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(54) ULTRASONIC ACTIVATOR.

(57) The proposed ultrasonic activator comprises at least two interconnected operating chambers (4) arranged within a housing (1); the first chamber is provided with an inlet nozzle (16), the second with an outlet nozzle (18). Within each operating chamber (4) is mounted a stator (7) and a rotor (6) which is mounted on a drive shaft; the stator and rotor are provided with opposing apertures (10, 12) through which the liquid can flow. Each rotor (6) comprises a runner (8) of a rotary pump, the runner being provided at the outlet (14) with a rigidly mounted ring (9) with apertures (10) through which the liquid flows. The width of each of these apertures is equal to the width of each aperture (12) of the stator (7), and the total area of the apertures (10) of the ring (9) of the rotor (6) is equal to the total area of the apertures (12) of the stator (7) and amounts to 0.1-0.7 of the area of the inlet (15) into the corresponding runner (8); the spacing of the apertures (10) of the ring (9) on the rotor (6) and that of the apertures (12) of the stator (7) is equal to 2-2.25 times the widths of these apertures (10, 12), the operating chambers (4) being interconnected by diffusers (13) connecting the outlet (14) of the preceding runner (8) with the inlet (15) of the subsequent runner (8) via a diffuser (13) which is provided with a choke (17) situated after the outlet nozzle (18).

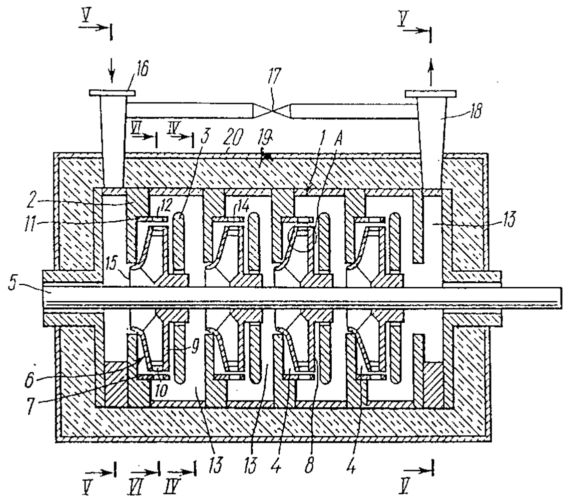

FIG.1

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Technical Field

The present invention relates in general to the technique of setting up vibrations in liquid media and more specifically it concerns an ultrasonic activator.

Background Art

At present hydrodynamic rotor-type ultrasonic activators are known to be used commonly (SU, A, 1,519,767; SU, A, 1,044,341), which are in fact the simplest highly efficient apparatus capable of performing a variety of chemical-engineering processes proceeding in liquid media.

Each of the aforesaid activators comprises a single working chamber that accommodates a stator and a rotor and provides for an ultrasonic radiation intensity at a level of 10 - 50 kW/sq.m. However, to increase the radiation intensity in the devices under consideration is impossible due to too high a flow resistance offered by the rotor and stator.

One state-of-the-art ultrasonic activator is known to use presently (FR, A, 3,717,058), aimed at mixing at least two liquid substances and bringing them in reaction with each other or initiating such a reaction in the course of mixing.

Said activator comprises at least two working chambers accommodated in a housing and communicating with each other through passages. The housing has a number of inlets and an outlet. Each of the chambers has a stator and a rotor set on a drive shaft. The stator and the rotor appear as disks arranged coaxially inside the housing of the device and having perforations for the liquid to pass. In addition, the activator comprises two standing-apart centrifugal-pump impellers set on the drive shaft in tandem with the rotor disks. The rotor and stator disks are located at the inlet of the impellers, that is, in the suction chamber.

As the rotor rotates in the liquid medium, shear strains arise in the zones between the rotor and stator perforations, the effect of said strains on the liquid resulting in virtually ideal intermixing of the various components of the mixture and in their uniform distribution over the entire volume of the liquid. Situation of the rotor and stator in the suction chamber of the centrifugal pump impeller contributes to a faster process of stirring the mixture due to its saturation with vapors and dissolved gases, which start evolving from the mixture at a reduced presure built up in the impeller suction chamber.

