No. 741,940. PATENTED OCT. 20, 1903.

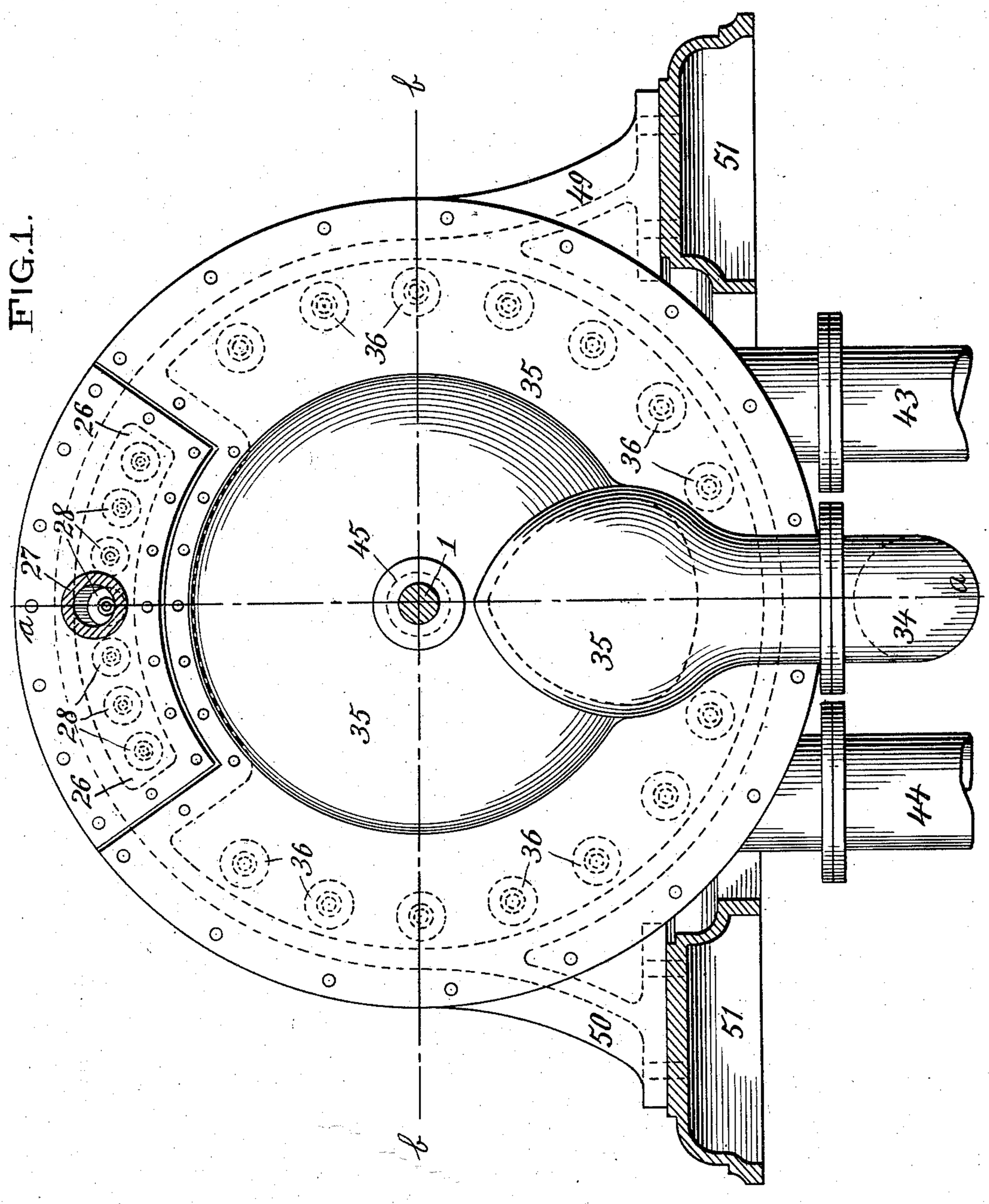
W. E. SHEPARD.

COMPOUND STEAM TURBINE.

APPLICATION FILED MAR. 27, 1903.

NO MODEL. 4 SHEETS—SHEET 1.

FIG. 1.



