

An Improved Mist Generating Apparatus and Method

The present invention relates to the field of mist generating apparatus. More specifically, the invention is directed to an improved apparatus and method for generating liquid droplet mists.

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Mist generating apparatus are known and are used in a number of fields. For example, such apparatus are used in fire suppression, decontamination and cooling applications, where the liquid droplet mists generated are more effective than a conventional fluid stream. Examples of such mist generating apparatus can be found in WO2005/082545 and WO2005/082546 to the same applicant.

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Whilst such apparatus are easily capable of generating liquid droplet mists, they are limited in that they can only project the mists over short distances and have a low efficiency.

It is an aim of the present invention to obviate or mitigate one or more of the aforementioned disadvantages.

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According to a first aspect of the present invention there is provided an apparatus for generating a mist comprising:

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a first transport fluid passage having a first transport fluid inlet, a first transport fluid outlet, and a throat portion intermediate the first transport fluid inlet and the first transport fluid outlet, the throat portion having a cross sectional area which is less than that of either the first transport fluid inlet or the first transport fluid outlet;

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at least one working fluid passage located radially outwardly of the first transport fluid passage and having a working fluid inlet and a working fluid outlet;

5 at least one second transport fluid passage having a second transport fluid inlet and a second transport fluid outlet in fluid communication with the working fluid passage; and

an outlet nozzle in fluid communication with the first transport fluid and working fluid outlets;

10 wherein the second transport fluid passage has an outlet located in the working fluid passage upstream of the working fluid outlet.

Preferably, the second transport fluid inlet is in fluid communication with the first transport passage such that the second transport fluid passage receives transport fluid from the first transport fluid passage.

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Preferably, the first fluid transport inlet receives transport fluid from a first source.

20 Alternatively, the first fluid transport passage receives transport fluid from a first source and the second transport fluid passage receives transport fluid from a second separate transport fluid source.

25 Preferably, the second transport fluid passage has an inlet located in the first transport fluid passage upstream of the throat portion of the first transport fluid passage.

Preferably, the working fluid outlet is located radially outwardly from the first transport fluid outlet.

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Preferably, the working fluid outlet is directed towards the longitudinal axis of the transport fluid passage.

5 Alternatively, the working fluid outlet is substantially parallel to the longitudinal axis of the first transport fluid passage.

10 Preferably, the second transport fluid passage and a portion of the working fluid passage adjacent the working fluid outlet are arranged such that there is a substantially straight-through passageway between the inlet to the second transport fluid passage and the working fluid outlet.

Preferably, the working fluid outlet is located adjacent the throat portion of the first transport fluid passage.

15 Preferably, the working fluid outlet is substantially perpendicular to the longitudinal axis of the first transport fluid passage.

20 Preferably, the first transport fluid passage is generally cylindrical in shape.

Preferably, the working fluid passage is generally annular in shape.

25 Preferably, the working fluid passage circumscribes the first transport fluid passage.

Preferably, the working fluid passage includes a plurality of working fluid inlets.

30 Preferably, the first transport fluid passage has a protrusion which protrudes towards the longitudinal axis of the first transport fluid passage,

the protrusion being located intermediate of the throat portion and outlet of the first transport fluid passage.

5 Preferably, the apparatus comprises a plurality of second transport fluid passages.

Preferably, the plurality of second transport fluid passages are arranged circumferentially around the first transport fluid passage.

10 According to a second aspect of the invention, there is provided a method of generating a mist, the method comprising the steps of:

supplying a first portion of a transport fluid to a first transport fluid passage having a first transport fluid inlet, a first transport fluid outlet and a throat portion intermediate the first transport fluid inlet and the first transport fluid outlet, the throat portion having a cross sectional area which is less than that of either the first transport fluid inlet or the first transport fluid outlet;

15 supplying a working fluid to at least one working fluid passage located radially outwardly of the first transport fluid passage and having a working fluid inlet and a working fluid outlet;

20 supplying a second portion of transport fluid through at least one second transport fluid passage into the working fluid passage, wherein the second transport fluid passage has an outlet upstream of the working fluid outlet;

25 imparting a shear force on the working fluid by way of the second portion of the transport fluid exiting the second transport fluid passage outlet, thereby partially atomising the working fluid as it passes through the working fluid passage; and

30 directing the partially atomised working fluid and the first portion of transport fluid to an outlet nozzle in fluid communication with the

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respective first transport fluid and working fluid outlets, wherein the respective outlets are arranged such that the first portion of transport fluid flow imparts a further shear force on the partially atomised working fluid to atomise the working fluid still further.

