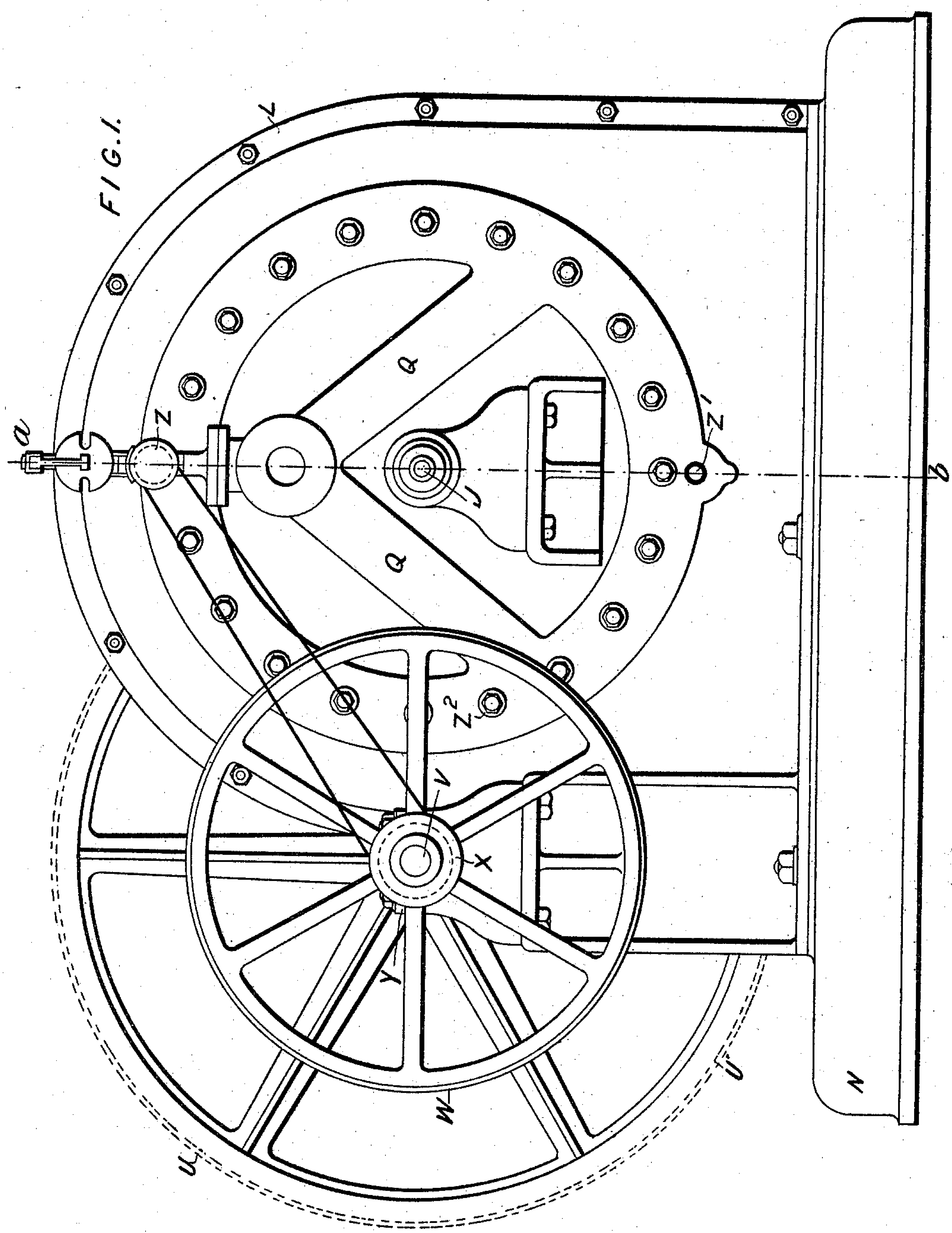
(No Model.)

8 Sheets—Sheet 1.

S. C. DAVIDSON.

IMPULSE TURBINE.

No. 584,578. Patented June 15, 1897.



WITNESSES:

Fred White

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INVENTOR:

Samuel Cleland Davidson,

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(No Model.)

8 Sheets—Sheet 2.

S. C. DAVIDSON.

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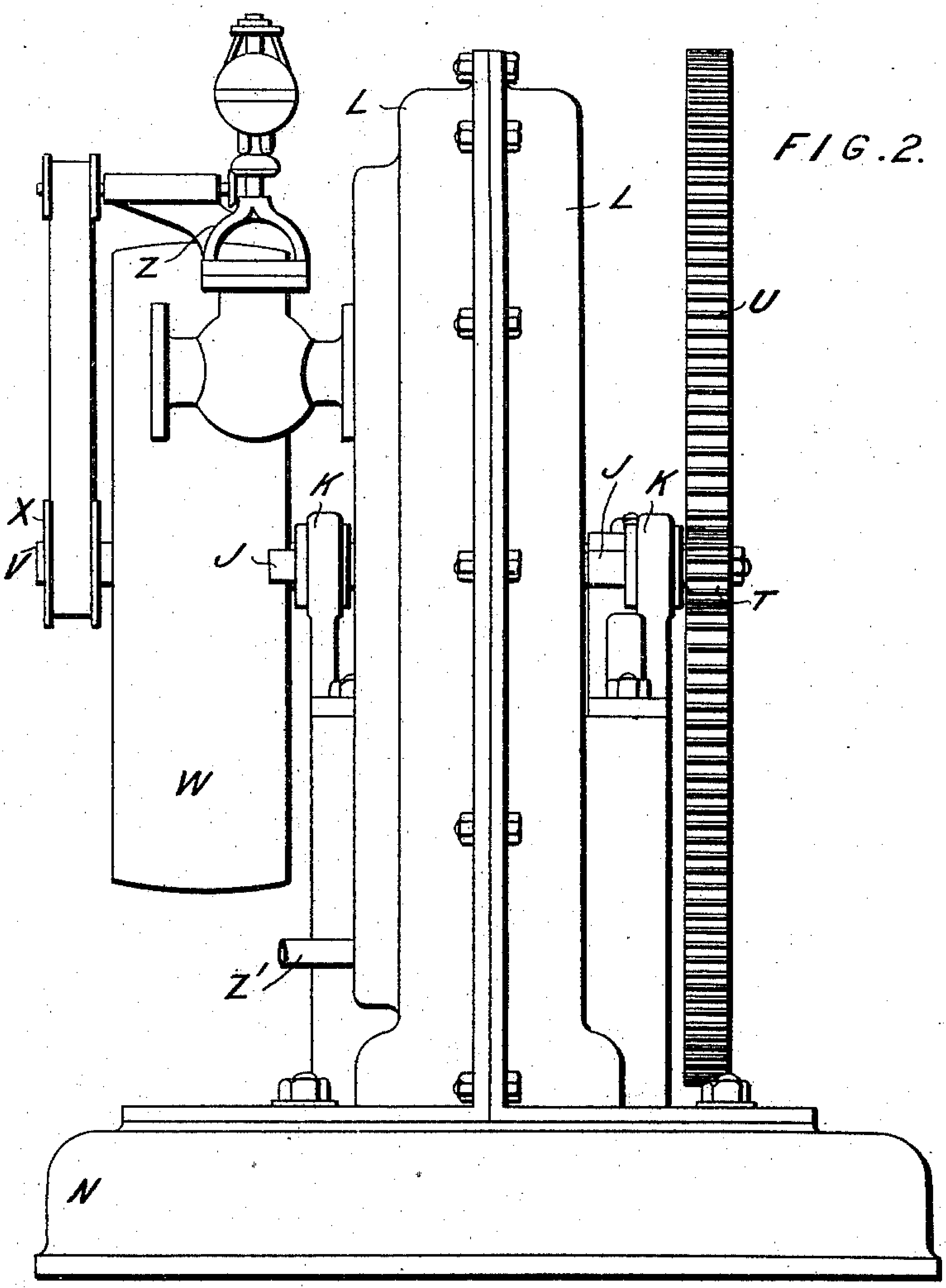

FIG. 2.