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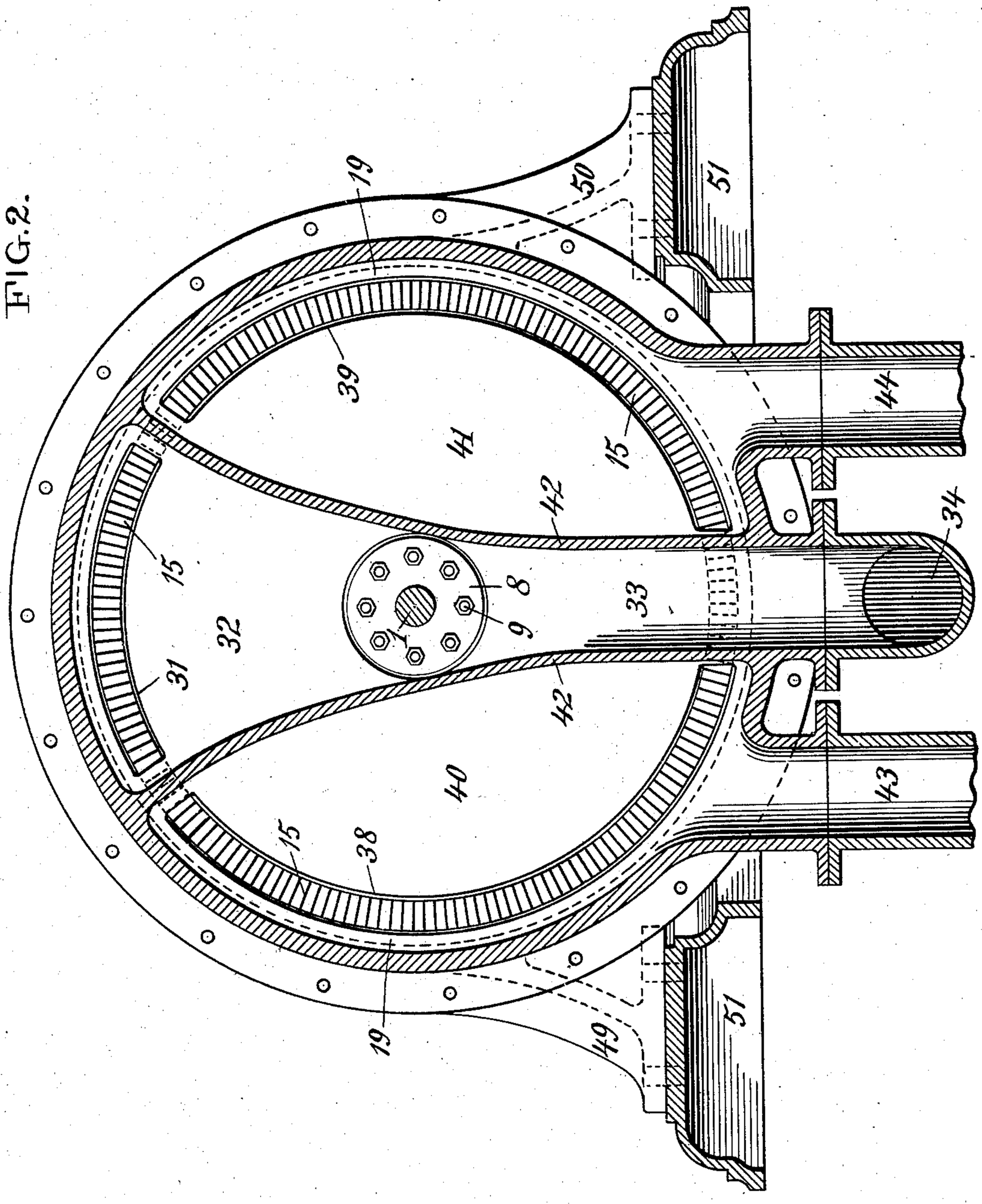
NO MODEL. 4 SHEETS—SHEET 2.

FIG. 2.



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NO MODEL. 4 SHEETS—SHEET 3.

FIG. 3.

