

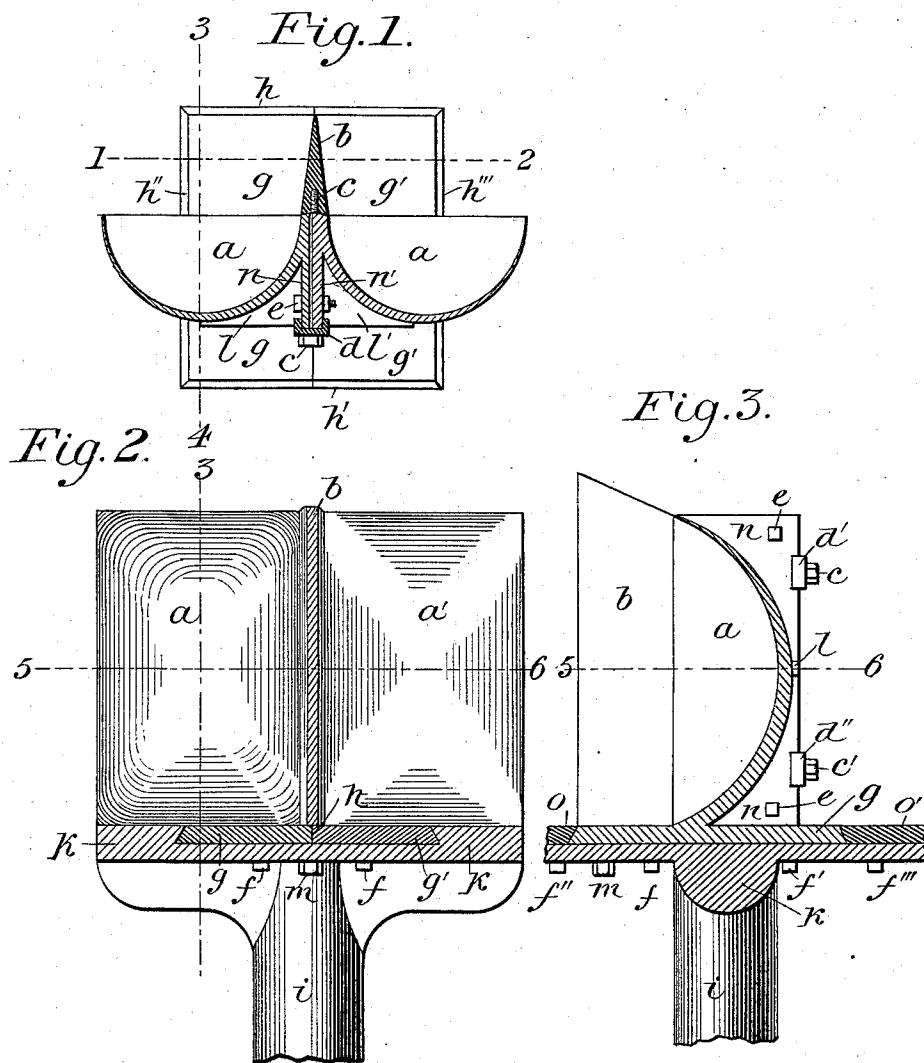
(No Model.)

3 Sheets—Sheet 1.

F. M. F. CAZIN.
PERCUSSION WATER WHEEL.

No. 578,812.

Patented Mar. 16, 1897.



Witnesses:

H. E. Carin.
C. A. Stader.

Inventor:

Francis M. F. Carin

(No Model.)

3 Sheets—Sheet 2.

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Fig. 5.

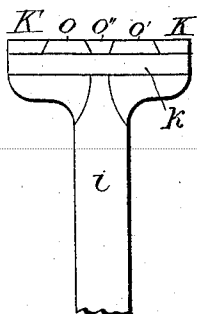


Fig. 4.

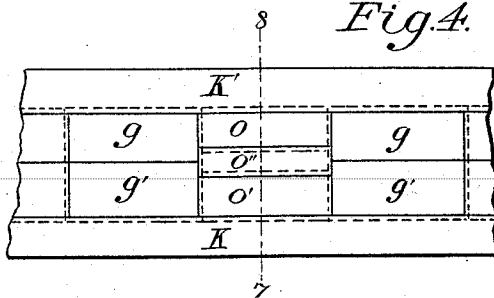


Fig. 9.

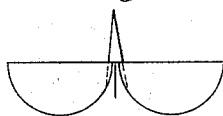


Fig. 9'.

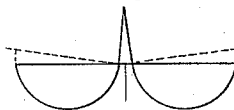


Fig. 6.

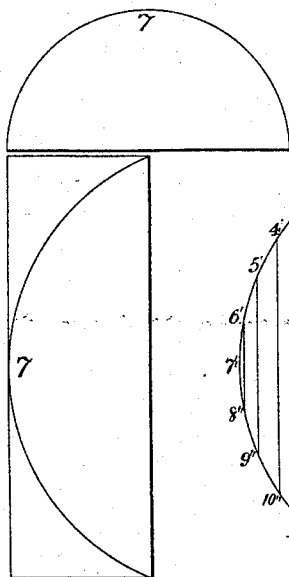


Fig. 7.

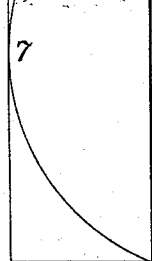
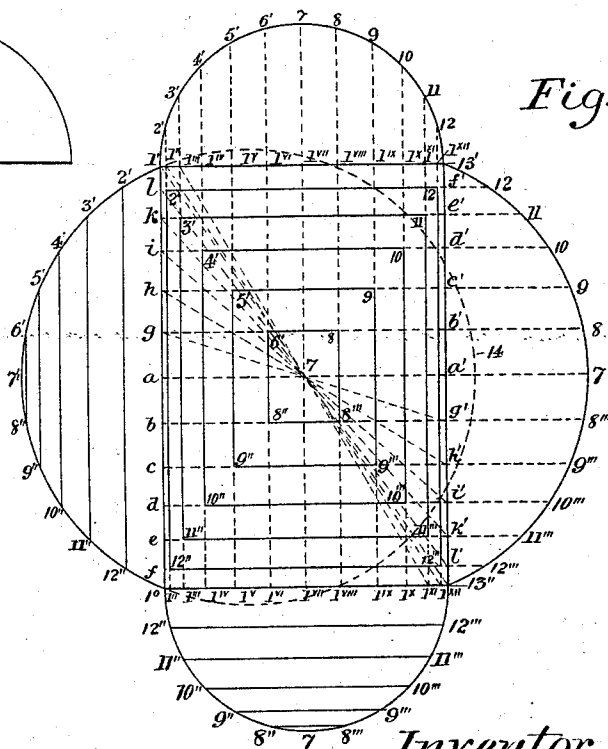


Fig. 10.



