

**APPARATUS AND METHOD FOR PRODUCING AN EMULSION OF A FUEL AND AN
EMULSIFIABLE COMPONENT**

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FIELD OF THE INVENTION

This invention relates to an apparatus and a method for producing an emulsion of a fuel and an emulsifiable component. The invention has particular, but not exclusive, application in producing emulsions for marine diesel engines and power plants.

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BACKGROUND OF THE INVENTION

A way of increasing fuel efficiency in engines, including diesel engines, and improving the ecological characteristics of their operation is the use of emulsions, such as water-fuel emulsions, although other emulsifiable components may also be used. Devices for producing an emulsion of fuel and water by cavitation treatment are already known. Cavitation is defined as the phenomenon of formation of vapour bubbles in a flowing liquid in a region where the pressure of the liquid falls below its vapour pressure. Subsequently, when the bubbles flow into a high pressure zone, the bubbles shrink and collapse, causing a sharp increase in the localized temperature and pressure which gives rise to pressure waves. The pressure waves cause the break up of globules of fuel and the emulsifiable component into smaller globules. This enables an improved distribution of micro globules of the emulsifiable component in the fuel resulting in the formation of an emulsion. An emulsion is defined as the suspension of micro globules of a first liquid in a second liquid, in which the first will not mix. An emulsion obtained by cavitation is such that there is a film of fuel surrounding a micro globule of the emulsifiable component. When such an emulsion burns, the fuel-coated emulsifiable component globules are heated, expand and then explode causing even smaller fuel-coated emulsifiable component globules to be formed. This cycle

of continuous micro explosions result in an increase in the overall surface area of the fuel, leading to an easier and complete combustion of fuel.

Depending on the physical and chemical properties of the fuel and the emulsifiable component, some emulsions may be easily formed by passing the mixture through a cavitation chamber or a similar apparatus to form emulsions. Some emulsifiable components and fuels may be difficult to mix owing to their incompatible physical properties such as viscosity and other chemical properties.

Typically, on forming emulsion by cavitation, a mixture of the fuel and the emulsifiable component is first formed which is then subjected to cavitation. The mixture may not be homogenous, with the concentration of fuel and the emulsifiable component differing in different volumetric zones of the mixture. When the mixture is subjected to cavitation and emulsified, the non-homogeneity will be manifested in the emulsion also, thus leading to a decrease in the quality of the emulsion. Decrease in quality can translate into a decrease in the efficiency of the fuel also.

SUMMARY

The invention is described in the independent claim. Some optional features of the invention are described in the dependent claims.

In an apparatus for producing an emulsion of a fuel and an emulsifiable component where the first and second cavitation chambers and the nozzle outlet from the first cavitation chamber to the second cavitation chamber are positioned in coaxial alignment, the first fluid from the first cavitation chamber is introduced into the centre of the second cavitation chamber, so that the first fluid may be distributed uniformly in the second fluid. Moreover, a coaxial positioning of the outlet with respect to the second cavitation chamber reduces the

risk of any disruption of the vortex of the second fluid that is generated in the second cavitation chamber.

When swirling flows of the fuel and the emulsifiable component are established in opposite
5 directions, a mixture of improved homogeneity is obtained. A homogenous mixture is one where the components of the mixture are distributed uniformly throughout the volume of the mixture. Improved homogeneity is desirable and influences the combustion efficiency of the mixture of the fuel and emulsifiable component.

10 The apparatus can have the outlet from the first cavitation chamber projecting into the second cavitation chamber to a distance that is determined with respect to the diameter of the second cavitation chamber. The apparatus can also have the distance of projection of the outlet from the first cavitation chamber into the second cavitation chamber being determined with respect to the position of the inlet to the second cavitation chamber. This
15 arrangement prevents the flow of the first fluid from the outlet interfering with the formation of the swirling flow of the second fluid in the second cavitation chamber.

The diameter of the outlet from the first cavitation chamber is preferably in the range of 0.7 to 0.75 times the diameter of the first cavitation chamber to provide turbulent flow conditions
20 in the apparatus as turbulence is preferred for cavitation to occur.