However, said device cannot be used for performing other more power-consuming technological processes due to restrictions imposed by its construction arrangement. Thus, for instance, to increase the energy of acoustic vibrations resulting from interaction between the rotor and the stator is impossible due to the following causes:

- firstly, because the stator and rotor are situated in the suction chamber of the centrifugal pump impeller where an insufficient differential pressure is established;
- secondly, because there are several pairs of the rotor and stator disks for one impeller that establishes a liquid flow, said rotor and stator transforming a constant flow into a variable one, i.e., they convert the energy of a constant flow into that of acoustic vibrations, which results in a reduced differential pressure per rotor-stator pair;
- thirdly, due to the fact that the rotor and stator of the construction described above offer too high a flow resistance, the pump power being uselessly spent to overcome the latter;
- fourthly, because the passage interconnecting the groups of the rotor and stator disks which are tandem-arranged in the chambers, are made without special profiling and therefor offer a high flow resistance.

Moreover, despite a multistage processing of the mixture in the device under discussion, the liquid hold-up time in the processing zone is determined by the ratio between the volume of said zone and the volumetric capacity of the device and ranged from 0.4 to 2 s, which is not enough for performing more energy-consuming technological processes.

There exist such chemical-engineering processes that feature the activation energy within 100 and 400 kJ/mole, and over. To intensify such energy-consuming processes an ultrasonic radiation having an intensity of or above 1 MW/sq.m is required. It is only in this case that an ultrasonic processing becomes economically justifiable.

Disclosure of the Invention

The present invention has for its principal object to provide an ultrasonic activator having such a construction arrangement that will be instrumental in increasing the intensity of ultrasonic radiation up to or above 1 MW/sq.m.

Said object is accomplished due to the provision of an ultrasonic activator, comprising at least two intercommunicating working chambers accommodated in a housing, the first of said chambers having an inlet pipe connector, while the last chamber has an outlet pipe connector; each of the working chambers has a stator and a rotor set on a drive shaft, both of them having holes situated one opposite the other and adapted for the liquid to pass, wherein, according to the invention, each rotor is essentially a centrifugal pump impeller provided with a ring rigidly fixed to the impeller at its outlet and having holes for the liquid to pass, each of said holes being equal in width with each of the stator holes, and a total area of the stator ring holes is equal to a total area of the stator holes and makes up 0.1 to 0.7 the inlet area of the corresponding impeller, the hole spacing of the rotor ring and of the stator being 2 to 2.25 the width of said holes; the working chambers intercommunicate through diffusers interconnecting the outlet of the preceding impeller and the inlet of the next impeller, while the outlet of the last impeller is connected to the inlet of the first impeller through a diffuser provided with a flow restrictor located past the outlet pipe connector.

As a result of the aforedescribed construction arrangement of the herein-proposed ultrasonic activator, it becomes possible to increase the intensity of ultrasonic radiation up to 1 MW/sq.m or more, whereby the capacity of the device is much enhanced.

This occurs as follows.

Once the activator is turned on, the liquid is free to pass through the inlet pipe connector to the inlet of the first impeller, which establishes a pressure of the liquid. Under the action of said pressure the liquid flows through the exit holes in the rotor ring at a definite velocity proportional to the square root of a difference between the liquid pressure upstream and downstream of the rotor. With the rotor rotating its holes are periodically exposed and shut up by the stator.

At the instant when the rotor holes are shut up the emerging jets of the liquid while moving under their own momentum, try to separate from the stator. While so doing the jets are stretched in the area adjacent ot the stator. As soon as the tension stress exceeds the tensile strength of the liquid, discontinuity of the liquid flow occurs, with the result that a cavitation void or bubble is formed. During the first half-time of its existence the bubble distends and gets filled with vapors of the liquid and gases dissolved therein.

At the instant when the rotor holes are exposed the emerging jets of the liquid compress the medium lying across their pathway, including the cavitation bubbles that have been formed during the preceding half-cycle of the pressure variation.

While being compressed a cavitation bubble behaves as an accelerator or promoter of the substance contained therein; its walls acquire a definite speed of motion towards the bubble center. At the instant when the bubble disappears (collapses), when the diametrically opposite areas of the bubble walls collide, there occurs a conversion of the kinetic energy of the moving liquid which is spent for performing a definite chemical-engineering process. It is necessary that the cavitation bubbles be prepared and collapsed with a corresponding energy level depending on the level of the energy of activation of the process. The energy of a cavitation bubble can be enhanced by increasing the rate of the bubble collapse, which increases with a rise in the compression pressure, that is, with an increase in the intensity of ultrasonic radiation. To this end, the device makes use of a gradual pressure rise in a number of the tandem-arranged impellers of the working chambers, having the corresponding rotors and stators.

