

A Mixing Device For An Exhaust System

The present invention relates to mixing device for exhaust systems and also method
5 treating exhaust gases of an internal combustion engine.

To clean up emissions from vehicles such as trucks and cars it is known to use diesel particulate filters (DPF) and selective catalytic reduction (SCR).

10 With regard to DPFs, in order to burn off the accumulated carbon on the DPF, it is known to inject diesel fuel or other hydrocarbons in front of a diesel oxidising catalytic (DOC) to create heat by catalytic oxidation. This heat then passes from the DOC to the DPF raising the temperature of the DPF and hence burning off the accumulated carbon.

15 SCR is used to remove oxides of nitrogen (NO_x). In this case urea, or a similar liquid is injected upstream of the SCR catalyst to act as a chemical reductant to remove NO_x.

For either system to work reliably and effectively it is necessary that the injected liquids are highly dispersed and are evenly distributed onto the catalyst. However, on a typical
20 installation there is little space available to allow good mixing to occur. It is known to provide devices to create turbulence to assist mixing, however, these devices cause a relatively high back pressure which adversely effects fuel economy and engine durability.

The present invention seeks to overcome or mitigate some or all of these problems.
25

Thus, according to the present invention there is provided a mixing device or a method of treating exhaust gases as defined in the independent claims.

The invention will now be described, by way of example only, with reference to the
30 accompanying drawings in which:-

Figures 1 to 4 show cross sections of exhaust systems including mixing devices according to the present invention,

Figures 5 and 6 show end views of parts of figure 4,

Figure 7 shows an enlarged view of figure 4,

Figures 8 to 10 show further embodiments of exhaust systems including mixing devices according to the present invention.

Figures 11 to 12F show a further embodiment of an exhaust system including mixing
5 devices according to the present invention.

Figure 1 shows part of an exhaust system 10 including a mixing device 12 and a catalyst 14. The mixing device 12 includes an inlet 16 and an outlet 18. Between the inlet and the outlet there is defined a gas flow path F1, F2, F3. The mixing device also includes an
10 injector 20. The exhaust system is connected to an exhaust manifold (not shown) of an internal combustion engine. When the engine is running, exhaust gases pass down the exhaust system generally from left to right as shown by the exhaust gas arrows EG. When required, a reagent is injected into the exhaust gas flow by injector 20. The injected reagent and exhaust gas then pass through the mixing device 12 and on to the catalyst 14.

15

Where the catalyst is a DOC, the reagent injected by injector 20 is diesel fuel or another type of hydrocarbon fuel. Where the catalyst is an SCR the reagent injected by injector 20 is urea or an equivalent reagent.

20 In summary, the mixing device is designed such that reverse flow of the exhaust gas and reagent occurs as they pass through the mixing device. Thus, it can be seen that the flow path F1 is generally left to right, the flow path F2 is generally right to left, and the flow path F3 is generally left to right. In this case, there are two general reversals of gas flow, though in further embodiments the mixing device could be designed to have a single
25 reversal of gas flow or three reversals of gas flow or four reversals of gas flow or more than four reversals of gas flow.

The gas flow reversal creates a homogeneous distribution of liquid within the exhaust gas which then passes onto the catalyst with minimum loss of space and minimum back
30 pressure.

In more detail, the mixing device 12 includes a shell 22 having an outer portion 24 made from sheet steel and an inner portion 26 made from a thermal insulation material.

A central tube 30 is positioned within the shell 22 and a sleeve 50 is positioned between the central tube and the shell. The left hand (when viewing figure 1) end 31 of tube 30 defines the inlet 16. The right hand (when viewing figure 1) end 32 of tube 30 is blanked off by blanking plate 33. Between ends 31 and 32 the tube has a perforated region 34. In this case the perforated region comprises over 200 holes 35.

The sleeve 50 includes a central cylindrical portion 51, a frustoconical end portion 52 and a frustoconical end portion 53.

The frustoconical end portion connects the cylindrical portion 51 with the right hand end 32 of central tube. There are no perforations in either the cylindrical portion 51 or the frustoconical end portion 52, and as such the frustoconical end portion 52 acts to blank off the right hand end of sleeve 50.

However, the frustoconical end portion 53 defines a perforated region 54 of the sleeve 50. The perforated region 54 includes holes 55 in this case over 200 holes. The right hand end of the central tube and the right hand end of the sleeve are both supported by a baffle 60. Baffle 60 includes holes to allow the passage of the exhaust gases, these holes are similar to those shown on baffle 360 on figure 5.

A support member 62 includes an outer frustoconical region 63 and an inner frustoconical region 64. There are no perforations in the outer frustoconical region and there are no perforations in the inner frustoconical region. The left hand end of the perforated region 54 of the sleeve 50 is connected to the right hand end of the outer frustoconical region, and is therefore supported by the outer frustoconical region. The left hand end 31 of the central tube is connected to and supported by the right hand end of the inner frustoconical region. The inner frustoconical region is, in turn, supported at its left hand end by the outer frustoconical region. The outer frustoconical region 63 includes a portion 65 which supports the injector 20.

Consideration of the perforated region 34 of the central tube and the perforated region 54 of the sleeve show that they do not axially overlap, i.e. there is a gap G between the axial

position of the left most hole of the perforated region 34 and the right most hole of the perforated region 54.

It will be appreciated that the exhaust gas and reagent must initially enter the central tube 30 via the inlet 16. At this point, all the exhaust gas is travelling from left to right when viewing figure 1. When the exhaust gas has reached the perforated region 34, the exhaust gas flow direction will turn and the exhaust gas will flow radially outwardly through the holes 35 into an inner annular region 27 defined between the central tube 30 and sleeve 50. When in this inner annular region exhaust gases will be forced to move from right to left towards the perforated region 54. Upon reaching the perforated region 54 the exhaust gas will again turn and flow generally radially outwardly through the holes 55 into an outer annular region defined between cylindrical portion 51 and the shell 22. When in this outer annular region 28, the exhaust gases will be forced to move from left to right.

It will therefore be appreciated that the flow path includes the first general reversal of the direction of exhaust flow which general reversal will occur as the exhaust gas passes through holes 35. The flow path also includes a second general reversal of the direction of exhaust gas flow, which will occur typically as the exhaust gas passes through the holes 55.

It will also be appreciated that since the central tube 30, the cylindrical portion 51 and the shell 22 are all cylindrical, and are all concentric, the exhaust gas flow path is substantially symmetrical about the centre line CL of the mixing device 12, and this is in spite of the fact that the injector 20 is positioned asymmetrically relative to the centre line.

It will also be appreciated that there is a space between the catalyst 14 and the blanking plate 33 which defines the outlet 18. Note that final mixing occurs in flow path F3 and in outlet 18 prior to the gas entering the catalyst 14.

Note that flow path F2 generally surrounds flow path F1 and that flow path F3 generally surrounds flow path F2.

Figure 2 shows an exhaust system 110 in which components that fulfil substantially the same function as those of exhaust system 10 are labelled 100 greater.

In exhaust system 110, the injector 120 injects reagent at the centre line CL of the mixing device 112 whereas the injector 20 injects reagent from the edge of the mixing device. It will be appreciated that the flow path F1, F2, F3 shown in figure 2 is identical to the flow path F1, F2, F3 shown in figure 1.

5

Figure 3 shows an exhaust system 210 in which components that fulfil substantially the same function as those of exhaust system 10 are labelled 200 greater. In summary the mixing device 212 is a "mirror image" version of mixing device 12. Thus, the exhaust gas flow is generally from left to right as shown by arrows EG. However, the exhaust gas enters the mixing device at inlet 216 and leaves the mixing device at outlet 218. It will be appreciated that flow F1 is from left to right along outer annular region 228. The flow then reverses by flowing radially inwardly through holes 255 into inner annular region 227 at which point the gas flow is from right to left. The flow then reverses again by flowing radially inwardly through holes 235 and then flows from left to right along the centre of central tube 230 and out of the mixing device. The injector is positioned upstream of the mixing device and positions X, Y and Z show examples of where the injector might be positioned.

Note that because the mixing device 212 is a "mirror image" version of mixing device 12, the flow path F1 generally surrounds the flow path F2 and the flow path F2 generally surrounds the flow path F3.

Figures 4 to 7 show an exhaust system 310 in which components that fulfil substantially the same function as those of exhaust system 10 are labelled 300 greater. In this case the injector is not shown, but will be positioned upstream of inlet 316. Holes 355 and 355 are only shown schematically (as crosses).

Figure 5 shows an end view of the baffle 360 which includes several holes 361 which allow the exhaust gases to pass through the baffle and onto the catalyst 314. A central region 366 of baffle 360 acts to blank off the end 332 of central tube 330. The cross section area of the central tube 330 is A1 (see figure 6). The cross section area of the inner annular region 327 is A4 and the cross section area of the outer annular region 328 is A5.