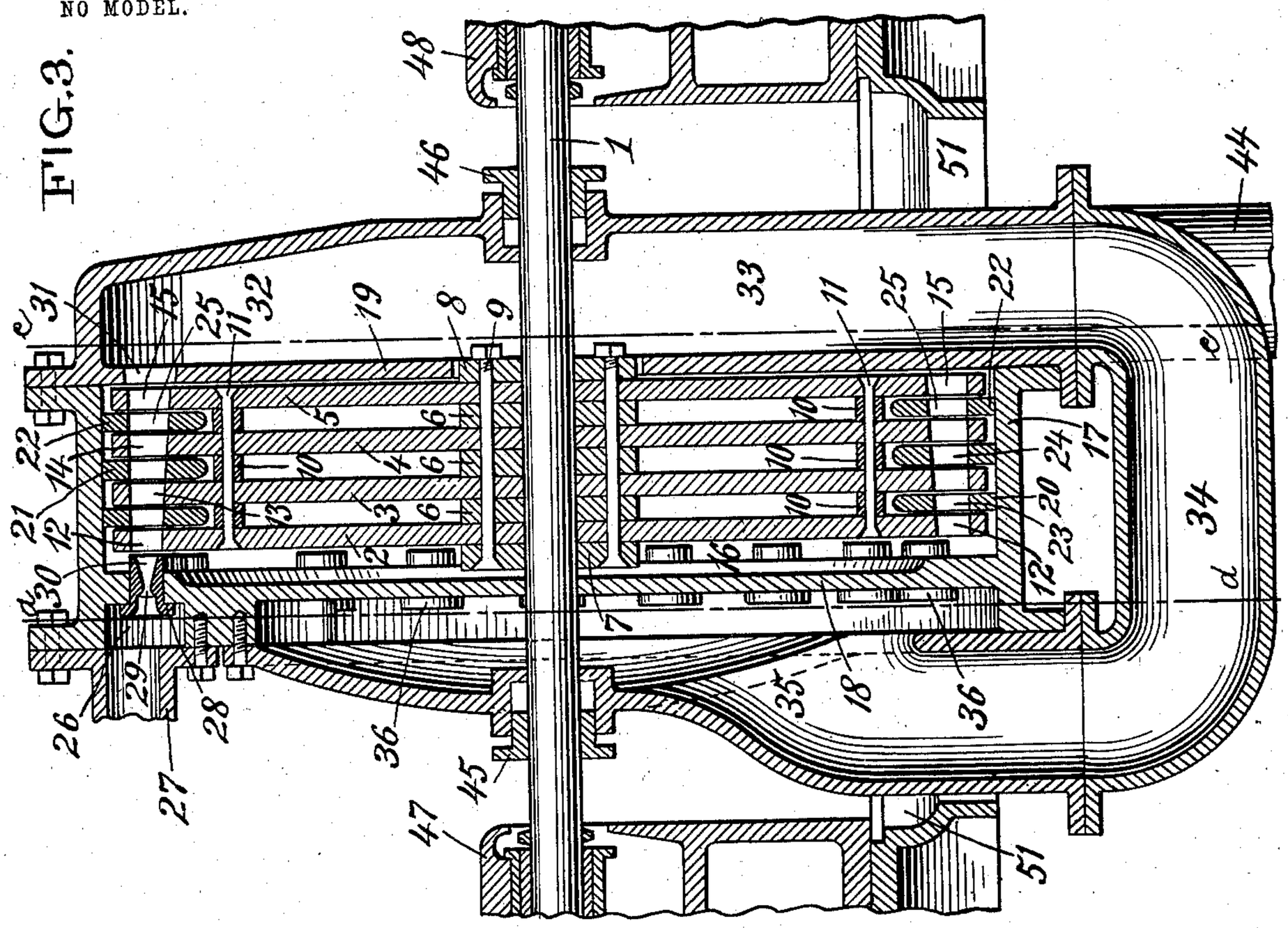
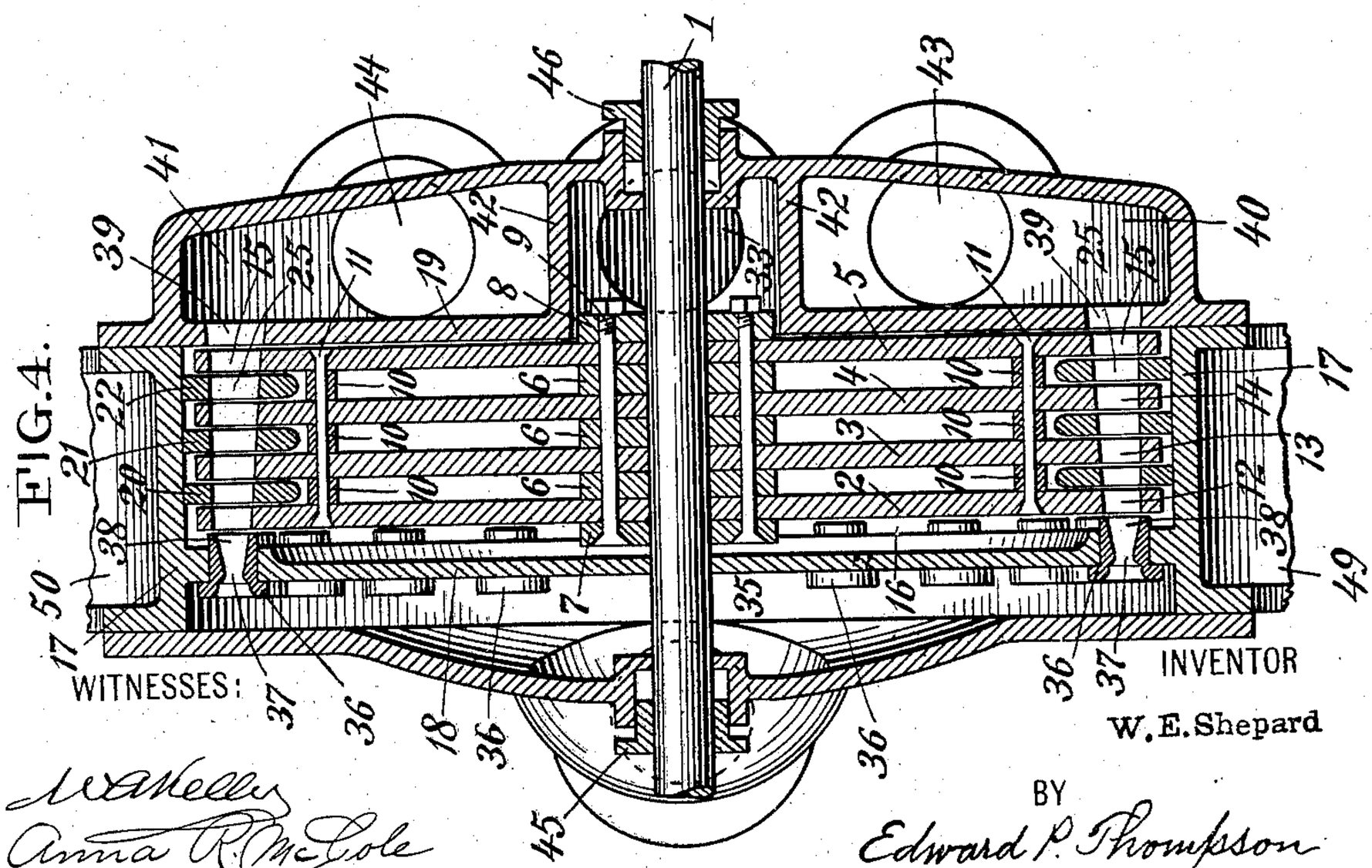


FIG. 4.



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NO MODEL. 4 SHEETS—SHEET 4.