With the same purpose in view the device makes use of a reduction of the flow resistance offered by the passages communicating the tandem-arranged impellers, said reduction being attained due to special profiling of said passages, that is, shaping them as diffusers.

In addition, intensity of ultrasonic radiation is increased also due to an appropriate construction arrangement enabling part of the processed liquid to be returned to the first working chamber, followed by its being multiply processed in a closed circulation circuit, which likewise adds to the liquid velocity at the outlet of the rotor holes in each of the working chambers, this being due to the fact that the liquid velocity is directly proportional to the amount of the liquid flow at a constant area of the rotor and stator holes.

Furthermore, the aforesaid connection of the last working chamber to the first one extends the processing time of the liquid in direct proportion to the recycle ratio and adds to the intensity of ultrasonic radiation due to an increased liquid flow velocity through the holes in the rotor and stator of each impeller, because said intensity is in a quadratic relation with the vibration rate (as transformation of a constant liquid flow into a variable one occurs in the course of the rotor-stator interaction).

The liquid flow velocity at the exit of the rotor holes can be increased by appropriately selecting the size of the holes in the rotor wheel and in the stator in the aforestated limits.

The construction features mentioned before make it possible to increase the intensity of ultrasound up to 1 MW/sq.m and over.

It is expedient that the stator be shaped as a ring provided with holes for the liquid to pass and rigidly held to the housing of the device opposite to the rotor ring.

Such a construction arrangement makes it possible to reduce loss of liquid in the course of transformation of a constant liquid flow into a variable one, due to a reduced unproductive leakage of the liquid.

It is desirable that all diffusers be vaned or scroll-shaped spiral, or a combination of both.

Intensity of ultrasonic radiation is directly proportional to the square of the amplitude of the vibration rate of the liquid flowing through the holes in the rotor and stator. The liquid flow velocity depends on the drop of pressure (energy) developed by the impeller. The lower amount of energy loses the liquid the higher may be the intensity of ultrasonic radiation. Vaned or spiral (volute) diffusers interconnecting the working chambers of the device are aimed at reducing hydraulic losses and, ultimately, at adding to the intensity of ultrasonic radiation.

It is favorable that the outer surface of the activator housing be coated with a layer of a sound- and heat-insulating material.

Sound- and heat-insulation of the device is aimed at reducing losses of sound and heat energy. Sound energy saving is directly concerned with an increase in the intensity of ultrasonic radiation in the working chambers, while heat saving also results, through the agency of liquid flow velocity, in an increase in the intensity of ultrasonic radiation.

With the purpose of simultaneously processing large amounts of liquid medium, it is necessary to considerably increase the overall dimensions of the working chambers. In this case it is expedient that each working chamber be accommodated in its own housing and that the impeller of each chamber be set on its own drive shaft.

Thus, the aforementioned construction arrangement of the ultrasonic activator allows of considerably increasing the intensity of ultrasonic radiation (up to 1 MW/sq.m or more), prolonging the time of action of ultrasound on the liquid under processing, extending the field of application of the activator for performing chemical-engineering proceses the energy of activation of which is within 100 and 400 kJ/mole, and increasing considerably the capacity of the device.

Brief Description of the Drawings

To promote understanding of the present invention given below is a detailed description of a specific exemplary embodiment thereof with reference to the accompanying drawings, wherein:

FIG.1 is a schematic cross-sectional view of an ultrasonic activator, according to the invention;

FIG.2 is the area A in FIG.1;

FIG.3 is a developed plan view of FIG.2;

FIG.4 is a section on the line IV-IV in FIG.1, the housing and the drive shaft being omitted intentionally;

FIG.5 is a section taken on the line V-V in FIG.1, the housing and the drive shaft being omitted intentionally;

FIG.6 is a section taken on the line VI-VI in FIG.1, the housing and the drive shaft being omitted intentionally; and

FIG.7 is an embodiment of the activator of FIG.1.

Best Method of Carrying Out the Invention

The ultrasonic activator, according to the invention, has a housing 1 (FIG.1), wherein working chambers 4 are defined by means of partitions 2 and 3. The number of the working chambers 4 depends on the density of the liquid under processing, i.e., the higher the density the greater the number of the chambers 4. FIG.1 illustrates four intercommunicating working chambers 4, each of them accommodating a rotor 6 set on a drive shaft 5 and a stator 7. Each rotor 6 is essentially an impeller 8 of a centrifugal pump which has a ring 9 (FIG.2) rigidly fixed at the outlet thereof and provided with holes 10 for the liquid under processing to pass. The ring 9 can be made integral with the impeller 8 (FIG.1). The stator 7 is in fact a ring 11 having holes 12 for the liquid being processed to pass and rigidly fixed in the housing 1 of the ultrasonic activator opposite to the ring 9 of the rotor 6.

