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TREATISE ON MILLS AND MILLWORK

WILLIAM FAIRBAIRN

CHAPTER III.

ON THE CONSTRUCTION OF WATER WHEELS.

In the present age, the same importance is not attached to water power as before the introduction of steam, as has been already shown. Nevertheless, since water is still largely employed in some districts and for certain kinds of work, it is of importance that the machinery for rendering it useful should be constructed upon the best principle, so as to secure a maximum effect. In numerous localities in Europe and America, water is the principal motive agent by which manufacturing processes are carried on; and the time has not yet arrived when it can be dispensed with even in our own country. We shall therefore endeavour to point out the difference between the ordinary and improved forms of water wheels, and to lay down sound principles of construction, accompanied by examples for the guidance of the millwright.

CLASSIFICATION OF WATER MACHINES.

Water may be expended upon water machines, 1st. By gravitation, as in vertical wheels generally; 2nd. By pressure simply, as in the water pressure engine, where the water acts on a reciprocating piston; 3rd. By the impulse of effluent water striking float boards, as in the Poncelet wheel; 4th. By the reaction of effluent water issuing from an orifice, as in the Barker's mill and Whitelaw's turbine; or lastly, by momentum, as in the case of the water ram.

It is not, however, always possible in practice to classify water machines according to the mode in which water expends its force, and hence it will be more convenient to divide them according to the point at which the water is applied, and the direction in which it passes through the wheel, as in the following summary:

1st. *Vertical Water Wheels*, the plane of rotation being vertical and the water received and afterwards discharged at the same orifice on the external periphery. These may be subdivided into

a. Overshot wheels, where the water is applied over the crest, or near the upper extremity of the vertical diameter.

b. Breast wheels, where the water is applied below the crest at the side of the wheel.

c. Undershot wheels, where the water is applied near the bottom of the wheel, and acts, 1. By gravitation, as in the improved undershot wheel; or 2. By impulse, as in the ordinary undershot and Poncelet wheels.

2nd. *Horizontal Wheels*, the plane of rotation being horizontal and the water passing through the wheel from one side to the other. These may be subdivided into

a. Horizontal wheels strictly so called, in which the water passes vertically down through the wheel, acting as it passes on curved buckets.

b. Turbines, annular wheels in which the water enters the buckets at the internal periphery, and passing horizontally is discharged at the external periphery.

c. Vortex wheels, in which the water entering at the external periphery flows horizontally and is discharged at the internal periphery.

3rd. *Reciprocating Engines*, in which the water is applied upon a piston and regulated by valves on the same principle as the steam engine.

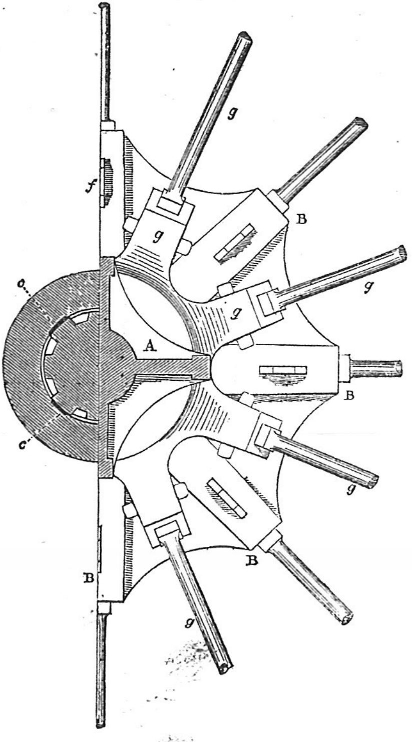
The Improvements of the Vertical Wheel.—In the present chapter it will be convenient to enter on the consideration of the construction of vertical wheels. Since the time of Smeaton's experiments in 1759, the principle on which vertical water wheels have been constructed has undergone no important change, although considerable improvements have been effected in the details. The substitution of iron for wood has afforded opportunities for extensive changes in their forms, particularly in the shape and arrangement of the buckets, and has given lighter and more permanent character to the machine than had previously been attained. A curvilinear form for the buckets has been adopted, the sheet iron of which they composed affording great facility for being moulded into required shape. It is not the object of the present treatise enter into the dates of past improvements, but it will suffice observe that the breast wheel has taken precedence of the overshot wheel, probably from the increased facilities which a wheel of this description affords for the reception of the water under a varying head. It is in most cases more convenient to apply the water of high falls on the breast at an elevation of about 30° from the vertical diameter, as the support of the pentrough is much less expensive and difficult than when it has to be carried over the top of the wheel. In cases of a variable head, when it is desirable to work down the supply of water, it cannot be accomplished without a sacrifice of power on an overshot wheel; but when applied at the breast, the water in all states of the river is received upon the wheel at the highest level of its head at the time, and no waste is incurred. On most rivers this is important, as it gives the manufacturer the privilege of drawing down the reservoir three or four feet before stopping time in the evening, in order to fill again during the night; or to keep the mill at work in dry seasons until the regular supply reaches it from the mills higher up the river. This becomes an essential arrangement where a number of mills are located upon the same stream, and hence the value of small regulating reservoirs behind the mill as a resource for a temporary supply.

Another advantage of the increased diameter of the breast wheel is the ease with which it overcomes the obstruction of back water. The breast wheel is not only less injured by floods, but the retarding force is overcome with greater ease, and the wheel works in a greater depth of back water.