FIG. 5.

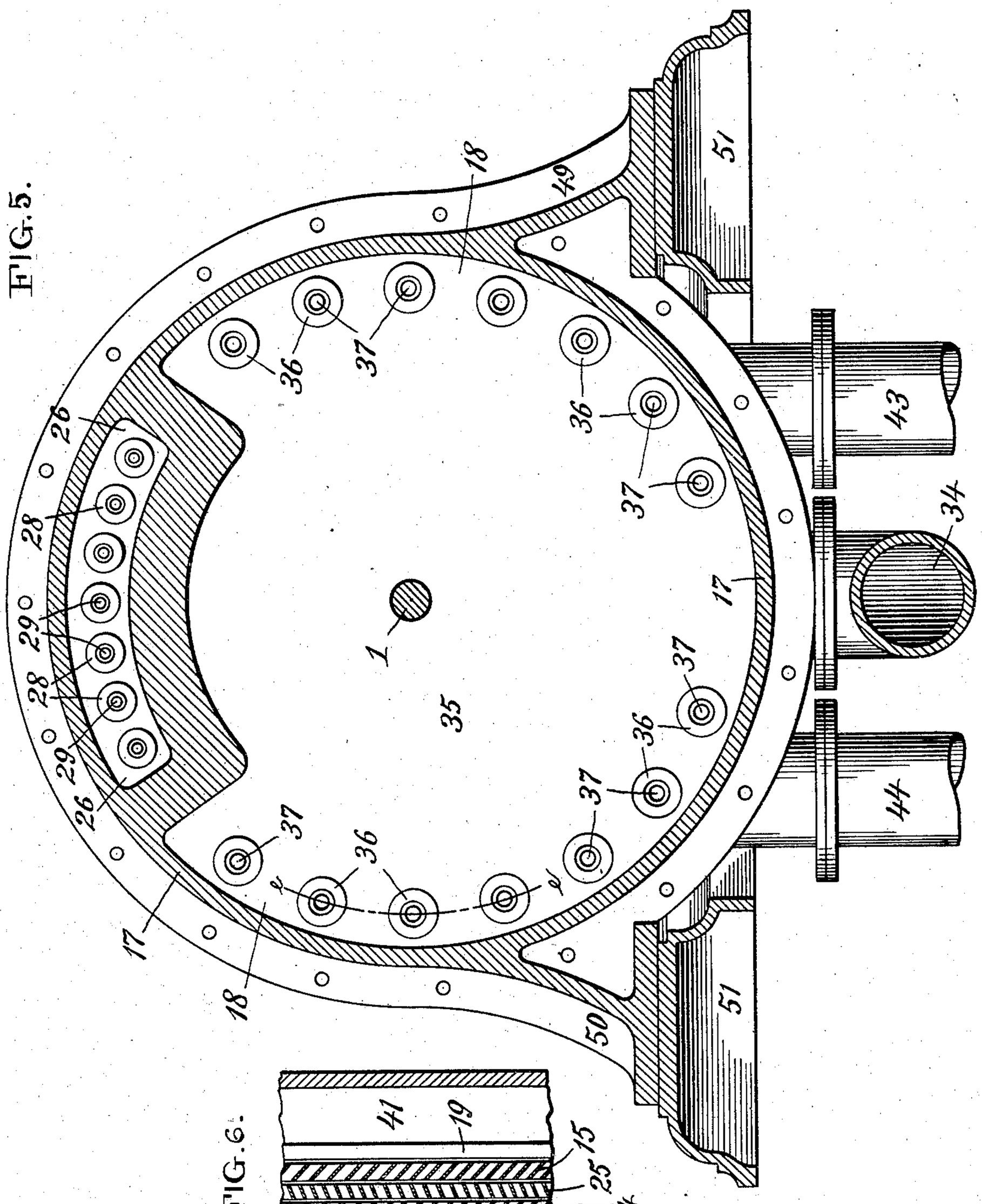
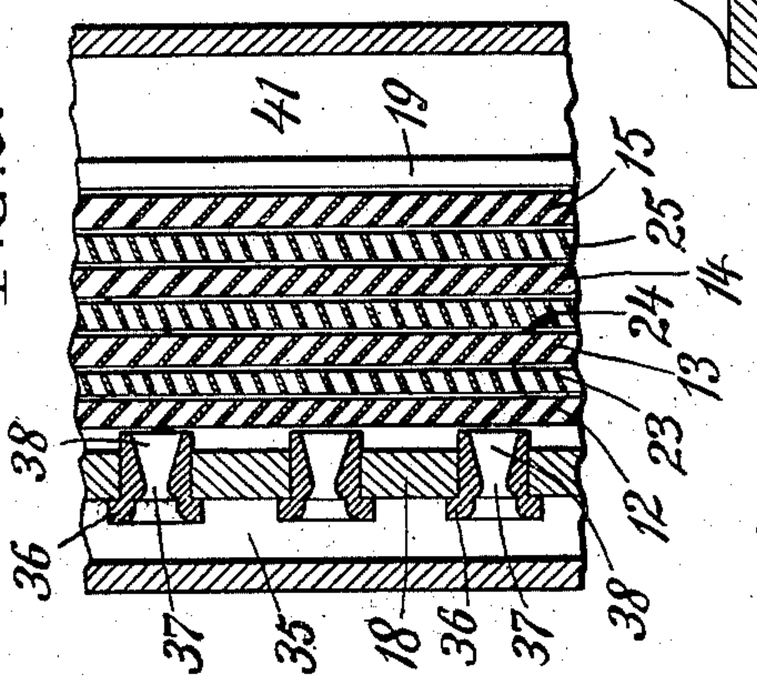


FIG. 6.