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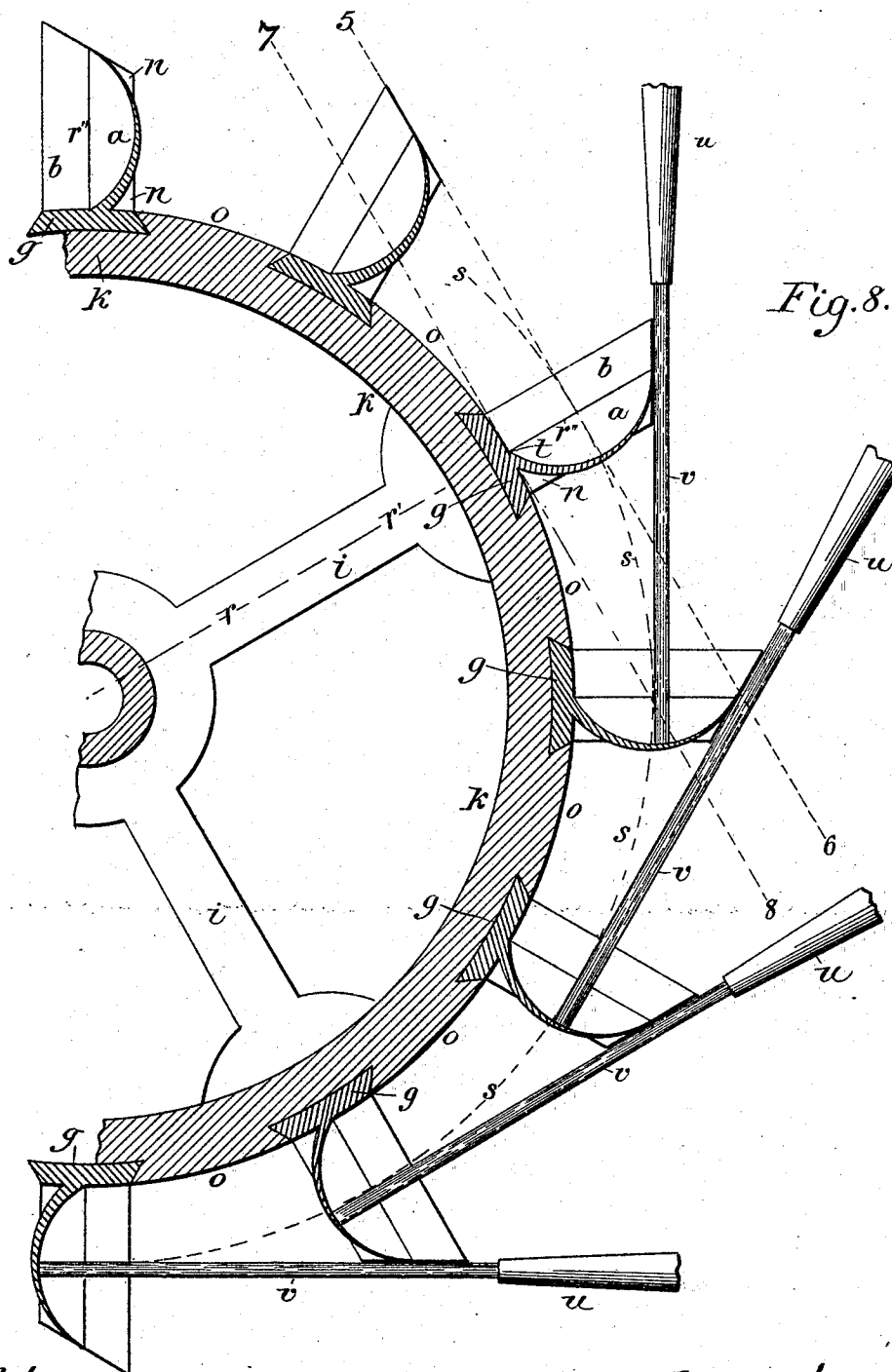
(No Model.)

3 Sheets—Sheet 3.

F. M. F. CAZIN.
PERCUSSION WATER WHEEL.

No. 578,812.

Patented Mar. 16, 1897.



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UNITED STATES PATENT OFFICE.

FRANCIS M. F. CAZIN, OF HOBOKEN, NEW JERSEY.

PERCUSSION WATER-WHEEL.

SPECIFICATION forming part of Letters Patent No. 578,812, dated March 16, 1897.

Application filed June 2, 1893. Renewed July 29, 1896. Serial No. 600,991. (No model.)

To all whom it may concern:

Be it known that I, FRANCIS M. F. CAZIN, a citizen of the United States, residing at Hoboken, in the county of Hudson and State of New Jersey, have invented certain new and useful Improvements in Percussion Water-Wheels; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

Apparatus employed for utilizing the energy set free by the gravitation of water from a higher to a lower level are properly divided into two classes, namely, first, such as are immersed into the gravitating water and acted upon on the entire circumference of the wheel, that is, made to revolve by the force of the gravitating water, which apparatus are commonly called "turbines," and, second, such as are not immersed in the gravitating water and are acted upon by free-flowing jets on part only of the circumference of the wheel, that is, made to revolve by the force of the gravitating water, which apparatus are commonly called "water-wheels" purely and simply or "percussion water-wheels."

My newly-invented improvement of such apparatus relates to the second class just mentioned, that is, to a percussion water-wheel that is driven by a single water-jet ejected underhead from a nozzle, or when by more than one jet by such only as flow in the same plane and act on part of the circumference of the wheel only.