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(No Model.)

3 Sheets—Sheet 3.

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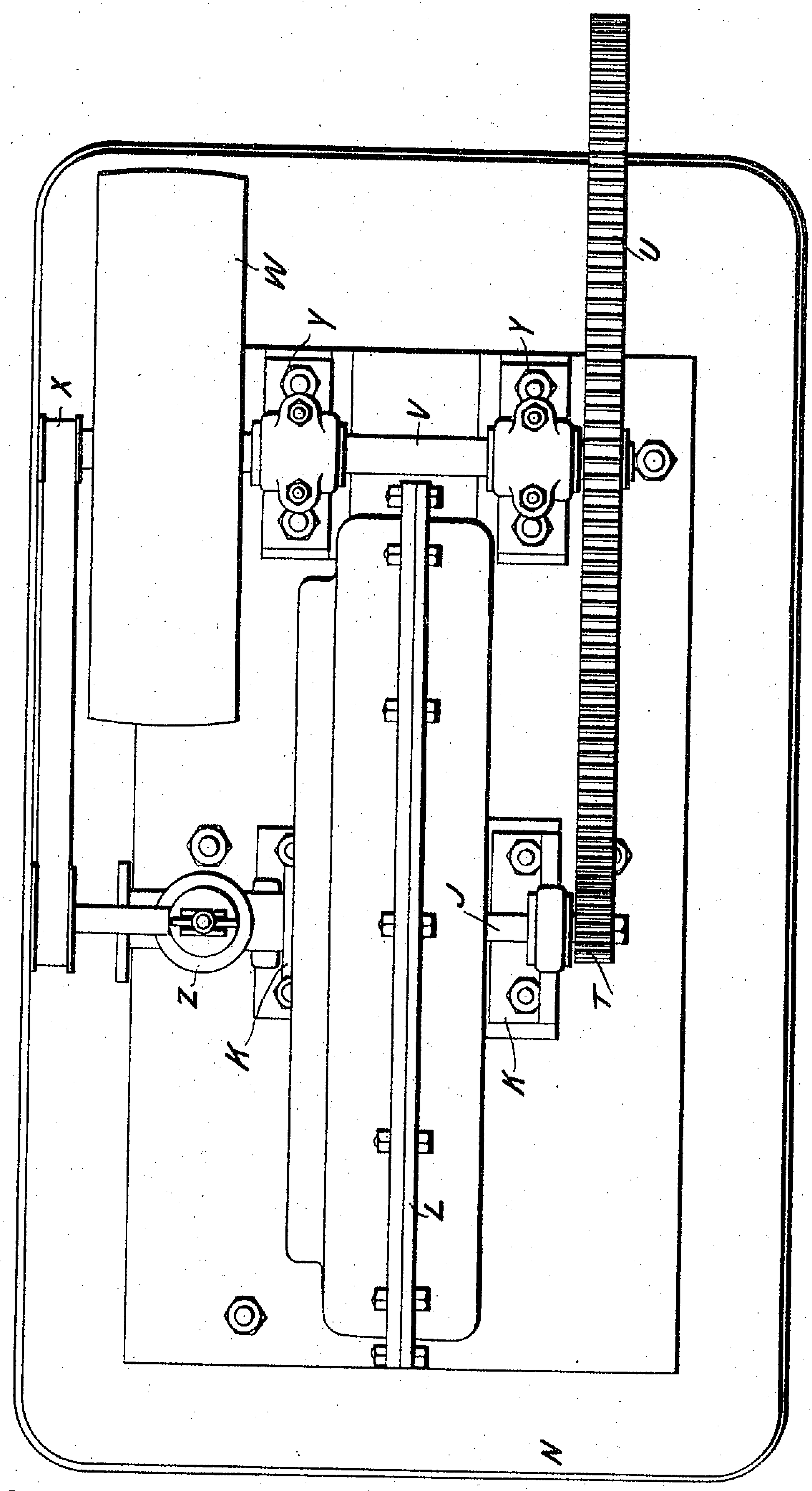

FIG. 3.

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(No Model.)

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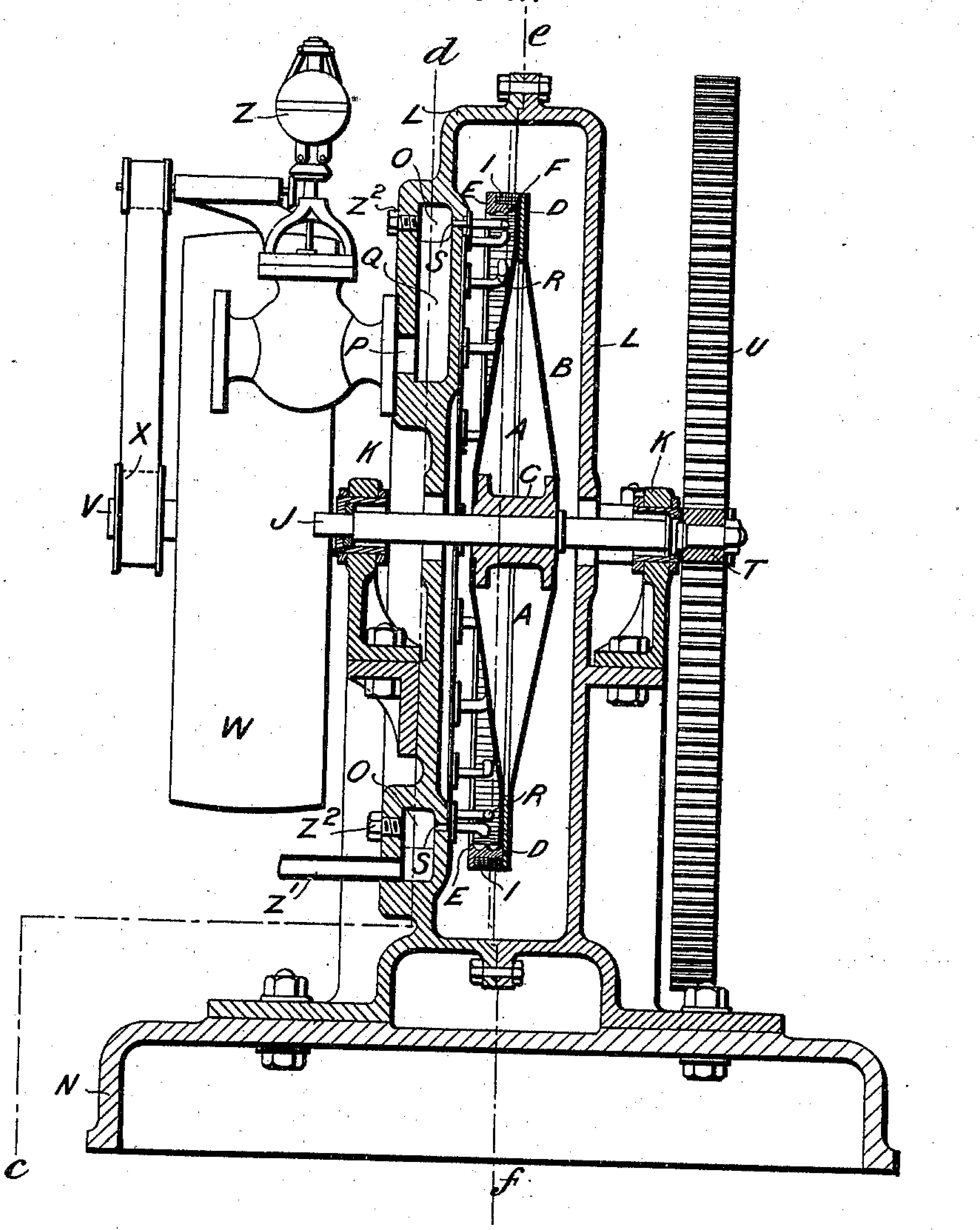
8 Sheets—Sheet 4.

