F. MARBURG, Jr.

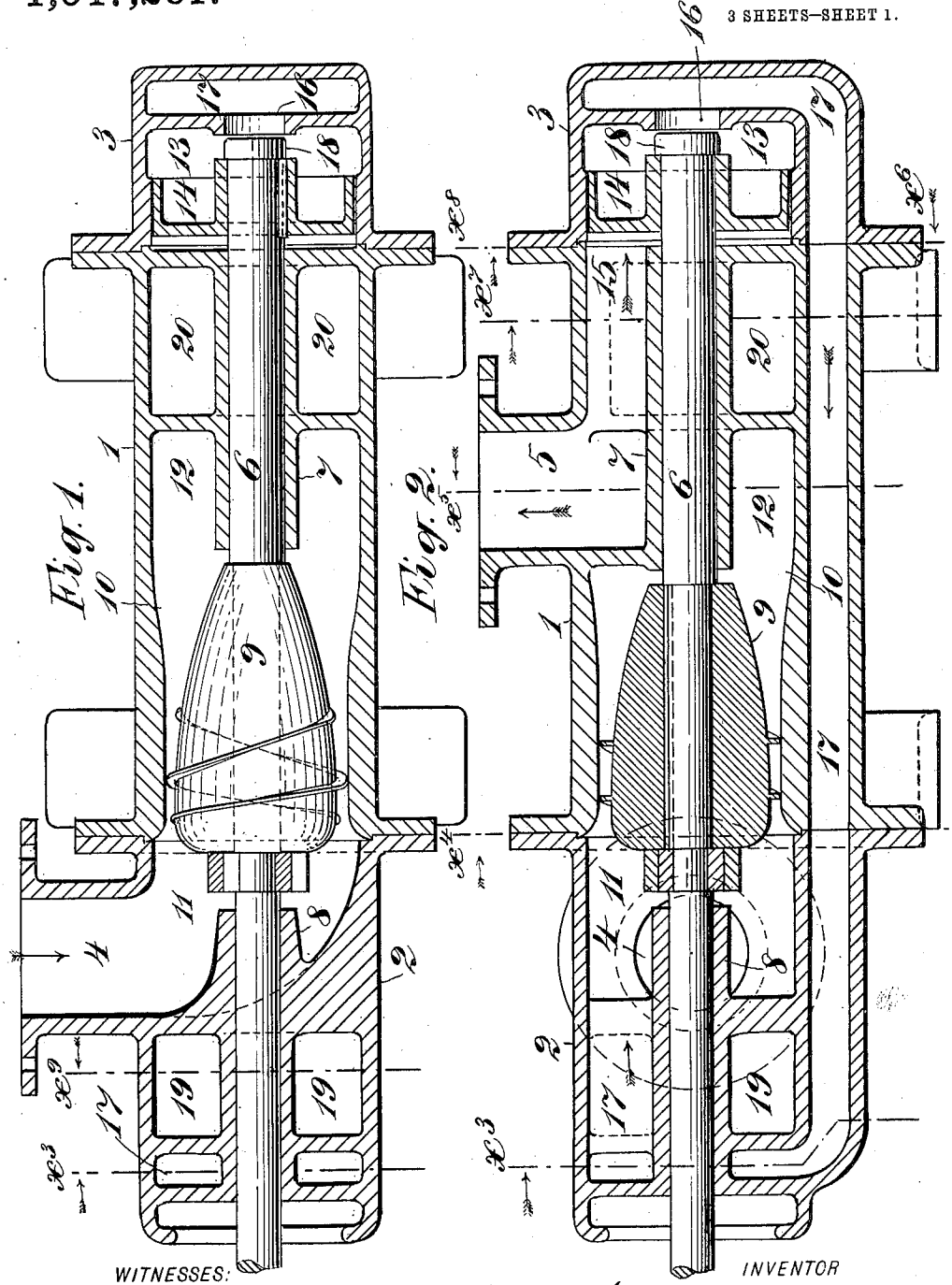
SCREW PROPELLER PUMP.

APPLICATION FILED SEPT. 23, 1903.

1,047,261.

Patented Dec. 17, 1912.

3 SHEETS—SHEET 1.



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3 SHEETS—SHEET 2.

Fig. 9.

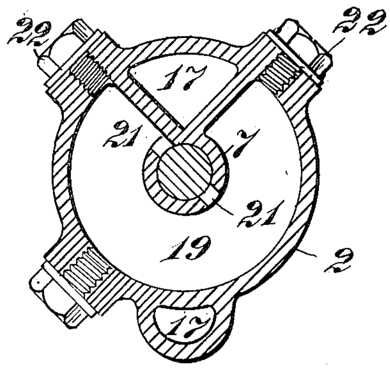


Fig. 3.

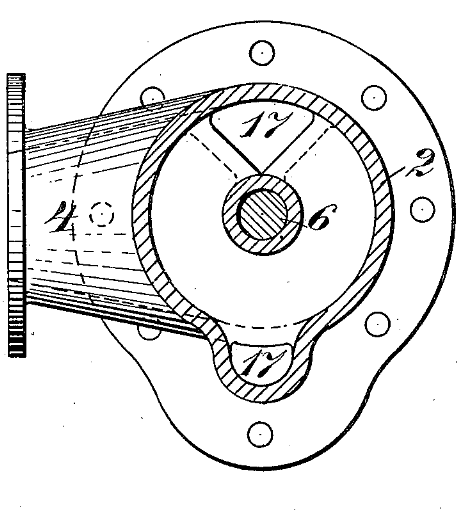
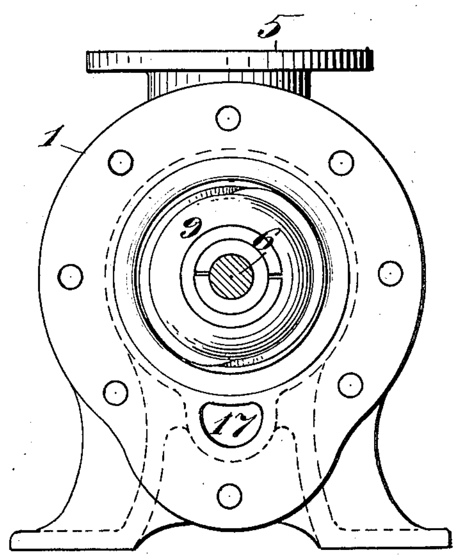


Fig. 4.



