United States Patent [19]

Javet

[11] **3,708,067**

[45] **Jan. 2, 1973**

[54] SEPARATING APPARATUS

[75] Inventor: **Alain Ferdinand Javet,** Geneva, Switzerland

[73] Assignee: **The Battelle Development Corporation,** Columbus, Ohio

[22] Filed: **June 29, 1970**

[21] Appl. No.: **50,509**

[52] **U.S. Cl.** **209/211,** 209/144, 210/330, 210/512

[51] **Int. Cl.**.....**B04c 5/28**

[58] **Field of Search** 209/144, 211; 210/512

[56] **References Cited**

UNITED STATES PATENTS

R25,099	12/1961	Hoffmann	209/144

FOREIGN PATENTS OR APPLICATIONS

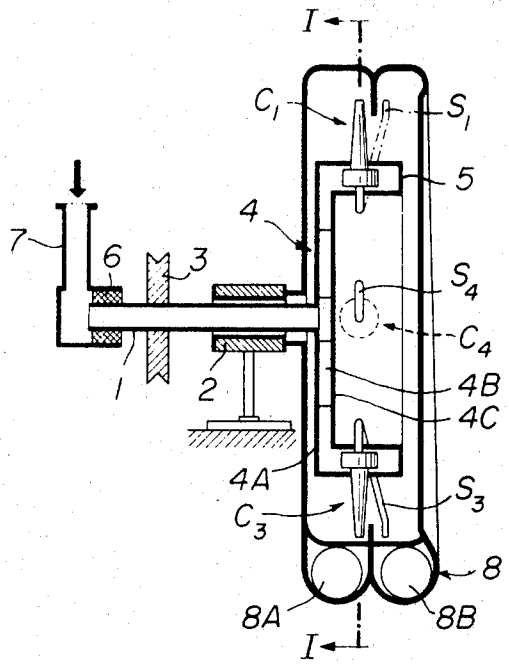
1,955,015	9/1970	Germany	209/211
455,177	2/1950	Italy	209/144

Primary Examiner—Frank W. Lutter
Assistant Examiner—Ralph J. Hill
Attorney—Gray, Mase & Dunson

[57] **ABSTRACT**

Apparatus for separating a suspension into at least two fractions of different densities, which comprises one or more cyclones, each mounted for rotation about an axis spaced therefrom and oriented transversely of said axis, and each having an inlet adapted to communicate with a source of said suspension, a first outlet for discharging the lighter of said two fractions and a second outlet for discharging the heavier of said two fractions and which is more distant from said axis than the first outlet.

