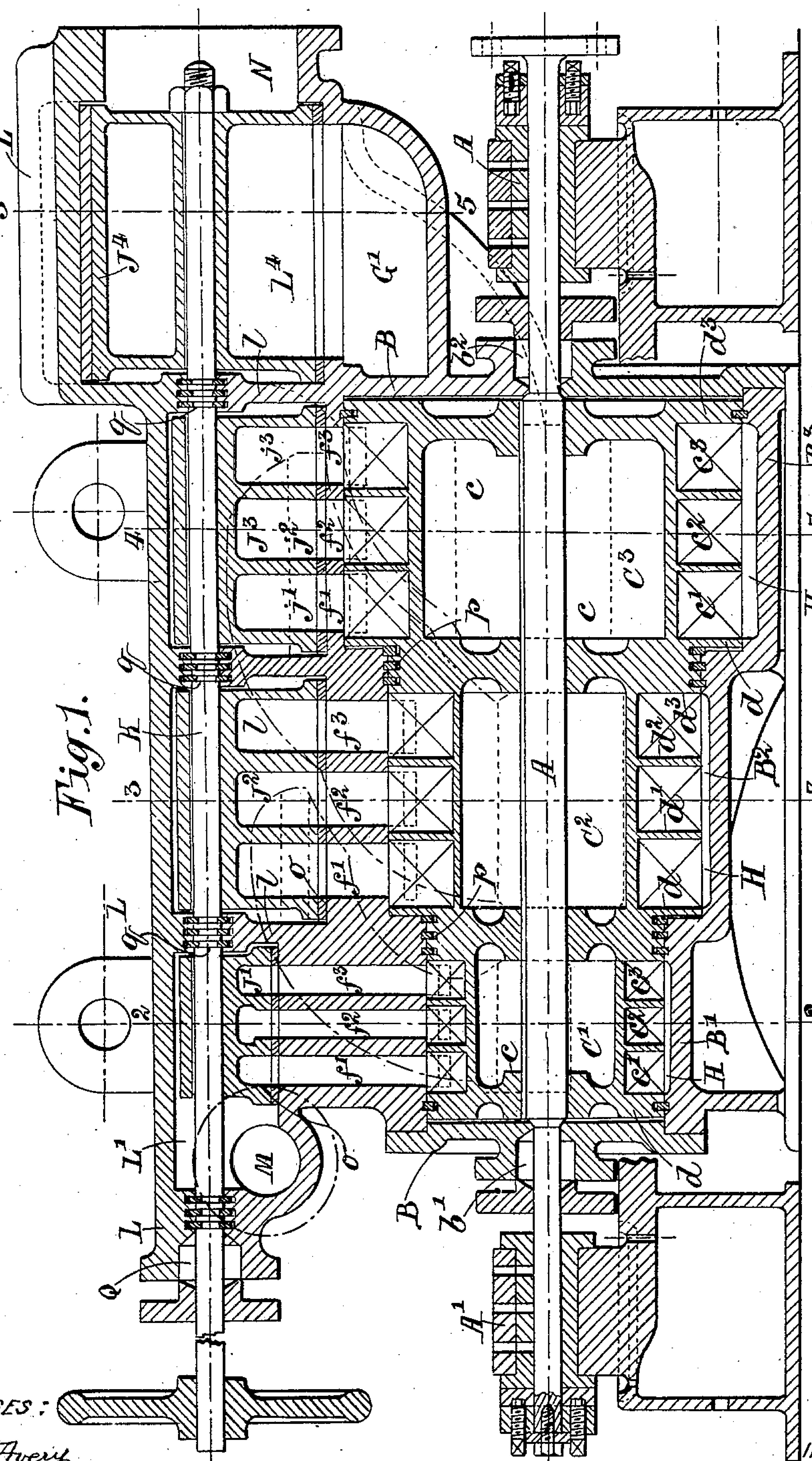
No. 854,482. PATENTED MAY 21, 1907.