I am aware of the fact that already as early as 1875 the then-appearing fifth edition of Prof. Julius Weisbach's *Lehrbuch der Theoretischen Mechanik* contained a full and exhaustive discussion of the more or less high degree of mechanical effect on such a water-wheel consequent to the shape of the face that is struck by the water-jet, and that there the statement was made (page 1158, paragraph 526, &c.) that the effect is higher for an opposing concave face than for an opposing convex face and that there the effect of dividing the water-jet centrally by a cone or wedge is also discussed and that the drawings representing a divided jet, that have become well known by trade publications in this country, are there already shown and published, as

they probably were even at a much earlier date in preceding editions of the same book. I therefore know that the process of dividing the water-jet into two halves by an opposing wedge is not patentable either to me or to any one else; but this process may be executed by a great variety of apparatus or combination of parts of the wheel and buckets and by specific and peculiar forms or shapes of any or all of the parts in the combination that are contributive to either a higher percentage of effect or to a more facile or solid construction, all tending to improve this second class of apparatus for the utilization of the natural water-power the same as the first class has been improved under many patents so far granted; and such improvement is the subject-matter of my new invention, as it will be described here below.

As the art now stands, the water-jet is either made to strike single concave buckets or single concave buckets which have in the plane of the wheel a central ridge or wedge-shaped projection that divides the jet into two parts and diverts these parts laterally and inversely to the wheel's motion; and in another instance two jets or a pair of jets ejected from a divided nozzle or pair of nozzles flowing in the same tangential plane are made to strike two buckets, set the one aside of the other and separated by a ring set on the crown of the wheel in the central plane, the two independent water-jets striking each a separate bucket without either jet being divided, each being diverted in total and the said ring not serving to the division of a jet into parts as it leaves the nozzle. As against these older forms of percussion water-wheels and as against the forms of buckets having been used therewith I have designed a new form of wheel, a new form of bucket, and a new combination or arrangement of buckets to the wheel and of buckets among themselves and of new parts combined therewith, all tending to improve the efficiency, the facility of application, and the general usefulness of this class of wheels for the utilization of natural water-power; and this entirely new and improved arrangement of wheel and buckets and their new and improved parts and shape is shown by the hereto adjoined drawings.

Figure 1 represents a pair of buckets *a a'*

and a water-dividing and water-directing piece *b* in transverse central section and a view, looking toward the center of the wheel, of base-plates *g g'*, the line of section being marked on Figs. 2 and 3 by a dotted line 5 6. Fig. 2 represents a view of a pair of buckets *a a'* and of a wheel-spoke *i* from a point in the line of the water-jet, as intended, and in the direction of such water-jet, at the moment when the plane of edges of the buckets stands at right angles with the jet, and looking toward the cavity side of the buckets *a a'*, which line of viewing also indicates a tangent to the working circumference of the wheel on the radius marked by the front edges of the buckets, as marked in Fig. 3 by the line 5 6, with transverse section on the line 1 2 of Fig. 1, of the wedge-shaped superstructure *b*, of the base-plates *g g'*, of the crown of the wheel *k*, and of the two rings *K K'*. Fig. 3 represents a transverse section on the line 3 4, as marked in Fig. 1, of one of a pair of buckets and of its base-plate *g* and of the wheel-crown *k* and of the additional crown parts or distance-plates *o o'*, with a side view of the superstructure *b*, of the check-plate *n*, and of the spoke *i*. Figs. 4 and 5 are diagrams representing or illustrating a selected manner of interlocking the base-plates of buckets with the rings and distance-plates of the wheel-crown. Figs. 6 and 7 are diagrams of the two circular lines, crossing one another at right angles in their centers, on which the bucket-cores are successively turned off, as illustrating the shape of the cavity of the water-buckets, such diagrams also showing the main configuration of the maximum sections of cores and cavities. Fig. 8 represents about half of a water-wheel to which my improvements as in this application specified have been applied in an assumed case when twelve pairs of buckets are distributed over the wheel-crown, and this half-wheel is represented on the plane in which it revolves and on the same plane of section wherein Fig. 3 is shown, the purpose of this figure being mainly to show the tangential line in which both the section of Fig. 1 is assumed and in which the water-jet, as well as the outer face of the superstructure *b* of the next preceding pair of buckets in the order of their being acted upon by the jet, are situate. Figs. 9 and 9' are diagrams illustrating the manner in which the maximum sections of cores illustrated by Figs. 6 and 7 may vary slightly from fundamental semicylindrical or segmental form. Fig. 10 is a diagram representing the method of forming the bucket-cavity as by me invented, such method only requiring the length of the two sides or edges that adjoin in the face parallelogram of edges to be known, in order to evolve therefrom the precise form of the bucket-cavity, the length of these two lines to be adapted to the dimensions of the jet and to its velocity, as well as to the number of revolutions of the wheel wanted, and the central or greatest depth of the bucket

being as half of its shortest side when one side is shorter than the other and adjoining side. The two curved lines shown in this figure also represent the maximum sections at right angles to one another of the bucket cores and cavities.

In making specific description of these drawings I shall state first in what essential qualities my invention varies from what is known at present in the art of constructing percussion water-wheels.

My wheel is necessarily of the usual form in so far as hub and spokes are concerned.

My improvements relate to the crown of the wheel, to the water-buckets to be connected in pairs to the said crown, and to the manner of connecting these pairs of buckets with the said wheel-crown; and the said connecting or joining is effected by dovetailing base-plates that are attached to the buckets into the wheel-crown, providing rings and space-plates with undercuts corresponding with the base-plates' dovetails and in such a manner and for the purpose that between these parts of the wheel-crown and the base-plates of the water-buckets, such base-plates being beveled, an interlocking or dovetailing takes place, resulting in this that when these buckets are put in place the entire percussion water-wheel is so solidly joined by means of these additional parts to its crown and the bevels on the base-plates of the buckets and by the wheel parts and the base-plates being dovetailed one with another, as if it were made in one piece. This is of the highest practicable solidity, and in consequence better adapted to bear the high strain to which these wheels are subjected.