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Preferably, the second portion of the transport fluid is directed to the second transport fluid passage from the first transport fluid passage.

10 Preferably, the supply of the first portion of transport fluid to the first transport fluid passage is from a first source.

Alternatively, the supply of the first portion of transport fluid to the first transport fluid passage is from a first source and the supply of the second portion of transport fluid to the second transport fluid passage is from a
15 second separate transport fluid source.

Preferably, the step of supplying the second portion of the transport fluid through the at least one second transport fluid passage includes directing transport fluid in the first transport passage to an inlet of the second
20 transport fluid passage located upstream of the throat portion of the first transport fluid passage.

Preferably, the second portion of the transport fluid is directed through a plurality of second transport fluid passages which connect the first
25 transport fluid passage and working fluid passage.

Preferably, the method of generating the mist comprises the further step of creating a stationary aerodynamic shockwave in the first transport fluid passage.

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Preferably, the step of creating the stationary aerodynamic shockwave includes the step of passing the transport fluid over a protrusion or a recess in the first transport fluid passage.

- 5 Preferably, the method comprises the further step of passing the atomised working fluid through the stationary aerodynamic shockwave to atomise the working fluid further still.

10 Preferred embodiments of the present invention will be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a cross sectional side view of part of a mist generating apparatus according to a first embodiment of the present invention;

15 Figure 2 is a cross sectional side view of part of a mist generating apparatus according to a second embodiment of the present invention; and

Figure 3 is a cross section side view of part of a mist generating apparatus according to a third aspect of the present invention.

20 Figure 1 shows a first embodiment of a mist generating apparatus 10 according to the present invention. The apparatus 10 comprises a first transport fluid passage 12, a working fluid passage 14 and an outlet nozzle 16.

25 The first transport fluid passage 12 is generally cylindrical in shape and has a first transport fluid inlet 12a and a first transport fluid outlet 12b. The first transport fluid passage 12 also has convergent-divergent internal geometry. The convergent-divergent geometry comprises a converging portion 18, a diverging portion 20 and a throat portion 22 located between
30 the converging and diverging portions 18, 20. The throat portion 22 is

located intermediate the first transport fluid inlet 12a and the first transport fluid outlet 12b and has a cross sectional area which is less than that of either the first transport fluid inlet 12a or the first transport fluid outlet 12b.

5 The working fluid passage 14 is located radially outwardly of the first transport fluid passage 12. In this arrangement, the working fluid passage 14 partially circumscribes the first transport fluid passage 12. The working fluid passage 14 has a working fluid inlet 14a and a working fluid outlet 14b. A portion 14e of the working fluid passage 14 adjacent the working
10 fluid inlet 14a is substantially perpendicular to the longitudinal axis 26 of the first transport fluid passage 12. The working fluid passage 14 also has a converging portion 14c between the inlet 14a and the outlet 14b. A portion 14d of the working fluid passage adjacent the working fluid outlet 14b is inclined relative to the longitudinal axis 26 of the first transport fluid
15 passage 12, such that the working fluid outlet 14b itself is also directed towards the longitudinal axis 26 of the first transport fluid passage 12.

The outlet nozzle 16 is in fluid communication with the first transport fluid outlet 12b and the working fluid outlet 14b.