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3 SHEETS—SHEET 3.

Fig. 5.

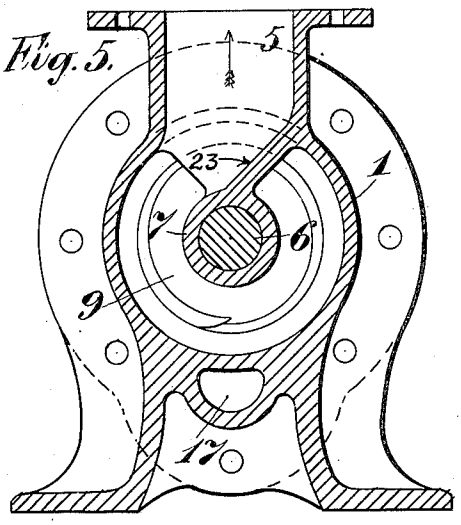


Fig. 8.

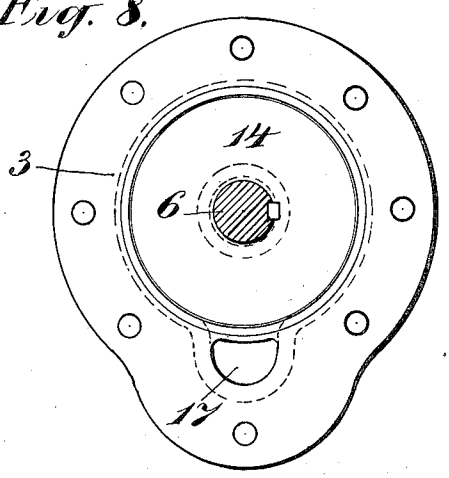


Fig. 6.

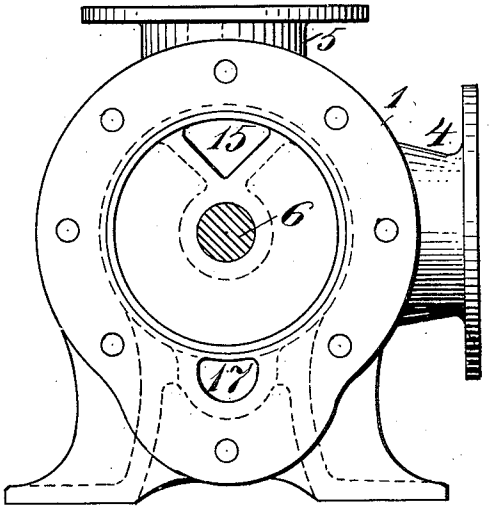
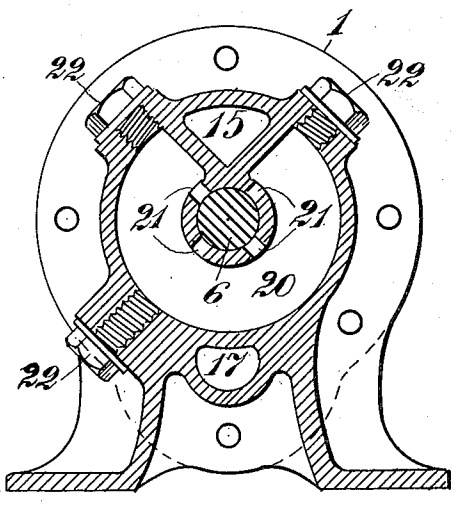


Fig. 7.



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FRANZ MARBURG, JR., OF NEW YORK, N. Y.

SCREW-PROPELLER PUMP.

1,047,261. Specification of Letters Patent. Patented Dec. 17, 1912.

Application filed September 23, 1903. Serial No. 174,249.

To all whom it may concern:

Be it known that I, FRANZ MARBURG, Jr., a citizen of the United States, residing in the borough of Brooklyn, in the county of Kings, in the city and State of New York, have invented certain new and useful Improvements in Screw-Propeller Pumps, of which the following is a specification.

This invention relates to axial propeller pumps, and the object of the invention is, in part, to improve the shape of the screw, in part to simplify the construction and increase the efficiency of the pump; and in part to provide simple means for balancing the thrust of end-pressure on the shaft.

In the accompanying drawings, which illustrate an embodiment of the invention, Figure 1 is a longitudinal, horizontal-axial section of the pump, and Fig. 2 is a similar vertical section of the same. Figs. 3, 4, 5, 6, 7, 8 and 9 are, respectively, transverse sections at lines x^3, x^4, x^5, x^6, x^7, x^8 and x^9 in the principal views. In Fig. 1 the screw is shown in elevation and in Fig. 2 it is represented in section.

1 designates the elongated and substantially cylindrical casing of the pump, which is provided with heads 2 and 3. In the head 2 is the inlet 4, and in the casing itself is the outlet 5. Extending through the casing axially is the pump-shaft 6, which has a bearing 7 in the casing and another bearing 8 in the head 2. On the shaft 6, which has a little endwise movement in its bearings, is secured the screw 9. This screw has an elongated, tapered body rounded at its larger end, and is provided, as herein represented, with two spiral blades somewhat in the form of screw-threads. These blades are disposed at the larger conical end or part of the body, adjacent to the pump-inlet, the blades beginning at the part of the core or screw-body which has the greatest diameter and extending to a part of said body of lesser diameter, and the lesser end of the screw-body is naked, or without blades. The outer contour of the main middle portion of the screw is shown cylindrical, which is preferable as it allows endwise movement of the screw and of the shaft. The screw-body being tapered from the screw-inlet toward the screw-outlet, it follows, that the fully radial width of the screw-blade, and consequently the capacity of the screw, increases from the screw-inlet toward the screw-outlet. Wherever the expression "main middle portion" or "main portion" of the screw or of the blade is used, it signifies the part of the screw or of the screw-blade which is at its outer contour in close proximity to the wall of the casing and the expression "full radial width" of the screw-blade signifies the radial width of said blade at the main portion of the screw only. The pitch of the spiral of the blades gradually increases from the receiving end, and the blades increase gradually to their full radial width from their respective ends toward the main middle portion of the screw. The object of this construction is to reduce the shock caused by the fluid entering the screw while the latter is rotating at a high velocity, and also to prevent suction and undue whirling at the screw-outlet. The bore in the casing where the blades of the screw are situated may be substantially cylindrical, but it may be gradually flared or enlarged at points adjacent to the ends of the blades, as seen at 10 in the principal views.