The improvement of the crown consists in this that along the center of its face there is a groove, being cast in one with the wheel or made by two outer rings *K K'*, the groove on both sides of the rings *K K'*, on their inner sides, being preferably undercut. Into this groove *h*, running around the face of the wheel—viz., of the crown *k*—the base-plates *g g'* of the pairs of buckets *a a'* are inserted, and the two base-plates *g g'* of a pair of buckets *a a'* fill a certain space in the groove, leaving spaces circumferentially between them, such spaces left being equal among themselves and to be filled by space-plates *o o'*, which, if the groove is undercut and if neither of the rings *K K'* is removable, are also in pairs, filling the same space of the circumference, and are beveled the same as the bucket base-plates *g g'* to match both the groove sides and the adjoining edges of the bucket base-plates *g g'*, all of these beveled plates being inserted into their proper position by being slid singly along the grooved sides until they meet in pairs and then bolted by tap-bolts *f f'*, with their heads inside of the wheel-crown, so as to dovetail with the crown. The last distance left unfilled in the groove is then filled by a triple space-plate *o o' o''* instead of a pair, the transverse section of the triplet being shown

in Figs. 4 and 5, thereby securing all parts of the water-wheel in a secure manner as against variation and looseness in their position; but whether none of the rings $K K'$ or only one thereof is made in one with the crown k all the distance-plates $o o' o''$ are made fast to the crown k , preferably by tap-bolts, as shown in Fig. 3, the essential of my invention being the interlocking and dovetailing of the crown and its additional parts, such as rings and distance-plates, with the beveled base-plates of the water-buckets.

The main and even more important improvements relate, first, to the peculiar and improved form that I give to the concavity of each bucket for the purpose of securing to the water-jet, striking them underhead, a regular curved or segmental line of contact in whichever of the possible directions the said water-jet may strike them while they recede from the nozzle as the wheel is revolving under the force imparted to it, such regularly-curved or true segmental lines of contact being in the older forms of buckets either not obtained at all or obtained only in certain isolated or single ones of the sundry positions that these buckets have to pass through while the wheel is revolving, and, second, to the arrangement of pairs of these buckets to the effect of being in immediate contact with one another as pairs, each of the pairs having the same regular cavity with no division or interruption by a ridge or projection and with no difference between them to distinguish between them, as right and left, with no cutting away of either front or side walls, and with no rim or wheel ring or wedge between them, but provided with a superstructure by which the jet is divided into halves even before it touches the buckets, all for the purpose of effecting such division of jet on as sharp an angle as practically possible. This is on a sharper angle than has been feasible under the at present known state of the art, the smallness of the angle of division being proportionate to the increase of kinetic effect as between a plane and a concave opposing face receiving the percussion. These two desirable and new improvements have been by me accomplished in the hereinbelow-described manner:

First. The buckets $a a'$ as by me invented have a true parallelogram forming their four edges, as shown in Fig. 2 and as marked by $1^{\circ} 1' 13'' 13'$ in Fig. 10, with no undercut of or into any one of the edges, all such edges forming straight lines, and these buckets have a cavity the core of which is prepared and obtained as follows: first, taking a half of a regular cylinder, such as shown by one end face in Fig. 6, the semicylinder having a regular parallelogram, such as shown in Figs. 2 and 10, as division-plane or base-plane, and, second, turn off this semicylinder in such a manner that all the longitudinal lines in the division or base plane of the semicylinder, such longitudinal lines being marked in Fig.

10 in the parallelogram $1^{\circ} 1' 13'' 13'$ by $1''' 1'''$, $1''' 1'''$, $1''' 1'''$, &c., become chords to the circle, such as shown in Fig. 10, and there marked 1 to 12 to 1° to 14, in which circle the semicylinder is cut in second place, the central point (marked 7 in Figs. 6, 7, and 10) of the curved half-cylinder surface being also situate in the second circle so cut, the two circle-segments used in cutting the core crossing one another at right angles in their apex, this apex point of intersection of the two circle-segments also forming, as shown in the different figures and diagrams, the deepest point in the bucket-cavity, and the same two circle-segments also forming the two maximum sections of core and of bucket-cavity. Between all opposing points of the parallelogram of edges, such as marked by its corners $1^{\circ} 1' 13'' 13'$ in Fig. 10, which parallelogram is preserved intact under such second cut also, be these opposing points, such as marked on Fig. 10 by $1''' 1'''$, $1''' 1'''$, $1' 13'$, $l l'$, $k k'$, $i i'$, $h h'$, and $g g'$, diagonal to the parallelogram or to the cavity or be they, as marked by $a a'$, transverse at right angles to the parallelogram or to the cavity, the core so prepared and obtained, as well as the cavity cast thereon of a bucket show the true segmental lines or true curves, as hereinabove specified, while the parallel edge lines remain, as stated, intact.

In buckets that have cavities corresponding to such core, made as hereinabove stated under first and second, and which buckets are so set in pairs, as shown in Figs. 1 and 3, that their two proximate edges will first meet the jet-halves previously divided by a projecting piece b , the water will be guided as successively it strikes the different points (indicated on Fig. 10 by the letters l' , l , k , i , h , g , and a) on the proximate sides on lines that are true concave curves for all or any of the starting-points, and these curves all pass over the center 7 of the cavity—that is, by its deepest part—and being first diagonal from corner to corner and longest, as $1' 13'$ in Fig. 10, they become shorter and diagonal between sides until the rectangular transverse section, as shown in Fig. 1, becomes the line followed by the jet-halves, which is the case when the bucket edges stand at right angles to the direction of the jet, with the sharp edge of the projecting piece b in the plane of rotation facing the central division-line of the jet in the said plane, and a further advantage resulting of the improved form, as above described, of the single bucket having a cavity in which, as shown, all opposite parts are symmetrical and equal consists in this that the jet-water entering the bucket over one of its edges is conducted so as to leave the bucket in inverse direction over the opposite edges exclusively—that is, when, as intended, the jet only enters the bucket over one of its edges—then the reversed water only takes its exit at a distance of the jet and never so as to counteract it and always so as to have an unimpeded exit, and, as shown in Fig. 3, the

parallelogram of edges stands always in the true radial planes of the wheel, with the sharp edge of the projecting dividing-piece *b* parallel to this plane, as also shown in Fig. 3, with the jet direction indicated by the line 5 6 when the buckets stand facing the jet in the middle point of its range of effective travel or action, which point I preferably make the end of the bucket's effective and working range of action, as shown in Fig. 8, by intercepting the jet in this position of the bucket by the next bucket in the series intervening, and the extreme outer edge of the projecting dividing-piece *b* is so regulated, as immediately here following further specified, as to cause such interception to transfer the jet from one bucket to the next following in the series without any part of the jet being diverted from passing on the lines as indicated of cavity curves of the bucket.