The open area (i.e. the gas flow area) of the holes 330 is A2 and the open area (i.e. gas flow area) of the holes 355 is A3.

Preferably A2 approximately equals A3.

5

Preferably A2 is greater than or equal to 1.5 times A1.

Preferably A2 is greater than or equal to 1.5 times A4.

Preferably A2 is greater than or equal to 1.5 times A5.

10 Preferably A3 is greater than or equal to 1.5 times A1.

Preferably A3 is greater than or equal to 1.5 times A4.

Preferably A3 is greater than or equal to 1.5 times A5.

Preferably A4 is approximately equal to A1 or is greater than A1.

15

Preferably A5 is approximately equal to A1 or greater than A1.

Figure 9 shows an exhaust system 410 in which components that fulfil substantially the same function as those shown in exhaust system 10 are labelled 400 greater. In this case
20 the injector 420 is positioned in a pipe 470, the diameter of the pipe 470 is smaller than the diameter of the shell 422. A further pipe 471 connects the mixing device 412 with the catalyst 414. The diameter of the pipe 471 is smaller than the diameter of shell 422. The diameter of pipe 471 is also smaller than the casing 472 of the catalyst. Pipe 471 can vary in length, and can include one or more bends, depending upon the particular installation.

25

Figure 8 shows an exhaust system 510 in which components that fulfil substantially the same function as those shown in 410 are labelled 100 greater. In this case exhaust system 510 is a modified version of exhaust system 410. It can be seen that the mixing device 512 and the catalyst 514 have been integrated into a single unit. Thus, the exhaust system 510
30 does not include a pipe the equivalent of pipe 471 of exhaust system 410. The integrated exhaust system 510 is more compact than the exhaust system 410, and also includes fewer components (in as much as it does not include pipe 471).

Thus, the exhaust system 510 is integrated in as much as the outlet 418 from the mixing device passes directly to the inlet 573 to the catalyst 514. In other words, the diameter of the shell 522 of the mixing device is substantially the same as the diameter of the casing 572 of the catalyst 514, i.e. when the exhaust gases pass from the mixing device to the catalyst, there is no significant reduction in cross section area of flow path.

Figure 10 shows an exhaust system 610 incorporating two mixing devices according to the present invention. The exhaust system 610 also incorporates 4 catalysts and a DPF.

Thus, catalyst 614A is a DOC, catalyst 614B is an SCR, catalyst 614C is DOC and catalyst 614D is DOC. A DPF 675 is provided between catalyst 614C and 614D. Injector 620A is a urea injector and injector 620B is a diesel fuel injector. As the exhaust gases pass through the exhaust system 610, they are treated as follows:-

- (a) the DOC catalyst 614A oxidises NO to NO₂.
- (b) Urea is injected at injector 620A and mixed with the exhaust gas in mixing device 612A.
- (c) The SCR catalyst 614B then removes NO_x.
- (d) The diesel injector 620B injects diesel into the gas stream and the mixing device 612B mixes the exhaust gas and the diesel.
- (e) The exhaust gas/diesel mixture pass into the DOC 614C and the diesel fuel is oxidised thereby generating heat.
- (f) the heat is passed into the DPF 675, thereby burning off accumulative carbon.
- (g) The exhaust gas then passes into the DOC catalyst 614D to oxidise any remaining hydrocarbons.

It will be appreciated by those skilled in the art the injector 620A and 620B only inject reagent as and when required. Various sensors on the engine and within the exhaust system will determine when injection of a particular reagent is required and this injection is controlled by a control system.

Figures 11 to 12F show an exhaust system 710 in which components that fulfil substantially the same function as those of exhaust system 10 are labelled 700 greater.

The mixing device 712 includes a shell 722. A central tube 730 is positioned partly within the shell and a sleeve 750 is positioned between the central tube and the shell. The tube defines an inlet 16. The right hand (when viewing figure 11) end 732 of tube 730 is
5 blanked off by blanking plate 733. Tube 730 has a perforated region 734 (shown schematically as a cross).

Sleeve 750 is connected to an extension of blanking plate 733 at its right hand end and includes a perforated region 754 at its left hand end (shown schematically as a cross).

10

Consideration of the perforated region 734 of the central tube and the perforated region 754 of the sleeve show that they do not axially overlap, i.e. there is a gap G' between the axial position of the left most hole of the perforated region 734 and the right most hole of the perforated region 754.

15

An injector (not shown) is included in central tube 730 to inject a reagent.

In use, exhaust gas and reagent are mixed in the mixing chamber and the flow is similar to that of exhaust system 10, i.e. the exhaust gas and reagent initially travel from left to right
20 until the perforated region 734 is reached, whereupon the exhaust gas flow production will turn and the exhaust gas will flow radially outward through the holes in the perforated region 734 and into the annular region 727 defined between the central tube 730 and the sleeve 750. When in this inner annular region exhaust gases will be forced to move from right to left towards the perforated region 754. Upon reaching the perforated regions 754
25 the exhaust gas will again turn and flow generally radially outwardly through the holes in the perforated region 754 into an outer annular region defined between the cylindrical portion 751 and the shell 722. When in this outer annular region 728, the exhaust gases will be forced to move from left to right, and will ultimately pass the blanking plate 733.

30 Figure 11 shows various axial positions A1', B1', C1', D1', E1' and F1' of the mixing chambers at the appropriate positions. For the purposes of explanation, we can consider a portion (or slug) of exhaust gas S travelling through the mixing chamber. At position A1', the slug is contained within the central tube 730 which has cross section area A1'. As the

slug of gas moves to the B1' position, it expands, since it is no longer constrained by the central tube, and is only constrained by the sleeve 750. As shown in figure 12B, the slug occupies a cross section area of the mixing chamber equivalent to A1' plus A4'.

- 5 Once the slug of gas has reached position C1', whilst it is still constrained within sleeve 750, it is constrained on its inner diameter by tube 730. The gas is therefore flowing through an area A4' which is necessarily smaller than the volume at position B1'.

10 Once the slug of gas reaches the position D1', it is no longer radially constrained by sleeve 750 and can therefore expand radially outwardly to occupy the volume as shown in figure 12D, i.e. the volume cross section area equivalent to A4' plus A5'. Continued flow of the exhaust gas to position E1' again causes a narrowing of the cross section of flow area to A5'. Finally, as the slug of exhaust gas passes blanking plate 733, it can expand into the outlet (position F1') which has a cross section flow area equivalent to A1' plus A4' plus
15 A5'.

In summary, the slug S, starting at position A1', will expand when it reaches position E1', and then will contract when it reaches position C1', and then will expand when it reaches position D1', and then will contract when it reaches position E1' and then will expand when
20 it reaches position F1'.

The mixer therefore causes the gas to expand then contract then expand then contract then expand, and this process of repeated expansion and contraction attenuates the exhaust gas noise.
25

Consideration of figure 11 shows that the diameter of tube 730 is L1. The radial distance between tube 730 and sleeve 750 is L2. The radial distance between sleeve 750 and shell 722 is L3.

30 The length over which tube 730 is perforated is M1. The length over which sleeve 750 is perforated is M2. It will be noted that M1 is larger than L1 and is also larger than L2.

Furthermore, the open area of the perforated region 734 is larger than A1' and is also larger than A4'. The open area of perforated region 754 is larger than area A4' and is also larger than area A5'.

5 In this manner, the mixing chamber can be arranged to expand, then contract, then expand, then contract, then expand exhaust gas as it passes through the mixing chamber. A similar process of expansion and contraction and expansion and contraction and expansion occurs as exhaust gas pass through the other embodiments shown in the accompanying figures.

10 Turning to figure 1, there are over 200 holes 35, and there are also over 200 holes 55. Depending upon the particular circumstances, there may be more or less holes 35 and there may be more or less holes 55. Typically there will be more than 100 holes 35 to provide for perforated region 34, and typically there will be over 100 holes 55 to provide for perforated region 54. However, in further embodiments the perforated region 34 of central
15 tube 30 could be completely removed, thereby creating a simple gap for the gases to pass through. Similarly, the perforated region 54 of the sleeve 50 could be completely removed, thereby creating a simple gap for the exhaust gases to pass through. Clearly, such modifications could be applied to any of the embodiments shown i.e. any of the set of perforations could be removed to create a simple gap for the gases to pass through.

20

Whilst the embodiments shown provide a substantially symmetrical flow path, in further embodiments this need not be the case.

As shown in figure 1, the perforated region 34 does not axially overlap with the perforated
25 region 54. However, in further embodiments these perforated regions could axially overlap whilst nevertheless ensuring that there is still a general reversal of the exhaust gas flow within the mixing device.