The apparatus can have a check valve on the inlet to the first cavitation chamber, wherein the check valve is arranged to be opened only if the pressure in the discharge zone of the second cavitation chamber reaches a threshold, thus enabling to achieve stability of
25 pressure in the second cavitation chamber, so that when the first fluid is introduced into the second cavitation chamber from the first chamber, an effective pressure gradient is obtained.

The cross-sectional area of the second cavitation chamber is preferably greater than or equal to 1.25 times the cross-sectional area of the outlet, to provide an increased uniformity in the distribution of the first fluid from the first cavitation chamber in the second fluid of the second cavitation chamber.

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BRIEF DESCRIPTION OF DRAWINGS

The accompanying drawings illustrate the invention, by way of example only and together with the description, serve to explain the principles of the invention.

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Figure 1 is an elevation view of a first apparatus for producing an emulsion of a fuel and an emulsifiable component

15 Figure 2 is a plan view of the first apparatus in one arrangement showing the swirling flows of the first and second fluids in opposite directions

Figure 3 is a plan view of the first apparatus in another arrangement showing the swirling flows of the first and second fluids in opposite directions

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Figure 4 is a plan view of the first apparatus in one arrangement showing the swirling flows in the first and second cavitation chambers in the same direction

Figure 5 is a plan view of the first apparatus in another arrangement showing the swirling flows in the first and second cavitation chambers in the same direction

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Figure 6 is an elevation view of a second apparatus for producing an emulsion of a fuel and an emulsifiable component

Figure 7 is a plan view taken along section line 7 - 7' of Figure 6

Figure 8 is a plan view taken along section line 8 - 8' of Figure 6

5 Figure 9 is an elevation view of a second chamber alone of the first apparatus

Figure 10 is an elevation view of a second chamber alone of the second apparatus

10 Figure 11 is an elevation view of the first apparatus with the pressure measurement and valve control elements

Figure 12 is an elevation view of the second apparatus with the pressure measurement and valve control elements

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DETAILED DESCRIPTION

A first apparatus 100 for producing an emulsion of a fuel and an emulsifiable component is illustrated in Figure 1. Apparatus 100 comprises a first cavitation chamber 10 and a second
20 cavitation chamber 20. In the example of Figure 1, apparatus 100 also comprises a resonance chamber 30. The first cavitation chamber has an inlet 2 through which the chamber 10 receives a first fluid. In the apparatus of Figure 1, at least two fluids are utilized: a fuel and an emulsifiable component. Water is one emulsifiable component which may be used, but other emulsifiable components may also be used. The first fluid may be a first one
25 of the fuel and the emulsifiable component. The inlet 2 is arranged in such a way so as to produce a swirling flow of the first fluid.

A swirling flow is one which establishes a vortex. As is illustrated in Figure 2, the first and the second cavitation chambers 10 and 20 are circular in cross section and the first fluid and the second fluid are introduced into the first chamber 10 and the second chamber 20 respectively in a manner such that they take on swirling motion profiles to establish the respective vortices. In the example of Figure 2, the swirling motion of the first fluid is brought about by the inlet 2 being arranged tangentially along the first chamber 10 so that when the first fluid enters the first chamber 10 it is directed towards the curved inner side of the circular-cross-section first chamber 10. Directing the first fluid thus imparts a swirling motion profile to the first fluid.

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Similarly, the second cavitation chamber 20 has an inlet 4 through which the second chamber 20 receives the second fluid. The second fluid may be a second one of the fuel and the emulsifiable component. In the example of Figure 2, the swirling motion of the second fluid is brought about by the inlet 4 being arranged tangentially along the second chamber 20 so that when the second fluid enters the second chamber 20 it is directed towards the curved inner side of the circular-cross-section second chamber 20. Directing the second fluid thus, imparts a swirling motion profile to the second fluid.

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It is evident from the above that either chamber may receive either the fuel or the emulsifiable component. The fuel may be heated up to a required temperature before it is introduced into any one of the first and second cavitation chambers. The temperature is dependent on the rheological properties of the fuel. The rheological properties of a fluid are properties like viscosity and elasticity which affect the flow characteristics of a fluid. The purpose of heating and the extent of heating the fuel is to bring the rheological properties of the fuel to a desired value, so as to facilitate a desired mixing of the fuel and an additive.