IMPULSE TURBINE.

No. 584,578.

Patented June 15, 1897.

FIG. 4.



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8 Sheets—Sheet 5.

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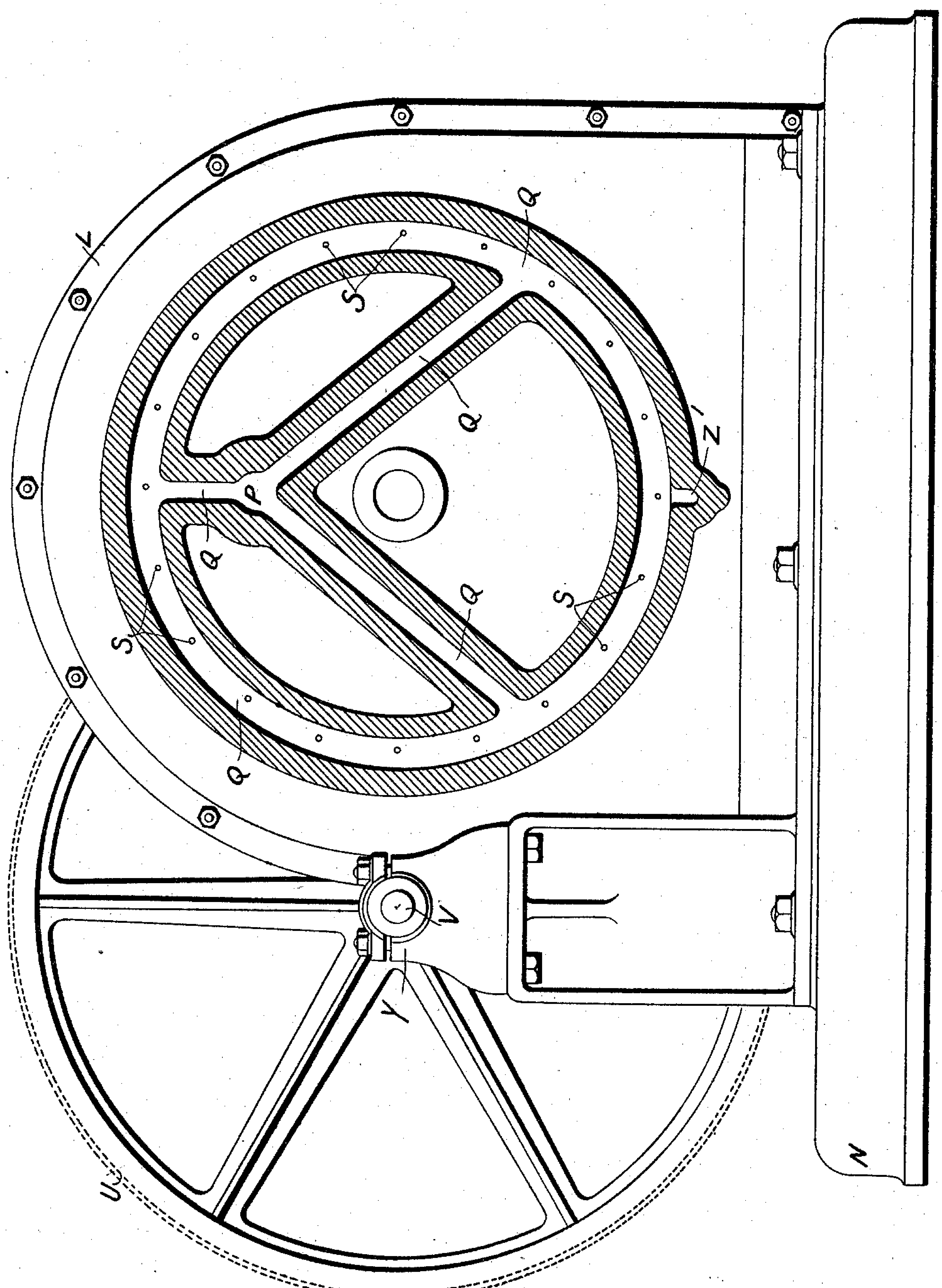
FIG. 5.



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(No Model.)

8 Sheets—Sheet 6.

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IMPULSE TURBINE.

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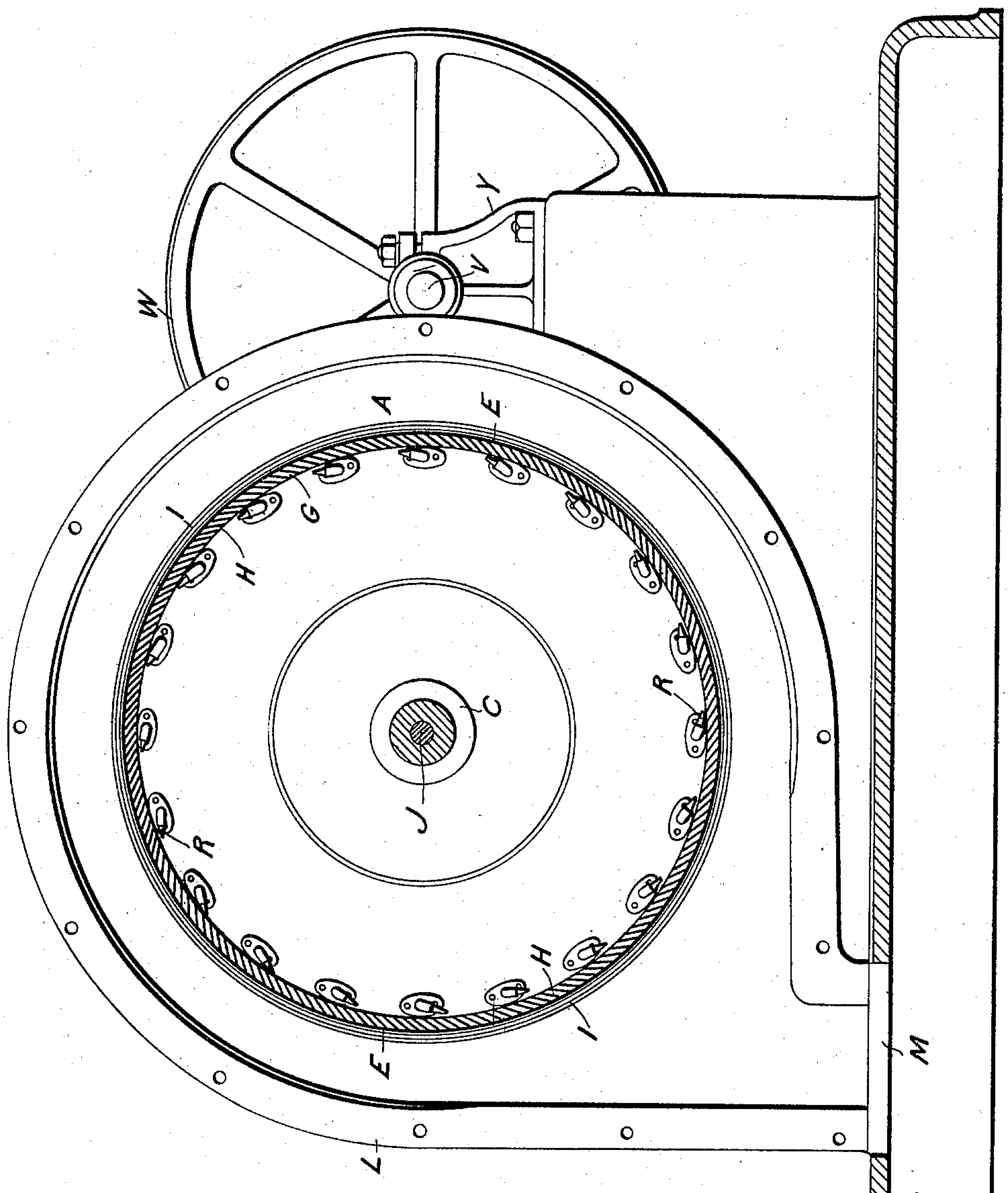
FIG. 6.