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No. 741,940. Patented October 20, 1903.

UNITED STATES PATENT OFFICE.

WILLIAM E. SHEPARD, OF PARIS, FRANCE.

COMPOUND STEAM-TURBINE.

SPECIFICATION forming part of Letters Patent No. 741,940, dated October 20, 1903.

Application filed March 27, 1903. Serial No. 149,805. (No model.)

To all whom it may concern:

Be it known that I, WILLIAM E. SHEPARD, a citizen of the United States of America, and a resident of Paris, Republic of France, have invented certain new and useful Improvements in Compound Steam-Turbines, of which the following is a specification.

My invention relates to improvements in steam-turbines, and has for its object to produce a compound turbine of great compactness, and more especially to secure this end by the use of only one cylinder and disks and vanes contained therein, the compounding being effected by passing the live and exhaust steam through the same vanes.

A second object is to secure a low angular velocity and at the same time have no portion of the circle of vanes idle, and this is accomplished by making the disks of large diameter and dividing the circle of vanes up into different portions, which portions are used, respectively, for high and low pressures. I can thus choose disks of a circumference such that after taking out a portion of the circle of vanes for the high-pressure stage there will yet remain enough in the arc to correspond to the increased volume of steam at the low-pressure stage.

Although the turbine I have shown is compounded only once, I do not limit the idea to directing the steam twice only against the same vanes or passing it twice only through the same cylinder. By still increasing the diameter of the disks in relation to the capacity of the machine and by using a less number of disks—say two or three instead of four—it may be found, especially for high degrees of superheating, that passing the steam through the machine and against the vanes three times is desirable.

My invention consists, more particularly, of a cylinder containing circular rows of vanes, a steam-chest having an admission-port, expansion-nozzles receiving steam from said chest and delivering jets to the vanes throughout a portion of said circle, an exhaust-port in the cylinder opposite the nozzles and opening into an exhaust-chamber, a passage connecting this exhaust-chamber with a second steam-chest, other nozzles receiving steam from this second chest and delivering jets to the vanes throughout another portion of the said circle, a second exhaust-port in the cylinder opposite to the last-named nozzles and opening into a second exhaust-chamber, and a final exhaust-passage for the last-named cylinder.

For description in detail reference will now be had to the drawings.

Figure 1 is a plan view of the front side of my improved turbine as viewed from the left of Figs. 3 and 4. The nozzles and walls are shown by dotted lines. Fig. 2 is a vertical section on the line *c c* of Fig. 3 as viewed from the right. Fig. 3 is a vertical section on the line *a a* of Fig. 1. Fig. 4 is a horizontal section on the line *b b* of Fig. 1. Fig. 5 is a vertical section on the line *d d* of Fig. 3 as viewed from the left. This view is in the same direction as Fig. 1 and in the opposite direction to Fig. 2. Fig. 6 is a detail sectional view on the curved line *e e* of Fig. 5.

The machine shown in the drawings as embodying my invention consists of the shaft 1; four disks 2 3 4 5, secured thereon so as to turn therewith; similar hub-pieces surrounding the shaft 1 between said disks; outside hub-pieces 7 8, said disks and hub-pieces being securely held together by bolts 9; similar annular distance-blocks 10 between the disks 2 3 4 5, near their periphery, said disks and blocks being held together by rivets 11; a circular row of vanes 12 13 14 15 on each of the said disks near the periphery thereof; a steam-tight cylinder 16; a peripheral shell 17 and heads 18 19 for said cylinder, said shaft passing through the center of the cylinder-heads 18 19 and the disks 2 3 4 5 thereon being contained within the said cylinder; three flattened rings 20 21 22, secured inside the peripheral shell 17 and extending inwardly alternately between the outer edges of the disks 2 3 4 5; a circular row of vanes 23 24 25 carried by each of the said rings at about its middle in a radial direction, the rows of vanes 12 13 14 15 and the rows of vanes 23 24 25 being even with and coöperating with each other, the vanes in each row being longer than those in the preceding row in the direction in which they are enumerated—12 23 13 24 14 25 15; a steam-chest 26, having an admission-pipe 27, a portion of the cylinder-head 18 forming also one wall of said chest; expansion-nozzles 28, located in the above-