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Referring again to Figure 1, the first chamber 10 has a base 6 having an outlet for discharging the first fluid from the first chamber 10. In the example of Figure 1, the outlet is a

nozzle 8 having a tip 12 at the bottom of the nozzle, which is the farthest point from the base 6 of the first cavitation chamber 10. The nozzle may be cylindrical, conical or a laval nozzle. The second chamber 20 receives the first fluid from the first chamber 10 through the nozzle 8. The first chamber 10, the second chamber 20 and the nozzle 8 are arranged coaxially along axis $X - X'$; that is, the respective centre-lines of the first and second cavitation chambers 10, 20 and the nozzle 8 are arranged on a common axis. The advantage of having a coaxial arrangement is that the first fluid from the first cavitation chamber 10 is introduced into the centre of the second cavitation chamber 20, so that the first fluid may be distributed uniformly in the second fluid. Moreover, a coaxial positioning of the nozzle 8 with respect to the second cavitation chamber 20 prevents any disruption of the vortex of the second fluid that is generated in the second cavitation chamber 20.

The direction of swirling flows in the first cavitation chamber 10 and the second cavitation chamber 20 may be the same or opposite. The motion of the first fluid in the first chamber 10 takes on a first direction and the motion of the second fluid in the second chamber 20 takes on a second direction. In the example of Figure 2, the first direction is counter-clockwise and the second direction is clockwise, leading to the first and second directions being opposite each other. Figure 3 illustrates another arrangement wherein the first direction is clockwise and the second direction is counter-clockwise. This arrangement also leads to the first and the second directions being opposite each other.

As illustrated in Figure 4, the swirling flows may also be arranged so that the first fluid and the second fluid in the first chamber and second chamber respectively are in the same clockwise direction. As illustrated in Figure 5, the swirling flows can also be arranged so that the first fluid and the second fluid in the first chamber and second chamber respectively are in the same counter-clockwise direction.

Having the first direction and the second direction of the swirling flow in opposite directions and in contact with each other enhances turbulent flows of the mixture, where the respective flows interrupt and interact with one another, leading to increased mixing of the first and second fluids. In other words, increased mixing leads to improved homogeneity of the emulsion. Additionally, turbulent flow helps to assist cavitation in the fluids. Turbulent flows result in rapid pressure and velocity gradients in space and time. These rapid gradients of pressure result in higher frequency of oscillation of the pressure waves in the cavitating mixture of fuel and the emulsifiable component. A higher frequency of oscillation of pressure waves contribute to the creation of numerous cavitation bubbles which are unstable and break up the emulsifiable component into very small droplets/globules, leading to a higher surface area of the fuel being available for combustion thereby providing improved combustion efficiency of the emulsion.

A second apparatus 200 as illustrated in Figure 6 can be arranged to have a plurality of tangential inlets in the first chamber 10 and a plurality of inlets in the second chamber 20. In such an arrangement, the first chamber 10 and the second chamber 20 are enclosed completely by a fluid reservoir along their sides to contain the first fluid and the second fluid before introducing them into the chambers through the inlets. Essentially, the reservoirs act as manifolds, helping to improve uniformity of rate of flow of fluid into the respective cavitation chambers through each of the plurality of inlets. As illustrated in Figure 6, the first chamber 10 is completely enclosed by a fluid reservoir 14. The reservoir 14 is supplied with the first fluid by pipeline 16. Similarly, there is shown a reservoir 18 enclosing the second chamber 20. The reservoir 18 is supplied with the second fluid by pipeline 22.