Claims

- 5 1. A mixing device for mixing a gas and a liquid in an exhaust system, the mixing device having an injector for injecting the liquid and having a shell and an inlet and an outlet and an exhaust gas flow path between the inlet and outlet, the mixing device defining an axis and the flow path having a first, second and third part,
- 10 the first part extending generally parallel to the axis to direct flow in a generally forward direction said first part extending up to a first axial position, the second part extending generally parallel to the axis to direct flow in a generally reverse direction, the third part extending generally parallel to the axis to direct flow in the generally
- 15 forward direction, in which the third part is a volume that allows mixing and extends past the first axial position.
2. A mixing device as defined in claim 1 in which the exhaust gas flow path is
- 20 substantially symmetrical about a centre line of the mixing device.
3. A mixing device as defined in any preceding claim in which the inlet is defined by a central tube at least partially positioned within the shell and the outlet is defined at least partially by said shell.
- 25 4. A mixing device as defined in claim 3 in which the tube includes a blanked off tube end.
5. A mixing device as defined in claim 4 in which the tube includes tube perforations
- 30 proximate said blanked off tube end.

6. A mixing device as defined in claim 5 including a sleeve positioned within the shell and surrounding said tube perforations and being spaced from said tube perforations, said sleeve having a blanked off sleeve end proximate said blanked off tube end.
- 5 7. A mixing device as defined in claim 6 in which the sleeve includes sleeve perforations remote from the said blanked off sleeve end.
8. A mixing device as defined in claim 6 or 7 in which said third part is in an annulus and the sleeve partially defines said annulus.
- 10 9. A mixing device as defined in any one of claims 4 to 8 in which the blanked off tube end is supported by a baffle.
10. A mixing device as defined in any one of claims 6 to 9 in which the blanked off sleeve
15 end is supported by a baffle.
11. A mixing device as defined in claim 9 or 10 in which a portion of the baffle acts to blank off the blanked off tube end and/or the blanked off sleeve end.
- 20 12. A mixing device as defined in claim 3 in which the tube is cylindrical.
13. A mixing device as defined in any one of claims 6 to 12 in which the sleeve is cylindrical.
- 25 14. A mixing device as defined in claim 7 when dependent upon claim 5 in which an open area of the tube perforations is approximately equal to an open area of the sleeve perforations.
15. A mixing device as defined in claim 7 when dependent on claim 5 in which an open
30 area (A2) of the tube perforations and/or an open area (A3) of the sleeve perforations is greater than or equal to 1.5 times the cross section area (A1) of the inlet.

16. A mixing device as defined in any preceding claim in which the cross section area (A5) of the third part is approximately equal to or greater than the cross section area (A1) of the first part and/or the cross section area (A5) of the third part is approximately equal to the cross section area (A4) of the second part and/or the cross section area (A4) of the second part is approximately equal to or greater than the cross sectional area of the first part (A1).
17. A mixing device as defined in claim 7 when dependent upon claim 5 in which the sleeve perforations do not axially overlap with the tube perforations.
18. A mixing device as defined in any preceding claim in which the shell includes thermal insulation.
19. A mixing device as defined in claim 1 or 2 in which an outlet is defined by a central tube positioned within the shell and an inlet is defined by an annulus, said annulus being partially defined by said shell.
20. A mixing device as defined in any preceding claim in which the injector is positioned to inject a reagent at the inlet of the mixing device.
21. An exhaust system including a mixing device as defined in claim 20 and an integrated catalyst.
22. An exhaust system including a mixing device as defined in any one of claims 1 to 19 in which the injector is positioned upstream of the mixing device.
23. An exhaust system as defined in claim 22 including an integrated catalyst.
24. A mixing device for mixing a gas and a liquid in an exhaust system, the mixing device having an injector for injecting the liquid and having a shell and an inlet and an outlet and an exhaust gas flow path between the inlet and outlet, the mixing device defining an axis and the flow path having a first, second and third part,

the first part extending generally parallel to the axis to direct flow in a generally forward direction,

the second part extending generally parallel to the axis to direct flow in a generally reverse direction,

5 the third part extending generally parallel to the axis to direct flow in the generally forward direction,

in which the second part generally surrounds the first part and the third part generally surrounds the second part.

10 25. A mixing device as defined in claim 24 in which the exhaust gas flow path is substantially symmetrical about a centre line of the mixing device.

26. A mixing device as defined in claim 24 or 25 in which the inlet is defined by a central tube at least partially positioned within the shell and the outlet is defined at least
15 partially by said shell.

27. A mixing device as defined in claim 26 in which the tube includes a blanked off tube end.

20 28. A mixing device as defined in claim 27 in which the tube includes tube perforations proximate said blanked off tube end.

29. A mixing device as defined in claim 28 including a sleeve positioned within the shell and surrounding said tube perforations and being spaced from said tube perforations,
25 said sleeve having a blanked off sleeve end proximate said blanked off tube end.

30. A mixing device as defined in claim 29 in which the sleeve includes sleeve perforations remote from the said blanked off sleeve end.

30 31. A mixing device as defined in claim 29 or 30 in which said third part is an annulus and the sleeve partially defines said annulus.

32. A mixing device as defined in any one of claims 27 to 31 in which the blanked off tube end is supported by a baffle.
- 5 33. A mixing device as defined in any one of claims 29 to 32 in which the blanked off sleeve end is supported by a baffle.
34. A mixing device as defined in claim 32 or 33 in which a portion of the baffle acts to blank off the blanked off tube end and/or the blanked off sleeve end.
- 10 35. A mixing device as defined in claim 26 in which the tube is cylindrical.
36. A mixing device as defined in any one of claims 29 to 35 in which the sleeve is cylindrical.
- 15 37. A mixing device as defined in claims 24 to 36 in which the shell is cylindrical.
38. A mixing device as defined in claim 30 when dependent upon claim 28 in which an open area of the tube perforations is approximately equal to an open area of the sleeve perforations.
- 20 39. A mixing device as defined in claim 30 when dependent on claim 28 in which an open area (A2) of the tube perforations and/or an open area (A3) of the sleeve perforations is greater than or equal to 1.5 times the cross section area (A1) of the inlet.
- 25 40. A mixing device as defined in claims 24 to 39 in which the cross section area (A5) of the third part is approximately equal to or greater than the cross section area (A1) of the first part and/or the cross section area (A5) of the third part is approximately equal to the cross section area (A4) of the second part and/or the cross section area (A4) of the second part is approximately equal to or greater than the cross sectional area of the first part (A1).
- 30 41. A mixing device as defined in claim 30 when dependent upon claim 28 in which the sleeve perforations do not axially overlap with the tube perforations.

42. A mixing device as defined in claims 24 to 41 in which the shell includes thermal insulation.

5 43. A mixing device as defined in claims 24 to 42 in which the injector is positioned to inject a reagent at the inlet of the mixing device.

44. An exhaust system including a mixing device as defined in claim 43 and an integrated catalyst.

10

45. An exhaust system including a mixing device as defined in any one of claims 24 to 42 in which the injector is positioned upstream of the mixing device.

46. An exhaust system as defined in claim 45 including an integrated catalyst.

15

47. A mixing device for mixing a gas and a liquid in an exhaust system, the mixing device having an injector for injecting the liquid and having a shell and an inlet and an outlet and an exhaust gas flow path between the inlet and outlet,

the mixing device defining an axis and the flow path having a first, second and third part,

20

the first part extending generally parallel to the axis to direct flow in a generally forward direction,

the second part extending generally parallel to the axis to direct flow in a generally reverse direction,

25

the third part extending generally parallel to the axis to direct flow in the generally forward direction,

in which the first part generally surrounds the second part and the second part generally surrounds the third part.

30

48. A mixing device as defined in claim 47 in which an outlet is defined by a central tube positioned within the shell and an inlet is defined by an annulus, said annulus being partially defined by said shell.

49. A mixing device for an exhaust system, the mixing device having a shell and an inlet and an outlet and an exhaust gas flow path between the inlet and the outlet in which the flow path includes a first general reversal of the direction of exhaust gas flow and the shell includes thermal insulation.

5

50. A mixing device as defined in claim 49 in which the exhaust gas flow path includes a second general reversal of the direction of exhaust gas flow.

10

51. A mixing device as defined in claim 49 or 50 in which the exhaust gas flow path is substantially symmetrical about a centre line of the mixing device.

52. A mixing device as defined in claims 49 to 51 in which the inlet is defined by a central tube at least partially positioned within the shell and the outlet is defined at least partially by said shell.

15

53. A mixing device as defined in claim 52 in which the tube includes a blanked off tube end.

20

54. A mixing device as defined in claim 53 in which the tube includes tube perforations proximate said blanked off tube end.

25

55. A mixing device as defined in claim 54 including a sleeve positioned within the shell and surrounding said tube perforations and being spaced from said tube perforations, said sleeve having a blanked off sleeve end proximate said blanked off tube end.

30

56. A mixing device as defined in claim 55 in which the sleeve includes sleeve perforations remote from the said blanked off sleeve end.