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(No Model.)

8 Sheets—Sheet 7.

S. C. DAVIDSON.

IMPULSE TURBINE.

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FIG. 7.

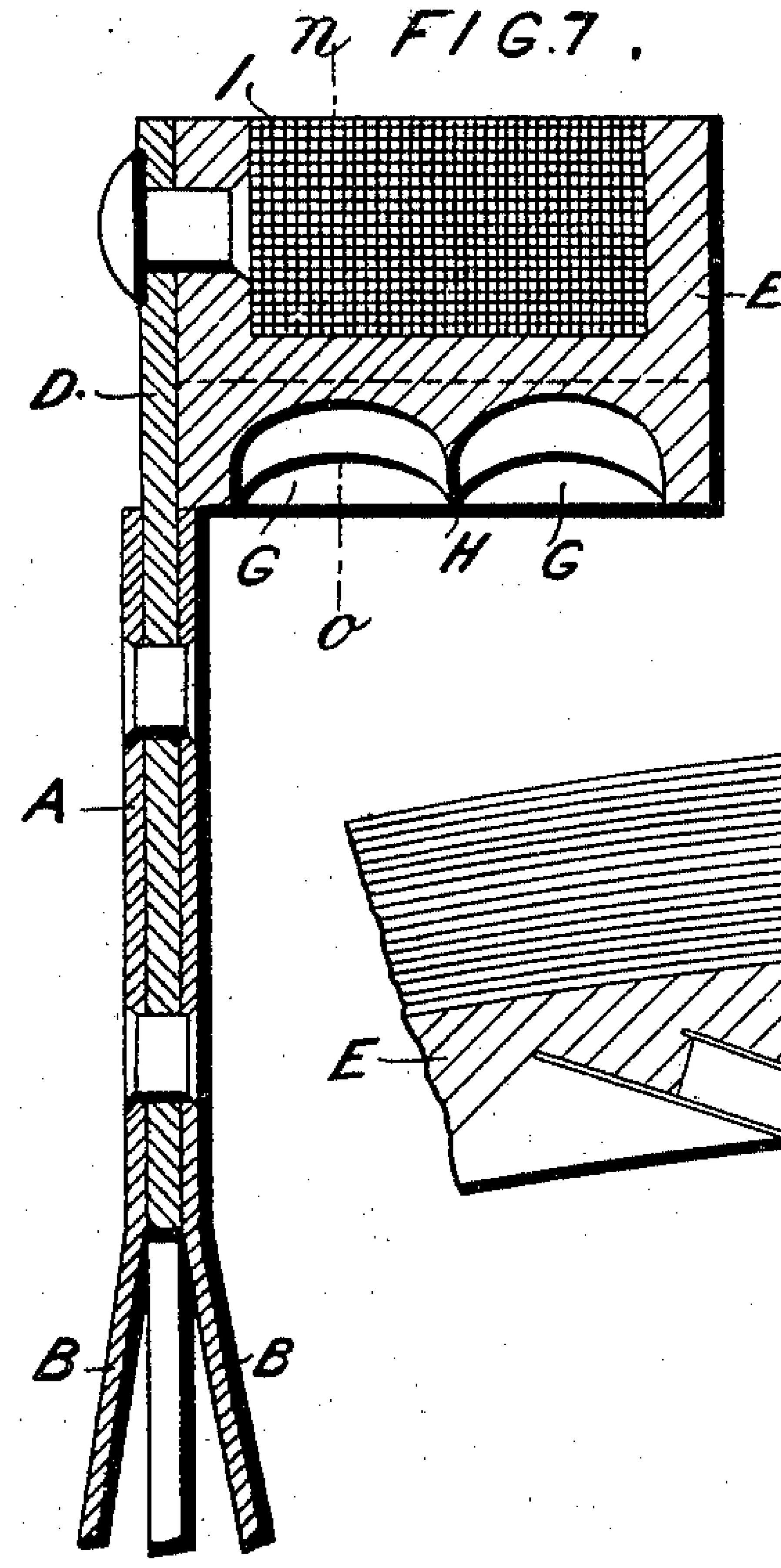
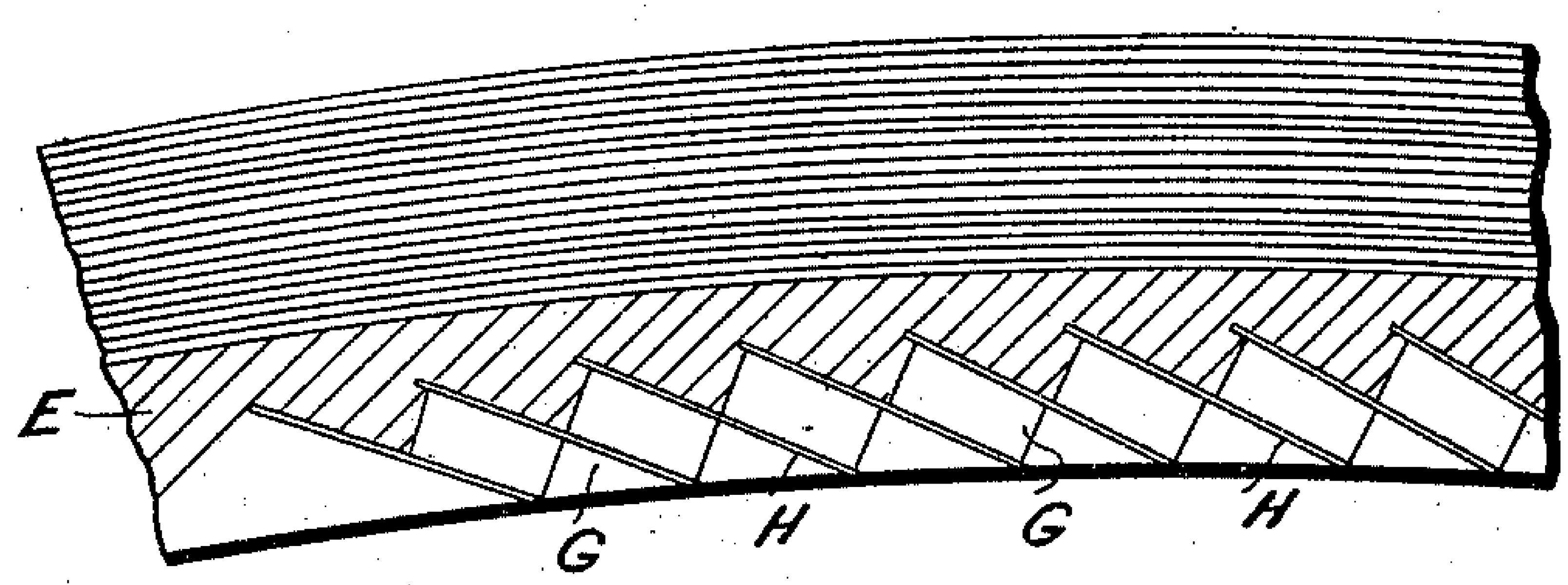