W. C. GARDINER.

REVERSING STEAM TURBINE.

APPLICATION FILED JULY 31, 1906.

3 SHEETS—SHEET 1.



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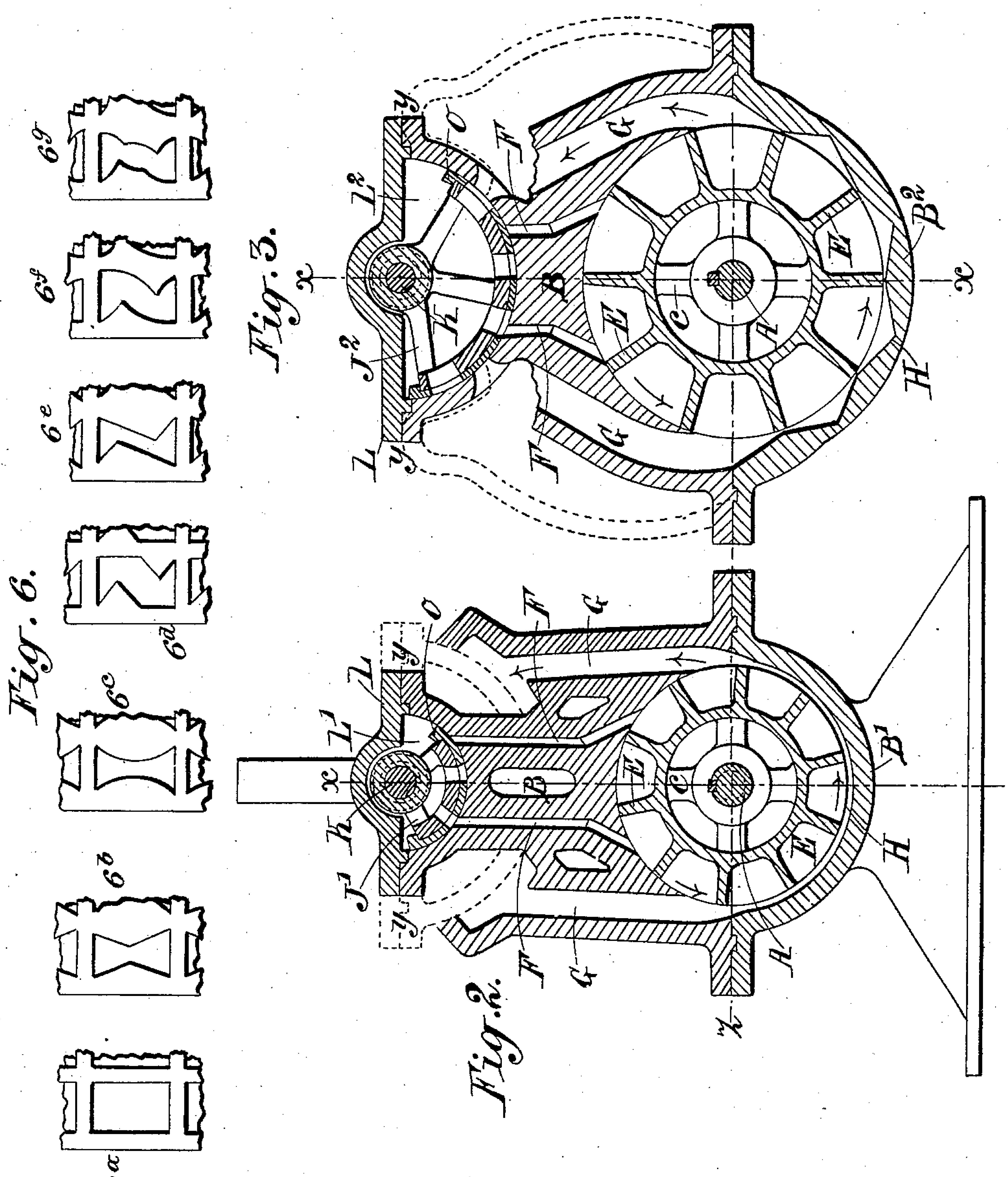

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3 SHEETS—SHEET 3.

