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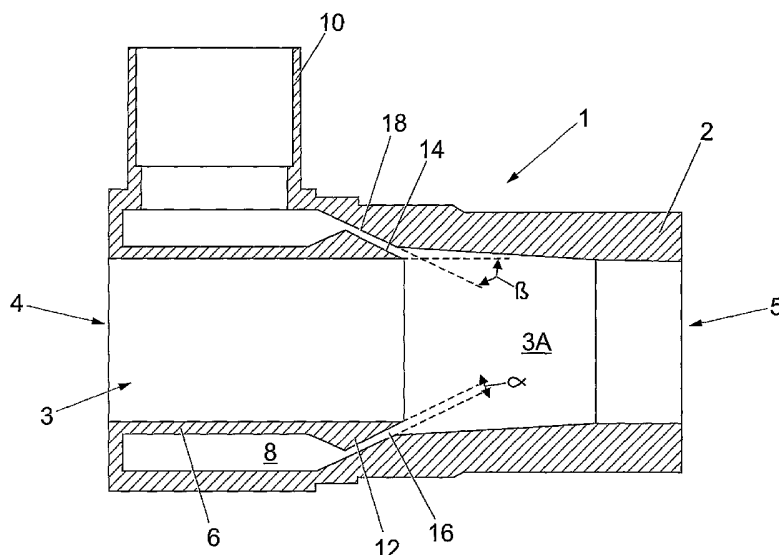
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(54) Title: IMPROVEMENTS IN OR RELATING TO A METHOD AND APPARATUS FOR GENERATING A MIST



(57) Abstract: The present invention relates to apparatus and method for generating a mist comprising a conduit having a mixing chamber and an exit; a working fluid inlet in fluid communication with said conduit; a transport nozzle in fluid communication with the said conduit, the transport nozzle adapted to introduce a transport fluid into the mixing chamber; the transport nozzle having an angular orientation and internal geometry such that in use the transport fluid interacts with the working fluid introduced into the mixing chamber through the working fluid inlet to atomise and form a dispersed vapour/droplet flow regime, which is discharged as a mist comprising working fluid droplets, a substantial portion of the droplets having a size less than 20µm.

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1     **Improvements in or Relating to a Method and**  
2     **Apparatus for Generating a Mist**

3

4     The present invention relates to improvements in or  
5     relating to a method and apparatus for generating a  
6     mist.

7

8     It is well known in the art that there are three  
9     major contributing factors required to maintain  
10    combustion. These are known as the fire triangle,  
11    i.e. fuel, heat and oxygen. Conventional fire  
12    extinguishing and suppression systems aim to remove  
13    or at least minimise at least one of these major  
14    factors. Typically fire suppression systems use  
15    inter alia water, CO<sub>2</sub>, Halon, dry powder or foam.  
16    Water systems act by removing the heat from the  
17    fire, whilst CO<sub>2</sub> systems work by displacing oxygen.

18

19    Another aspect of combustion is known as the flame  
20    chain reactions. The reaction relies on free  
21    radicals that are created in the combustion process  
22    and are essential for its continuation. Halon

1 operates by attaching itself to the free radicals  
2 and thus preventing further combustion by  
3 interrupting the flame chain reaction.

4  
5 The major disadvantage of water systems is that a  
6 large amount of water is usually required to  
7 extinguish the fire. This presents a first problem  
8 of being able to store a sufficient volume of water  
9 or quickly gain access to an adequate supply. In  
10 addition, such systems can also lead to damage by  
11 the water itself, either in the immediate region of  
12 the fire, or even from water seepage to adjoining  
13 rooms. CO<sub>2</sub> and Halon systems have the disadvantage  
14 that they cannot be used in environments where  
15 people are present as it creates an atmosphere that  
16 becomes difficult or even impossible for people to  
17 breathe in. Halon has the further disadvantage of  
18 being toxic and damaging to the environment. For  
19 these reasons the manufacture of Halon is being  
20 banned in most countries.

21  
22 To overcome the above disadvantages a number of  
23 alternative systems utilising liquid mist have  
24 emerged. The majority of these utilise water as the  
25 suppression media, but present it to the fire in the  
26 form of a water mist. A water mist system overcomes  
27 the above disadvantages of conventional systems by  
28 using the water mist to reduce the heat of the  
29 vapour around the fire, displace the oxygen and also  
30 disrupt the flame chain reaction. Such systems use  
31 a relatively small amount of water and are generally

1 intended for class A and B fires, and even  
2 electrical fires.

3

4 Current water mist systems utilise a variety of  
5 methods for generating the water droplets, using a  
6 range of pressures. A major disadvantage of many of  
7 these systems is that they require a relatively high  
8 pressure to force the water through injection  
9 nozzles and/or use relatively small nozzle orifices  
10 to form the water mist. Typically these pressures  
11 are 20bar or greater. As such, many systems utilise  
12 a gas-pressurised tank to provide the pressurised  
13 water, thus limiting the run time of the system.  
14 Such systems are usually employed in closed areas of  
15 known volume such as engine rooms, pump rooms, and  
16 computer rooms. However, due to their finite  
17 storage capacity, such systems have the limitation  
18 of a short run time. Under some circumstances, such  
19 as a particularly fierce fire, or if the room is no  
20 longer sealed, the system may empty before the fire  
21 is extinguished. Another major disadvantage of these  
22 systems is that the water mist from these nozzles  
23 does not have a particularly long reach, and as such  
24 the nozzles are usually fixed in place around the  
25 room to ensure adequate coverage.

26

27 Conventional water mist systems use a high pressure  
28 nozzle to create the water droplet mist. Due to the  
29 droplet formation mechanism of such a system, and  
30 the high tendency for droplet coalescence, an  
31 additional limitation of this form of mist  
32 generation is that it creates a mist with a wide

1 range of water droplet sizes. It is known that  
2 water droplets of approximately 40-50µm in size  
3 provide the optimum compromise for fire suppression  
4 for a number of fire scenarios. For example, a  
5 study by the US Naval Research Laboratories found  
6 that a water mist with droplets less than 42µm in  
7 size was more effective at extinguishing a test fire  
8 than Halon 1301. A water mist systems comprised of  
9 droplets in the approximate size range of 40-50µm  
10 provides an optimum compromise of having the  
11 greatest surface area for a given volume, whilst  
12 also providing sufficient mass to project a  
13 sufficient distance and also penetrate into the heat  
14 of the fire. Conventional water mist systems  
15 comprised of droplets with a lower droplet size will  
16 have insufficient mass, and hence momentum, to  
17 project a sufficient distance and also penetrate  
18 into the heat of a fire.

19  
20 The majority of conventional water mist systems only  
21 manage to achieve a low percentage of the water  
22 droplets in this key size range.

23  
24 An additional disadvantage of the conventional water  
25 mist systems, generating a water mist with such a  
26 wide range of droplet sizes, is that the majority of  
27 fire suppression requires line-of-sight operation.  
28 Although the smaller droplets will tend to behave as  
29 a gas the larger droplets in the flow will  
30 themselves impact with these smaller droplets so  
31 reducing their effectiveness. A mist which behaves  
32 more akin to a gas cloud has the advantages of

1 reaching non line-of-sight areas, so eliminating all  
2 hot spots and possible re-ignition zones. A further  
3 advantage of such a gas cloud behaviour is that the  
4 water droplets have more of a tendency to remain  
5 airborne, thereby cooling the gases and combustion  
6 products of the fire, rather than impacting the  
7 surfaces of the room. This improves the rate of  
8 cooling of the fire and also reduces damage to items  
9 in the vicinity of the fire.

10

11 A water mist comprised of droplets with a droplet  
12 size less than 40µm will improve the rate of cooling  
13 the fire and also reduce damage to items in the  
14 vicinity of the fire. However, such droplets from  
15 conventional systems will have insufficient mass,  
16 and hence momentum, to project a sufficient distance  
17 and also penetrate into the heat of a fire.

18

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

22 a conduit having a mixing chamber and an exit;

23 a working fluid inlet in fluid communication  
24 with said conduit;

25 a transport nozzle in fluid communication with  
26 the said conduit, the transport nozzle adapted to  
27 introduce a transport fluid into the mixing chamber;  
28 the transport nozzle having an angular orientation  
29 and internal geometry such that in use the transport  
30 fluid interacts with the working fluid introduced  
31 into the mixing chamber through the working fluid  
32 inlet to atomise and form a dispersed vapour/droplet

1 flow regime, which is discharged as a mist  
2 comprising working fluid droplets, a substantial  
3 portion of the droplets having a size less than  
4 20 $\mu$ m.

5  
6 Preferably the working fluid droplets have a  
7 substantially uniform droplet distribution having  
8 droplets with a size less than 20 $\mu$ m.

9  
10 Typically at least 60% of the droplets by volume  
11 have a size within 30% of the median size, although  
12 the invention is not limited to this. In a  
13 particularly uniform mist the proportion may be 70%  
14 or 80% or more of the droplets by volume having a  
15 size within 30%, 25%, 20% or less of the median  
16 size.

17  
18 Preferably the substantial portion of the droplets  
19 has a cumulative distribution greater than 90%.

20  
21 Optionally, a substantial portion of the droplets  
22 have a droplet size less than 10 $\mu$ m.

23  
24 Preferably the transport nozzle substantially  
25 circumscribes the conduit.

26  
27 Preferably the mixing chamber includes a converging  
28 portion.

29  
30 Preferably the mixing chamber includes a diverging  
31 portion.

32

1 Preferably the internal geometry of the transport  
2 nozzle has an area ratio, namely exit area to throat  
3 area, in the range 1.75 to 15, having an included  $\alpha$ -  
4 angle substantially equal to or less than 6 degrees  
5 for supersonic flow, and substantially equal to or  
6 less than 12 degrees for sub-sonic flow.

7

8 Preferably the transport nozzle is oriented at an  
9 angle  $\beta$  of between 0 to 30 degrees.

10

11 Preferably the transport nozzle is shaped such that  
12 transport fluid introduced into the mixing chamber  
13 through the transport nozzle has a divergent or  
14 convergent flow pattern.

15

16 Preferably the transport nozzle has inner and outer  
17 surfaces each being substantially frustoconical in  
18 shape.

19

20 Preferably the apparatus further includes a working  
21 nozzle in fluid communication with the conduit for  
22 the introduction of working fluid into the mixing  
23 chamber.

24

25 Preferably the working nozzle is positioned nearer  
26 to the exit than the transport nozzle.

27

28 Preferably the working nozzle is shaped such that  
29 working fluid introduced into the mixing chamber  
30 through the working nozzle has a convergent or  
31 divergent flow pattern.

32

1 Preferably the working nozzle has inner and outer  
2 surfaces each being substantially frustoconical in  
3 shape.

4

5 Preferably the apparatus further includes a second  
6 transport nozzle being adapted to introduce further  
7 transport fluid or a second transport fluid into the  
8 mixing chamber.

9

10 Preferably the second transport nozzle is positioned  
11 nearer to the exit than the transport nozzle.

12

13 Preferably the second transport nozzle is positioned  
14 nearer to the exit than the working nozzle, such  
15 that the working nozzle is located intermediate the  
16 two transport nozzles.

17

18 Preferably the conduit includes a passage.

19

20 Preferably the inner wall of the passage is adapted  
21 with a contoured portion to induce turbulence of the  
22 working fluid upstream of the transport nozzle.

23

24 Preferably the mixing chamber includes an inlet for  
25 the introduction of an inlet fluid.

26

27 Preferably the mixing chamber is closed upstream of  
28 the transport nozzle.

29

30 Preferably the apparatus further includes a  
31 supplementary nozzle arranged inside the transport  
32 nozzle and adapted to introduce further transport

1 fluid or a second transport fluid into the mixing  
2 chamber.

3

4 Preferably the supplementary nozzle is arranged  
5 axially in the mixing chamber.

6

7 Preferably the supplementary nozzle extends forward  
8 of the transport nozzle.

9

10 Preferably the supplementary nozzle is shaped with a  
11 convergent-divergent profile to provide supersonic  
12 flow of the transport fluid which flows  
13 therethrough.

14

15 Preferably the apparatus further includes control  
16 means adapted to control one or more of droplet  
17 size, droplet distribution, spray cone angle and  
18 projection distance.

19

20 Preferably the apparatus further includes control  
21 means to control one or more of the flow rate,  
22 pressure, velocity, quality, and temperature of the  
23 inlet and/or working and/or transport fluids.

24

25 Preferably the control means includes means to  
26 control the angular orientation and internal  
27 geometry of the working and/or transport and/or  
28 supplementary nozzles.

29

30 Preferably the control means includes means to  
31 control the internal geometry of at least part of

1 the mixing chamber or exit to vary it between  
2 convergent and divergent.

3

4 Preferably the exit of the apparatus is provided  
5 with a cowl to control the mist.

6

7 Preferably the cowl comprises a plurality of  
8 separate sections arranged radially, each section  
9 adapted to control and re-direct a portion of the  
10 discharge of mist emerging from the exit.

11

12 Preferably the apparatus is located within a further  
13 cowl.

14

15 Preferably at least one of the transport,  
16 supplementary or working nozzles is adapted with a  
17 turbulator to enhance turbulence.

18

19 According to a second aspect of the present  
20 invention there is provided a method of generating a  
21 mist comprising the steps of:

22 providing apparatus for generating a mist  
23 comprising a transport nozzle and a conduit, the  
24 conduit having a mixing chamber and an exit;

25 introducing a stream of transport fluid into  
26 the mixing chamber through the transport nozzle;

27 introducing a working fluid into the mixing  
28 chamber;

29 atomising the working fluid by interaction of  
30 the transport fluid with the working fluid to form a  
31 dispersed vapour/droplet flow regime; and

1           discharging the dispersed vapour/droplet flow  
2 regime through the exit as a mist comprising working  
3 fluid droplets, a substantial portion of the  
4 droplets having a size less than 20 $\mu$ m.

5  
6 Preferably the apparatus is an apparatus according  
7 to the first aspect of the present invention.

8  
9 Preferably the stream of transport fluid introduced  
10 into the mixing chamber is annular.

11  
12 Preferably the working fluid is introduced into the  
13 mixing chamber via an inlet of the mixing chamber of  
14 the apparatus.

15  
16 Preferably the working fluid is introduced into the  
17 mixing chamber via a working nozzle in fluid  
18 communication with the conduit of the apparatus.

19  
20 Preferably an inlet fluid is introduced into the  
21 mixing chamber via an inlet of the mixing chamber of  
22 the apparatus.

23  
24 Preferably the method includes the step of  
25 introducing the transport fluid into the mixing  
26 chamber in a continuous or discontinuous or  
27 intermittent or pulsed manner.

28  
29 Preferably the method includes the step of  
30 introducing the transport fluid into the mixing  
31 chamber as a supersonic flow.

32

1 Preferably the method includes the step of  
2 introducing the transport fluid into the mixing  
3 chamber as a sub-sonic flow.

4

5 Preferably the method includes the step of  
6 introducing the working fluid into the mixing  
7 chamber in a continuous or discontinuous or  
8 intermittent or pulsed manner.

9

10 Preferably the mist is controlled by modulating at  
11 least one of the following parameters:

12 the flow rate, pressure, velocity, quality  
13 and/or temperature of the transport fluid;

14 the flow rate, pressure, velocity, quality  
15 and/or temperature of the working fluid;

16 the flow rate, pressure, velocity, quality  
17 and/or temperature of the inlet fluid;

18 the angular orientation of the transport and/or  
19 working and/or supplementary nozzle(s) of the  
20 apparatus;

21 the internal geometry of the transport and/or  
22 working and/or supplementary nozzle(s) of the  
23 apparatus; and

24 the internal geometry, length and/or cross  
25 section of the mixing chamber.

26

27 Preferably the mist is controlled to have a  
28 substantial portion of its droplets having a size  
29 less than 20 $\mu\text{m}$ .

30

1 Preferably the mist is controlled to have a  
2 substantial portion of its droplets having a size  
3 less than 10 $\mu$ m.  
4

5 Preferably the method includes the generation of  
6 condensation shocks and/or momentum transfer to  
7 provide suction within the apparatus.  
8

9 Preferably the method includes inducing turbulence  
10 of the inlet fluid prior to it being introduced into  
11 the mixing chamber.  
12

13 Preferably the method includes inducing turbulence  
14 of the working fluid prior to it being introduced  
15 into the mixing chamber.  
16

17 Preferably the method includes inducing turbulence  
18 of the transport fluid prior to it being introduced  
19 into the mixing chamber.  
20

21 Preferably the transport fluid is steam or an  
22 air/steam mixture.  
23

24 Preferably the working fluid is water or a water-  
25 based liquid.  
26

27 Preferably the mist is used for fire suppression.  
28

29 Preferably the mist is used for decontamination.  
30

31 Preferably the mist is used for gas scrubbing.  
32

1     Embodiments of the present invention will now be  
2     described, by way of example only, with reference to  
3     the accompanying drawings in which:

4

5     Fig. 1 is a cross-sectional elevation view of an  
6     apparatus for generating a mist in accordance with a  
7     first embodiment of the present invention;

8

9     Figs. 2 to 7 show alternative arrangements of a  
10    contoured passage to initiate turbulence;

11

12    Fig. 8 is a cross sectional view of the apparatus of  
13    Fig. 1 located in a casing;

14

15    Fig. 9 is a cross-sectional elevation view of an  
16    alternative embodiment of the apparatus of Fig 1,  
17    including a working nozzle;

18

19    Figs. 10 to 12 are schematics showing an over  
20    expanded transport nozzle, an under expanded  
21    transport nozzle, and a largely over expanded  
22    transport nozzle, respectively;

23

24    Fig. 13 is a schematic showing the interaction of a  
25    transport and working fluid as they issue from a  
26    transport and working nozzle;

27

28    Fig. 14 is a cross-sectional elevation view of an  
29    alternative embodiment of the apparatus of Fig. 9  
30    having a diverging mixing chamber;

31

1 Fig. 15 is a cross-sectional elevation view of an  
2 alternative embodiment of the apparatus of Fig. 14  
3 having an additional transport nozzle;

4

5 Fig. 16 is a cross-sectional elevation view of an  
6 apparatus for generating a mist in accordance with a  
7 further embodiment of the present invention;

8

9 Fig. 17 is a cross-sectional elevation view of an  
10 apparatus for generating a mist in accordance with  
11 yet a further embodiment of the present invention;

12

13 Fig. 18 is a cross-sectional elevation view of an  
14 alternative embodiment of the apparatus of Fig. 17  
15 having an additional transport nozzle;

16

17 Fig. 19 is a cross-sectional elevation view of an  
18 apparatus for generating a mist in accordance with a  
19 further embodiment of the present invention;

20

21 Fig. 20 is a cross-sectional elevation view of an  
22 alternative embodiment of the apparatus of Fig. 19  
23 having an additional transport nozzle;

24

25 Fig. 21 is a cross-sectional elevation view of an  
26 apparatus for generating a mist in accordance with a  
27 further embodiment of the present invention;

28

29 Fig. 22 is a cross-sectional elevation view of an  
30 alternative embodiment of the apparatus of Fig. 21  
31 having a modification; and

32

1 Fig. 23 is a graph showing performance data of an  
2 embodiment of the present invention.

3

4 Where appropriate, like reference numerals have been  
5 substantially used for like parts throughout the  
6 specification.

7

8 Referring to Fig. 1 there is shown an apparatus for  
9 generating a mist, a mist generator 1, comprising a  
10 conduit or housing 2 defining a passage 3 providing  
11 an inlet 4 for the introduction of a working fluid  
12 to be atomised, an outlet or exit 5 for the  
13 emergence of a mist plume, and a mixing chamber 3A,  
14 the passage 3 being of substantially constant  
15 circular cross section.

16

17 The passage 3 may be of any convenient cross-  
18 sectional shape suitable for the particular  
19 application of the mist generator 1. The passage 3  
20 shape may be circular, rectilinear or elliptical, or  
21 any intermediate shape, for example curvilinear.

22

23 The mixing chamber 3A is of constant cross-sectional  
24 area but the cross-sectional area may vary along the  
25 mixing chamber's length with differing degrees of  
26 reduction or expansion, i.e. the mixing chamber may  
27 taper at different converging-diverging angles at  
28 different points along its length. The mixing  
29 chamber may taper from the location of the transport  
30 nozzle 16 and the taper ratio may be selected such  
31 that the multi-phase flow velocity and trajectory is  
32 maintained at its optimum or desired position.

1  
2 The mixing chamber 3A is of variable length in order  
3 to provide a control on the mist emerging from the  
4 mist generator 1, i.e. droplet size, droplet  
5 density/distribution, projection range and spray  
6 cone angle. The length of the mixing chamber is  
7 thus chosen to provide the optimum performance  
8 regarding momentum transfer and to enhance  
9 turbulence. In some embodiments the length may be  
10 adjustable in situ rather than pre-designed in order  
11 to provide a measure of versatility.

12  
13 The mixing chamber geometry is determined by the  
14 desired and projected output performance of the mist  
15 and to match the designed steam conditions and  
16 nozzle geometry. In this respect it will be  
17 appreciated that there is a combinatory effect as  
18 between the various geometric features and their  
19 effect on performance, namely droplet size, droplet  
20 density, mist spray cone angle and projected  
21 distance.