57. A mixing device as defined in claim 55 or 56 when dependent upon claim 50 in which the sleeve partially defines an annulus through which the exhaust gas flows following the second general reversal of the direction of exhaust gas flow.

58. A mixing device as defined in any one of claims 53 to 57 in which the blanked off tube end is supported by a baffle, and preferably a portion of the baffle acts to blank off the blanked off tube end.

5 59. A mixing device as defined in any one of claims 55 to 58 in which the blanked off sleeve end is supported by a baffle, and preferably a portion of the baffle acts to blank off the blanked off sleeve end.

60. A mixing device as defined in claim 52 in which the tube is cylindrical.

10

61. A mixing device as defined in any one of claims 55 to 60 in which the sleeve is cylindrical.

15 62. A mixing device as defined in claim 56 when dependent upon claim 54 in which an open area of the tube perforations is approximately equal to an open area of the sleeve perforations.

20 63. A mixing device as defined in claim 56 when dependent on claim 54 in which an open area (A2) of the tube perforations and/or an open area (A3) of the sleeve perforations is greater than or equal to 1.5 times the cross section area (A1) of the inlet.

25 64. A mixing device as defined in claims 50 to 63 in which the cross section area (A5) of the flow path following the second general reversal is approximately equal to or greater than the cross section area (A1) of the inlet and/or the cross section area (A5) of the flow path following the second general reversal is approximately equal to the cross section area (A4) of the flow path following the first general reversal of the direction of exhaust gas flow and/or the cross section area (A4) of the flow path following the first general reversal of the direction of exhaust gas flow is approximately equal to or greater than the cross sectional area of the inlet (A1).

30

65. A mixing device as defined in claim 56 when dependent upon claim 54 in which the sleeve perforations do not axially overlap with the tube perforations.

66. A mixing device as defined in any claims 49 to 65 including an injector positioned to inject a reagent at the inlet of the mixing device.

5 67. An exhaust system including a mixing device as defined in claim 66 and an integrated catalyst.

68. An exhaust system including a mixing device as defined in any one of claims 49 to 65 and an injector positioned upstream of the mixing device.

10 69. An exhaust system as defined in claim 68 including an integrated catalyst.

70. An exhaust gas treatment system including

a first exhaust gas treatment device selected from a filter and a catalyst,

a second exhaust gas treatment device selected from a filter and a catalyst and

15 a mixing device for mixing exhaust gas and a liquid, the mixing device having an injector for injecting the liquid and having a shell and an inlet and an outlet and an exhaust gas flow path between the inlet and outlet,

the mixing device defining an axis and the flow path having a first, second and third part,

20 the first part extending generally parallel to the axis to direct flow in a generally forward direction,

the second part extending generally parallel to the axis to direct flow in a generally reverse direction,

25 the third part extending generally parallel to the axis to direct flow in the generally forward direction,

in which the first gas treatment device is generally cylindrical with a first cross section area the second gas treatment device is generally cylindrical with a second cross section area

and the mixing device is generally cylindrical with a third cross section area

30 and the first cross sectional area, second cross sectional area and third cross sectional area are generally the same.

71. A mixing device as defined in claim 70 in which the exhaust gas flow path is substantially symmetrical about a centre line of the mixing device.

5 72. A mixing device as defined in claim 70 or 71 in which the inlet is defined by a central tube at least partially positioned within the shell and the outlet is defined at least partially by said shell.

73. A mixing device as defined in claim 72 in which the tube includes a blanked off tube end.

10

74. A mixing device as defined in claim 73 in which the tube includes tube perforations proximate said blanked off tube end.

15

75. A mixing device as defined in claim 74 including a sleeve positioned within the shell and surrounding said tube perforations and being spaced from said tube perforations, said sleeve having a blanked off sleeve end proximate said blanked off tube end.

76. A mixing device as defined in claim 75 in which the sleeve includes sleeve perforations remote from the said blanked off sleeve end.

20

77. A mixing device as defined in claim 75 or 76 in which said third part is an annulus and the sleeve partially defines said annulus.

25

78. A mixing device as defined in any one of claims 73 to 77 in which the blanked off tube end is supported by a baffle.

79. A mixing device as defined in any one of claims 75 to 78 in which the blanked off sleeve end is supported by a baffle.

30

80. A mixing device as defined in claim 78 or 79 in which a portion of the baffle acts to blank off the blanked off tube end and/or the blanked off sleeve end.

81. A mixing device as defined in claim 72 in which the tube is cylindrical.

82. A mixing device as defined in any one of claims 75 to 81 in which the sleeve is cylindrical.
- 5 83. A mixing device as defined in claim 76 when dependent upon claim 74 in which an open area of the tube perforations is approximately equal to an open area of the sleeve perforations.
84. A mixing device as defined in claim 76 when dependent on claim 74 in which an open
10 area (A2) of the tube perforations and/or an open area (A3) of the sleeve perforations is greater than or equal to 1.5 times the cross section area (A1) of the inlet.
85. A mixing device as defined in claims 70 to 84 in which the cross section area (A5) of
15 the third part is approximately equal to or greater than the cross section area (A1) of the first part and/or the cross section area (A5) of the third part is approximately equal to the cross section area (A4) of the second part and/or the cross section area (A4) of the second part is approximately equal to or greater than the cross sectional area of the first part (A1).
- 20 86. A mixing device as defined in claim 76 when dependent upon claim 74 in which the sleeve perforations do not axially overlap with the tube perforations.
87. A mixing device as defined in claims 70 to 86 in which the shell includes thermal
25 insulation.
88. A mixing device as defined in claim 70 in which an outlet is defined by a central tube positioned within the shell and an inlet is defined by an annulus, said annulus being partially defined by said shell.
- 30 89. A mixing device as defined in claims 70 to 88 including an injector positioned to inject a reagent at the inlet of the mixing device.

90. An exhaust system including a mixing device as defined in claim 89 and an integrated catalyst.
91. An exhaust system including a mixing device as defined in any one of claims 70 to 88
5 and an injector positioned upstream of the mixing device.
92. An exhaust system as defined in claim 91 including an integrated catalyst.
93. A mixing device for an exhaust system, the mixing device having a shell and an inlet
10 and an outlet and an exhaust gas flow path between the inlet and the outlet, the mixing device defining an axis and the flow path having a first, second and third region, the first region extending generally parallel to the axis to direct flow in a generally forward direction, the second region being defined by perforated holes in a tube to direct flow in a generally radial direction, the third region extending generally parallel to the axis
15 to direct flow in the generally forward direction.
94. A mixing device as defined in claim 93 in which the flow path includes a first general reversal of the direction of exhaust gas flow.
- 20 95. A mixing device as defined in claim 93 or 94 in which the exhaust gas flow path includes a second general reversal of the direction of exhaust gas flow.
96. A mixing device as defined in claims 93 or 94 or 95 in which the exhaust gas flow path is substantially symmetrical about a centre line of the mixing device.
25
97. A mixing device as defined in claims 93 to 96 in which the tube is a central tube and the inlet is defined by the central tube which is at least partially positioned within the shell and the outlet is defined at least partially by said shell.
- 30 98. A mixing device as defined in claim 97 in which the perforated holes are formed on a cylindrical or conical portion of the tube.

99. A mixing device as defined in claim 97 or 98 in which the tube includes a blanked off tube end.

5 100. A mixing device as defined in claim 99 in which the tube includes said perforated holes positioned proximate said blanked off tube end.

101. A mixing device as defined in claims 93 to 100 in which the flow path has a fourth region between the second and third region, said fourth region being defined by further perforated holes in a sleeve to direct flow in a generally radial direction.

10

102. A mixing device as defined in claim 101 in which the further perforated holes are formed on a cylindrical or conical portion of the sleeve.

15 103. A mixing device as defined in claim 101 or 102 in which the sleeve is positioned within the shell and surrounding said perforated holes and being spaced from said perforated holes, said sleeve having a blanked off sleeve end proximate said blanked off tube end.

20 104. A mixing device as defined in claim 103 in which the further perforated holes are remote from the said blanked off sleeve end.

105. A mixing device as defined in claim 103 or 104 in which said third region is an annulus in which the sleeve partially defines said annulus.

25 106. A mixing device as defined in any one of claims 99 to 105 in which the blanked off tube end is supported by a baffle.

107. A mixing device as defined in any one of claims 103 to 106 in which the blanked off sleeve end is supported by a baffle.

30

108. A mixing device as defined in claim 106 or 107 in which a portion of the baffle acts to blank off the blanked off tube end and/or the blanked off sleeve end.

109. A mixing device as defined in claim 93 in which the tube is cylindrical.

110. A mixing device as defined in any one of claims 103 to 109 in which the sleeve is cylindrical.

5

111. A mixing device as defined in claim 101 in which an open area of the perforated holes is approximately equal to an open area of the further perforated holes.