Fig. 4.

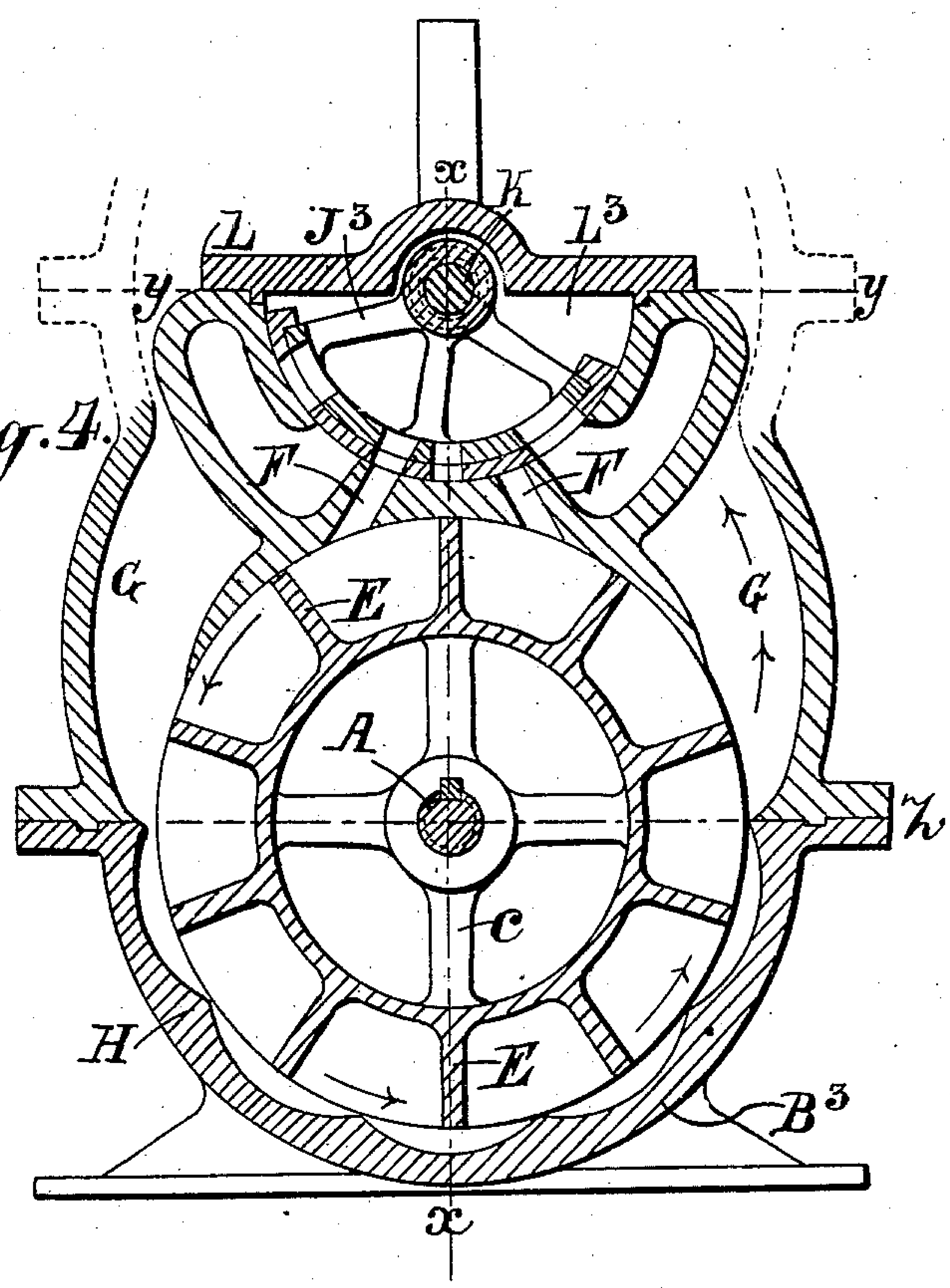