The expression "semicylinder" used in this application is intended to signify such a body mainly, though a fraction thereof may be taken off its or the core's base, as shown in Fig. 9, starting from one of its edges with a sharp angle cutting to the opposite edge for the purpose of making the side of the superstructure *b* tangent at the point of contact to the circle of the semicylinder—that is, with the cavity for which it is making the core—while the parallelogram of edges is at right angles with a perpendicular from the apex to the base of the superstructure *b*, and in another case the edges near which two buckets making a pair are intended to adjoin one another, as shown in Fig. 9'.

Second. The buckets *a a'* are so set, the one adjoining the other, that their adjoining edges, being of more or less thickness, leave room for the base of a wedge-shaped superstructure *b*, this wedge-shaped superstructure *b* having its outer or circumferential wedge-shaped face in a line that lies in the direction of the jet when the bucket first enters into its range of action, causing this line to form an obtuse angle with the line of the adjoining bucket edges and an acute angle with the sharp edge of the superstructure or wedge itself, which latter line or edge is nearly radial and parallel with the adjoining bucket edges; and by the conditions thus described the aforesaid obtuse angle is always the sum of the distance degrees between buckets on the same side of the piece *b* plus ninety degrees; and the fourth or inner line of the wedge-shaped superstructure conforms the same as the base-plates *g g'* and the distance-plates *o o'* with the circumferential line of the wheel, as shown in Fig. 8; and the transverse section of this piece *b* is of wedge shape, as aforesaid, with its indented base against and covering the adjoining edges of the buckets and with its apex parallel thereto.

For a more specific showing of the manner in which these two material points of improvement are carried out I refer to the adjoined drawings, in which identical parts are indi-

cated in the different figures by the same letters.

Fig. 1, being a transverse central section of a pair of buckets *a a'* on the line 5 6 of Fig. 2, only represents the parts of the pair of buckets which in Fig. 2 are situate below the line 5 6. The fact that all front edges of both buckets in the pair are represented by only one straight line demonstrates the three facts, namely, first, that all front edges of a pair of buckets the members of which pair are directly adjoining one another are situate in the same plane; second, that all front edges of each bucket are situate in the same plane; third, that the line of vision being toward the center of the wheel the plane in which the front edges of buckets are situate is a radial plane and at right angles to the plane of rotation of the wheel; and Fig. 1 further demonstrates that in a pair of buckets in which one front edge of one bucket directly adjoins an equal front edge of the other bucket in the pair the base of a wedge-shaped water-dividing and water-directing piece *b* covers both these adjoining edges of buckets; and Fig. 1 further shows the semicircular form of the transverse central section of each bucket and also the fact that the part of the line 3 4 which is inclosed between the line that indicates the plane of front edges and the semicircular line, such part indicating the radius of the semicircle, is of the same length as the rise of the curve shown in Fig. 3, which is indicated by that part of the line 5 6 in Fig. 3 which is situate between the base-line of the piece *b* and the curve, both these lines being at right angles to and in the center of the plane of front edges and both ending in the deepest point of the bucket-cavity; and it is also shown by Fig. 1 that the two buckets in a pair are equal in their cavities and that there is nothing in either cavity in a pair that adapts one in contradistinction to the other for one side of the center line only, and it is also shown that none of the four edges to a bucket is in a different plane from the other three edges, that no side of the bucket-cavity is cut down or cut into, and that all four sides to a cavity reach to the plane of front edges; and in conjunction with the other figures Fig. 1 also shows that all opposite parts in the bucket-cavity are of identical form and unmodified in form on account of position relative to the other bucket in the pair; and Fig. 1 also shows that the base-plates *g g'* of the buckets *a a'* have bevels *h''* and *h'''* on their outer lateral edges and *h* and *h'* on both opposite edges that are transverse to the circumference of the wheel; and Fig. 1 also indicates a method of supporting the single buckets by check-plates *n n'* and by brackets *l l'* and of fastening directly-adjoining buckets in a pair to one another by bolts *e* and nuts *e'* and by a clamp *d* and of fastening the water-dividing and water-directing piece *b* to the check-plates and buckets.

Fig. 2 illustrates the shape of the cavity of either bucket in a pair. The front edges of either bucket are shown to form a right-angled parallelogram. The semicircular lines shown in Fig. 1 correspond to a section indicated in Fig. 2 by the line 5 6, and the curved line shown in Fig. 3 corresponds to a section indicated in Fig. 2 by the central division-line 3 4, these two sectional planes 5 6 and 3 4 standing at right angles to one another, and the shape of the cavity of both buckets in a pair is indicated also by a series of straight lines parallel to each of the four sides of the parallelogram of front edges, thus indicating that all lines drawn in such cavity at a uniform distance from and parallel with the parallelograms of front edges also form mainly straight-lined parallelograms, leaving the four sides of each cavity in a triangular shape, with their base-lines forming the parallelograms of edges, their side lines adjoining in pairs and meeting all in the deepest point of the cavity, such point being the center of both the curves, as they are shown, the one in Fig. 1 and the other in Fig. 2.

The two cavities in Fig. 2 are shown with an essentially immaterial difference between them, illustrating two methods of execution, of which in a given case only one is selected, namely, the one with the edges, where the side lines of the four triangles join, rounded off and the other without such rounding off of corners; and in Fig. 2 the position relative to one another and to the wheel of two directly-adjointing or serially-arranged buckets of a pair of buckets is also shown, and the dovetailing of their base-plates $g g'$ in the crown of the wheel, as well as a method of fastening the base-plates $g g'$ by tap-bolts to the crown of the wheel, and the piece b by the tap-bolt m to the same.

