APPENDIX,

CONTAINING

A Description of a Merchant Flour Mill, on the most approved Construction, with the recent Improvements, with two additional Plates,

BY CADWALLADER AND OLIVER EVANS, ENGINEERS;

AND

EXTRACTS

FROM SOME OF THE BEST MODERN WORKS ON THE SUBJECT OF MILLS, WITH OBSERVATIONS BY THE EDITOR.

Description of a Merchant Flour Mill, driving four Pairs of five feet Mill-Stones; arranged by CADWALLADER *and* OLIVER EVANS, *Engineers, Philadelphia.*

PLATE XXVII.

1—A hollow cast-iron shaft, circular, 15 inches in diameter, except at those points where the water and main bevel wheels are hung, where it is increased to 19 inches in diameter. The water-wheel is secured on this shaft by 3 sockets, as represented in Plate XXVIII., fig. 3, and makes 10 revolutions per minute.

2—The main driving bevel-wheel, on the water-wheel shaft, 8 feet in diameter, to the pitch line; 100 cogs, 3 inches pitch, and 8 inches on the face; revolving 10 times per minute, and driving.

3—A bevel-wheel on the upright, 4 feet in diameter to pitch line; 50 cogs, same pitch and face of cogs as above, revolving 20 times per minute.

4—The large pit spur-wheel, making 20 revolutions per minute, 9 feet $\frac{1}{8}$th inch diameter, to pitch line; 114

cogs, 3 inches pitch, face 10 inches; this wheel gives motion to

5, 5, 5, 5—Four pinions on the spindles of the mill-stones, 18,1 inches in diameter to pitch line, 19 cogs, same face and pitch.

6, 6, 6, 6—Iron upright shafts, extending the height of the building, and coupled at each story.

7, 7, 7, 7—Are 4 pairs of five feet mill-stones, making 120 revolutions per minute. Two of them shown in elevation; and the position of the 4, shown in Plate XXVIII. as represented by the dotted lines, fig. 1.

8—A pulley on the upright shaft, which, by a band, gives motion to

8—The fan for cleaning grain, revolving 140 times per minute, wings 3 feet long, 20 inches in width.

9—A bevel wheel 2 feet diameter, cogs 2 inches pitch, face 2,5 inches, on the upright shaft, gearing into a bevel wheel, the face of which is shown, drives the bolting screen 18 revolutions per minute.

10—A bevel wheel on upright shaft, 56 cogs, 2 inches pitch, 2,5 inches face, gearing into

10—A bevel wheel on the shaft of the bolting reels, 31 cogs, same pitch and face.

10, 10—Are two of four bolting reels shown, 18 feet long, 30 inches diameter, revolving 36 times per minute.

11—A large pulley on the upright shaft, which, by a band, gives motion to the rubbing stones 11.

12—A bevel wheel, on the top of the upright shaft, gearing into

12—A bevel wheel, on the horizontal shaft, at one end of which is

13—A bevel wheel, 1 foot diameter, gearing into a bevel wheel

14—of 5 feet diameter, which reduces the motion of the hopper-boy down to 4 revolutions per minute, which sweeps a circle of 20 feet.

15—Meal elevator attending 4 pairs of stones.

16—Grain elevator.

17—Packing-room and press.

PLATE XXVIII.

Figure 1.

A bird's eye view of the mode of giving motion to 4 pairs of mill-stones.

4—The large pit spur-wheel, driving at equal distances on its periphery, the pinions

5, 5, 5, 5—attached to the spindles of the mill-stones.

7, 7, 7, 7—Mill-stones, 5 feet diameter, represented by dotted circles.

Figure 2.

An enlarged view of the couplings of the upright shaft. They are of cast-iron, with their holes truly reamed, to receive the ends of the iron upright shafts.

2—The face of a coupling, divided into 6 equal parts, radiating from the centre: three of the parts project, and three are depressed; so that when two of them are coupled, the projections of one will fill the depressions in the other, as 1, the coupling connected.

Figure 3.

A cast-iron socket for the water-wheel; it is a plate $\frac{3}{4}$ths of an inch thick; the eye for the shaft to pass through, $1\frac{1}{4}$ inch thick, and 12 inches deep: the sockets, for receiving the arms, are 14 inches long, and have projections 5 inches deep; 3 3 3, &c., are the projections; the intermediate space, between the sockets, are cut out to lessen the weight of metal, but in such a manner as to preserve the strength. It requires three of these sockets for a large water-wheel; the arms for receiving the buckets, are dressed to fit tightly in the sockets, and secured firmly by bolts, as 2 2.

Figure 4,

Is an arm for the water-wheel, as dressed; 1, the end to be bolted in the socket; 2, the end for screwing on the bucket.

The advantages of this mode of constructing water-wheels, is, that the shaft is not weakened, by having mortises cut in to receive the arm: that it is not so liable to decay, and if an arm, or bucket, be destroyed by accident, they can be dressed out, and the mill stopped, only while you unscrew the broken part, and replace it by a new one.

Figure 5.

An elevation of the flour press. 1, the barrel of flour; 2, the funnel; 3 3, the driver; 4 5, the lever; 4 3, the connecting bars, fastened by a strong pin to each side of the lever, at 4, and to the driver at 3. 6, a strong bolt, passing through the floor, and keyed below the joist: there is a hole in the upper part of the bolt, to receive a pin which the lever works on, which, when brought down by the hand, moves the pin 4, in the dotted circle; the connecting bars drawing down the driver 3 3, pressing the flour into the barrel; and as it becomes harder packed, the power of the machine increases; as the pin 4 approaches the bolt 6, the under sliding part of the lever is drawn out, to increase its length; and is assisted in rising by a weight fastened to a line passing over pulleys.

When the pin 4 is brought down within half an inch of the centre of the bolt 6, or plumb line, the power increases from 1 to 288; and with the aid of a simple wheel and axis, as 1 to 15, from 288 to 4320; or, if the wheel and axis be as 1 to 30, it will be increased to 4320; that is to say, one man will press as hard with this machine as 8640 men could do with their natural strength. It is extremely well calculated for cotton, tobacco, cider, or, in short, any thing that requires a powerful press.

Operation of the Mill:—The grain, after having been weighed, by drawing a slide, is let into the grain elevator 16, then hoisted to the top of the building, and by a spout moving on a circle, can be deposited into spouts leading to any part of the mill, when wanted for use: by drawing sliders in other spouts, converging to the grain elevator 16, it can be re-elevated, and thrown into the hopper of the rubbing stones 11; after passing through which, it descends into the bolting screen 9, and when screened, falls into the fan 8, is there cleaned, and from that descends into a very large hopper, over the centre of the four pairs of mill-stones, which are supplied regularly with grain. After being ground, the meal descends into a chest, is taken by the elevator 15, to the top of the building, there deposited under the hopper-boy, which spreads, cools, and collects it to the bolting reels, where the several qualities are separated, and the flour descends into the packing room 17, where it is packed in barrels.

By this arrangement, we dispense with all conveyers, and have only one grain, and one flour elevator, to attend two pair of stones; we also dispense with one-half the quantity of gearing usually put into mills, and, consequently, occupy much less space, leaving the rest of the building for stowing grain, &c.