Component parts of Water Wheels.—Vertical water wheels consist essentially of a main axis resting on masonry foundations, and together with arms and braces forming the means of support for the machine. Chambers for the reception of the water constructed of shrouding, sole plate, and buckets. A pentrough with sluice for laying on the water, and a tail-race for conveying it away; and an internal or external geared spur wheel and pinion for transmitting the power. These parts we shall treat of successively, before describing the modifications of the vertical wheel.

The main axis is a large and heavy cast-iron shaft carried upon plummer blocks bolted to the masonry foundations of the wheel house. It sustains the weight of all the moving parts of the wheel, and in some cases the power is taken from it, when it is subjected to a force of torsion. It is usually cast with deep ribs or wings, calculated to resist the tensile and compressive strain to which they are alternately subjected as the wheel revolves. A section and elevation of the main axis of a water wheel, 20 feet in diameter and 22 feet wide, are shown in figs. 100 and 101.* A A is one half the main axis with its four deep ribs. The part *e* is the journal on which the wheel revolves, and *d* is left square for the convenience of fixing a screw-jack should the wheel require raising. B B B are the recesses for the radical arms of $2\frac{1}{2}$-inch round iron fixed by the keys *f f*; *g g* the corresponding recesses for the braces which pass diagonally across the wheel and alternate with the arms; *c c* are the key beds on the main axis for fixing the main centre. It is difficult to estimate the strain on this shaft when the wheel is on the suspension principle, although the work it has to perform is trifling compared with what it would have to sustain in the event of the power being taken from the axle. In the latter case the wheel has to sustain not only the weight of the wheel and the water in the buckets, but also the force of torsion, as the power is transmitted from the periphery through the arms and axle to the main gearing of the mill.

Fig. 100.



The following table exhibits the dimensions of the journals which for high and low breast wheels, where the depth of the buckets is nearly the same, I have found effective, and is

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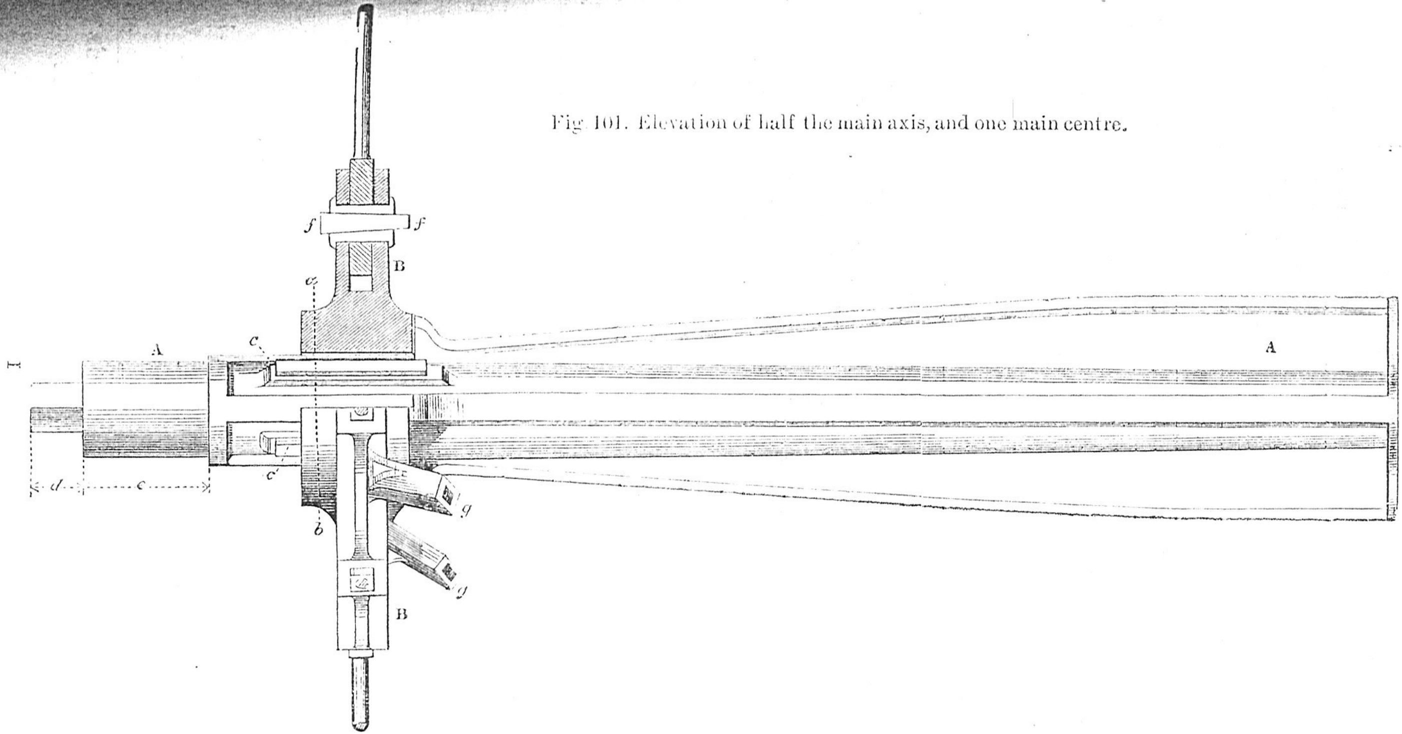
* The wheel is shown in Plate IV. Fig. 110 is also an enlarged detail drawing of this wheel.

Fig. 101. Elevation of half the main axis, and one main centre.



summary of my own practice in this respect for the last forty years:

TABLE OF DIAMETERS OF THE MAIN AXIS JOURNALS OF WATER WHEELS.