10 112. A mixing device as defined in claim 101 in which an open area (A2) of the perforated holes and/or an open area (A3) of the further perforated holes is greater than or equal to 1.5 times the cross section area (A1) of the inlet.

15 113. A mixing device as defined in claims 93 to 112 in which the cross section area (A5) of the flow path following the second general reversal is approximately equal to or greater than the cross section area (A1) of the inlet and/or the cross section area (A5) of the flow path following the second general reversal is approximately equal to the cross section area (A4) of the flow path following the first general reversal of the direction of exhaust gas flow and/or the cross section area (A4) of the flow path following the first general reversal of the direction of exhaust gas flow is approximately equal to or
20 greater than the cross sectional area of the inlet (A1).

114. A mixing device as defined in claim 101 in which the further perforated holes do not axially overlap with the perforated holes.

25 115. A mixing device as defined in claims 93 to 114 in which the shell includes thermal insulation.

116. A mixing device as defined in claim 93 in which an outlet is defined by a central tube positioned within the shell and an inlet is defined by an annulus, said annulus
30 being partially defined by said shell.

117. A mixing device as defined in claims 93 to 116 including an injector positioned to inject a reagent at the inlet of the mixing device.

118. An exhaust system including a mixing device as defined in claim 117 and an integrated catalyst.

5 119. An exhaust system including a mixing device as defined in any one of claims 93 to 116 and an injector positioned upstream of the mixing device.

120. An exhaust system as defined in claim 119 including an integrated catalyst.

10 121. A mixing device for an exhaust system, the mixing device having a shell and an inlet and an outlet and an exhaust gas flow path between the inlet and the outlet in which the flow path includes a first general reversal of the direction of exhaust gas flow, and a second general reversal of the direction of exhaust gas flow,
a first intermediate region between the first general reversal and the second general
15 reversal
a second intermediate region between the second general reversal and the outlet,
the exhaust gas flow path having
an inlet gas flow area at the inlet,
a first reversal gas flow area proximate the first general reversal
20 a first intermediate gas flow area at the first intermediate region
a second reversal gas flow area proximate the second general reversal
a second intermediate gas flow area at the second intermediate region
an outlet gas flow area at the outlet in which
the first reversal gas flow area is greater than the inlet gas flow area and greater than
25 the first intermediate gas flow area
the second reversal gas flow area is greater than the first intermediate gas flow area and
second intermediate gas flow area
outlet gas flow area is greater than the second intermediate gas flow area so that the
exhaust gas expands, then contracts, then expands, then contracts, then expands when
30 passing from the inlet to the outlet.

122. A mixing device as defined in claim 121 in which the exhaust gas flow path is substantially symmetrical about a centre line of the mixing device.

123. A mixing device as defined in claims 121 or 123 in which the inlet is defined by a central tube at least partially positioned within the shell and the outlet is defined at least partially by said shell.
- 5 124. A mixing device as defined in claim 123 in which the tube includes a blanked off tube end.
125. A mixing device as defined in claim 124 in which the tube includes tube perforations proximate said blanked off tube end, an open area of said tube perforations
10 defining the first reversal gas flow area.
126. A mixing device as defined in claim 125 including a sleeve positioned within the shell and surrounding said tube perforations and being spaced from said tube perforations, said sleeve having a blanked off sleeve end proximate said blanked off
15 tube end.
127. A mixing device as defined in claim 126 in which the sleeve includes sleeve perforations remote from the said blanked off sleeve end, an open area of said sleeve perforations defining the second reversal gas flow area.
20
128. A mixing device as defined in claim 126 or 127 in which said second intermediate gas flow region is an annulus in which the sleeve partially defines said annulus.
129. A mixing device as defined in any one of claims 124 to 128 in which the blanked
25 off tube end is supported by a baffle.
130. A mixing device as defined in any one of claims 126 to 129 in which the blanked off sleeve end is supported by a baffle.
- 30 131. A mixing device as defined in claim 129 or 130 in which a portion of the baffle acts to blank off the blanked off tube end and/or the blanked off sleeve end.
132. A mixing device as defined in claim 123 in which the tube is cylindrical.

133. A mixing device as defined in any one of claims 126 to 132 in which the sleeve is cylindrical.
- 5 134. A mixing device as defined in claim 127 when dependent upon claim 125 in which an open area of the tube perforations is approximately equal to an open area of the sleeve perforations.
- 10 135. A mixing device as defined in claim 127 when dependent on claim 125 in which an open area (A2) of the tube perforations and/or an open area (A3) of the sleeve perforations is greater than or equal to 1.5 times the inlet gas flow area.
- 15 136. A mixing device as defined in claims 121 to 135 in which the second intermediate gas flow area is approximately equal to or greater than the inlet gas flow area and/or the second intermediate gas flow area is approximately equal to the first intermediate gas flow area and/or the first intermediate gas flow area is approximately equal to or greater than the inlet gas flow area.
- 20 137. A mixing device as defined in claim 127 when dependent upon claim 125 in which the sleeve perforations do not axially overlap with the tube perforations.
138. A mixing device as defined in claims 121 to 137 in which the shell includes thermal insulation.
- 25 139. A mixing device as defined in claims 121 to 138 including an injector positioned to inject a reagent at the inlet of the mixing device.
140. An exhaust system including a mixing device as defined in claim 139 and an integrated catalyst.
- 30 141. An exhaust system including a mixing device as defined in any one of claims 121 to 138 and an injector positioned upstream of the mixing device.

142. An exhaust system as defined in claim 141 including an integrated catalyst.

143. A method of treating exhaust gases of an internal combustion engine including the steps of

- 5 providing an exhaust system having an injector at an upstream position and, a mixing device at a downstream position,
passing exhaust gas into the exhaust system,
using the injector to inject a reagent into the gas stream,
passing the reagent and exhaust gas into the mixing device and substantially
10 reversing the direction of flow of the gas and reagent in the mixing device.