Figure 7 illustrates an example where the first chamber 10 is provided with two tangential inlets 2. The space between the first chamber 10 and the reservoir 14 serves to contain the first fluid and simultaneously force the first fluid through the tangential inlets 2 to produce a swirling flow. The number of inlets need not be restricted to two, but can be greater than two,

such as 4 or 6, or other suitable numbers. Similarly, Figure 8 illustrates an example where the second chamber 20 is provided with two tangential inlets 4. The space between the second chamber 20 and the reservoir 18 serves to contain the second fluid and simultaneously force the second fluid through the tangential inlets 4 to produce a swirling flow. The number of inlets need not be restricted to two, but can be greater than two, such as 4 or 6, or other suitable numbers. Figure 7 illustrates that the inlets 2 in the first chamber 10 are positioned to produce a swirling flow in the clockwise direction. Similarly, Figure 8 illustrates that the inlets 4 in the second chamber 20 are positioned to produce a swirling flow in the counter-clockwise direction. The direction of swirling flow or vortex in Figure 7 and Figure 8 are just an illustration, though the direction of swirling flow can be arranged as required. In other words, the direction of swirling flows in the first chamber 10 and the second chamber 10 may be in the opposite direction or in the same direction.

The inlets in the second chamber may be arranged such that they are at different levels in the second chamber. The advantage of having the tangential inlets in the second chamber at different levels is to provide improved uniformity of pressure distribution in the second cavitation chamber. This is illustrated in Figure 10.

The first chamber 10 and the second chamber 20, by virtue of their producing a swirling flow of the first fluid and the second fluid are vortex cavitation devices. The principle of working of a vortex cavitation device is by imposing rotational speed components on the vortex, the device produces pressure variations according to Bernoulli's principle. The pressure variations lead to alternate high and low pressure in the first and second fluids. The initial cavitation which occurs in the first chamber and the second chamber due to the above leads to cracking of the fluids. Cracking is the breakdown of the fluids on a molecular level which is a preferable step prior to intense cavitation and mixing of fluids. Higher molecular chains of hydrocarbons are disrupted. The process of cracking may be termed as activation of the fluids. This is advantageous especially when the fuel and the emulsifiable component are

difficult to mix and emulsify owing to their physical and chemical properties under normal conditions.

The first chamber 10 has a first radius r and the second chamber 20 has a second radius R .

5 In the example of Figure 1 and 6, r is smaller than R . Consequently, the cross sectional area of the first chamber 10 is smaller than the cross sectional area of the second chamber 20. The smaller cross sectional area in the first chamber 10 will mean that for constant fluid flow rate and fluid temperature, fluid pressure in the first chamber 10 will be higher than fluid pressure in the second chamber 20.

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The pressure gradient (pressure differential) between the first chamber 10 and the second chamber 20, which is denoted by ΔP , contributes to the effectiveness of the working of the apparatus. Where the pressure in the first chamber 10 is P_1 and the pressure in the second chamber 20 is P_2 , the pressure gradient ΔP can be deduced as follows:

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$$\Delta P = P_1 - P_2$$

The first fluid flowing from the first chamber 10 having pressure P_1 to the second chamber 20 experiences a pressure drop which is equivalent to ΔP . The pressure P_2 is maintained
20 lower than P_1 to achieve the pressure drop. This pressure drop induces cavitation as cavitation inception occurs when the pressure of the flowing fluid goes below the vapour pressure of the flowing fluid. So if the pressure drop is higher, the greater is the intensity of cavitation which translates to a higher effectiveness of the system.

25 A greater pressure drop induces a higher velocity of the flow of the first fluid from the first chamber 10 to the second chamber 20, the higher velocity translating into higher frequency of oscillation of pressure waves resulting from cavitation. Thereby, a higher value of ΔP is desirable. ΔP can be increased by either increasing P_1 or decreasing P_2 .

The first fluid from the first chamber 10 is introduced into the second chamber 20 through the nozzle 8. The nozzle 8 is situated downstream the inlet 4 of the second chamber 20. In the case of a plurality of inlets 4, the tip 12 of nozzle 8 is situated downstream the plurality of inlets 4.

Downstream of the inlet is defined as a position which is at a distance farther from the inlet in a direction from the first chamber to the second chamber.

The distance of projection of the outlet into the second cavitation chamber 20 with respect to the base 6 of the first cavitation chamber 10 is determined with respect to a diameter of the second cavitation chamber. Preferably, the distance above is the distance of projection of the tip 12 of nozzle 8 into the second cavitation chamber 20. The optimum distance is in the range of 0.1 to 0.15 times the diameter of the second cavitation chamber 20.