Fig. 3, in which one of a pair of buckets is represented without regard to the position of the other bucket in the pair, illustrates first the curve that forms the central section of the bucket on the plane of rotation of the wheel, the rise of which curve is of equal length with the radius of the semicircle forming the central section of the bucket in a plane standing at right angles to the plane of rotation of the wheel; and the curve thus shown is dependent, not only on the said radius, but also on the length of the semicylinder chosen as the means for making the bucket-core therewith, such length being a matter of adaptation to the conditions under which the wheel is to be used; and the curve shown in Fig. 3 is correspondingly the same as shown in Figs. 7 and 8, the center in either case being located on a perpendicular to the face of the piece b which is most remote from the center of the wheel; and Fig. 3 is further and mainly intended to show the precise position and character of this face of the piece b that is most remote from the center of the wheel. The line which in the selected position of Fig. 3 stands vertical between the pieces b and the bucket-cavity

proper indicates the plane of the parallelogram of edges of the bucket and at the same time the base-line of the piece b . The face of the piece b that is most remote from the center of the wheel is shown to stand at an obtuse angle to the said base-line, which angle by the preceding specification must always be ninety degrees plus the degrees for which the pairs of buckets stand distant from one another on the circumference of the wheel, and it should be understood that whenever the single buckets in a pair do not adjoin one another directly the said degrees of distance are those relating to the single buckets of the different pairs that stand on the same side of the wheel and of the water-jet. The stated quantity of the angle formed in the plane of rotation by the outer and most remote edge of the piece b with the base-line of the same piece and likewise with the plane of the parallelogram of front edges of the bucket is the necessary consequence of the outer edge of the piece b being in the line of the jet when the parallelogram of front edges of the next preceding bucket in the order of successive interception of jet is perpendicular to the jet, or vice versa; and this view, Fig. 3, also indicates the dovetailing of the base-plate g with the space-plates $o o'$, set on the wheel-crown k . The line 5 6 in Fig. 3 is the same as the one marked the same in Fig. 8, and indicates also the sectional plane on which Fig. 1 is represented; and this line 5 6, that stands perpendicular to the plane of bucket front edges in Fig. 3, also indicates the direction of the water-jet relative to the bucket at the moment when the bucket stands with the plane of its front edges at right angles to the direction in which the water-jet flows, which moment is also the one in which the bucket has arrived in the center or middle of its longest possible range of effective travel, and which moment is also the same in which the water-jet (indicated in Fig. 3 by the line 5 6) is first intercepted by the next following bucket; and in consequence this line 5 6, that is perpendicular to the plane of front edges in one bucket, is also the very line in which the outer face or edge of the piece b that belongs to the next following bucket in the order of successive interception must be situate; and as the interception takes place when the bucket stands, as indicated in Fig. 3, with its plane of front edges perpendicular to the jet, and as all buckets are, as shown, intended to have their plane of front edges in a radial plane, or at all events in equal relative positions to the radial plane that intersects each bucket, the angle between the line 5 6 that relates to one bucket and the radius that relates to the other next following bucket is of necessity dependent on the angle formed by the two radiuses belonging to these two successive buckets. If, for instance, the pairs of buckets follow one another on the circumference of the wheel at a distance of thirty degrees, which would give twelve pairs of buckets on the wheel-crown,

then the angles formed by the line 5 6 that relates to one bucket and the radius that relates to the next following bucket in the order of jet interception are the one of ninety 5 degrees plus thirty degrees and the other of ninety degrees minus thirty degrees, the former one being the obtuse angle spoken of heretofore, that is, the obtuse angle formed by the base of the piece *b* (the radius) and 10 the outer edge or face most remote from the center of the wheel of the piece *b*, (the line 5 6 that relates to the next preceding bucket.) The perpendicular position of the line 5 6 to the plane of front edges therefore is indicative 15 of the position of the water-jet relative to each bucket when in the course of rotation the bucket has come to the middle of its longest possible range of effective travel, thus showing that its real effective or working 20 range of travel is only the first half of its possible longest range of effective travel and is the range within which the water-jet strikes the bucket on the radius of greater length and comparative highest effect.

25 Figs. 4 to 7 have been sufficiently described hereinabove.

Fig. 8 shows how the end face of the super-structure *b* remotest from the center of the wheel is in its angle to its sharp front edge 30 regulated by the position of the other buckets in the series, and in special that the prolongation of the line of this outer face divides the next preceding bucket into mainly two halves, as heretofore specified, that is, mainly on the 35 line 5 6, as shown in Figs. 2, 3, and 8, and that this line is tangential to the working circumference *s s s s* of the wheel, and as such rectangular to the radius on which the next preceding bucket in the order of contact with 40 the water-jet mainly stands, and that this line is also, as hereinabove described, the same with the direction of the water-jet when the bucket first enters into its range of action and rectangular to the radial plane in which the paral- 45 lelogram of edges of the preceding bucket is situate, and the working circumference *s s s s* is thus shown to be the circle on which all buckets are struck squarely when they arrive in the middle of their longest possible working 50 range, but at the end of their actual working range when under my construction the jet is intercepted by the next following bucket. The nozzles *u u u* have stable or permanent positions, while the wheel-crown revolves.

55 Figs. 9 and 9' are diagrams of end faces of semicylinders set with one edge adjoining and with the base plane of both in the same plane as they, when worked into cores, would ultimately stand in a pair of buckets, the same 60 as shown in Fig. 1, with a slight part of the semicylinders removed for the purpose of producing a true continuity of direction between the side of the projecting water-dividing piece *b* and the curves of the cavity of the buckets, 65 which direction the water is to follow.

Fig. 10 is a diagram showing for given lengths of bucket edges the evolution there-

from of the form of the bucket-cavity as by me newly invented.

The central or greatest depth of the cavity 70 is, as repeatedly stated, the radius of the semicylinder, or half of the shortest of the two sides, if one is shorter than the other, and the two curves that intersect one another in the 75 deepest central point have both one of the known sides as their chord and can be drawn in the usual geometrical way. When from these segmental lines or curves perpendiculars are drawn to their chords at points that are dividing either curve into an equal num- 80 ber of parts, then these perpendiculars at proportionate division-points are of equal length in both curves, indicating the points of intersection at right angles of these curves as well in the cutting of the core as in the 85 cavity made from the core, as described in this specification; and lines parallel with the base-line or chord drawn through these points of intersection give with the parts of curves remaining at either end of such parallel line 90 a true diagram of a section of the cavity perpendicular to the plane of front edges and through these points. The diagram shows these sections at right angles to the sides when the cavity is cut at equal distances, measured 95 on the curves, dividing the central curves, which intersect one another, into twelve parts each.