FIG. 8.



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(No Model.) 8 Sheets—Sheet 8.

S. C. DAVIDSON.

IMPULSE TURBINE.

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FIG. 9.

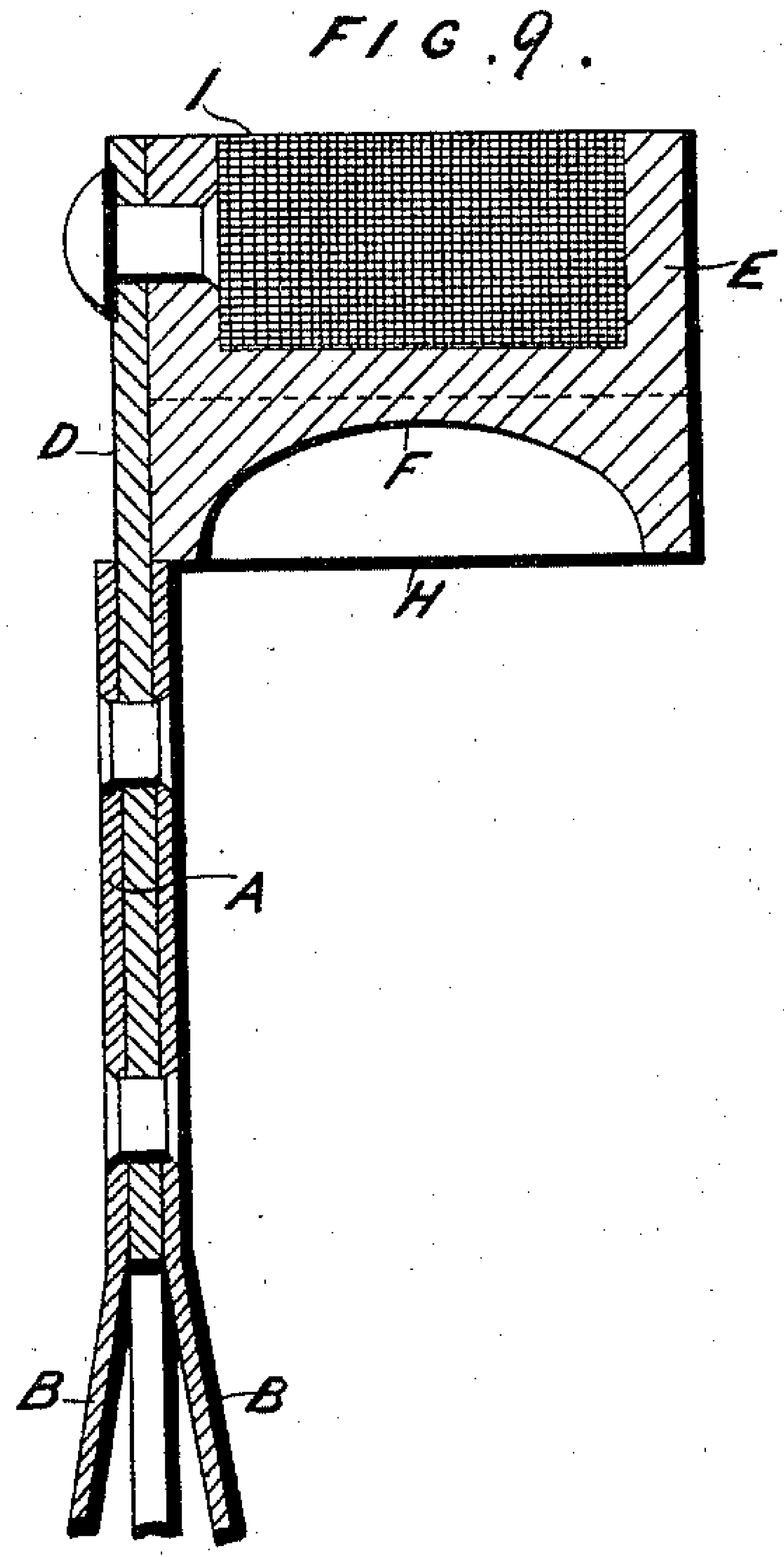
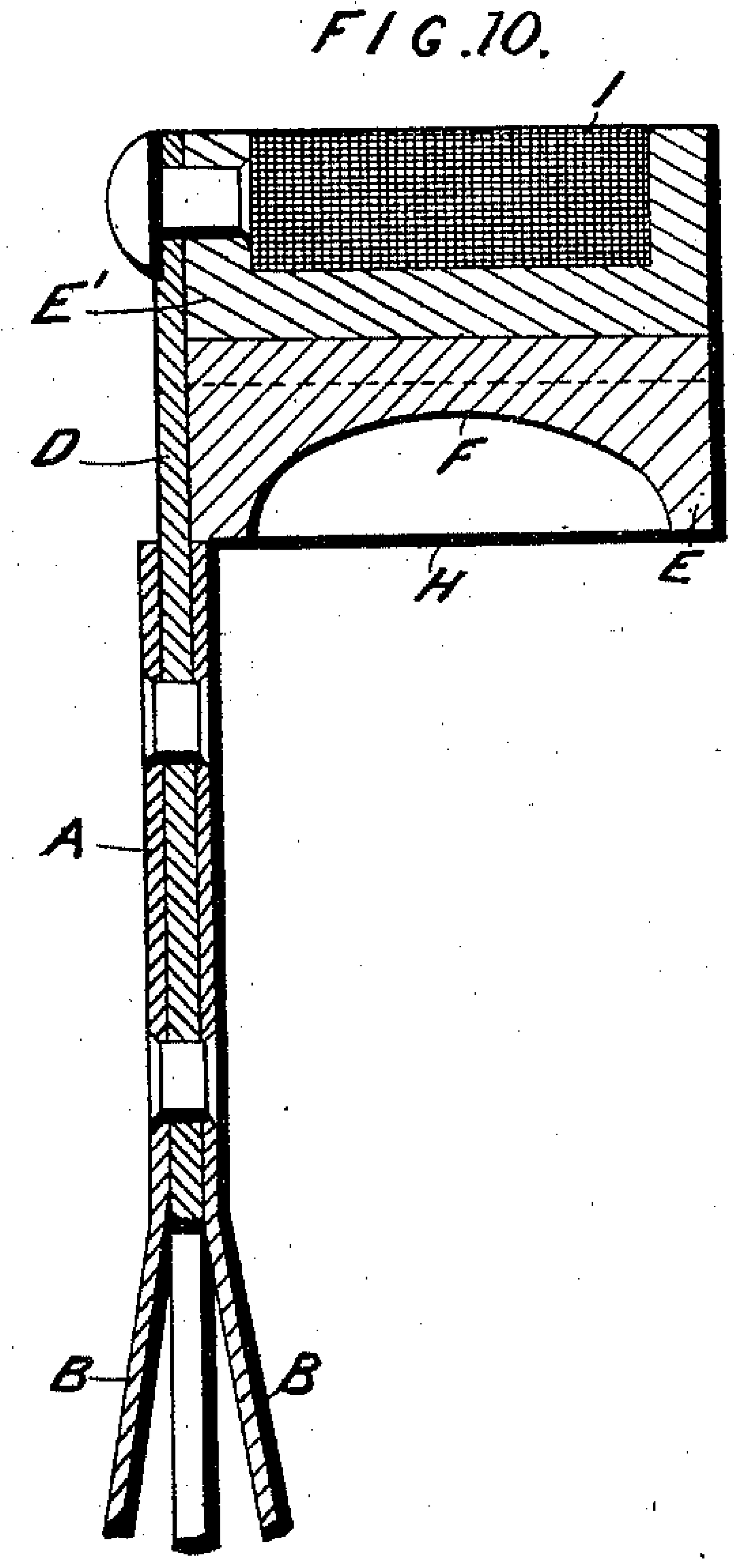