The width (a) (FIG.3) of the holes 10 in the ring 9 of the rotor 6 is equal to the width of the holes 12 (FIG.1) in the ring 11 of the stator 7. A total area of the holes 10 in the ring 9 of the rotor 6 is equal to a total area of the holes 12 in the ring 11 of the stator 7 and makes up from 0.1 to 0.7 the area of the inlet to the respective impeller 8. The spacing (b) (FIG.3) of the holes 10 in the ring 9 of the rotor 6 and that of the holes 12 (FIG.1) in the ring 11 of the stator 7 is equal to 2 - 2.25 the width of said holes 10 and 12.

The velocity of flow of the liquid under processing and hence the intensity of ultrasonic radiation is adjusted from 0.1 MW/sq.m upwards by selecting the size of the holes 10, 12 in the rings 9, 11 of the rotor 6 and the stator 7, respectively. However, the aforestated ratio between a total area of the holes 10, 12 in the rings 9, 11 of the rotor 6 and the stator 7, and the inlet area of the respective impeller 8 is to be used differentially. The larger area of the holes 10 in the ring 9 of the rotor 6 corresponds to the initial impellers 8 from the exit of the ultrasonic activator, and the smaller area, to the last impellers 8. Smaller webs (c) (FIG.3) between the holes 10 in the ring 9 of the rotor 6 corresponds to a larger diameter of the impellers 8 (FIG.1) and to a higher rotation speed thereof. A decrease in a total area of the holes 10, 12 in the rings 9, 11 of the rotor 6 and the stator 7 down to 0.1 the exit area of the respective impeller 8 adds to the liquid flow velocity at the outlet of the holes

10, 12, thereby adding to the intensity of ultrasonic radiation. An increase in a total area of the holes 10, 12 up to 0.7 the entrance area of the respective impeller 8 reduces the intensity of ultrasonic radiation down to 1 MW/sq.m. When a total area of the holes 10, 12 is in excess of 0.7 the exit area of the respective impeller 8 the cavitation process in the liquid fails to occur and the working process ceases. When a total area of the holes 10, 12 is less than 0.1 the exit area of the respective impeller 8, it proves to be inexpedient because loss of the liquid rises faster than the intensity of ultrasonic radiation. The spacing (b) (FIG.3) of the holes 10 in the ring 9 of the rotor 6 is equal to the sum of the width (a) of said holes 10 and the web (c) between the holes 10. With the spacing (b) of the holes 10 less than two widths (a) of said holes the width of the web (c) between holes 10 becomes smaller than the width (a) of the hole 10 itself and hence the web (c) will not shut up completely the opposite hole 12 (FIG.1) of the stator 7, which in turn will result in unproductive leakage (losses) of the liquid and affect adversely the intensity of ultrasonic radiation. With the spacing of the holes 10 (FIG.3) in excess of 2.25 the width (a) of said holes 10, the width of the web (c) becomes much larger than the width (a) of the hole 10 itself so that the hole 10 remains shut up for a majority of the working cycle of the device. As a result, flow resistance of the cascade of the holes 10 increases, while the vibration rate and the sound intensity of the ultrasonic radiation decrease. Insofar as the liquid flow velocity is associated with the flow resistance of passages, as well as the intensity of ultrasonic radiation is associated with the liquid flow velocity by a quadratic relation, the intensity of ultrasonic radiation varies quadratically with respect to the flow resistance and hence with the spacing of the holes 10 in excess of 2.25 the width of said holes, the intensity of ultrasonic radiation is badly reduced.

The working chambers 4 intercommunicate through diffusers 13 that convert kinetic energy of the liquid into potential energy and connect an outlet 14 of the preceding impeller 8 to an inlet 15 of the next impeller 8. The first working chamber 4 has an inlet pipe connector 16. The outlet 14 of the last impeller 8 is connected to the inlet 15 of the first impeller 8 through the diffuser 13 provided with a flow restrictor 17 and an outlet pipe connector 18 which is interposed between the flow restrictor 17 and the last impeller 8. The diffusers 13 interconnecting all the working chambers 4 (including the last with the first ones) are either vaned (as shown at Ref.No.13a in FIG.4), or scroll-shaped (volute) spiral-type (as illustrated at Ref.No.13b in FIG.5), or else are a combination of both (FIG.6).

