June 13, 1967 D. VOGLER 3,325,089

FLOW MACHINES

Filed Feb. 2, 1965 3 Sheets-Sheet 1

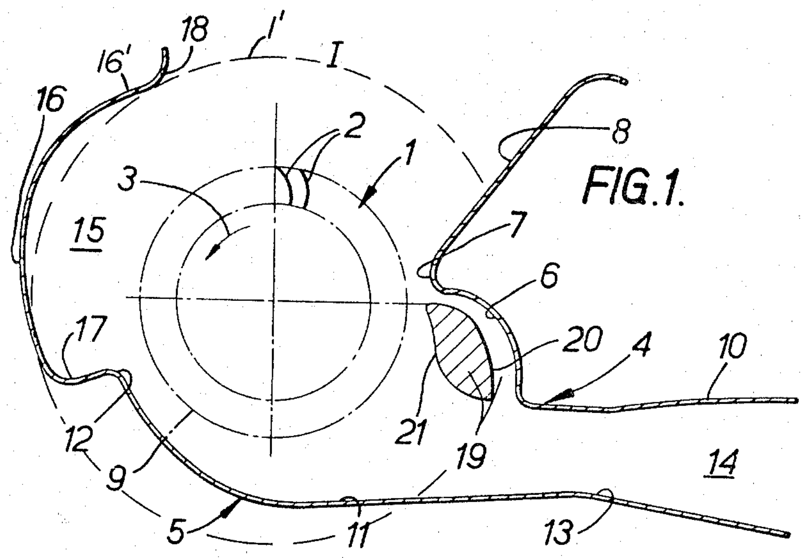


FIG. 1.

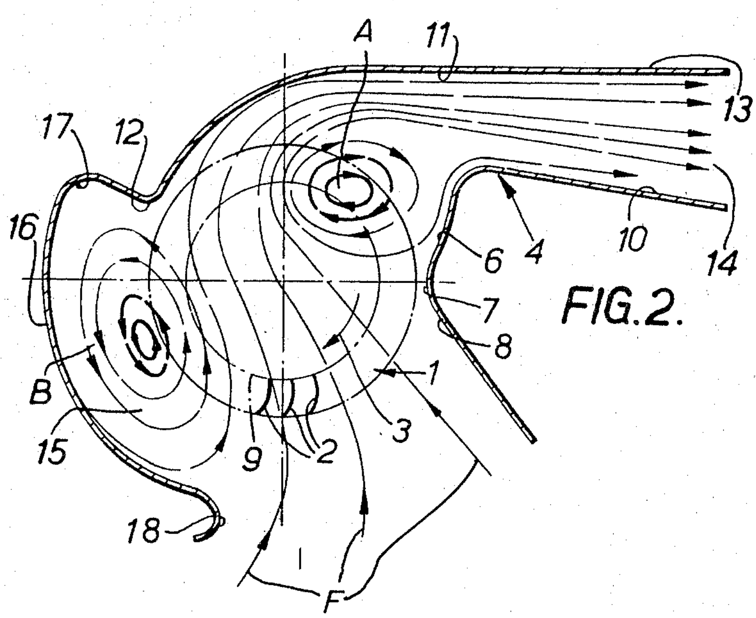


FIG. 2.

FIG. 1a.