All the wheels in this mill are of cast-iron, and the face of the cogs very deep; for experience justifies the assertion that depth of face in cog-wheels, when properly constructed, does not increase friction; and that the wheels will last treble the time, by a small increase of depth; we recommend the main driving wheels to be 10 inches on the face. The journals of all shafts, when great pressure is applied, should be of double the length now generally used; increase of length does not increase friction; say for water wheels, journals of from 8 to 14 inches.

Draughts of mills are furnished by the subscribers; and the cast-iron work can be obtained, at the Steam Engine Manufactory and Iron Foundry of Messrs. Rush & Muhlenberg, Bush Hill, Philadelphia.

CADWALLADER EVANS,
OLIVER EVANS.

June 15, 1826.

WATER-WHEELS.

On the Construction of Water-Wheels, and the Method of applying the Water for propelling them, so as to produce the greatest Effect.

The following article is from the pen of a practical engineer of experience and talents; his observations are, in general, in perfect accordance with those of the editor. The principles which he advocates are undoubtedly correct, and it is hoped that their publication in this work will induce some of our most intelligent mill-wrights to forsake the beaten track, and to practise the modes recommended. Let them recollect that Mr. Parkin was not a mere theorist, but a practical man, like themselves. The death of this gentleman has deprived society of the services of one of its members, from whose liberality, experience, and skill, much was expected.

[FROM THE FRANKLIN JOURNAL.]

In constructing water-wheels, especially those of great power, the introduction of iron is a most essential improvement; and if this metal, and artisans skilled in working it, could be obtained at reasonable rates, water-wheels might be made wholly of it, and would prove, ultimately, the cheapest; as, if managed with due care, and worked with pure (not salt) water, they would last for centuries; but, as the first cost would be an objection, I would recommend, in all very large wheels, that the axis be made of cast-iron; and, in order to obtain the greatest strength with the least weight, the axis or shaft ought to be cast hollow, and in the hexagon or octagon form, with a strong iron flanch, to fix each set of arms, and the cog-wheel, upon; these flanches to be firmly fixed in their places with steel keys.

On the adaptation of water-wheels to the different heights of the water falls by which they are to be worked, I will remark that falls of from 2 to 9 feet are most advantageously worked with the undershot wheel; falls of

10 feet and upwards by the bucket or breast wheel, which, up to 20 or 25 feet, ought to be made about one-sixth higher than the fall of water by which it has to be worked; and in wheels of both descriptions, the water ought to flow on the wheel from the surface of the dam. I am aware that this principle is at direct variance with the established practice, and perhaps there are few wheels in these States that can be worked, as they are now fixed, by thus applying the water; the reasons will be apparent from what follows.

In adjusting the proportions of the internal wheels by which machinery is propelled, it is necessary, in order to obtain the greatest power, to limit the speed of the skirt of the water-wheel, so that it shall not be more than from 4 to 5 feet per second; it having been ascertained by accurate experiments, that the greatest obtainable force of water, is within these limits. As a falling body, water descends at the speed of about 16 feet in the first second, and it will appear evident that if a water-wheel is required to be so driven, that the waterewith which it is loaded has to descend 10, 11, or 12 feet per second, at which rate wheels are generally constructed to work, a very large proportion of the power is lost, or, rather, is spent, in destroying, by unnecessary friction, the wheel upon which it is flowing.

In the common way of constructing mill work, and of applying water to wheels, it has been found indispensably necessary to have a head of from 2 to 4 feet abovee the aperture through which the water flows into the buckets, or against the floats of a water-wheel, in order to be able to load the wheel instantaneously, without which precaution, it could not be driven at the required speed: from this circumstance it has been erroneously inferred, that the impulse or shock which a water-wheel, so filled, receives, is greater than the power to be derived from the actual gravity of the water alone. This theory I have heard maintained among practical men; but it is, in fact, only resorting to one error to rectify another. Overshot wheels have been adopted, in numerous cases, merely for the purpose of getting the water more readily into the buckets; but confine the wheel to the proper working speed, and that difficulty will not exist.

In consequence of the excessive speed at which water-wheels are generally driven, a small accumulation of back water either suspends or materially retards their operations; but, by properly confining their speed, the resistance from back water is considerably diminished, and only amounts to about the same thing as working from a dam as many inches lower, as the wheel is immersed; and in undershot wheels worked from a low head, or situated in the tide-way, the resistance from back water may be farther obviated by placing the floats not exactly in a line from the centre of the wheel, but deviating 6 or 8 inches from it, so as to favour the water in leaving the ascending float.

In constructing water-wheels to be driven at the speed of 4 or 5 feet per second, it will be requisite to make them broader, to work the same quantity of water which is required to drive a quick-speeded wheel. Thus, if a person intending to erect a mill, has a stream sufficient to work a wheel 5 feet broad, the skirt to move 10 feet per second, it is evident that if he wishes to work all the water which such wheel takes, he must have his wheel 10 or 12 feet broad, instead of 5, otherwise the water must run to waste, as there would not be room, in a slow-moving wheel of 5 feet broad, to receive more than half of it. The principal advantages resulting from the proposed method of adapting wheels to the falls by which they are to be worked, and the method of applying water, are—

1. The lessening of friction upon the main gudgeons, (and first pair of cog-wheels) by which, with a little care, they may be kept regularly cool, and the shaft or axis be preserved much longer in use than when the gudgeons cannot be kept cool.

2. By working water upon the principle of its actual gravity alone, and applying it always at the height of the surface of the dam, its power is double what is obtained by the common method of applying it.

3. The expensive penstock required to convey the water to the wheels, generally used, will not be needed,

as one much shallower, and consequently less expensive, will be sufficient.

4. The resistance of back water is reduced as far as possible.

5. The risk of fire is less, as the friction is reduced.

W. Parkin, *Engineer.*

September 24, 1825.

That water, whenever the fall is sufficient, ought always to be applied upon the principle of its actual gravity, appears to be a conclusion so obvious, that it is astonishing it should ever be disputed. The acknowledged difference between the effect of overshot and undershot wheels, is an evidence of the truth of the principle. The whole moving power of water is derived from its gravity; it is this which causes it to fall, and although in falling from a given height it acquires velocity, its gravitating force remains the same, and all the effect which this might have produced, has been expended upon itself, and not in moving any other body. The force with which water strikes, after it has fallen from any height, is calculated to deceive those who are not well grounded in the principles of hydrostatics; but it is admitted, both by Mr. Evans and Mr. Ellicott, that the effect upon overshot wheels is diminished, by increasing the head, and the reason given for leaving the head so great as they prescribe, is the necessity of filling the buckets with sufficient rapidity; this necessity, however, is created by giving too much velocity to the wheel.