Diameter of Wheels in feet	Diameter of Journal for a Wheel				
	5 ft. broad	10 ft. broad	15 ft. broad	20 ft. broad	
	inches	*inches*	*inches*	*inches*	
15	6	7	8½	10	The lengths of the bearings are usually equal to one and a half diameters of the journal.
18	6½	7½	9	11	
20	7	8	10	12	
25	7½	8½	11	12½	
30	8	9	11½	13	
40	8¾	10	12½	14½	
50	9½	11	14	16	

Tredgold's rule for the diameter of water-wheel journals is that

$$d = \frac{1}{9} (l\ \mathrm{w})^{\frac{1}{3}} \ldots (1)$$

where d = diameter of gudgeon in inches, l = its length in inches, and w = the maximum load placed on it in lbs.; or, supposing the power to be taken off at the loaded side and the pinion to carry the weight of water, w = half the weight of the wheel.

Example.—A wheel 18 feet in diameter and 20 feet broad weighs 34 tons; required the diameter of the gudgeon of the main axis, taking its length at 10 inches.

$$\text{Here, } d = \frac{1}{9} \left(10 \times \frac{34}{2} \times 2240\right)^{\frac{1}{3}} = 8 \text{ in.}$$

Another rule which has been proposed is

$$d = \frac{1}{25} \sqrt{\mathrm{w}} \ldots (2).$$

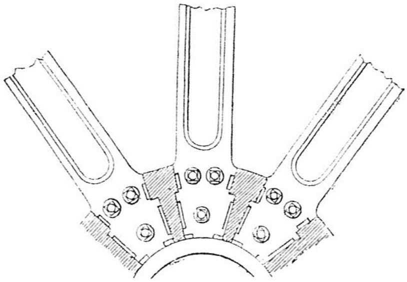
Example.—Taking the same wheel as before—

$$d = \frac{1}{25} \sqrt{\frac{34 \times 2240}{2}} = 7{\cdot}8 \text{ in.}$$

where the length is nearly equal to the diameter; but both these give a somewhat smaller journal than in the table above.

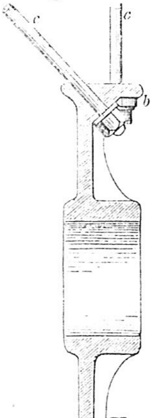
There exists a wide difference of principle amongst millwrights as to the mode of attaching the wheel to the axis may either be rigidly fixed by cast-iron arms which resist weight, as a series of columns alternately exposed to a tensile and compressive strain, or it may be supported by tension rods on the principle now most generally practised in the construction of improved iron water wheels. In the former case the arms are of cast-iron fixed in recesses in a cast-iron main centre, to which they are accurately fitted on chipping strips, and then bolted, as shown in fig. 102. Flat wrought-iron arms are sometimes riveted to the main centre in a somewhat similar manner.

Fig. 102.



It was reserved for Mr. T. C. Hewes, of Manchester, to introduce an entirely new system in the construction of water wheels, in which the wheels, attached to the axis by light wrought-iron rods, are supported simply by suspension. I am informed that a wheel on this principle in Ireland was actually constructed with chains, with which, however, from the pliancy of the links, there was some difficulty. But the principle on which this wheel was constructed was as sound in theory as economical in practice, and is due originally, it is said, to the suggestion of Mr. William Strutt, and was carried out fifty years ago by Mr. Hewes, whilst at the same time Mr. Henry Strutt applied the principle to cart wheels, some of which, thus put together, were for a long time in use. Mr. Hewes employed round bars of malleable iron in place of the chains, and this arrangement has kept its ground to the present time, as the most effective and perfect that has yet been introduced.

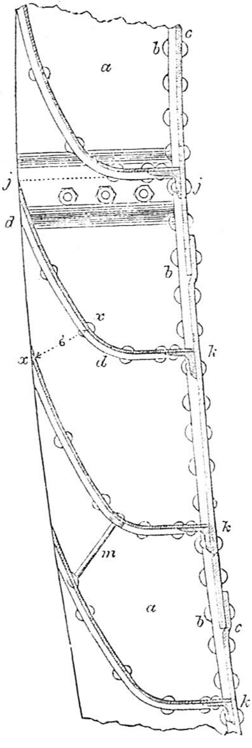
Fig. 103.



In the earlier construction of suspension wheels the arms and braces were attached to the centre by screws and nuts, as shown in fig. 103. The arms *c c* passed through the rim *b b*, and the braces *e e*, are set diagonally in the angle of the rim. This arrangement, although convenient for tightening up the arms and braces, was liable to many objections; the nuts were subject to become loose from the vibration in working, so as to endanger the wheel, and to create a difficulty in keeping it truly circular in form. To obviate this, in 1824, I substituted gibs and cotters, on the same principle as those which secure the piston rod of a steam engine, as shown in figs. 100 and 101: the ends of the arms are forged square, and are fixed in sockets in the cast-iron centre, and are there retained by the gibs and cotters *f f* in perfect security from the danger of becoming loose.

The shrouds a a consist of cast-iron plates cast in segments with curved flanches to receive the bucket plates, which are attached to them by bolts or rivets (*d d*, fig. 104), and round the inner periphery a projecting flanch (*b*, figs. 104 and 105) is formed for the reception of the sole plates (*c*). Fig. 104 is a side elevation, and fig. 105 a section of a large shrouding of this description 15 inches deep; *a a* the cast-iron segmental plate of the shroud; *b* the flanch to which the sole plate *c c* is riveted; *d d* the curved flanches and bucket plates; [illegible] the bucket. The segments of the shroud are bolted together by overlap joints, *j j*, shown also in section in fig. 106. The overlap is placed on the bucket side of the shroud to preserve a smooth face on the outside of the wheel. The arms are attached to the shrouds either by riveting or, according to my own practice, by dovetailing into recesses cast upon the inner face of the shroud. Fig. 107* represents this arrangement in section, and fig. 108 in plan. The ends of the arms *c c* are forged into a ⊤ form, and are fitted into a similar shaped recess on the shroud. To retain the arms in position, it is only requisite to give to the recess and ⊤-head a dovetail, as shown at *d*.