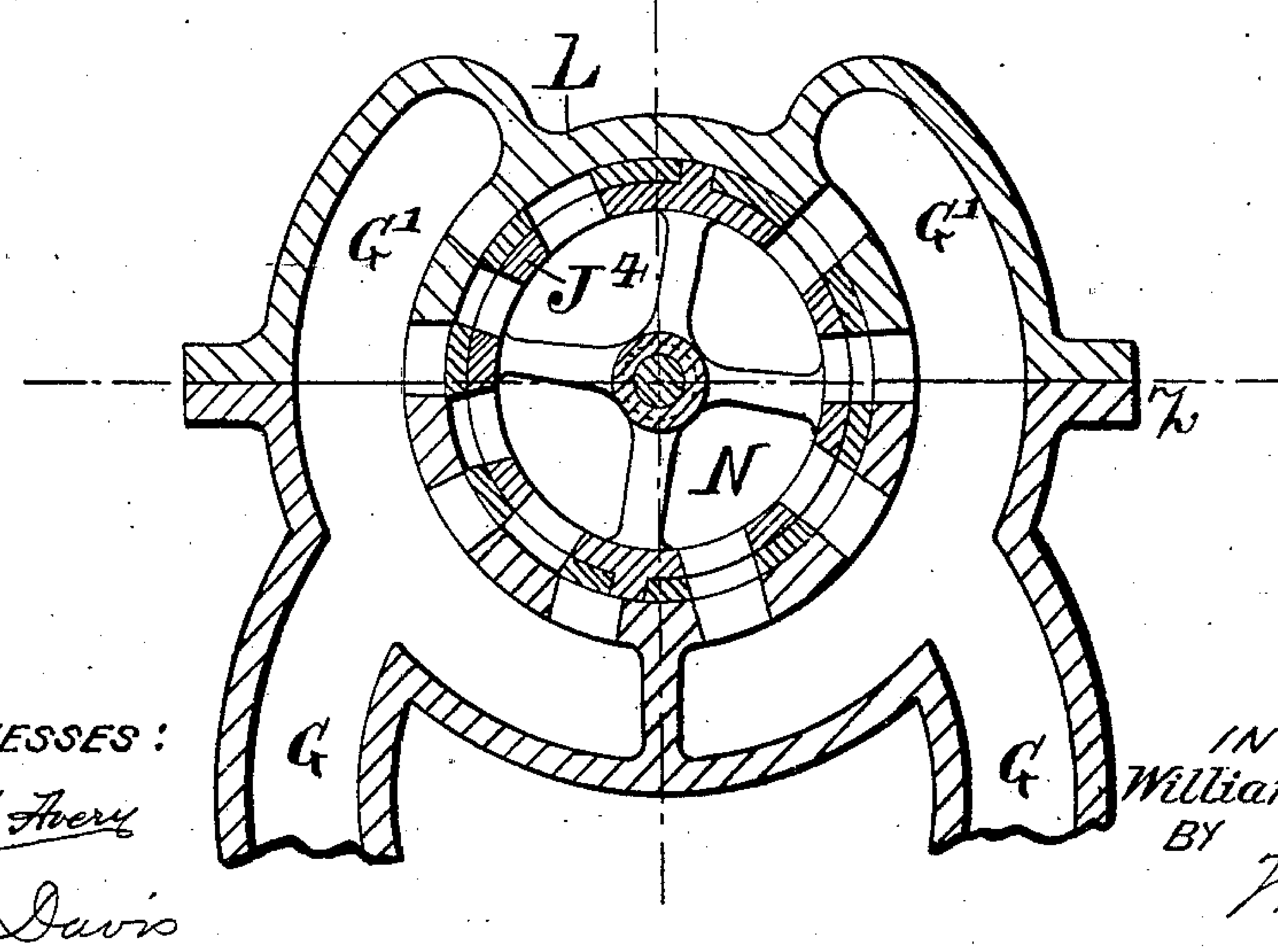


Fig. 5.



