

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: **83306210.2**

(51) Int. Cl.⁴: **B 04 C 5/081**
B 04 C 5/02, B 04 C 5/00

(22) Date of filing: **13.10.83**

(43) Date of publication of application:
17.04.85 Bulletin 85/16

(84) Designated Contracting States:
AT BE CH DE FR GB IT LI LU NL SE

(71) Applicant: **DORR-OLIVER INCORPORATED**
77, Havemeyer Lane
Stamford Connecticut 06904(US)

(72) Inventor: **Vegter, Herman Johan**
Olga van Götschlaan 11
Santpoort(NL)

(74) Representative: **Main, Peter Stephen**
HYDE, HEIDE & O'DONNELL 146 Buckingham Palace
Road
London SW1W 9TR(GB)

(54) **Hydrocyclones.**

(57) A small hydrocyclone (maximum vortex chamber diameter in the range 7 to 14 mm), particularly for use in separating starch from a starch-containing feedstock, has a feed passage (7) leading via a volute (8) into the vortex chamber (3, 4) of the hydrocyclone. The feed passage (7) is formed so that its hydraulic radius (i.e. the ratio of the cross-sectional area of the feed passage to the peripheral extent of the cross-section) is in the range 5.7 to 6.5% of the diameter of the vortex chamber. By this means the feed energy requirements of the hydrocyclone for achieving a given separating efficiency are reduced.

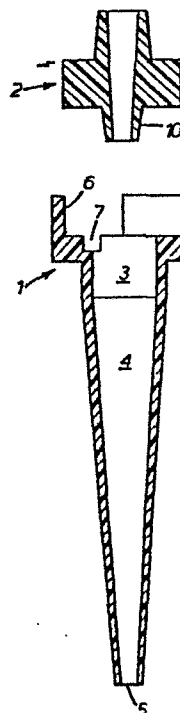


Fig. 1.

- 1 -

HYDROCYCLONES

This invention relates to small hydrocyclones, having a maximum vortex chamber diameter in the range 7 to 14 mm, and having a feed passage which at its inner end communicates with a channel
5 extending around part of the periphery of the chamber, such channel forming a volute guideway which curves progressively inwardly to merge with the radially symmetrical wall of the vortex chamber. The invention also relates to starch recovery processes using such hydrocyclones.

10 A hydrocyclone, as is well known, comprises a radially symmetrical chamber, herein called "vortex chamber", which tapers over the whole or the greater part of its length and has a feed passage opening into its wider end, and opposed axial discharge apertures. When liquid is fed continuously under pressure through
15 the feed passage, the liquid forms in the chamber a vortex wherein the angular velocity increases from the inner surface of the chamber towards the vortex core and liquid continuously discharges from the chamber through its opposed axial discharge apertures. When solid particles are entrained in the liquid their movement in
20 the vortex chamber is governed by centrifugal and centripetal forces and they may leave the hydrocyclone through the discharge aperture in its wider end, or through its apex discharge aperture, depending on the settling rate of the particles in a static body of the liquid. Hydrocyclones have been used very successfully for
25 several decades as a tool for separating particles of different

compositions into fractions of particles of different settling rates.

Small hydrocyclones within the range 7 to 14 mm are used mainly in the starch industry for concentrating starch suspensions and, more particularly, for separating starch particles from proteinaceous particles (see e.g. UK patent specification 763 291 and United States patent specification 2 689 810). Because of their very small size, a multiplicity of individual hydrocyclones are connected in parallel. The hydrocyclones are plastics mouldings. The hydrocyclones can be individually moulded, or a moulded block and a cover plate therefor can be shaped to define a plurality of hydrocyclones having their feed passages communicating with a common entrance.

In the early years of development and use of hydrocyclones the hydrocyclone feed passage was invariably a straight passage disposed so that part of its periphery was tangential to the periphery of the vortex chamber. This design feature gives rise to undesirable energy losses within the vortex chamber because of the turbulence resulting from the collision of the tangential inlet flow with the layers of liquid rotating around the periphery of the chamber. Any such energy losses have adverse effects on the performance of the hydrocyclone because for achieving maximum efficiency it is important that as much as possible of the energy of the feed stream should be translated into kinetic energy of rotation near the core of the vortex. The magnitude of that kinetic energy is a most important factor influencing the separating action in the hydrocyclone and indeed the separating efficiency tends to be higher the higher is the rotation speed of the particles immediately prior to their discharge from the hydrocyclone.

