if well fixed, it will not get out of order in a long time; they will move with sufficient velocity and power with 9 or 10 feet total fall, if there be plenty of water; and, if they be well fixed, they will not require much more water than undershot wheels; they are, therefore, preferable in all seats which have a surplus of water, and above 8 feet fall.

In order that the reader may fully understand how the following table for tub-mills is calculated, let him consider,

1. That the tub-wheel moves altogether by percussion, the water flying clear of the wheel the instant it

per than the lower end, these defects will cause much loss of power. To remedy all this, put the gate H at the bottom of the shute to regulate the quantity of water by, and make a valve at A to shut on the inside of the shute, like the valve of a pair of bellows, which will close when the gate A is drawn, and open when the gate shuts, and let air into the shute; this plan will do better for saw-mills with flutter-wheels, or tub-mills, than long open shutes, as by it we avoid the friction of the shute and the resistance of the air.

To understand what is here said, the reader must be acquainted with the theory of the pressure of the atmosphere, vacuums, &c. See these subjects touched on in Art. 56.