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UNITED STATES PATENT OFFICE.

WILLIAM CHARLES GARDINER, OF ABERDEEN, SCOTLAND.

REVERSING STEAM-TURBINE.

No. 854,482. Specification of Letters Patent. Patented May 21, 1907.

Application filed July 31, 1906. Serial No. 328,498.

To all whom it may concern:

Be it known that I, WILLIAM CHARLES GARDINER, a subject of the King of Great Britain, residing at 17 St. Clement street, Aberdeen, Scotland, marine engineer, have invented an Improved Multiple-Expansion Reversing Steam Turbine or Rotary Engine, of which the following is a specification.

This invention relates to multiple expansion reversible steam turbines wherein rotary distribution valves are employed for the purpose of varying the expansion of the steam and determining the direction of revolution of the rotor.

In the accompanying drawings Figure 1 is a central vertical longitudinal section (through the steam inlet ports) of a horizontal triple-expansion reversible steam turbine embodying the improvements which form the subject of the present invention, Figs. 2, 3, 4, and 5 being transverse sections on lines 2—2, 3—3, 4—4 and 5—5 respectively of Fig. 1. In Fig. 6 are shown, by way of example, a series of modified forms of bucket.

Similar letters of reference denote corresponding parts throughout the drawings.

A is the rotor shaft, which is arranged axially of the cylindrical body portion of the turbine casing B and passes out through stuffing boxes b^1 b^3 in the end covers thereof, the shaft being journaled, externally of the casing, in bearings A^1 A^2. The rotor comprises (for a triple-expansion turbine as illustrated) a series of three bucket wheels C^1 C^2 C^3 mounted fast, side by side, upon the shaft A so as to revolve in corresponding chambers B^1 B^2 B^3 in the casing, the second and third bucket wheels C^2 C^3 being of progressively increased diameter and their chambers B^2 B^3 correspondingly enlarged to accommodate them.

According to the present invention each bucket wheel C^1 C^2 C^3 is made of a breadth considerably greater in the direction of the rotor axis than has heretofore been usual in turbines of this class, the increased breadth being divided, in the case of each wheel, into a series of sections c^1, c^2 c^3 (three being shown in the example illustrated) by means of partitions d^1 d^2 which, like the outer ends d d^3 of the bucket wheels, are disposed in planes perpendicular to the rotor axis. The several sections c^1 c^2 c^3 of each wheel are preferably (as shown) of the same breadth and diameter, while the successive wheels C^1 C^2 C^3 are of progressively increased diameter, or breadth, or both, in order to afford space for the expansion of the steam as it passes from one bucket wheel chamber to the next. For the same reason the buckets of successive wheels may be of progressively increased depth.

The buckets in each circumferential series constituting a bucket wheel section c^1 c^2 or c^3 are separated as before by flat-faced radial vanes E which intersect the wheel ends d d^3 and the section partitions d^1 d^2 at right angles, the buckets, which are of equal length circumferentially of the rotor in all the sections of one wheel, being preferably arranged so that those of each successive section have an angular advance on those of the preceding section.

The steam ports in the casing are, for each bucket wheel chamber, disposed symmetrically on either side of a longitudinal axial plane $x—x$ which may be termed the median plane of the turbine and which in the example illustrated is vertical, the two inlet ports F F used respectively for opposite directions of running being equidistant at opposite sides of said plane while the two exhaust ports G G open from the bucket wheel chamber by way of tangential passages situated likewise at opposite sides of the plane $x—x$ but at a greater distance therefrom than the inlet ports F F. The steam ports F and G are divided into sections (whereof those of the inlet ports F are indicated at f^1 f^2 f^3 in Fig. 1) separated by partitions so as to register, lengthwise of the rotor axis, with the corresponding sections c^1 c^2 c^3 of the respective bucket wheels, the major dimension of each port section (more particularly in the case of the inlet ports F) being preferably disposed lengthwise of the rotor axis.