The shaft being rotated in the proper direction, the fluid enters through the main inlet to a chamber 11 (Fig. 2) in the head 2, and is drawn by the blades of the screw through the annular space between the larger part of the screw-body and the casing, and is forced into a delivery chamber 12, in the casing, which chamber is connected with the eduction outlet 5 of the pump.

In forcing the fluid under a head toward the outlet the screw tends to move or be forced back toward the inlet, or to the left in the principal views, and this puts an end-thrust or pressure on the shaft 6 which it is very necessary to obviate by counterbalancing. To effect this, the head 3 is constructed to form a cylindrical piston-chamber 13, and on the shaft 6 is secured a piston 14, which may rotate loosely or freely in said chamber and also move endwise therein with the shaft. The chamber 13 is open at the inner face of the piston 14, to fluid from the outlet 5, through a passage 15, so that the liquid may press on the piston 14 with substantially the pressure due to the head at the main outlet, and acting on the piston in the opposite axial direction as on the screw; but as the piston 14 fits loosely in the chamber, a small quantity of the fluid may flow past it into the chamber at its outer side.

Opening from the outer part of the cham-

ber is an exhaust-port 16, leading into a passage or conduit 17, which extends back to the inlet chamber 11. This port 16 is adapted to be closed by a valve 18 on the end of the shaft 6, when the latter is moved endwise toward the right under the pressure of the fluid behind the piston 14.

The operation of this device is substantially as follows: When the pump is set in motion the liquid under a pressure at the outlet acts on the piston to move the shaft endwise, to the right as seen in the principal views, and to cause the valve 18 to close the exhaust-port 16. But as a small quantity of the fluid may find its way past the piston, as explained, the valve-chest will fill at the outer side of the piston 14, and the pressure be increased thereon, thus tending to balance the pressure on both faces thereof. However, as the pressure tends to be thus equalized the pressure on the screw will move the shaft and the piston 14 to the left, thus opening the exhaust from the chamber and permitting the pressure to again attain an equilibrium. That is to say, the pressure on the screw tending to move the shaft in one direction will be exactly counterbalanced by the pressure on the piston 14 tending to move the shaft in the other direction, and this will be adjusted automatically. The rapidly rotating piston 14 and valve 18 will always be out of contact with the fixed or non-moving parts, thereby avoiding heat, friction and wear; and the bearings 7 and 8 will be kept cool by the water flowing about and in contact with them at all times while the pump is in operation. The blades of the screw 9 will also rotate out of contact with the casing, but of course in near proximity thereto.

In order to supply the bearings with oil for lubrication, an oil-chamber 19 is provided in the head 2, about the bearing 8, and a similar chamber 20 is provided in the casing about the bearing 7. There are oil-holes 21 in the bearings, as seen in Figs. 7 and 9, and oil-inlets for supplying oil to the chambers, closed by screw-plugs 22.

The object of the construction of the screw 9 as shown in the drawing, and as described, will now be fully explained.

I have found by carefully conducted experiments that the main difficulty with screw-pumps, if operating against a high head, is the unavoidable slip of the fluid, the axial velocity of the fluid being approximately only from one-half to one-quarter of the forward velocity of the spiral blade, the slip increasing with the pressure against which the pump operates. As a result of this action there is a heavy shock or blow when the fluid enters the screw, and a consequent sudden high peripheral velocity and whirling of the fluid with consequent loss of energy and efficiency. After the fluid has attained a high peripheral velocity, little or no pressure in a forward direction can further be exerted on the fluid by the spiral blades. It is not the object of this invention to prevent the slip, but it is rather the intention to produce a screw wherein this unavoidable slip can take place gradually from the screw-inlet toward the screw-outlet. The sectional area or capacity at the screw-outlet is greater than the sectional area or capacity at the screw-inlet, taken in a plane at right-angles to the screw-axis, and as a result the fluid will travel at a greater axial velocity at the screw-inlet than at the screw-outlet, the axial velocity of the fluid at the screw-inlet being equal or nearly equal to the peripheral velocity of the screw blade multiplied by the tangent of the angle which the blade forms at the screw-inlet with a vertical plane through the pump axis. Thus it will be clearly seen that the pressure exerted by the spiral blade on the fluid increases gradually as the axial velocity of the fluid decreases, the pressure being greatest at the screw-outlet, or at the point of greatest sectional area or capacity. The increase of the pitch of the spiral blade and the increase of the full radial width of the spiral-blade, both produce increasing capacity from the screw-inlet toward the screw-outlet, and in the construction shown in the drawings the increasing pitch of the spiral blade toward the delivery end of the screw accentuates the increase of pressure on the fluid, as the blade travels forward in an axial direction with increasing speed, while the fluid flows forward with decreasing speed. It is also clear that it is essential, in all cases, that the screw-outlet capacity should be greater than the screw-inlet capacity. I do not claim an increase of capacity of any part of the screw, or an increase of the pitch of any part of the spiral blade, and smaller screw-outlet capacity than screw-inlet capacity, as shown in the patent to Miles and Storch No. 736,421, but I claim a greater screw-outlet capacity than screw-inlet capacity.