Fig. 104.



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* Figs. 104 to 109 are enlarged details of the Catrine Wheels, [illegible] and II.

boss on the shroud must be tapered gradually down, to avoid injury in casting from unequal contraction in cooling. The

Fig. 105.

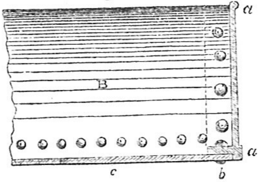
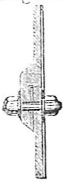


Fig. 106.



arms are usually 2 to 2½ inches in diameter for almost all wheels, and the braces 1¾ to 2 inches.

Fig. 107.

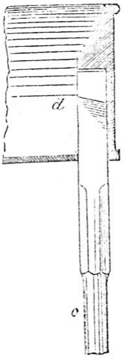
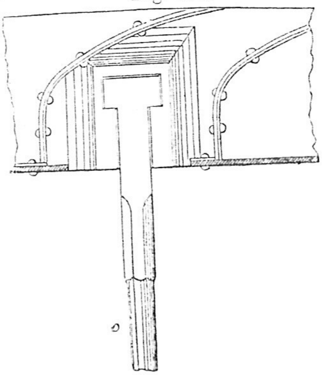


Fig. 108.



To strengthen the wheel laterally, diagonal arms, called braces, are used (*g g*, *g g*, figs. 100 and 101), and where the wheel is not of great width these braces pass from the main centre on one side to the shroud on the opposite side of the wheel, alternating with the radial arms and fixed in the same manner (fig. 109). Where the wheel is broad I prefer to attach the braces to a middle ring of cast-iron, riveted to the interior of the sole plates in their centre between the shroudings. This ring strengthens the wheel in an important degree, by supporting the bucket and sole plate at their weakest part, where they are liable to yield to the weight of the water. The middle ring is cast in segments like the shrouding, and the braces are attached in the way already described.

Fig. 109.

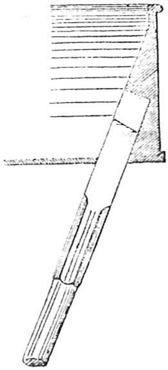


Fig. 110.

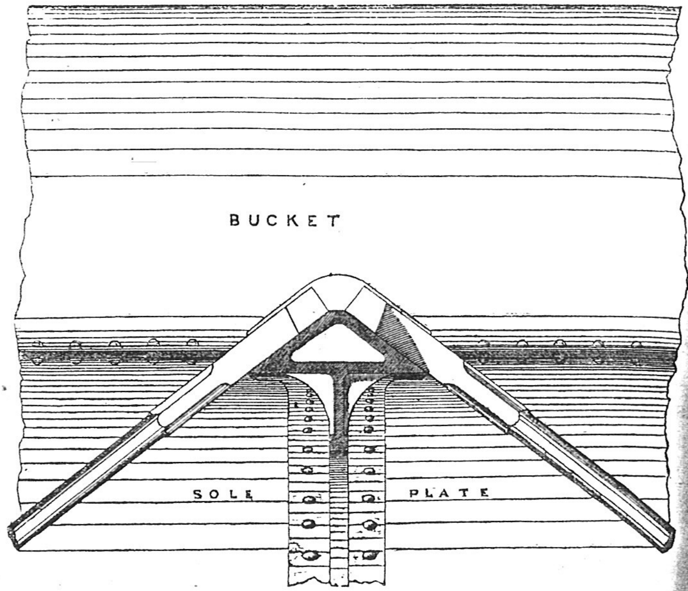
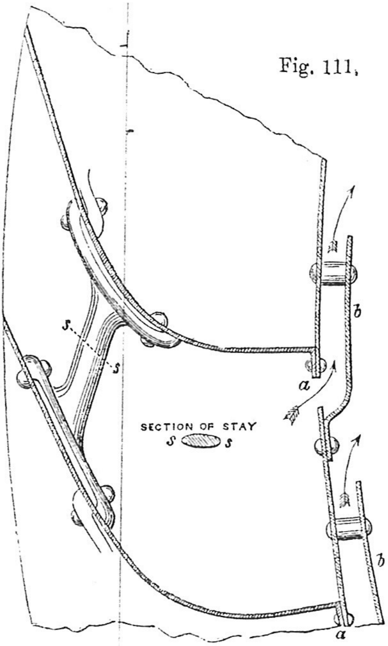


Fig. 110 shows the middle ring of a wheel 20 feet diameter and 22 feet broad.

Fig. 111.