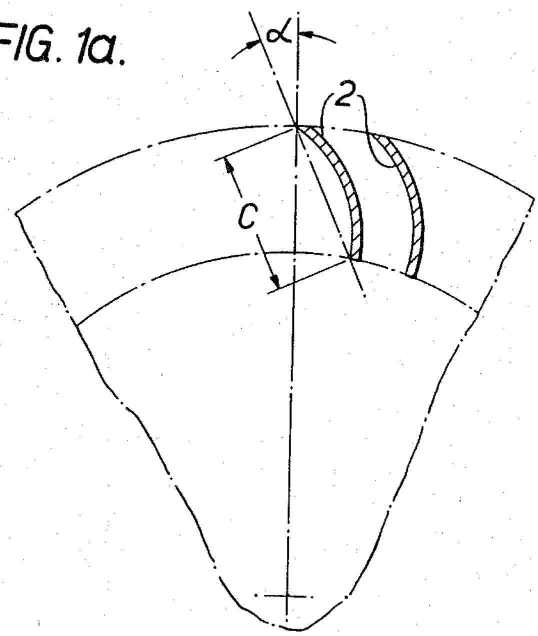
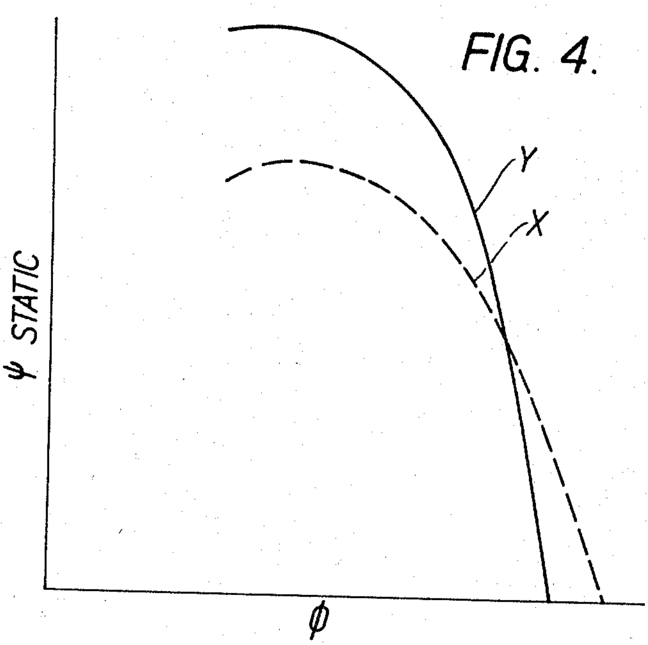


FIG. 4.



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FLOW MACHINES

Filed Feb. 2, 1965 3 Sheets-Sheet 3

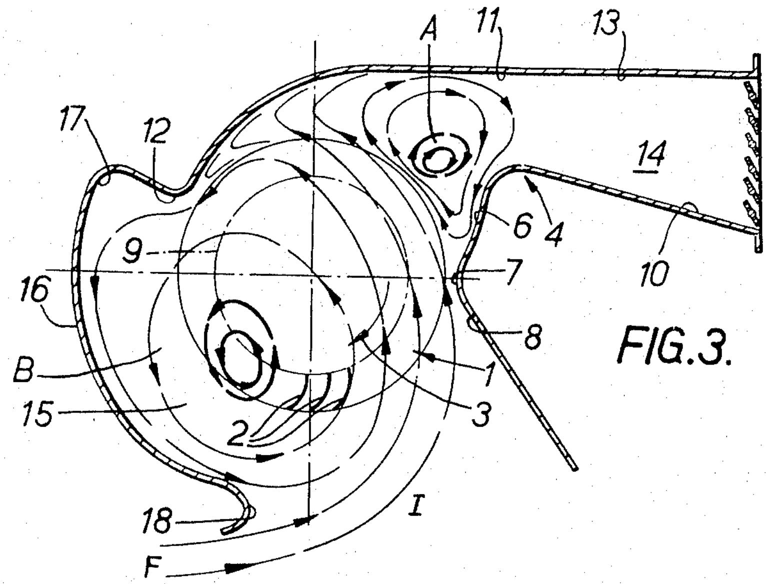


FIG. 3.

FIG. 5.