22  
23 The inlet 4 is formed at a front end of a protrusion  
24 6 extending into the housing 2 and defining  
25 exteriorly thereof a chamber or plenum 8 for the  
26 introduction of a transport fluid into the mixing  
27 chamber 3A, the plenum 8 being provided with a  
28 transport fluid feed port 10. The protrusion 6  
29 defines internally thereof part of the passage 3.

30  
31 The transport fluid is steam, but may be any  
32 compressible fluid, such as a gas or vapour, or may

1 be a mixture of compressible fluids. It is  
2 envisaged that to allow a quick start to the mist  
3 generator 1, the transport fluid can initially be  
4 air. Meanwhile, a rapid steam generator or other  
5 means can be used to generate steam. Once the steam  
6 is formed, the air supply can be switched to the  
7 steam supply. It is also envisaged that air or  
8 another compressible fluid and/or flowable fluid can  
9 be used to regulate the temperature of the transport  
10 fluid, which in turn can be used to control the  
11 characteristics of the plume, i.e. the droplet size,  
12 droplet distribution, spray cone angle and  
13 projection of the plume.

14

15 A distal end 12 of the protrusion 6 remote from the  
16 inlet 4 is tapered on its relatively outer surface  
17 14 and defines an annular transport nozzle 16  
18 between it and a correspondingly tapered part 18 of  
19 the inner wall of the housing 2, the nozzle 16 being  
20 in fluid communication with the plenum 8.

21

22 The transport nozzle 16 is so shaped (with a  
23 convergent-divergent portion) as in use to give  
24 supersonic flow of the transport fluid into the  
25 mixing chamber 3A. For a given steam condition,  
26 i.e. dryness (quality), pressure, velocity and  
27 temperature, the transport nozzle 16 is preferably  
28 configured to provide the highest velocity steam  
29 jet, the lowest pressure drop and the highest  
30 enthalpy between the plenum and nozzle exit.

31 However, it is envisaged that the flow of transport  
32 fluid into the mixing chamber may alternatively be

1 sub-sonic in some applications for application or  
2 process requirements, or transport fluid and/or  
3 working fluid property requirements. For instance,  
4 the jet issuing from a sub-sonic flow will be easier  
5 to divert compared with a supersonic jet.  
6 Accordingly, a transport nozzle could be adapted  
7 with deflectors to give a wider cone angle than  
8 supersonic flow conditions. However, whilst sub-  
9 sonic flow may provide a wider spray cone angle,  
10 there is a trade-off with an increase in the mist's  
11 droplet size; but in some applications this may be  
12 acceptable.

13

14 Thus, the transport nozzle 16 corresponds with the  
15 shape of the passage 3, for example, a circular  
16 passage would advantageously be provided with an  
17 annular transport nozzle circumscribing the said  
18 passage.

19

20 It is anticipated that the transport nozzle 16 may  
21 be a single point nozzle which is located at some  
22 point around the circumference of the passage to  
23 introduce transport fluid into the mixing chamber.  
24 However, an annular configuration will be more  
25 effective compared with a single point nozzle.

26

27 The term "annular" as used herein is deemed to  
28 embrace any configuration of nozzle or nozzles that  
29 circumscribe the passage 3 of the mist generator 1,  
30 and encompasses circular, irregular, polygonal,  
31 elliptical and rectilinear shapes of nozzle.

32

1 In the case of a rectilinear passage, which may have  
2 a large width to height ratio, transport nozzles  
3 would be provided at least on each transverse wall,  
4 but not necessarily on the sidewalls, although the  
5 invention optionally contemplates a full  
6 circumscription of the passage by the nozzles  
7 irrespective of shape. For example the mist  
8 generator 1, could be made to fit a standard door  
9 letterbox to allow fire fighters to easily treat a  
10 house fire without the need to enter the building.  
11 Size scaling is important in terms of being able to  
12 readily accommodate differing designed capacities in  
13 contrast to conventional equipment.

14  
15 The transport nozzle 16 has an area ratio, defined  
16 as exit area to throat area, in the range 1.75 to 15  
17 with an included angle ( $\alpha$ ) substantially equal to or  
18 less than 6 degrees for supersonic flow, and  
19 substantially equal to or less than 12 degrees for  
20 sub-sonic flow; although the included angle( $\alpha$ ) may  
21 be greater. The angular orientation of the  
22 transport nozzle 16 is  $\beta = 0$  to 30 degrees relative  
23 to the boundary flow of the fluid within the conduit  
24 at the nozzle's exit. However, the angle  $\beta$  may be  
25 greater.

26  
27 The transport nozzle 16 may, depending on the  
28 application of the mist generator 1, have an  
29 irregular cross section. For example, there may be  
30 an outer circular nozzle having an inner ellipsoid  
31 or elliptical nozzle which both can be configured to  
32 provide particular flow patterns, such as swirl, in

1 the mixing chamber to increase the intensity of the  
2 shearing effect and turbulence.

3

4 In operation the inlet 4 is connected to a source of  
5 working fluid to be atomised, which is introduced  
6 into the inlet 4 and passage 3. The feed port 10 is  
7 connected to a source of transport fluid.

8

9 For fire fighting applications, typically the  
10 working fluid is water, but may be any flowable  
11 fluid or mixture of flowable fluids requiring to be  
12 dispersed into a mist, e.g. any non-flammable liquid  
13 or flowable fluid (inert gas) which absorbs heat  
14 when it vaporises may be used instead of the water.

15

16 The transport nozzle 16 is conveniently angled  
17 towards the working fluid in the mixing chamber to  
18 occasion penetration of the working fluid. The  
19 angular orientation of the transport nozzle 16 is  
20 selected for optimum performance to enhance  
21 turbulence which is dependent inter alia on the  
22 nozzle orientation and the internal geometry of the  
23 mixing chamber, to achieve a desired plume mist  
24 exiting the exit 5. Moreover, the creation of  
25 turbulence, governed inter alia by the angular  
26 orientation of the transport nozzle 16, is important  
27 to achieve optimum performance by dispersal of the  
28 working fluid in order to increase acceleration by  
29 momentum transfer and mass transfer.

30

31 Simply put, the more turbulence there is generated,  
32 the smaller the droplet size achievable.

1

2 The transport fluid, steam, is introduced into the  
3 feed port 10, where the steam flows into the plenum  
4 8, and out through the transport nozzle 16 as a high  
5 velocity steam jet.

6

7 The high velocity steam jet issuing from the  
8 transport nozzle 16 impacts with the water with high  
9 shear forces, thus atomising the water and breaking  
10 it into fine droplets and producing a well mixed  
11 two-phase condition constituted by the liquid phase  
12 of the water, and the steam. In this instance, the  
13 energy transfer mechanism of momentum and mass  
14 transfer occasion's induction of the water through  
15 the mixing chamber 3A and out of the exit 5. Mass  
16 transfer will generally only occur for hot transport  
17 fluids, such as steam.

18

19 In simple terms, the present invention uses the  
20 transport fluid to slice up the working fluid. As  
21 already touched on, the more turbulence you have,  
22 the smaller the droplets formed.

23

24 The present invention has a primary break up  
25 mechanism and a secondary break up mechanism to  
26 atomise the working fluid. The primary mechanism is  
27 the high shear between the steam and the water,  
28 which is a function of the high relative velocities  
29 between the two fluids, resulting in the formation  
30 of small waves on the boundary surface of the water  
31 surface, ultimately forming ligaments which are  
32 stripped off.

1  
2 The secondary break up mechanism involves two  
3 aspects. The first is further shear break up, which  
4 is a function of any remaining slip velocities  
5 between the water and the steam. However, this  
6 reduces as the water ligaments/droplets are  
7 accelerated up to the velocity of the steam. The  
8 second aspect is turbulent eddy break up of the  
9 water droplets caused by the turbulence of the  
10 steam. The turbulent eddy break up is a function of  
11 transport nozzle exit velocities, local turbulence,  
12 nozzle orientation (this effects the way the mist  
13 interacts with itself), and the surface tension of  
14 the water (which is effected by the temperature).

15  
16 The primary break up mechanism of the working fluid  
17 may be enhanced by creating initial instabilities in  
18 the working fluid flow. Deliberately created  
19 instabilities in the transport fluid/working fluid  
20 interaction layer encourages fluid surface turbulent  
21 dissipation resulting in the working fluid  
22 dispersing into a liquid-ligament region, followed  
23 by a ligament-droplet region where the ligaments and  
24 droplets are still subject to disintegration due to  
25 aerodynamic characteristics.

26  
27 The interaction between the transport fluid and the  
28 working fluid, leading to the atomisation of the  
29 working fluid, is enhanced by flow instability.  
30 Instability enhances the droplet stripping from the  
31 contact surface of the flow of the working fluid. A  
32 turbulent dissipation layer between the transport

1 and working fluids is both fluidically and  
2 mechanically (geometry) encouraged ensuring rapid  
3 fluid dissipation.

4  
5 The internal walls of the flow passage immediately  
6 upstream of the transport nozzle 16 exit may be  
7 contoured to provide different degrees of turbulence  
8 to the working fluid prior to its interaction with  
9 the transport fluid issuing from the or each nozzle.

10  
11 Fig. 2 shows the internal walls of the passage 3  
12 provided with a contoured internal wall in the  
13 region 19 immediately upstream of the exit of the  
14 transport nozzle 16 is provided with a tapering wall  
15 130 to provide a diverging profile leading up to the  
16 exit of the transport nozzle 16. The diverging wall  
17 geometry provides a deceleration of the localised  
18 flow, providing disruption to the boundary layer  
19 flow, in addition to an adverse pressure gradient,  
20 which in turn leads to the generation and  
21 propagation of turbulence in this part of the  
22 working fluid flow.

23  
24 An alternative embodiment is shown in Fig. 3, which  
25 shows the internal wall 19 of the flow passage 3  
26 immediately upstream of the transport nozzle 16  
27 being provided with a diverging wall 130 on the bore  
28 surface leading up to the exit of the transport  
29 nozzle 16, but the taper is preceded with a step  
30 132. In use, the step results in a sudden increase  
31 in the bore diameter prior to the tapered section.  
32 The step 'trips' the flow, leading to eddies and

1     turbulent flow in the working fluid within the  
2     diverging section, immediately prior to its  
3     interaction with the steam issuing from the  
4     transport nozzle 16. These eddies enhance the  
5     initial wave instabilities which lead to ligament  
6     formation and rapid fluid dispersion.

7  
8     The tapered diverging section 130 could be tapered  
9     over a range of angles and may be parallel with the  
10    walls of the bore. It is even envisaged that the  
11    tapered section 130 may be tapered to provide a  
12    converging geometry, with the taper reducing to a  
13    diameter at its intersection with the transport  
14    nozzle 16 which is preferably not less than the bore  
15    diameter.

16  
17    The embodiment shown in Fig. 3 is illustrated with  
18    the initial step 132 angled at 90° to the axis of  
19    the bore 3. As an alternative to this  
20    configuration, the angle of the step 132 may display  
21    a shallower or greater angle suitable to provide a  
22    'trip' to the flow. Again, the diverging section  
23    130 could be tapered at different angles and may  
24    even be parallel to the walls of the bore 3.  
25    Alternatively, the tapered section 130 may be  
26    tapered to provide a converging geometry, with the  
27    taper reducing to a diameter at its intersection  
28    with the transport nozzle 16 which is preferably not  
29    less than the bore diameter.

30  
31    Figs. 4 to 7 illustrate examples of alternative  
32    contoured profiles 134, 136, 138, 140. All of these

1 are intended to create turbulence in the working  
2 fluid flow immediately prior to the interaction with  
3 the transport fluid issuing from the transport  
4 nozzle 16.

5

6 Although Figs. 2 to 7 illustrate several  
7 combinations of grooves and tapering sections, it is  
8 envisaged that any combination of these features, or  
9 any other groove cross-sectional shape may be  
10 employed.

11

12 Similarly, the transport, working and supplementary  
13 nozzles, and the mixing chamber, may be adapted with  
14 such contours to enhance turbulence.

15

16 The length of the mixing chamber 3A can be used as a  
17 parameter to increase turbulence, and hence,  
18 decrease the droplet size, leading to an increased  
19 cooling rate.

20

21 The properties or parameters of the working fluid  
22 and transport fluid, for example, flow rate,  
23 velocity, quality, pressure and temperature, can be  
24 regulated or controlled or manipulated to give the  
25 required intensity of shearing and hence, the  
26 required droplet formation. The properties of the  
27 working and transport fluids being controllable by  
28 either external means, such as a pressure regulation  
29 means, and/or by the angular orientation (exit  
30 angle) and internal geometry of the nozzle 16.

31

1 The quality of the inlet and working fluids refer to  
2 its purity, viscosity, density, and the  
3 presence/absence of contaminants.

4  
5 The mechanism of the present invention primarily  
6 relies on the momentum transfer between the  
7 transport fluid and the working fluid, which  
8 provides for shearing of the working fluid on a  
9 continuous basis by shear dispersion and/or  
10 dissociation, plus provides the driving force to  
11 propel the generated mist out of the exit. However,  
12 when the transport fluid is a hot compressible gas,  
13 for example steam, i.e. the transport fluid is of a  
14 higher temperature than the working fluid, it is  
15 thought that this mechanism is further enhanced with  
16 a degree of mass transfer between the transport  
17 fluid and the working fluid as well. Again, when  
18 the transport fluid is hotter than the working fluid  
19 the heat transfer between the fluids and the  
20 resulting increase in temperature of the working  
21 fluid further aids the dissociation of the liquid  
22 into smaller droplets by reducing the viscosity and  
23 surface tension of the liquid.

24  
25 The intensity of the shearing mechanism, and  
26 therefore the size of the droplets created, and the  
27 propelling force of the mist, is controllable by  
28 manipulating the various parameters prevailing  
29 within the mist generator 1 when operational.  
30 Accordingly the flow rate, pressure, velocity,  
31 temperature and quality, e.g. in the case of steam  
32 the dryness, of the transport fluid, may be

1 regulated to give a required intensity of shearing,  
2 which in turn leads to the mist emerging from the  
3 exit having a substantial uniform droplet  
4 distribution, a substantial portion of which have a  
5 size less than 20 $\mu$ m.

6  
7 Similarly, the flow rate, pressure, velocity,  
8 quality and temperature of the working fluid, which  
9 are either entrained into the mist generator by the  
10 mist generator itself (due to shocks and the  
11 momentum transfer between the transport and working  
12 fluids) or by external means, may be regulated to  
13 give the required intensity of shearing and desired  
14 droplet size.

15  
16 In carrying out the method of the present invention  
17 the creation and intensity of the dispersed droplet  
18 flow is occasioned by the design of the transport  
19 nozzle 16 interacting with the setting of the  
20 desired parametric conditions, for example, in the  
21 case of steam as the transport fluid, the pressure,  
22 the dryness or steam quality, the velocity, the  
23 temperature and the flow rate, to achieve the  
24 required performance of the transport nozzle, i.e.  
25 generation of a mist comprising a substantially  
26 uniform droplet distribution, a substantial portion  
27 of which have a size less than 20 $\mu$ m.

28  
29 The performance of the present invention can be  
30 complimented with the choice of materials from which  
31 it is constructed. Although the chosen materials  
32 have to be suitable for the temperature, steam

1 pressure and working fluid, there are no other  
2 restrictions on choice. For example, high  
3 temperature composites could be used. For example,  
4 high temperature composites, stainless steel, or  
5 aluminium could be used.

6  
7 The nozzles may advantageously have a surface  
8 coating. This will help reduce wear of the nozzles,  
9 and avoid any build up of agglomerates/deposits  
10 therein, amongst other advantages.

11  
12 The transport nozzle 16 may be continuous (annular)  
13 or may be discontinuous in the form of a plurality  
14 of apertures, e.g. segmental, arranged in a  
15 circumscribing pattern that may be circular. In  
16 either case each aperture may be provided with  
17 substantially helical or spiral vanes formed in  
18 order to give in practice a swirl to the flow of the  
19 transport fluid and working fluid respectively.

20  
21 Alternatively swirl may be induced by introducing  
22 the transport/working fluid into the mist generator  
23 in such a manner that the transport/working fluid  
24 flow induces a swirling motion in to and out of the  
25 transport nozzle 16. For example, in the case of an  
26 annular transport nozzle, and with steam as the  
27 transport fluid, the steam may be introduced via a  
28 tangential inlet off-centre of the axial plane,  
29 thereby inducing swirl in the plenum before passing  
30 through the transport nozzle. As a further  
31 alternative the transport nozzle may circumscribe  
32 the passage in the form of a continuous

1 substantially helical or spiral scroll over a length  
2 of the passage, the nozzle aperture being formed in  
3 the wall of the passage.

4

5 A cowl (not shown) may be provided downstream of the  
6 exit 5 from the passage 3 in order to further  
7 control the mist. The cowl may comprise a number of  
8 separate sections arranged in the radial direction,  
9 each section controlling and re-directing a portion  
10 of the mist spray emerging from the exit 5 of the  
11 mist generator 1.

12

13 With reference to Fig. 8, the mist generator 1 is  
14 disposed centrally within a cowl or casing 50. The  
15 casing 50 comprises a diverging inlet portion 52  
16 having an inlet opening 54, a central portion 56 of  
17 constant cross-section, leading to a converging  
18 outlet portion 58, the outlet portion 58 having an  
19 outlet opening 60. Although Fig. 8 illustrates use  
20 of the mist generator 1 of Fig. 1 disposed centrally  
21 within the casing 50, it is envisaged that any of  
22 the embodiments of the present invention may also be  
23 used instead.

24

25 In use the inlet opening 54 and the outlet opening  
26 60 are in fluid communication with a body of the  
27 working fluid either therewithin or connected to a  
28 conduit.

29

30 In operation the working fluid is drawn through the  
31 casing 50 (by shocks and momentum transfer), or is  
32 pumped in by external means, with flow being induced

1 around the housing 2 and also through the passage 3  
2 of the mist generator 1.

3  
4 The convergent portion 58 of the casing 50 provides  
5 a means of enhancing a momentum transfer (suction)  
6 in mixing between the flow exiting the mist  
7 generator 1 at exit 5 and the fluid drawn through  
8 the casing 50. The enhanced suction and mixing of  
9 the mist with the fluid drawn through the casing 50  
10 could be used in such applications as gas cooling,  
11 decontamination and gas scrubbing.

12  
13 As an alternative to this specific configuration  
14 shown in Fig. 8, inlet portion 52 may display a  
15 shallow angle or indeed may be dimensionally  
16 coincident with the bore of the central portion 56.  
17 The outlet portion 58 may be of varied shape which  
18 has different accelerative and mixing performance on  
19 the characteristics of the mist plume.

20  
21 Fig. 9 shows an alternative embodiment to the  
22 previous embodiments, whereby the mist generator 1  
23 includes a working nozzle 34 for the introduction of  
24 the working fluid (water) into the mixing chamber.  
25 In this respect, an inlet fluid, which may be any  
26 flowable fluid, can be introduced into the passage 3  
27 through the inlet 4. For example, the inlet fluid  
28 may be air.

29  
30 However, it is anticipated that the working fluid  
31 may still be introduced into the mixing chamber via  
32 the inlet 4, where a second working fluid may be

1 introduced into the mixing chamber via the working  
2 nozzle.

3

4 The working nozzle 34 is in fluid communication with  
5 a plenum 32 and a working fluid feed port 30. The  
6 working nozzle 34 is located downstream of the  
7 transport nozzle 16 nearer to the exit 5, although  
8 the working nozzle 34 may be located upstream of the  
9 transport nozzle nearer to the inlet 4. The working  
10 nozzle 34 is annular and circumscribes the passage  
11 3.

12

13 The working nozzle 34 corresponds with the shape of  
14 the passage 3 and/or the transport nozzle 16 and  
15 thus, for example, a circular passage would  
16 advantageously be provided with an annular working  
17 nozzle circumscribing said passage.

18

19 However, it is to be appreciated that the working  
20 nozzle 34 need not be annular, or indeed, need not  
21 be a nozzle. The second nozzle 34 need only be an  
22 inlet to allow a working fluid to be introduced into  
23 the mixing chamber 3A.

24

25 In the case of a rectilinear passage, which may have  
26 a large width to height ratio, working nozzles would  
27 be provided at least on each transverse wall, but  
28 not necessarily on the sidewalls, although the  
29 invention optionally contemplates a full  
30 circumscription of the passage by the working  
31 nozzles irrespective of shape.

32

1 The working nozzle 34 may be used for the  
2 introduction of gases or liquids or of other  
3 additives that may, for example, be treatment  
4 substances for the working fluid or may be  
5 particulates in powder or pulverant form to be mixed  
6 with the working fluid. For example, water and an  
7 additive may be introduced together via a working  
8 nozzle (or separately via two working nozzles). The  
9 working fluid and additive are entrained into the  
10 mist generator by the low pressure created within  
11 the unit (mixing chamber). The fluids or additives  
12 may also be pressurised by an external means and  
13 pumped into the mist generator, if required.

14  
15 For fire fighting applications, typically the  
16 working fluid is water, but may be any flowable  
17 fluid or mixture of flowable fluids requiring to be  
18 dispersed into a mist, e.g. any non-flammable liquid  
19 or flowable fluid (inert gas) which absorbs heat  
20 when it vaporises may be used instead of, or in  
21 addition to via a second working nozzle, the water.

