A method and cyclonic separator are disclosed for degassing a fluid mixture comprising a carrier liquid and one or more gaseous and/or vaporizable components, wherein: - the fluid mixture is accelerated in a throat section (6) of a vortex tube (1) such that the static pressure of the fluid mixture is decreased and vaporizable components evaporate into a gaseous phase; - the accelerated fluid mixture is induced to swirl within the vortex tube such that the fluid mixture is separated by centrifugal forces into a degassed liquid fraction and a gas enriched fraction; - the degassed liquid fraction is induced to flow into a liquid outlet conduit (4) which is located at or near the outer circumference of the vortex tube (1); and - the gas enriched fraction is induced to flow into a gas outlet conduit (3) which is located at or near a central axis of the vortex tube (1).
Title: CYCLONIC SEPARATOR AND METHOD FOR DEGASSING A FLUID MIXTURE

Abstract: A method and cyclonic separator are disclosed for degassing a fluid mixture comprising a carrier liquid and one or more gaseous and/or vaporizable components, wherein: - the fluid mixture is accelerated in a throat section (6) of a vortex tube (1) such that the static pressure of the fluid mixture is decreased and vaporizable components evaporate into a gaseous phase; - the accelerated fluid mixture is induced to swirl within the vortex tube such that the fluid mixture is separated by centrifugal forces into a degassed liquid fraction and a gas enriched fraction; - the degassed liquid fraction is induced to flow into a liquid outlet conduit (4) which is located at or near the outer circumference of the vortex tube (1); and - the gas enriched fraction is induced to flow into a gas outlet conduit (3) which is located at or near a central axis of the vortex tube (1).
BACKGROUND OF THE INVENTION

The invention relates to a cyclonic separator and method for degassing a fluid mixture.

US patent 6402799 discloses a cyclonic separator in which a gas-liquid mixture is injected via a tangential inlet into a horizontal vortex tube in which the gaseous and liquid fractions are at least partly separated and the liquid fraction forms a film alongside the inner wall of the vortex tube and is discharged via a radial outlet, whereas the gaseous fraction is concentrated near the central axis of the vortex tube and discharged via a central outlet.

International patent applications WO9901194 and WO03029739 disclose cyclonic separators wherein a gas stream is accelerated in a vortex tube to a near sonic or supersonic velocity and thereby expanded and adiabatically cooled such that liquid or solid particles are formed which are discharged via an outlet at the outer circumference of the tube, whereas a dry gas fraction is discharged via a central outlet. These known separators are configured to remove liquefied and/or solidified components from a gas stream and not to remove a gaseous fraction from a carrier liquid.

UK patent GB2035150; US patents 2811219 and 4596586 and International patent application W003055575 disclose cyclonic separators in which a gas-liquid mixture is injected via a tangential inlet into a vertical vortex tube which has at its upper end a central gas outlet.
conduit via which the gaseous fraction is discharged and at its lower end a liquid collecting basin which is connected to a liquid discharge conduit.

A disadvantage of the latter group of known cyclonic separators is that they generally are large pieces of equipment and have a limited separation efficiency.

It is an object of the present invention to provide a compact cyclonic separator for degassing a fluid mixture and an efficient method for degassing a fluid mixture.

SUMMARY OF THE INVENTION

In accordance with the invention there is provided a method for degassing a fluid mixture comprising a carrier liquid and one or more gaseous and/or vaporizable components in a cyclonic separator in which:

- the fluid mixture is accelerated in a throat section of a vortex tube such that the static pressure of the fluid mixture is decreased and vaporizable components evaporate into a gaseous phase;
- the accelerated fluid mixture is induced to swirl within the vortex tube such that the fluid mixture is separated by centrifugal forces into a degassed liquid fraction and a gas enriched fraction;
- the degassed liquid fraction is induced to flow into a liquid outlet conduit which is located at or near the outer circumference of the vortex tube; and
- the gas enriched fraction is induced to flow into a gas outlet conduit which is located at or near a central axis of the vortex tube.

In a preferred embodiment of the method according to the invention:
- the degassed liquid is induced to flow in a swirling motion along the inner surface of the vortex tube in downstream direction from a proximal end towards a distal
end of the vortex tube and is discharged via an annular liquid outlet conduit which is arranged co-axially between a bullet-shaped deflection body and the inner surface of the distal end of the vortex tube; and

-the gas enriched fraction is induced to flow in a countercurrent swirling motion from a nose section of the bullet-shaped deflection body towards the gas outlet conduit which is arranged co-axially within the proximal end of the vortex tube.

The central gas outlet conduit may have a ring-shaped entrance which performs as a vortex finder for the countercurrent swirling motion of the gas enriched fraction stream around a central axis of the vortex tube, which countercurrent swirling motion is induced at the edge of the nose section of the bullet-shaped deflection body by means of the Ranque-Hills effect.