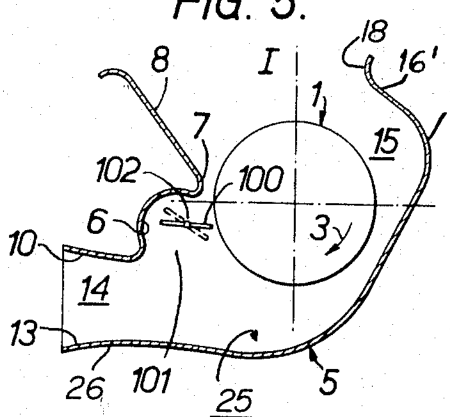
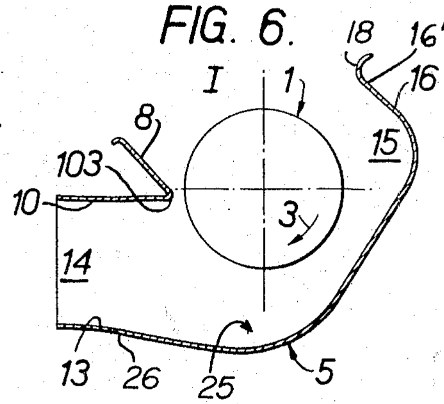


FIG. 6.



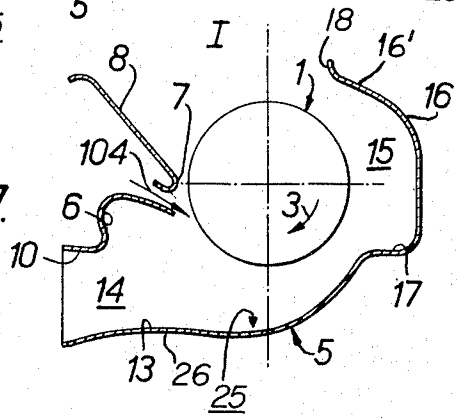


FIG. 7.

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FLOW MACHINES

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11 Claims. (Cl. 230—125)

This invention relates to machines for inducing a flow of fluid, whether liquid or gaseous, and more particularly to cross-flow machines i.e. machines comprising a bladed cylindrical rotor and guide means co-operating with the rotor on rotation thereof whereby to induce a flow of fluid in a direction transverse to the rotor axis and twice traversing the path of the rotating blades of the rotor. Advantageous forms of cross-flow machines are disclosed in British specifications Nos. 757,543 and 876,611.

British specification No. 876,611 discloses a cross-flow machine wherein the rotor has its interior clear of stationary guides, and rotor and guide means co-operate in operation to stabilize an approximately cylindrical vortex including a field region with a velocity profile approximately that of a Rankine vortex and a core region eccentric to the rotor axis. In a preferred form of this flow machine the guide means comprises a guide body and a guide wall extending the length of the rotor, the guide body subtending a small angle (say 40° or less) at the rotor axis and the guide wall extending around the rotor in a curve from about opposite the guide body and defining therewith an outlet from the rotor: in normal operation the vortex core takes up a position interpenetrating the path of the rotating blades between the guide body and the guide wall and nearer to the guide body. In a simple form of this flow machine the guide body is provided by a main guide wall portion which merges with a further wall portion extending opposite the guide wall and defining therewith an outlet duct: the main guide wall portion defines with the rotor a gap which may converge in the direction of rotor rotation, as disclosed in specification No. 757,543.

In the earlier proposals mentioned the guide wall has been terminated about opposite the guide body, or if continued has been so constructed as to have little influence on flow through the rotor.

Certain flow machines exhibiting the features of the simple machine mentioned in the penultimate paragraph and constructed as previously proposed have been found to produce only small static pressure. Such machines under test perform satisfactorily under free-delivery or slight back-pressure conditions, but when the back-pressure rises they exhibit an erratically fluctuating static pressure and even at times a flow reversal, when air is periodically ejected from the inlet. Researches leading up to the present invention have suggested that the vortex becomes unstable and that its core has a tendency to wander away from the guide body and rotate with the rotor. As throttling continues the vortex tends to enlarge and centre on the rotor axis.

The main object of the present invention is to provide improvements in the preferred form of flow machine defined in the second paragraph hereof, these improvements being directed to increasing the static pressure and improving the stability of operation under conditions of considerable throttling.