22  
23 The working nozzle 34 may be located as close as  
24 possible to the projected surface of the transport  
25 fluid issuing from the transport nozzle 16. In  
26 practice and in this respect a knife edge separation  
27 between the transport fluid stream and the working  
28 fluid stream issuing from their respective nozzles  
29 may be of advantage in order to achieve the  
30 requisite degree of interaction of said fluids. The  
31 angular orientation of the transport nozzle 16 with

1 respect to the stream of the working fluid is of  
2 importance.

3

4 The transport nozzle 16 is conveniently angled  
5 towards the stream of working fluid issuing from the  
6 second nozzle 34 since this occasions penetration of  
7 the working fluid. The angular orientation of both  
8 nozzles is selected for optimum performance to  
9 enhance turbulence, which is dependent inter alia on  
10 the nozzle orientation and the internal geometry of  
11 the mixing chamber, to achieve a desired droplet  
12 formation (i.e. size, distribution, spray cone angle  
13 and projection). Moreover, the creation of  
14 turbulence, governed inter alia by the angular  
15 orientation of the nozzles, is important to achieve  
16 optimum performance by dispersal of the working  
17 fluid in order to increase acceleration by momentum  
18 transfer and mass transfer.

19

20 Simply put, the more turbulence there is generated,  
21 the smaller the droplet size achievable.

22

23 Figs. 10 to 12 show schematics of different  
24 configurations of the transport and working nozzles,  
25 which provide different degrees of turbulence.

26

27 Fig. 10 shows over expanded transport nozzle. The  
28 transport nozzle can be configured to provide a  
29 particular steam pressure gradient across it. One  
30 parameter that can be changed/controlled is the  
31 degree of expansion of the steam through the nozzle.  
32 Different steam exit pressures provide different

1 steam exit velocities and temperatures with a  
2 subsequent effect on the droplet formation of the  
3 mist.

4  
5 With an over expanded nozzle the steam exiting the  
6 transport nozzle is over expanded such that its  
7 local pressure is less than local atmospheric  
8 pressure. For example, typical pressures are 0.7 to  
9 0.8 bar absolute, with a subsequent steam  
10 temperature of approximately 85°C.

11  
12 This results in the formation of very weak shocks B  
13 and a possible weak expansion wave C in the flow.  
14 The advantages of this arrangement is that the steam  
15 velocity is high, therefore there is a very high  
16 primary and secondary break up, which results in  
17 relatively smaller droplets. It can also be quieter  
18 in operation than other nozzle arrangements (as will  
19 be discussed), due to the lack of strong shocks.

20  
21 There is a trade-off though in that there is reduced  
22 suction pressure created within the mist generator  
23 due to the lack of condensation shocks. However,  
24 this feature is only desired to entrain the process  
25 or working fluid through the mist generator rather  
26 than pumping it in.

27  
28 Fig. 11 shows an under expanded transport nozzle.  
29 With under expanded nozzles the exit steam pressure  
30 is higher than local atmospheric pressure, for  
31 example it can be approximately 1.2 bar absolute, at  
32 a temperature of approximately 115°C. This results

1 in local expansion and condensation shocks D. A  
2 higher temperature differential between the steam  
3 and water can exist, therefore local condensation  
4 shocks are generated. This results in a higher  
5 suction pressure being generated through the mist  
6 generator for the entrainment of the working fluid  
7 and inlet fluid.

8  
9 However, there is a trade-off in that an under  
10 expanded nozzle has a lower steam velocity,  
11 resulting in a less efficient primary and secondary  
12 break up, leading to slightly larger droplet sizes.

13  
14 Fig. 12 shows a largely over expanded transport  
15 nozzle. This alternative arrangement has a typical  
16 exit pressure of approximately 0.2 bar absolute.  
17 However, the exit velocity can be very high,  
18 typically approximately 1500m/s (approximately Mach  
19 3). This high velocity results in the generation of  
20 a very strong localised aerodynamic shocks E (normal  
21 shock) at the steam exit. This shock is so strong  
22 that theoretically downstream of the shock the  
23 pressure increases to approximately 1.2bar absolute  
24 and rises to a temperature of approximately 120°C.  
25 This higher temperature may help to reduce the  
26 surface tension of the water, so helping to reduce  
27 the droplet size. This resultant higher temperature  
28 can be used in applications where heat treatment of  
29 the working and/or inlet fluid is required, such as  
30 the treatment of bacteria.

31

1     However, the trade-off with this arrangement is that  
2     the strong shocks reduce the velocity of the steam,  
3     therefore there is a reduced effect on the high  
4     shear droplet break up mechanism. In addition, it  
5     may be noisy.

6  
7     Fig. 13 shows a schematic of the interaction of the  
8     working and transport flows as they issue from their  
9     respective nozzles. Current thinking suggests that  
10    optimum performance is achieved when the length of  
11    the mixing chamber is limited to the point where the  
12    increasing thickness boundary layer A between the  
13    steam and the water touches the inner surface of the  
14    housing 2. Keeping the mixing chamber short like  
15    this also allows air to be entrained at the exit 5  
16    from the outside surface of the mist generator,  
17    where the entrained air increases the mixing and  
18    turbulence intensity, and therefore droplet  
19    formation. In other words, the intensity of the  
20    turbulence allows for the generation of smaller  
21    working fluid droplets, which have a relatively  
22    increased cooling rate compared with larger droplet  
23    sizes.

24  
25    In operation the inlet 4 is connected to a source of  
26    inlet fluid which is introduced into the inlet 4 and  
27    passage 3. The working fluid, water, is introduced  
28    into a feed port 30, where the water flows into the  
29    plenum 32, and out through the transport nozzle 34.  
30    The transport fluid, steam, is introduced into the  
31    feed port 10, where the steam flows into the plenum

1 8, and out through the transport nozzle 16 as a high  
2 velocity steam jet.

3

4 The high velocity steam jet issuing from the  
5 transport nozzle 16 impacts with the water stream  
6 issuing from the nozzle 34 with high shear forces,  
7 thus atomising the water breaking it into fine  
8 droplets and producing a well mixed three-phase  
9 condition constituted by the liquid phase of the  
10 water, the steam and the air. In this instance, the  
11 energy transfer mechanism of momentum and mass  
12 transfer occasion's induction of the water through  
13 the mixing chamber 3A and out of the exit 5. Mass  
14 transfer will generally only occur for hot transport  
15 fluids, such as steam.

16

17 As with the previous embodiment, the atomisation  
18 mechanisms involved are substantially similar and  
19 likewise, the properties or parameters of the inlet,  
20 working and transport fluids can be regulated or  
21 controlled or manipulated to give the required  
22 intensity of shearing and hence, a mist comprising a  
23 substantially uniform droplet distribution, a  
24 substantial portion of which have a size less than  
25 20 $\mu$ m.

26

27 Whilst the nozzles 16, 34 are shown in Fig. 9 as  
28 being directed towards the exit 5, it is also  
29 envisaged that the working nozzle 34 may be  
30 directed/angled towards the inlet 4, which may  
31 result in greater turbulence. Also, the working  
32 nozzle 34 may be provided at any angle up to 180

1 degrees relative to the transport nozzle in order to  
2 produce greater turbulence by virtue of the higher  
3 shear associated with the increasing slip velocities  
4 between the transport and working fluids. For  
5 example, the working nozzle may be provided  
6 perpendicular to the transport nozzle.

7  
8 In some embodiments of the present invention a  
9 series of transport fluid nozzles is provided  
10 lengthwise of the passage 3 and the geometry of the  
11 nozzles may vary from one to the other dependent  
12 upon the effect desired. For example, the angular  
13 orientation may vary one to the other. The nozzles  
14 may have differing geometries to afford different  
15 effects, i.e. different performance characteristics,  
16 with possibly differing parametric transport  
17 conditions. For example some nozzles may be  
18 operated for the purpose of initial mixing of  
19 different liquids and gasses whereas other nozzles  
20 are used simultaneously for additional droplet break  
21 up or flow directionalisation. Each nozzle may have  
22 a mixing chamber section downstream thereof. In the  
23 case where a series of nozzles are provided, the  
24 number of transport nozzles and working fluid  
25 nozzles is optional.

26  
27 Fig. 14 shows an embodiment of the present invention  
28 substantially similar to that shown in Fig. 9 save  
29 that the mist generator 1 is provided with a  
30 diverging mixing chamber section 3A, and the angular  
31 orientation ( $\beta$ ) of the nozzles 16, 34 have been  
32 adjusted and angled to provide the desired

1 interaction between the steam (transport fluid) and  
2 the water (working fluid) occasioning the optimum  
3 energy transfer by momentum and mass transfer to  
4 enhance turbulence.

5  
6 This embodiment operates in substantially the same  
7 way as previous embodiments save that this  
8 embodiment provides a more diffuse or wider spray  
9 cone angle and therefore a wider discharge of mist  
10 coverage. Angled walls 36 of the mixing chamber 3A  
11 may be angled at different divergent and convergent  
12 angles to provide different spray cone angles and  
13 discharge of mist coverage.

14  
15 Referring now to Fig. 15, which shows an embodiment  
16 of the present invention substantially similar to  
17 that illustrated in Fig. 14 save that an additional  
18 transport fluid feed port 40 and plenum 42 are  
19 provided in housing 2, together with a second  
20 transport nozzle 44 formed at a location downstream  
21 of the second nozzle 34 nearer to the exit 5.

22  
23 The second transport nozzle 44 is used to introduce  
24 the transport fluid (steam) into the mixing chamber  
25 3A downstream of the working fluid (water). The  
26 second transport nozzle may be used to introduce a  
27 second transport fluid.

28  
29 In this embodiment the three nozzles 16, 34, 44 are  
30 located coincident with one another thus providing a  
31 co-annular nozzle arrangement.

32

1 This embodiment is provided with a diverging mixing  
2 chamber section 3A and the nozzles 16, 34, 44 are  
3 angled to provide the desired angles of interaction  
4 between the two streams of steam and the water, thus  
5 occasioning the optimum energy transfer by momentum  
6 and mass transfer to enhance turbulence. This  
7 arrangement illustrated provides a more diffuse or  
8 wider spray cone angle and therefore a wider  
9 discharge of mist coverage. The angle of the walls  
10 36 of the mixing chamber 3A may be varied  
11 convergent-divergent to provide different spray cone  
12 angles.

13

14 In operation two high velocity streams of steam exit  
15 their respective nozzles 16, 44, and sandwich the  
16 water stream issuing from the second nozzle 34.  
17 This embodiment both enhances the droplet formation  
18 by providing a double shearing action, and also  
19 provides a fluid separation or cushion between the  
20 water and the walls 36 of the mixing chamber 3A,  
21 thus preventing small water droplets being lost  
22 through coalescence on the angled walls 36 of the  
23 mixing chamber 3A before exiting the mist generator  
24 1 via the exit 5. In alternative embodiments, not  
25 shown, the mixing chamber section 3A of Figs. 15 and  
26 16 may be converging. This will provide a greater  
27 exit velocity for the discharge of mist and  
28 therefore a greater projection range.

29

30 In a further embodiment of the present invention, as  
31 shown in Fig. 16, there is no straight-through  
32 passage 3 as with previous embodiments. Thus there

1 is no requirement for the introduction of the inlet  
2 fluid.

3

4 In this embodiment the apparatus for generating a  
5 mist (mist generator 1) comprises a conduit or  
6 housing 2, providing a mixing chamber 9, a transport  
7 fluid inlet 3, a working fluid inlet 4 and an outlet  
8 or exit 5.

9

10 The transport fluid inlet 3 has an annular chamber  
11 or plenum 8 provided in the housing 2, the inlet 3  
12 also has an annular transport nozzle 16 for the  
13 introduction of a transport fluid into the mixing  
14 chamber 9.

15

16 A protrusion 6 extends into the housing 2 and  
17 defines a plenum 8 for the introduction of the  
18 transport fluid into the mixing chamber 9 via the  
19 transport nozzle 16.

20

21 A distal end 12 of the protrusion 6 is tapered on  
22 its relatively outer surface 14 and defines the  
23 transport nozzle 16 between it and a correspondingly  
24 tapered part 18 of the housing 2.

25

26 The working fluid inlet 30 has a plenum 32 provided  
27 in the housing 2, the working fluid inlet 30 also  
28 has a working nozzle 34 formed at a location  
29 coincident with that of the transport nozzle 16.

30

1 The transport nozzle 16 and working nozzle 34 are  
2 substantially similar to that of previous  
3 embodiments.

4  
5 In operation the working fluid inlet 30 is connected  
6 to a source of working fluid, water. The transport  
7 fluid inlet 3 is connected to a source of transport  
8 fluid, steam. Introduction of the steam into the  
9 inlet 3, through the plenum 8, causes a jet of steam  
10 to issue forth through the transport nozzle 16. The  
11 parametric characteristics or properties of the  
12 steam, for example, pressure, temperature, dryness,  
13 etc., are selected whereby in use the steam issues  
14 from the transport nozzle 16 at supersonic speeds  
15 into a mixing region of the chamber 10, hereinafter  
16 described as the mixing chamber 9. The steam jet  
17 issuing from the transport nozzle 16 impacts the  
18 working fluid issuing from the second nozzle 34 with  
19 high shear forces, thus atomising the water into  
20 droplets and occasioning induction of the resulting  
21 water mist through the mixing chamber 9 towards the  
22 exit 5.

23  
24 The parametric characteristics, i.e. the internal  
25 geometries of the nozzles 16, 34 and their angular  
26 orientation, the cross-section (and length) of the  
27 mixing chamber, and the properties of the working  
28 and transport fluids are modulated/manipulated to  
29 discharge a mist with a substantially uniform  
30 droplet distribution having a substantial portion of  
31 droplets with a size less than 20 $\mu$ m.

32

1 Fig. 17 shows a further embodiment similar to that  
2 illustrated in Fig. 16 save that the protrusion 6  
3 incorporates a supplementary nozzle 22, which is  
4 axial to the longitudinal axis of the housing 2 and  
5 which is in fluid communication with the mixing  
6 chamber 9. An inlet 3a is formed at a front end of  
7 the protrusion 6 (distal from the exit 5) extending  
8 into the housing 2 incorporating interiorly thereof  
9 a plenum 7 for the introduction of the transport  
10 fluid, steam. The plenum 7 is in fluid  
11 communication with the plenum 8 through one or more  
12 channels 11.

13  
14 A distal end 12 of the protrusion 6 remote from the  
15 inlet 3A is tapered on its internal surface 20 and  
16 defines a parallel axis aligned supplementary nozzle  
17 22, the supplementary nozzle 22 being in fluid  
18 communication with the plenum 7.

19  
20 The supplementary nozzle 22 is so shaped as in use  
21 to give supersonic flow of the transport fluid into  
22 the mixing chamber 9. For a given steam condition,  
23 i.e. dryness (quality), pressure and temperature,  
24 the nozzle 22 is preferably configured to provide  
25 the highest velocity steam jet, the lowest pressure  
26 drop and the highest enthalpy between the plenum and  
27 the nozzle exit. However, it is envisaged that the  
28 flow of transport fluid into the mixing chamber may  
29 alternatively be sub-sonic as hereinbefore  
30 described.

31

1 The supplementary nozzle 22 has an area ratio in the  
2 range 1.75 to 15 with an included angle ( $\alpha$ ) less  
3 than 6 degrees for supersonic flow, and 12 degrees  
4 for sub-sonic flow; although ( $\alpha$ ) may be higher.

5  
6 It is to be appreciated that the supplementary  
7 nozzle 22 is angled to provide the desired  
8 interaction between the transport and working fluid  
9 occasioning the optimum energy transfer by momentum  
10 and mass transfer to obtain the required intensity  
11 of shearing suitable for the required droplet size.  
12 The supplementary nozzle 22 as shown in Fig. 17 may  
13 be located off-centre and/or may be tilted.

14  
15 In operation the working fluid inlet 30 is connected  
16 to a source of the working fluid to be dispersed,  
17 water. The transport fluid inlet 3a is connected to  
18 a source of transport fluid, steam. Introduction of  
19 the steam into the inlet 3a, through the plenums 7,  
20 8 causes a jet of steam to issue forth through the  
21 transport nozzle 16 and the supplementary nozzle 22.  
22 The parametric characteristics or properties of the  
23 steam are selected whereby in use the steam issues  
24 from the nozzles at supersonic speeds into the  
25 mixing chamber 9. The steam jet issuing from the  
26 nozzles 16, 22 impact the working fluid issuing from  
27 the working nozzle 34 with high shear forces, thus  
28 atomising the water into droplets and occasioning  
29 induction of the resulting water mist through the  
30 mixing chamber 9 towards the exit 5.

31

1 Alternatively, the supplementary nozzle may be  
2 connected to a source of a second transport fluid.

3  
4 The parametric characteristics, i.e. the internal  
5 geometries of the nozzles 16, 34 and their angular  
6 orientation, the cross-section (and length) of the  
7 mixing chamber, and the properties of the working  
8 and transport fluids are modulated/manipulated to  
9 discharge a mist having substantially uniform  
10 droplet distribution having a substantial portion of  
11 droplets with a size less than 20 $\mu$ m.

12  
13 It is to be appreciated that the supplementary  
14 nozzle 22 will increase the turbulent break up, and  
15 also influence the shape of the emerging mist plume.

16  
17 The supplementary nozzle 22 may be incorporated into  
18 any embodiment of the present invention.

19  
20 Fig. 18 shows an embodiment substantially similar to  
21 that illustrated in Fig. 17 save that an additional  
22 transport fluid inlet 40 and plenum 42 are provided  
23 in the housing 2, together with a second transport  
24 nozzle 44 formed at a location coincident with that  
25 of the working nozzle 34, thus providing a co-  
26 annular nozzle arrangement.

27  
28 The third nozzle 34 is substantially similar to the  
29 transport nozzle 16 save for the angular  
30 orientation.

31

1 The transport nozzles 16, 44, the supplementary  
2 nozzle 22 and the working nozzle 34 are angled to  
3 provide the desired angles of interaction between  
4 the steam and water, and optimum energy transfer by  
5 momentum and mass transfer to enhance turbulence.  
6

7 In operation the high velocity steam jets issuing  
8 from the nozzles 16, 22, 44 impact the water with  
9 high shear forces, thus breaking the water into fine  
10 droplets and producing a well mixed two phase  
11 condition constituted by the liquid phase of the  
12 water, and the steam. This both enhances the  
13 droplet formation by providing a double shearing  
14 action, and also provides a fluid separation or  
15 cushion between the water and the internal walls 36  
16 of the mixing chamber 9. This prevents small water  
17 droplets being lost through coalescence on the  
18 internal walls 36 of the mixing chamber 9 before  
19 exiting the mist generator 1 view the outlet 5.  
20 Additionally the nozzles 16, 22, 44 are angled and  
21 shaped to provide the desired droplet formation. In  
22 this instance, the energy transfer mechanism of  
23 momentum and mass transfer occasion's projection of  
24 the spray mist through the mixing chamber 9 and out  
25 of the exit 5.  
26

27 Fig. 19 shows an embodiment substantially similar to  
28 that illustrated in Fig. 17 save that it is provided  
29 with a diverging mixing chamber 9 and a radial  
30 transport fluid inlet 3 rather than the parallel  
31 axis inlet 3a shown in Fig. 17. However, either  
32 inlet type may be used.

1  
2 The transport nozzle 16, the supplementary nozzle 22  
3 and the working nozzle 34 are angled to provide the  
4 desired angles of interaction between the transport  
5 and the working fluid occasioning the optimum energy  
6 transfer by momentum and mass transfer to enhance  
7 turbulence.

8  
9 The arrangement illustrated provides a more diffuse  
10 or wider spray cone angle and therefore a wider mist  
11 coverage. The angle of the internal walls 36 of the  
12 mixing chamber 9 relative to a longitudinal  
13 centreline of the mist generator 1, and the angles  
14 of the nozzles 16, 22, 34 relative to the walls 36,  
15 may be varied to provide different droplet sizes,  
16 droplet distributions, spray cone angles and  
17 projection ranges. In an alternative embodiment,  
18 not shown, the mixing chamber 9 may be converging.  
19 This will provide a narrow concentrated mist plume,  
20 and may provide a greater axial velocity for the  
21 plume and therefore a greater projection range.

22  
23 Fig. 20 shows a further embodiment of the present  
24 invention substantially similar to the embodiment  
25 illustrated in Fig. 19 save that an additional  
26 transport fluid inlet 40 and plenum 42 are provided  
27 in the housing 2, together with a second transport  
28 nozzle 44 formed at a location coincident with that  
29 of the working nozzle 34, thus providing a co-  
30 annular nozzle arrangement.

31

1 This embodiment is provided with a diverging mixing  
2 chamber section 9 and nozzles 16, 22, 34, 44 are  
3 also angled to provide the desired angles of  
4 interaction between the transport and working fluid,  
5 thus occasioning the optimum energy transfer by  
6 momentum and mass transfer to enhance turbulence.

7  
8 The arrangement illustrated provides a more diffuse  
9 or wider spray cone angle and therefore a wider mist  
10 coverage. The angle of the inner walls 36 of the  
11 mixing chamber 9 relative to the longitudinal  
12 centreline of the mist generator 1, and the angles  
13 of the nozzles 16, 22, 34, 44 relative to the walls  
14 36, may be varied to provide different droplet  
15 sizes, droplet distributions, spray cone angles and  
16 projection ranges. In an alternative embodiment,  
17 not shown, the mixing chamber 9 may be converging.  
18 This will provide a narrow concentrated plume, and  
19 may provide a greater axial velocity for the plume  
20 and therefore a greater projection range.