It has been stated by Mr. Evans, and is generally believed by mill-wrights, that it is necessary to give a much greater velocity to wheels, than that which is recommended by Smeaton and others, in order to cause the mill to run steadily, and prevent its being suddenly checked by any increased resistance. This is saying that the water-wheel ought to be made to operate as a fly-wheel, which it will not do if its motion be slow. The objection to this is twofold. By giving to the skirt of the wheel a motion much exceeding 4 or 5 feet per second, its power is considerably reduced below the maximum, and this loss of power is perpetual; wasting a considerable portion of water, to convert the water-wheel into a fly-wheel, which water might be employed in giving greater power to the mill. When a mill, from the nature of the work which it has to perform, requires the action of a fly-wheel, the situation of the water-wheel is often the worst that could be devised for this purpose, especially where there is any considerable gearing in the mill. A fly-wheel does not add actual power, but it serves to collect power, where the resistance is unequal; and in order to its producing this effect most perfectly, it ought to be placed as near as possible to the working part of the machinery. In grist mills there is no necessity for a fly-wheel; the stones perform this office in the most effectual manner, and the same remark is applicable to every kind of mill without a crank, and in which the resistance is equal, or nearly so, during the whole time of its action.

Although we have spoken highly of the general views given by Mr. Parkin, in his communication to the Franklin Journal, he has fallen into some mistakes, which were pointed out by a writer in the same publication, Vol. IV., page 166. A part of this communication is subjoined, as it contains remarks, and a tabular view of the velocities attained, and the distances fallen through, by bodies, in fractional parts of a second, which may be of great practical utility:—

"I suppose that, at the present day, no man who professes to be capable of directing the construction of a water-wheel, or of estimating the amount of a water power, is ignorant of the fact, that water falls through a distance of about sixteen feet in the first second. But I suspect that many who assume the above qualifications, do not know the ratio of increase, either in the distance, or the velocity. I have drawn this conclusion, not only from conversations with several practical engineers, but, also, from essays published in our scientific journals. As an instance of the latter, I will select, for its convenience of reference, an article on water-wheels, published in this Journal, (Vol. I. p. 103,) which, being the production of a practical engineer, and having passed the inspection of a scientific committee, may be considered as corroborating my commencing observations. In the third paragraph of that article, is the following sentence: 'As a falling body, water descends at the *speed* of nearly 16 feet in the first second, and it will appear evident, that if a water-wheel is required to be so driven, that the water with which it is loaded has to descend 10, 11, or 12 feet per second, at which rates wheels are generally constructed to work, that a *very large proportion* of the power is lost.'

"Here, in the first place, we find *speed*, or *velocity*, confounded with the *distance* fallen in the first second; whereas, the latter is 16 feet, and the former is accelerated, from nothing, at the commencement, to 32 feet per second, at the end of the first second; so that this part of the sentence conveys, strictly, no intelligible meaning; it is, nevertheless, made a standard, by a comparison between which, and any given velocity of a water-wheel, we are to infer the loss of power sustained through excess of speed; thus, in the case of a wheel whose velocity is 10 or 12 feet per second, comparing these numbers with the mysterised number 16, the writer concludes, 'that a very large proportion of the power is lost.' The height of the fall which indicates the whole amount of the power, is not mentioned, but surely, to estimate the *proportion* between a defined part, and an undefined whole, is impossible.

* * * * * * *

"I have made a calculation of the distances, and velocities, attained by falling bodies, in various fractional parts of a second, which is here introduced for the information of those practical and theoretical engineers, who have avoided the labour of doing it for themselves.

"I have proceeded on the following established data; namely:—

"Heavy bodies fall through a distance of 16 feet, in the first second; at the end of which, they have acquired a velocity of 32 feet per second.—The velocity increases as the times.—The distance increases as the square of the times.

Time of Descent.	Distance fallen. feet.	inches.	Velocity attained per second. feet.	inches.
1 - -	0	$0\frac{1}{90}$	0	3
2 - -	0	$0\frac{1}{21}$	0	6
3 - -	0	$0\frac{2}{16}$	0	9
4 128ths of a sec.	0	$0\frac{3}{16}$	1	
5 - -	0	$0\frac{2}{7}$	1	3
6 - -	0	$0\frac{2}{5}$	1	6
7 - -	0	$0\frac{3}{5}$	1	9
2 - -	0	$0\frac{3}{4}$	2	
3 - -	0	$1\frac{2}{3}$	3	
4 32nds of a sec.	0	3	4	
5 - -	0	$4\frac{2}{3}$	5	
6 - -	0	$6\frac{3}{4}$	6	
7 - -	0	$9\frac{1}{4}$	7	
1-4th of a sec.	1	0	8	
9 - -	1	$3\frac{1}{6}$	9	
10 - -	1	$6\frac{3}{4}$	10	
11 - -	1	$10\frac{2}{3}$	11	
12 32nds of a sec.	2	3	12	
13 - -	2	$7\frac{2}{3}$	13	
14 - -	3	$0\frac{3}{4}$	14	
15 - -	3	$6\frac{2}{11}$	15	
1 half of a sec.	4	0	16	
17 - -	4	$6\frac{1}{5}$	17	
18 - -	5	$0\frac{2}{3}$	18	
19 - -	5	$7\frac{2}{3}$	19	
20 32nds of a sec.	6	3	20	
21 - -	6	$10\frac{2}{3}$	21	
22 - -	7	$6\frac{3}{4}$	22	
23 - -	8	$3\frac{1}{5}$	23	
3-4ths of a sec.	9	0	24	
25 - -	9	$9\frac{1}{5}$	25	
26 - -	10	$6\frac{3}{4}$	26	
27 - -	11	$4\frac{2}{3}$	27	
28 32nds of a sec.	12	3	28	
29 - -	13	$1\frac{2}{3}$	29	
30 - -	14	$0\frac{3}{4}$	30	
31 - -	15	$0\frac{1}{5}$	31	
1 - -	16		32	
2 seconds.	64		64	
15 seconds.	3600		480	
30 - -	14400		960	
1 minute.	57600		1920	

"To determine what *proportion* of a given water power is lost by a given velocity of the wheel, it is only necessary to ascertain what distance the water must descend to acquire that velocity. Then, this distance compared with the whole fall, answers the question. Thus: suppose the whole fall to be 10 feet, and the velocity of the wheel 4 feet per second; this velocity is due to a fall of 3 inches, or one-fortieth part of the whole fall, which is the proportion sought. Or, suppose the velocity to be 13 feet per second, which is due to a fall of 2 feet 7⅜ inches, then the loss is rather more than one-fourth of the whole fall of 10 feet. But, it must be especially noted, that these estimates embrace the supposition, that the water issues upon the wheel in the direction of the motion of its skirt, and precisely at that distance below the surface of the dam, which answers to the velocity of the wheel. Inattention to this particular, is a very important and frequent cause of loss. L. M."

With respect to the actual advantage of giving to overshot wheels a motion much less rapid than that usually given, the following example will probably have more effect on the mind of the mere practical workman, than any reasoning that could be offered; and, in fact, reasoning would be of little value, were it not supported by practical results.