The invention accordingly provides a cross-flow machine wherein the guide means comprises a guide body subtending a small angle at the rotor axis and a guide wall extending around the rotor from about opposite the guide body and defining therewith an outlet from the rotor, and wherein the guide wall provides a concave pocket on the inlet side of the machine which faces the rotor but is open to the inlet side, the rotor and guide means co-operating in operation to set up a main vortex adjacent the guide body and also a second vortex in said pocket, both vortices interpenetrating the path of the rotating blades of the rotor in normal operation.

Essentially the invention requires the guide wall to define with the rotor a narrow spacing towards the outlet (though preferably not a mere working clearance), and a wide spacing towards the inlet, with an abrupt transition between these spacings and with the wide spacing continuing to the inlet and extending over an appreciable arc of the rotor. The radial spacing of the guide wall from the rotor should in general be at least a quarter of the rotor diameter within the pocket. This open pocket arrangement of the invention is to be contrasted with a mere recess in a wall which otherwise presents a substantially continuous surface to the rotor, or a recess the boundary surface of which returns markedly towards the rotor so that its spacing is substantially reduced at the inlet end of the recess, as illustrated in FIGURE 2 of British patent specification No. 892,138. In general the inlet region should never be narrower than the rotor diameter, and is preferably much wider than this.

It is to be appreciated that the chief purpose of the open pocket arrangement, in combination with the other features of the invention set forth in the penultimate paragraph, is the formation of the second vortex. According to the invention, the second vortex stabilizes the first vortex in approximate position, particularly upon throttling of the machine, and thereby reduces its tendency to wander away from the guide body and to rotate with the rotor. This in turn increases the stability of the machine so that it is able to operate satisfactorily under a greater back pressure than would be possible in a comparable machine which did not have the open pocket arrangement. The flow machine will however, not necessarily operate satisfactorily at zero throughput.

In one preferred construction according to the invention the pocket has a rear wall which is about as far from the rotor at the open end of the pocket as at the inner end thereof: the rear wall may be substantially concentric with the rotor. Preferably also the guide wall rounds into said pocket at its line of nearest approach to the rotor, and is without sharp corners.

The guide body and guide wall preferably define a diffuser receiving fluid leaving the rotor, the entry to the diffuser being much narrower than the inlet to the rotor.

The guide body may simply be a wall portion defining with the rotor a gap (which preferably converges therewith), and merging with an outlet wall, as in the simple construction above mentioned; in a more complex construction an auxiliary body is provided defining a channel with such a wall portion.

In all cases it is preferred to have the guide body and guide wall well spaced from the rotor at their nearest approach thereto, e.g. by over one third and preferably over half of the radial blade depth. It is also strongly preferred to have the space within the rotor entirely unobstructed.

A further important feature of the invention is the provision of an extension of the guide body on the inlet side to form a lead-in portion directing inflow about the periphery of the core of the main vortex. It is found that this lead-in portion can substantially increase the throughput and also reduce noise.

It has been found that if the length/diameter ratio of the machine is made relatively small (e.g. 1:2) better static pressures can be obtained.

Various embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

FIGURE 1 is a cross-section of a preferred form of flow machine according to the invention;

FIGURE 1*a* is a detail view of the FIGURE 1 blades;

FIGURES 2 and 3 are views similar to FIGURE 1 and showing a machine somewhat similar to that of FIGURE 1 under free-delivery and fully throttled conditions respectively;

FIGURE 4 shows curves where pressure number is plotted against flow number, and

FIGURES 5, 6 and 7 show further examples of flow machines according to the invention.

Referring to the drawings, FIGURE 1 shows a flow machine comprising a bladed cylindrical rotor **1** mounted for rotation about its axis and having closely spaced blades **2** extending parallel to the axis and in a ring thereabout, the blades being concave facing the direction of intended rotation shown by the arrow **3** and having their outer edges leading.

FIGURE 1*a* shows one preferred blade design for a 100 mm. diameter blower rotor designed for the FIGURE 1 configuration. The blade chord C is 14.8 mm., the blade curvature is 13.6 mm. radius and the angle between chord and radius through outer edge is 20½°: there are 36 holes. Other blade designs can be used, depending on the requirements which the flow machine has to fulfill.