8 Claims, 7 Drawing Figures



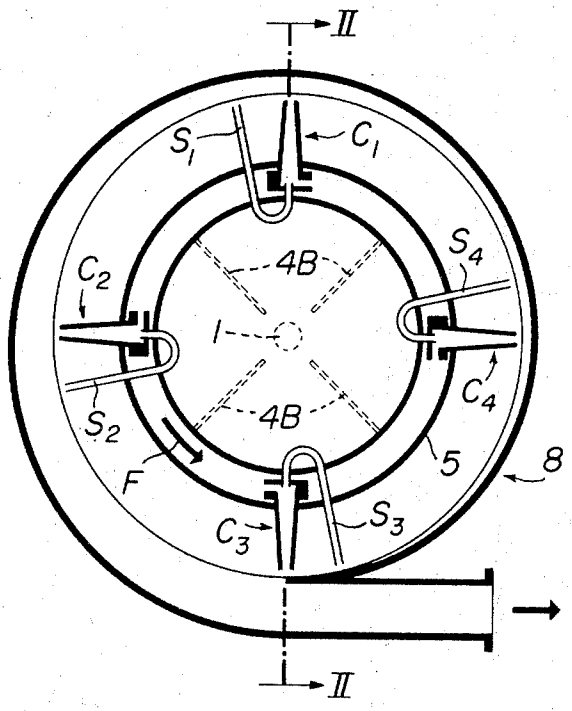

II
S1
C1
C2
4B
S4
1
C4
S2
4B
F
5
8
C3
S3
II

FIG. 1

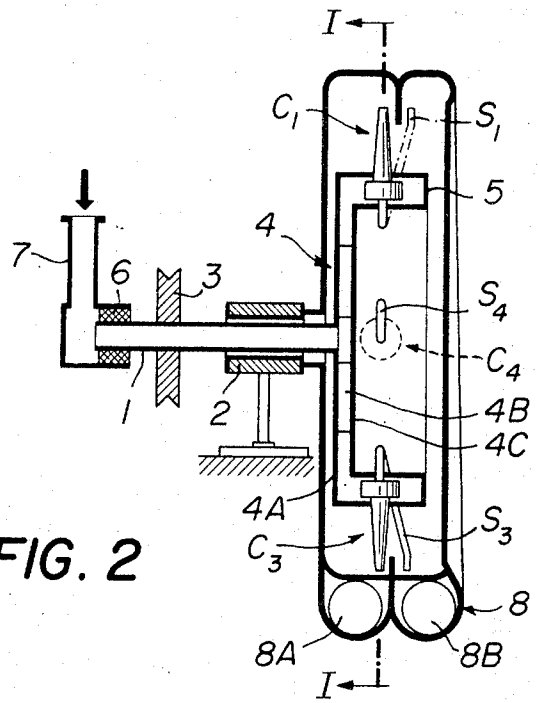

I
C1
S1
5
4
7
6
3
S4
C4
4B
4C
1
2
4A
S3
C3
8
8A
8B
I

FIG. 2

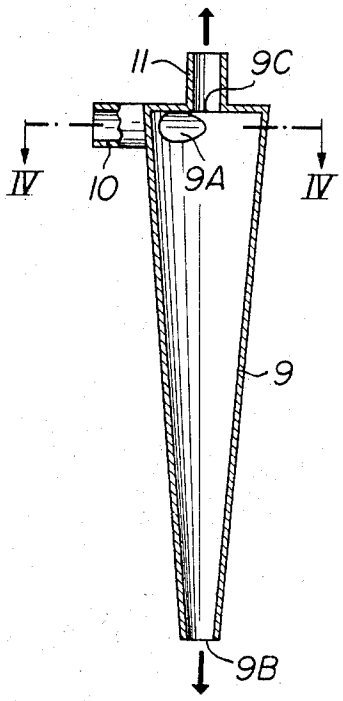


FIG. 3

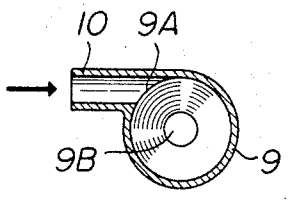


FIG. 4

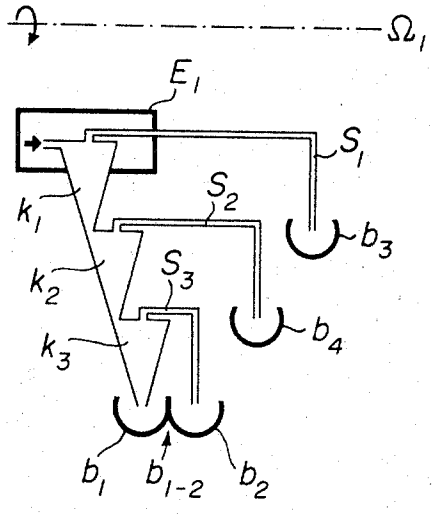


FIG. 5

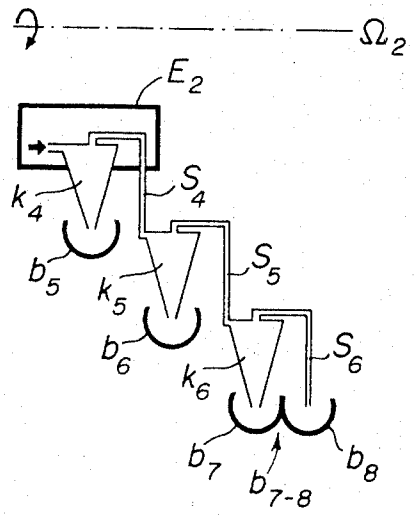


FIG. 6

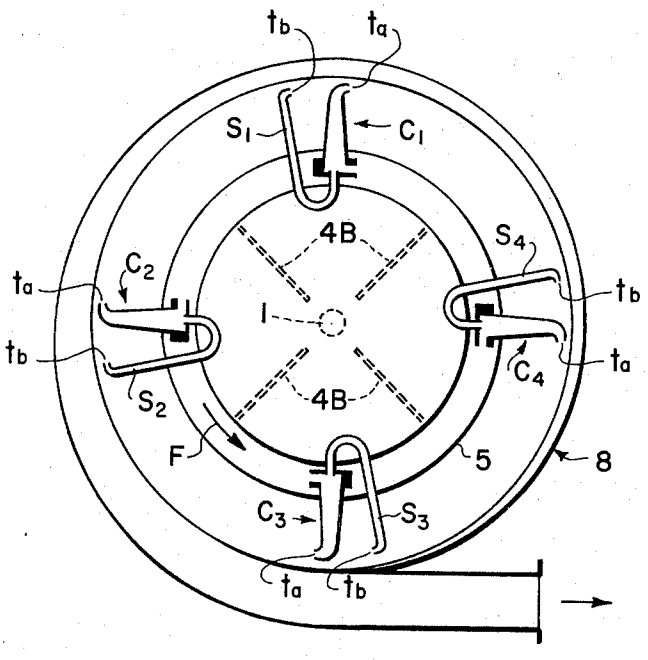


Fig. 7

SEPARATING APPARATUS

This invention provides apparatus for separating a suspension into at least two fractions of different densities.

The separation of solid particles in suspension in a fluid can be done by sedimentation, the speed at which such separation takes place being mainly dependent on

a. the ratio between the density of the solid particles and that of the fluid in which these particles are in suspension,
b. the size and shape of the particles, and
c. the viscosity of the fluid.

It has also been proposed artificially to accelerate the speed of separation by the application of centrifugal force. Among the means resorted to to this end, use is in particular made of cyclones, whether alone or in sets of several units, a cyclone consisting, as is known, of a casing of conical form having a first opening in its side wall, near its base, a second opening located at the top of the casing and a third opening in the middle of its base, these three openings respectively acting as an inlet into the cyclone for the suspension to be separated, which suspension is introduced under pressure by suitable feed means, as an outlet for the heavier separated fraction and as an outlet for the lighter separated fraction.

As is known, the smaller the size of a cyclone the greater is its efficiency so that in industrial installations where a high degree of separation is required cyclones are generally arranged in batteries or sets wherein they are fed in parallel.

Although the extent of the separation that is achieved with such batteries is particularly good, the energy that has to be supplied for their operation is, for a given result, greater by far then that used to achieve a similar result when resorting to separators of a different construction, such as for instance centrifugal, rotary drum, separators. Because the separating operations are concerned with the separation of suspensions in a liquid medium, this difference in efficiency is mainly due to the poor conditions in which operate the pumping installations needed to feed the cyclones, and in particular to the fact that some of these installations become more or less completely choked by sediments. This defect is particularly noticeable in pumping installations fitted with multistage pumps as their diffuser becomes quite easily stopped up.

Such installations could of course, in order to avoid this drawback, comprise one or more single-stage pumps but a pump of this kind has, for a relatively low output rate, a wheel of relatively large diameter, relatively narrow flow channels and a high rotational speed. Moreover, the efficiency of an industrial separating installation having cyclones that are fed by a single-stage pump is relatively low, of the order of 20 percent.

An object of the invention is to devise a cyclone apparatus which enables the drawbacks of the known apparatus to be overcome.