The circumscribing wall of each bucket wheel chamber B^1 B^2 B^3, instead of embracing the wheel closely around its entire periphery fits the wheel closely only around that portion of its periphery which extends, by way of the inlet ports F F, from the one exhaust port G to the other, the remainder of the chamber wall (in the example illustrated, the lower part) being made of greater radius than the bucket wheel. Consequently there is provided between the exhaust ports G G a continuous channel H through which the steam, after having struck and acted upon a vane E as the latter passed the open inlet port F, finds a partially free passage whereby to travel around the periphery of the wheel to the open exhaust port G at the opposite side of the median plane, the steam in its course along the channel H being enabled to act successively upon all the vanes E which for the time being intervene between the inlet and exhaust ports which are open.

The enlarged portion of each bucket wheel chamber B^1 B^2 B^3 which constitutes the channel H may be of constant radius as shown by way of example in Fig. 2. Or, in order to increase the propulsive effect of the steam by enabling it to impinge upon successive vanes E at the most favorable angle, the radial enlargement or channel H may take the form of a circumferentially extending series of cavities having either plane or curved surfaces (as indicated for example in Figs. 3 and 4 respectively) of such configuration as may be found best adapted for the purpose. In such cases the wall of the chamber may, as indicated at *h*, approach somewhat closely the periphery of the bucket wheel between successive cavities.

In order to further assist the propulsive effect of the steam, each bucket may be contracted in width, or made of zig-zag form, at a point or points in its circumferential length, so as to offer additional surfaces against which the steam can impinge, or exert pressure due to its expansion, while traveling around the channel H, the contractions in the width of the buckets causing the latter to serve to a certain extent as what may be termed expansion nozzles. Several forms of such contracted and zig-zag buckets are indicated by way of example in Fig. 6, the bucket shown at 6^a therein being plain, while those shown at 6^b and 6^c have their sides formed by flat and curved convergent surfaces respectively. The buckets shown at 6^d, 6^e, 6^f and 6^g are of various types of zig-zag configuration.

A series of sector-shaped rotary steam distribution valves J^1 J^2 J^3 are mounted fast side by side upon a spindle K which extends, in the median plane $x—x$ and preferably parallel to the rotor shaft A, through a series of valve chests L^1 L^2 L^3 corresponding respectively to the bucket wheel chambers B^1 B^2 B^3. The inlet ports F of each bucket wheel chamber open into the corresponding valve chest, in positions symmetrically disposed on opposite sides of the median plane, at a semicircular or segmental face over which the sector-shaped valve is fitted to be moved by the partial rotation of the spindle K, while the exhaust ports G of each bucket wheel chamber open similarly but into the next succeeding valve chest. The valve J^1 has inlet ports *f* adapted to register alternatively with those F of the high pressure valve chest L^1 and each succeeding valve J^2 and J^3 is provided with both steam inlet ports *f* and exhaust ports *g* adapted to register with those F and G in the respective valve chests in such manner that when the spindle K is turned through a certain angle in either direction, the steam inlet ports on one side and the exhaust ports on the opposite side of the median plane $x—x$, which appertain to the several bucket wheel chambers, will be opened simultaneously and those on the opposite side of said plane will be closed, and vice versa. The arrangement is such that steam admitted to the high pressure valve chest L^1 from the main steam pipe M will pass thence round the first bucket wheel C^1 and, leaving the corresponding chamber by the exhaust port G thereof, will enter the intermediate valve chest L^2, and so on, circulating round the rotor always in the same direction with the result that the rotor will be caused to revolve in the direction corresponding to that in which the spindle K was turned.

Each valve J^1 J^2 J^3 is divided into sections j^1 j^2 j^3 corresponding to those of the steam and exhaust ports F and G over which it works.