In recognition of the foregoing facts, so-called "volute" cyclones were introduced, i.e. hydrocyclones as described in the first paragraph of this specification wherein there is a volute guideway which promotes a more gradual merging of the entry stream with the liquid vortex.

A small volute hydrocyclone is shown in the accompanying drawings. In these drawings, Fig.1 is a longitudinal cross-section of the hydrocyclone. The hydrocyclone comprises a body component 1 defining the vortex chamber and a cover component 2 therefor. For clarity, these two components are shown separated. Fig.2 is a plan view of the body component and Fig.3 is a plan view of the cover component.

The vortex chamber defined by the body component 1 has a short cylindrical section 3 at one end and an adjoining tapering section 4 which occupies the major part of the length of the chamber and terminates in an apex discharge aperture 5. The wider end of the moulding is shaped to define a recess outwardly bounded by a rim 6 which is interrupted over part of the periphery of the moulding. In the bottom of this recess there is a groove 7 leading from the periphery of the moulding towards a marginal portion of the vortex chamber and this groove leads into a rebate 8 which extends around part of the periphery of the vortex chamber. The rebate is, over its length, in radially inward communication with that chamber. The radially outward wall of the rebate follows a volute path which curves progressively inwardly towards the radially symmetrical wall of the vortex chamber and merges with that wall at point 9. The volute subtends an angle of about 90° at the axis of the chamber

The cover component 2 is shaped to fit into the recess bounded by the rim 6. When so fitted, the cover piece closes off the top of the groove 7 and the rebate 8 so that the groove 7 becomes the hydrocyclone feed passage and rebate 8 becomes the volute guide channel. The cover piece includes the so-called "vortex finder" 10 which is a tubular portion which intrudes into the cylindrical section of the vortex chamber and defines the axial discharge aperture in the wider end of the hydrocyclone.

The presence of the volute makes it possible to achieve higher vortex speeds and therefore a sharper separation between starch particles and particles of insoluble protein of relatively low settling rate such as gluten particles. However in order to realise the potential benefits of a conventional volute hydrocyclone in

comparison with a hydrocyclone of the older type, it is necessary to maintain an appreciably higher pressure drop across the hydrocyclone. In practice this means maintaining a higher feed pressure. This higher pressure is necessary because an increase in rotational velocities within the vortex necessarily increases its resistance to the entry of the feed stream. If the feed pressure were not increased then, other things being equal, the input energy, equal to the pressure multiplied by the input volume per second would be less, as would therefore be the kinetic energy in the critical regions of the vortex and the volume throughput capacity of the hydrocyclone.

In practice it has been found necessary to feed conventional volute hydrocyclones at a pressure which is at least 30% higher than the feed pressure employed when using hydrocyclones of the older type and of comparable size. To be more specific, volute hydrocyclones currently in use in the starch industry, which have a diameter (measured at the wider end of the vortex chamber) of about 10 mm, are generally operated with a pressure drop of from 6 to 6.5 bar, whereas for achieving a similar operating throughput capacity using older type hydrocyclones it would suffice to operate at a pressure drop of 3 to 3.5 bar.

The higher feed pressures have been accepted in the starch industry as a necessary price to pay for the important benefit of the higher separating efficiency made possible by the volute hydrocyclone. In fact volute hydrocyclones have been used extensively in the starch industry in many countries of the world for at least the last twenty years, notwithstanding the need which has been widely recognised for several years to reduce energy consumption wherever possible. The cost of the increase in input energy necessary when using the known volute hydrocyclones is very high. For example in a nine-stage maize starch washing installation the additional 3 bar feed pressure represents an energy consumption of about 5 kwh per tonne of the processed maize.

The present invention is based on the discovery that the feed energy requirements of the known volute hydrocyclones can be

substantially reduced by the very simple expedient of increasing the hydraulic radius of the feed passage in relation to the diameter of the hydrocyclone. The hydraulic radius is the ratio of the cross-sectional area of the feed passage to the peripheral
5 extent of the cross-section.