21  
22 In operation the high velocity streams of steam  
23 exiting their respective nozzles 16, 22, 44,  
24 sandwich the water stream exiting the fluid nozzle  
25 34. This both enhances the droplet formation by  
26 providing a double shearing action, and also  
27 provides a fluid separation or cushion between the  
28 water and the walls 36 of the mixing chamber 9.  
29 This prevents small water droplets being lost  
30 through coalescence on the internal walls of the  
31 mixing chamber 9 before exiting the mist generator  
32 via the exit 5.

1  
2 Referring now to Fig. 21 which shows a further  
3 embodiment of an apparatus for generating a mist  
4 (mist generator 1) comprising a conduit or housing  
5 2, a transport fluid inlet 3a and plenum 7 provided  
6 in the housing 2 for the introduction of the  
7 transport fluid, steam, into a mixing chamber 9.  
8 The mist generator 1 also comprises a protrusion 38  
9 at the end of the plenum 7 which is tapered on its  
10 relatively outer surface 40 and defines an annular  
11 transport nozzle 16 between it and a correspondingly  
12 tapered part 18 of the inner wall of the housing 2,  
13 the nozzle 16 being in fluid communication with the  
14 plenum 7.

15  
16 The mist generator 1 includes a working fluid inlet  
17 30 and plenum 32 provided in the housing 2, together  
18 with a working nozzle 34 formed at a location  
19 coincident with that of the transport nozzle 16.

20  
21 This embodiment is provided with a diverging mixing  
22 chamber section 9 and the transport nozzle 16 and  
23 the working nozzle 34 are also angled to provide the  
24 desired angles of interaction between the transport  
25 and working fluid, thus occasioning the optimum  
26 energy transfer by momentum and mass transfer to  
27 enhance turbulence. The arrangement illustrated  
28 provides a diffuse or wide spray cone angle and  
29 therefore a wider plume coverage. The angle of the  
30 internal walls 36 of the mixing chamber 9 relative  
31 to the longitudinal centreline of the mist generator  
32 1, and the angles of the nozzles 16, 34 relative to

1 the walls 36, may be varied to provide different  
2 droplet sizes, droplet distributions, spray cone  
3 angles and projection ranges. In an alternative  
4 embodiment, not shown, the mixing chamber 9 may be  
5 converging. This provides a narrow concentrated  
6 plume, a greater axial velocity for the plume and  
7 therefore a greater projection range.

8

9 Fig. 22 shows a further embodiment substantially  
10 similar to that illustrated in Fig. 21 save that the  
11 protrusion 38 incorporates a parallel axis aligned  
12 supplementary nozzle 22, the nozzle 22 being in flow  
13 communication with a plenum 7.

14

15 The supplementary nozzle 22 is substantially similar  
16 to previous supplementary nozzles.

17

18 In operation the working fluid inlet 30 is connected  
19 to a source of working fluid, water. The inlet 3a  
20 is connected to a source of transport fluid, steam.  
21 Introduction of the steam into the inlet 3a, through  
22 the plenum 7 causes jets of steam to issue forth  
23 through the transport nozzles 16, 22. The  
24 parametric characteristics or properties of the  
25 steam are selected whereby in use the steam issues  
26 from the nozzles 16, 22 at supersonic speeds into  
27 the mixing chamber 9. The steam jet issuing from  
28 the nozzle 16 impacts the working fluid issuing from  
29 the working nozzle 34 with high shear forces, thus  
30 atomising the water into droplets and occasioning  
31 induction of the resulting water mist through the  
32 mixing chamber 9 towards an exit 5. The angle of

1 the walls 36 of the mixing chamber 9 relative to the  
2 longitudinal centreline of the mist generator 1, and  
3 the angles of the nozzles 16, 22, 34 relative to the  
4 walls 36, may be varied to provide different droplet  
5 sizes, spray cone angles and projection ranges.

6  
7 Fig. 23 is a graph showing the distribution of  
8 droplet diameters achieved [A] by percentage volume  
9 in a test of an apparatus according to the present  
10 invention, along with the associated cumulative  
11 distribution percentage [B]. The measurement was  
12 taken at a distance of 10m from the exit of the  
13 apparatus, and at an angle of 5 degrees off a  
14 longitudinal centre-line of the apparatus. The  
15 total combined water and steam flow rate was  
16 25.6kg/min.

17  
18 The droplet diameters achieved [A] show a  
19 substantial portion of droplets (cumulative  
20 distribution [B] in excess of 95%) with a size less  
21 than 10 $\mu$ m. The droplet diameters achieved [A] also  
22 have a tight uniform distribution between 4 and 6 $\mu$ m.  
23 This is a particular advantage of the present  
24 invention in that a substantially uniform droplet  
25 distribution having a substantial portion of  
26 droplets with a size less than 20 $\mu$ m can be achieved.  
27 Also, such droplets have sufficient momentum to  
28 project a sufficient distance and also penetrate  
29 into the heat of a fire.

30  
31 In tests, the apparatus according to the present  
32 invention was configured to give the following

1 technical data: mist output=25Kg/min, droplet  
2 size= $Dv0.9 < 10\mu\text{m}$ , projection=20m, exit  
3 velocity=12m/s, exit temperature at 2m= an ambient  
4 atmospheric temperature of 15°C, steam  
5 requirements=8kg/min, water/chemical  
6 entrainment=17kg/min, volume flux at 10m= $2.71 \times 10^{-8}$   
7  $\text{m}^3/(\text{m}^2 \text{ s})$ , water surface area=500 $\text{m}^2/\text{s}$ , droplet  
8 production= $6.3 \times 10^{12}$  /sec.  
9

10 It is to be appreciated that any feature or  
11 derivative of the embodiments shown in Figs. 1 to 22  
12 may be adopted or combined with one another to form  
13 other embodiments.  
14

15 It is also to be appreciated that whilst the  
16 supplementary nozzles have been described in fluid  
17 communication with the transport fluid, it is  
18 anticipated that the supplementary nozzles may be  
19 connected to a second transport fluid.  
20

21 It is an advantage of the present invention that the  
22 working nozzle(s) provides an annular flow having an  
23 even distribution of working fluid around the  
24 annulus.  
25

26 With reference to the aforementioned embodiments of  
27 the present invention, the parametric  
28 characteristics or properties of the inlet, working  
29 and transport fluids, for example the flow rate,  
30 pressure, velocity, quality and temperature, can be  
31 regulated to give the required intensity of shearing  
32 and droplet formation. The properties of the inlet,

1 working and transport fluids being controllable by  
2 either external means, such as a pressure regulation  
3 means, or by the gap size (internal geometry)  
4 employed within the nozzles.

5  
6 Although Figs. 17, 18, 21, 22 illustrate the  
7 transport fluid inlet 3a located in a parallel axis  
8 to the longitudinal centreline of the mist generator  
9 1, feeding transport fluid directly into plenum 7,  
10 it is envisaged that the transport fluid may be  
11 introduced through alternative locations, for  
12 example through a radial inlet such as inlet 3 as  
13 illustrated in Fig. 19, which in turn may feed  
14 either or both plenums 7 and 8 directly, or through  
15 an alternative parallel axis location feeding  
16 directly into plenum 8 rather than plenum 7 (not  
17 shown). Additionally the fluid inlet 30 may  
18 alternatively be positioned in a parallel axis  
19 location (not shown), feeding working fluid along  
20 the housing to the plenum 32.

21  
22 In all embodiments of the present invention, the  
23 working nozzles may alternatively form the inlet for  
24 other fluids, or solids in flowable form such as a  
25 powder, to be dispersed for use in mixing or  
26 treatment purposes. For example, a further working  
27 fluid inlet nozzle may be provided to provide  
28 chemical treatment of the working fluid, such as a  
29 fire retardant, if necessary. The placement of the  
30 second working nozzle may be either upstream or  
31 downstream of the transport nozzle or where more  
32 than one transport nozzle is provided, the placement

1 may be both upstream and downstream dependent upon  
2 requirements.

3

4 For using the mist generator as a fire suppressant  
5 in a room or other contained volume, the mist  
6 generator 1 may be either located entirely within  
7 the volume or room containing a fire, or located  
8 such that only the exit 5 protrudes into the volume.  
9 Consequently, the inlet fluid entering via inlet 4  
10 may either be the gasses already within the room,  
11 these may range from cold gasses to hot products of  
12 combustion, or may be a separate fluid supply, for  
13 example air or an inert gas from outside the room.  
14 In the situation where the mist generator 1 is  
15 located entirely within the room, the induced flow  
16 through the passage 3 of the mist generator 1 may  
17 induce smoke and other hot combustion products to be  
18 drawn into the inlet 4 and be intimately mixed with  
19 the other fluids within the mist generator. This  
20 will increase the wetting and effect on these gases  
21 and particles. It is also to be appreciated that  
22 the actual mist will increase the wetting and  
23 cooling effect on the gasses and particles too.

24

25 Generating and introducing a mist containing a large  
26 amount of air into a potentially explosive  
27 environment such as a combustible gas filled room  
28 will result in both the reduction of risk of  
29 ignition from the mist plus the dilution of the gas  
30 to a safe gas/oxygen ratio from the air.

31

1 If a fire in a contained volume has burnt most of  
2 the available oxygen, a water mist may be introduced  
3 but with the flow of air stopped. This helps to  
4 extinguish the remaining fire without the risk of  
5 adding more oxygen. To this end, the flow of the  
6 inlet fluid (air) through the inlet 4 may be  
7 controllable by restricting or even closing the  
8 inlet 4 completely. This could be accomplished by  
9 using a control valve. Alternatively, the  
10 embodiments shown in Figs. 16 to 22 may be used in  
11 this scenario.

12

13 In a modification, an inert gas may be used as the  
14 inlet fluid in place of air, or, with regard to  
15 using the embodiments shown in Figs. 16 to 22, a  
16 further working nozzle may be added to introduce an  
17 inert gas or non-flammable fluid to suppress the  
18 fire.

19

20 Similarly, powders or other particles may be  
21 entrained or introduced into the mist generator,  
22 mixed with and dispersed with another fluid or  
23 fluids. The particles being dispersed with the  
24 other fluid or fluids, or wetted and/or coated or  
25 otherwise treated prior to being projected.

26

27 The mist generator of the present invention has a  
28 number of fundamental advantages over conventional  
29 water mist systems in that the mechanism of droplet  
30 formation and size is controlled by a number of  
31 adjustable parameters, for example, the flow rate,  
32 pressure, velocity, quality and temperature of the

1 inlet, transport and working fluid; the angular  
2 orientation and internal geometry of the transport,  
3 supplementary and working nozzles; the cross-  
4 sectional area and length of the mixing chamber 3A.  
5 This provides active control over the amount of  
6 water used, the droplet size, the droplet  
7 distribution, the spray cone angle and the projected  
8 range (distance) of the mist.

9

10 A key advantage of the present invention is that it  
11 generates a substantially uniform droplet  
12 distribution, a substantial portion of which have a  
13 size less than  $20\mu\text{m}$  that have sufficient momentum,  
14 because of the momentum transfer, to project a  
15 sufficient distance and also penetrate into the heat  
16 of a fire, which is distinct with the prior art  
17 where droplet sizes less than  $40\mu\text{m}$  will have  
18 insufficient momentum to project a sufficient  
19 distance and also penetrate into the heat of a fire.

20

21 A major advantage of the present invention is its  
22 ability to handle relatively more viscous working  
23 fluids and inlet fluids than conventional systems.  
24 The shocks and the momentum transfer that takes  
25 place provide suction causing the mist generator to  
26 act like a pump. Also, the shearing effect and  
27 turbulence of the high velocity steam jet breaks up  
28 the viscous working fluid and mixes it, making it  
29 less viscous.

30

1 The mist generator can be used for either short  
2 burst operation or continuous or pulsed  
3 (intermittent) or discontinuous running.

4

5 As there are no moving parts in the system and the  
6 mist generator is not dependent on small sized and  
7 closely toleranced fluid inlet nozzles, there is  
8 very little maintenance required. It is known that  
9 due to the small orifice size and high water  
10 pressures used by some of the existing water mist  
11 systems, that nozzle wear is a major issue with  
12 these systems.

13

14 In addition, due to the use of relatively large  
15 fluid inlets in the mist generator it is less  
16 sensitive to poor water quality. In cases where the  
17 mist generator is to be used in a marine  
18 environment, even sea water may be used.

19

20 Although the mist generator may use a hot  
21 compressible transport fluid such as steam, this  
22 system is not to be confused with existing steam  
23 flooding systems which produce a very hot  
24 atmosphere. In the current invention, the heat  
25 transfer between the steam and the working fluid  
26 results in a relatively low mist temperature. For  
27 example, the exit temperature within the mist at the  
28 point of exit 5 has been recorded at less than 52°C,  
29 reducing through continued heat transfer between the  
30 steam and water to room temperature within a short  
31 distance. The exit temperature of the mist plume is  
32 controllable by regulation of the steam supply

1 conditions, i.e. flow rate, pressure, velocity,  
2 temperature, etc., and the water flow rate  
3 conditions, i.e. flow rate, pressure, velocity, and  
4 temperature, and the inlet fluid conditions.

5

6 Droplet formation within the mist generator may be  
7 further enhanced with the entrainment of chemicals  
8 such as surfactants. The surfactants can be  
9 entrained directly into the mist generator and  
10 intimately mixed with the working fluid at the point  
11 of droplet formation, thereby minimising the  
12 quantity of surfactant required.

13

14 It is an advantage of the straight-through passage  
15 of the mist generator, and the relatively large  
16 inlet nozzle geometries, that it can accommodate  
17 material that might find its way into the passage.  
18 It is a feature of the present invention that it is  
19 far more tolerant of the water quality used than  
20 conventional systems which depend on small orifices  
21 and closely toleranced nozzles.

22

23 The ability of the mist generator to handle and  
24 process a range of working fluids provides  
25 advantages over many other mist generator. As the  
26 desired droplet size is achieved through high  
27 velocity shear and, in the case of steam as the  
28 transport fluid, mass transfer from a separate  
29 transport fluid, almost any working fluid can be  
30 introduced to the mist generator to be finely  
31 dispersed and projected. The working fluids can  
32 range from low viscosity easily flowable fluids and

1 fluid/solid mixtures to high viscosity fluids and  
2 slurries. Even fluids or slurries containing  
3 relatively large solid particles can be handled.

4  
5 It is this versatility that allows the present  
6 invention to be applied in many different  
7 applications over a wide range of operating  
8 conditions. Furthermore the shape of the mist  
9 generator may be of any convenient form suitable for  
10 the particular application. Thus the mist generator  
11 may be circular, curvilinear or rectilinear, to  
12 facilitate matching of the mist generator to the  
13 specific application or size scaling.

14  
15 The present invention thus affords wide  
16 applicability with improved performance over the  
17 prior art proposals in the field of mist generator.

18  
19 In some embodiments of the present invention a  
20 series of transport nozzles and working nozzles is  
21 provided lengthwise of the passage and the geometry  
22 of the nozzles may vary from one to the other  
23 dependent upon the effect desired. For example, the  
24 angular orientation may vary one to the other. The  
25 nozzles may have differing geometries in order to  
26 afford different effects, i.e. different performance  
27 characteristics, with possibly differing parametric  
28 steam conditions. For example, some nozzles may be  
29 operated for the purpose of initial mixing of  
30 different liquids and gases whereas others are used  
31 simultaneously for additional droplet break-up or  
32 flow directionalisation. Each nozzle may have a

1 mixing chamber section downstream thereof. In the  
2 case where a series of nozzles is provided the  
3 number of operational nozzles is variable.

4

5 The mist generator of the present invention may be  
6 employed in a variety of applications ranging from  
7 fire extinguishing, suppression or control to smoke  
8 or particle wetting.

9

10 Due to the relatively low pressures involved in the  
11 present invention, the mist generator can be easily  
12 relocated and re-directed while in operation. Using  
13 appropriate flexible steam and water supply pipes  
14 the mist generator is easily man portable. The unit  
15 can be considered portable from two perspectives.

16 Firstly the transport nozzle(s) can be moved  
17 anywhere only constrained by the steam and water  
18 pipe lengths. This may have applications for fire  
19 fighting or decontamination when the nozzle can be  
20 man-handled to specific areas for optimum coverage  
21 of the mist. This 'umbilical' approach could be  
22 extended to situations where the nozzle is moved by  
23 a robotic arm or a mechanised system, being operated  
24 remotely. This may have applications in very  
25 hazardous environments.

26

27 Secondly, the whole system could be portable, i.e.  
28 the nozzle, a steam generator, plus a water/chemical  
29 supply is on a movable platform (e.g., self  
30 propelled vehicle). This would have the benefits of  
31 being unrestricted by any umbilical pipe lengths.

1 The whole system could possibly utilise a back-pack  
2 arrangement.

3  
4 The present invention may also be used for mixing,  
5 dispersion or hydration and again the shearing  
6 mechanism provides the mechanism for achieving the  
7 desired result. In this connection the mist  
8 generator may be used for mixing one or more fluids,  
9 one or more fluids and solids in flowable or  
10 particulate form, for example powders. The fluids  
11 may be in liquid or gaseous form. This mechanism  
12 could be used for example in the fighting of forest  
13 fires, where powders and other additives, such as  
14 fire suppressants, can be entrained, mixed and  
15 dispersed with the mist spray.

16  
17 In this area of usage lies another potential  
18 application in terms of foam generation for fire  
19 fighting purposes. The separate fluids, for example  
20 water, a foaming agent, and possibly air, are mixed  
21 within the mist generator using the transport fluid,  
22 for example steam, by virtue of the shearing effect.

23  
24 Additionally, in fire or other high temperature  
25 environments the high density fine droplet mist  
26 generated by the mist generator provides a thermal  
27 barrier for people and fuel. In addition to  
28 reducing heat transfer by convection and conduction  
29 by cooling the air and gasses between the heat  
30 source and the people or fuel, the dense mist also  
31 reduces heat transfer by radiation. This has  
32 particular, but not exclusive, application to fire

1 and smoke suppression in road, rail and air  
2 transport, and may greatly enhance passenger post-  
3 crash survivability.

4  
5 The fine droplet mist generated by the present  
6 invention may be employed for general cooling  
7 applications. The high cooling rate and low water  
8 quantities used provide the mechanism for cooling of  
9 industrial machinery and equipment. For example,  
10 the fine droplet mist has particular application for  
11 direct droplet cooling of gas turbine inlet air.  
12 The fine droplet mist, typically a water mist, is  
13 introduced into the inlet air of the gas turbine and  
14 due to the small droplet size and large evaporative  
15 surface area, the water mist evaporates, cooling  
16 the inlet air. The cooling of the inlet air boosts  
17 the power of the gas turbine when it is operating in  
18 hot environments.

19  
20 Also, the very fine droplet mist produced by the  
21 mist generator may be utilised for cooling and  
22 humidifying area or spaces, either indoors or  
23 outdoors, for the purpose of providing a more  
24 habitable environment for people and animals.

25  
26 The mist generator may be employed either indoors or  
27 outdoors for general watering applications, for  
28 example, the watering of the plants inside a  
29 greenhouse. The water droplet size and distribution  
30 may be controlled to provide the appropriate  
31 watering mechanism, i.e. either root or foliage  
32 wetting, or a combination of both. In addition, the

1 humidity of the greenhouse may also be controlled  
2 with the use of the mist generator.

3

4 The mist generator may be used in an explosive  
5 atmosphere to provide explosion prevention. The  
6 mist cools the atmosphere and dampens any airborne  
7 particulates, thus reducing the risk of explosion.  
8 Additionally, due to the high cooling rate and wide  
9 droplet distribution afforded by the fine droplet  
10 mist the mist generator may be employed for  
11 explosion suppression, particularly in a contained  
12 volume.

13

14 A fire within a contained room will generally  
15 produce hot gasses which rise to the ceiling. There  
16 is therefore a temperature gradient formed with high  
17 temperatures at or near the ceiling and lower  
18 temperatures towards the floor. In addition, the  
19 gasses produced will generally become stratified  
20 within the room at different heights. An advantage  
21 of the present invention is that the turbulence and  
22 projection force of the mist helps to mix the gasses  
23 within the room, mixing the high temperature gasses  
24 with the low temperature gasses, thus reducing the  
25 hot spot temperatures of the room.

26

27 This mixing of the room's gasses, and the turbulent  
28 mist itself, which behaves more akin to a gas cloud,  
29 is able to reach non line-of-sight areas, so  
30 eliminating all hot spots (pockets of hot gasses)  
31 and possible re-ignition zones. A further advantage  
32 of the present invention is that the smaller water

1 droplets have more of a tendency to remain airborne,  
2 thereby cooling the gases and the combustion  
3 products of the fire. This improves the rate of  
4 cooling of the fire and also reduces damage to items  
5 in the vicinity of the fire.

6  
7 The turbulence and projection force of the mist  
8 allows for substantially all of the surfaces in the  
9 room to be cooled, even the non line of sight  
10 surfaces.