named portion of the head 18 and arranged in an arc opposite the row of vanes 12, each of the nozzles 28 having a throat 29 of a given size and an expansion-tip 30 of a given length, said nozzles communicating with said steam-chest and being directed toward a portion of the circle of vanes 12; an exhaust-port 31 through the cylinder-head 19, said exhaust-port being in shape the segment of an annulus, registering with a portion of the circle of vanes 15 and occupying the same circumferential and radial location as the row of nozzles 28; an exhaust-chamber 32, into which the port 31 opens, a portion of the cylinder-head 19 forming one side of the said exhaust-chamber; a passage 33, constituting an outlet for the chamber 32; a pipe 34, connecting the passage 33 with a second steam-chest 35, said second steam-chest also having one of its sides formed by a portion of the cylinder-head 18; an arc-shaped row of expansion-nozzles 36, located in that portion of the head 18 which is common to the cylinder 16 and to the chest 35, the nozzles 36 having each a throat 37 of larger diameter than the throats 29 and an expansion-tip 38 of greater length than the tips 30, the nozzles 36 communicating with the chest 35 and opening into the cylinder 16 opposite a portion of the circle of vanes 12 different from that occupied by the nozzles 28, the nozzles 36 being collectively of greater capacity and occupying a longer arc of the same circle than the nozzles 28; other exhaust-ports 38 39, said ports 38 39 being each in shape the segment of an annulus and registering with other portions of the circle of vanes 15 than that covered by the port 31 and being located opposite to the row of nozzles 36; a pair of exhaust-chambers 40 41, into which the ports 38 39 open, respectively, the chambers 40 41 being virtually one, but separated into two parts by walls 42 of the passage 33; final exhaust-pipes 43 44 for the chambers 40 41, respectively; packing-glands 45 46 for the shaft 1; bearings 47 48 for said shaft, and supports 49 50, resting upon a base 51. The nozzles 28 and 36 are disposed in the same circle, of which the nozzles 36 fill the larger portion, the space occupied by the nozzles 36, as shown, being approximately four times that occupied by the nozzles 28. As a result of this a correspondingly larger portion of the circle of vanes 12, &c., is exposed to the nozzles 36 than to the nozzles 28. The increase in the length of the vanes from 12 to 23, and so on to 15, is rather rapid, and the ends of the vanes 12 to 15 are sloping, so that the increase in length is continuous without any abrupt corners.

In the operation of my improved turbine steam at boiler pressure enters by the pipe 27 into the steam-chest 26 and from the chest 26 is supplied to the expansion-nozzles 28. The nozzles 28 expand the steam, converting a part of the pressure into velocity and deliver jets against the movable vanes 12. The vanes 12 abstract a part of the velocity from the steam, and it passes on to the stationary vanes 23, which direct it at the most effective angle against the second row of movable vanes 13, and so on from one row of vanes to the next till all are passed. Owing to the constantly-increasing length of the vanes in the direction in which the steam is traveling, the steam is further expanded as it passes over the vanes, thus having its velocity constantly renewed; but it is intended that by the time the steam escapes from the last vanes 15 practically all its velocity, both that generated in the nozzles 28 and while passing the vanes 12 to 15, will have been abstracted. From the vanes 15 the steam exhausts through the port 31 into the chamber 32. The steam contained in the chamber 32 has not been expanded clear down, a portion only of the absolute pressure having been converted into velocity and that velocity abstracted. We will say, for example, that the steam contained in the chamber 32 has one-fourth the pressure and four times the volume of that found in the chest 26. From the chamber 32 the exhaust-steam is led by a passage 33 and pipe 34 to a second or low-pressure steam-chest 35, and from the chest 35 the steam is supplied to the expansion-nozzles 36. The increased capacity of the nozzles 36 over the nozzles 28 is now brought into play in handling the now largely increased volume of steam. The nozzles 36 reëxpand the steam, converting nearly all the remaining pressure into velocity, and deliver their jets against the vanes 12, above mentioned, and, as is seen, in a different portion of the same circle with the jets from the other nozzles 28. The reason for the greater length of the arc of the circle of vanes allotted to the nozzles 36 over the portion given up to the nozzles 28 is now apparent, it being in order to give room for the increased volume of steam resulting from the lower pressure. The steam from the nozzles 36, after acting on the vanes 12, passes in succession the vanes 23 13 24 14 25 15 in the same manner as the steam from the nozzles 28. The long expansion-tips 38 of the nozzles 36 expand the steam nearly clear down, so that practically all of the little pressure remaining can be expanded out in its passage over the vanes from 12 to 15. In order that the same increase in the length of the vanes from 12 to 15 may answer for both high and low pressure steam, the expansion is not carried too far in the nozzles 28 and is carried proportionately farther in the nozzles 36. The steam which was given a velocity by the nozzles 36 after passing the last row of vanes 15 exhausts through the ports 38 and 39 into the final exhaust-chambers 40 and 41. The steam finally leaving the vanes 15 will have practically no velocity and only sufficient pressure to prevent choking. From the final exhaust-chambers 40 41 the dead steam passes out by the pipes 43 and 44.

I claim as my invention—

1. In a compound steam-turbine, the com-

bination of a steam-tight cylinder containing vanes, a steam-chest, an admission-port for said chest, expansion-nozzles communicating with said chest and directed toward said vanes, an exhaust-port, a second steam-chest, a passage connecting said exhaust-port with said last-named steam-chest, a second set of nozzles communicating with said second chest and directed toward said vanes, and a final exhaust-port for said cylinder.

2. In a compound steam-turbine, the combination of a steam-tight cylinder containing movable and stationary vanes, said movable vanes arranged in a number of circular rows, said stationary vanes arranged in a number of circular rows interposed alternately between the said rows of movable vanes, said movable and stationary vanes coöperating with each other, an annular passage within which all of said vanes are contained, a set of expansion-nozzles opening into a segment of said passage, a second set of expansion-nozzles opening into a second segment of said passage, said second set of nozzles belonging to the second stage of compounding, and exhaust-ports for said cylinder.