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The apparatus 10 also comprises a second transport fluid passage 24 which allows fluid communication between the first transport fluid passage 12 and the working fluid passage 14. The second transport fluid passage 24 has a second fluid inlet 24a located in the first transport fluid passage 12 upstream of the convergent-divergent portion 18, 20. The second
25 transport fluid passage 24 also has a second fluid outlet 24b located in the working fluid passage 14 upstream of the working fluid outlet 14b.

In the embodiment of figure 1, the working fluid outlet 14b is located
30 radially outwardly from first transport fluid outlet 12b. Also, the second

transport fluid passage 24 and the portion 14d of the working fluid passage 14 adjacent the working fluid outlet 14b are arranged such that there is a substantially straight-through passageway between the second inlet 24a of the second transport fluid passage 24 and the working fluid outlet 14b.

In the embodiment of figure 1, the apparatus 10 includes a mixing chamber 12d located downstream of the working fluid outlet 14b. The mixing chamber 12d allows further mixing and atomisation of working fluid thereby creating even smaller droplet sizes. The mixing chamber 12d is short in comparison to the length of the first transport fluid passage 12. Typically, the mixing chamber 12d is approximately 10mm in length. However, it should be appreciated that dimensions of the mixing chamber 12d may be altered depending on, *inter alia*, the type of transport fluid and/or working fluid being used and the application of the apparatus 10.

The operation of the first embodiment will now be described. A working fluid, such as water for example, is introduced to the working fluid passage 14. The working fluid flows along the chamber 14 and exits the working fluid outlet 14b at the outlet nozzle 16. Since the working fluid outlet 16 is directed towards the longitudinal axis 26 of the transport fluid passage 12, the working fluid exits the working fluid outlet 16 and comes into contact with the transport fluid. A transport fluid (an example of a first portion of a transport fluid), such as steam for example, is introduced to the first transport fluid passage 12. Due to the convergent-divergent geometry of the first transport fluid passage 12, the passage 12 acts as a venturi section, accelerating the transport fluid as it passes therethrough. The accelerated transport fluid exits the first transport fluid outlet 12b at the outlet nozzle 16. This acceleration of the transport fluid ensures that the transport fluid exits the outlet nozzle 16 at a supersonic velocity.

Upstream of the convergent-divergent section a portion of the transport fluid (an example of a second portion of transport fluid) also flows through the second transport fluid passage 24 towards the working fluid passage 14. The transport fluid enters at the second fluid inlet 24a and exits at the second fluid outlet 24b. The transport fluid enters the working fluid passage 14 upstream of the working fluid outlet 14b. As the transport fluid enters the working fluid passage 14 it imparts a shear force on the working fluid thereby partially atomising the working fluid as it passes through the working fluid passage 14 and/or creating a bubble flow regime.

With the first portion of the transport fluid flowing at such high velocity and the partially atomised working fluid exiting the working fluid passage 14 at the working fluid outlet 14b, the partially atomised working fluid is subjected to further shear forces by the transport fluid. The result of this is that the partially atomised working fluid is atomised further by the transport fluid and a dispersed droplet flow regime is produced having extremely small water droplets. Furthermore, the turbulence created by the transport fluid also aids in the atomisation of the working fluid. Also, the expansion of the working fluid, or working fluid mixture, exiting the outlet nozzle 16 causes further atomisation of the working fluid. Furthermore, the expansion and/or contraction of transport fluid, or transport fluid mixture, may enhance further atomisation of the working fluid.

The apparatus 10 therefore creates a flow of substantially uniform sized droplets from the working fluid. Due to the fact that the transport fluid is transported centrally along the first transport fluid passage 12, the apparatus is capable of projecting the droplets a great distance.

Figure 2 shows a second embodiment of the mist generating apparatus 100. In figure 2 the working fluid outlet 114b is located adjacent the throat portion 122 of the convergent-divergent portion 118, 120. In this arrangement a portion 114d of the working fluid passage 114 adjacent the working fluid outlet 114b is inclined relative to the longitudinal axis 126 of the first transport fluid passage 112, such that the working fluid outlet 116 itself is also directed towards the longitudinal axis 126 of the first transport fluid passage 112.