The subjoined account is from the Technical Repository, a work published in Londont—

"*On the comparative Advantages of different Water-Wheels, erected in the United States of America, by* JACOB PERKINS, *Esq.; and in this Country, by Mr.* GEORGE MANWARING, *Engineer.*

"Mr. PERKINS erected, at Newburyport, a water-wheel of 30 feet in diameter, on the plan of what is termed in America, a *pitch-back;* but, in this country, a *back-shut;* that is, one which receives the water near to its top, but not upon it, as in *overshot-wheels;* this is, indeed, the most judicious mode of laying water upon the wheel; as, in case of floods, the wheel moves in the same direction with the water, and uot in the opposite one;t neither is it encumbered, as in the *overshot* wheel, with a useless load of water at its top, where it does nothing but add to the weight upon the necks or pivots of the wheel-shaft, and to the consequent loss of power by the increased friction upon them; whereas, in the *pitch-back*, or *back-shut wheel*, the water is laid on at a point, where it acts by its leverage in impelling the wheel, and has yet time to become settled in the buckets, previously to its reaching the point level with the axis, where it acts with its greatest power. The wheel itself was constructed of oak, but with iron buckets; and it had a ring of teeth around it, which drove a cast-iron pinion, of three feet in diameter, which gave motion to three lying shafts, each of thirty feet in length, coupled together, so as to form a line of ninety feet; and from which, the necessary movements were communicated to the machinery for making nails.

"Mr. Perkins placed his pinion as close as possible under the pentrough, which delivered the water upon the wheel; and he thus greatly lessened the weight upon the necks or gudgeons of the wheel-shaft, by suspending it, as it were, upon the pinion; whereas, had he, as is usual, placed it on a horizontal line with the axis of the wheel, and on the opposite side of it, he would have loaded the necks with a double weight; namely, the water upon one side of the wheel, and the resistance opposed by the machinery to be driven by it, on the other. He also took care that the teeth upon the wheel, and the pinion, should always *be kept wet, or run in water*, instead of being *greased*, as is usual, and this he found sufficient to cause them to run smoothly and without the least noise. The motion of the wheel's periphery was about three feet per second, agreeably to the improved theory, so ably demonstrated by the late scientific Mr. Smeaton; and it continued to perform its work, with great satisfaction to its owners, for ten years, when it was unfortunately destroyed by fire.

"An opportunity soon presented itself of comparing the advantages of this water-wheel with another, which the proprietors were induced to erect, on the representations of a mill-wright, that the wheel was too high, and that it would be much better, were it only twenty-three feet in diameter, and received its water at the breast.

The trial, however, proved, that in driving the nail machinery, which had escaped the fire that destroyed the water-wheel, *the new wheel required twice the quantity of water to work it which actuated the former one, and only did the same work.*

"Mr. Manwaring has also had an opportunity of verifying, in this country, the advantages of a construction similar to Mr. Perkins's, in a cast-iron *back-shut* water-wheel of the same diameter as his, (namely, thirty feet,) and which also has a ring of teeth around it, driving a pinion of three feet in diameter, posited on the same side of the wheel as Mr. Perkins's, but not quite so high, it being a little above the centre of the wheel, and the teeth of the wheel and pinion are always kept wet. This wheel is employed in grinding flour, at a corn-mill in Sussex, and drives six pair of stones, besides the other necessary machinery, it moving at the rate of about three feet per second; and so great satisfaction has it given, that Mr. Manwaring is now constructing another water-wheel upon the same plan, and for the same proprietor; only, that it will be wider, and is calculated to drive eight pairs of stones.

"We are glad to have this opportunity of communicating these valuable practical facts: the same results being also obtained in two countries so widely separated as the United States and England, make them more valuable; and prove, that when persons think rightly, they will naturally think alike."

The foregoing example, although it relates to a *pitch-back* wheel, may serve our purpose as well as if it had been an overshot; there being an evident similarity between an overshot, with the water delivered on the top, with but little head, and the *pitch-back*, as constructed by Mr. Perkins; and also, between an overshot with considerable head, and the breast wheel.

The remarks made upon pitch-back wheels, are worthy the serious attention of the mill-wright. Mr. Evans very correctly compares them, in their action, to overshots: Mr. Ellicott thinks "an overshot with equal head and fall, is fully equal in power," and has dismissed them in a very few words. The reason of this is evident; the *head*, which they thought to be necessary, was not so easily managed with the pitch-back, as with the overshot; but when it is admitted, that the water should be delivered at the surface of the dam, that the velocity of the wheel should not exceed 4 or 5 feet per second, and that its capacity for containing water should be increased, the difficulty vanishes altogether. The water, when emptied from the buckets, has its impulse in the right direction to carry it down the tail-race; and in case of back water, the greater facility with which it will move is undeniable.

With respect to undershot wheels, Mr. Evans concludes that they ought to move with a velocity nearly equal to two-thirds of that of the water, and Mr. Ellicott estimates the velocity at quite two-thirds. It would be saying but little to assert that this did not agree with theory; but it does not accord with the opinions of many intelligent and experienced mill-wrights. It was asserted, upon theory, that the power of an undershot wheel would be at a maximum, when the velocity of the floats of the wheel was equal to one-third of the velocity of the water; practice, however, did not confirm the truth of this theory; and Borda has shown that the conclusion was theoretically incorrect, applying only to the supposition that the water impelled a single float-board; but that in the action upon a number of float-boards, as in a mill-wheel, the velocity of the wheel will be *one-half* the velocity of the water, when the effect is a maximum. The demonstration of this may be seen under the article Hydrodynamics, in the Edinburgh Encyclopædia. This was fully confirmed by the experiments of Smeaton, who, in speaking upon them, observes, that "in all the cases in which most work is performed in proportion to the water expended, and which approach the nearest to the circumstances of great works, when properly executed, the maximum lies much nearer to one-half, than *one-third*, one-half seeming to be the true maximum."

The succeeding observations are extracted from "Practical Essays on Mill-work and other Machinery, by Robertson Buchanan." Cast iron is very generally employed in England, not only for the wheel-work of mills, but, also, for many parts of the framing; the same practice obtains in those parts of our own country, where castings can be procured with facility, and will gain ground as its real value becomes known. Of course, the following extracts apply, in many instances, to the use of this material; but it will be found that the principles upon which they are founded, will, in general, apply to wood, as well as to iron.

"A Practical Inquiry respecting the Strength and Durability of the Teeth of Wheels used in Mill-work.

"Having treated of the forms of the teeth of wheels, I come now to consider their proportional strength, with relation to the resistance they have to overcome.

"I am aware, that owing to a great variety of circumstances, this subject is involved in much difficulty, and that it is no easy task to form any general rule with regard to the pitches and breadths of the teeth of wheels. I do not pretend to more than a mere approximation towards general rules; yet, were this judiciously done, I am of opinion that it might be useful to the mill-wright, who has not had leisure or opportunity for scientific inquiries. A rule, though not absolutely perfect, is better in all cases than to have no guide whatever.

"And it is too evident to require proof, that it is essential to the beauty and utility of any machine, that the strength and bulk of its several parts be duly proportioned to the stress, or wear, to which the parts may be subject.

"Some general observations on the wheel work of mills, will serve greatly to simplify our inquiries on the subject."