The shape of the diffusers 13 depends on intensity of ultrasonic radiation to be obtained, the overall dimensions of the ultrasonic activator, and rotation speed of the impellers 8.

The outside surface of the housing 1 of the ultrasonic activator is coated with a layer 19 of a sound- and heat-insulating material and is protected with a metal casing 20.

When a large amount of a liquid medium is to be processed, the overall dimensions of the working chambers need be increased considerably. In such a case it is expedient that each working chamber 21 (FIG.7) be accommodated in its own housing 22, and the impeller 8 of each chamber 21 be set on its own drive shaft 23.

The ultrasonic activator of the present invention operates as follows.

The liquid being processed is fed to the inlet pipe connector 16 of the activator, whence it passes successively onto all the impellers 8 rotating either on the common drive shaft 5 or on each on its own shaft 23. So the liquid acquires some kinetic energy on each of the impellers 8 which is partly converted into the energy of elastic vibrations of the liquid when the liquid passes through a system of periodically aligned and shut-up holes 10, 12 in the rings 9, 11 of the rotors 6 and the stators 7. The rest of the kinetic energy of the liquid is converted, with the aid of the scroll-shaped spiral or vaned diffusers 13, 13a, 13b provided past each of the impellers 8, into potential energy of static pressure. In order to make an efficient use of the sound energy generated by each pair rotor 6 - stator 7, it is necessary to maintain an optimum static pressure, which is determined by specific physical properties of the liquid under processing. The liquid processing time depends on the period of time within which the liquid passes throughout the activator working cycle and can be extended for part of the liquid under processing due to its being passed many times through the activator working cycle with the aid of a pipe interconnecting the activator outlet pipe connector to the inlet pipe connector 16 thereof. The recycle ratio is adjusted by the flow restrictor 17. After having been processed in the activator the liquid is discharged through the outlet pipe connector 18. To reduce energy losses into the surrounding atmosphere, the outside surface of the activator housing 1 is protected by the sound- and heat-insulating layer 19.

The multistage activator construction makes it possible to increase the intensity of ultrasonic radiation about 20 - 1000 times, to prolong the time of action of ultrasound on the liquid medium under processing 10 - 1000 times, and to enhance the activator efficiency up to 50 - 60 percent, i.e., 1.5 - 2 times.

Industrial Applicability

The present invention can find application in diverse branches of industry for performing various chemical-engineering processes based on use of the effect of ultrasonic radiation on a substance and on the nature of physico-chemical processes performed. The invention can find most utility when applied for carrying out chemical and physical transformations featuring an activation energy of from 100 to 400 kJ/mole.

Claims

1. An ultrasonic activator, comprising at least two intercommunicating working chambers (4) accommodated in a housing (1), the first of said chambers having an inlet pipe connector (16), while the last chamber has an outlet pipe connector (18); each of the working chambers (4) has a stator (7) and a rotor (6) set on a drive shaft (5), both of them having holes (10, 12) situated one opposite the other and adapted for the liquid to pass, CHARACTERIZED in that each rotor (6) is essentially a centrifugal pump impeller (8) provided with a ring (9) rigidly fixed to the impeller at its outlet (14) and having holes (10) for the liquid to pass, the width (a) of each of the holes (10) being equal to the width (a) of each of the holes (12) of the stator (7), and a total area of the holes (10) in the ring (9) of the rotor (6) is equal to a total area of the holes (12) of the stator (7) and makes up 0.1 to 0.7 the area of the inlet (15) of the corresponding impeller (8), the spacing (b) of the holes (10) in the ring (9) of the rotor (6) and the spacing (b) of the holes (12) in the stator (7) being equal to 2 to 2.25 the width (a) of said holes (10, 12); the working chambers (4) intercommunicate through diffusers (13) interconnecting the outlet (14) of the preceding impeller (8) to the inlet (15) of the next impeller (8), while the outlet (14) of the last impeller (8) is connected to the inlet (15) of the first impeller (8) through a diffuser (13) provided with a flow restrictor (17) located past the outlet pipe connector (18).

2. An ultrasonic activator according to Claim 1, CHARACTERIZED in that the stator (7) is shaped as a ring (11) provided with holes (12) for the liquid under processing to pass and rigidly held to the housing (1) opposite to the ring (9) of the rotor (6).

3. An ultrasonic activator according to Claim 2, CHARACTERIZED in that all the diffusers (13, 13a) are the vaned ones.

4. An ultrasonic activator according to Claim 2, CHARACTERIZED in that all the diffusers (13, 13a) are scroll-shaped spiral ones.