The transverse section on the line *l f'* of the base plane or of the plane of parallelo- 100 gram of edges is represented by the lines partly curved at the two ends and straight in the middle and is marked by $1^{\circ} 12'' 12''' 13''$. The transverse section on the line *k e'* is represented by the line marked $1^{\circ} 12'' 11'' 11'''$ 105 $12''' 13''$. The transverse section *g b'* is marked by the line $1^{\circ} 12'' 11'' 10'' 9'' 8'' 8''' 9''' 10''' 11''' 12''' 13''$; but the section through the central or half division-line *a a'* is represented by the semicircle $1^{\circ} 13''$, such as shown in Fig. 1 on 110 the similar line 5 6 of Figs. 2 and 3. In the same manner the longitudinal sections at right angles to both the face plane of parallelograms and the shorter edge are also shown. The longitudinal section on the line *l' l_{ii}* is 115 represented by the line marked $1' 2' 12'' 1^{\circ}$, and the section *l' l_{vi}* by the line marked $1' 6' 8'' 1^{\circ}$, and the central section is again marked by the curve $1' 7' 1^{\circ}$, being a segment of a larger circle $1' 7' 1^{\circ}$ to 1° to 14 120 to $1'$, but with the same central distance *a 7* as *l' l_{vi}* 7 from its chord, and the diagonals in broken lines show the direction that the jet-half takes through the cavity of the bucket and how the water passes and crosses the lines 125 indicated that are parallel to the outer edges, themselves forming at equal distance from these edges parallelograms of straight lines, while their continuance is curved and indicated in dotted lines. 130

Having now described my invention and explained its nature and mode of operation, what I claim as new and useful, and desire to protect by Letters Patent, is—

1. In a water-wheel buckets, having base-plates and cheek-plates, preferably at right angles to each other, the buckets being fastened together by the cheek-plates, as and for the purpose set forth.

2. In a water-wheel buckets, having base-plates and cheek-plates, preferably at right angles to each other, in combination with the crown of the water-wheel, the said buckets being fastened together by the cheek-plates, and being fastened to the wheel-crown by the base-plates, as and for the purpose set forth.

3. In a percussion water-wheel a wheel-crown, having a circumferential central groove in combination with buckets, arranged in pairs and having base-plates, and distance-plates for filling the spaces between the base-plates of successive buckets, as and for the purpose set forth.

4. In a percussion water-wheel a pair of buckets, each member of the pair having a base-plate with one beveled edge, a wheel-crown having a circumferential central groove, dovetailed for receiving the base-plates, and distance-plates having beveled edges, the whole being arranged so, that the parts are capable of being dovetailed together, as and for the purpose set forth.

5. In a percussion water-wheel a series of buckets around the crown of the said wheel, the said buckets being arranged in pairs and having base-plates with beveled edges, a wheel-crown having a circumferential central groove, dovetailed for receiving the base-plates, and distance-plates having beveled edges, the said distance-plates being designed for filling the spaces between the base-plates of successive pairs of buckets, and the whole being arranged so, that the parts can be dovetailed together, as and for the purpose set forth.

6. In a percussion water-wheel a wheel-crown, having on its outer face two rings leaving a space between them, the inner edges of which rings are undercut, in combination with buckets arranged in pairs, that have base-plates, and with distance-plates, the latter filling the spaces between the said base-plates of the successive buckets, all of which plates are so beveled on their two outer opposite sides, as to dovetail and interlock with the undercut inner edges of the rings, and the base-plates on their edges facing the distance-plates being so beveled, and the distance-plates on their edges facing the base-plates being so undercut, as to dovetail and interlock with one another, as and for the purpose set forth.

7. In a percussion water-wheel a wheel-crown, having on its outer face distance-plates, filling the spaces between the base-plates of buckets, such distance-plates being undercut on the two opposite edges, that join the said base-plates, and both kinds of plates conforming in their shape to a concentric circular line with the wheel, in combination with buckets, that are provided with the base-

plates as described, the latter being beveled on their opposite edges adjoining the distance-plates, so as to dovetail and interlock therewith as and for the purpose set forth.

8. In a water-wheel a pair of buckets, the outer edges of which form two immediately and directly adjoining parallelograms with right-angled corners, a wedge-shaped projecting piece, the sharp apex-line of which is parallel with the bucket edges but not in the same plane therewith and not in immediate proximity thereto but at a distance therefrom, and the base of which projecting piece covers the two adjoining edges of a pair of buckets, as and for the purpose set forth.

9. In a water-wheel a pair of buckets having a wedge-shaped piece with its base upon the top of the adjoining edges of the buckets, and locking devices for holding the wedge and the buckets firmly together, as and for the purpose set forth.

10. In water-wheel buckets, arranged in pairs on the crown of the wheel in each of which buckets the outer edges form a parallelogram, with the side lines of such parallelogram at right angles to one another, and sharp-edged pieces, each projecting out of the plane of edges, and resting with its base on one edge of such buckets and between the cavities of them, and having its sharp apex-line in the plane of rotation of the wheel and facing the central division-line of the water-jet, and the parallelogram of bucket edges standing in a radial plane to the wheel, as and for the purpose set forth.

11. The combination with the crown of a water-wheel, of a pair of buckets fastened to the said crown, each pair of buckets having a wedge-shaped piece resting on top of their immediately and directly adjoining edges and with its base covering these directly-adjoining edges, and the apex-line of which wedge-shaped piece is materially projecting beyond these adjoining edges and not in the same plane with the edges of the pair of buckets, as and for the purpose set forth.

12. The combination with the crown of a water-wheel, a groove in the said crown, and pairs of buckets having base-plates seated in the said groove, of wedge-shaped pieces surmounting the adjoining edges of a pair of buckets and projecting beyond the edges of the said pairs, as and for the purpose set forth.

13. In a water-wheel the combination with buckets set in series on the face of the said wheel of sharp-edged pieces, surmounting one edge of the said buckets on alternate sides, the said piece extending above and out of the said bucket, and having its outer face or edge, that is farthest from the center of the wheel, on a line, which is in the direction of the water-jet line, when the bucket comes to the starting-point of its effective and working travel, as and for the purpose set forth.