The bullet-shaped deflection body may have a conical nose section and a substantially cylindrical tail section, and the distal end of the vortex tube may have an in downstream direction diverging shape.

The central gas outlet conduit may be co-axially arranged around a torpedo-shaped central body having conical nose and tail sections and a substantially cylindrical mid section; and

-the gas enriched fraction in the central gas outlet conduit may be deswirled by an assembly of flow deswirling vanes which is arranged in the central gas outlet conduit between the outer surface of the central body and the inner surface of the wall of the central gas outlet conduit.

Optionally the vortex tube has a trumpet-shaped proximal end which is connected to a fluid inlet tube, such that an annular fluid inlet conduit is formed which
co-axially surrounds the wall of the central gas outlet conduit and in which a series of swirl-imparting vanes are arranged which induce the fluid mixture to flow in a swirling motion into the vortex tube and the swirl-imparting vanes are arranged in a section of the annular fluid inlet conduit in which the fluid inlet tube has a larger inner diameter than other parts of the fluid inlet tube which vanes induce the fluid mixture to flow at a subsonic velocity through the annular fluid inlet conduit and the fluid mixture is accelerated to a substantially transonic or supersonic velocity in the trumpet-shaped proximal end of the vortex tube.

The method according to the invention may be configured to degas a fluid mixture which comprises crude oil as carrier liquid which carries gaseous and/or vaporizable components comprising natural gas and/or condensates such as methane, ethane, propane, butane and pentane, carbon dioxide and/or hydrogen sulfide.

The cyclonic separator according to the invention for degassing a fluid mixture comprising a carrier liquid and one or more gaseous and/or vaporizable components comprises:
- a vortex tube having a throat section in which the fluid mixture is accelerated such that the static pressure of the fluid mixture is decreased and vaporizable components evaporate into a gaseous phase;
- one or more swirl imparting vanes for inducing the fluid mixture to swirl within the vortex tube thereby inducing the mixture to be separated by centrifugal forces into a degassed liquid fraction and a gas enriched fraction;
- a degassed liquid outlet conduit which is located at or near the outer circumference of the vortex tube for discharging the degassed liquid fraction; and
- a gas outlet conduit which is located at or near a central axis of the vortex tube for discharging the gas enriched fraction.

These and other features and embodiments of the method and cyclonic separator according to the invention are described in the accompanying claims, abstract and following detailed description in which reference is made to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 depicts a schematic longitudinal sectional view of a first embodiment of a cyclonic liquid degassing separator according to the invention in which a fluid mixture is degassed and separated and the degassed liquid fraction L and the gaseous fraction G are discharged at opposite ends of the separator;

FIG.2 depicts a schematic longitudinal sectional view of a second embodiment of a cyclonic liquid degassing separator according to the invention in which a fluid mixture is degassed and separated and the degassed liquid fraction L and the gaseous fraction G are both discharged at the same end of the separator; and

FIG.3 shows expected flow regimes and pressures in different parts of the cyclonic liquid degassing separator.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

FIG.1 depicts a cyclonic liquid degassing separator, which comprises a vortex tube 1, an untreated fluid inlet conduit 2, a gas outlet conduit 3 and a degassed liquid outlet conduit 4.

The vortex tube 1 has a trumpet-shaped proximal end 1A and a diverging distal end 1B.

The liquid outlet conduit 4 is formed by an annular space between the inner surface of the diverging distal
end 1B of the vortex tube 1 and a bullet-shaped
deflection body 5.
The trumpet-shaped proximal end 1A of the vortex tube 1
is connected to the diverging outer wall 2B of the fluid
inlet conduit 2.

A series of swirl imparting vanes 8 is arranged in
the diverging annular end-section 2C of the inlet conduit
2B, which vanes 8 induce the untreated fluid to swirl
into an annular throat section 6 formed between the inner
surface of the trumpet-shaped proximal end 1A of the
vortex tube 1 and the outer surface of the wall 3A of the
fluid outlet conduit 3.