The sole plates are of wrought-iron, ⅛th inch thick (No. 10 Wire Gauge), riveted together with lap-joints. The buckets are riveted throughout their whole length to the sole plate by a bend at the bottom, or in some cases by a small angle iron (*k k*, fig. 104). For the further support of the bucket plates, at every two feet of their length they are riveted to bucket stays forming a complete ring of auxiliary columns round the wheel at every two feet of its breadth. These bucket stays may be of wrought-i turned, with two collars, an riveted through each bu

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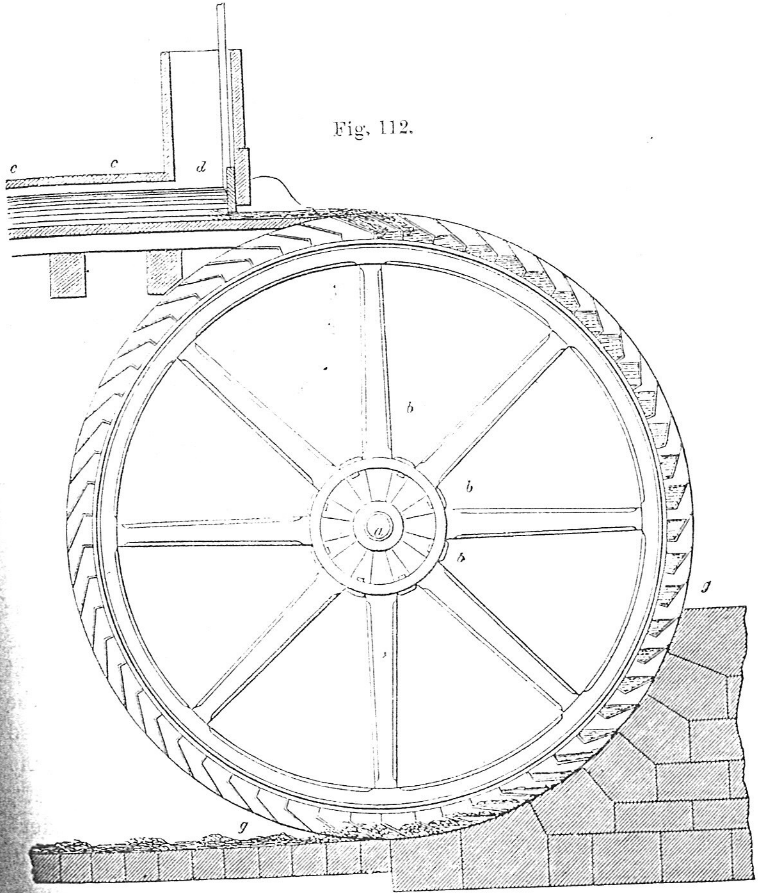
plate, as at *m*, fig. 104, or else of cast-iron, as at *s s*, fig. 111.

The Overshot Water Wheel.—By the overshot water wheel was originally intended that form of wheel in which the stream of water was led *over the summit* of the wheel, and thrown upon it just beyond the extremity of the vertical diameter. The water is retained upon the wheel in troughs or buckets, and by its weight continuously depresses the loaded side of the wheel, so as to create a motion of revolution. By a convenient modification of the mode of applying the water, however, the stream was laid on to the wheel upon the same side as it

Fig. 112.



approached, by reversing the direction of the spout or sluice, and for this form the name of pitch-back overshot wheel was employed. In present use the term overshot is no longer used strictly, but is arbitrarily applied to all wheels in which the water is laid on near the summit, although high-breast is perhaps a more correct and descriptive designation.

The form of the overshot wheel, as constructed about seventy to eighty years ago, is shown in fig. 112. The wheel revolves on a cast-iron shaft *a*, with broad flanches to which the wooden arms *b b* are bolted, as shown in section fig. 113,* with wedges between them to retain them in place. The water is brought from the dam and carried to the summit of the wheel in a wooden trough *c c*, which is nearly horizontal, as in fig. 112, or has an inclined apron or spout over the wheel, that the water may flow with a velocity somewhat greater than that of the wheel, so as not to be struck by the back of the revolving float-boards, and thrown off the wheel. This apron is usually made to incline at an angle of about 15° with the course, and is 18 or 24 inches long. A sluice or shuttle *d* is generally placed at the end of the pentrough, to regulate the discharge on the wheel.

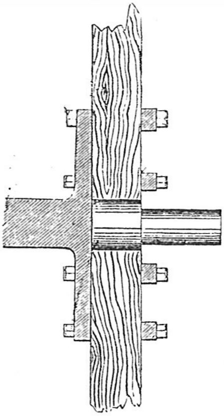


Fig. 113.

Useful Effect.—Thus provision is made for a constant supply of water falling into the buckets at the summit of the wheel, and by its weight constantly depressing the loaded side, whilst at the bottom it is discharged with the same facility as it was received. Owing to the form of the buckets, however, the water begins to be discharged at a point considerably above the bottom of the wheel, and thus escapes before it has performed all the work due to the fall. The amount of this waste may be reduced

1. By adopting a curvilinear form of bucket.
2. By only partially filling the buckets.

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* In earlier wheels, in which the main axis is of wood instead of iron, [illegible] principal arms are usually placed in parallel pairs extending across the [illegible] axis to the shrouding on either side.

3. By a close-fitting breast to retain the water on the wheel.

But when decreased as far as possible, this waste is still an important item in the performance of the wheel, and hence the useful effect secured is never equal to the work of the water due to the space through which it falls. The fraction expressing the percentage of useful effect derived from a given quantity of power expended by the water is called the efficiency of the machine, and is found by the formula

$$m = \frac{100\ U}{u} = \frac{100\ w\ h}{W\ H}$$

$$U = \frac{m\ W\ H}{100}$$

where m is the efficiency of the machine per cent.; u the work of the water employed per minute, or the weight W of the water in pounds multiplied by the fall H in feet, measured from the surface of the water in the pentrough to that in the tail-race; U the useful effect of the machine, or the pressure p in pounds moved by the working point of the machine, multiplied by h, the space in feet through which this point is moved per minute, or the number of pounds raised one foot high by the machine per minute. In ordinary overshot water wheels, the useful effect amounts to about 60 per cent. of the power; or a supply of 12 cubic feet of water per second will give one-horse power for every foot of fall. In the improved iron high-breast wheels, as I have been in the habit of constructing them, the efficiency amounts to 75 per cent., in which case 10·8 cubic feet of water per second will give one-horse power per foot of fall. This is about a maximum effect for water machines, and hence the improved high-breast wheel may be considered as nearly perfect as a water machine.