1/7

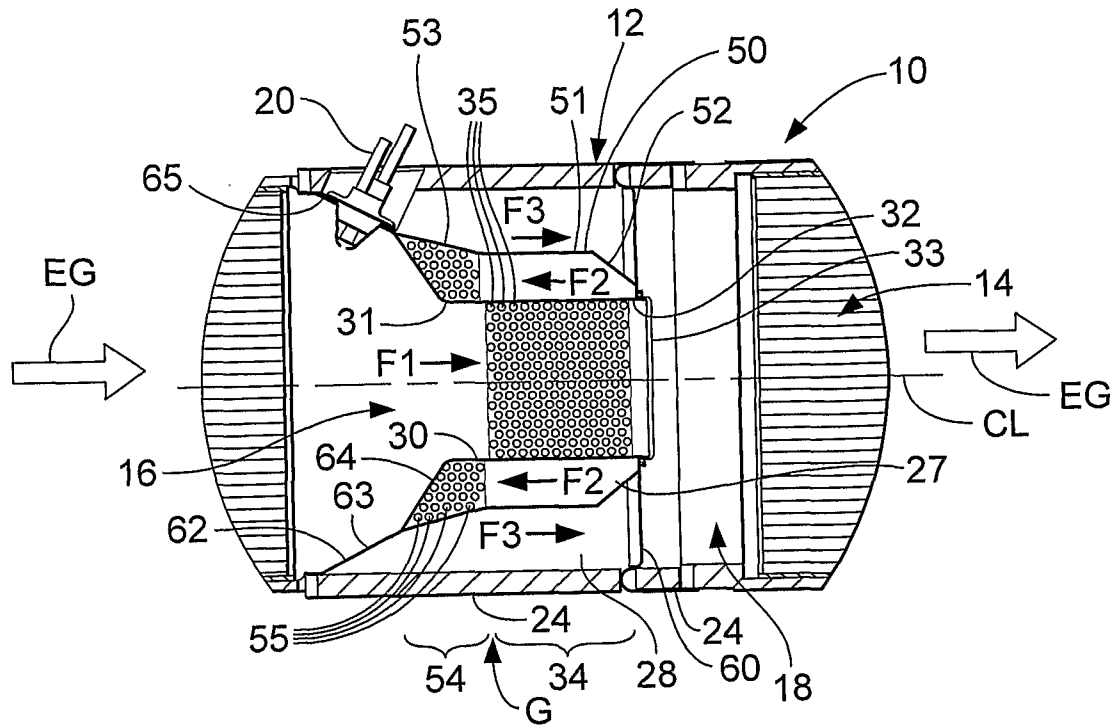


Fig.1

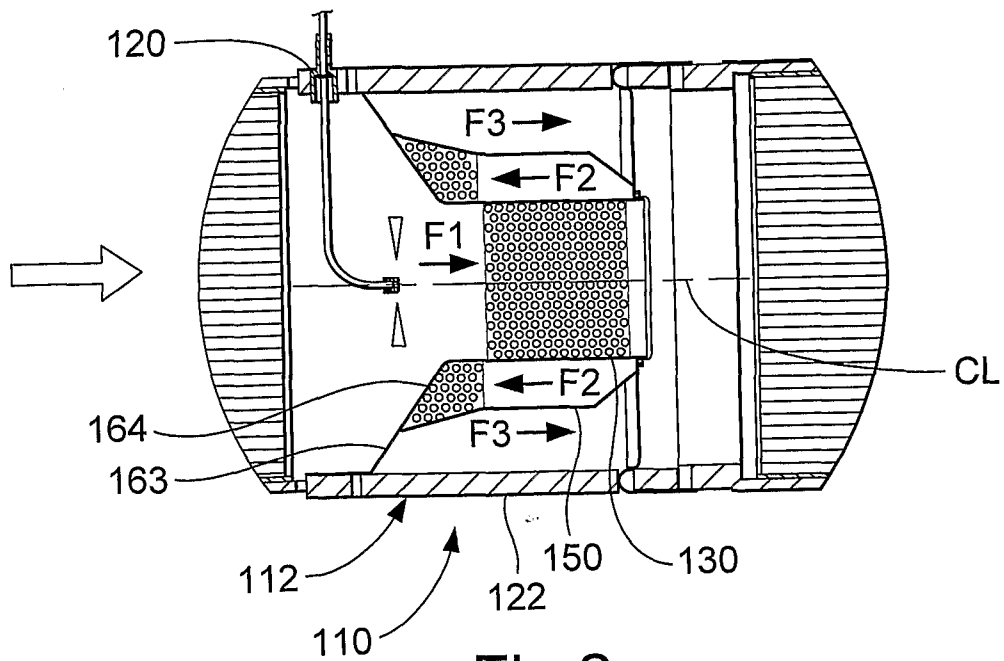
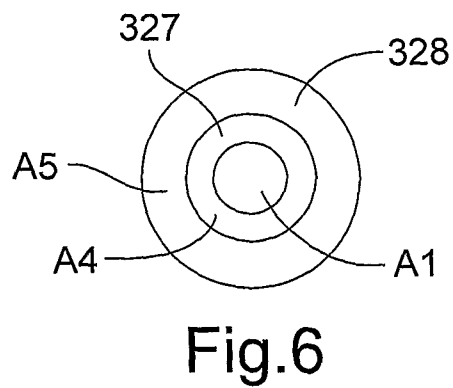
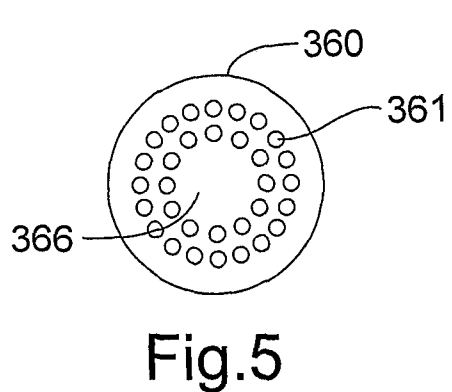