10 The operation of the second embodiment is similar to that of the first embodiment, the major difference being that the working fluid exits the working fluid passage 114 adjacent the throat portion 122 of the convergent-divergent portion 118, 120 and the working fluid enters the first transport fluid passage 112 against the flow of the transport fluid. In the second embodiment the working fluid is again partially atomised by the transport fluid exiting the second transport fluid passage 124 upstream of the working fluid outlet 114b. The partially atomised working fluid entering the first transport fluid passage 112 at the throat portion 122 is subjected to the same shearing by the accelerated transport fluid as in the first embodiment. As explained above, the partially atomised working fluid enters the first transport fluid passage 112 against the flow of the transport fluid. This aids the shearing effect of the accelerated transport fluid, thus increasing the atomisation of the working fluid. In this embodiment the main shearing atomisation takes place adjacent the throat portion 122, i.e. where the transport fluid is flowing at supersonic velocities. This shearing atomisation process is therefore extended through the entire divergent portion 120 towards the outlet nozzle 126. Furthermore, working fluid located on the walls of the divergent portion 120 is stripped therefrom by the transport fluid and the expansion of the working fluid exiting at the nozzle outlet 116 causes further atomisation of the working fluid.

Figure 3 shows a third embodiment of the mist generating apparatus 200.

In figure 3 the divergent portion 220 of the transport fluid passage 212 includes a protrusion 228 which protrudes towards the longitudinal axis 226 of the transport fluid passage 212. The protrusion 228 is located intermediate of the throat portion 222 and outlet 212b of the transport fluid passage 212. The protrusion 228 produces a stepped portion which includes a ring-shaped surface 222a, which lies in a plane which is substantially perpendicular to the longitudinal axis 226.

The purpose of the portion 228 is to create a stationary aerodynamic shockwave in the apparatus 200.

The operation of the third embodiment is similar to that of the first and second embodiments, the only difference being that the dispersed droplet flow regime exiting the outlet nozzle 216 passes through the stationary aerodynamic shockwave. This shockwave creates further atomisation of the dispersed droplet flow regime.

The mist generating apparatus 10 therefore obviates or mitigates the disadvantages of previous proposals by pre-atomising the working fluid upstream of the working fluid outlet 14b and providing centralised transportation of the transport fluid. Pre-atomising the working fluid upstream of the working fluid outlet 14b results in less transport fluid being required to produce the dispersed droplet flow regime. This increases the efficiency of the apparatus 10. Also, providing centralised transportation of the transport fluid allows the dispersed droplet flow regime to be projected further than conventional methods.

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Modifications and improvements may be made to the above without departing from the scope of the present invention. For example, although the portion 14e of the working fluid passage 14 adjacent the working fluid inlet 14a has been illustrated and described above as being substantially perpendicular to the longitudinal axis 26 of the first transport fluid passage 12, it should be appreciated that the portion 14e of the working fluid passage 14 adjacent the working fluid inlet 14a may be substantially parallel to the longitudinal axis 26 of the first transport fluid passage 12. In this case the working fluid passage 14 is generally annular in shape and circumscribes the first transport fluid passage 12.

Also, although the working fluid passage 14 has been described above as having one working fluid inlet 14e, it should be appreciated that working fluid passage 14 may have a plurality of working fluid inlets 14e.

Also, although the portion 14d of the working fluid passage 14 adjacent the working fluid outlet 14b has been described and illustrated above as being inclined relative to the longitudinal axis 26 of the first transport fluid passage 12, it should be appreciated that the portion 14d of the working fluid passage 14 adjacent the working fluid outlet 14b may be substantially parallel to the longitudinal axis 26 of the first transport fluid passage 12.

Furthermore, although the portion 114d of the working fluid passage 114 adjacent the working fluid outlet 114b has been described and illustrated above as being inclined relative to the longitudinal axis 126 of first transport fluid passage 112, it should be appreciated that the portion 114d of the working fluid passage 114 adjacent the working fluid outlet 114b may be substantially perpendicular to the longitudinal axis 126 of first transport fluid passage 112.