The waste of water from spilling may to a certain extent be reduced by decreasing the opening of the buckets, but with the disadvantage of at the same time increasing the difficulty of the exit of the water at the bottom of the wheel, and of its entrance at the summit. The waste may be further lessened in an important degree by increasing the breadth of the wheel and the capacity of the buckets, but in general it is not advisable that the buckets should ever be more than two-thirds

CHAPTER IX.

POWDER MILLS.

The manufacture of gunpowder is always a precarious operation, and this is not surprising when we consider the properties and chemical combinations of the ingredients of which it is composed. An admixture of sulphur, nitre, and charcoal in due proportion when fired by a spark, whether accidentally or otherwise, will produce the phenomenon of explosion, and cause serious injury to surrounding objects within range of its destructive effects.

This well-known composition is used for every description of fire-arms, and its safe application depends upon a knowledge of the fact that, at the moment of ignition, violent deflagration takes place, accompanied by the evolution of a large quantity of gas.

The quantity produced by explosion is about 900 times the volume of the powder; but, owing to the high temperature it attains as it passes from the solid to the gaseous state, and the space it occupies at the moment of formation, it is probably three times that amount, or 2,700 times the actual volume of the powder from which it is evolved. This immense increase of volume, and corresponding amount of expansive force, will account for the effects of explosive substances, and the velocity with which a projectile is discharged from a gun. There are many fulminating substances, chiefly compounds of nitrogen and chlorine, besides gunpowder, which explode with great rapidity, the whole mass to every appearance being instantaneously converted into gas. Now this is not the case with gunpowder, as time is an element in its combustion, and it frequently happens that, in a gun loaded with an extra charge of powder, the combustion is incomplete; and hence follows the necessity of limiting the quantity to the power of the gun, in order that the projectile may have the full force of the exploded powder. This is well known to artillerists, and, also, that no composition fulfils the conditions required in fire-arms so effectually as a well-proportioned mixture of nitre, sulphur, and charcoal. It is this composition which constitutes the propulsive force of projectiles, and the more pure these substances are when properly mixed, the more perfect is the powder.

In powder mills, as in others where chemical operations are carried on, it would be foreign to the objects of this treatise to enter upon the various processes by which a certain article is manufactured from the crude materials of which it is composed; but simply to describe the mechanical operations by which the objects are attained, and that more particularly when it comes within what has been considered the province of the millwright. In treating of this particular manufacture, and the machinery by which its ingredients are mixed, ground, and sifted, which from the time of its invention has been entrusted to the hands of the millwright, it may be interesting to trace, as simply as possible, the preparatory process by which the ingredients already described are manipulated in combination before they arrive at what is called the finished state of gunpowder.

We have noticed that nitre forms one of its principal ingredients, and this is prepared from its crude state, as nitre of commerce, by solution in hot water and crystallisation. By this process, after being carefully washed and every impurity removed, it is in a pulverulent state ready for combination.

Sulphur is prepared by fusion in an iron pot, at a temperature of about 230°; the impurities are then removed by skimming, and the denser parts allowed to sink to the bottom, from whence they are discharged into a receptacle or vessel to cool.

Charcoal, of the three ingredients of gunpowder, is the most important, and much depends on the quality of the wood used. I give the article as it appears in the last edition of Dr. Ure's "Dictionary of Arts and Manufactures."

He states that, "Woods which are best adapted for the production of pyroligneous acid are not fitted for the manufacture of gunpowder; the charcoal must therefore be prepared specially. The following are the essential properties of good charcoal for powder:—1. It should be light and porous. 2. It black, so that it may retain a dark-brownish hue, the powder will be more explosive than it would be if it were pushed until the charcoal had attained a deep black colour. When it has been found that no more volatile products are being given off, the fire is damped, and in a few hours the contents of the cylinders are transferred to well-closed iron boxes to cool."

The three ingredients having been carefully prepared are now mixed so as to effect a thorough incorporation necessary for the production of good powder. The original method was by stampers shod with brass beaters working in wooden mortars, the stampers in this case being raised by a revolving shaft and tappets worked by a water-wheel, or horses, as most convenient.*

The government powder mills at Waltham Abbey, and other private establishments, have not, until of late years, undergone any material improvement since their erection. They could not, however, escape the changes which for the last twenty years have been in operation in almost every other kind of manufacture. New contrivances and improvements upon old ones have been applied to powder mills as well as to those of a different character; and although the system of grinding by edge stones has not been superseded, great improvements have nevertheless been introduced, by substituting turned cast-iron rollers or runners in place of edge stones, and these revolving on turned cast-iron beds give greatly increased accuracy to the movements, and less danger from sparks or small crystals from the runners than when composed of stone. As this kind of machinery has been renewed at Waltham Abbey, a descrip-

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* In the year 1839 the author visited Constantinople, at the request of Sultan Mahmoud, for the purpose of inspecting and reporting upon the then existing state of the founderies, fire-arms manufactory, powder mills, &c.; and during this investigation he found the powder mills driven by relays of horses, working in the interior of large wooden wheels, the same as a dog-spit. About the same time steam engines were introduced for working the machinery at a distance by compressed air. The engine, boilers, air cylinder, &c. were in this case at a distance of 200 yards from the machinery, in order to prevent accident. This arrangement was subsequently changed, as it was found that more than one-half the power of the engine was lost, by friction, in forcing the air through the pipes, and working it over again into cylinders giving motion to the machinery at that distance from the motive power.