Hitherto, small volute hydrocyclones have had a feed passage having a constant hydraulic radius which is less than 5.6% of the hydrocyclone diameter. In fact the dimensional specifications of the small volute hydrocyclones used in the starch industry were
10 standardised very many years ago and these provide a vortex chamber diameter of approximately 10 mm and a feed passage of uniform rectangular cross-section measuring approximately 2.2 x 2.2 mm. The choice of a rectangular section for the feed passage rather than a circular section which was more usual in larger
15 hydrocyclones was desirable for facilitating manufacture by moulding. The hydraulic radius of the feed passage of these hydrocyclones is therefore approximately 0.55 which is 5.5% of the hydrocyclone diameter. It has been found that a very small increase in the hydraulic radius/hydrocyclone diameter ratio enables
20 performance characteristics at least as good as those obtainable with the conventional volute hydrocyclones to be achieved with a much lower energy consumption.

A small volute hydrocyclone according to the present invention is characterised in that the ratio of the hydraulic radius, or of
25 the minimum hydraulic radius, of the feed passage to the diameter of the vortex chamber, is in the range 5.7 to 6.5%.

Although it is generally preferred for the feed passage to be of uniform cross-section (and therefore of constant hydraulic radius) along its length, the feed passage can taper over the whole
30 or part of its length, in either direction. In the latter case it is the minimum hydraulic radius of the feed passage which should be in the above range relative to the diameter of the vortex chamber.

Notwithstanding the very small departure from conventional practice in regard to the dimensional specifications of the
35 hydrocyclone which is required for carrying out the present

invention, the invention affords remarkable advantages in terms of energy saving. With a hydrocyclone according to the invention, performance results can be achieved which are as good as or better than are possible using conventional small volute hydrocyclones, while operating the hydrocyclone according to the invention under a much lower feed pressure.

Although the principal use for small volute hydrocyclones is the recovery of starch from a feedstock comprising a suspension of starch and insoluble gluten and containing soluble material, the separation being usually performed by passing the feedstock through a succession of hydrocyclone stages in counter-current with wash water, the efficiency of such a hydrocyclone can be determined for this and other purposes by determining the operating throughput capacity and the composition of the underflow (i.e. the material discharging from the apex aperture of the hydrocyclone) when feeding the hydrocyclone with a given purified starch suspension of a given density at a given temperature and under a given pressure.

The following are the critical performance data relating to a series of tests in which a hydrocyclone was fed with an aqueous suspension of purified maize starch of 12° Bé (Baumé) at 17°C, the suspension being the same for all the tests. In Tests 1 and 2 a conventional 10 mm volute hydrocyclone having a feed passage cross-section measuring approximately 2.2 x 2.2 mm as hereinbefore referred to was used. The hydrocyclone was moulded from polyamide 6.6 and was as described with reference to the accompanying drawings. The hydrocyclone had a cone angle of 6°, and underflow (apex) discharge aperture 2.3 mm in diameter and an overflow aperture 2.5 mm in diameter. The hydrocyclone used in each of the other Tests (Tests 3 to 8) was identical with the hydrocyclone used in Tests 1 and 2 except for the dimensions of the feed passage.

Test 1 (Pressure drop across hydrocyclone 4 bars):

Operating throughput capacity	270 litres/hr
Underflow density	19.1° Bé
Ratio of starch in the underflow to starch on the feed stream	81.4%

Test 2 (Pressure drop 6 bars):

Operating throughput capacity	320 litres/hr
Underflow density	19.9° Bé
Ratio of starch in the underflow to	
starch in the feed stream	87.2%

For most purposes the throughput capacity and starch recovery values achieved by means of the lower feed pressure (4 bars) are insufficient and it is for that reason that the hydrocyclones are generally operated in a higher feed pressure range of 6 to 6.5 bars

In the following Tests 3 and 4 the hydrocyclone was according to the present invention. The hydrocyclone used had a rectangular feed passage measuring 2.5 x 2.1 mm. The ratio of the hydraulic radius of the feed passage to the hydrocyclone diameter was therefore 5.71%. The relevant performance data were as follows:

Test 3 (pressure drop 4.5 bars):

Operating throughput capacity	305 litres/hr
Underflow density	19.1° Bé
Ratio of starch in the underflow to	
starch in the feed stream	87.6%

Test 4 (pressure drop 6 bars):