It should also be appreciated that the angle of inclination between the portion 14d, 114d of the working fluid passage 14 adjacent the working fluid outlet 14b, 114b and the longitudinal axis 26, 126 of the first transport fluid passage 12, 112 may be any angle between 0 and 90 degrees.

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Also, although the apparatus 10 has been illustrated and described above as having a single second transport fluid passage 24, it should be appreciated that the apparatus 10 may comprise a plurality of second transport fluid passages. In this case the second transport fluid passages are arranged circumferentially around the first transport fluid passage 12.

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Furthermore, although the portion 228 has been illustrated and described above as creating a stationary aerodynamic shockwave in the apparatus 10, it should be appreciated that a stationary aerodynamic shockwave may be created in the apparatus 10 by selecting a suitable geometry of the apparatus 10.

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Also, although the second transport fluid passage 24 has been illustrated and described above as receiving transport fluid from the first transport fluid passage 12 by directing a portion of transport fluid from the first transport fluid passage 12 to the second transport fluid passage, it should be appreciated that the second transport fluid passage 24 could receive transport fluid from a separate source of transport fluid. For example, if the first transport passage 12 receives transport fluid from a first source, the second transport fluid passage 24 could receive transport fluid from a second separate source.

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Furthermore, although the transport fluid has been described above as exiting the outlet nozzle 16 at a supersonic velocity, it should be appreciated that, by alternative arrangement of the internal geometry of

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the transport fluid passage 12, the transport fluid may exit the outlet nozzle 16 at lower, sonic or subsonic, velocities.

5 Also, although the working fluid outlet 14b, 114b has been illustrated above as being annular, it should be appreciated that the working fluid outlet 14b, 114b may comprise a series of holes circumscribing the first transport fluid passage 12, 112. Using a series of holes instead of an annular outlet increases the dispersion of the working fluid.

10 Furthermore, although the working fluid has been described above as being water, it should be appreciated that the working fluid may be any suitable liquid and may also include an additive (e.g. a surfactant) or a decontaminant. Similarly, although the transport fluid has been described above as being steam, it should be appreciated that the transport fluid
15 may also be gas (e.g. compressed air, Nitrogen or Helium).

Also, although the apparatus 10 described in figure 1 above has been described as including a mixing chamber 12d located downstream of the working fluid outlet 14b, it should be appreciated that the mixing chamber
20 12d is optional and is not essential for the function of the apparatus 10.

Furthermore, although the apparatus 200 has been described above as having a protrusion 228 which creates a stationary aerodynamic shockwave in the first transport fluid passage 212, it should be
25 appreciated that a stationary aerodynamic shockwave may also be created by a recess in the first transport fluid passage. Also a stationary aerodynamic shockwave may also be created in the apparatus by configuration of the internal geometry of the apparatus and by varying, *inter alia*, the flow conditions (e.g. pressure, temperature, density etc.) of
30 the transport fluid working fluid.

Claims

1. An apparatus for generating a mist comprising:
a first transport fluid passage having a first transport fluid inlet, a
5 first transport fluid outlet, and a throat portion intermediate the first
transport fluid inlet and the first transport fluid outlet, the throat portion
having a cross sectional area which is less than that of either the first
transport fluid inlet or the first transport fluid outlet;
at least one working fluid passage located radially outwardly of the
10 first transport fluid passage and having a working fluid inlet and a working
fluid outlet;
at least one second transport fluid passage having a second
transport fluid inlet and a second transport fluid outlet in fluid
communication with the working fluid passage; and
15 an outlet nozzle in fluid communication with the first transport fluid
and working fluid outlets;
wherein the second transport fluid passage has an outlet located in
the working fluid passage upstream of the working fluid outlet.
- 20 2. An apparatus for generating a mist as claimed in claim 1, wherein
the second transport fluid inlet is in fluid communication with the first
transport passage such that the second transport fluid passage receives
transport fluid from the first transport fluid passage.
- 25 3. An apparatus for generating a mist as claimed in claim 1 or claim 2,
wherein the second transport fluid passage has an inlet located in the first
transport fluid passage upstream of the throat portion of the first transport
fluid passage.