It is important in a pump as embodied in this invention, that the full radial width of the screw-blade should be less than one-sixth part of the corresponding diameter of the outer contour of the screw. The importance of this proportion I have proved by experiments. If the radial width of the screw-blade is greater than stated herein, the efficiency of the pump as herein described is low, either through backflow of the fluid at the inner portion of the screw-blade, nearest the pump-axis, while operating under great pressure or head at the discharge outlet, or through a large over-expenditure of energy at the outer portion of the screw-blade. The first loss occurs if the angular velocity of the screw, and consequently the peripheral velocity of the screw-blade, is

not sufficient at its inner portion or near the pump-axis, to create the required pressure; the latter loss occurs, if the angular velocity is sufficient to create the required pressure at the inner portion of the blade, in which case the outer portion of the blade travels with a greater velocity than necessary to produce the required pressure or head. The amount of these losses can be estimated from the following rules which have been established by me through experiment. The pressure produced and which can be utilized by this pump, is proportional to the square of the peripheral velocity of the screw-blade or any portion thereof. The capacity increases in this particular pump about directly proportional to the velocity of the screw-blade, at various pressures within certain limits, while the amount of energy necessary to operate this pump is proportional to the cube of the peripheral velocity of the screw-blade or any portion thereof. These rules are substantially correct only in a screw-pump of a smaller inlet capacity than outlet capacity, and the amount of energy used at a given velocity of the screw-blades is very nearly independent of the pressure or head at the main discharge outlet of the pump. The reduced or limited inlet area or capacity of the screw produces a more nearly constant discharge against different heads or pressures, and for this reason a high peripheral velocity is always imparted to the fluid in a pump of this character. However, if this pump is operated at the proper speed for each pressure or head, and if the full radial width of the screw-blade is within the limits above stated, and if a fixed director of the proper shape, or other means are employed to gradually reduce the high velocity of the fluid adjacent to the screw-outlet, then in that case, the efficiency of the pump is very high.

One other unavoidable feature of these pumps, as just stated, is the resultant high rotary velocity of the fluid about the pump-axis at the discharge end of the screw; and the object of the annular space or chamber adjacent to the screw-outlet, and of the gradual increase of the capacity of said chamber in the direction from the screw-outlet, is to gradually reduce this high rotary velocity and thus to utilize a part of this energy by transforming it into useful pressure, thereby increasing the efficiency of the pump.

Adjacent to the screw-outlet 5 is a fixed director 23, which may be in one part with the casing as herein shown, or which may be separate and secured in the casing, as may be convenient. The object of this fixed director is to direct the fluid gradually toward the main pump outlet, which object is herein accomplished with little shock or whirling, thereby saving some energy. This invention is not limited to the use of a director of the exact shape as herein shown, or of the device shown herein for reducing the velocity of the fluid adjacent the screw-outlet.

There are two spiral blades shown in the drawings, but this invention is not limited in this respect and it is obvious that one or more spiral blades can be used; and the number of blades used should increase with the diameter of the screw and with the pressure against which the pump operates.

Whenever the expression "spiral blade" occurs in this application, it signifies a blade of oblique shape and gradually curved from the screw-inlet toward the screw-outlet. The expression "screw" signifies a body having one or more spiral blades, which blades extend in the direction from the screw-inlet toward the screw-outlet in a peripheral and substantially axial direction.

A screw-wheel, as understood in this application, may be a screw with or without a rotating outer ring.

I claim herein, of some of the characteristics, only the specific construction, these same characteristics being claimed more broadly in my Patent No. 872,361, dated December 3, 1907.

Having thus described my invention, I claim:

1. A screw pump, having a casing, with a fluid inlet and fluid outlet, a screw wheel having a substantially spiral blade, the outer contour of the main portion of said blade being substantially cylindrical, corresponding to the inner wall of the casing and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter internally beyond the screw outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw.

2. A screw pump, having a casing, with a fluid inlet and fluid outlet, a screw wheel having a substantially spiral blade, the radial width of the main portion of said blade increasing from the screw-inlet toward the screw-outlet, the outer contour of the main portion of said blade being substantially cylindrical, corresponding to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter internally beyond the screw outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw.

3. A screw pump, having a casing, with a fluid inlet and fluid outlet, a screw wheel, having a substantially spiral blade, the pitch of said blade increasing from the screw-inlet toward the screw-outlet, the outer contour of the main portion of said blade being substantially cylindrical, corresponding

to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter internally beyond the screw-outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw.

4. A screw pump, having a casing with a fluid inlet and fluid outlet, a screw wheel, having a substantially spiral blade, the radial width and the pitch of said blade increasing from the screw-inlet toward the screw-outlet, the outer contour of the main portion of said blade being substantially cylindrical, corresponding to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter internally beyond the screw-outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw.

5. A screw pump, having a casing with a fluid inlet and fluid outlet, a screw wheel, having a substantially spiral blade, the capacity of the screw increasing from the screw-inlet toward the screw-outlet, the outer contour of the main portion of said blade being substantially cylindrical, corresponding to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter internally beyond the screw-outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw.

6. In a device for the purpose set forth, an internally cylindrical casing with a fluid inlet and fluid outlet, a screw wheel with its main portion being of substantially cylindrical outer contour, fitted in and mounted rotatively within said casing between the fluid inlet and fluid outlet, said screw wheel having a substantially spiral blade, whose pitch and width increases from the screw inlet toward the screw outlet, and means for gradually reducing the velocity of the fluid, adjacent to the screw outlet.

7. In a device for the purpose set forth, a casing with a fluid inlet and fluid outlet, a screw wheel mounted rotatively within said casing between the fluid inlet and fluid outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw inlet toward the screw outlet, and means for gradually reducing the velocity of the fluid, adjacent to the screw outlet.

8. A screw pump, having a casing with a fluid inlet and fluid outlet, a screw wheel, having a substantially spiral blade, which gradually increases to its full radial width from one end toward the main portion of the screw, the outer contour of said blade at its main portion being substantially cylindrical, corresponding to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter beyond the screw outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw.

9. A screw pump, having a casing with a fluid inlet and fluid outlet, a screw wheel, having a substantially spiral blade, which gradually increases to its full radial width from each end toward the main middle portion of the screw, the outer contour of said blade at its main middle portion being substantially cylindrical, corresponding to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter beyond the screw outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw.

10. A screw pump, having a casing with a fluid inlet and fluid outlet, a screw wheel, having a substantially spiral blade, which gradually increases to its full radial width from one end toward the main portion of the screw, the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, the outer contour of said blade at its main portion being substantially cylindrical, corresponding to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter beyond the screw outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw.

11. A screw pump, having a casing with a fluid inlet and fluid outlet, a screw wheel, having a substantially spiral blade, which gradually increases to its full radial width from one end toward the main portion of the screw, the pitch of said blade increasing from the screw-inlet toward the screw-outlet, the outer contour of said blade at its main portion being substantially cylindrical, corresponding to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter beyond the screw outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw.