The apparatus provided by the present invention comprises at least one cyclone having a first opening, for the introduction of the suspension, a second opening, for the discharge of the heavier of the separated fractions, and a third opening, for the discharge of the lighter of said fractions, and means for feeding said suspension to said cyclone from a source, said means including at least a rotary housing for receiving said suspension, said cyclone being attached to said housing, in spaced relationship with respect to the rotational axis of the housing, and communicating with the housing through said first opening.

In the accompanying diagrammatic drawings:

FIG. 1 is a section taken along line I—I of FIG. 2 through one possible form of embodiment of the apparatus provided by the invention;

FIG. 2 is a sectional taken along line II—II of FIG. 1;

FIG. 3 is an axial section through a cyclone used in the apparatus of FIGS. 1 and 2;

FIG. 4 is a section taken along line IV—IV of FIG. 3;

FIG. 5 illustrates a first modified constructional arrangement of the apparatus shown in FIGS. 1 and 2; and

FIG. 6 illustrates a second modified constructional arrangement of the apparatus shown in FIGS. 1 and 2.

FIG. 7 illustrates a constructional variation of the apparatus of FIGS. 1 and 2.

The apparatus of FIGS. 1 and 2 is more particularly intended to separate out solid particles in suspension in a liquid and comprises a hollow shaft 1 which is rotatably mounted in a bearing 2 and which carries a pulley 3 whereby it may be rotatably driven by a motor and belt, not shown.

The right hand end of the shaft 1, as viewed in FIG. 2, carries a discoid flange 4A to which is secured, by fins 4B, a second flange 4C which, in conjunction with the first flange 4A, defines a discoid chamber 4 in communication with an annular chamber 5.

The left hand of the shaft 1, as viewed in FIG. 2, is connected via a rotary seal 6 to a conduit 7 connected to a source, not shown, of suspension in a liquid medium which the apparatus being described is intended to separate into two fractions of different densities.

This separation is performed by four radially oriented cyclones C_1 to C_4 (FIG. 1) which are surrounded by a spiral trough 8 formed with two channels 8A and 8B (FIG. 2) for respectively collecting the heavier and the lighter of the separated fractions.

As is known, a cyclone consists of a conical casing (FIGS. 3 and 4) formed with three openings 9A, 9B and 9C respectively for the introduction into the casing of the suspension to be separated, the discharge of the heavier separated fraction and the discharge of the lighter separated fraction.

The suspension to be separated is fed into the cyclone through a delivery tube 10 projecting from the edges of the opening 9A in a direction perpendicular to a plane containing the longitudinal axis of the casing 9 and in a position offset in relation to this axis. In this way, the suspension entering the casing 9 is subjected to a circular motion that gives rise, within the casing, to a vortex having a particularly high rotational speed. Without wishing to go into the whole theory about cyclones, suffice it to say that as a result of this vortex the fraction of greater density issues from the cyclone through the opening 9B whereas the lighter fraction moves back up the casing 9 and issues therefrom through the opening 9C from the edges of which a discharge tube 11 projects axially.

As will be observed from FIGS. 1 and 2, cyclones C_1 to C_4 are partly disposed inside the annular chamber 5,

i.e. the end portions including the inlet openings **9A** and the delivery tubes **10**, and the remainder of their casings project radially outwardly with their discharge openings **9B** lying opposite the recovery channel **8A** of trough **8**.

Each cyclone moreover comprises a siphon, S_1 to S_4 respectively, having one end connected to the opening **9C** of the associated cyclone and having its opposite end spaced from the rotational axis of the unit formed by the chambers **4** and **5**, by a distance equal to that between this axis and the opening **9B** of the associated cyclone. It will moreover be observed that each of the tubes forming the siphons S_1 to S_4 is so shaped that its free end lies opposite the recovery channel **8B** of trough **8** (see FIG. **2**) and that the discharge tube **11**, previously mentioned with reference to FIG. **3**, in fact forms part of the siphon of the associated cyclone.