4. An apparatus for generating a mist as claimed in claim 1, wherein the first fluid transport passage receives transport fluid from a first source and the second transport fluid passage receives transport fluid from a second separate transport fluid source.
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5. An apparatus for generating a mist as claimed in any preceding claim, wherein the working fluid outlet is located radially outwardly from the first transport fluid outlet.
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6. An apparatus for generating a mist as claimed in any preceding claim, wherein the working fluid outlet is directed towards the longitudinal axis of the first transport fluid passage.
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7. An apparatus for generating a mist as claimed in claim 5 or claim 6, wherein the second transport fluid passage and a portion of the working fluid passage adjacent the working fluid outlet are arranged such that there is a substantially straight-through passageway between the inlet to the second transport fluid passage and the working fluid outlet.
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8. An apparatus for generating a mist as claimed in any preceding claim, wherein the working fluid outlet is located adjacent the throat portion of the first transport fluid passage.
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9. An apparatus for generating a mist as claimed in claim 8, wherein the working fluid outlet is substantially perpendicular to the longitudinal axis of the first transport fluid passage.
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10. An apparatus for generating a mist as claimed in any preceding claim, wherein the first transport fluid passage has a protrusion which protrudes towards the longitudinal axis of the first transport fluid passage,

the protrusion being located intermediate of the throat portion and outlet of the first transport fluid passage.

11. A method of generating a mist, the method comprising the steps of:
- 5 supplying a first portion of a transport fluid to a first transport fluid passage having a first transport fluid inlet, a first transport fluid outlet and a throat portion intermediate the first transport fluid inlet and the first transport fluid outlet, the throat portion having a cross sectional area which is less than that of either the first transport fluid inlet or the first transport
- 10 fluid outlet;
- supplying a working fluid to at least one working fluid passage located radially outwardly of the first transport fluid passage and having a working fluid inlet and a working fluid outlet;
- supplying a second portion of transport fluid through at least one
- 15 second transport fluid passage into the working fluid passage, wherein the second transport fluid passage has an outlet upstream of the working fluid outlet;
- imparting a shear force on the working fluid by way of the second portion of the transport fluid exiting the second transport fluid passage
- 20 outlet, thereby partially atomising the working fluid as it passes through the working fluid passage; and
- directing the partially atomised working fluid and the first portion of transport fluid to an outlet nozzle in fluid communication with the respective first transport fluid and working fluid outlets, wherein the
- 25 respective outlets are arranged such that the first portion of transport fluid flow imparts a further shear force on the partially atomised working fluid to atomise the working fluid still further.

12. A method of generating a mist as claimed in claim 11, wherein the second portion of the transport fluid is directed to the second transport fluid passage from the first transport fluid passage.

5 13. A method of generating a mist as claimed in claim 11 or claim 12, wherein the step of supplying the second portion of the transport fluid through the at least one second transport fluid passage includes directing transport fluid in the first transport passage to an inlet of the second transport fluid passage located upstream of the throat portion of the first
10 transport fluid passage.

14. A method of generating a mist as claimed in claim 11, wherein the supply of the first portion of transport fluid to the first transport fluid passage is from a first source and the supply of the second portion of
15 transport fluid to the second transport fluid passage is from a second separate transport fluid source.

15. A method of generating a mist as claimed in any of claims 11 to 14, wherein the method comprises the further step of creating a stationary
20 aerodynamic shockwave in the first transport fluid passage.

16. A method of generating a mist as claimed in claim 15, wherein the step of creating the stationary aerodynamic shockwave includes the step of passing the transport fluid over a protrusion or a recess in the first
25 transport fluid passage.

17. A method of generating a mist as claimed in claim 15 or claim 16, wherein the method comprises the further step of passing the atomised working fluid through the stationary aerodynamic shockwave to atomise
30 the working fluid further still.