"*General Observations on the Wheel-Work of Mills.e*

"Mistaken attempts at economy have often prompted the use of wheels of too small diameter. This is an evil which ought carefully to be avoided. Knowing the pressure on the teeth, we cannot, with propriety, reduce the diameter of the wheel below a certain measure.

"Suppose, for instance, a water-wheel of 20 horses'h power, moving at the pitch line with a velocity of $3\frac{1}{2}$ feet per second. It is known, that a pinion of 4 feet diameter might work into it, without impropriety; but we also know that it would be exceedingly improper to substitute a pinion of only one foot diameter, although the pressure and velocity at the pitch lines, in both cases, would be, in a certain sense, the same. In the case of the small pinion, however, a much greater stress would be thrown on the *journeys* (or *journals*) of the shaft. Not, indeed, on account of torsion or twist, but on account of transverse strain, arising as well from greater direct pressure, as from the tendency which the oblique action of the teeth, particularly when somewhat worn, would have to produce great friction, and to force the pinion from the wheel, and make it bear harder on the journals. The small pinion is also evidently liable to wear much faster, on account of the more frequent recurrence of the friction of each particular tooth.

"That these observations are not without foundation, is known to mill-wrights of experience. They have found a great saving of power, by altering corn mills, for example, from the old plan of using only one wheel and pinion, (or *trundle*,) to the method of bringing up the motion, by means of more wheels and pinions, and of larger diameters and finer pitches.

"The increase of power has often, by these means, been nearly doubled, while the tear and wear has been much lessened; although it is evident, the machinery, thus altered, was more complex.

"The due consideration of the proper communication of the original power, is of great importance for the construction of mills, on the best principles. It may easily be seen that, in many cases, a very great portion of the original power is expended, before any force is actually applied to the work intended to be performed.

"Notwithstanding the modern improvements in this department, there is still much to be done. In the usual modes of constructing mills, due attention is seldom given to scientific principles. It is certain, however, that were these principles better attended to, much power, that is unnecessarily expended, would be saved. In general, this might be, in a great measure, obtained, by bringing on the desired motions in a gradual manner, beginning with the first very slow, and gradually bringing up the desired motions, by wheels and pinions of larger diameters. This is a subject which should be well considered, before we can determine, in any particular case, what ought to be the pitch of the wheels. In the case above alluded to, where the supposition is a pinion of 4 feet diameter, or of 1 foot diameter, it is obvious, that the same pitch for both would not be prudent: that for the small pinion, ought to be much less than that which might be allowed in the case of the larger pinion. It is also equally obvious, that the breadth of the teeth, in the case of the small pinion, ought to be much greater than that in the case of the larger pinion.

"It is evident, however, that although great advantage may often be derived from a fine pitch, that there is a limit in this respect, as also with regard to the breadth. We shall endeavour to find some trace of this limit in what follows; and that we may the better do this, we shall call in the aid of propositions, which are true with respect to pieces of timber, or metal, subjected to ordinary causes of pressure. It is allowed, that they cannot here, in strictness, be *demonstrated*, as applicable to wheel-work. Yet they will, for want of better light, serve at least to prevent any material practical error, with regard to the strength of the teeth of the wheels. For it is to be remembered, that we are not so much here in search of truths of curious or profound mathematical speculation, as of that kind of evidence of which the subject admits, and which may be sufficiently satisfactory for any practical purpose.

"As cast-iron pinions are now generally used, and as the teeth of the pinion are most subject to wear, I think we are safe in the present inquiry, in considering them all as cast-iron.

"The laws to which I have alluded in this investigation, are these:—

"'*Principles of proportioning the Strength of Teeth of Wheels.*

"'PROPOSITION I.

"'*The Strength of any Piece of Timber or Metal, whose Section is a Rectangle, is in direct Proportion to the Breadth, and as the Square of the Depth.*'*

"Hence may be inferred, that the strength of the teeth of wheels, moving at the same velocity, and under the same circumstances, is directly in proportion to their breadth, and as the square of their thickness. Thus, for example, if we double the breadth, we only double the strength; but if we double the thickness, or, in other words, double the pitch, keeping the original breadth, we increase the strength four times.

"For although when wheels are working accurately, the strain is, at the same time, divided over several teeth; yet as a very small inaccuracy, or even the interposition of any small body, such as a chip of wood, or stone, throws the whole stress upon a single tooth, in practice; therefore, and in order to simplify this case, we may consider the strength of a single tooth, as resisting the pressure of the whole work.

"But as the length of the teeth commonly varies with the pitch, this circumstance must be taken into account, and the most simple view we can take of it seems to be that of having the strain of each tooth, thrown all to the outward extremity: we have then the following proposition to guide this part of our inquiry:—

"'PROPOSITION II.

"'*If any Force be applied laterally to a Lever or*

* See Emerson, Prop. 67.

*Beam, the Stress upon any Plate is directly as the Force and its Distance from that Plate.'**

"'PROPOSITION III.

"'*The Pitch being the same, the Stress is inversely as the Velocity.'*†

"For example—if the pitch lines of one pair of wheels be moving at the rate of 6 feet in a second, and another pair of wheels, in every other respect under the same circumstances, be moving at the rate of 3 feet in a second, the stress on the latter, is double of that on the former."

"*Of arranging the Numbers of Wheel-Work.*

"In a machine, the velocity of the impelled point should be to that of the working point, in the ratio which is adapted to the maximum effect of the moving power on the one part, and the best working effect on the other part. Any other arrangement of the relative motions of the parts of a machine must clearly be attended with a loss of power, or the work will not be done properly. But when the best working velocity is known, and, also, that which enables the first mover to produce the greatest effect, the proper arrangement of the numbers of the teeth of the wheels and pinions, is a very simple operation.

"It will be an advantage to advertise the young mechanic of one or two essential particulars, before proceeding to the principal object.

"In the first place, when the wheels drive the pinions, the number of teeth in any one pinion should not be less than 8; but rather let there be 11 or 12 if it can be done conveniently. And in the particular form of teeth previously described, the number of teeth in a pinion should not be less than 10; but it would be better to have 13 or 14.

"Secondly—When the pinions drive the wheels, the number of teeth on a pinion may be less; but it will not,

* See Emerson, Prop. 69.

† See Emerson, Prop. 119, Rule 8.

in any case, be desirable to have fewer than 6 teeth on a pinion; and give the preference to 8 or 9, where it can be done with convenience.

"Thirdly—The number of teeth in a wheel should be prime to the number of teeth in its pinion; that is, the number representing the teeth in the wheel should not be divisible by the number of teeth in the pinion without a remainder. And as the numbers of pinions will, in general, be first settled, it will be an advantage to take a prime number for each pinion, as 7, 11, 13, 17, 19, 23, &c., because such numbers are more seldom factors than others. But when it happens that a prime number can be directly fixed upon for the wheel, any whole number which approaches near to the required ratio will answer for the pinion; as minute accuracy is not required. A prime number for the wheel, or one which is not divisible by the number of the pinion, is esteemed the best, because the same teeth will not always come together, and the wear will be more uniform.