The valve chests L^1 L^2 L^3 are separated from one another by partitions *l* and are preferably closed externally by a single cover L, the valve spindle K working in bearings halved together about the transverse plane passing through the spindle axis at right angles to the median plane $x—x$.

The exhaust ports G of the low pressure bucket wheel chamber B^3 deliver into passages G^1 (Fig. 5) which may extend the greater part of the way round the corresponding sides of the final exhaust valve chest L^4, wherein the valve J^4 is fitted to turn in contact with a face which (like that of the valve) may be completely cylindrical so as the more conveniently to afford the requisite area of port opening, the exhaust pipe N opening out at the farther end ofthe valve chest as indicated in Fig. 1.

It will be obvious that the speed of revolution of the rotor may be regulated, independently of the throttle valve, by turning the spindle K so as to cause the various ports to be opened to a greater or less extent. If a condenser be coupled to the exhaust pipe N, its action will materially assist the propulsive effect of the steam in whichever direction the latter is discharged through the final exhaust valve J^4.

The radial dimensions of successive valve chests and valves may, as indicated, be increased progressively so as to afford the requisite capacity within each chest for the steam passed through it, and thus obviate the necessity of employing intermediate receivers for the steam.

As the inlet and exhaust passages appertaining to each bucket wheel chamber are independent and distinct from one another, the exhaust passages G may be provided with non-return valves (not shown).

In consequence of the relative arrangement of the inlet ports F and exhaust ports

G in each bucket wheel chamber, it follows that the passages connecting the exhaust port openings in the bucket wheel chamber and the next valve chest respectively are of considerable length and are always open, from their commencement in the bucket wheel chamber to the valve face whereat they are controlled. Hence, when the rotor is revolving in either direction, that exhaust passage which for the time being is out of use constitutes in effect what may be termed an eddy chamber or steam abutment pocket in rear of the vanes E as these pass forward on leaving the inlet port opening. This eddy chamber becomes filled with steam at about the pressure of the steam then entering the bucket wheel chamber through the adjacent inlet port, the steam in the eddy chamber serving as a kind of reaction-cushion or elastic abutment behind the successive vanes, with the result that the engine operates not only by impact but also by reaction and that the propulsive force of the steam is correspondingly increased or economized.

For the purpose of enabling wear to be taken up between the faces of the valves J^1 J^2 J^3 J^4 and their seats in the respective valve chests L^1 L^2 L^3 L^4, each valve may be fitted with an independently adjustable shoe or shoes as indicated at *o*. These shoes may be made adjustable either automatically by the pressure of the steam from within the respective valve chests, or by suitable mechanism (not shown) provided for the purpose. Or each valve while adapted to turn with the spindle K might be made adjustable as a whole transversely of said spindle, as for example in substantially the same manner as in the case of a Corliss rotary steam valve.

The entire series of bucket wheels C^1 C^2 C^3, whether cast in one or built up in sections, are preferably combined in a single structure supported by means of spider frames *c* keyed upon the rotor shaft A, while adjacent bucket wheels and the chambers wherein they revolve are separated from one another by a steam-tight closure formed by a spring ring or rings as at *p*. These rings would have lap joints and each would preferably be received and fit within grooves provided in both surfaces between which it forms a joint.

Similar spring rings may be employed as at *q* to form a steam-tight closure around the valve spindle K where the latter passes through each of the partitions *l* separating the successive valve chests. The spindle K would pass out through the end wall of the high pressure valve chest L^1 by way of a stuffing box as at Q and be coupled externally thereof to any convenient means for effecting the necessary angular adjustment of the spindle and valves.

The valve chest cover L being halved about the axial transverse plane through the spindle K as already mentioned, the fitting of the spring rings *q* is rendered easy. The turbine casing B is also preferably divided on the transverse plane passing through the rotor axis at right angles to the median plane *x*—*x* so as to afford ready access to the interior and permit of the rings *p* being fitted in place.