The apparatus described with reference to FIGS. **1** and **2** operates as follows: the rotary portion of the apparatus i.e. the shaft **1**, the housing defining chambers **4** and **5** and the cyclones C_1 to C_4, is rotated for instance at a speed of about 3,000 r. p. m. and the conduit **7** is connected to a source supplying the suspension it is desired to separate into two distinct fractions. The source may for example consist of a tank filled with such suspension.

Since the chambers **4** and **5** are rotated, the suspension is subjected to the action of centrifugal force, thereby exerting a radial pressure which increases as the distance from the rotational axis of chambers **4** and **5** becomes larger. It follows therefore that the four cyclones of the apparatus are supplied with suspension at a relatively high pressure, which pressure can be adjusted and adapted to suit each particular case, for instance in dependence on the characteristics of the suspension to be separated, by correspondingly varying the rotational speed of the rotary portion of the apparatus. It is to be noted that the radial and angular acceleration to be given to the suspension flowing through the shaft **1** into chamber **4** is mainly provided by the fins **4B**. It will of course be clear that the shape of these fins can be so designed from a hydrodynamic point of view that their action may be optimal for a given working speed.

It should at this juncture be pointed out that the cyclones, because they are rotated, do not operate in quite the same way as stationary cyclones since the suspension, which enters each cyclone at a predetermined pressure under the action of centrifugal force, as described, continues to be subjected to this force and hence to an additional acceleration, thereby correspondingly improving the separating action of the cyclone.

In the embodiment described with reference to FIGS. **1** and **2**, the kinetic energy of the liquids issuing through the opening **9B** of each cyclone or through the corresponding siphon is lost since it is dissipated in the trough **8** by friction.

In a constructional variant, this energy could be put to use at least to some extent, in particular by causing it to contribute to the rotation of the rotary portion of the apparatus. To this end, each cyclone and its associated siphon are provided, at their radially outer ends, with a nozzle oriented in a direction opposite to that in which the rotary portion of the apparatus is intended to rotate.

This constructional variant is shown in FIG. **7**, where it will be observed that the cyclones C and their siphons S are provided at their radially outer ends, with nozzles t_a and t_b, the direction in which the rotary portion of the apparatus is intended to rotate being indicated by arrow F. With these nozzles, the heavier and lighter fractions that have been separated and that are being discharged give rise to a reactional force on the cyclones and on their siphons that helps to drive the rotary portion of the apparatus round in the direction of arrow F.

The invention is of course not restricted to what has been described above : in particular, the chambers **4** and **5** can clearly be fed in a different manner, for instance by means of a flexible tube having one end connected to any point of these chambers and its opposite end connected to a source of suspension to be divided out.

Further, the cyclones must not necessarily occupy radial positions, it being of course appreciated that the further removed they are from the radial position the lesser will be the action of the centrifugal force inside the cyclones.

Moreover, the number of cyclones in the apparatus can be different from that shown, i.e. either more or less than four. Preferably, but not exclusively, the cyclones are equidistantly positioned so that the conditions under which they are fed may be substantially the same from cyclone to cyclone.

It is also possible to design apparatuses having one or more groups of cyclones arranged in cascade formation.

FIG. **5** diagrammatically illustrates one such arrangement involving three interconnected cyclones k_1, k_2 and k_3, the first, k_1, being secured to a housing E_1 that is rotated by means not shown about an axis Ω_1 and being connected to a source of suspension to be divided out, also not shown.

As can be seen from FIG. **5**, the cyclones are connected in series, with the discharge opening of the first cyclone k_1 for the heavier fraction communicating with the inlet opening of the second cyclone k_2 and so on, the inlet opening of the first cyclone k_1 being in direct communication with the interior of the housing E_1 for the supply of suspension and the last cyclone, k_3, discharging the heavier fraction that it has separated into a channel b_1 of a trough $b_{1\text{-}2}$ having two channels b_1 and b_2.

Cyclones k_1, k_2 and k_3 have associated therewith siphons S_1, S_2 and S_3, respectively, the discharge ends of these siphons terminating in individual spiral troughs b_3 and b_4, in the case of siphons S_1 and S_2, and in the channel b_2 of trough $b_{1\text{-}2}$ in the case of siphon S_3.