11  
12 In addition, the turbulence and projection force of  
13 the mist cause the water droplets to become attached  
14 to hygroscopic nuclei suspended in the gasses,  
15 causing the nuclei to become heavier and fall to the  
16 floor, where they are more manageable; particularly  
17 in decontamination applications. The water droplets  
18 generated by the present invention have more of a  
19 tendency to become attached to the nuclei by virtue  
20 of their smaller size.

21  
22 The mist generator may be used to deliberately  
23 create hygroscopic nuclei within the room for the  
24 purpose outlined above.

25  
26 Due to the particle wetting of the gasses in a  
27 contained volume by the mist generator and the  
28 turbulence created within the apparatus and by the  
29 cooling mist itself, pockets of gas are dispersed,  
30 thereby limiting the chance of explosion.

31

1 The mist generator has a further advantage for use  
2 in potentially explosive atmospheres as it has no  
3 moving parts or electrical wires or circuitry and  
4 therefore has minimum sources of ignition.

5  
6 The present invention has the additional benefit of  
7 wetting or quenching of explosive or toxic  
8 atmospheres utilising either just the steam, or with  
9 additional entrained water and/or chemical  
10 additives. The later configuration could be used for  
11 placing the explosive or toxic substances in  
12 solution for safe disposal.

13  
14 Using a hot compressible transport fluid, such as  
15 steam, may provide an additional advantage of  
16 providing control of harmful bacteria. The shearing  
17 mechanism afforded by the present invention coupled  
18 with the heat input of the steam destroys the  
19 bacteria in the fluid flow, thereby providing for  
20 the sterilisation of the working fluid. The  
21 sterilisation effect could be enhanced further with  
22 the entrainment of chemicals or other additives  
23 which are mixed into the working fluid. This may  
24 have particular advantage in applications such as  
25 fire fighting, where the working fluid, such as  
26 water, is advantageously required to be stored for  
27 some time prior to use. During operation, the mist  
28 generator effectively sterilises the water,  
29 destroying bacterium such as legionella pneumophila,  
30 during the droplet creation phase, prior to the  
31 water mist being projected from the mist generator.

32

1 The fine droplet mist produced by the mist generator  
2 might be advantageously employed where there has  
3 been a leakage or escape of chemical or biological  
4 materials in liquid or gaseous form. The atomised  
5 spray provides a mist which effectively creates a  
6 blanket saturation of the prevailing atmosphere  
7 giving a thorough wetting result. In the case where  
8 chemical or biological materials are involved, the  
9 mist wets the materials and occasions their  
10 precipitation or neutralisation, additional  
11 treatment could be provided by the introduction or  
12 entrainment of chemical or biological additives into  
13 the working fluid. For example disinfectants may be  
14 entrained or introduced into the mist generator, and  
15 introduced into a room to be disinfected in a mist  
16 form. For decontamination applications, such as  
17 animal decontamination or agricultural  
18 decontamination, no premix of the chemicals is  
19 required as the chemicals can be entrained directly  
20 into the unit and mixed simultaneously. This  
21 greatly reduces the time required to start  
22 decontamination and also eliminates the requirement  
23 for a separate mixer and holding tank.

24  
25 The mist generator may be deployed as an extractor  
26 whereby the injection of the transport fluid, for  
27 example steam, effects induction of a gas for  
28 movement from one zone to another. One example of  
29 use in this way is to be found in fire fighting when  
30 smoke extraction at the scene of a fire is required.

31

1 Further the mist generator may be employed to  
2 suppress or dampen down particulates from a gas.  
3 This usage has particular, but not exclusive,  
4 application to smoke and dust suppression from a  
5 fire. Additional chemical additives in fluid and/or  
6 powder form may be entrained and mixed with the flow  
7 for treatment of the gas and/or particulates.

8

9 Further the mist generator for scrubbing particulate  
10 materials from a gas stream, to effect separation of  
11 wanted elements from waste elements. Additional  
12 chemical additives in fluid and/or powder form may  
13 be entrained and mixed with the flow for treatment  
14 of the gas and/or particulates. This usage has  
15 particular, but not exclusive, application to  
16 industrial exhaust scrubbers and dust extraction  
17 systems.

18

19 The use of the mist generator is not limited to the  
20 creation of water droplet mists. The mist generator  
21 may be used in many different applications which  
22 require a fluid to be broken down into a fine  
23 droplet mist. For example, the mist generator may  
24 be used to atomise a fuel, such as fuel oil, for the  
25 purpose of enhancing combustion. In this example,  
26 using steam as the transport fluid and a liquid fuel  
27 as the working fluid produces a finely dispersed  
28 mixture of fine fuel droplets and water droplets.

29 It is well known in the art that such mixtures when  
30 combined with oxygen provides for enhanced  
31 combustion. In this example, the oxygen, possibly  
32 in the form of air, could also be entrained, mixed

1 with and projected with the fuel/steam mist by the  
2 mist generator. Alternatively, a different  
3 transport fluid could be used and water or another  
4 fluid can be entrained and mixed with the fuel  
5 within the mist generator.

6

7 Alternatively, using a combustible fuel and air as  
8 the working fluids, but with a source of ignition at  
9 the exit of the unit, the mist generator may be  
10 employed as a space heater.

11

12 Further, the mist generator may be employed as an  
13 incinerator or process heater. In this example, a  
14 combustible fluid, for example propane, may be used  
15 as the transport fluid, introduced to the mist  
16 generator under pressure. In this example the  
17 working fluid may be an additional fuel or material  
18 which is required to be incinerated. Interaction  
19 between the transport fluid and working fluid  
20 creates a well mixed droplet mist which can be  
21 ignited and burnt in the mixing chamber or a  
22 separate chamber immediately after the exit.

23 Alternatively, the transport fluid can be ignited  
24 prior to exiting the transport nozzles, thereby  
25 presenting a high velocity and high temperature  
26 flame to the working fluid.

27

28 The mist generator affords the ability to create  
29 droplets created of a multi fluid emulsion. The  
30 droplets may comprise a homogeneous mix of different  
31 fluids, or may be formed of a first fluid droplet  
32 coated with an outer layer or layers of a second or

1 more fluids. For example, the mist generator may be  
2 employed to create a fuel/water emulsion droplet  
3 mist for the purpose of further enhancing  
4 combustion. In this example, the water may either  
5 be separately entrained into the mist generator, or  
6 provided by the transport fluid itself, for example  
7 from the steam condensing upon contact with the  
8 working fluid. Additionally, the oxygen required  
9 for combustion, possibly in the form of air, could  
10 also be entrained, mixed with and projected with the  
11 fuel/steam mist by the generator.

12

13 The mist generator may be employed for low pressure  
14 impregnation of porous media. The working fluid or  
15 fluids, or fluid and solids mixtures being dispersed  
16 and projected onto a porous media, so aiding the  
17 impregnation of the working fluid droplets into the  
18 material.

19

20 The mist generator may be employed for snow making  
21 purposes. This usage has particular but not  
22 exclusive application to artificial snow generation  
23 for both indoor and outdoor ski slopes. The fine  
24 water droplet mist is projected into and through the  
25 cold air whereupon the droplets freeze and form a  
26 frozen droplet 'snow'. This cooling mechanism may  
27 be further enhanced with the use of a separate  
28 cooler fitted at the exit of the mist generator to  
29 enhance the cooling of the water mist. The  
30 parametric conditions of the mist generator and the  
31 transport fluid and working fluid properties and  
32 temperatures are selected for the particular

1 environmental conditions in which it is to operate.  
2 Additional fluids or powders may be entrained and  
3 mixed within the mist generator for aiding the  
4 droplet cooling and freezing mechanism. A cooler  
5 transport fluid than steam could be used.

6  
7 The high velocity of the water mist spray may  
8 advantageously be employed for cutting holes in  
9 compacted snow or ice. In this application the  
10 working fluid, which may be water, may  
11 advantageously be preheated before introduction to  
12 the mist generator to provide a higher temperature  
13 droplet mist. The enhanced heat transfer with the  
14 impact surface afforded by the water being in a  
15 droplet form, combined with the high impact velocity  
16 of the droplets provide a melting/cutting through  
17 the compacted snow or ice. The resulting waste  
18 water from this cutting operation is either driven  
19 by the force of the issuing water mist spray back  
20 out through the hole that has been cut, or in the  
21 case of compacted snow may be driven into the  
22 permeable structure of the snow. Alternatively,  
23 some or all of the waste water may be introduced  
24 back into the mist generator, either by entrainment  
25 or by being pumped, to provide or supplement the  
26 working fluid supply. The mist generator may be  
27 moved towards the 'cutting face' of the holes as the  
28 depth of the hole increases. Consequently, the  
29 transport fluid and the water may be supplied to the  
30 mist generator co-axially, to allow the feed supply  
31 pipes to fit within the diameter of the hole  
32 generated. The geometry of the nozzles, the mixing

1 chamber and the outlet of the mist generator, plus  
2 the properties of the transport fluid and working  
3 fluid are selected to produce the required hole size  
4 in the snow or ice, and the cutting rate and water  
5 removal rate.

6  
7 Modifications may be made to the present invention  
8 without departing from the scope of the invention,  
9 for example, the supplementary nozzle, or other  
10 additional nozzles, could be used in the form of  
11 NACA ducts, which are used to bleed high pressure  
12 from a high pressure surface to a low pressure  
13 surface to maintain the boundary layer on the  
14 surfaces and reduce drag.

15  
16 The NACA ducts may be employed on the mist generator  
17 1 from the perspective of using drillings through  
18 the housing 2 to feed a fluid to a wall surface  
19 flow. For example, additional drillings could be  
20 employed to simply feed air or steam through the  
21 drillings to increase the turbulence in the mist  
22 generator and increase the turbulent break up. The  
23 NACA ducts may also be angled in such a way to help  
24 directionalise the mist emerging from the mist  
25 generator. Holes or even an annular nozzle may be  
26 situated on the trailing edge of the mist generator  
27 to help to force the exiting mist to continue to  
28 expand and therefore diffuse the flow (an exiting  
29 high velocity flow will tend to want to converge).

30  
31 NACA ducts could be employed, depending on the  
32 application, by using the low pressure area within

1 the mist generator to draw in gasses from the  
2 outside surface to enhance turbulence. NACA ducts  
3 may have applications in situations where it is  
4 beneficial to draw in the surrounding gasses to be  
5 processed with the mist generator, for example,  
6 drawing in hot gasses in a fire suppression role may  
7 help to cool the gasses and circulate the gasses  
8 within the room.

9  
10 Enhancing turbulence in the mist generator helps to  
11 both increase droplet formation (with smaller  
12 droplets) and also the turbulence of the generated  
13 mist. This has benefits in fire suppression and  
14 decontamination of helping to force the mist to mix  
15 within the mist generator and wet all surfaces  
16 and/or mix with the hot gasses. In addition to the  
17 aforesaid, turbulence may be induced by the use of  
18 guide vanes in either the nozzles or the passage.  
19 Turbulators may be helical in form or of any other  
20 form which induces swirl in the fluid stream.

21  
22 As well as turbulators increasing turbulence, they  
23 will also reduce the risk of coalescence of the  
24 droplets on the turbulator vanes/blades.

25  
26 The turbulators themselves could be of several  
27 forms, for example, surface projections into the  
28 fluid path, such as small projecting vanes or nodes;  
29 surface groves of various profiles and orientations  
30 as shown in Figs 2 to 7; or larger systems which  
31 move or turn the whole flow - these may be angled  
32 blades across the whole bore of the flow, of either

1 a small axial length or of a longer 'Archimedes type  
2 design. In addition, elbows of varying angles  
3 positioned along various planes may be used to induce  
4 swirl in the flow streams before they enter their  
5 respective inlets.

6

7 It is anticipated that the mist generator may  
8 include piezoelectric or ultrasonic actuators that  
9 vibrate the nozzles to enhance droplet break up.

1     **Claims**

2

3     1.   Apparatus for generating a mist comprising:  
4         a conduit having a mixing chamber and an exit;  
5         a working fluid inlet in fluid communication  
6         with said conduit;  
7         a transport nozzle in fluid communication with  
8         the said conduit, the transport nozzle adapted to  
9         introduce a transport fluid into the mixing chamber;  
10        the transport nozzle having an angular orientation  
11        and internal geometry such that in use the transport  
12        fluid interacts with the working fluid introduced  
13        into the mixing chamber through the working fluid  
14        inlet to atomise and form a dispersed vapour/droplet  
15        flow regime, which is discharged as a mist  
16        comprising working fluid droplets, a substantial  
17        portion of the droplets having a size less than  
18        20 $\mu\text{m}$ .

19

20     2.   The apparatus of claim 1, wherein the working  
21        fluid droplets have a substantially uniform droplet  
22        distribution having droplets with a size less than  
23        20 $\mu\text{m}$ .

24

25     3.   The apparatus of claim 1 or 2, wherein the  
26        substantial portion of the droplets has a cumulative  
27        distribution greater than 90%.

28

29     4.   The apparatus of any preceding claim, wherein a  
30        substantial portion of the droplets have a droplet  
31        size less than 10 $\mu\text{m}$

32

1 5. The apparatus of any preceding claim, wherein  
2 the transport nozzle substantially circumscribes the  
3 conduit.

4

5 6. The apparatus of any preceding claim, wherein  
6 the mixing chamber includes a converging portion.

7

8 7. The apparatus of any of claims 1 to 5, wherein  
9 the mixing chamber includes a diverging portion.

10

11 8. The apparatus of any preceding claim, wherein  
12 the internal geometry of the transport nozzle has an  
13 area ratio, namely exit area to throat area, in the  
14 range 1.75 to 15, having an included  $\alpha$ -angle  
15 substantially equal to or less than 6 degrees for  
16 supersonic flow, and substantially equal to or less  
17 than 12 degrees for sub-sonic flow.

18

19 9. The apparatus of any preceding claim, wherein  
20 the transport nozzle is oriented at an angle  $\beta$  of  
21 between 0 to 30 degrees.

22

23 10. The apparatus of any preceding claim, wherein  
24 the transport nozzle is shaped such that transport  
25 fluid introduced into the mixing chamber through the  
26 transport nozzle has a divergent or convergent flow  
27 pattern.

28

29 11. The apparatus of claim 10, wherein the  
30 transport nozzle has inner and outer surfaces each  
31 being substantially frustoconical in shape.

32

1 12. The apparatus of any preceding claim, further  
2 including a working nozzle in fluid communication  
3 with the conduit for the introduction of working  
4 fluid into the mixing chamber.

5

6 13. The apparatus of claim 12, wherein the working  
7 nozzle is positioned nearer to the exit than the  
8 transport nozzle.

9

10 14. The apparatus of claim 12 or 13 , wherein the  
11 working nozzle is shaped such that working fluid  
12 introduced into the mixing chamber through the  
13 working nozzle has a convergent or divergent flow  
14 pattern.

15

16 15. The apparatus of any of claims 12 to 14,  
17 wherein the working nozzle has inner and outer  
18 surfaces each being substantially frustoconical in  
19 shape.

20

21 16. The apparatus of any preceding claim, further  
22 including a second transport nozzle being adapted to  
23 introduce further transport fluid or a second  
24 transport fluid into the mixing chamber.

25

26 17. The apparatus of claim 16, wherein the second  
27 transport nozzle is positioned nearer to the exit  
28 than the transport nozzle.

29

30 18. The apparatus of claim 17, wherein the second  
31 transport nozzle is positioned nearer to the exit  
32 than the working nozzle, such that the working

1 nozzle is located intermediate the two transport  
2 nozzles.

3

4 19. The apparatus of any preceding claim, wherein  
5 the conduit includes a passage.

6

7 20. The apparatus of claim 19, wherein the inner  
8 wall of the passage is adapted with a contoured  
9 portion to induce turbulence of the working fluid  
10 upstream of the transport nozzle.

11

12 21. The apparatus of any preceding claim, wherein  
13 the mixing chamber includes an inlet for the  
14 introduction of an inlet fluid.

15

16 22. The apparatus of any preceding claim, wherein  
17 the mixing chamber is closed upstream of the  
18 transport nozzle.

19

20 23. The apparatus of any preceding claim, further  
21 including a supplementary nozzle arranged inside the  
22 transport nozzle and adapted to introduce further  
23 transport fluid or a second transport fluid into the  
24 mixing chamber.

25

26 24. The apparatus of claim 23, wherein the  
27 supplementary nozzle is arranged axially in the  
28 mixing chamber.

29

30 25. The apparatus of claim 23 or 24, wherein the  
31 supplementary nozzle extends forward of the  
32 transport nozzle.

1

2 26. The apparatus of any of claims 23 to 25,  
3 wherein the supplementary nozzle is shaped with a  
4 convergent-divergent profile to provide supersonic  
5 flow of the transport fluid which flows  
6 therethrough.

7

8 27. The apparatus of any preceding claim, further  
9 including control means adapted to control one or  
10 more of droplet size, droplet distribution, spray  
11 cone angle and projection distance.

12

13 28. The apparatus of any preceding claim, further  
14 including control means to control one or more of  
15 the flow rate, pressure, velocity, quality, and  
16 temperature of the inlet and/or working and/or  
17 transport fluids.

18

19 29. The apparatus of claim 27 or 28, wherein the  
20 control means includes means to control the angular  
21 orientation and internal geometry of the working  
22 and/or transport and/or secondary nozzles.

23

24 30. The apparatus of any of claims 27 to 29,  
25 wherein the control means includes means to control  
26 the internal geometry of at least part of the mixing  
27 chamber or exit to vary it between convergent and  
28 divergent.

29

30 31. The apparatus of any preceding claim, wherein  
31 the exit of the apparatus is provided with a cowl to  
32 control the mist.

1

2 32. The apparatus of claim 31, wherein the cowl  
3 comprises a plurality of separate sections arranged  
4 radially, each section adapted to control and re-  
5 direct a portion of the discharge of mist emerging  
6 from the exit.

7

8 33. The apparatus of any preceding claim, wherein  
9 the apparatus for generating a mist is located  
10 within a further cowl.

11

12 34. The apparatus of any preceding claim, wherein  
13 at least one of the transport, secondary or working  
14 nozzles is adapted with a turbulator to enhance  
15 turbulence.

16

17 35. A spray system comprising apparatus of any of  
18 claims 1 to 34 and transport fluid in the form of  
19 steam.

20

21 36. The spray system of claim 35, further including  
22 working fluid in the form of water.

23

24 37. The spray system of claim 35 or 36, further  
25 including a steam generator and water supply.

26

27 38. The spray system of claim 37, wherein the spray  
28 system is portable.

29

30 39. A method of generating a mist comprising the  
31 steps of:

1           providing apparatus for generating a mist  
2    comprising a transport nozzle and a conduit, the  
3    conduit having a mixing chamber and an exit;  
4           introducing a stream of transport fluid into  
5    the mixing chamber through the transport nozzle;  
6           introducing a working fluid into the mixing  
7    chamber;  
8           atomising the working fluid by interaction of  
9    the transport fluid with the working fluid to form a  
10   dispersed vapour/droplet flow regime; and  
11          discharging the dispersed vapour/droplet flow  
12   regime through the exit as a mist comprising working  
13   fluid droplets, a substantial portion of the  
14   droplets having a size less than 20 $\mu$ m.

15

16   40. The method of claim 39, wherein the apparatus  
17   is an apparatus according to any of claims 1 to 38.

18

19   41. The method of claim 39 or 40, wherein the  
20   stream of transport fluid introduced into the mixing  
21   chamber is annular.

22

23   42. The method of any of claims 39 to 41, wherein  
24   the working fluid is introduced into the mixing  
25   chamber via an inlet of the mixing chamber of the  
26   apparatus.

27

28   43. The method of any of claims 39 to 41, wherein  
29   the working fluid is introduced into the mixing  
30   chamber via a working nozzle in fluid communication  
31   with the conduit of the apparatus.

32

1 44. The method of claim 43, wherein an inlet fluid  
2 is introduced into the mixing chamber via an inlet  
3 of the mixing chamber of the apparatus.

4

5 45. The method of any of claims 39 to 44, wherein  
6 the method includes the step of introducing the  
7 transport fluid into the mixing chamber in a  
8 continuous or discontinuous or intermittent or  
9 pulsed manner.

10

11 46. The method of any of claims 39 to 45, wherein  
12 the method includes the step of introducing the  
13 transport fluid into the mixing chamber as a  
14 supersonic flow.

15

16 47. The method of any of claims 39 to 46, wherein  
17 the method includes the step of introducing the  
18 transport fluid into the mixing chamber as a sub-  
19 sonic flow.

20

21 48. The method of any of claims 39 to 47, wherein  
22 the method includes the step of introducing the  
23 working fluid into the mixing chamber in a  
24 continuous or discontinuous or intermittent or  
25 pulsed manner.

26

27 49. The method of any of claims 39 to 48, wherein  
28 the mist is controlled by modulating at least one of  
29 the following parameters:

30 the flow rate, pressure, velocity, quality  
31 and/or temperature of the transport fluid;

1           the flow rate, pressure, velocity, quality  
2           and/or temperature of the working fluid;  
3           the flow rate, pressure, velocity, quality  
4           and/or temperature of the inlet fluid;  
5           the angular orientation of the transport and/or  
6           working and/or secondary nozzle(s) of the apparatus;  
7           the internal geometry of the transport and/or  
8           working and/or secondary nozzle(s) of the apparatus;  
9           and  
10          the internal geometry, length and/or cross  
11          section of the mixing chamber.