Guide means are provided which comprise first and second walls extending with uniform section over the whole length of the rotor **1** and indicated generally by the numerals **4**, **5**. The wall **4** includes a concave main guide portion **6** which converges with the rotor **1** in the direction of rotor rotation to meet at rounded nose **7** a straight lead-in portion **8** which runs in a direction approximately tangential to the inner envelope **9** of the rotor blades **2**. The nose **7**, at its closest approach to the rotor is distant therefrom by some two-thirds of the radial depth of the blades **2**: the radius of the nose is about half this depth. The main guide portion **6** of the wall **4** joins an outlet wall portion **10** and defines therewith an angle of some 90° where the wall portions merge. The guide wall **5** comprises a main guide portion **11** which diverges steadily from the rotor **1** going in the direction of rotation from a line of nearest approach **12** about opposite the nose **7** and spaced from the rotor by a distance about equal to the radial blade depth. The main guide portion **11** merges into an outlet portion **13** which defines with the outlet portion **10** of the wall **4** a diverging outlet duct **14**.

On the inlet side of the line **12** of its nearest approach to the rotor **1**, the wall **5** is formed with a recess to define a pocket **15** which is open to the inlet side and subtends an arc of some 90° with the rotor. The pocket **15** is formed by a rear wall portion **16** approximately concentric with the rotor and distant therefrom by some three times the radial blade depth (about one third of the rotor diameter) and ends in an inner wall portion **17** which is approximately radial. The inner wall portion **17** is rounded into the main guide portion **11** and rear wall portion **16**. The rear wall portion **16** slopes toward the rotor **1** in region **16'**, as can be seen by comparison with circle **1'** concentric with rotor **1**. A rounded turnout **18** at the inlet side defines the other end of pocket **15**.

The inlet I is a great deal wider than the rotor diameter.

An auxiliary guide body **19** is located adjacent the main guide portion **6** and presents thereto a rounded rear surface **20** which is roughly parallel to this guide portion and spaced from it to define a channel leading from the entry of the outlet duct **14** back to the rotor adjacent the nose **7**. The auxiliary guide body **19** has a surface **21** defining with the rotor a converging gap; at its end remote from the rotor this surface rounds away from the rotor towards the outlet duct **10**.

FIGURES 2 and 3 show an alternative construction where the auxiliary guide body is omitted, and where the main guide portion **6** is somewhat differently curved from that of FIGURE 1.

The operation of the flow machine illustrated in FIGURES 2 and 3 will now be described.

Under free-delivery or small back-pressure conditions, represented in FIGURE 2, a vortex of Rankine type forms with its core A adjacent the main portion **6** of the wall **4** and its centre within the outer envelope of the rotor blades, in accordance with the teachings of British specification No. 876,611. A second vortex forms with its core B partly within the pocket **15**. Both vortices interpenetrate the path of the rotating blades. Flow through the rotor is guided by both vortices and follows the lines indicated at F. Flow is strongly curved about the core A. An important part of the flow enters along the lead-in portion **8** of the wall **4** and is directed thereby towards the periphery of the core A. Some of the flow is turned in an opposite sense about the vortex core B on entry to the rotor.

On heavy (say 70%) throttling, as seen in FIGURE 2, the vortex B expands and the vortex A shifts so that its core is completely or almost completely outside the rotor. The presence of the second vortex B helps to keep the vortex A in the desired position adjacent the main guide portion **6** of the wall **4**. Although the vortex A is not as stable as in free-delivery conditions, the presence of the vortex B prevents it from wandering away from the guide wall portions **6**, and the static pressure remains reasonably constant.

In FIGURE 3 the throttling means is more or less diagrammatically shown at T by pivoting louvres. In practice this throttling might be accomplished by the resistance of a duct system, heat exchanger or some other fluid utilizing device.