"Fourthly—If it be desired that a given increase or decrease of velocity should be communicated with the least quantity of wheel work, it has been shown that the number of teeth on each pinion should be to the number on its wheel, as 1 : 3,59 (Dr. Young's Nat. Phil. Vol. II. Art. 366.) But, on account of the space required for several wheels, and the expense of them, it will often be necessary to have 5 or 6 times the number of teeth on the wheel, that there is on the pinion. The ratio of 1 : 6 should, however, not be exceeded, unless there be some other important reason for a higher ratio."

"Practical Observations with regard to the making of Patterns of Cast-Iron Wheels.

"Having determined the pitch of the wheel strong enough for the purpose to which it is to be applied, the thickness of the tooth serves to regulate the proportionate strength of the other parts.

"A very respectable mill-wright informs me, that he has for a considerable time adopted the following rule for determining the length of the teeth of wheels, the practical efficacy of which he has found quite satisfactory†:—

"Rule—*Make the length of the teeth equal to the pitch, deducting freedom,* (by the freedom is meant the distance at the top of one tooth and the root of another, measured at the line of centres,) in other words, the distance from root to root of the teeth, at the line of teeth, when the wheels are in action, exactly equal to the pitch.

"For example—he makes the teeth of two inches pitch, one inch and thirteen-sixteenths in length, which is allowing three-sixteenths of freedom.

"Another respectable mill-wright, who has had much experience, particularly in mills moved by horses, has, for a considerable time past, made the teeth of his wheels only one-half of the pitch in length, and works them as deep as possible, without the point touching the bottoms. Before he fell on this expedient, he found the teeth exceedingly liable to be broken from any sudden motion of the horses.

"Indeed, upon reflection, it will be found that there is no occasion for more freedom, than that the point of the tooth of the one wheel, shall just clear the ring of the other; more than this must only serve to weaken the teeth. The mode of gearing, however, above alluded to, is more necessary in horse mills than where the moving power is steady and regular.

"Hutton (on clock-work) recommends making the distance of the pitch line three-fourths of what we call the thickness of the tooth. Thus, suppose the rule applied to a two inch pitch, and that the tooth and space were exactly equal, then the tooth would project three-fourths of an inch beyond the pitch line, and its root would be as far within the pitch line, as to receive freely the tooth intended to act on it: suppose it also three-fourths, then the tooth would be one and a half inch long, besides the freedom, which making, as above, three-sixteenths, the tooth would be in all one and eleven-sixteenths inch long.

"But it is to be remarked, that the mill-wrightt, in making his pattern for a cast-iron wheel, has to attend to a circumstance arising from the nature of that material. The pattern must not only be of such a form as to be sufficiently strong, calculating by the bulk of the parts, but also proportioned, so that when the fluid metal is poured in the mould, it may cool in every part nearly at the same time.

"When due attention is not paid to this circumstance, as the metal is cooling, if it contract faster in one part than in another, it will be apt to break somewhere, just as a drinking glass is broken by suddenly cooling or heating in any particular part of it. In all patterns for cast-iron, about one-eighth of an inch to the foot should be allowed for the contraction of the metal in cooling.

"Attention must also be paid to taper the several parts, so that they may rise freely without injuring the mould, when the founder is drawing them out of the sand. A little observation of the operations of a common foundry, will better instruct in this part of the subject than many words. We may observe, however, that about one-sixteenth of an inch, in a depth of 6 inches, is commonly a sufficient taper.

"Attending to those circumstances, I beg leave to offer the following proportions as having been found to answer in practice.

"Make the thickness of the ring equal to the thickness of the tooth near its root. When the ring is made thinner than the root of the tooth, the ring commonly gives way to a strain, which would not break the tooth.

"Make the arm, at the part where it proceeds from the ring, of the same breadth and thickness as the ring, and, at the junction, let it be so formed as to take off any acute angle which would be apt to break off in the sand.

"The arms should become larger as they approach the centre of the wheel, (see Emerson, Prop. 119, Rule 8,) and the eye should be sufficiently strong to resist the driving of the wedges, by means of which it is to be fixed on the shaft. This cannot be brought easily to calculation.

"On the other hand, care must be taken not to make the eye so thick as to endanger unequal cooling.

"It should be somewhat broader than the breadth of the teeth, in order that it may be the firmer on the shaft: this breadth must be greater in proportion as the wheel is large.

"When the ring is about an inch thick, it is common to make the eye about an inch and a quarter in thickness, and about one-fifth broader than the ring, when the wheel is about four feet in diameter.

"Small wheels have generally but four arms, but it being improper to have a great space of the ring unsupported, the number of arms should be increased in large wheels.

"In order to strengthen the arms with little increase of metal, it is not unusual to make them feathered, which is done by adding a thin plate to the metal at right angles to the arm.h

"The same rules apply to bevelled wheels; of the practical mode of laying down the working drawings of which we have already spoken. But it is proper to observe that the eye of a bevelled wheel should be placed more on that side which is farthest from the centre of the ideal cone, of which the wheel forms a part.

"When wheels are beyond a certain size, it becomes necessary to have patterns sometimes made for them, cast in parts, which are afterwards united by means of bolts.

"A very good mode to prevent the bad effects of unequal contraction, is to have the arms curved; the curved parts are commonly of the same radius as the wheel, and spring from the half length of the arms."

"*Of Malleable or Wrought-Iron Gudgeons.*

"Professor Robinson states,* that the cohesive force of a square inch of cast-iron is from 40,000 to 60,000 lbs. wrought iron from 60,000 to 90,000 lbs.

"In the year 1795, I had occasion to substitute cast-

* Encyclopædia Britannica, article, Strength of Materials, 40.

iron gudgeons for those of wrought iron, and made some experiments on those metals, from which I drew the following inference: *that gudgeons of the same size, of cast and of wrought iron, in practice, are capable, at a medium, of sustaining weights without flexure, in the proportion of 9 to* 14.

"Taking it for granted that this proportion is near the truth, we may find the diameter which any wrought iron gudgeon ought to have when its lateral pressure is given, in the following manner:—

"1. Find the diameter which a cast-iron gudgeon should have to sustain the given pressure; then say, as 14 is to the cube of the diameter of the cast-iron gudgeon, so is 9 to the cube of the diameter of the wrought iron gudgeon.

"2. The root of this last number gives the diameter required of the wrought iron gudgeon.

EXAMPLE.

"Suppose the lateral pressure to be 125 hundred weights, the cube root of which is 5, the diameter in inches of the cast-iron gudgeon: then say,

As	14
Is to	125
So is	9
To	80,357

"The cube root of which is 4,30887."

"*Of the Bearings of Shafts.*

"The bearings on which gudgeons and journals rest and revolve, are sometimes termed *Pillows*, and frequently *Brasses*, from being often made of that substance.

"It has become general to fix pillows in blocks of cast-iron. Hence the term *Pillow Block*, and sometimes, corruptly, *Plumber Block*.

"At the cotton works of Deanston, near Down, a water-wheel has run nearly 30 years on pillows of cast-iron, with little sensible wear on the gudgeons, nor were they ever found liable to heat.