Operating throughput capacity	339 litres/hr
Underflow density	19.8° Bé
Ratio of starch in the underflow to	
starch in the feed stream	89.4%

In the following Tests 5 and 6 the hydrocyclone was also according to the invention. The hydrocyclone used had a rectangular feed passage measuring 2.5 x 2.2 mm. The ratio of the hydraulic radius of the feed passage to the hydrocyclone diameter was therefore 5.85%. The relevant performance data were as follows:

Test 5 (pressure drop 4.5 bars):

Operating throughput capacity	323 litres/hour
Underflow density	19.0° Be
Ratio of starch in the underflow	
to starch in the feed stream	93.2%

Test 6 (pressure drop 6 bars)

Operating throughput capacity	359 litres/hour
Underflow density	19.4° Bé
Ratio of starch in the underflow	
5 to starch in the feed stream	94.6%

Comparison of the results of Tests 3 and 4 with those of Tests 1 and 2 shows that even with a hydraulic radius/hydrocyclone diameter ratio of 5.71% the invention gives significant improvement in respect of operating throughput capacity and starch recovery, particularly at the lower pressure drop of 4 bars.

When using a hydrocyclone with a somewhat higher hydraulic radius/hydrocyclone diameter ratio as in Tests 5 and 6, in which such ratio was 5.85%, the invention gives even better results. At 4.5 bars (Test 5) the starch recovery reaches a level far higher than can be achieved, at such a high underflow density, by feeding the given maize starch suspension at 4.5 bars through a conventional volute hydrocyclone. And it will be seen that the results in Test 5 are even better than are obtained when operating the conventional hydrocyclone at a feed pressure of 6 bars.

If the ratio of the hydraulic radius to the hydrocyclone diameter is further increased within the range up to 6.5% an improvement in performance over the conventional hydrocyclone is still achieved. However, if other factors remain unchanged, the improvement does not increase with the hydraulic radius. This is apparent from Tests 7 and 8 in which the hydrocyclone used had a feed passage measuring in cross-section 2.8 x 2.2 mm (hydraulic radius 0.616). The hydraulic radius to hydrocyclone diameter ratio was therefore 6.16%

Test 7 (pressure drop 4 bars):

30 Operating throughput capacity	301 litres/hour
Underflow density	19.3 Bé
Ratio of starch in the underflow to	
starch in the feed stream	85.7%

Test 8 (pressure drop 6 bars):

Operating throughput capacity	350 litres/hour
Underflow density	19.9 Bé
Ratio of starch in the underflow	
5 to starch in the feed stream	90.6%

It will be seen that in each of these tests the starch recovery was less than in the corresponding feed pressure Test 5 or 6 although still significantly better than in the tests using the conventional hydrocyclone.

10 In general it is preferred to have a feed passage with a hydraulic radius or a minimum hydraulic radius such that the ratio of this radius to the hydrocyclone diameter is in the range 5.8 to 6.4%

The ratio of the hydraulic radius to the diameter of the hydrocyclone should not exceed 6.5%. If the hydraulic radius is too large the residence time of the starch in the hydrocyclone will be too short.

15 The extent of the advantages attainable by using a volute hydrocyclone with a feed passage having a hydraulic radius which is in the range 5.7 to 6.5% of the hydrocyclone diameter depends, other things being equal, on the length of the volute. The conventional small volute hydrocyclones have a volute subtending about 90° at the axis of the vortex chamber. Tests indicate that
 20 the performance of hydrocyclones according to the invention in terms of operating throughput capacity and starch recovery tend to improve if the volute is lengthened as suggested by the broken line 11 in Fig.2 of the accompanying drawings. In certain hydrocyclones according to the invention, the volute exceeds 100° . In optimum
 25 embodiments the volute subtends an angle within the range 160° to 200° . By increasing the length of the volute of the hydrocyclone used in Test 8, e.g to 180° , the performance data could be improved to compare more favourably with those of Test 6, so making the larger hydraulic radius feed passage equally useful.
 The use of a volute hydrocyclone having a feed passage with a
 35 hydraulic radius in the range 5.7 to 6.5% of the hydrocyclone

diameter affords benefits in terms of operating throughput capacity and starch recovery not only for 10 mm hydrocyclones as used in the comparative tests, but also for other small volute hydrocyclones within the diameter range 7 to 14 mm. However for the purposes
5 primarily in view, which are the recovery of starch, hydrocyclones at the lower and upper ends of such size range will not generally be so suitable. At the lower end of the size range, problems with blockage of the hydrocyclone may arise, while at the upper end of the size range, the feed pressure requirements are relatively high
10 and the maximum possible starch recovery is appreciably less than is possible when using hydrocyclones in the middle part of the size range. In preferred embodiments of the invention, the hydrocyclone has a diameter in the range 8 to 12 mm.