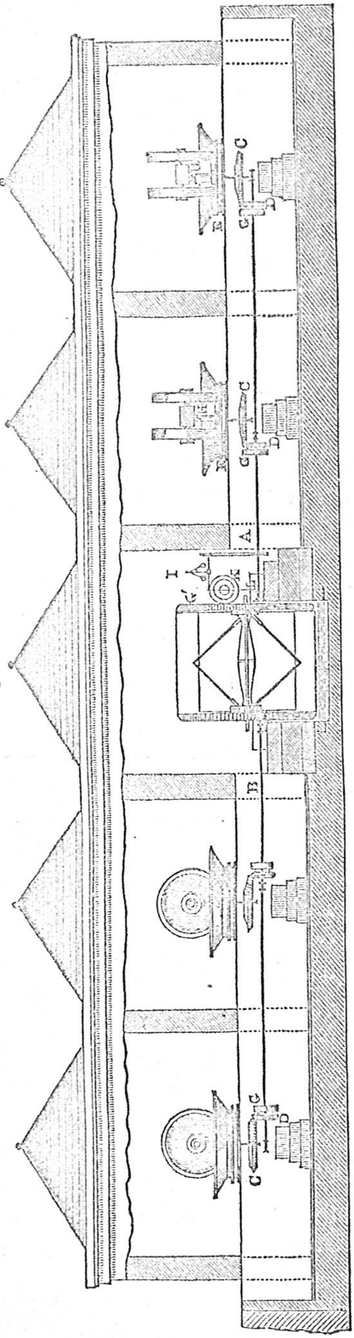


Fig. 320.

tion of the arrangements and improvements introduced by Mr. Anderson, of Woolwich, and others, may not be without interest.

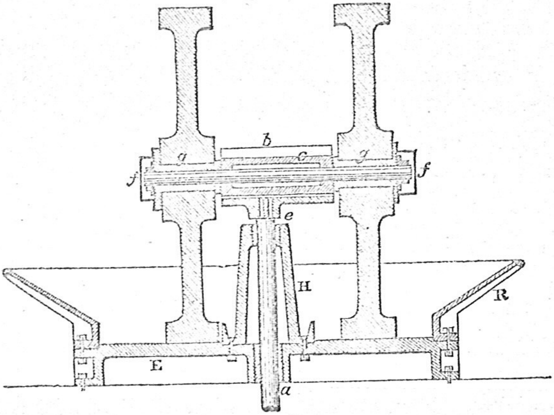
Two entirely new establishments were constructed under the direction of these gentlemen by Messrs. W. Fairbairn and Sons, of Manchester, and Messrs. B. Hick and Co. of Bolton, the former executing the water-wheels, edge runners, hydraulic presses, and granulating machines; the latter a 40-horse power steam engine and six pairs of edge runners.

In the construction of powder mills, it is a question of much importance to have the grinding and other processes separate from each other, that in case of explosion in any one department it should not communicate to the others. This precaution has been considered essential in every well-regulated powder mill, and to attain that object, most establishments have their mills at 100 to 150 yards distant from each other. Where this arrangement is found inconvenient, and the mills have to be nearer together, they are then separated by butts or mounds of earth, at a considerable height, and tapering at the top like the roof of a house. The more recent erections are, however, different since the introduction of the cast-iron runners, as may be seen by the preceding arrangement, fig. 320, where the mill is driven by a water-wheel.

On this plan it will be observed, that the water-wheel is 14 feet diameter, 12 feet wide inside the buckets, with segments on the shrouds, giving motion to two pairs of runners on each side of the water-wheel. Each pair of runners is in a separate house, covered with a light iron roof, and partitioned from each other by a thick wall, intended in case of explosion to save the adjoining mill. How far this arrangement will answer the purpose has not been determined, as no explosion has taken place since the mills were finished, and there is therefore no proof of the amount of security afforded, nor of the direction of the explosion; which, it is expected, would be vertical through the roof. It will be observed that the water-wheel gives motion to a line of shafts A and B, fig. 320, one on each side of the water-wheel placed in an underground tunnel, and by the bevel wheels C, D, gives motion to the vertical spindle which passes through a tight brass stuffing box (see also fig. 321) in the large bed plates E E, and gives motion to the edge runners above; the spindle in this case being steadied by the conical standard H, into which is inserted a brass bush for that purpose. The pinion on the tunnel shaft is bored and keyed upon the sliding clutch G, which works by friction on the principle described at page 92 of this work. All the wheels in these mills have wood and iron teeth, as iron working into iron is always attended with danger, where they are liable to come in contact with particles of powder. The bed plates on which the runners revolve rest upon the side walls of the tunnel, and the apparatus for starting and stopping the runners (which consists of a worm-wheel and crank) is worked by a wheel and handle from the outside.

In order to illustrate more in detail the method of constructing the mixing mill, and the connection between the vertical shaft and the runners, fig. 321 has been introduced. E is the bed plate, which is grooved out to admit the conical standard H. The inclined side R is bolted to the bed plate E, which contains the brass bush *a*. The standard is bolted to the bed plate with countersunk headed bolts, and a brass bush, *e*, is firmly inserted in its upper extremity to steady the vertical spindle. A box, *b*, planed in the inside and keyed on to the vertical spindle, in which another square brass box is allowed freely to slide, forms the connection between the spindle through the runner and the vertical shaft. A brass bush, *g*, is driven into the runner, which is prevented from sliding off the spindle by a collar through which a split pin is driven. A brass cap, *f*, bolted to the collar of the brass bush, completes the mill. The object of this cap is to prevent any grease from falling into the powder.