The distance of projection of the outlet into the second cavitation chamber 20 and a position of the inlet 4 of the second cavitation chamber 20 are determined with respect to one another.

Preferably, the tip 12 of nozzle 8 projects into the second cavitation chamber 20 to a first distance H from a first end 7 of the second cavitation chamber 20. In the example of Figure 1, the first end 7 is the "upper" end in the cross-sectional view of Figure 6. The inlet 4 of the second cavitation chamber 20 is located at a position which is a second distance h from the first end 7 of the second cavitation chamber 10. The first distance is greater than the second distance. One useful range for the relationship between H and h is the first distance, H being greater than or equal to 1.2 times the second distance, h . H being greater than h is illustrated in Figure 9.

Preferably, for the second apparatus 200 with multiple inlets in the second cavitation chamber 20, as illustrated in Figure 10, the nozzle 12 projects into the second cavitation chamber 20 to a first distance H from the first end 7 of the second cavitation chamber 10. A second distance, h is a distance from the first end 7 of the second cavitation chamber 10 of an inlet of the plurality of inlets 4 positioned farthest from the first end 7 of the second cavitation chamber 10. The first distance is greater than the second distance. One useful range for the relationship between H and h is the first distance, H being greater than or equal to 1.2 times the second distance, h. This is illustrated in Figure 10.

One advantage arising from a nozzle arrangement as explained above is that it may help to prevent flow of the first fluid from the tip 12 of the nozzle 8 from interfering with the formation of the swirling flow of the second fluid in the second cavitation chamber 20.

The first apparatus 100 can have either of the nozzle arrangements described above or both of them. Similarly, the second apparatus 200 can have either of the nozzle arrangements described above or both of them.

The first chamber 10 has a first diameter and the outlet of the first chamber 10 has a second diameter. One useful range for the second diameter is for it to be around 0.7 to 0.75 times of the first diameter. The advantage of this is to provide turbulent flow conditions, as turbulent flow conditions are preferred for cavitation. This is because if the turbulence is higher, the lesser is the globule size resulting from the cavitated fluid. Smaller globule sizes are preferred in the emulsion.

There is a discharge zone 13 in the second cavitation chamber 20 near the tip 12 of the nozzle 8. Accordingly, the second cavitation chamber 20 is arranged to receive the first fluid through the nozzle 8 in the discharge zone. Once the first fluid is introduced into the second

cavitation chamber 20, it then mixes with the second fluid, which is either rotating in the same direction or in the opposite direction.

When the first fluid is introduced continuously into the second chamber at a controlled rate, this assists the second fluid in mixing uniformly and continuously with the first fluid as the second fluid enters the second chamber through the second inlet or the plurality of second inlets, succeeded by intense cavitation of the mixture. A continuous mixing, arising from continuous introduction of fluid flow into the first and/or second chambers 10, 20 can help to provide a homogeneous emulsion.

Where water is used as the emulsifiable component, the percentage of the emulsifiable component by weight may be kept below 70%. If the percentage of the emulsifiable component exceeds 70%, there is a tendency for the emulsion to gel which may not be desirable.

The mixture subsequently passes through the resonance chamber 30, in which the pressure waves at certain frequencies which are close to the resonant frequencies of the resonating chamber are amplified leading to intense cavitation and homogenization of the mixture. The mixture after passing through the resonance chamber either goes to another working vessel for further treatment or goes directly to the consumer for combustion.

The construction described above for the first and second apparatus is a relatively simple arrangement with minimal numbers of component parts, imparting a compact nature to the apparatus. The absence of any moving parts and provision of a simple mechanical design leads to simplified maintenance requirements as well. The above advantages also provide a reduction in the associated costs.