If the machine illustrated is designed as a fan, the rotor may have for example a length of 45 mm. and a diameter of 90 mm. This relatively low length/diameter ratio is found to improve static pressure. Such a fan can advantageously be run at high speed: a speed of 9,000 r.p.m. has given successful results, though lower speeds are possible.

FIGURE 4 shows two curves, labeled X and Y which show the variations of pressure number ψ with volume number ϕ. Both curves were obtained from fans having rotors of 300 mm. length, 90 mm. diameter and 22 profiled blades, the rotors running at 1,500 r.p.m. The only difference between the fans was the shape of the guide means and the blade angles, the latter being given optimum values having regard to the guide means. In the case of the curve X, the guide means was of the simple form referred to in the second paragraph hereof, being substantially that of FIGURE 1 but with the guide wall **5** stopped at the point **12** and the wall **4** at the nose **7** and the body **19** omitted. The fan producing curve Y was substantially similar to that of FIGURE 1. Curve X shows a rise in pressure as throughput drops from the maximum to a little under 50%: this is the useful working range since with lower throughputs performance is generally erratic. The curve Y, for the FIGURE 1 construction however exhibits a faster rise of pressure and a higher maximum pressure. It is also stable over a larger working range: its main field of use will be over the range of about 30%–60% throughput at free-delivery.

The preferred form of the invention provides an easily manufactured flow machine, in that there are no close tolerances or sharp corners. Due to the rounded surfaces and spacing the noise level is low. The machine has a large stable range and can produce higher static pressures than previously obtainable.

Naturally the embodiments described may be varied in a number of ways. Thus, the blades may be skewed and not parallel to the axis. The lead-in portion **8** need not be absolutely straight, and its angle can vary provided that it guides flow to the periphery of the vortex core A. The spacings of the guide portion **6** and guide wall **5** from the rotor, at their respective lines **7**, **12** of nearest approach, may be varied, though it is advantageous for noise-reduction, flow efficiency and ease of construction that these spacings should not be less than one-third of the radial blade depth.

FIGURES 5, 6 and 7 show further different forms of the invention: for parts similar to those of FIGURE 1 similar reference numerals are used, and no further description will be required. In each case the shape of the pocket **15** will be self-explanatory from the figure.

In FIGURES 5 and 6 the pocket **15** lacks the radial wall portion **17** of FIGURE 1; the rear wall portion **16** returns somewhat towards the rotor at the inlet end **18**. In FIGURE 5 the main guide wall portion **6** is more concave than in FIGURE 1 to form an additional pocket **101** and a flap member **100** is provided in the space **101** between the wall portion **6** and the rotor **1**, which member **100** is pivotally mounted at **102** and provides for a measure of control of the vortex A (see FIGURES 2 and 3). In FIGURE 6 the guide wall portion **6** is eliminated and the vortex A forms adjacent a rounded nose **103**. FIGURE 7 shows a pocket **15** more like that of FIGURE 1 than those of FIGURES 5 and 6. The guide wall portion **6** is however shaped differently and provides an opening **104** immediately adjacent the nose **103** on the outlet side. Fluid can enter through the opening **104** more or less tangentially to the vortex A.

Features of some embodiments may be combined with those of others: for example first vortex control means may be provided in the FIGURE 1 embodiment, as by a flap between the walls **6**, **20**.

In FIGS. 5, 6, and 7, the guide wall **5**, at its outlet portion **13**, converges slightly towards the outlet portion **10** as seen at **26**, to define a further recess, or concave pocket **25**. Pocket **25**, like pocket **15** is of such size that the radial spacing of the wall **5** from the rotor **1** is, within the pockets, at least a quarter of the rotor diameter, as best seen in FIGS. 5 and 6, where pockets **25** are pronounced.