Fig. 321.



Scale $\frac{1}{4}''=1$ foot.

The water-wheel is on the ventilated principle, applicable to a variable fall, which does not exceed 3 feet in low ebbs; at other times, when the river is flooded, there is a large supply of water and a considerable increase of head. The runners are regulated by the governor I, which acting upon the worm wheels K, L, communicates motion to the shuttle, which moves upon the back surface of the cast-iron breast, and increases or diminishes the supply to the wheel, as may be necessary to maintain a steady uniform motion in the machines. It will be observed that the iron runners are not equidistant from the vertical spindle which carries them round on the surface of the bed plate. This is for the purpose of grinding the ridges which are thrown up by the outer edge of the central runner, and with the aid of scrapers the powder is brought immediately under the runners, the more effectually to incorporate the mixture of the ingredients. During the grinding, the powder is kept moist by a little water at proper intervals, to make the particles adhere together, and form the mass into a sort of paste.

Another water-wheel is employed to give motion to the hydraulic presses, crushing, sifting, and granulating machines; and these operations are carried on by a series of machines, adapted to the different kinds of powder which the Government requires for small arms and cannon. Other methods, besides those of edge stones or cast-iron runners, have been called into use for effecting the thorough incorporation of the ingredients for the production of good gunpowder, but none of them have been found to answer so well as the cast-iron runners or edge stones; the only objection to the edge stones being their liability to strike fire.

Previous to the grinding and mixing process under the runners, the ingredients have to be pulverised, which is accomplished by means of a number of revolving drums and balls. The pulverised materials require to be sifted in cylinders in order to be properly mixed; and this completes the preparatory processes, and renders the compound ready for grinding.

The subsequent processes as described by Dr. Ure are as follow:—

"The cake produced by the action of the stones is ready for graining or corning. For this purpose the cake is subjected to powerful pressure by means of an hydraulic press. The mass is then broken up and transferred to a species of sieve of skin or metal pierced with holes. A wooden flail is placed on the fragments, and the sieves are violently agitated by machinery. By this means the grains and dust produced by the operation fall through the holes in the skin or metal discs, and are afterwards separated by sifting. Sometimes the machinery is so arranged that the graining and separation of the meal powder is effected at one operation. The meal powder is reworked, so as to convert it into grains. The next operation to which the powder is subjected is glazing. Its object is to render it less liable to injury, by absorption of moisture or disintegration during its carriage from place to place. The glazing is effected by causing the grained powder to rotate for some time in a wooden drum or cylinder, containing rods of wood running from end to end. The grains, as they rub against each other and against the wooden ribs, have their angles and asperities rubbed off, and at the same time the surface becomes harder and polished. It is finally dried by exposure to a stream of air, heated by means of steam."

The following Table shows the composition of the various gunpowders in use amongst the different nations of Europe and America:—

TABLE OF THE COMPOSITION OF VARIOUS GUNPOWDERS.

	Nitre	Sulphur	Charcoal
English war powder	75·0	10·0	15·0
,, sporting powder	77·0	9·0	14·0
French war powder	75·0	12·5	12·5
,, sporting powder	76·9	9·6	13·5
,, blasting ,,	62·0	20·0	18·0
,, ,, ,, (another kind)	65·0	20·0	15·0
United States war powder	75·0	12·5	12·5
Prussian war powder	75·0	11·5	13·5
Russian ,, ,,	73·8	12·6	13·6
Austrian ,, ,,	75·0	10·0	15·0
Spanish ,, ,,	76·5	12·7	10·8
Swedish ,, ,,	75·0	16·0	9·0
Chinese ,, ,,	75·7	14·4	9·9

It will be seen from the above that the different nations do not materially differ in the proportions at which they have arrived by experience. They approximate nearly to each other, and the differences which exist may be accounted for by the superior or diminished purity of the substances of which they are composed. We regret to remark that the limits of our treatise preclude us from taking advantage of the drawings of the granulating machines, presses, &c. in our possession.

For the speed of the runners, and of the shafting and governor gear, we beg to refer the reader to the annexed list of wheels and speeds which enter into this description of Powder Mills:—

List of Wheels and Speeds.

Description of Gearing	Driver		Driven	Result
	Diameter	Revolutions	Diameter	Revolutions per Minute
	ft. in.		ft. in.	
Water-wheel .	14 0	—	—	6·68 revolutions per minute, equal to 4·89 ft. per second.
Segments G′ .	12 9	6·68	3 6½	24·2 revolutions of main horizontal shaft.
Bevel-wheel C .	2 3	24·20	5 4⅝	10 revolutions of runner.
Governor Gear.				
Pulley H . .	1 9	24·20	1 2	36 revolutions of governors.
Worm-wheel K	0 4	36·00	0 8¼	1·79 ,, vertical shaft.
Worm-wheel L.	0 5	1·79	2 0	0·031 ,, rack shaft.

It might have been interesting to have noticed in this place a new process of manufacture which to some extent is superseding the use of gunpowder, and that is gun-cotton, first invented by Professor Schonbein, and now greatly improved by General von Linz and the Austrian Government; but as that manufacture is now under the consideration of the authorities at Woolwich, and as experiments are instituted for the purpose of analysing its constituents, and testing its powers as compared with our best qualities of gunpowder, it would be premature in this stage of investigation to venture an opinion upon its comparative merits as a substitute for the present compounds.