12

13       50. The method of claim 49, wherein the mist is  
14       controlled to have a substantial proportion of its  
15       droplets having a size less than 20 $\mu$ m.

16

17       51. The method of claim 49, wherein the mist is  
18       controlled to have a substantial proportion of its  
19       droplets having a size less than 10 $\mu$ m.

20

21       52. The method of any of claims 39 to 51, including  
22       the generation of condensation shocks and/or  
23       momentum transfer to provide suction within the  
24       apparatus.

25

26       53. The method of any of claims 39 to 52, including  
27       inducing turbulence of the inlet fluid prior to it  
28       being introduced into the mixing chamber.

29

30       54. The method of any of claims 39 to 53, including  
31       inducing turbulence of the working fluid prior to it  
32       being introduced into the mixing chamber.

1

2 55. The method of any of claims 39 to 54, including  
3 inducing turbulence of the transport fluid prior to  
4 it being introduced into the mixing chamber.

5

6 56. The method of any of claims 39 to 55, wherein  
7 the transport fluid is steam or an air/steam  
8 mixture.

9

10 57. The method of any of claims 39 to 56, wherein  
11 the working fluid is water or a water-based liquid.

12

13 58. The method of any of claims 39 to 57, wherein  
14 the mist is used for fire suppression.

15

16 59. The method of any of claims 39 to 58, wherein  
17 the mist is used for decontamination.

18

19 60. The method of any of claims 36 to 59, wherein  
20 the mist is used for gas scrubbing.

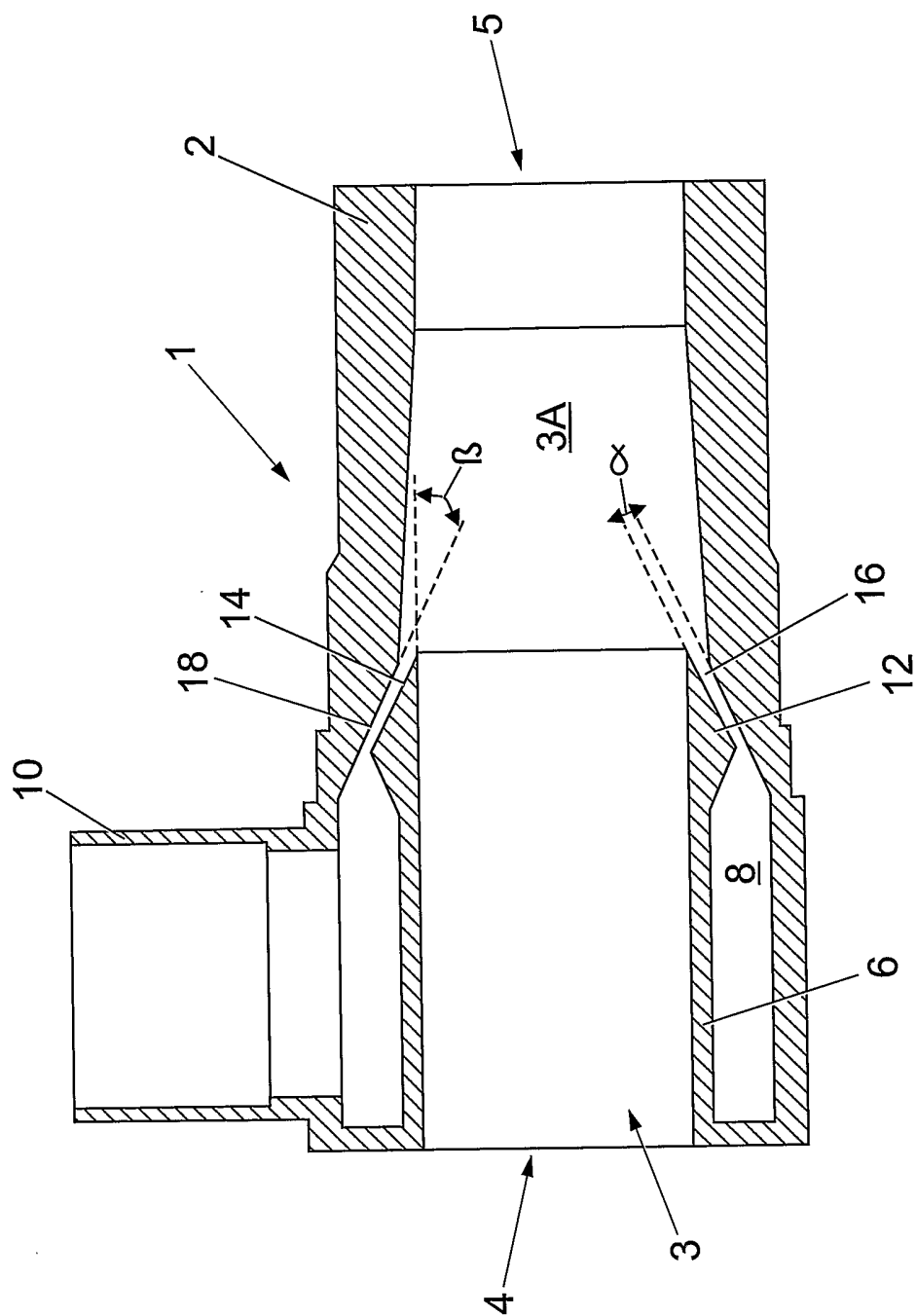
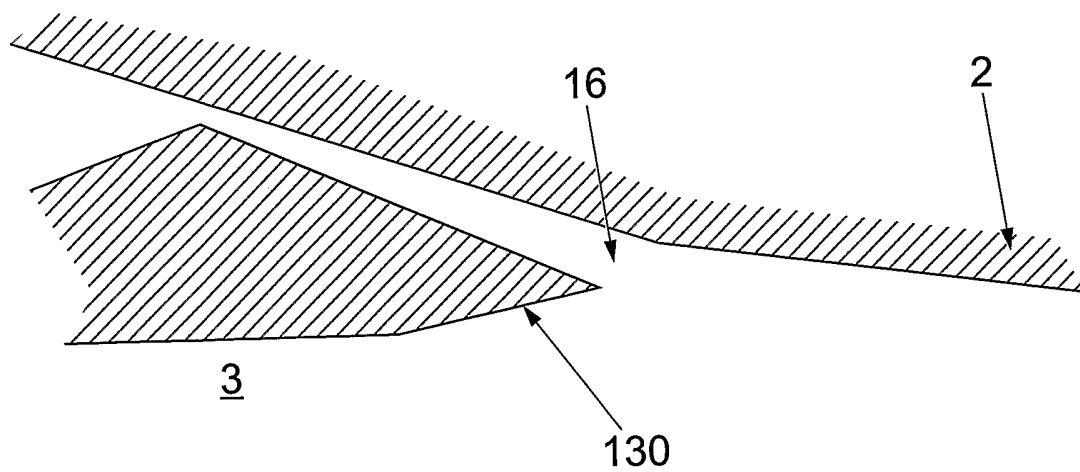
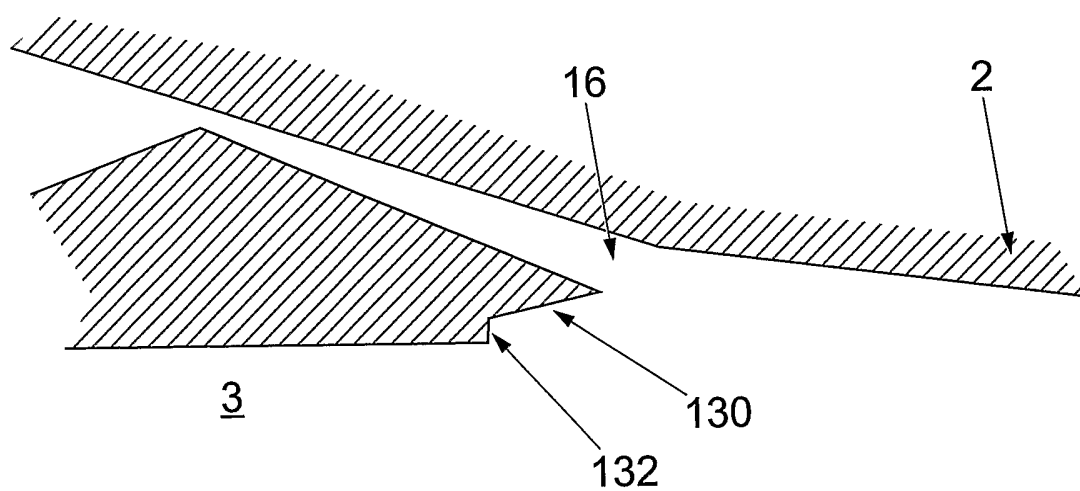