In the examples of Figures 1 and 6, the respective apparatuses are provided with a check valve 3 for controlling the flow of the first fluid into the first cavitation chamber 10. As illustrated in Figure 1, check valve 3 is provided to control flow of first fluid through the inlet 2 in the apparatus. In Figure 6, a check valve 3 is provided in the pipeline 16. The check valve is used to control the flow of the first fluid into the first cavitation chamber 10 and is opened when the pressure in the second cavitation chamber 20 reaches a predetermined value. As described earlier, the first fluid may be any one of the emulsifiable component and the fuel. The advantage of this is to achieve stability of the pressure in the second chamber, so that when the first fluid is introduced into the second chamber from the first chamber, an effective pressure gradient ΔP is obtained.

The pressure inside the second cavitation chamber 20 is measured with a suitable pressure measurement device 32 fitted inside the cavitation chamber 20. The pressure measurement device 32 may be a suitable pressure sensor such as a piezoelectric pressure sensor. As illustrated in Figures 11 and 12, the pressure signals from the device are relayed to a processing device 34 such as a controller or a computer through signal communication lines 36. The processing device 34 comprises signal input / output elements, signal processing elements and control elements. The signal processing elements compares the measured value of pressure with a threshold value which is configured and stored in the processing device 34. If the measured value of the pressure is greater than the threshold value of the pressure, signals are transmitted from the control elements of the processing device 34 to the valve 3 through signal communication lines 38 to open the valve 3. Once the valve 3 is open, the first fluid flows into the apparatus. The threshold value in the processing device 34 may be varied and stored. The pressure inside the second cavitation chamber 20 is measured continuously and the valve 3 is open as long as the measured pressure value is higher than the threshold value. The measured pressure value that is used for comparison with the threshold value is usually a value of the pressure that is averaged over time.

The amount of fuel and the emulsifiable components supplied to the apparatus 100 and 200 may be controlled through metering pumps installed in the pipelines leading to the first cavitation chamber and second cavitation chamber.

- 5 In Figure 1 and Figure 6, the nozzle 8 has a first cross-sectional area and the second cavitation chamber 20 has a second cross-sectional area, wherein the second cross sectional area is greater than or equal to 1.25 times the first cross sectional area. The advantage of this is to introduce the first fluid into the second cavitation chamber in such a way that it is distributed uniformly in the second fluid.

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Provided that the flow rate through first inlet 2 of the first chamber is f_1 , then the equivalent diameter d_2 of at least one inlet 4 is determined by the following expression:

$$R \geq d_2 \geq d_1 \sqrt{(f_2/f_1)}$$

- 15 wherein d_1 is an equivalent diameter of first inlet 2, d_2 is an equivalent diameter of at second inlet 4, R is the radius of second chamber 20, f_1 and f_2 are flow rates through inlets 2 and 4, correspondingly, $d_1 = \sqrt{(4S_1/\pi)}$, $d_2 = \sqrt{(4S_2/\pi)}$, where S_1 is the total cross-sectional area of the first inlets and S_2 is the total cross sectional area of the second inlets.

- 20 It is to be understood that the foregoing description is intended to be purely illustrative of the principles of the disclosed techniques, rather than exhaustive thereof, and that changes and variations will be apparent to those skilled in the art, and that the present invention is not intended to be limited other than as expressly set forth in the following claims.

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CLAIMS

1. An apparatus for producing an emulsion of a fuel and an emulsifiable component, the apparatus comprising:

5 a first cavitation chamber for receiving a first fluid, the first fluid being a first one of the fuel and the emulsifiable component, the apparatus being arranged to produce a swirling flow of the first fluid in the first cavitation chamber;

a second cavitation chamber for receiving a second fluid, the second fluid being a second one of the fuel and the emulsifiable component, the apparatus being
10 arranged to produce a swirling flow of the second fluid in the second cavitation chamber;

the first cavitation chamber further comprises an outlet;

the first cavitation chamber, the outlet and the second cavitation chamber being arranged coaxially; and

15 wherein the second cavitation chamber is arranged to receive the first fluid from the first cavitation chamber through the outlet.

2. The apparatus as claimed in Claim 1, wherein the apparatus is arranged:

20 to produce the swirling flow of the first fluid in the first cavitation chamber in a first direction;

to produce the swirling flow of the second fluid in the second cavitation chamber in a second direction;

wherein the second direction is opposite the first direction.