The performance of a volute hydrocyclone is influenced to
15 some extent by the cone angle, the sizes of the overflow and underflow discharge apertures, and the length of the vortex finder intruding into the vortex chamber. This fact is well known, and it is also well known what are appropriate values of these dimensions for obtaining satisfactory performance results when using
20 conventional small volute hydrocyclones. These various parameters have a similar influence on the performance of a volute hydrocyclone according to the present invention and appropriate values of the said dimensions can easily be selected by persons skilled in the art. The most suitable values of the said dimensions
25 for hydrocyclones according to the present invention (vortex chamber diameters 7 to 14 mm), particularly hydrocyclones for use in the recovery of starch from starch-containing feedstocks, lie within the following ranges:

	Cone angle	3° to 10°
30	Diameter of underflow aperture	2 to 3 mm
	Diameter of overflow aperture	2 to 3 mm

The cone angle is selected having regard to the vortex chamber diameter so that the residence time of the material in the hydrocyclone will be sufficient for the separation to occur. In
35 preferred embodiments of the invention the hydrocyclone has a

diameter of between 8 and 12 mm. The most preferred cone angle range is from 4 to 8°. The most preferred underflow aperture sizes are from 2.2 to 2.5 mm diameter, and the most preferred range for the overflow aperture is from 2.3 to 2.7 mm.

5 The conventional 10 mm volute hydrocyclones have a vortex finder whose length (distance over which the vortex finder intrudes into the vortex chamber) is approximately 3.5 mm. Tests indicate that in a volute hydrocyclone according to the present invention there may be advantages in using a longer vortex finder. It is
10 suitable to use a vortex finder of a length in the range 2.5 to 8 mm. The vortex finder should not be so long that it has an objectionable braking action on the rotation of the suspension in the vortex chamber.

 The present invention includes a method of recovering starch
15 from a feedstock in which the starch is entrained in a liquid medium, by passing the feedstock under pressure through hydrocyclones, characterised in that use is made of small volute hydrocyclones according to the invention as hereinbefore defined

 In some embodiments of the starch recovery method according to
20 the invention, the pressure drop across the hydrocyclones is less than 5 bars. The Tests show that even when working under a pressure drop of no more than 5 bars, it is possible to achieve better results than those obtained by using conventional hydrocyclones at a pressure drop of 6 bars. When carrying out a method according to
25 the invention under a pressure drop higher than 5 bars, the results can be further improved. in terms of both throughput capacity and starch recovery. Because of the higher throughput capacity, a given starch recovery can be achieved with the aid of fewer hydrocyclones than would be required if conventional hydrocyclones
30 were used.

 In a variation of Test 5 herein referred to the pressure drop across the hydrocyclone was 4 bars (the same pressure drop as in Test 1), all other conditions remaining the same as in Test 5. The corresponding performance data were as follows:

- 12 -

Operating throughput capacity	300 litres/hour
Underflow density	19.0 Bé
Ratio of starch in the underflow to starch in the feed stream	88.4%

- 5 This demonstrates the improvement in starch recovery as compared with Test 1 in which a conventional volute hydrocyclone was used at the same pressure drop.