"The outer skin of cast-iron, particularly when cast in metallic moulds, is remarkably hard, and it is reasonable to suppose that it would make a durable pillow, as we have seen is the case in the above instance."

" *On the Framing of Mill-Work.*

" Mill-work, from its motion, occasions a tremor on all the parts of its framing, which subjects it to much more speedy decay than the mere pressure upon carpentry.

" Besides this general tremor, it is often subjected to violent, sudden thrusts, from the bad actions of the wheels, or from reciprocating motions.

" It ought, therefore, to be not only sufficiently *strong* and *stiff*, but sufficiently *heavy*, to give solidity and steadiness.

" Where the framing of the machinery is not firm and well bound, a vibratory motion in its parts, of course, takes place; which vibratory motion expends a considerable portion of the power applied. This loss of power is very difficult of investigation. It is certain, however, that whatever motion of a vibratory nature is communicated to the framing and objects in contact with it, (abstracted from the elasticity of the parts,) must be lost to the effect the machine would produce, were the parts sufficiently strong and well bound together; and it is to be observed, that firm and well-bound framing is much preferable to heavy framing, not so well connected in its parts. It is as certain, that though the framing in either case may be constructed so as to be equally strong, yet the heavy framing, from its vibration, will expend more of the original power than that which is less heavy, but firmly connected.

" Besides *strength*, *stiffness*, and *solidity*, the framing of mill-work requires to be constructed so as *to be easy of repair;* and so contrived, that *any particular part may be repaired or renewed* with the least possible derangement to the other parts of the framing.

"There is another circumstance in this species of framing which demands great attention. *The shafts often require to be restored to their true situations,* from which they may have deviated by the wearing of the parts. Now the framing ought to he so constructed as easily to admit of this *restoration of the shafts,* as also of any other shifting of them which may in practice become necessary.

"But though the framing which supports the parts of mills and machines should be firm, it is an advantage that the part on which any axis rests should have a small degree of elastic tremor, when the machine is in motion. Such tremor has considerable power in diminishing the friction. It may farther be observed, that framing to support machinery should be as independent of the building as possible, because the tremor it always communicates is exceedingly injurious."

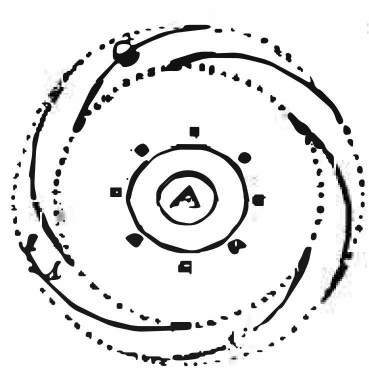
On Reaction Wheels.

These wheels were slightly noticed at page 176; and a description of Barker's mill is to be found in nearly every work upon hydraulics, together with the improvement made in it by Rumsey. Within a few years past, wheels which operate upon the principle of the rotary trunk, in Barker's mill, have been extensively brought into use. We are not informed by whom they were invented; Mr. Evans alludes to them in the first edition of this work, published in 1795; but it does not appear certain that he had then seen them; it is manifest, at all events, that they were not publicly known. His words are, "One of these is said to do well where there is much back water; it being small, and of a true circular form, the water does not resist it much. I shall say but little of these, supposing the proprietors mean to treat of them."

Their great merit, certainly, is their simplicity; and where there is a plentiful supply of water, they may, in many cases, be preferable to any other. Those interested in them aver that they are but little, if at all, inferior in economy to overshot mills; this, however, we are, by no means, prepared to admit. In back water they will undoubtedly operate better than any other, as there will not be any sensible loss from their wading, but only from the diminution of the effective head. In an eight feet fall, for example, should there be four feet of back water, the remaining four feet will produce nearly, or quite, its full effect.

Many patents have been obtained for modifications of, and variations in, this wheel; and from the specification of one of them, as published in the Journal of the Franklin Institute, at Philadelphia, we will give such extracts as will suffice to exhibit their nature and mode of action. In doing this, we shall omit the claims of the patentee, as this is a point with which we, in this place, have nothing to do.

Figure 1.



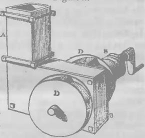
"Fig. 1, a bird's eye view of the wheel, the end to which the shaft is to be attached, at the perforation, A, being downwards, and the open end, or rim, upwards. To show the floats, the upper rim, which covers them, is not represented. The lines C C exhibit the form of the floats, or buckets, and the manner in which they are arranged. The diameter of this wheel, and the width of the floats between the two heads, and the depth of aperture between the floats, will, of course, be varied according to the quantity and head of water which can be obtained, and the purpose to which it is to be applied. The curved floats, it will be seen, are made to lap over each other; and, in practice, it has been found that the proportion in which they do so is a point of considerable importance. The proportion between the aperture and lap, which was found to be the best, is as three to two; that is, for every inch of aperture, measuring from float to float, at the point where the water escapes, the floats should pass each other one and a half inch. It will be manifest that a slight deviation from this proportion, in either way, will not be attended by any sensible loss of power. Any considerable deviation, however, is found to be injurious. The mechanic should be careful so to construct his wheel that the part of the aperture seen at *e* should be less than that seen at *d*.

"Upon the inner edge of the rim there is a projecting fillet, or flanch, which may be seen in the section D, of this wheel, at the lower part of Fig. 3, with this difference, that said fillets or flanches are to be made flat, as they are to work against, and not within, each other.

"Wheels so constructed may be applied either on a horizontal or vertical shaft, and either singly or in pairs, according to circumstances.

"Fig. 2 represents the double reacting wheel, placed on a horizontal shaft, in which manner they are to be used, whenever it is desirable to obtain motion from such a shaft. S is the horizontal shaft, A the penstock, and B the cistern; the heads, or sides of the cistern, are formed in whole, or in part, of cast-iron plates, securely bolted together. D D are two water-wheels, one of which is placed on each side of the cistern B, their open ends standing against the side plates of the cistern, which are perforated, having openings in them equal in size to those on the heads of the wheels, and being concentric with them. The fillet, or flanch, upon the rim of each wheel, is made flat, and is fitted to run as closely to a similar fillet or flanch on the cistern head as may be, without actually bearing against it, so as to prevent too much waste of water, and yet to avoid friction by touching it.

Figure 2.



"The size of the orifices in the wheel and cistern plates is a point of essential importance, and should greatly exceed what has been heretofore thought necessary. Their area should be such as to permit the whole column of water to act unobstructedly on the wheel, whatever may be the height of the head. It is found that for a head of four feet, the area of the orifice should never be permitted to fall short of three times the number of square inches which can be delivered by all the openings of the floats. The penstock, or gate way, should also be sufficiently large to admit freely the same proportionate quantity of water through every part of its section; say about three times the area of the orifices of the cistern heads and wheels.

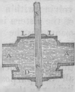
"For a greater head these openings must be proportionally increased, or the whole intention will be defeated, as it has been from want of attention to this principle, that numerous failures have occurred in the attempt to drive mills by reaction wheels. Whenever it is practicable, the limit which has been given should be exceeded, but never can be diminished without loss.