FIG. 10.



WITNESSES:

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UNITED STATES PATENT OFFICE.

SAMUEL CLELAND DAVIDSON, OF BELFAST, IRELAND.

IMPULSE-TURBINE.

SPECIFICATION forming part of Letters Patent No. 584,578, dated June 15, 1897.

Application filed August 7, 1896. Serial No. 602,005. (No model.)

To all whom it may concern:

Be it known that I, SAMUEL CLELAND DAVIDSON, of Belfast, Ireland, have invented certain new and useful Improvements in Impulse-Turbines, of which the following is a specification.

My improvements refer more particularly to the class or type of impulse-turbines in which motion is imparted thereto by water, steam, vapor, air, or gases (hereinafter called the "motive fluid") as jets from fixed nozzles within the periphery of the turbine into vanes or buckets therein, and in which class of turbines as hitherto ordinarily made the said motive fluid (usually water) passes from the inner to the outer edges of the vanes or buckets and escapes therefrom off the periphery of the wheel in what is known as "radial outward flow." In this form of turbines the aggregate curvature or deflection that said buckets impart to the motive fluid in passing through them seldom exceeds one hundred and forty degrees when the turbine is held stationary, while if revolving at working speed its absolute or actual deflection is only about one-half of the above, and therefore approximately only about seventy or eighty degrees. In the opinion of experts, however, the efficiency of turbines in respect of the action of the motive fluid on the vanes "depends only on the angles of entrance and exit and not on the intermediate form of the curve, assuming the latter to be continuous and the curvature not too abrupt," (*Bodmer on Hydraulic Motors*, page 21,) and, further, that to obtain the best possible results from the motive fluid used a deflection of about one hundred and eighty degrees ought to be effected in its path through the buckets, even when the turbine is revolving at full speed, and as in the turbines above referred to and as hitherto ordinarily made this amount of deflection is not accomplished. As their vanes are usually cast in as an integral part of the turbine they are consequently unduly thick for working advantageously with the very fine jets which have to be used when employing steam or extra-high pressures of water as motive fluid, and the said vanes have also a very considerable fan action on the surrounding atmosphere when the turbine is running at high speeds, whereby a further loss of efficiency in the power obtained is involved.

The objects (among others) of my hereinafter-described improvements in impulse-turbines are to obviate the above-mentioned defects, and for this purpose in my improved turbines I so construct the buckets that they work with water at extra-high pressures, (such as one thousand pounds and upward per square inch,) steam, vapor, air, or gases in the form of jets from fixed nozzles within their circumferential line around the periphery of the wheel and cause a deflection thereof in passing through them of on or about one hundred and eighty degrees, even when the turbine is revolving at full working speed. In my construction of buckets the vanes or diaphragms forming the dividing-walls between the buckets are very thin, so that a maximum number of buckets may be employed around the periphery of the wheel consistent with the minimum pitch between the vanes, being sufficient to avoid any undue friction in the passage of the motive fluid through the buckets, and, further, the vanes have almost no fan action on the surrounding atmosphere, while at the same time they are held so strongly on the wheel that they themselves and the turbine as a whole have ample strength to withstand the enormous centrifugal force developed when the turbine is running at full speed, more especially when steam is used as the motive fluid.

In constructing my improved turbines I preferably make the central part of the wheel (hereinafter called the "turbine" wheel) either as a disk annulus mounted on the arms or spokes of the wheel or between a pair of disks diverging toward the center and riveted to a central hub keyed on the turbine-shaft or as a solid disk similarly mounted on the said shaft or spindle and with a flange or rim (hereinafter called the "annular" rim) attached to the periphery of the said disk annulus or solid disk, so as to form a flange thereon, and in the said annular rim the buckets are formed by one or more circumferential and suitably-shaped concave grooves, formed, preferably, by turning them in the central part of the inner face of the annular rim, (and hereinafter called the "rim-grooves,") with thin sheet-metal diaphragms or vanes (hereinafter called the "bucket-vanes") inserted into slits or cuts (hereinafter called the "cross-cuts") incised across the inner face of the annular rim to the bottom of the said rim-grooves, and into which cross-cuts the bucket-vanes fit firmly, whereby the said rim-grooves are divided into a series of buckets; and I preferably set the bucket-vanes at such an angle with the inner face of the annular rim that when they come opposite to any of the jets of motive fluid driving the turbine they are approximately in parallel line therewith or only face the same to the extent of a few degrees, and the cross-section of the concave curve in the rim-groove is such that the line of junction between it and the transversely-inserted bucket-vanes forms an axially-directed semicircular or semielliptical curvature which constitutes the back of the buckets and around which the path of the motive fluid is directed in passing through the buckets. The diameter of this curvature I preferably make equal to about four to six times the cross-sectional thickness of the jet of motive fluid at the time of its entry thereto, in practice, however, commencing with a minimum diameter of at least half an inch for the smallest sizes of jets used therewith, and the distance apart between the bucket-vanes constitutes the pitch or length of the buckets as measured around the rim. This length I preferably adjust so that the clear width of entrance for the jets of motive fluid between the bucket-vanes is equal to about one-half the cross-sectional diameter of the jets of motive fluid at the time of their entry into the buckets, in practice, however, commencing with a minimum space of at least one-eighth of an inch between the bucket-vanes for the smallest sizes of jets used therewith. I may also alternatively construct my herein-described improved impulse-turbines with two of the said rim-grooves so located side by side in the annular rim that when each is turned out to its proper concave curvature in the inner face thereof their curves meet or cut into one another at their inner edges, whereby a sharp wedge-like projection is formed between them, and which edge is preferably a little below the exposed edge of the bucket-vanes when inserted, as hereinbefore described, across the double groove thus formed. The jets of motive fluid on being directed upon the said short projecting edge between the grooves are split thereby to right and left into the axially-directed curvatures forming the back of the buckets between the vanes in each of the rim-grooves, so that a double-acting bucket is formed by this combination of double rim-groove with the bucket-vanes, from which the return current of the motive fluid is discharged inwardly from the bucket in approximately equal parts from its opposite ends, and I connect the wheel-body to the rim at one side of the line of this discharge, so that there is no interference with the free discharge from both buckets inwardly. On the outer face of said annular rim either a metal ring is shrunk on over same or a coil of wire is wound tightly around it in order to bind in the annular rim, so that its divided parts between the inserted vanes on its inner face shall be sufficiently compressed thereon to hold them rigidly in position and to impart sufficient strength to the annular rim and to its contained vanes to enable it as a whole to withstand the centrifugal bursting force developed by the enormously-high velocities at which the same must necessarily revolve when working with steam or with high-pressure hydraulic jets of about one thousand pounds and upward as motive fluid. As the cross-cuts for the inserted vanes are only incised to the bottom of the rim-grooves across the inner face of the annular rim the outer face of the annular rim thus forms of itself a solid ring around the buckets, and when this is further strengthened by a shrunk-on metal ring its outer side is turned as a plain flat surface, but when a coil of wire is employed in lieu of a metal ring the said outer face is grooved in the center, so that a flange is formed on each side to laterally hold in the coils of wire when wound around it, and as the centrifugal force acting on the divided parts of the annular rim and on the vanes between same tends to force them in an outward direction the effect of this is only to tighten both more firmly together when the wheel is revolving at its highest speed. This form of turbine wheel, with its buckets on the inner face of the rim, is therefore specially suitable for steam-driven turbines in which the revolving velocity and centrifugal force thereby developed are so enormously high.