3. A compound steam-turbine, consisting of the combination of a steam-tight cylinder, vanes contained therein, heads and a peripheral shell for said cylinder, a high and a low pressure steam-chest, both of said chests located on the same side of said cylinder and adjoining one of said cylinder-heads, said cylinder-head forming one wall of each of said chests, nozzles located in said dividing-wall, said nozzles receiving steam from said chests and delivering jets to said vanes, two exhaust-chambers located on the opposite side of said cylinder from said steam-chests, the other cylinder-head forming one wall of each of said chambers, communication between said cylinder and each of said chambers, a final exhaust-passage for one of said chambers, and a passage connecting the other of said chambers with said low-pressure steam-chest.

4. A compound steam-turbine, consisting of the combination of a cylinder, vanes contained in said cylinder, said vanes arranged in circular rows, a steam-chest having an admission-port, expansion-nozzles receiving steam from said chest and delivering jets to said vanes throughout a portion of said circle, an exhaust-chamber, an exhaust-port on the opposite side of said cylinder from said nozzles, said exhaust-port occupying the same radial space and extending over the same circumferential spaces as said nozzles, said exhaust-port opening into said chamber, a second steam-chest, a passage connecting said chamber with said second chest, a second group of nozzles receiving steam from said second chest and delivering jets to said vanes throughout a different and larger portion of said circle, said second group of nozzles being collectively of greater capacity than the first-mentioned nozzles taken collectively, a second exhaust-chamber, a second exhaust-port occupying the same radial space and extending over the same circumferential space as nozzles belonging to the said second group, said second exhaust-port opening into said second chamber, and a final exhaust-passage for the last-named chamber.

5. A compound steam-turbine, consisting of the combination of a cylinder, vanes contained in said cylinder, said vanes arranged in circular rows, a steam-chest having an admission-port, nozzles receiving steam from said chest and delivering jets to said vanes throughout a portion of said circle, expansion-tips for said nozzles, an exhaust-chamber, an exhaust-port on the opposite side of said cylinder from said nozzles, said exhaust-port occupying the same radial space and extending over the same circumferential space as said nozzles, said exhaust-port opening into said chamber, a second steam-chest, a passage connecting said chamber with said second chest, a second group of nozzles receiving steam from said second chest and delivering jets to said vanes throughout a different and larger portion of said circle, expansion-tips for the last-named nozzles, the last-named tips being of greater length than the first-named, a second exhaust-chamber, a second exhaust-port occupying the same radial space and extending over the same circumferential space as said second group of nozzles, said second exhaust-port opening into said second chamber, and a final exhaust-port for said second chamber.

6. A compound steam-turbine, consisting of the combination of a steam-tight cylinder, a high and a low pressure steam-chest both adjoining said cylinder, nozzles communicating with each of said chests and delivering jets within said cylinder, two exhaust-chambers adjoining said cylinder and communicating therewith, a final exhaust-passage for one of said chambers, a passage connecting the other of said chambers with said low-pressure steam-chest, and devices contained within said cylinder for utilizing said jets.

7. In a compound steam-turbine, the combination of a shaft, a number of disks on said shaft, ring-like distance-blocks surrounding said shaft and spacing said disks apart from each other, and annular distance-rings between said disks near the periphery thereof, all of said rings and disks being rigidly secured together.

8. In a compound steam-turbine, the combination of a number of circular rows of movable vanes, a number of circular rows of stationary vanes interposed alternately between the said rows of movable vanes and coöperating therewith, the length of both said movable and stationary vanes increasing progressively from row to row in one direction forming an annular expansion-passage, a steam-tight cylinder containing all of said vanes, exhaust-ports for said cylinder, a set of expansion-nozzles opening into a segment of said passage, and a second set of expansion-nozzles

opening into a second segment of said passage, said second set of nozzles belonging to the second stage of compounding.

9. In a compound steam-turbine, the combination of a cylinder containing vanes, a steam-chest having an admission-port, expansion-nozzles receiving boiler steam from said chest and delivering jets to said vanes, an exhaust-chamber, an exhaust-port opening from said cylinder into said chamber, a second steam-chest, a passage connecting said exhaust-chamber and said second chest, nozzles receiving exhaust-steam from said second chest and delivering jets to said vanes, a second exhaust-chamber, a second exhaust-port opening from said cylinder into said second chamber, and a final exhaust-passage leading from said second chamber.

10. In a compound steam-turbine, the combination of a steam-tight cylinder having exhaust-ports, a shaft passing through said cylinder, disks secured to said shaft within said cylinder and spaced apart on said shaft, a circular row of movable vanes near the periphery of each of said disks, annular rings secured to the inner periphery of said cylinder and projecting inwardly between said disks, a circular row of stationary vanes carried by each of the said rings, said movable and said stationary vanes coöperating with each other, and means for directing the same steam against said vanes a successive number of times.

11. In a compound steam-turbine, the combination of a steam-tight cylinder having exhaust-ports, a shaft passing through said cylinder, disks secured to said shaft within said cylinder and spaced apart on said shaft, a circular row of movable vanes near the periphery of each of said disks, annular rings secured to the inner periphery of said cylinder and projecting inwardly between said disks, a circular row of stationary vanes carried by each of the said rings, said movable and said stationary vanes coöperating with each other, and devices for directing steam of different pressures against said vanes simultaneously.