The annular throat section 6 has a gradually
decreasing cross-sectional area and thus acts as a so-
called Laval nozzle in which the liquid is accelerated to
a subsonic, or preferably to a transonic or supersonic
velocity. In the accelerated fluid mixture the fluid will
expand and the static pressure will drop, so that the
dissolved or free gas fraction in the carrier liquid will
evaporate and liquid flow is transformed into a bubbly
flow of carrier liquid and gas bubbles L+G.
Simultaneously, the swirl imparting vanes 8 will impose a
swirling motion on the bubbly flow L+G, which is enhanced
by the gradual decrease of the outer diameter of the
annular throat section 6 as a result of the conservation
of moment of momentum, which is also known as the
spinning ice skater effect. The swirling motion may
impose centrifugal forces of 100.000 g on the bubbly flow
L+G causing the low density gas bubbles G to migrate
towards the central axis 7 of the vortex tube 1 and the
high density liquid fraction L to migrate towards the
tubular inner surface of the vortex tube 1.
The high-density liquid fraction L will spin as an annular film 11 along the tubular inner surface of the vortex tube 1 into the gas outlet conduit 3. The gas bubbles G will coalesce and form a continuous gaseous phase near the central axis 7 of the vortex tube 1, which gaseous phase will hit the pointed nose section 5A of the bullet-shaped reflection body 5 which is then reflected and induced by the Ranque-Hills effect to flow as a countercurrent swirl 12 from the pointed nose section 5A in a direction from the distal end 1B towards the proximal end 1A of the vortex tube 1 into the gas outlet conduit 3. The ring-shaped co-axial entrance 3B of the fluid outlet conduit 3 will perform as a vortex seeker for the gaseous stream G. A torpedo-shaped central body is arranged within the gas outlet conduit 3 and a series of deswirling vanes will deswirl and straighten the gaseous stream G within said conduit 3.

The bullet shaped deflection body 5 can be axially moved within the diverging distal end 1B of the vortex tube, as illustrated by arrow 15, so that the width of the annular liquid outlet conduit 4 and the flow rate of the degassed liquid L can be adjusted.

FIG.2 depicts an alternative embodiment of the cyclonic liquid degassing separator which comprises a vortex tube 20 having a narrow throat section 21 in which the a fluid mixture of a carrier liquid and dissolved gaseous and/or vaporizable components is accelerated to a near-sonic or supersonic velocity and swirled by one or more swirl imparting vanes 22, so that the vaporizable components evaporate and the high-density liquid fraction L is separated from the low density gaseous fraction G by centrifugal forces. The high-density liquid fraction will form a swirling annular film alongside the inner surface.
of the vortex tube 20 which is discharged from the vortex tube 20 via an annular outlet conduit 23, which is formed between the inner surface of a distal end 20B of the vortex tube 20 and the outer surface of the wall 24 of a central gas outlet conduit 25 through which the gaseous fraction G is discharged.

A gas/liquid gravity separation assembly (not shown) comprising mechanical weirs under and over flow systems may separate the three phases: oil, water and residual gas discharged by the annular outlet conduit 23. The gas pressure equalises the pressure for the three phases and the differences in specific gravity provides the difference in gas / liquid and oil / water levels for separation. The different heights of the weirs traps one of the phases upstream of the weir and another phase will pass under and over the weir.

FIG.3 is a schematic view of the fluid flow and static pressure reduction in the cyclonic liquid degassing separator according to the invention. It illustrates how in the separator depicted in FIG.1 the liquid flow is transformed into a fine bubbly flow within the throat section 6 and segregated into an annular swirling liquid fraction L and a central countercswirling gas fraction G. The pressure of the injected liquid mixture may be about 100 bar and the pressure of the discharged gaseous fraction in the gas outlet conduit 3 may be about 30 bar.
CLAIMS

1. A method for degassing a fluid mixture comprising a carrier liquid and one or more gaseous and/or vaporizable components in a cyclonic separator in which:
   - the fluid mixture is accelerated in a throat section of a vortex tube such that the static pressure of the fluid mixture is decreased and vaporizable components evaporate into a gaseous phase;
   - the accelerated fluid mixture is induced to swirl within the vortex tube such that the fluid mixture is separated by centrifugal forces into a degassed liquid fraction and a gas enriched fraction;
   - the degassed liquid fraction is induced to flow into a liquid outlet conduit which is located at or near the outer circumference of the vortex tube; and
   - the gas enriched fraction is induced to flow into a gas outlet conduit which is located at or near a central axis of the vortex tube.

2. The method of claim 1, wherein
   - the degassed liquid is induced to flow in a swirling motion along the inner surface of the vortex tube in downstream direction from a proximal end towards a distal end of the vortex tube and is discharged via an annular liquid outlet conduit which is arranged co-axially between a bullet-shaped deflection body and the inner surface of the distal end of the vortex tube; and
   - the gas enriched fraction is induced to flow in a countercurrent swirling motion from a nose section of the bullet-shaped deflection body towards the gas outlet.
conduit which is arranged co-axially within the proximal end of the vortex tube.

3. The method of claim 2, wherein the bullet-shaped deflection body has a conical nose section and a substantially cylindrical tail section, and the distal end of the vortex tube has an in downstream direction diverging shape.