5. An ultrasonic activator according to Claim 4, CHARACTERIZED in that the outer surface of its housing (1) is coated with a layer (19) of a sound- and heat-insulating material.

6. An ultrasinic activator according to Claim 5, CHARACTERIZED in that each working chamber (21) is accommodated in its own housing (22), and the impeller (8) of each chamber (21) is set on its own drive shaft (23).

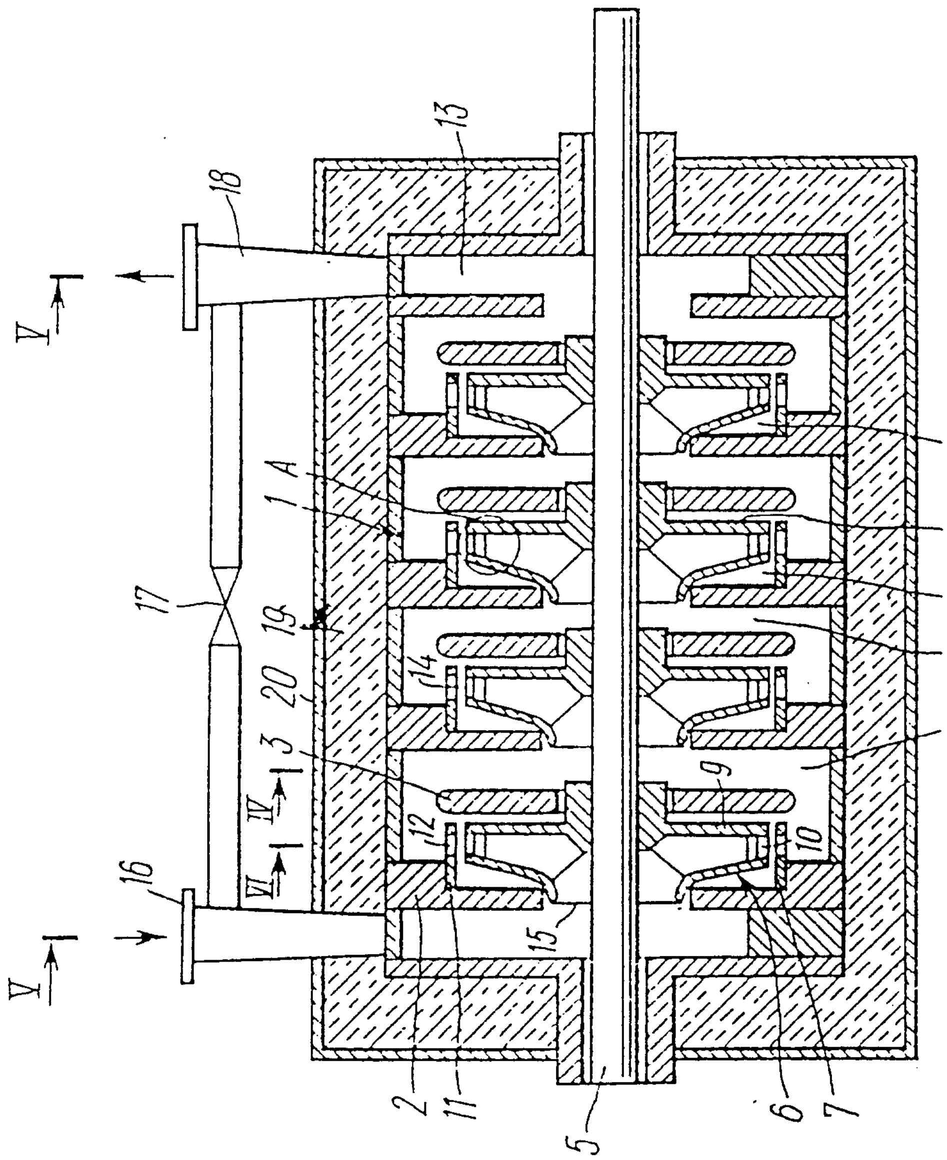

FIG.1

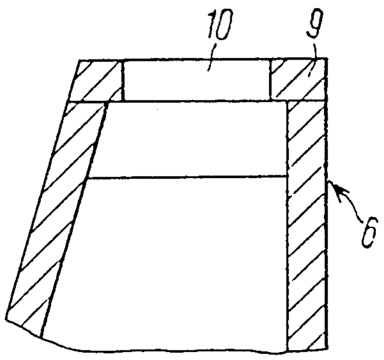

FIG.2

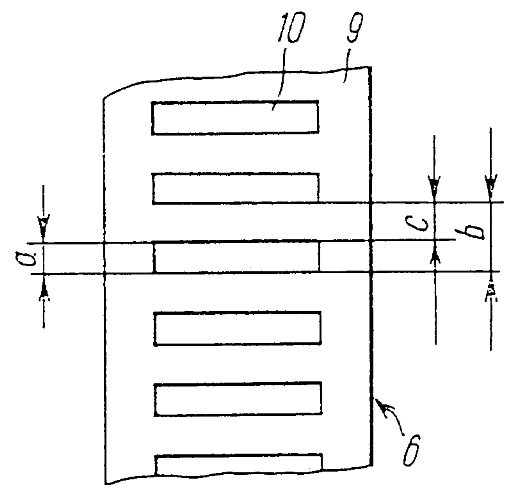

FIG.3

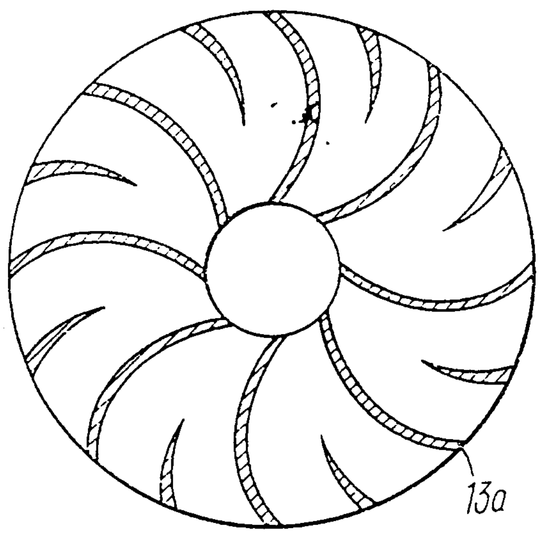