Claims.

1. In a multiple - expansion reversible steam turbine, a series of bucket-wheels of progressively increasing diameter, a casing forming a series of chambers of progressively increasing size in which said bucket wheels rotate, each chamber being in the shape of segments of two cylinders and of such cross sectional area that the internal diameter of the one segment of each chamber from outlet pipe to outlet pipe is greater than the diameter of the bucket wheel which the casing incloses, and the internal diameter of the other segment of each chamber from outlet pipe to outlet pipe is substantially the same as the diameter of the corresponding bucket-wheel so that a channel is left on the one side only, between the casing and the bucket-wheels for the passage of the steam, substantially as and for the purpose specified.

2. In a multiple - expansion reversible steam turbine, a series of bucket-wheels of progressively increasing size, a series of chambers of progressively increasing size in which the bucket wheels rotate, each chamber having its lower side of greater internal diameter than the external diameter of the corresponding bucket wheel, the bucket wheel being provided with buckets each of which is divided in the axial direction into a series of sections by means of partitions disposed in planes perpendicular to the axis of rotation substantially as described.

3. In a multiple - expansion reversible steam turbine, a series of bucket-wheels of progressively increasing size, a series of chambers of progressively increasing size in which said bucket wheels rotate, each chamber having its lower side of greater internal diameter than the external diameter of the corresponding bucket-wheel, and buckets contracted in their width and made of irregular shape so as to be adapted to offer additional surfaces against which the steam can impinge, substantially as specified.

4. In a multiple - expansion reversible steam turbine, the combination with a casing fomed of a series of bucket wheel chambers, valve chests, and exhaust chambers, and a series of bucket wheels each mounted to rotate in one of the bucket wheel chambers, of a series of sector-shaped valves moving together on the same axis, each valve being mounted to oscillate in one of the valve chests, and having pairs of inlet and outlet ports for controlling the entrance of the steam into the bucket-wheel chambers substantially as specified.

5. In a multiple-expansion reversible steam turbine, a casing formed of a series of bucket wheel chambers, valve chests, and exhaust chambers, a series of bucket wheels, each mounted to rotate in one of the bucket wheel chambers, a series of sector-shaped valves all of progressively increasing cross-sectional area, and adjustable wearing shoes for said valves.

6. In a multiple-expansion steam turbine, a series of bucket wheels of progressively increasing size, a series of chambers of progressively increasing size in which said bucket wheels rotate, each chamber having its lower side of greater internal diameter than the external diameter of the bucket wheel, so as to form a narrow channel for the passage of the steam between the walls of the chamber and the bucket wheels, the walls of said portion of the chamber having a series of cavities extending parallel to the axis of the corresponding bucket wheel, the wall of the chamber between the cavities extending adjacent to the periphery of the bucket wheel, substantially as described.

7. A multiple-expansion reversible steam turbine, comprising a casing containing a series of bucket wheel chambers, valve chests and exhaust chambers of progressively increasing cross-sectional area, a series of bucket wheels of progressively increasing cross-sectional area, each wheel being of smaller cross-sectional area in its lower part than that of the chamber in which it rotates, a shaft extending through the bucket wheel chambers and carrying the bucket-wheels, thrust rings fitting into annular grooves formed on the inner surfaces of the bucket-wheel chambers, and valve chests respectively, a sector-shaped high pressure valve with a series of pairs of inlet ports, and intermediate sector-shaped valves with a series of pairs of inlet and outlet ports, each valve being fitted with an adjustable wearing shoe and fitted on a shaft extending the whole length of the valve chests, with means for oscillating the shaft, an intermediate body portion of the casing having series of pairs of inlet ports leading from the valve chests to the bucket-chambers, said portion of the casing constituting steam-tight working surfaces for the valves and bucket wheels, a cylindrical exhaust valve chest, and an exhaust pipe opening out of the valve chest, substantially as described.

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Witnesses:
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HENRY ALEXANDER BOTHWELL.