12. A screw pump, having a casing with a fluid inlet and fluid outlet, a screw wheel, having a substantially spiral blade, which gradually increases to its full radial width from one end toward the main portion of the screw, the pitch and the full radial width of said blade increasing from the screw inlet toward the screw outlet, the outer contour of said blade at its main portion being substantially cylindrical, corre-

sponding to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter beyond the screw-outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw.

13. A screw pump, having a casing with a fluid inlet and fluid outlet, a screw wheel, having a substantially spiral blade, which gradually increases to its full radial width from one end toward the main portion of the screw, the capacity increasing from the screw inlet toward the screw outlet, the outer contour of said blade at its main portion being substantially cylindrical, corresponding to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter beyond the screw outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw.

14. A screw pump, having a casing, with a fluid inlet and fluid outlet, a screw wheel having a substantially spiral blade, the outer contour of the main portion of said blade being substantially cylindrical, corresponding to the inner wall of the casing and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter internally beyond the screw outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw, and a fixed director near the fluid outlet of the casing.

15. A screw pump, having a casing, with a fluid inlet and fluid outlet, a screw wheel having a substantially spiral blade, the radial width of the main portion of said blade increasing from the screw inlet toward the screw outlet, the outer contour of the main portion of said blade being substantially cylindrical, corresponding to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter internally beyond the screw outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw, and a fixed director near the fluid outlet of the casing.

16. A screw pump, having a casing with a fluid inlet and fluid outlet, a screw wheel, having a substantially spiral blade, the pitch of said blade increasing from the screw-inlet toward the screw-outlet, the outer contour of the main portion of said blade being substantially cylindrical, corresponding to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter internally beyond the screw-outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw, and a fixed director near the fluid-outlet of the casing.

17. A screw-pump, having a casing with a fluid inlet and fluid-outlet, a screw wheel, having a substantially spiral blade, the radial width and the pitch of said blade increasing from the screw-inlet toward the screw-outlet, the outer contour of the main portion of said blade being substantially cylindrical, corresponding to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter internally beyond the screw outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw, and a fixed director near the fluid outlet of the casing.

18. A screw pump, having a casing with a fluid inlet and fluid outlet, a screw wheel, having a substantially spiral blade, the capacity of the screw increasing from the screw-inlet toward the screw-outlet, the outer contour of the main portion of said blade being substantially cylindrical, corresponding to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, the casing increasing gradually in diameter internally beyond the screw-outlet, to form a gradually enlarging annular chamber, into which the fluid flows from the screw, and a fixed director near the fluid outlet of the casing.

19. A screw pump, having a casing with a fluid inlet and fluid outlet, a screw wheel, having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, the outer contour of the main portion of said blade being substantially cylindrical, corresponding to the inner wall of the casing, and said screw wheel being fitted in and mounted rotatively within said casing, and adjacent to the screw outlet a fixed director.

20. A screw pump, having a casing with a fluid inlet and fluid outlet, a screw wheel, having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, said screw wheel being fitted in and mounted rotatively within said casing and adjacent to the screw-outlet a fixed director.

21. A device for the purpose specified, having an internal cylindrical casing with a fluid inlet and fluid outlet, and a screw wheel the main portion of which is of cylindrical outer contour, mounted rotatively within said casing between the said fluid inlet and outlet, said screw wheel having a substantially spiral blade and having also a core or body which is conical and tapers from the screw-inlet toward the

screw-outlet, the pitch of said spiral blade increasing from the screw-inlet toward the screw-outlet.

22. A device for the purpose specified, having a casing with a fluid inlet and fluid outlet, and a screw wheel mounted rotatively within said casing between the said fluid inlet and outlet, said screw-wheel having a substantially spiral blade the pitch of said spiral blade and the full radial width of the same increasing from the screw-inlet toward the screw-outlet.

23. A device for the purpose specified, having a casing with a fluid inlet and fluid outlet, and a screw-wheel mounted rotatively within said casing between the said fluid inlet and outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and the capacity of the screw-outlet being greater than the capacity of the screw-inlet.

24. A device for the purpose set forth, having a casing with a fluid inlet and fluid outlet, and a screw-wheel mounted rotatively within said casing between said fluid inlet and outlet, said screw wheel having a substantially spiral blade, whose pitch and width increase from the screw-inlet toward the screw-outlet.

25. A device for the purpose specified, having a casing with a fluid-inlet and fluid-outlet, and a screw wheel fitted in and mounted rotatively within said casing, between the said fluid inlet and outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, the outer contour of the main portion of said screw being substantially cylindrical, and the capacity of the screw outlet being greater than the capactiy of the screw inlet.

26. A device for the purpose set forth, having a casing with a fluid-inlet and fluid-outlet, and a screw wheel fitted in and mounted rotatively within said casing between said fluid-inlet and outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing throughout from the screw-inlet toward the screw-outlet and the outer contour of the main portion of said screw being substantially cylindrical.

27. A device for the purpose specified, having a casing with a fluid-inlet and fluid-outlet, and a screw wheel mounted rotatively within said casing between the said fluid-inlet and outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and said screw wheel having a core or body which extends beyond the screw-outlet, said extended screw-body being naked and of conical outer shape and tapering in the direction from the screw-outlet.

28. A device for the purpose specified, having a casing with a fluid-inlet and fluid-outlet, and a screw wheel mounted rotatively within said casing between the said fluid-inlet and outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and said screw wheel having a core or body which extends beyond the screw-inlet, said extended screw body being naked and of conical outer shape and tapering in the direction from the screw inlet.

29. A device for the purpose specified, having a casing with a fluid inlet and fluid outlet, and a screw wheel mounted rotatively within said casing between the said fluid-inlet and fluid-outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and said screw wheel having a core or body, which extends beyond the screw-inlet and beyond the screw-outlet, said extended screw body being naked and of conical outer shape and tapering in the direction from the screw-inlet and in the direction from the screw-outlet.

30. A device for the purpose set forth, having a casing with a fluid inlet and fluid-outlet, and a screw wheel mounted rotatively within said casing between said fluid inlet and outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw inlet toward the screw outlet, the outer contour of the main portion of said screw being substantially cylindrical, and adjacent to one screw end an annular space, which increases gradually in capacity in the direction from the screw.