4. The method of claim 2, wherein the central gas outlet conduit is co-axially arranged around a torpedo-shaped central body having conical nose and tail sections and a substantially cylindrical mid section; and -the gas enriched fraction in the central gas outlet conduit is deswirled by an assembly of flow deswirling vanes which is arranged in the central gas outlet conduit between the outer surface of the central body and the inner surface of the wall of the central gas outlet conduit.

5. The method of claim 4, wherein the central gas outlet conduit has a ring-shaped entrance which performs as a vortex finder for the countercurrent swirling motion of the gas enriched fraction stream around a central axis of the vortex tube, which countercurrent swirling motion is induced at the edge of the nose section of the bullet-shaped deflection body by means of the Ranque-Hills effect.

6. The method of claim 4, wherein the vortex tube has a trumpet-shaped proximal end which is connected to a fluid inlet tube, such that an annular fluid inlet conduit is formed which co-axially surrounds the wall of the central gas outlet conduit and in which a series of swirl-imparting vanes are arranged which induce the fluid mixture to flow in a swirling motion into the vortex tube.
7. The method of claim 6, wherein the swirl-imparting vanes are arranged in a section of the annular fluid inlet conduit in which the fluid inlet tube has a larger inner diameter than other parts of the fluid inlet tube which vanes induce the fluid mixture to flow at a subsonic velocity through the annular fluid inlet conduit and the fluid mixture is accelerated to a substantially transonic or supersonic velocity in the trumpet-shaped proximal end of the vortex tube.

8. The method of any preceding claim, wherein the fluid mixture comprises crude oil as carrier liquid and the gaseous and/or vaporizable components comprise natural gas and/or condensates such as methane, ethane, propane, butane and pentane, carbon dioxide and/or hydrogen sulfide.

9. A cyclonic separator for degassing a fluid mixture comprising a carrier liquid and one or more gaseous and/or vaporizable components, comprising:
- a vortex tube having a throat section in which the fluid mixture is accelerated such that the static pressure of the fluid mixture is decreased and vaporizable components evaporate into a gaseous phase;
- one or more swirl imparting vanes for inducing the fluid mixture to swirl within the vortex tube thereby inducing the mixture to be separated by centrifugal forces into a degassed liquid fraction and a gas enriched fraction;
- a degassed liquid outlet conduit which is located at or near the outer circumference of the vortex tube for discharging the degassed liquid fraction; and
- a gas outlet conduit which is located at or near a central axis of the vortex tube for discharging the gas enriched fraction.
10. The cyclonic separator of claim 9, wherein
the vortex tube comprises a proximal end and a distal end;
the separator comprises one or more swirl imparting
vanes for inducing the fluid mixture to flow in swirling
motion in downstream direction along the inner surface of
the vortex tube from the proximal end towards the distal
end of the vortex tube;
the liquid outlet conduit has an annular shape and is
coa-xially arranged between a bullet-shaped deflection
body and the inner surface of the distal end of the
vortex tube;
the gas outlet conduit is arranged co-axially within
the proximal end of the vortex tube; and
the bullet-shaped deflection body comprises a nose
section for inducing the gas enriched fraction to flow in
a countercurrent swirling motion the nose section of the
bullet-shaped deflection body towards the gas outlet
conduit.

11. The cyclonic separator of claim 10, wherein the
bullet-shaped deflection body has a substantially
cylindrical tail section and the distal end of the vortex
tube has an in downstream direction diverging shape.

12. The cyclonic separator of claim 10, wherein the
central gas outlet conduit is co-axially arranged around
a torpedo-shaped central body having conical nose and
tail sections and a substantially cylindrical mid
section; and
an assembly of flow deswirling vanes is arranged in the
central gas outlet conduit between the outer surface of
the central body and the inner surface of the wall of the
central gas outlet conduit for deswirling the gas
enriched fraction in the central gas outlet conduit.
13. The cyclonic separator of claim 9, wherein the vortex tube has a trumpet-shaped proximal end which is connected to a fluid inlet tube, such that an annular fluid inlet conduit is formed which co-axially surrounds the wall of the central gas outlet conduit and in which a series of swirl-imparting vanes are arranged which induce the fluid mixture to flow in a swirling motion into the vortex tube.

14. The cyclonic separator of claim 9, wherein a plurality of swirl-imparting vanes are arranged in a section of the annular fluid inlet conduit in which the fluid inlet tube has a larger inner diameter than other parts of the fluid inlet tube and are configured to induce the fluid to swirl at a subsonic velocity through the annular fluid inlet conduit and the trumpet-shaped proximal end of the vortex tube provides an annular throat section which is configured to accelerate the fluid mixture to a substantially transonic or supersonic velocity.

15. The cyclonic separator of claim 9, wherein the degassed liquid outlet conduit is connected to a gravity separation assembly comprising mechanical weirs under and over flow systems for separating the oil, water and residual gas discharged by the degassed liquid outlet conduit.