"Instead of using a trunk or penstock, smaller than the horizontal section of the cistern B, extend the sides front and back of said cistern, upwards in one continued line, whenever the same can be done; the cistern and penstock then form one trunk, of equal section throughout.

"When greater power is requisite, place other reacting wheels, or pairs of wheels, upon the same shaft, so that each may operate in the same way.

"Fig. 3 represents one of the reacting wheels, placed upon a vertical shaft, with the cistern by which it is supplied with water; to this is also attached what is denominated *the lighter*, which is intended to relieve the lower gudgeon and step from the pressure of the column of water, and also, when desired, the weight of the wheel, and whatever is attached thereto. The whole being shown in a vertical section through the axis of the wheel.

Figure 3.



"A A is the cistern of water, the construction of which, with its penstock, may be seen at B A, fig. 4.

"D the wheel, the flanch on its upper side passing within the edge of that on the lower plate of the cistern.

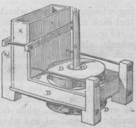
"L L the *lighter* for relieving the gudgeon and step of the shaft and wheel from the downward pressure.

"Thetlighter is a circular plate oftiron, concentric with the wheel, and attachedtto thetsame shaft. Upon its lower side is a flanch, or projecting rim, fitting into an orifice in the upper plate of thecistern, in the same manner in which that of the wheel fitstinto the lower plate; allowing, therefore, of a vertical motion of the shaft to a certainextent,twithout binding upon the plates of the cistern.

"Fromtthetequaltpressure of fluids in alltdirections, the lighter, (when equal in itstarea to that of thetorifice of thetwheel,) will be pressed upwards withtthetsametdegree of force with which the latter, (the wheel,) is pressed downwards; and if made larger, it will be pressed upwards with a greater force; and may betso proportioned as to take off the weight both of the machinery and of the water, from the gudgeon and its step.

"When a single wheel is placed upon a horizontal shaft, the lighter will take the place of thetsecond wheel, and so alsotin the case of any odd number of wheels, eitherton a verticaltorta horizontaltshaft.

Figure 4.



"Fig. 4 represents the double reacting wheel on a verticalshaft. A being thetpenstock—Btthet cistern—D D tthetwheels,revolving within the plates oftthetcistern in the same manner as the wheel and lighter in Fig. 3.

"The upper wheel in this arrangement answers all the purposes of the lighter in the former, the orifice of which may be enlarged, if desired, with the sametviews."

Thetforegoing is a description oftthe reaction wheel, as patented by Mr. Calvin Wing, and is given in the languagetof histspecification; it exhibits,therefore,*his* views upon the subject. The buckets are sometimes so made as not to lap, thetinner end of onetterminating in a line with the outer end oftanother. Sometpersons construcitthem so that the buckets are adjustable, thus allowing the apertures to be enlarged or diminished, according to the quantity of water employed, or of machinery to be driven. There are, in fact, not fewer, we believe, than eight or ten patents for different modifications of this wheel, and from the interest which it has excited, it may be considered as in a fair way to have its relative merits fully tested.

Explanation of the Technical Terms, &c., used in this Work.

Aperture—The opening by which water issues.

Area—Plain surface, superficial contents.

Algebraic signs used are $+$ for more, or addition. $-$ Less, subtracted. $\times$ Multiplication. $\div$ Division. $=$ Equality. $\surd$ The square root of; 86^2 for 86 squared; 88^3 for 88 cubed.

Biquadrate—A number squared, and the square multiplied into itself—the biquadrate of 2 is 16.

Corollary—Inference.

Cuboch—A name for the unit or integer of a power, being the effect produced by one cubic foot of water in one foot perpendicular descent.

Cubic foot of water—What a vessel one foot square and one foot deep will hold.

Cube of a number—The product of a number multiplied by itself twice.

Cube root of a number—Say of 8;—the number which multiplied into itself twice will produce 8; namely, 2. Or, it is that number by which if you divide a number twice, the quotient will be equal to itself.

Decimal point—Set at the left hand of a figure, shows the whole number to be divided into tens,eas ,5 for $\frac{5}{10}$ths; ,57 for $\frac{57}{100}$ths; ,557 for $\frac{557}{1000}$ths parts.

Equilibrio, Equilibrium—Equipoise or balance of weight.

Elastic—Springy.

Friction—The act of rubbing together.

Gravity—That tendency all matter has to fall downwards.

Hydrostatics—The science which treats of the weight of fluids.

Hydraulics—The science which treats of the motion of fluids, as in pumps, water-works, &c.

Impulse—Force communicated by a stroke, or other power.

Impetus—Violent effort of a body inclining to move.

Momentum—The force of a body in motion.

Maximum—Greatest possible.

Nonelastic—Without spring.

Octuple—Eight times told.

Paradox—Contrary to received opinion; an apparent contradiction.

Percussion—Striking together, impact.
Problem—A question proposed.
Quadruple—Four times, fourfold.
Radius—Half the diameter of a circle.
Right angle—A line square, or perpendicular to another.
Squared—Multiplied into itself; 2 squared is 4.
Theory—Speculative plan existing only in the mind.
Tangent—A line perpendicular to, or square with, a radius, and touching the periphery of a circle.
Theorem—Position laid down as an acknowledged truth. A rule.
Velocity—Swiftness of motion.
Virtual or effective descent of water—(See Article 61.

SCALE FROM WHICH THE FIGURES ARE DRAWN IN THE PLATES FROM II. TO XI.

PLATE II. Fig. 11, 12,8 feet to an inch; fig. 19, 10 feet to an inch.
III. Fig. 19, 20, 23, 26, 10 feet to an inch.
IV. Fig. 28, 29, 30, 31, 32, 33, 10 feet to an inch.
VI. Fig. 1, 10 feet to an inch; fig. 2, 3, 8, 9, 10, 11, 2 feet to an inch.
VII. Fig. 12, 13, 14, 15, 2 feet to an inch; fig. 16, 10 feet to an inch.
X. Fig. 1, 2, 18 feet to an inch; fig. H, I, in fig. 1, 4 feet to an inch.
XI. Fig. 1, 2, 3, 2 feet to an inch; fig. 6, 8, 1 foot to an inch.

THE END.

ERRATA.

PAGE 9—*line* 4th, from bottom, for "relate," read *retain*.
16—caption of Article 6, for "power," read *powers*.
48—*l*. 17th, for "this kind," read *first kind*.
49—*l*. 7th, for "part," read *where*.
72—at the end of problem read $V = \frac{V\sqrt{P}-1}{\sqrt{P}} = 16,2$ { The velocity of the wheel.
95—*l*. 15th, for "inches," read *arches*.
98—*l*. 10th, for "into," read *in*.
113—*l*. 8th, after "cubochs," insert *of power*.
193—*l*. 13th, for "not be," read *be not*.
203—*l*. 9th, from bottom, for "wagonner," read *wagoner*.
240—*l*. 12th, from bottom, for "wooden," read *wood*.
252—*l*. 11th, for "81," read 31.
277—first line of prefatory remarks, read *was* written.
290—*l*. 1 and 2, from bottom, *dele* *un-fore*.