14. In a water-wheel a pair of buckets, the outer edges of which pair as well as of each bucket in the pair form a straight-lined par-

allelogram, with no distinction between the cavities of the two buckets, by which they become distinct as right and left, lateral opposite parts in each bucket-cavity being equal and symmetrical, the cavities of both buckets in the pair being formed on the same core, and this core being formed by rounding off the two flat ends of a semicylinder, leaving the end edges of the base parallelogram of the semicylinder as the end edges also of the curved end faces formed by such rounding off, which latter is perfected by turning off the semicylinder on a second segmental line running at right angles to the semicircle of the semicylinder, the second segmental line ending in the two said end edges and having the same rise as the said semicircle and having its chords in the said base plane, leaving two opposite triangular parts of the curved face of the semicylinder intact, and leaving a central apex-point of both curved faces common to all, as and for the purpose set forth.

15. In a water-wheel a bucket, the outer or front edges of which form a parallelogram, and the concavity of which is the counterpart of a core, the transverse maximum section or section by the apex-point of which exclusively is substantially semicircular, and the central section of which, that is at right angles with the aforesaid maximum transverse section is mainly an arc of fewer degrees of a larger circle, having the same rise or maximum perpendicular to the base plane of the core, and in which bucket all points in the face of its cavity, as formed on the core as described, are situate either in the lines described as the main section-lines of the core, standing rectangular to one another, or situate in lines that are parallel to either of these two lines and standing rectangular on the front edges, on opposite sides, and in the cavity of which bucket all the lines in its face, leading from a point on one edge to the diagonally opposite point on the opposite edge, or leading over the described line of maximum transverse section from edge to edge, are true curves.

16. The combination of a water-wheel with a bucket, the outer or front edges of which bucket as well as all lines in its cavity drawn at uniform distance from such front edges, form a true and right-angled parallelogram, the dimensions of which parallelogram decrease toward the deepest point in the cavity, and the cavity of which bucket at its said deepest point has a depth of mainly half the shorter front edge, and the cavity of which bucket is formed by four triangular sides, that are curved in only one direction, and which sides stand at right angles to one another, each triangular curved side having one straight base-line or front edge and two side lines forming curves, which side lines join in a point, that is common to all and is the deepest point in the cavity, and in which cavity-face four perpendiculars dropped at right angles to one another from the said deepest point to the four front edges form, the one

continuous pair of perpendiculars, a semicircle, and the other an arc of less degrees of a larger circle, both these arcs forming the two maximum sections of core and cavity.

17. In a water-wheel a pair of buckets the members of which pair adjoin one another with one of their front edges directly in the central plane of rotation of the wheel, having a wedge-shaped piece provided with a sharp edge extending beyond the limit of the bucket edges, so that the water will be divided by it before reaching the bucket proper, as and for the purpose set forth.

18. In a water-wheel buckets with cavities equal in all and with equal opposite sides in each, arranged as right-sided and left-sided ones, such buckets having on their inner edge a water dividing and directing piece, provided with a straight sharp edge extending beyond the said inner edge, so as to portion out or distribute the water of a jet between the single buckets and to properly direct these portions into the right-side and left-side buckets, as they stand in series on the crown of the water-wheel, as and for the purpose set forth.

19. In a water-wheel a wheel proper forming one member, in combination with buckets forming another member, the said members interlocking one with the other, by means of beveled edges, the one having spaces for receiving dovetail-shaped members, which spaces are all equally distributed over the wheel-crown, and equally situate relative to the wheel, and into all of which spaces the dovetail-shaped members are received in the same direction and manner, and the base-line or base-face of which spaces is concentric with and circular as the wheel-face as and for the purposes set forth.

20. The combination with a percussion water-wheel and with buckets, two of which form a pair, supplementing one another as such in the function of dividing the water-jet and of directing its parts, such single buckets being set on two different sides of a central plane of rotation and following one another on the crown of the wheel, of a water dividing and directing piece with each single bucket, resting with its base on the inner edge of such single bucket, and with its body mainly in the said central plane of rotation and projecting beyond the edge of the bucket, its base and the bucket edges standing in a radial plane to the wheel, as and for the purposes set forth.

21. In a percussion water-wheel bucket, the front edges of which form a perfect right-angled parallelogram, and in which buckets all opposite parts of their cavities are symmetrical and equal in form and dimensions, and which buckets stand with the plane of their edges absolutely at right angles in all directions to the plane of rotation of the wheel, these buckets having on the edge confronting the central division-line of the water-jet in the plane of rotation and surmounting the

said edge, a projecting piece dividing and directing the water of the jet, as and for the purpose set forth.

22. In a percussion water-wheel a pair of
5 buckets, the front edges of which form two
directly and immediately adjoining parallelo-
grams situate in the same plane, and a pro-
jecting water-dividing and water-directing
piece, the base of which covers the adjoining
10 sides of the two parallelograms of edges, and
the outer face or edge of which piece, being
most remote from the center of the wheel, is
within such tangent to the constructive work-
ing circumference of the wheel, as will strike
15 this circumference in the end point of the
radius, on which the next preceding pair of
buckets in the order of facing the water-jet,
is situate, and such tangent being also the
line of direction of the water-jet, when the
20 buckets first come into contact with the wa-
ter-jet in their rotation, the said outer face
or edge of the water dividing and directing
piece being in consequence at an angle to its
base of ninety degrees plus the degrees, that
25 the buckets are distant from one another on
the wheel-crown, as and for the purpose set
forth.

23. In a percussion water-wheel a pair of

buckets, the single members of which pair
have front edges, that form a parallelogram, 30
the plane of which parallelogram stands at
right angles to the wheel's plane of rotation,
and of which front edges one faces the central
division-line of the water-jet in the wheel's
plane of rotation, and a projecting piece on 35
the last-specified front edge of each member
of the pair, which projecting piece with its
sharp front edge, that faces the jet, divides
the water-jet centrally in the wheel's middle
plane of rotation, causing one half of the jet 40
only to enter into the cavity of one member
of the pair of buckets and the other half into
another member of a pair of buckets, such
members standing on different sides of the
middle plane of rotation of the wheel, and 45
which projecting piece has its outer face or
edge that is most remote from the center of
the wheel, at an obtuse angle to its base-line,
as and for the purpose set forth.

In testimony whereof I have signed my 50
name, in the presence of two witnesses, this
1st day of June, A. D. 1893.

FRANCIS M. F. CAZIN.

Witnesses:

G. H. STOCKBRIDGE,
C. L. BELCHER.