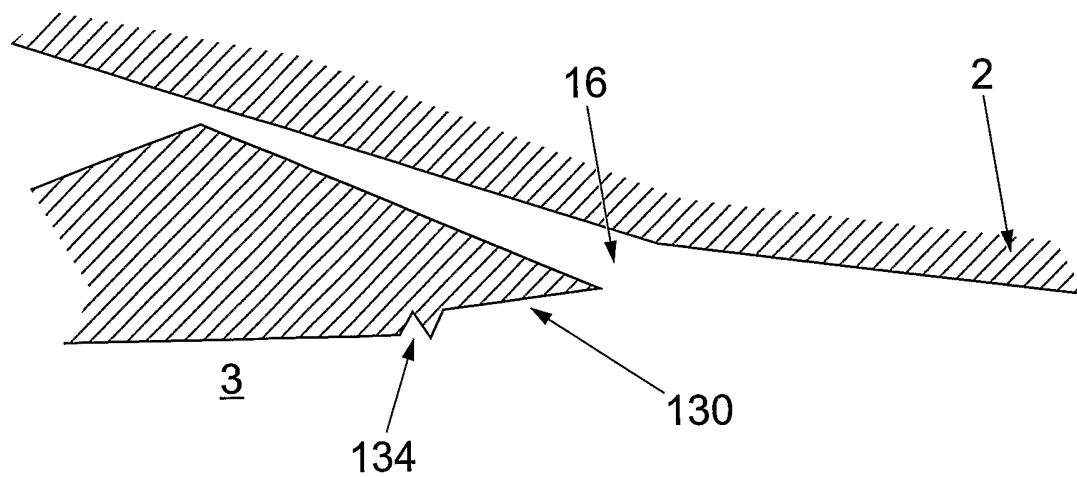
Fig. 1



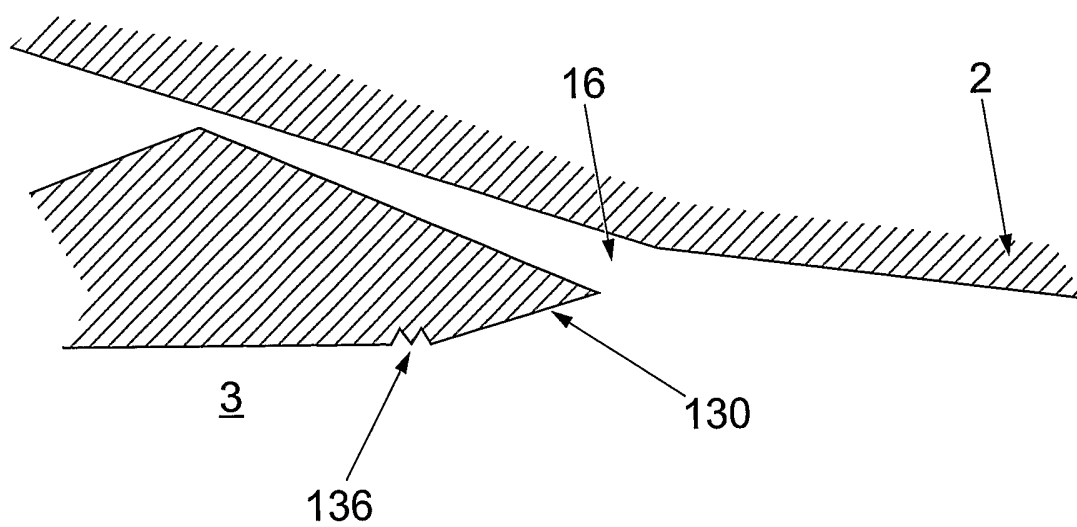
*Fig. 2*



*Fig. 3*



*Fig. 4*



*Fig. 5*

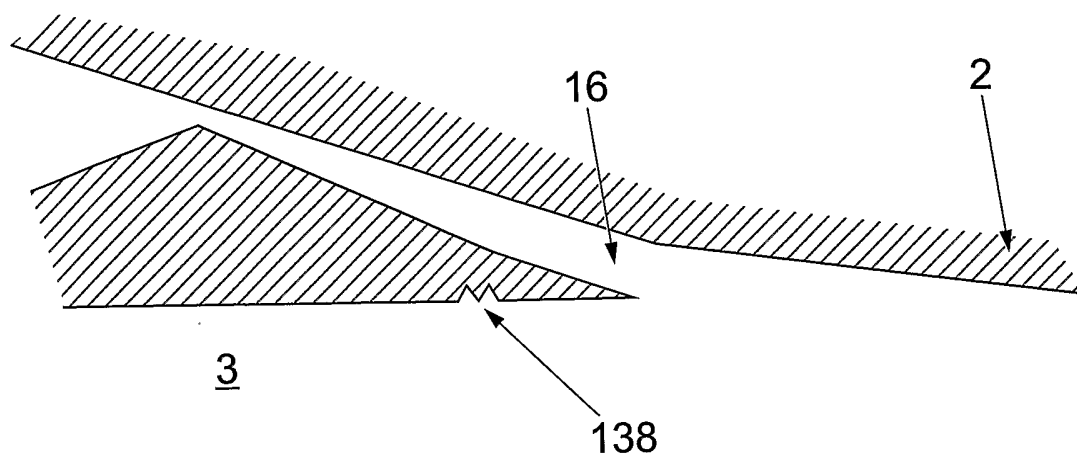


Fig. 6

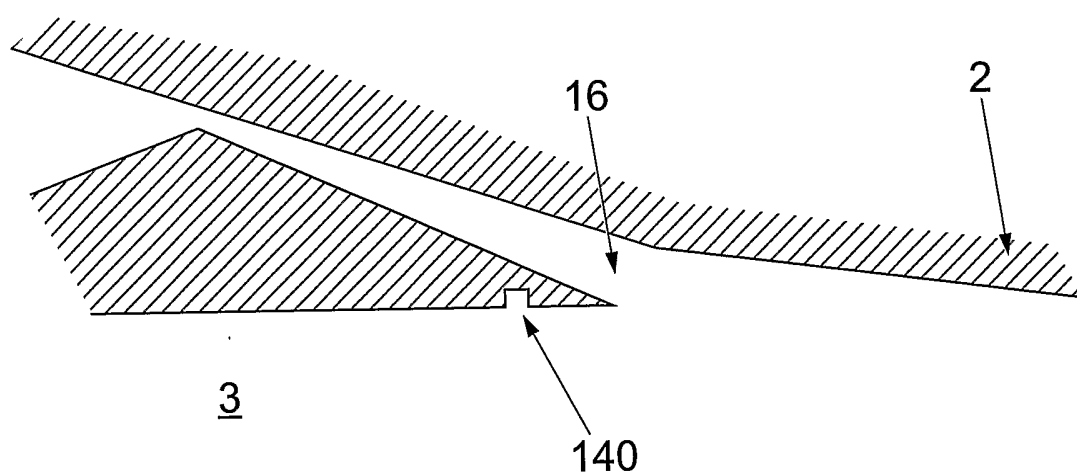


Fig. 7

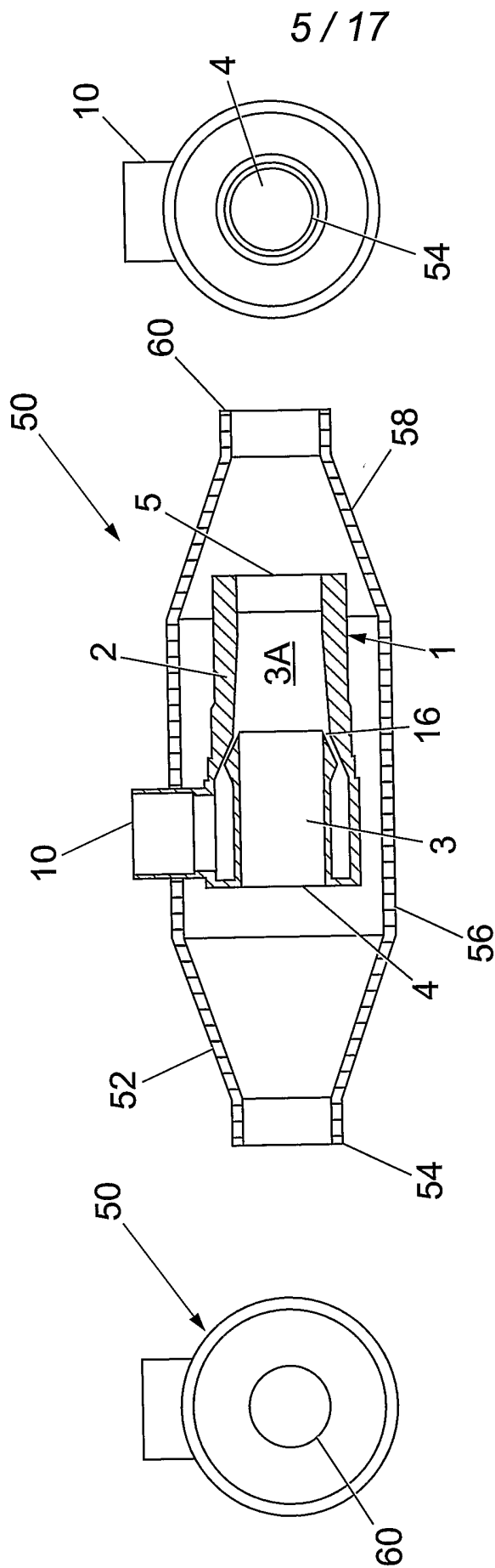


Fig. 8

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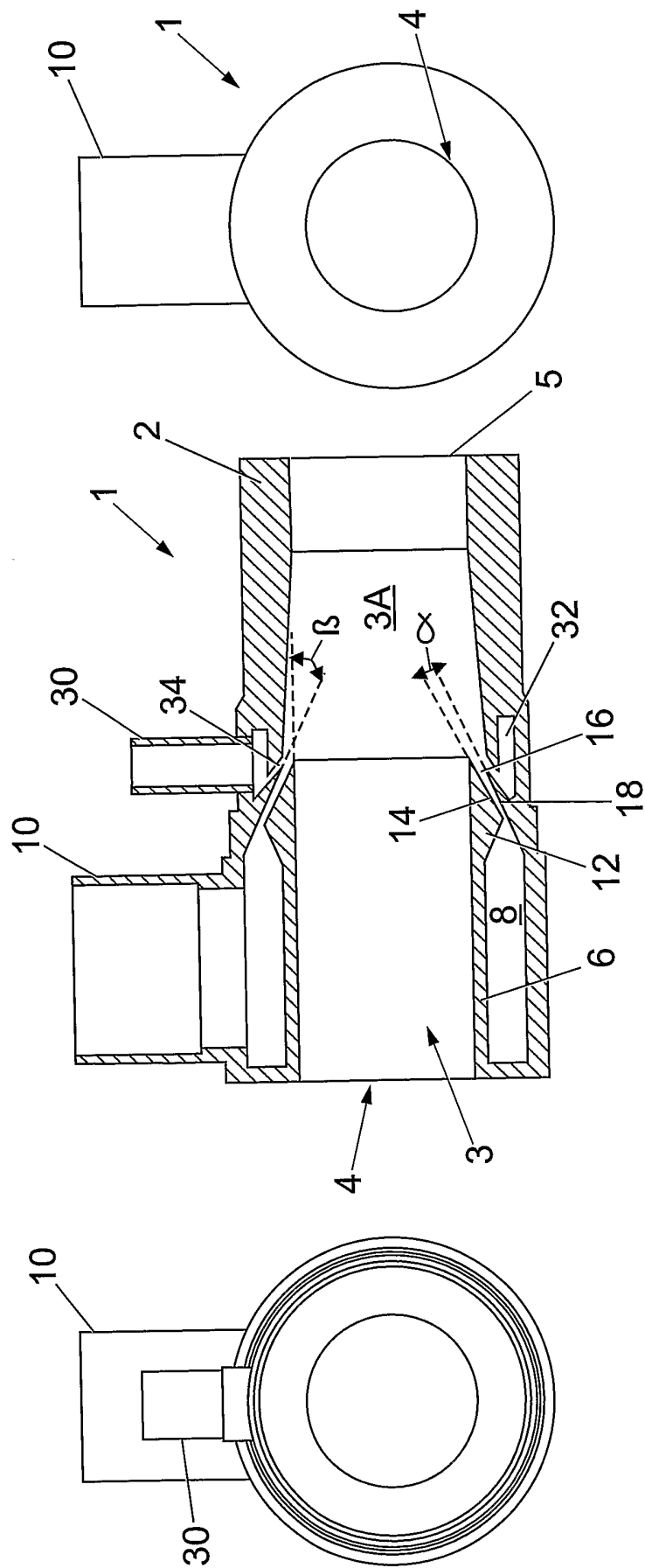
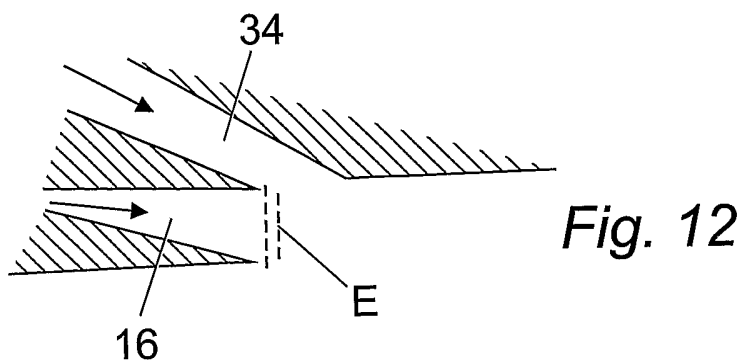
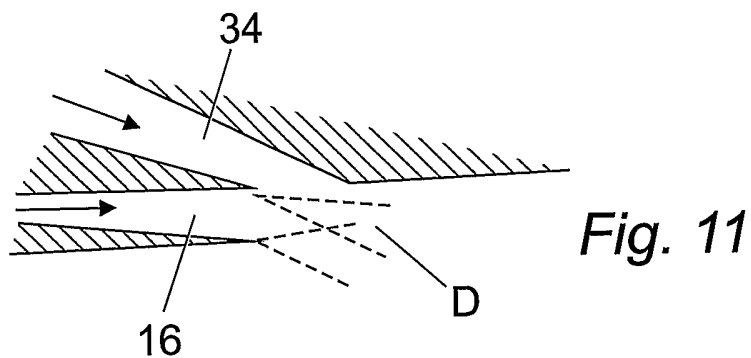
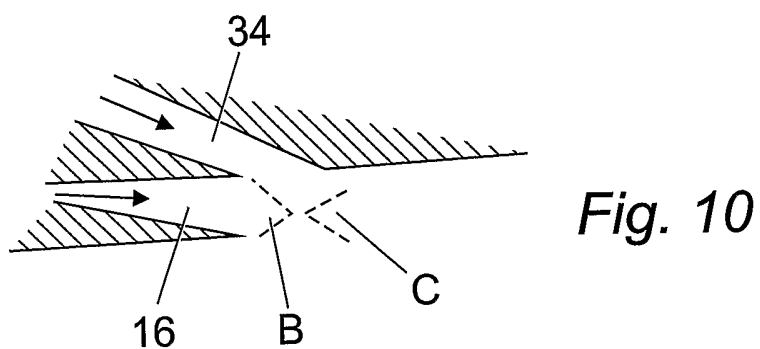
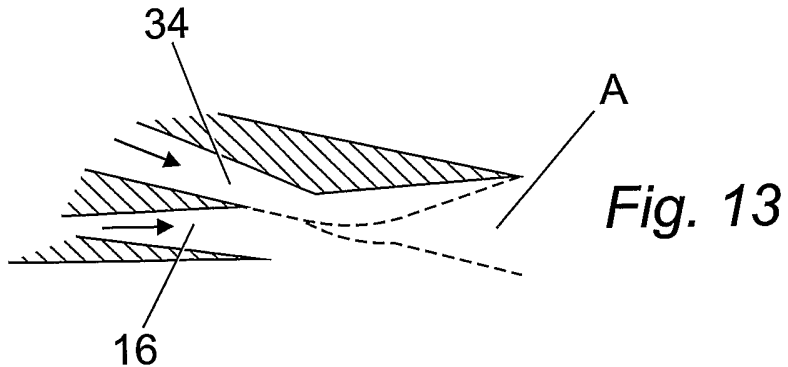


Fig. 9

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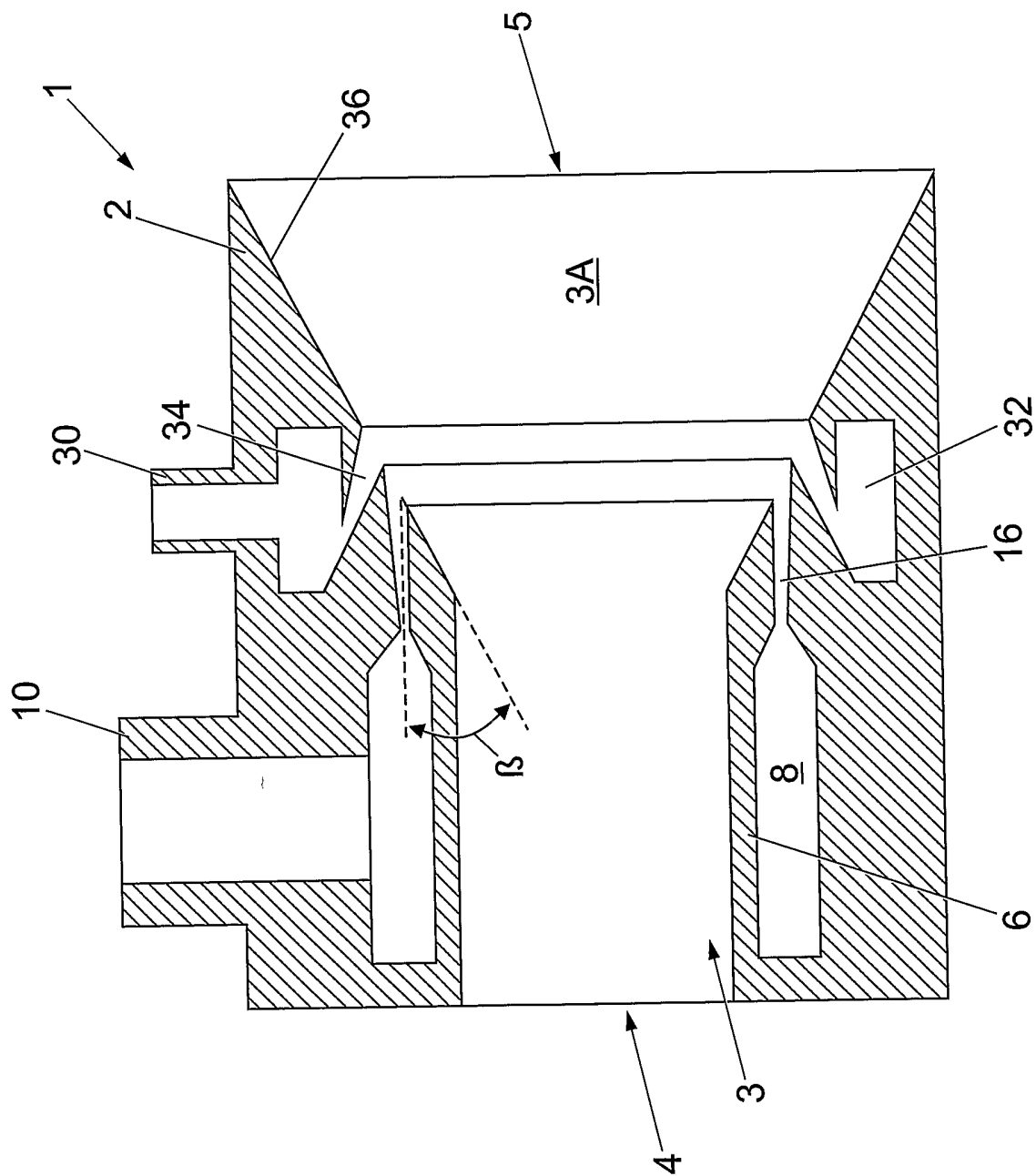


Fig. 14

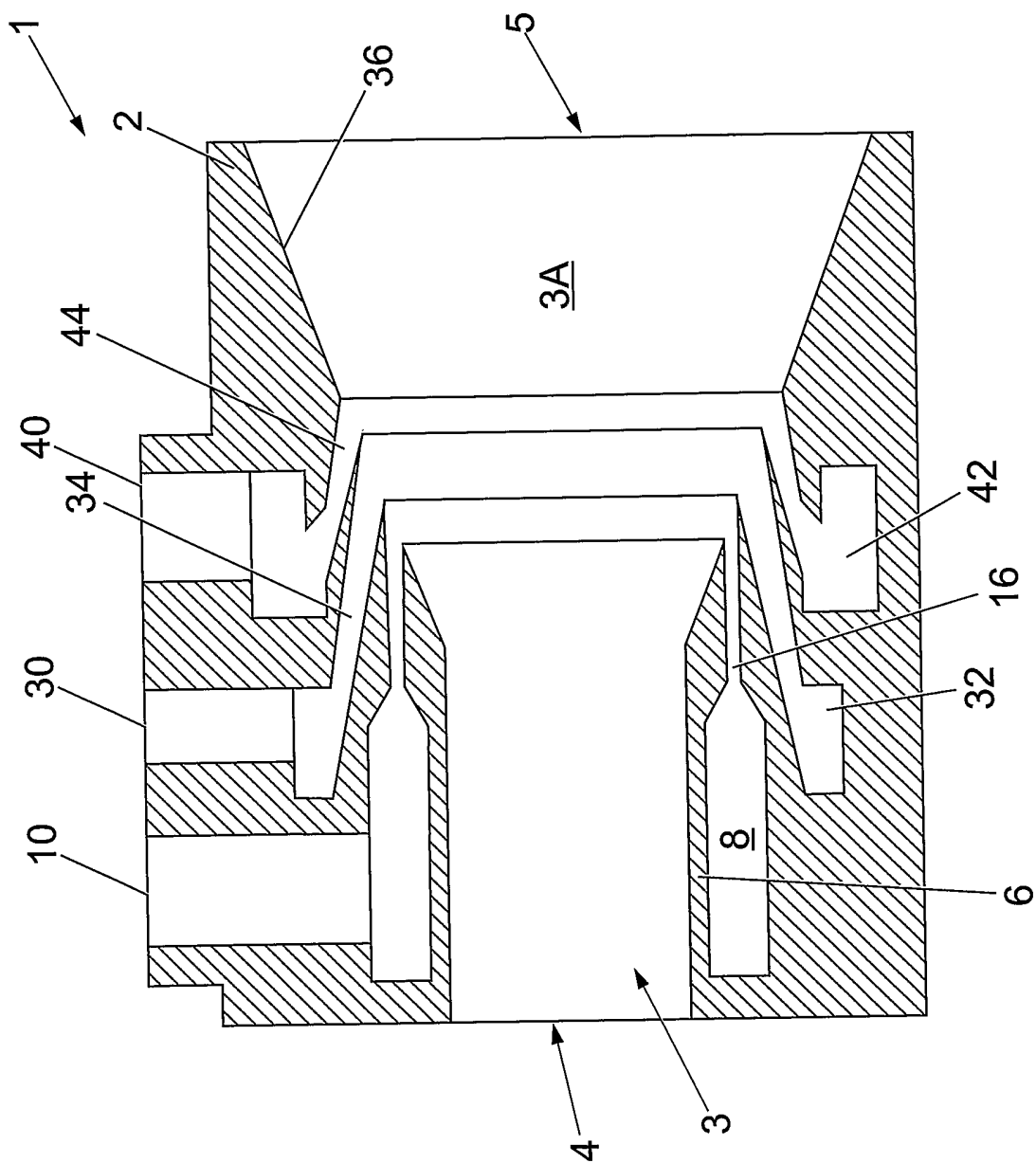


Fig. 15

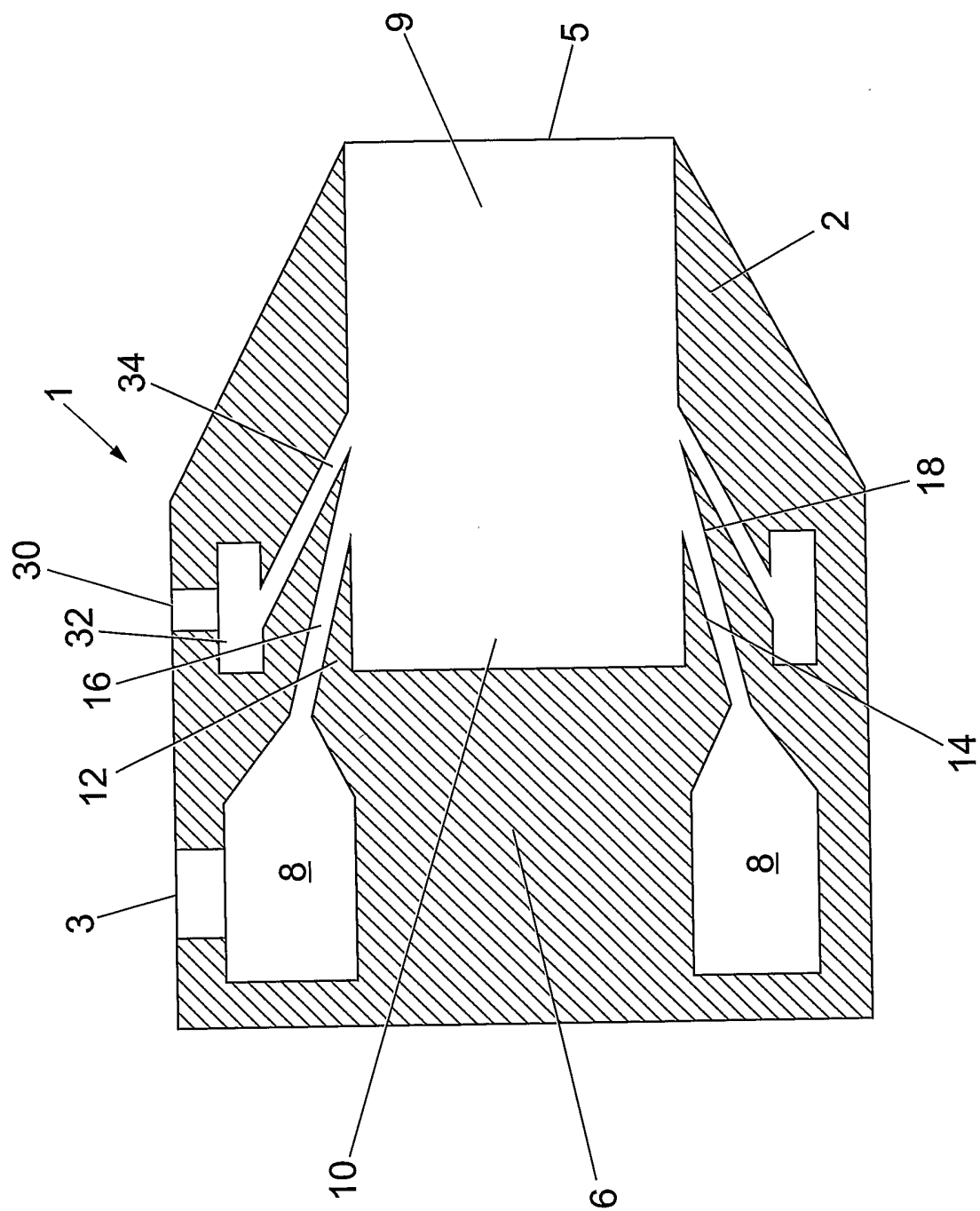
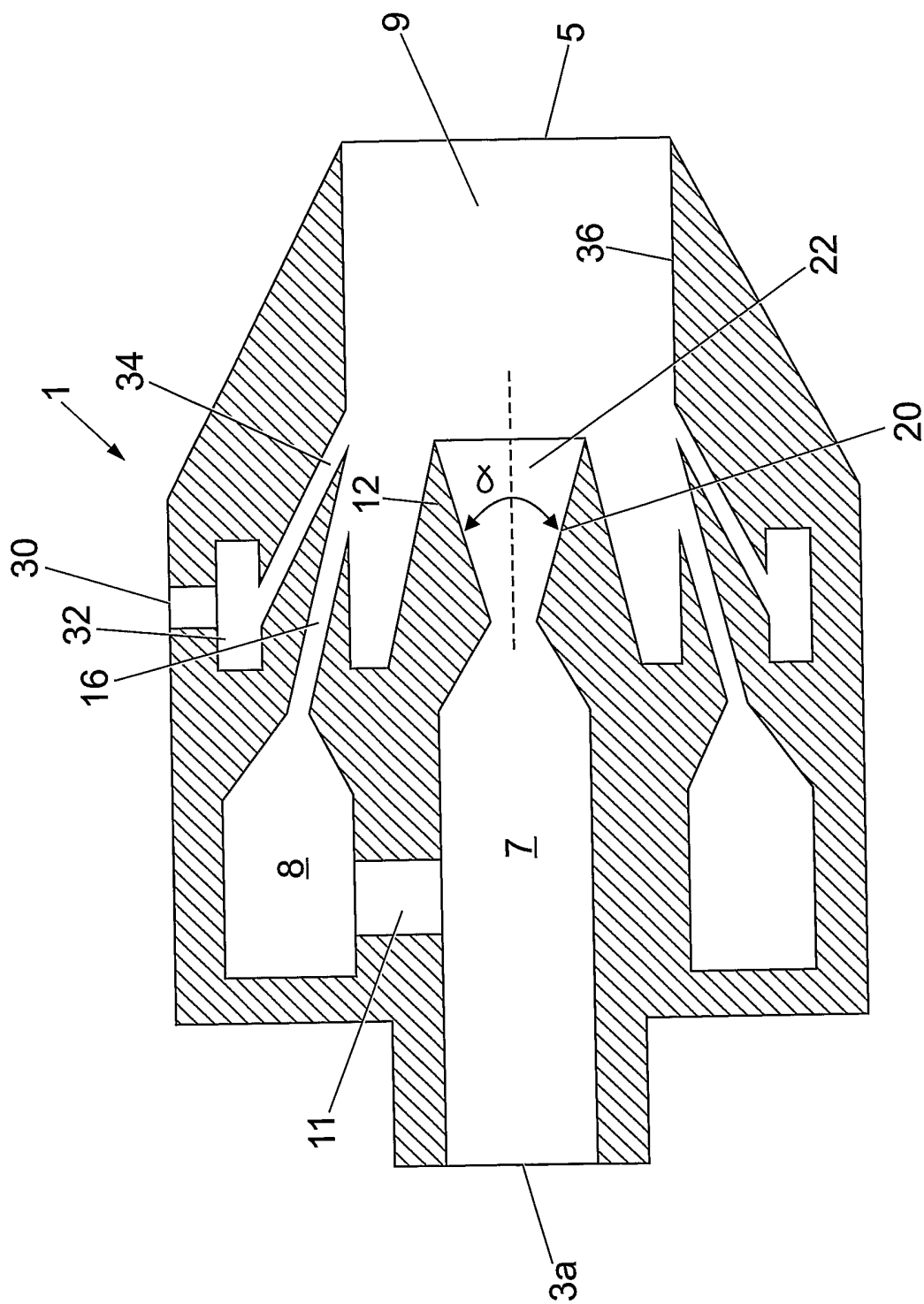