31. A device for the purpose set forth, having a casing with a fluid inlet and fluid outlet, and a screw wheel mounted rotatively within said casing between said fluid inlet and fluid outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw inlet toward the screw outlet, the outer contour of the main portion of said screw being substantially cylindrical, adjacent to the screw inlet an annular inlet space which increases gradually in capacity in the direction from the screw-inlet, and adjacent to the screw-outlet an annular outlet space which increases gradually in capacity in the direction from the screw outlet.

32. A device for the purpose set forth, having a casing with a fluid inlet and fluid outlet, and a screw wheel mounted rotatively within said casing between said fluid inlet and outlet, said screw wheel having a sub-

stantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and having adjacent to one screw-end an annular space which increases gradually in capacity in the direction from the screw.

33. A device for the purpose set forth, having a casing with a fluid inlet and fluid outlet, and a screw wheel mounted rotatively within said casing between said fluid inlet and outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and having adjacent to the screw-inlet an annular inlet-space which increases gradually in the direction from the screw-inlet, and adjacent to the screw-outlet an annular outlet-space which increases gradually in the direction from the screw-outlet.

34. A device for the purpose specified, having a casing with a fluid inlet and fluid outlet, and a screw wheel, mounted rotatively within said casing between said fluid inlet and fluid outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and said spiral blade increasing gradually to its full radial width from one end toward the main portion of the screw, the outer contour of the main portion of said screw being substantially cylindrical.

35. A device for the purpose specified, having a casing with a fluid inlet and fluid outlet, and a screw wheel mounted rotatively within said casing between said fluid inlet and fluid outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and said spiral blade increasing gradually to its full radial width from each end toward the main middle portion of the screw, the outer contour of the main portion of said screw being substantially cylindrical.

36. A device for the purpose specified, having a casing with a fluid inlet and fluid outlet, and a screw wheel mounted rotatively within said casing between said fluid inlet and outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and said spiral blade increasing gradually to its full radial width from one end toward the main portion of the screw.

37. A device for the purpose specified, having a casing with a fluid inlet and fluid outlet, and a screw wheel mounted rotatively within said casing between said fluid inlet and outlet, said screw-wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and said spiral blade increasing gradually to its full radial width from each end toward the main middle portion of the screw.

38. A device for the purpose specified, having a casing with a fluid inlet and fluid outlet, and a screw wheel mounted rotatively within said casing between said fluid inlet and outlet, said screw wheel having a substantially spiral blade, which increases gradually to its full radial width from one end toward the main portion of the screw, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and adjacent to one end of the screw an annular space which increases gradually in capacity in the direction from the screw, the outer contour of the main portion of said screw being substantially cylindrical.

39. A device for the purpose specified, having a casing with a fluid inlet and fluid outlet, and a screw wheel mounted rotatively within said casing, between said fluid inlet and outlet, said screw wheel having a substantially spiral blade which increases gradually to its full radial width from each end toward the main middle portion of the screw, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and adjacent to each end of the screw an annular space which increases gradually in capacity in the direction from the screw, the outer contour of the main portion of said screw being substantially cylindrical.

40. A device for the purpose specified, having a casing with a fluid inlet and fluid outlet, and a screw-wheel mounted rotatively within said casing between said fluid inlet and outlet, said screw wheel having a substantially spiral blade which increases gradually to its full radial width from one end toward the main portion of the screw, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and having adjacent to one end of the screw an annular space which increases gradually in capacity in the direction from the screw.

41. A device for the purpose specified, having a casing with a fluid inlet and fluid outlet, and a screw wheel mounted rotatively within said casing between said fluid inlet and outlet, said screw wheel having a substantially spiral blade which increases gradually to its full radial width from each end toward the main middle portion of the screw, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and having adjacent to each end of the screw an annular space which increases gradually in capacity in the direction from the screw.

42. A device for the purpose specified, having a casing with a fluid inlet and fluid outlet, a shaft, a screw wheel on said shaft, and mounted rotatively within said casing between the fluid inlet and outlet thereof, said screw wheel having a substantially spiral blade and being subjected to end-thrust, and means for balancing said end-thrust, said means comprising a cylindrical piston-chamber open at one end to fluid under pressure and having at its opposite end a fluid outlet independent of the shaft, a piston on the screw-shaft, said piston being located in and playing loosely within said chamber between the fluid inlet and fluid outlet, and a valve on the shaft, said valve controlling the fluid outlet from the piston-chamber, and said valve being automatically actuated by the longitudinal movement of the screw-shaft, substantially as set forth.

43. A device for the purpose set forth, having a casing with an inlet and outlet, a screw-shaft mounted rotatively within said casing, a screw-wheel on said shaft having a substantially spiral blade and being subjected to end-thrust, and means for balancing said end-thrust, said means comprising a cylindrical piston-chamber open at one end to fluid under pressure and having at its opposite end a fluid outlet independent of the shaft, the said screw-shaft extending axially through the piston-chamber, a piston fitted in and mounted rotatively on said shaft within said chamber between the fluid inlet and fluid outlet thereof, means for permitting part of the fluid to escape from the fluid inlet end to the fluid outlet end of said chamber, and a valve controlling the fluid outlet from the chamber, said valve being automatically actuated by the longitudinal movement of the shaft.

44. A device for the purpose set forth, having a casing with an inlet and outlet, a screw-wheel on a shaft and mounted rotatively within said casing, said screw wheel having a substantially spiral blade and being subjected to end-thrust, and means for balancing said end-thrust, said means comprising a cylindrical piston-chamber, the said screw-shaft, extending through the piston-chamber, a piston on the shaft and fitted in and mounted rotatively within said chamber, means for admitting fluid under pressure to said chamber at both sides of the piston, and a fluid outlet independent of the shaft from said chamber, said fluid outlet being automatically controlled by the shaft in its longitudinal movement.

45. A device for the purpose set forth, having a casing with an inlet and outlet, a shaft mounted rotatively within said casing and slidable endwise, a cylindrical piston-chamber through which the shaft extends, a piston on the shaft, said piston fitted in peripherally and mounted rotatively within the piston-chamber, means for admitting fluid under pressure to said chamber and at both sides of said piston, and a fluid outlet independent of the shaft from said chamber, said fluid outlet being automatically controlled by the shaft in its longitudinal movement.