A further advantage of the inward-acting buckets for the employment of steam as motive fluid is that the specific gravity of steam is less than that of the atmosphere, and consequently the centrifugal force developed when the turbine is running at extremely high speeds causes the steam, after passing around the curvature of the buckets, to be displaced inwardly therefrom by the greater specific gravity of the atmosphere, so that it freely rebounds inwardly out of the buckets without any tendency to residual lodgment or carrying around therewith and to which it consequently imparts its kinetic energy with almost full theoretical efficiency. When extra-high pressures of water, such as one thousand pounds and upward per square inch, are employed, this form of turbine also gives great efficiency, owing to the fact that such jets burst into fine spray almost like steam and freely rebound inwardly from the buckets in a similar manner, and in order to prevent the return current from the ends of the buckets next the turbine wheel striking its disk or arms and being thrown thereby back against the buckets I apply an annular deflecting duct or guide within the interior circumference of the jet-nozzles, with its edge projected sufficiently beyond the interior ends of the buckets to intercept the return current of the motive fluid therefrom and guide it toward the side of the casing, so that it is directed to the exhaust-pipe clear of the wheel-buckets.

According to another feature of improvement in the construction of the buckets in my improved impulse-turbines, instead of turning out the rim groove or grooves, forming the axially-directed back curvature of the buckets as a continuous concave groove around the inner face of the annular rim, whereby the circumferential line of the same is at an acute angle to the face of the bucket-vanes and an obtuse angle to the back thereof, I form the axially-directed back curvature of the buckets substantially at right angles to the back of each bucket-vane by substituting for the said continuous rim-groove a series of similarly-sized, equidistant, and preferably milled-out semicircular-faced steps around the central part of the interior face of the rim, each of which steps is of a depth equal to about one-half diameter of the jet of motive fluid employed with the same at the time of its entry into the buckets, but in practice commencing with a minimum of at least one-eighth of an inch for the smallest jets used therewith. In front of each step there is a flat plane the line of which is at such an angle with the rim of the wheel that it is approximately parallel with that of the jets of motive fluid when opposite the same, so that the said jets may impinge direct into the concave curvature formed by the semicircular face of each step without any material deflection thereof by said plane, on the face of which a thin sheet-metal vane is closely fitted by inserting it into cuts incised across the face of the annular rim from edge to edge in corresponding line with said planes and extended sufficiently back past the face of each step for the inserted edge of the vanes to be quite covered thereby.

I preferably form the back concave curvature of each step in pairs, located sufficiently closely together for their inner curves to meet in a sharp wedge-like projection, whereby double return-buckets are formed between each pair of vanes, as hereinbefore referred to. The outer ends of the vanes and the divided parts of the rim between the vanes are also similarly compressed upon the vanes to securely bind them together as a whole by a shrunk-on metal ring or coil of wire.

With my improvements in the construction of the buckets it will be evident that as there is no exterior exit from the buckets toward the periphery of the wheel there can be no outward discharge of air therefrom, and consequently they can have no fan action on the surrounding atmosphere, and as the vanes are sloped backward from the direction in which the wheel is running they act with a minimum of friction upon the atmosphere through which they pass when the wheel is revolving.

It will also be obvious that as the path of the motive fluid through the buckets is deflected round a semicircular or semielliptical curvature it necessarily returns therefrom in a line practically parallel with and in opposite direction to that of the initial flow of the jet, and as it takes place in an inward direction tangential to a circle to which the line of the vanes and of the jet (as these coincide) are also tangential the forward movement of the wheel between the time that the motive fluid enters the bucket and its return flow therefrom does not alter this tangential direction of the vanes. Consequently the return flow of the motive fluid still takes place in the direction of the nozzle from which the jet issued, so that a deflection of about one hundred and eighty degrees is continuously maintained, even when the turbine is running at full speed, and as the impulse of the motive fluid is communicated to the buckets of my herein-described improved turbines from within the line of their inner circumference and is also returned back again therefrom in an inward direction opposite to that of its initial flow they may consequently be appropriately termed "intro-impulse" turbines.

In the accompanying drawings, Figure 1 is a front elevation, Fig. 2 is a side elevation, and Fig. 3 a plan, of a turbine constructed in accordance with the preferred form of my invention. Fig. 4 is a cross-section taken through line *a b* of Fig. 1. Fig. 5 is a section through line *c d* of Fig. 4. Fig. 6 is a section through line *e f* of Fig. 4. Fig. 7 is a cross-section through the annular rim and buckets shown in Figs. 4 and 6, showing, on a large scale, the preferred construction, in which the faces of the curves at the back of the buckets are at right angles, or nearly so, to one face of the vanes. Fig. 8 is a section through line *n n* of Fig. 7, showing a portion of the turbine-wheel rim and buckets. In the construction shown in Figs. 1 to 8 the annular rim is fixed to one side of the turbine wheel and is formed with two rim-grooves. Fig. 9 is a cross-section through the annular rim of a turbine wheel, showing a modification in which single buckets are employed and the annular rim is fixed direct to the annulus. Fig. 10 is a cross-section through the annular rim of a turbine wheel with single buckets, showing a modification in which the annular rim is held by a shrunk-on metal ring E′ with its outer circumference formed as a channel for the reception of binding-wire. This type of wheel may, however, be made with a plain metal ring and without binding-wire.

A is the turbine wheel complete, which is made up of dished disks B, boss C, and disk annulus D, to which is fixed the annular rim E, with circumferential grooves F on its inner face and divided into spaces or buckets G by the insertion of vanes H, set, preferably, in approximately parallel line with that of the jets of motive fluid acting on the buckets. The outer circumference of the annular rim E is shown grooved or constructed in the form of a channel to receive and keep in position a coil of binding-wire I.

A deflecting-guide is formed in any suitable manner inwardly of the buckets G and their jet-nozzles for directing the discharge from the buckets outwardly and preventing its crossing to and interfering with opposite buckets. This can be formed in any suitable way and on any suitable part, but I prefer to form it on the wheel by making it a part thereof, preferably using one of the disks B for this purpose.