Fig. 16



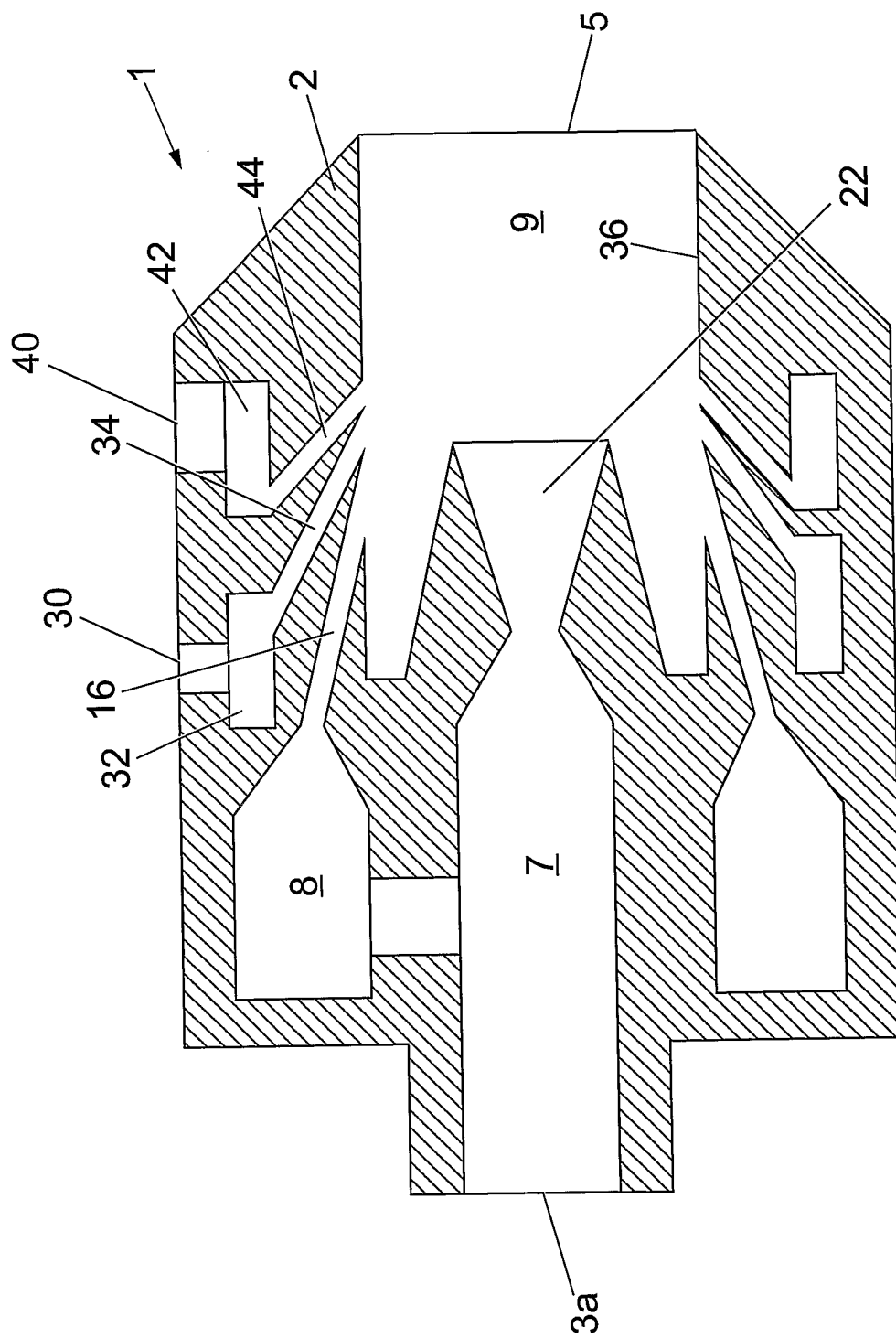


Fig. 18

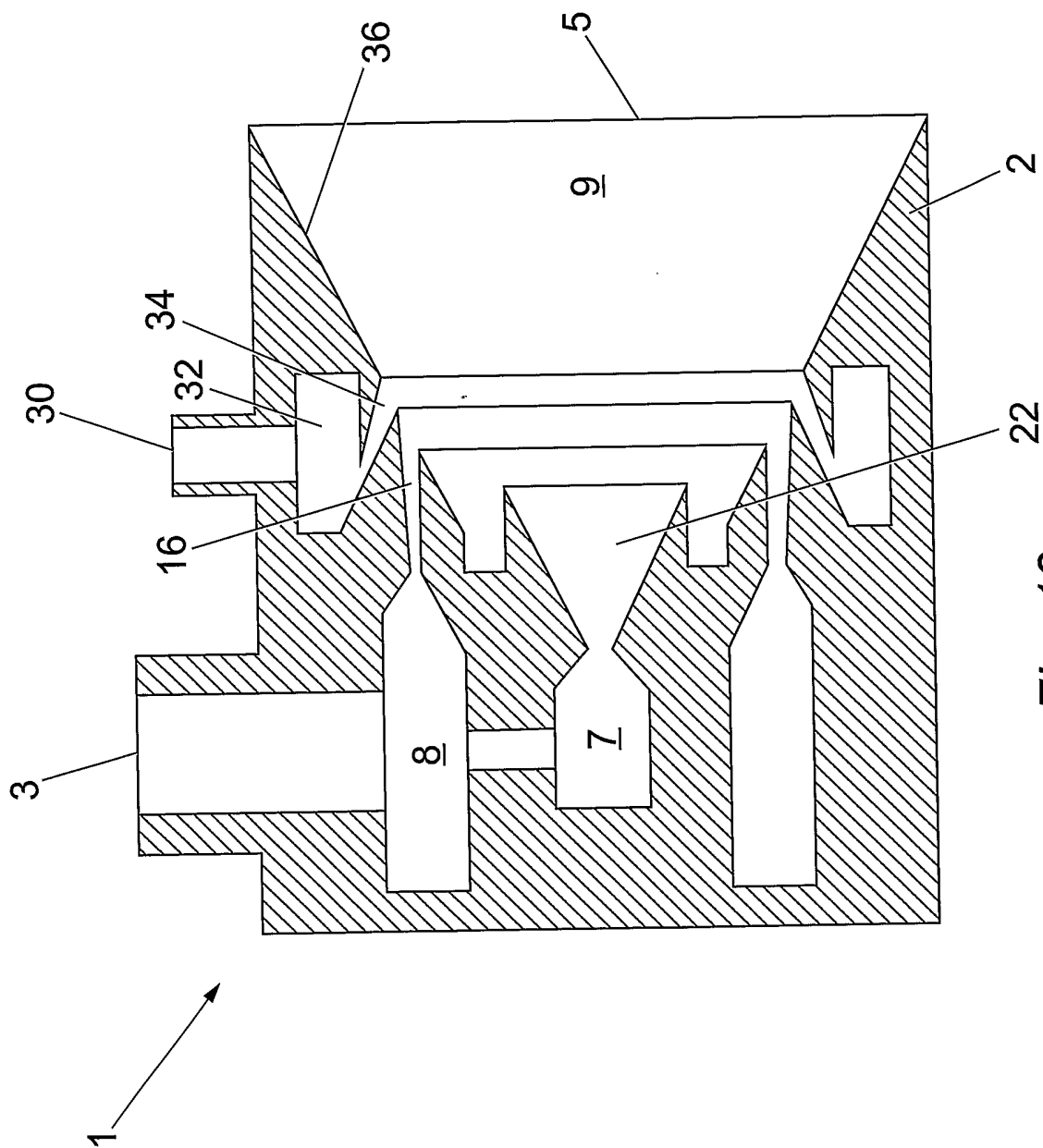


Fig. 19

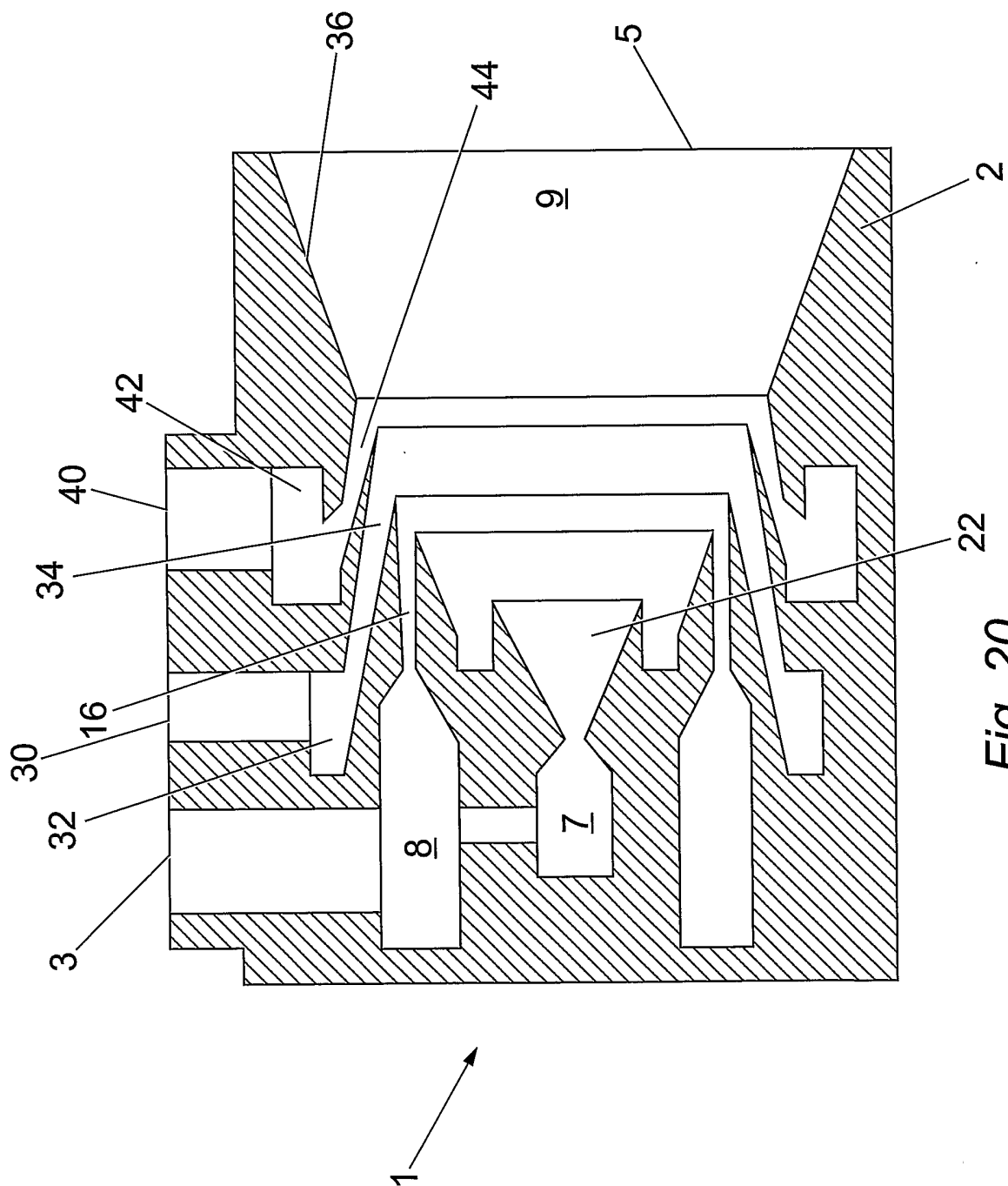


Fig. 20

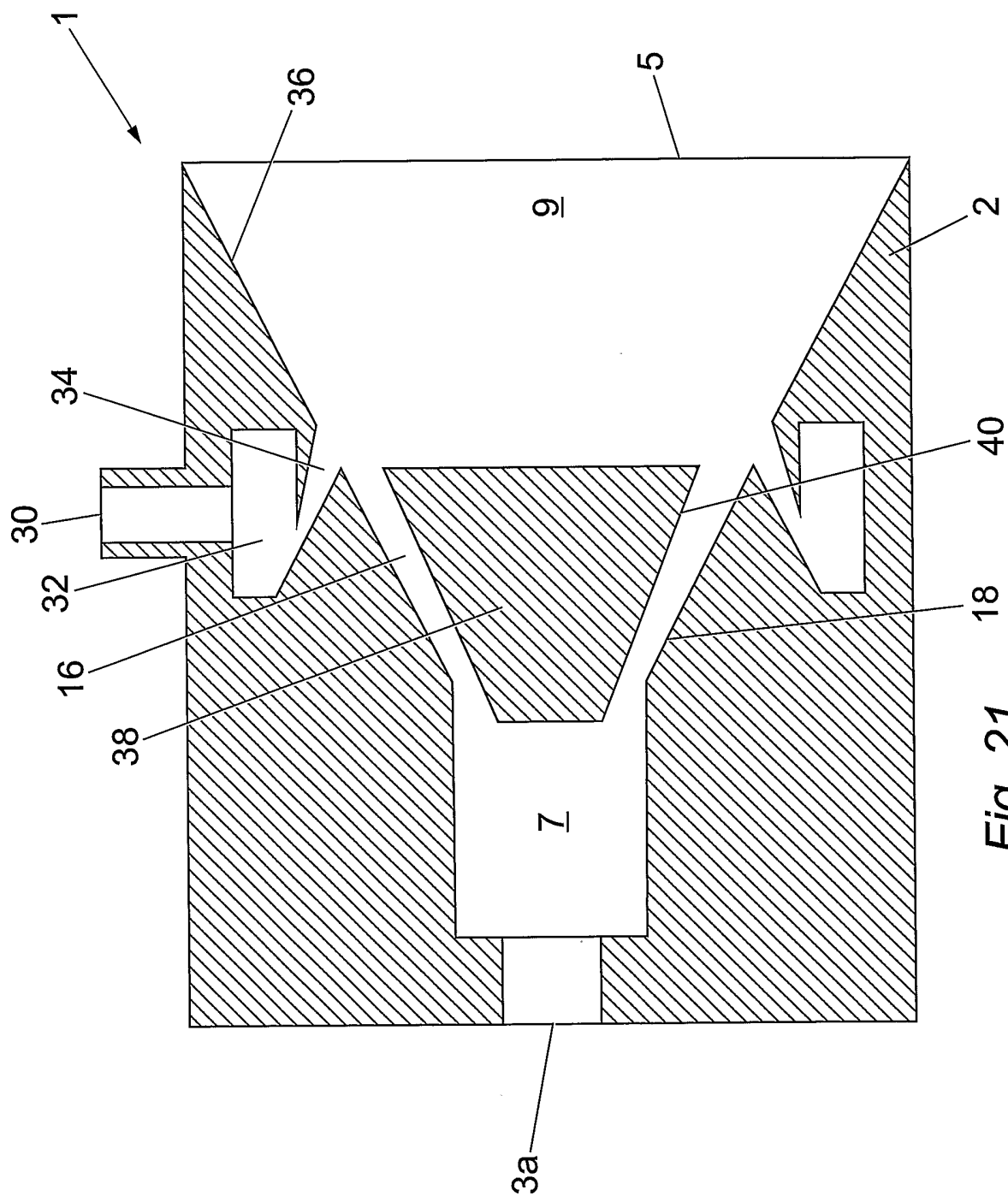


Fig. 21

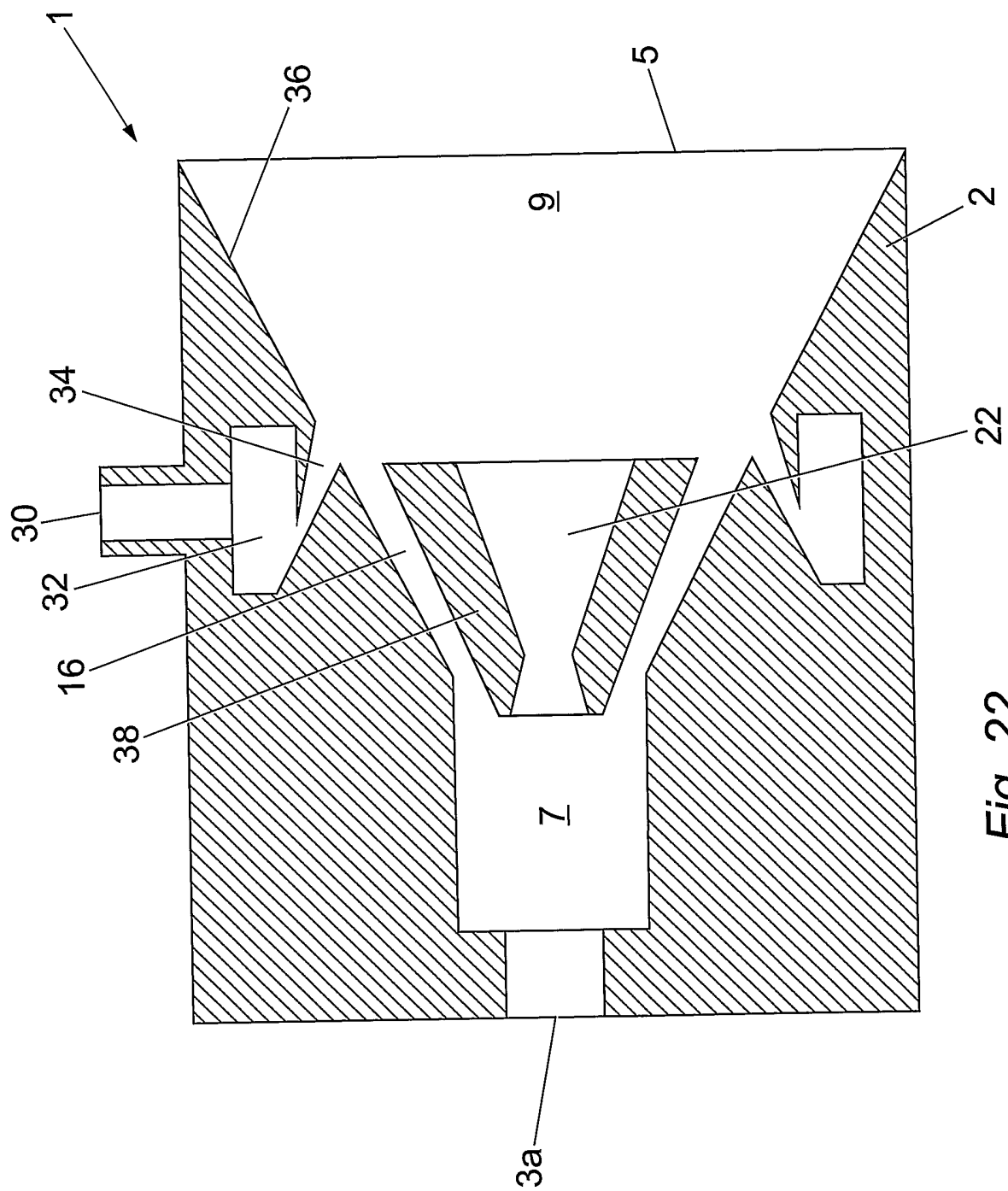


Fig. 22

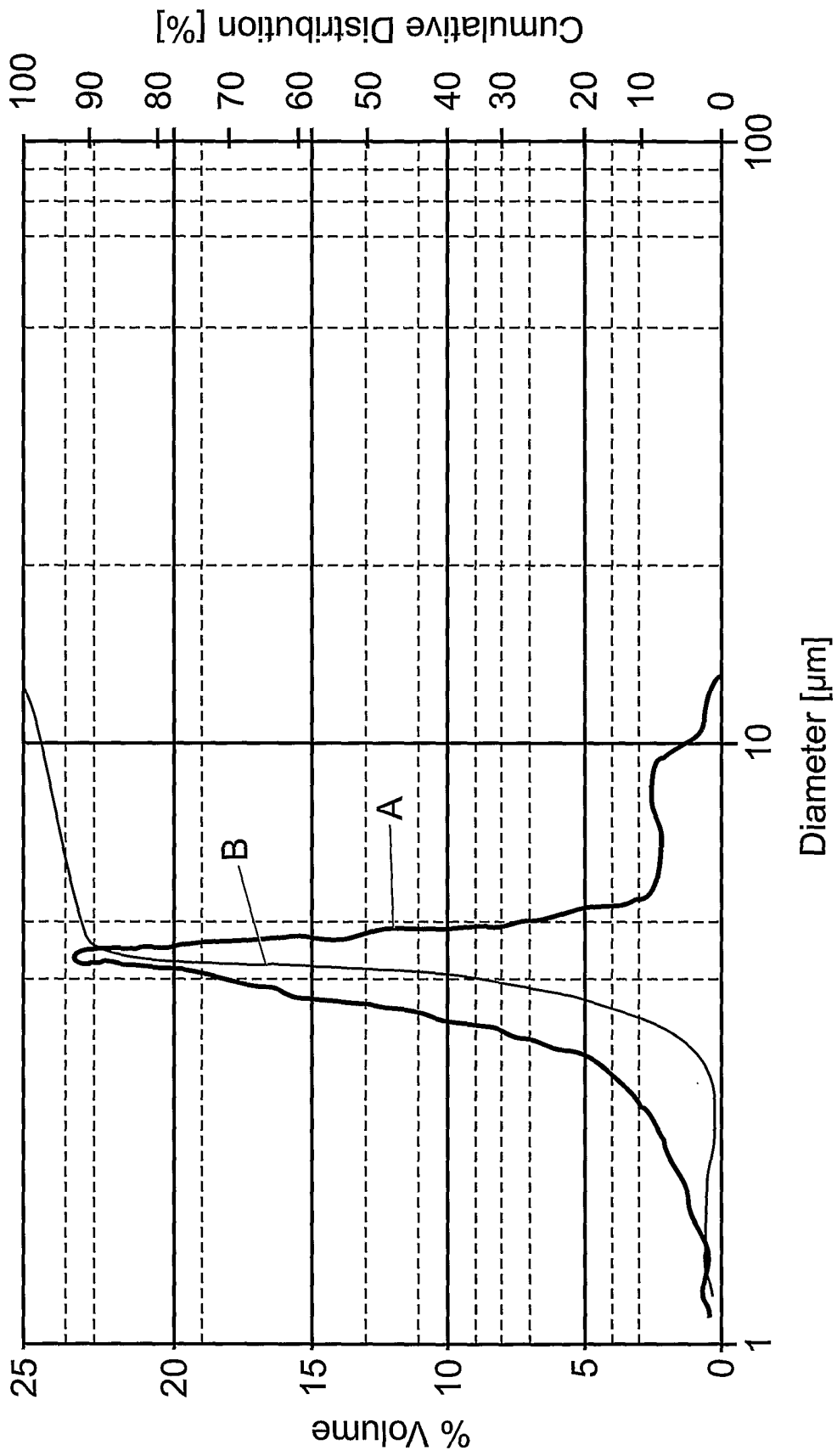


Fig. 23

**INTERNATIONAL SEARCH REPORT**

PCT/GB2005/000708

**A. CLASSIFICATION OF SUBJECT MATTER**  
 IPC 7 B05B7/06 B05B7/04 A62C31/02

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
 IPC 7 B05B A62C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01/76764 A (CHROBAK, JULIUS) 18 October 2001 (2001-10-18) the whole document	1,5,6, 39,40
X	FR 2 613 639 A (RECLUS EDOUARD) 14 October 1988 (1988-10-14) the whole document	1,5,6, 39,40
X	US 5 779 159 A (WILLIAMS, DECEASED ET AL) 14 July 1998 (1998-07-14) the whole document	1,5,6, 39,40

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Date of the actual completion of the international search

Date of mailing of the international search report

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Eberwein, M

# INTERNATIONAL SEARCH REPORT

Information on patent family members

PCT/GB2005/000708

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