Claims

1. A hydrocyclone having a maximum vortex chamber diameter in the range 7 to 14 mm, and having a feed passage which at its inner end communicates with a channel extending around part of the periphery of the chamber, such channel forming a volute guideway which curves progressively inwardly to merge with the radially symmetrical wall of the vortex chamber, characterised in that the ratio of the hydraulic radius, or of the minimum hydraulic radius, of the feed passage to the diameter of the vortex chamber, is in the range 5.7 to 6.5%.
2. A hydrocyclone according to claim 1, wherein the said ratio is in the range 5.8 to 6.4%.
3. A hydrocyclone according to claim 1 or 2, wherein the volute guideway subtends an angle greater than 100° at the axis of the vortex chamber.
4. A hydrocyclone according to claim 3, wherein the volute guideway subtends an angle in the range 160° to 200° at the axis of the vortex chamber.
5. A hydrocyclone according to any preceding claim, wherein the maximum vortex chamber diameter is in the range 8 to 12 mm.
6. A hydrocyclone according to claim 5, wherein the hydrocyclone cone angle is from 4° to 8° .
7. A hydrocyclone according to claim 5 or 6, wherein the underflow aperture has a diameter of 2.2 to 2.5 mm and the overflow aperture has a diameter of 2.3 to 2.7 mm.

8. A hydrocyclone according to any preceding claim, said hydrocyclone having a vortex finder of a length substantially greater than 3.5 mm.

5 9. A method of recovering starch from a feedstock in which the starch is entrained in a liquid medium, by passing the feedstock under pressure through hydrocyclones, characterised in that use is made of small volute hydrocyclones according to any preceding claim.

1/1

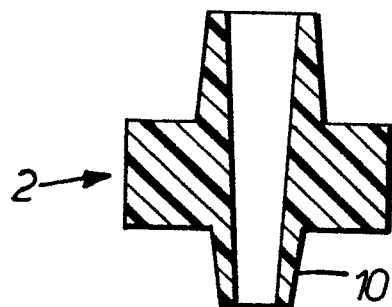


FIG. 1.

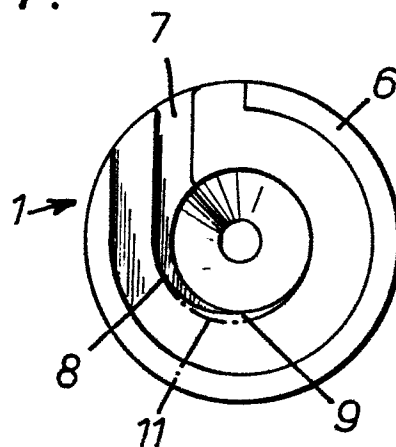
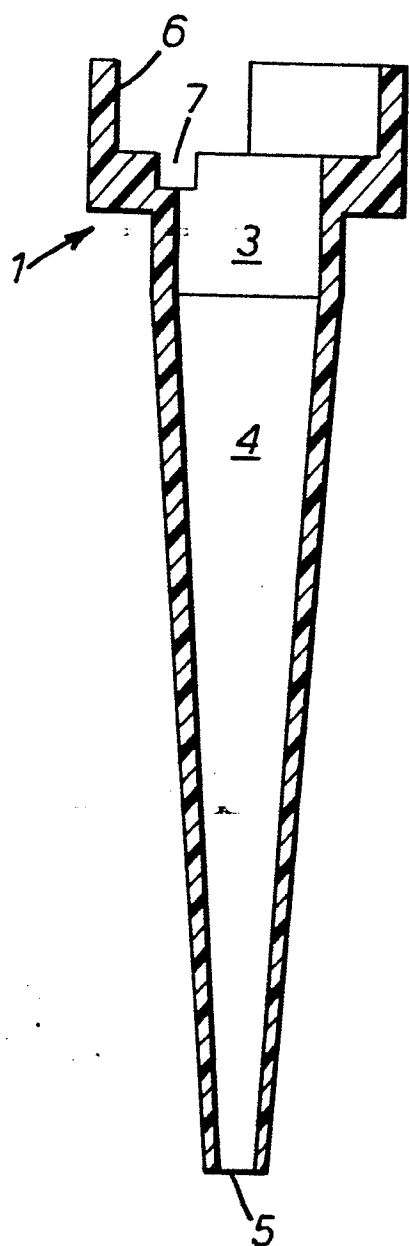


FIG. 2.

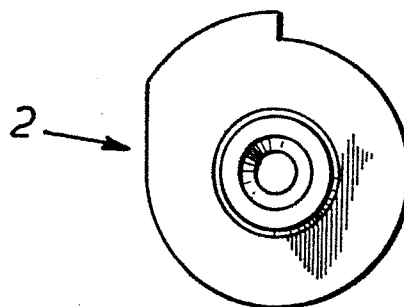


FIG. 3.