I claim:

1. A flow machine comprising a bladed cylindrical rotor and guide means cooperating with the rotor on rotation thereof to induce a flow of fluid in a direction transverse to the rotor axis and twice traversing the path of the rotating blades of the rotor, the guide means comprising a guide body subtending a small angle at the rotor axis and a guide wall extending around the rotor from opposite the guide body and defining therewith an outlet from the rotor, and an inlet to the rotor, said inlet having a width of the order of the rotor diameter; said guide wall being formed with an empty recess projecting away from said rotor on the inlet side of the machine to provide an empty pocket, the radial spacing of the guide wall from the rotor in the region of said recess being at least a quarter of the rotor diameter; the rotor and guide means cooperating in operation to set up a main vortex adjacent the guide body and also a second vortex in said pocket.

2. A machine as claimed in claim **1** wherein the guide wall provides at said pocket a rear wall having a major part thereof approximately concentric with the rotor.

3. A flow machine, as claimed in claim **1** wherein said guide body defines a second pocket and facing that portion of the rotor which lies towards the discharge region, the first guide wall defining said pocket within the inlet region, and being formed with a further recess within the discharge region opposite the second pocket to define a third pocket, the second pocket being deeper than the other two pockets and subtending a small angle at the rotor axis, said guide wall and said guide body converging and defining, in the outlet from the rotor, a throat adjacent the first pocket and then diverging to define an outlet which diverges, going in the direction of flow from said throat, the rotor and guide means cooperating in operation to set up a main vortex in the region of the second and third pockets and a second vortex in the region of the first pocket.

4. A flow machine as claimed in claim **3**, wherein a vane is provided within the second pocket, fluid circulation in said main vortex taking place around the vane.

5. A flow machine as claimed in claim **1**, said guide wall providing said pocket on the entry side of the machine which faces the rotor, said pocket being open to the entry region, said guide wall being formed to provide a further, concave pocket located in the discharge region, the radial spacing of the guide wall from the rotor being at least a quarter of the rotor diameter within each of said pockets, the rotor and guide means co-operating in operation to set up a main vortex adjacent the guide body and also said second vortex in said first pocket.

6. A machine as claimed in claim **1**, wherein the guide wall provides at said pocket a rear wall approximately concentric with the rotor.

7. A machine as claimed in claim **6**, wherein the guide wall provides at said pocket a wall extending substantially radially away from the rotor and joining the rear wall at the side thereof adjacent the rotor.

8. A machine as claimed in claim **7**, wherein the guide wall at said pocket slopes towards the rotor at the side of the pocket adjacent the inlet to the rotor.

9. A flow machine comprising a bladed cylindrical rotor defining an unobstructed interior space and mounted for rotation about its axis in a predetermined direction; first and second guide walls extending lengthwise of the rotor and defining an inlet region which in cross-section of the machine is wider than the rotor diameter at all points along the path of fluid flow to the rotor and an outlet region including a diffuser, the first wall defining a main guide portion adjacent the rotor and subtending at the axis thereof an angle less than 30° and a first outlet wall portion providing a first wall of the diffuser and merging with the main guide portion at a substantial angle, the second guide wall defining a second outlet portion extending from adjacent the rotor and opposite the main guide portion and providing remote from the rotor a second wall of the diffuser opposite to and diverging from said first wall thereof, the second guide wall providing in the inlet region a first wall portion extending outwardly from the rotor and a second wall portion merging with the first wall portion and extending substantially concentrically with the rotor over an arc of the order of 90°, said second wall portion being spaced from the rotor by a distance greater than a quarter of the rotor diameter, said first and second wall portions of the second guide wall defining an open pocket, open to the inlet region, the rotor and guide walls cooperating on rotation of the rotor in said predetermined direction to set up and stabilize a first vortex of Rankine character adjacent said main guide portion and a second vortex of Rankine character adjacent and extending into the open pocket said vortices guiding fluid from the inlet region through the path of the rotating blades to the interior of the rotor and thence again through the path of the rotating blades to said outlet region.

10. A machine as claimed in claim **9**, wherein the main guide portion defines a space with said rotor within which space is mounted a flap pivotable to control the first vortex.

11. A machine as claimed in claim **9**, wherein said second guide wall terminates at said inlet region in an inlet portion merging with said second wall portion, which inlet portion returns towards said rotor.

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