- 25 3. The apparatus as claimed in Claim 1, wherein the apparatus is arranged:

to produce the swirling flow of the first fluid in the first cavitation chamber;

to produce the swirling flow of the second fluid in the second cavitation chamber;

wherein the swirling flow of the first fluid is in the same direction as the swirling flow of the second fluid.

4. The apparatus as claimed in any preceding claim, arranged for fluid pressure in the first cavitation chamber to be higher than fluid pressure in the second cavitation chamber.

5. The apparatus as claimed in Claim 4, wherein the first cavitation chamber has a first radius, and the second cavitation chamber has a second radius, the first radius being smaller than the second radius.

6. The apparatus as claimed in any preceding claim, wherein the outlet projects into the second cavitation chamber to a distance determined with respect to a diameter of the second cavitation chamber.

7. The apparatus as claimed in Claim 6, wherein the outlet projects into the second cavitation chamber to a distance within the range of 0.1 to 0.15 times the diameter of the second cavitation chamber.

8. The apparatus as claimed in Claim 6 or Claim 7, the second cavitation chamber having a discharge zone, and wherein the second cavitation chamber is arranged to receive the first fluid through the outlet in the discharge zone.

9. The apparatus as claimed in any preceding claim, the second cavitation chamber comprising an inlet arranged to receive the second fluid; wherein the outlet is located downstream the inlet.

10. The apparatus as claimed in Claim 9, wherein a distance of projection of the outlet into the second cavitation chamber and a position of the inlet are determined with respect to one another.
- 5 11. The apparatus as claimed in Claim 10, wherein the outlet projects into the second cavitation chamber to a first distance from a first end of the second cavitation chamber and the inlet is located at a position which is a second distance from the first end of the second cavitation chamber, wherein the first distance is greater than the second distance.
- 10 12. The apparatus as claimed in Claim 11, wherein second cavitation chamber comprises a plurality of inlets for receiving the second fluid;
the second distance is a distance from the first end of the second cavitation chamber of an inlet of the plurality of inlets positioned farthest from the first end of the second
15 cavitation chamber.
13. The apparatus as claimed in Claim 11 or Claim 12, wherein the first distance is greater than or equal to 1.2 times the second distance.
- 20 14. The apparatus as claimed in any one of the preceding claims, the first cavitation chamber having a first diameter, the outlet having a second diameter, and wherein the second diameter is in the range 0.7 to 0.75 times of the first diameter.
15. The apparatus as claimed in any one of the preceding claims, the apparatus further
25 comprising a check valve on the inlet to the first cavitation chamber, and
wherein the check valve is arranged to be opened only if the pressure in the discharge zone of the second cavitation chamber reaches a threshold.

16. The apparatus as claimed in any one of the preceding claims, wherein the outlet has a first cross-sectional area and the second cavitation chamber has a second cross-sectional area and the second cross-sectional area is greater than or equal to 1.25 times the first cross-sectional area.

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17. The apparatus as claimed in any one of the preceding claims comprising a check valve in a conduit in fluid communication with an inlet for receiving the emulsifiable component, the apparatus being arranged to open the check valve responsive to satisfaction of a pressure criterion in the second cavitation chamber.

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18. A method for producing an emulsion of a fuel and an emulsifiable component, the method comprising:

introducing a first fluid into a first cavitation chamber, the first fluid being a first one of the fuel and the emulsifiable component, and producing a swirling flow of the first fluid in the first cavitation chamber;

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introducing a second fluid into a second cavitation chamber, the second fluid being a second one of the fuel and the emulsifiable component, and producing a swirling flow of the second fluid in the second cavitation chamber;

wherein the first cavitation chamber, the outlet and the second cavitation chamber being arranged coaxially; and

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wherein receiving the first fluid in the second cavitation chamber from the first cavitation chamber through the outlet.

19. The method of Claim 18, wherein the emulsifiable component is water and wherein a percentage by weight of the emulsifiable component in the emulsion is less than or equal to 70 per cent.

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20. A method for producing an emulsion of a fuel and an emulsifiable component using the apparatus of any one of claims 1 to 17.

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