FIG.4

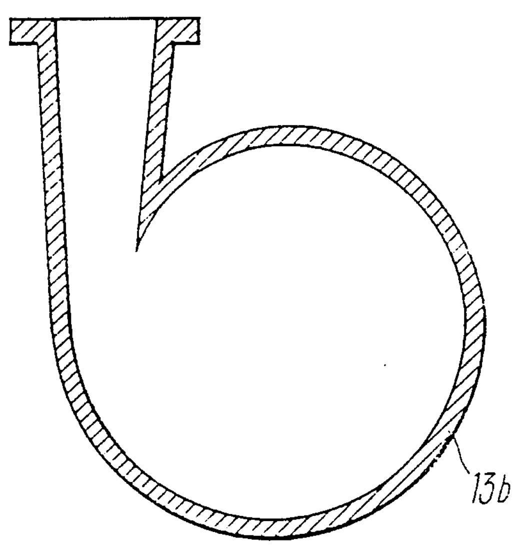

FIG.5

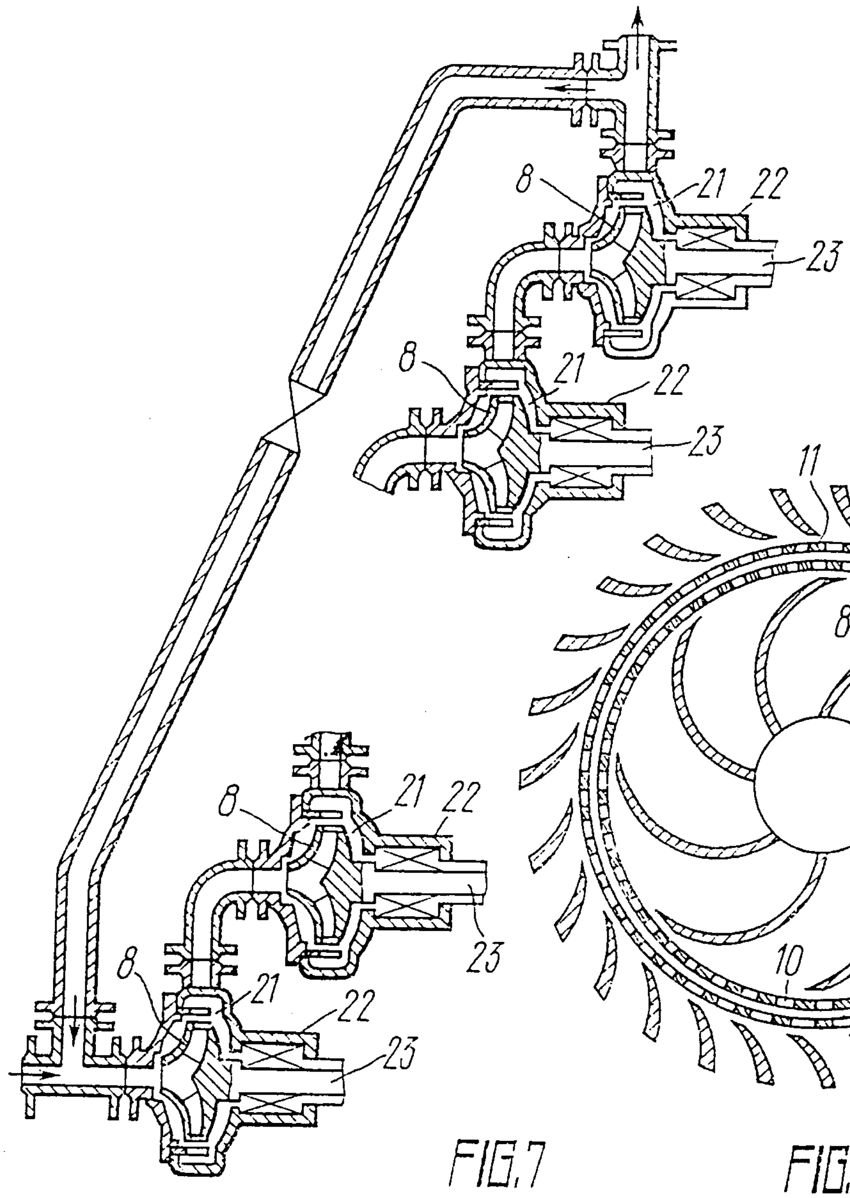

FIG.7

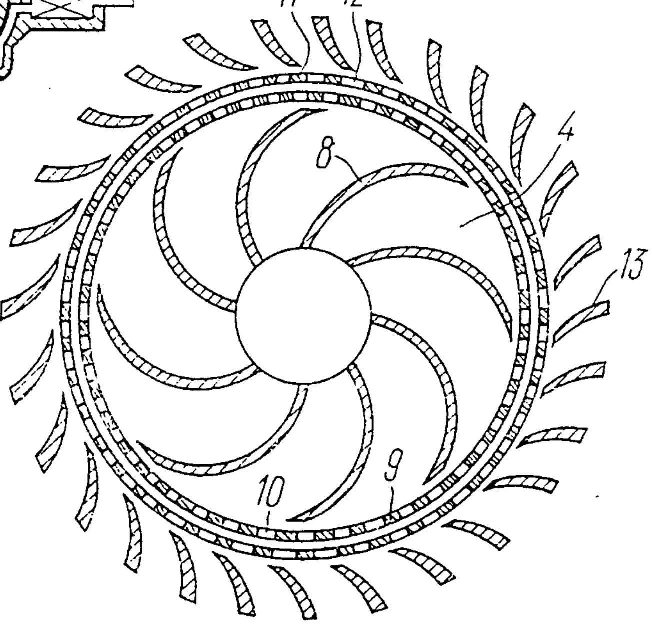

FIG.6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/RU 92/00195

A. CLASSIFICATION OF SUBJECT MATTER

IPC 5 B01F 7/00, B01F 11/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols) IPC5

B01F 11/02, B01F 7/00, B01F 7/10, B01F 7/12, B01F 7/26, B01F 7/28, B01F 5/06, B01F 5/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE, A1, 2909422 (E.T. OAKES LTD), 13 September 1979 (13.09.79), figure 1, the claims ---	1,2
A	US,A, 4915509 (HEINZ SAUER ET AL), 10 April 1990 (10.04.90), figure 1, the claims ---	1,2
A	US,A, 4511256 (ROLAND KARG ET AL), 16 April 1985 (16.04.85), figures 1,3, the claims ---	1,2
A	US,A, 4610548 (PETER HALLET ET AL), 09 September 1986 (09.09.86) ---	
A	GB,B 1388889 (GLUSTI & SON LIMITED) 26 March 1975 (26.03.75), figures 1,3,4, the claims ----	1,2

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 June 1993 (08.06.93)	21 July 1993 (21.07.93)
Name and mailing address of the ISA/ ISA/RU Facsimile No.	Authorized officer Telephone No.