With such an arrangement, it is possible to achieve a particularly effective separation as regards grading the heavier particles divided out by the first cyclone k_1.

It would of course also be possible to design an apparatus having a number of cyclones greater than that shown in the constructional form illustrated in FIG. **5**.

The modified constructional form shown in FIG. **6** is more particularly intended to divide into several subclasses the lighter fraction of a suspension.

To this end, the apparatus shown in FIG. **6** comprises three cyclones k_4, k_5 and k_6, which are rigid solid in relation to one another, the first cyclone, k_4, being secured to a housing E_2 which is mounted for rotation

about an axis Ω_2 and which is driven round by means not shown and each cyclone being fitted with a siphon S_4, S_5 and S_6 respectively, cyclone k_5 being supplied by the siphon S_4 of cyclone k_4 and cyclone k_6 being supplied by the siphon S_5 of cyclone k_5. The housing E_2 is supplied with suspension from a source not shown.

The FIG. 6 arrangement moreover comprises three spiral recovery troughs of which two, b_5 and b_6, have a single channel and the third, $b_{7\text{-}8}$, has two channels b_7 and b_8.

As will be observed from FIG. 6, cyclones k_4, k_5 and k_6 discharge the heavier fraction they help to separate, into troughs b_5 and b_6, in the case of cyclones k_4 and k_5, and into the channel b_7 of trough $b_{7\text{-}8}$, in the case of cyclone k_6, the material issuing from the siphon S_6 of this latter cyclone being discharged into the channel b_8 of trough $b_{7\text{-}8}$.

By way of modification, it is also possible to design a similar arrangement having a number of cyclones greater than three.

As is known, cyclones can also be used to separate out solid particles that are in suspension in a gaseous fluid : it follows therefore that the above described inventive concepts, described with reference to the separation of suspensions in liquid media, can also be used for the construction of a cyclone apparatus intended solely for the separation of suspensions in gaseous media.

I claim:

1. Apparatus for separating a suspension into at least two fractions of different densities, which comprises at least one cyclone having a first opening, for the introduction of the suspension, a second opening, for the discharge of the heavier of the separated fractions, and a third opening, for the discharge of the lighter of said fractions, and means for feeding said suspension to said cyclone from a source, said means including at least a rotary housing for receiving said suspension and said cyclone being rigid with said housing, in spaced relationship with respect to the rotational axis of the housing, and communicating with the housing through said first opening.

2. Apparatus according to claim 1, wherein said cyclone has a longitudinal axis transverse to the rotational axis of said housing and said cyclone is so oriented that its second opening may discharge said heavier fraction in a substantially radially outward direction, and which further comprises a conduit connected to said third opening and directing the discharge of said lighter fraction in a substantially radially outward direction.

3. Apparatus according to claim 2, wherein the outlet end of the conduit and the second opening of said cyclone are substantially equally spaced from the rotational axis of the housing.

4. Apparatus according to claim 2, wherein said cyclone and said conduit are so oriented that said heavier and lighter fractions may be discharged in different planes transverse to the rotational axis of the housing, and which further comprises a recovery trough having a first channel so disposed as to receive the heavier fraction discharge and a second channel so disposed as to receive the lighter fraction discharge throughout rotation of said cyclone about the rotational axis of the housing.

5. Apparatus according to claim 2, wherein said cyclone and said conduit each have a nozzle oriented in a direction opposite to the rotational direction of the housing.

6. Apparatus according to claim 1, wherein the housing is adapted to be connected to said source through a hollow rotary shaft which is solid with said housing and which is subjected to the action of a drive mechanism.

7. Apparatus according to claim 6, wherein the housing includes an annular chamber coaxial with said hollow shaft and rigidly attached thereto, and a connecting means between said housing and said shaft.

8. Apparatus according to claim 1, further comprising a second cyclone arranged in cascade relationship with respect to the preceding cyclone and having its first opening connected to the second opening of said preceding cyclone.

* * * * *