12. In a compound steam-turbine, the combination of a steam-tight cylinder, a number of circular rows of movable vanes, a number of circular rows of stationary vanes interposed alternately between the said rows of movable vanes, said movable and stationary vanes cooperating with each other, all of said vanes being contained within said cylinder, expansion-nozzles directed toward said vanes throughout a portion of said circle, a second group of expansion-nozzles, the nozzles of said second group being directed toward vanes in a second portion of said circle, said second group of nozzles belonging to the second stage of compounding, and exhaust-ports for said cylinder.

13. A compound steam-turbine, consisting of the combination of a shaft, a number of disks secured on said shaft, ring-like distance-blocks between said disks and near the periphery thereof, hub-pieces for said disks, movable vanes on said disks near the periphery thereof, a steam-tight cylinder, heads and a peripheral shell for said cylinder, said cylinder containing said vanes bearing disks, and said shaft passing through the said cylinder-heads, annular rings secured inside the peripheral shell of said cylinder, said rings being interposed alternately between the peripheries of said disks, stationary vanes carried by said rings, said movable and stationary vanes coöperating with each other, an annular expansion-passage extending through all of said rings and disks, said passage gradually increasing in width from one side to the other, all of said vanes located within said passage, a steam-chest having an admission-port, expansion-nozzles receiving steam from said chest and delivering jets to said vanes throughout a portion of said annular passage, an exhaust-port through one of the cylinder-heads, said exhaust-port being a segment of an annulus and registering with a portion of said annular passage, said portion being opposite to said nozzles, an exhaust-chamber receiving the steam from said exhaust-port, a second steam-chest, an exhaust-passage connecting said exhaust-chamber with said second chest, expansion-nozzles receiving steam from said second chest and delivering jets to said vanes throughout another portion of said annular passage, a second exhaust-port opposite said last-named nozzles and through the same cylinder-head as the first-named exhaust-port, said second exhaust-port also being a segment of an annulus and registering with a second portion of said annular passage, a second exhaust-chamber receiving the steam from said second exhaust-port, and a final exhaust-passage for said second chamber.

14. A compound steam-turbine, consisting of the combination of a shaft, a number of disks secured on said shaft, ring-like distance-blocks between said disks and near the periphery thereof, hub-pieces for said disks, movable vanes on said disks near the periphery thereof, a steam-tight cylinder, heads and a peripheral shell for said cylinder, said cylinder containing said vane-bearing disks, and said shaft passing through the said cylinder-heads, annular rings secured inside the peripheral shell of said cylinder, said rings being interposed alternately between the peripheries of said disks, stationary vanes carried by said rings, said movable and stationary vanes coöperating with each other, an annular expansion-passage extending through all of said disks and rings, said passage gradually increasing in width from one side to the other, all of said vanes located within said passage, a steam-chest having an admission-port, one of said cylinder-heads forming one wall of said chest, expansion-nozzles located in said common wall, said nozzles receiving steam from said chest and delivering jets to said vanes throughout a portion of said an-

nular passage, an exhaust-port through the other cylinder-head, said exhaust-port being a segment of an annulus and registering with a portion of said annular passage, said portion being opposite to said nozzles, an exhaust-chamber receiving the steam from said exhaust-port, the last-named cylinder-head forming one wall of said exhaust-chamber, a second steam-chest, an exhaust-passage connecting said exhaust-chamber with said second chest, said second chest also having one of its walls formed by said first-named cylinder-head, expansion-nozzles located in said last-named common wall, said last-named nozzles receiving steam from said second chest and delivering jets to said vanes throughout another portion of said annular passage, a second exhaust-port opposite said last-named nozzles and through said other cylinder-head, said second exhaust-port also being a segment of an annulus and registering with a second portion of said annular passage, a second exhaust-chamber receiving the steam from said second exhaust-port, a portion of said other cylinder-head also forming one wall of said second exhaust-chamber, and a final exhaust-passage for said second chamber.

15. In a compound steam-turbine, the combination of a steam-tight cylinder having exhaust-ports, a shaft passing through said cylinder, disks secured to said shaft within said cylinder and spaced apart on said shaft, a circular row of movable vanes near the periphery of each of said disks, annular rings secured to the inner periphery of said cylinder and projecting inwardly between said disks, a circular row of stationary vanes carried by each of the said rings, said movable and said stationary vanes coöperating with each other, and means for directing the same steam against said vanes a successive number of times, and always from the same side of said disks.

16. In a compound steam-turbine, the combination of a circular row of radially-disposed vanes, expansion-nozzles directing boiler steam against said vanes throughout a portion of said circle, and other expansion-nozzles of collectively greater capacity than those first named directing exhaust-steam against said vanes throughout a second and larger portion of said circle, all of said nozzles being located in a circle concentric with said vanes and disposed laterally at one side thereof.

17. In a compound steam-turbine, the combination of a disk, a circular row of radially-disposed vanes mounted on the periphery of said disk, said vanes having steam-passages therebetween, expansion-nozzles directed toward said vanes throughout a portion of said circle; and other expansion-nozzles of collectively greater capacity directed toward said vanes throughout a second and larger portion of said circle, all of said nozzles being arranged in a circle concentric with said vanes and located laterally at one side thereof.

Signed this 10th day of March, 1903.

WILLIAM E. SHEPARD. [L. S.]

Witnesses:
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PAUL F. PÂIQUET.