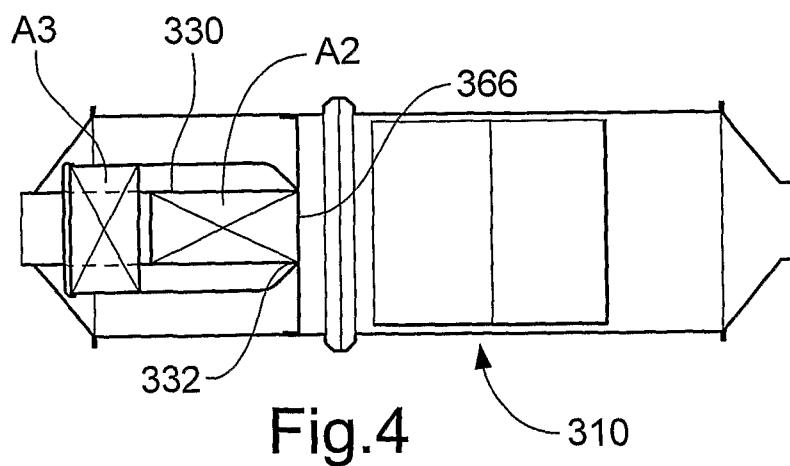
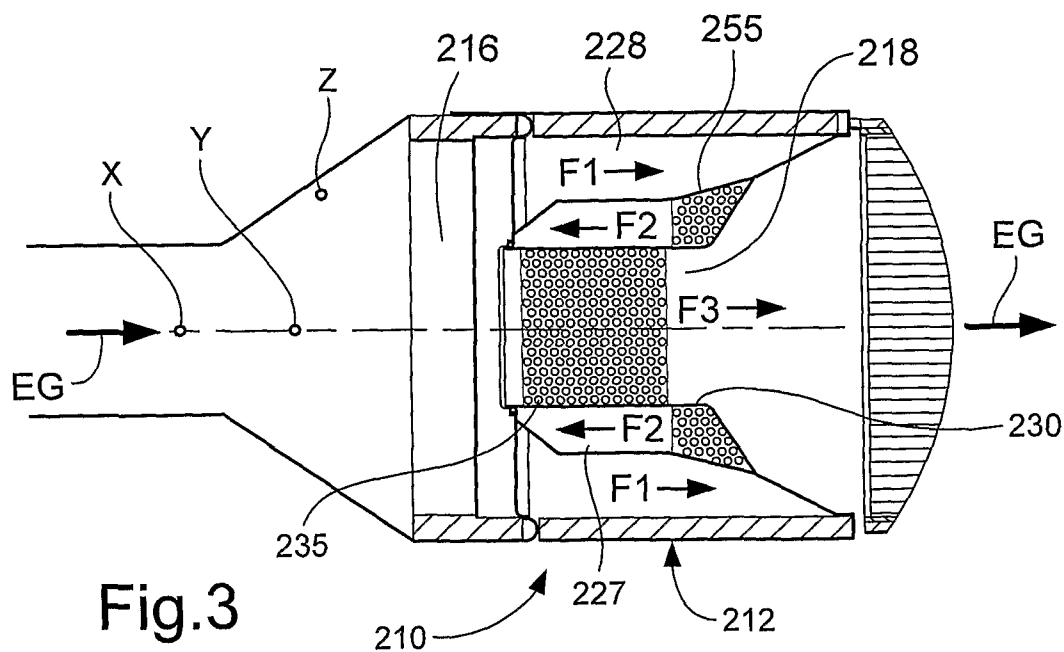
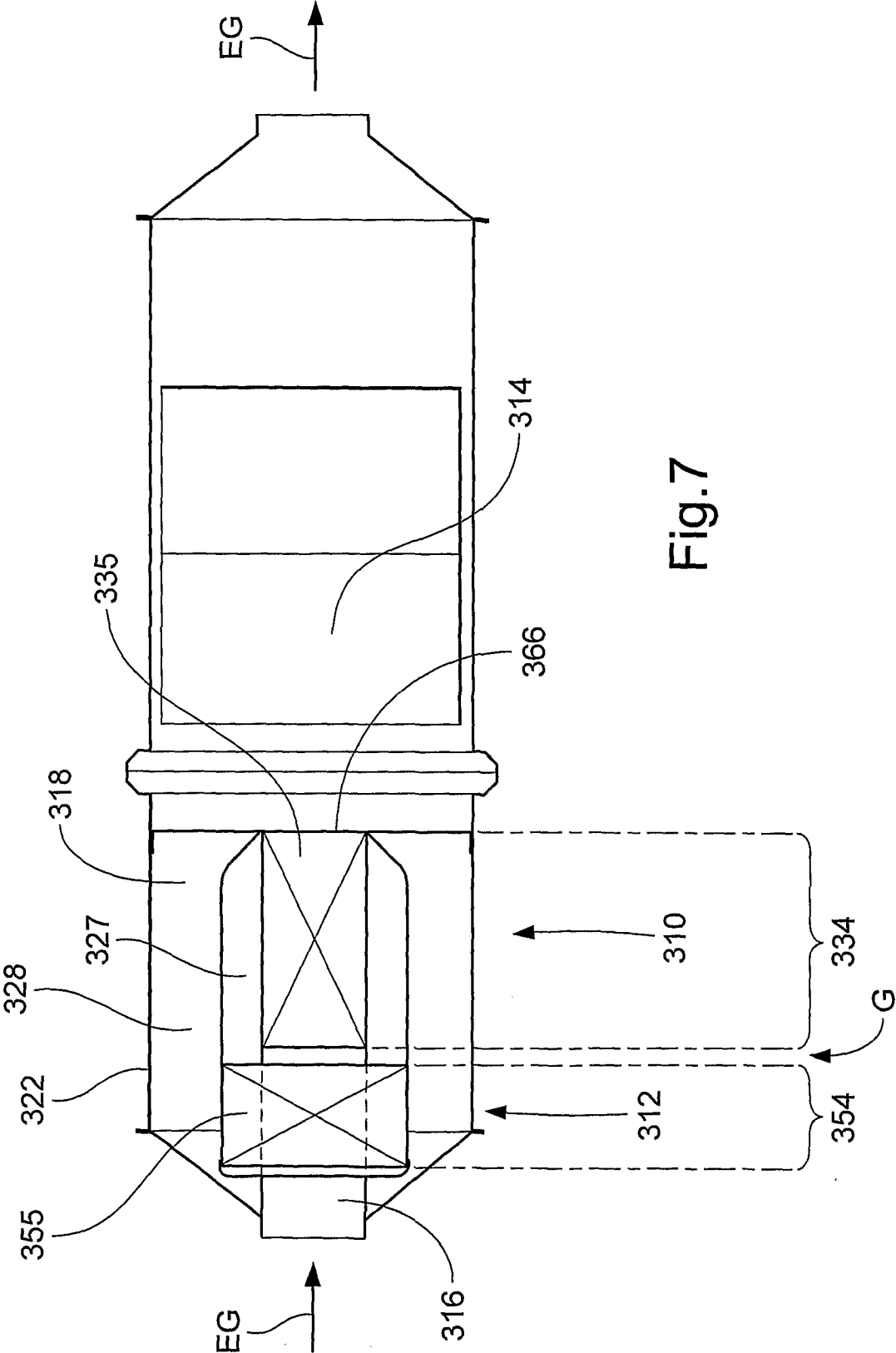
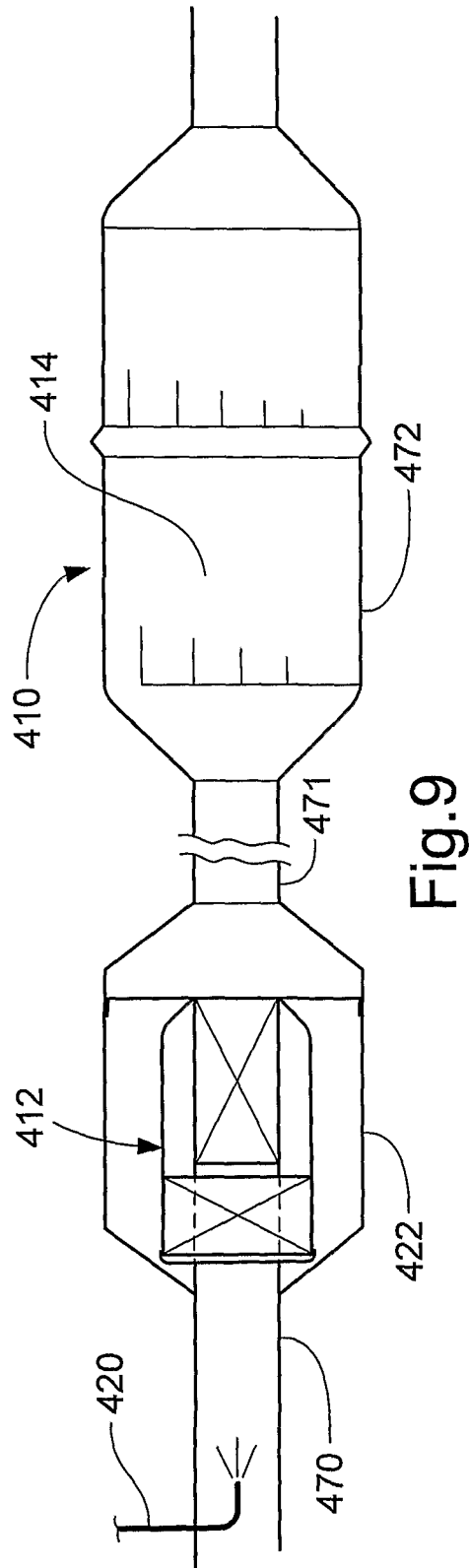
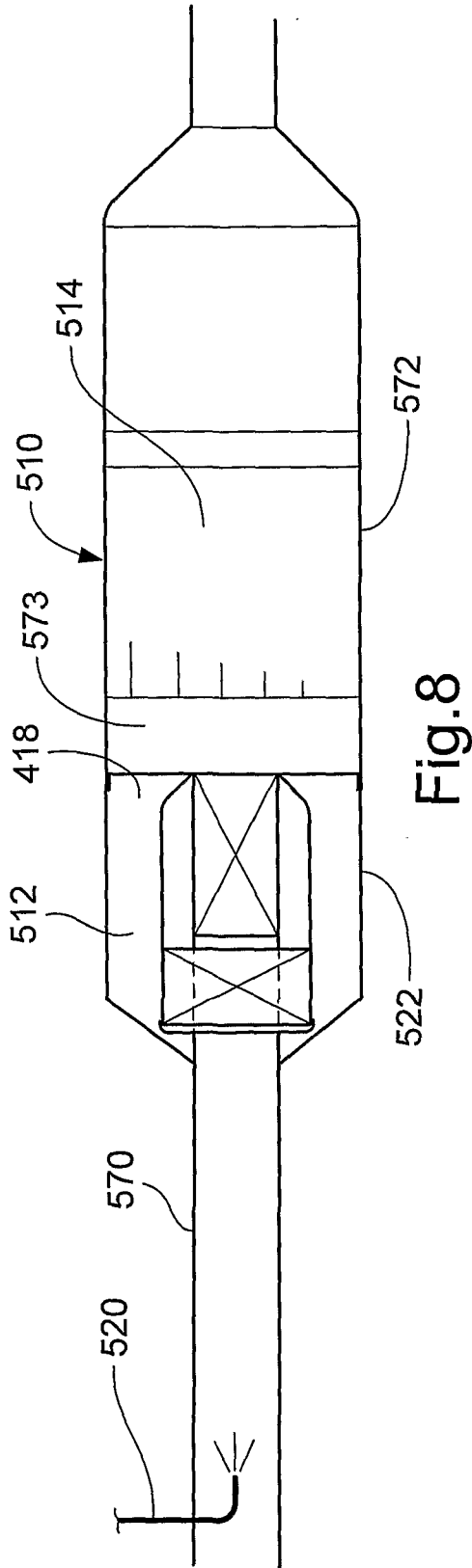