46. In a device for the purpose set forth, a casing having a fluid inlet and fluid outlet, a screw wheel on a shaft fitted in and mounted rotatively within said casing between the fluid inlet and fluid outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, the outer contour of the main portion of said blade being substantially cylindrical, and means for balancing the end-thrust on said screw wheel, said means comprising a balancing device which is automatically controlled by the endwise movement of said shaft.

47. In a device for the purpose set forth, a casing having a fluid inlet and fluid outlet, a screw wheel on a shaft and mounted rotatively within said casing between the fluid inlet and fluid outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw-inlet toward the screw-outlet, and means for balancing the end-thrust on said screw wheel, said means comprising a balancing device which is automatically controlled by the endwise movement of said shaft.

48. A device of the character described having a casing with a fluid-inlet and fluid-outlet, a shaft and a propeller wheel on said shaft, mounted rotatively within said casing and slidable endwise, a piston-chamber through which the shaft extends, a piston on the shaft and mounted rotatively within the piston-chamber, means for admitting fluid under pressure to one end of said chamber and at one side of said piston, means for permitting part of the fluid to escape to the other end of said chamber at the opposite side of said piston, and a fluid outlet independent of the shaft from the latter end of said chamber and controlled from the endwise movement of the piston.

49. A device for the purpose specified, having a casing with a fluid-inlet and fluid-outlet, a shaft and a propeller wheel on said shaft, mounted rotatively within said casing and slidable endwise, a piston-chamber through which the shaft extends, a piston on the shaft and being mounted rotatively within the piston-chamber, means for admitting fluid under pressure to one end of said chamber and at one side of said piston, means for permitting part of the fluid to escape to the other end of said chamber at the opposite side of said piston, and a fluid outlet independent of the shaft from the lat-

ter end of said chamber, said fluid-outlet being controlled by the piston through its endwise movement.

50. A device of the character described having a casing with a fluid-inlet and fluid-outlet, a shaft mounted to turn in the casing and slidable endwise, a cylindrical piston-chamber through which the shaft extends, a piston on said shaft and mounted to turn in said chamber and having its peripheral surface fitted within the chamber, means for admitting fluid under pressure to one end of said chamber and at one side of said piston, means for permitting a part of the fluid to escape to the other end of said chamber and to the opposite side of said piston, and a fluid-outlet independent of the shaft from the latter end of said chamber, and controlled from the endwise movement of the piston.

51. A device for the purpose specified, having a casing with a fluid-inlet and fluid-outlet, a shaft mounted rotatively within said casing and slidable endwise, a cylindrical piston-chamber through which the shaft extends, a piston on said shaft, said piston being fitted in peripherally and mounted rotatively within the piston-chamber, means for admitting fluid under pressure to one end of said chamber and at one side of said piston, means for permitting a part of the fluid to escape to the other end of said chamber and to the opposite side of said piston and a fluid-outlet independent of the shaft from the latter end of said chamber, said outlet being controlled by the piston through its endwise movement.

52. In a device for the purpose set forth, a casing with a fluid inlet and fluid outlet, a screw wheel fitted in and mounted rotatively within said casing, between said fluid inlet and fluid outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing throughout the screw from its inlet, and means for gradually reducing the velocity of the fluid, adjacent to the screw-outlet.

53. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel mounted rotatively within the casing between said fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, the screw-outlet capacity being greater than the screw-inlet capacity and the full radial width of said blade being less than one sixth part of the corresponding diameter of the outer contour of the screw.

54. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel having at its main portion a substantially cylindrical outer contour, mounted rotatively in the casing between said fluid-inlet and fluid-outlet, said screw-wheel having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, the screw-outlet capacity being greater than the screw-inlet capacity and the full radial width of said blade being less than one sixth part of the corresponding diameter of the outer contour of the screw.

55. A device of the character described having a casing with a fluid-inlet and fluid-outlet, a screw wheel mounted to turn in the casing between said fluid-outlet and fluid-inlet, said screw wheel having a substantially spiral blade, the pitch of said blade and the capacity of the screw increasing throughout from the screw-inlet toward the screw-outlet and the full radial width of said blade being less than one sixth part of the corresponding diameter of the outer contour of the screw.

56. A device of the character described having a casing with a fluid-inlet and fluid-outlet, a screw-wheel having a substantially cylindrical outer contour mounted to turn in the casing between the fluid-inlet and fluid-outlet, said screw-wheel having a substantially spiral blade, the pitch of said blade and the capacity of the screw increasing throughout from the screw-inlet toward the screw-outlet and the full radial width of said blade being less than one sixth part of the corresponding diameter of the outer contour of the screw.

57. A device of the character described having a casing with a fluid-inlet and fluid-outlet, a screw-wheel having at its main portion a substantially cylindrical outer contour mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet and the full radial width of which is less than one sixth part of the corresponding diameter of the outer contour of the screw, and means for gradually reducing the velocity of the fluid adjacent to the screw-outlet.

58. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel mounted to turn in said casing between said fluid-inlet and fluid-outlet and having a substantially spiral blade, the pitch of which increases from the screw-inlet to the screw-outlet, the screw-outlet capacity being greater than the screw-inlet capacity and the full radial width of the blade being less than one sixth part of the corresponding diameter of the outer contour of the screw, and means for gradually reducing the velocity of the fluid adjacent to the screw-outlet.

59. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel having a substan-

tially cylindrical outer contour mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, the screw-outlet capacity being greater than the screw-inlet capacity and the full radial width of the blade being less than one sixth part of the corresponding diameter of the outer contour of the screw, and means for gradually reducing the velocity of the fluid adjacent to the screw-outlet.

60. A device of the character described having a casing with a fluid-inlet and fluid-outlet, a screw-wheel having a substantially cylindrical outer contour mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of said blade and the capacity of the screw increasing throughout from the screw-inlet toward the screw-outlet, and the full radial width of the blade being less than one sixth part of the corresponding diameter of the outer contour of the screw, and means for gradually reducing the velocity of the fluid adjacent to the screw-outlet.

61. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, said screw-wheel having a core or body which extends beyond the screw-outlet, said extended screw-body being naked and of conical outer shape and tapering from the screw-outlet, and an annular space around said tapered body, said annular space gradually increasing in capacity and in width in the direction from the screw-outlet.

62. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel having a substantially cylindrical outer contour mounted to turn in the casing between the fluid-inlet and fluid-outlet, said screw-wheel having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, said screw-wheel having a core or body which extends beyond the screw-outlet, the extended screw-body being naked and of conical outer shape and tapering from the screw-outlet, and an annular space around the screw-body, said annular space gradually increasing in capacity and in width in the direction from the screw-outlet.

63. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, and said screw-wheel having a core or body extended beyond the screw-inlet, said extended screw-body being naked and of conical outer contour and tapering in the direction from the screw-inlet.

64. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel having a substantially cylindrical outer contour mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, and said screw-wheel having a core or body which extends beyond the screw-inlet, said extended screw-body being naked and of conical outer contour and tapering in the direction from the screw-inlet.

65. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, and adjacent to the screw-outlet an annular outlet space which gradually increases in capacity and in width in the direction from the screw-outlet.

66. A device of the character described having a casing with a fluid-outlet and fluid-inlet, and a screw-wheel having a substantially cylindrical outer contour mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade, the pitch of which increases from the screw-inlet toward the screw-outlet, and adjacent to the screw-outlet an annular outlet space which gradually increases in capacity and in width in the direction from the screw-outlet.

67. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, and adjacent to one screw-end an annular space which increases gradually in capacity and in width in the direction from the screw.

68. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel having a substantially cylindrical outer contour mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, and adjacent to one screw-end an annular space which increases gradually in capacity and in width in the direction from the screw.

69. A device of the character described

having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel mounted to turn in the casing between said fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, and adjacent to the screw-inlet an annular inlet space which increases gradually in capacity and in width in the direction from the screw-inlet, and adjacent to the screw-outlet an annular outlet space which increases gradually in capacity and in width in the direction from the screw-outlet.

70. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel having a substantially cylindrical outer contour mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, adjacent to the screw-inlet an annular space increasing gradually in capacity and width in the direction from the screw-inlet, and adjacent to the screw-outlet, an annular outlet space increasing gradually in capacity and width in the direction from the screw-outlet.

71. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, and said spiral blade gradually increasing to its full radial width from one end toward the main portion of the screw.

72. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel having a substantially cylindrical outer contour mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, and said spiral blade gradually increasing to its full radial width from one end toward the main portion of the screw.

73. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, and said spiral blade gradually increasing to its full radial width from each end toward the main middle portion of the screw.

74. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel having a substantially cylindrical outer contour mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade the pitch of which increases from the screw-inlet toward the screw-outlet, and said spiral blade gradually increasing to its full radial width from each end toward the main middle portion of the screw.

75. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade which gradually increases to its full radial width from one end toward the main portion of the screw and the pitch of which increases from the screw-inlet toward the screw-outlet, and adjacent to one screw-end an annular space increasing gradually in capacity and width in the direction from the screw.

76. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel having a substantially cylindrical outer contour mounted to turn in the casing between said inlet and outlet and having a substantially spiral blade which gradually increases to its full radial width from one end toward the main portion of the screw and the pitch of which increases from the screw-inlet toward the screw-outlet, and adjacent to the screw-end an annular space which increases gradually in capacity and width in the direction from the screw.

77. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel mounted to turn in the casing between said inlet and outlet and having a substantially spiral blade which increases gradually to its full radial width from each end toward the main middle portion of the screw and the pitch of which increases from the screw-inlet toward the screw-outlet, and adjacent to each screw-end an annular space increasing gradually in capacity and width in the direction from the screw.

78. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel having a substantially cylindrical outer contour mounted to turn in the casing between said inlet and outlet and having a substantially spiral blade which increases gradually to its full radial width from each end toward the main middle portion of the screw and the pitch of which increases from the screw-inlet toward the screw-outlet, and adjacent to each screw-end an annular space increasing gradually in capacity and width in the direction from the screw.

79. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel mounted to turn in the casing between said inlet and outlet

and having a substantially spiral blade which increases gradually to its full radial width from one end toward the main portion of the screw and the pitch of which increases from the screw-inlet toward the screw-outlet, and means for gradually reducing the velocity of the fluid adjacent to the screw-outlet.

80. A device of the character described having a casing with a fluid-outlet and fluid-inlet, and a screw-wheel with a substantially cylindrical outer contour mounted to turn in the casing between said inlet and outlet and having a substantially spiral blade which gradually increases to its full radial width from one end toward the main portion of the screw and the pitch of which increases from the screw-inlet toward the screw-outlet, and means for gradually reducing the velocity of the fluid adjacent to the screw-outlet.

81. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel mounted to turn in the casing between said inlet and outlet and having a substantially spiral blade which increases gradually to its full radial width from each end toward the main middle portion of the screw and the pitch of which increases from the screw-inlet toward the screw-outlet, and means for gradually reducing the velocity of the fluid adjacent to the screw-outlet.

82. A device of the character described having a casing with a fluid-inlet and fluid-outlet, and a screw-wheel with a substantially cylindrical outer contour mounted to turn in the casing between the fluid-inlet and fluid-outlet and having a substantially spiral blade which increases gradually to its full radial width from each end toward the main portion of the screw and the pitch of which increases from the screw-inlet toward the screw-outlet, and means for gradually reducing the velocity of the fluid adjacent to the screw-outlet.

83. In a device for the purpose set forth, a casing with a fluid inlet and fluid outlet, a screw wheel with its main portion of substantially cylindrical outer contour mounted rotatively within said casing between the fluid inlet and fluid outlet, said screw wheel having a substantially spiral blade, the pitch and the full radial width of said blade increasing from the screw inlet toward the screw outlet, and means for gradually reducing the velocity of the fluid, adjacent to the screw outlet.

In witness whereof I have hereunto signed my name this 18th day of September, 1903, in the presence of two subscribing witnesses.

FRANZ MARBURG, JR.

Witnesses:
BENJAMIN H. HOLT,
WILLIAM J. FIRTH.