As shown in Fig. 4, the disk nearest to the rim E is dished outwardly from near the rim, where it is inwardly of the discharge from the innermost bucket to near the axle, where it is outwardly from the discharge of the outermost buckets, so that none of the discharge from either of the buckets can pass directly across the wheel to the opposite buckets thereof.

The wheel A is mounted on and fixed to the turbine-shaft J, which may be carried in any suitable bearings, but is herein shown as mounted in ball-bearings K, supported on the outsides of the turbine-casing L, which is preferably made in two parts for convenience of manufacture, with an exhaust or discharge outlet M and mounted on a bed-plate N. In one side of the turbine-casing L a duct O is constructed and connected with the motive-fluid inlet P by branch ducts Q, along which the motive fluid is conducted to the bent and pointed nozzles R, fixed to the outer side of the duct O, which faces the turbine through small openings or orifices S, the nozzles R having a corresponding hole or passage right through them, with suitably-proportioned orifices at their points.

On one end of the turbine-shaft J is fixed a pinion T, which gears into a spur-wheel U, mounted on a shaft V, to which are fixed the driving-pulley W and the governor-pulley X, and which shaft V is carried in bearings Y, supported by the casing L.

Z is an ordinary form of governor and throttle-valve and is fixed over the inlet P for the purpose of regulating the admission of motive fluid to the nozzles R, and thus controlling the speed of the turbine wheel A.

Z′ is a drain or blow-off pipe through which, when steam is the motive fluid used, the condensed steam may be drained off at intervals by the employment of an ordinary blow-off cock, or any sediment which may have been carried into the duct O with the motive fluid can be blown off, and thus minimize the possibility of any sediment stopping up the orifice of the nozzles R.

Z^2 Z^2 are plugs screwed into the outside of the casing L, each one immediately opposite to one of the openings or passages S, so that when unscrewed and removed they permit of a wire being passed through the orifice of the nozzle R to clear away any dirt that may have been lodged therein.

The action of the turbine may be described as follows: The motive fluid first passes through the governor or throttle-valve Z into the inlet P, along the branch ducts Q into the duct O, and passing through the small openings or passages S to the nozzles R, from the pointed ends of which it issues as jets, which are directed into one end of the buckets G, and after traversing same round the semicircular or semielliptical curvature forming the back thereof is discharged at the opposite end of the bucket in a line approximately parallel with and in opposite direction to that of its initial flow, whereby the kinetic energy of the motive fluid is imparted to the turbine wheel with a maximum of efficiency and the rotation of the turbine wheel A is thus effected on its shaft J, on which the pinion T is mounted, so as to engage the spur-wheel U, mounted on the driving-shaft V, whereby the velocity of revolution of the turbine wheel is suitably reduced and the power equivalently increased in the driving-shaft V, on which the driving-pulley W may be mounted.

The discharge from the buckets is so guided or conducted after leaving the latter that it cannot reach opposite buckets and cannot interfere with the revolution of the wheel or the operating-jets, the guide or deflector disk B crossing within the rim sufficiently to intercept and deflect or guide the discharge from within the interior circumference of the jet-nozzles, with its edge projecting sufficiently beyond the interior ends of the buckets to intercept the return current of the motive fluid therefrom and guide it toward the side of the casing, so that it is directed to the exhaust-pipe clear of the wheel-buckets.

While the modifications of my invention as above described, and represented in the accompanying drawings, illustrate different methods of applying the leading features of my invention in impulse-turbines, I do not limit myself to the particular details of construction as therein embodied.

What I claim, and desire to secure by Letters Patent, is—

1. In impulse-turbines in which the initial flow of the motive fluid driving the same is directed into the buckets from one or more jet-nozzles within their inner circumference and in which both the flow and the return current are on the same side of the disk or arms of the turbine wheel, the combination with the body of the turbine wheel of an overhanging annular rim revolving therewith, a circumferential concave groove of approximately semicircular cross-section in the inner face of said rim, thin sheet-metal vanes dividing said groove into buckets said vanes being inserted across said groove into slits cut transversely across the inner face of said rim to the full depth of said groove and at

such an angle to the inner face of said rim that when said vanes come opposite the jets of motive fluid driving the turbine they are approximately in parallel line therewith whereby the motive fluid in passing from the inlet to the outlet end of a bucket is deflected axially around said curve and the return current is discharged inwardly therefrom in a line approximately parallel with and in opposite direction to that of its initial flow, and a band around said rim compressing and holding together the said vanes and the divided portions of said rim, substantially as and for the purpose set forth.

2. In impulse-turbines in which the initial flow of the motive fluid driving the same is directed into the buckets from one or more jet-nozzles within their inner circumference and in which the turbine wheel has an overhanging annular rim formed with a circumferential concave groove of approximately semicircular cross-section in its inner face as and for the purpose set forth, the combination with said rim and its circumferential groove of a second similar groove in said rim parallel with the first-described groove and in sufficiently close proximity to it that their curves meet in a sharp edge and form a wedge-like projection between the two grooves, and thin sheet-metal vanes dividing both of said grooves into buckets said vanes being inserted across said grooves into slits cut transversely across the inner face of said rim to the full depth of said grooves and at an angle as described whereby when the jets of motive fluid are directed upon the edge between the two grooves said edge divides it between the two grooves and it is discharged inwardly of the rim from the opposite ends of the double buckets thereby formed in a line approximately parallel with and in opposite direction to that of its initial flow and a wheel-body carrying said rim and connected thereto at one side of the discharge from said buckets, substantially as and for the purpose set forth.

3. In impulse-turbines in which the initial flow of the motive fluid driving the same is directed into the buckets from one or more jet-nozzles within their inner circumference, the combination with the body of the turbine wheel of an overhanging annular rim revolving therewith, a successive series of semicylindrical concave-faced steps around the inner face of said rim the concave face of each step forming a back curvature thereof and each of which steps is at right angles to the line of the jets of motive fluid when opposite same, thin sheet-metal vanes dividing said concave-faced steps into buckets, said vanes being inserted into slits cut transversely across the inner face of said rim to the full depth of said concave-faced steps and at such an angle to the inner face of said rim that when said vanes come opposite the jets of motive fluid driving the turbine they are approximately in parallel line therewith, whereby the motive fluid in passing from the inlet to the outlet end of a bucket is deflected axially around the concave face of each step, and the return current is discharged in a line approximately parallel with and in opposite direction to that of its initial flow, and a band around said rim compressing and holding together said vanes and the divided portion of said rim, substantially as and for the purpose set forth.

4. In impulse-turbines in which the initial flow of the motive fluid driving the same is directed into the buckets from one or more jet-nozzles within their inner circumference, the combination with the body of the turbine wheel having an overhanging annular rim revolving therewith, having a successive series of concave buckets around its inner face forming a back curvature thereof, and a jet-nozzle discharging outwardly within said rim into said buckets whereby the motive fluid is deflected axially around the concave face of each bucket and the return current is discharged inwardly in a line approximately parallel with and in opposite direction to that of its initial flow, of a deflecting-guide within the wheel inwardly of said nozzle and buckets, for intercepting the return flow from the latter and directing it clear of such buckets, substantially as and for the purpose set forth.

In witness whereof I have hereunto signed my name in the presence of two subscribing witnesses.

SAMUEL CLELAND DAVIDSON.

Witnesses:
GEORGE GOOLD WARD,
HUGH TAYLOR COULTER.