Fig.2

2/7







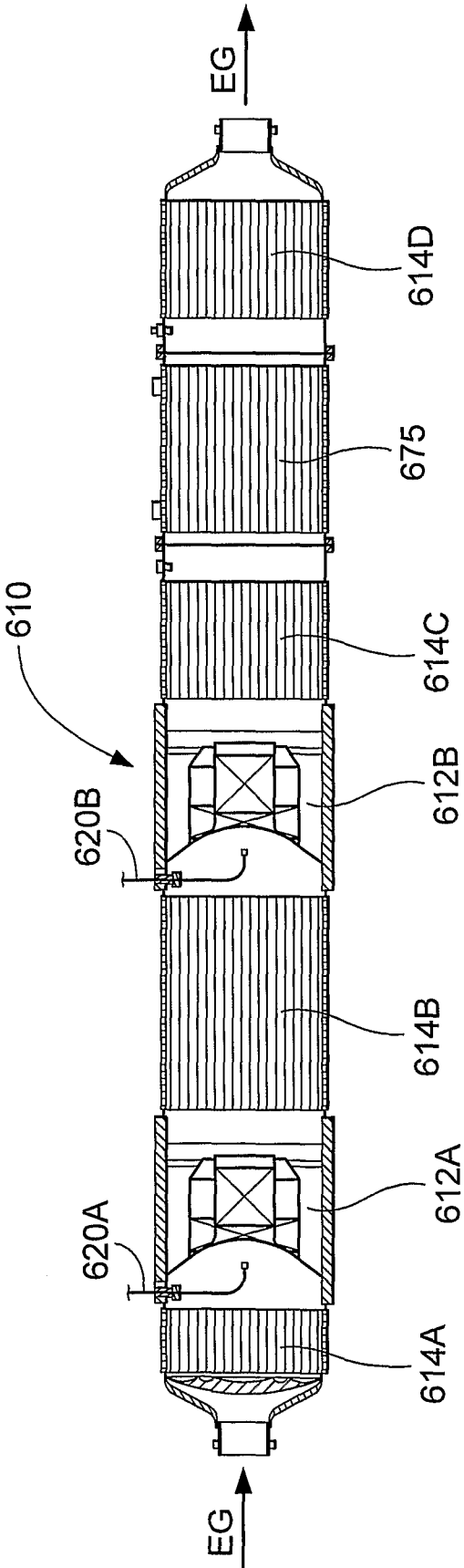
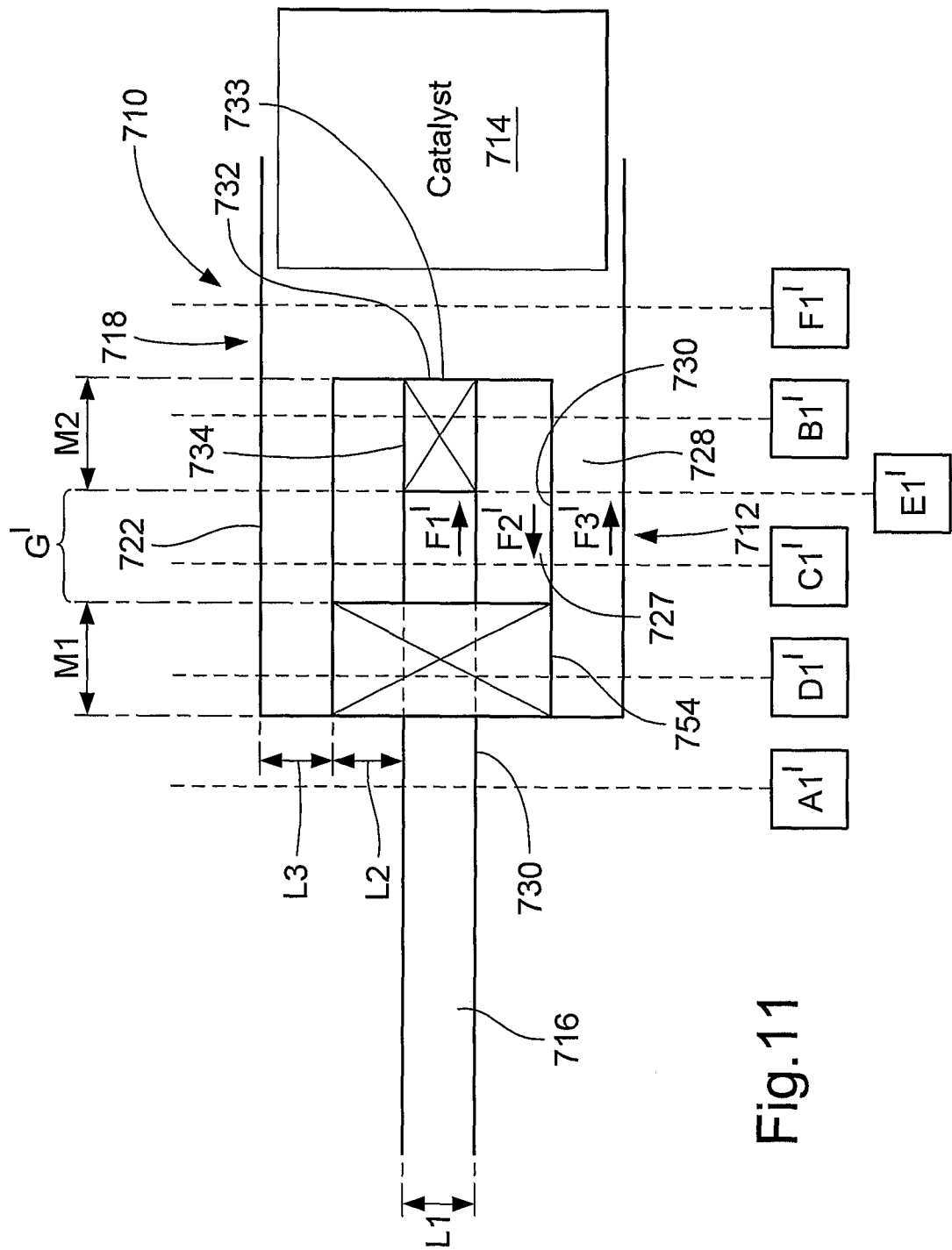


Fig.10



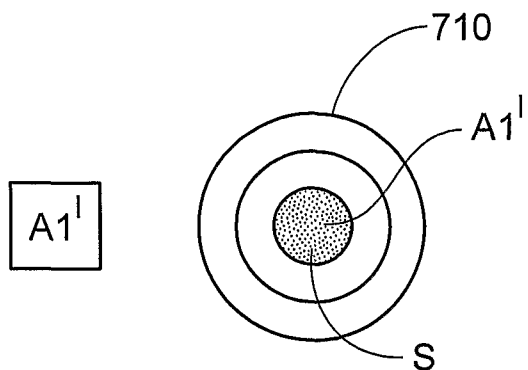


Fig12A

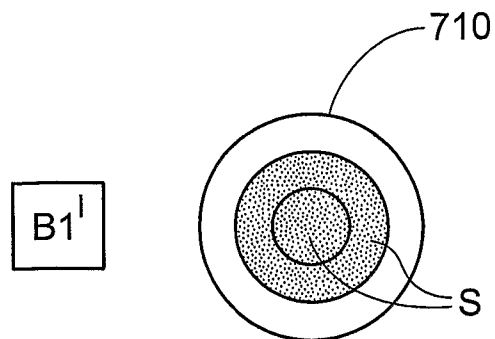


Fig12B

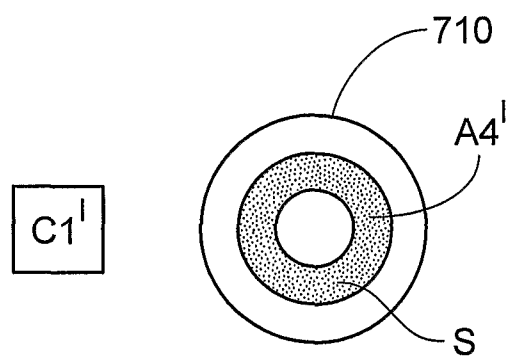


Fig12C

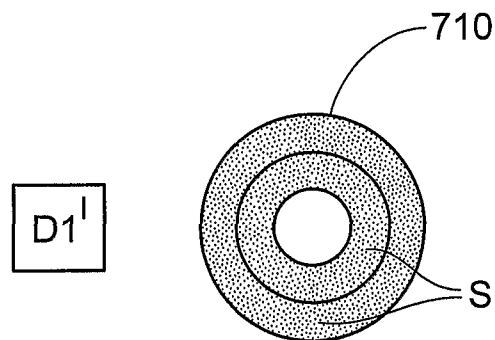


Fig12D

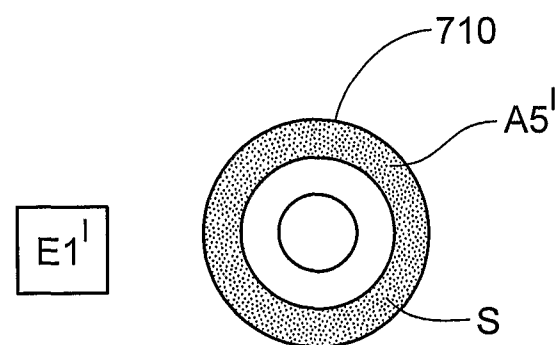


Fig12E

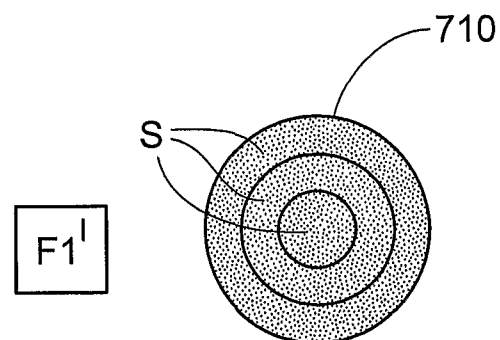


Fig12F

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2007/000844

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01N3/20

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)

F01N

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 97/01387 A (SIEMENS AG [DE]; MUELLER RAIMUND [DE]; HOFMANN LOTHAR [DE]; SCHARDT KU) 16 January 1997 (1997-01-16) page 9, line 13 - page 11, line 19; figure 5	1,143
X	----- EP 0 558 452 A1 (HUG HANS THOMAS [CH]; HARTENSTEIN AXEL [CH]; HUG MICHAEL [CH]) 1 September 1993 (1993-09-01) abstract; figure 1	1,143
A	----- US 3 741 730 A (ALCOTT F) 26 June 1973 (1973-06-26) abstract; figure 1	1
A	----- US 2005/210865 A1 (BOLANDER THOMAS E [US] ET AL) 29 September 2005 (2005-09-29) abstract; figure 1	1



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *8* document member of the same patent family

Date of the actual completion of the international search

6 June 2007

Date of mailing of the international search report

15/06/2007

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Tatus, Walter

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB2007/000844

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.: 24-142
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 24-142

Although claims 1, 24, 47, 70, 93 and 121 have been drafted as separate independent claims, they appear to relate effectively to the same subject-matter and to differ from each other only with regard to the definition of the subject-matter for which protection is sought or in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness and as such do not meet the requirements of Article 6 PCT.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.5), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2007/000844

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 9701387	A	16-01-1997	AT 193222 T	15-06-2000
			DK 835160 T3	09-10-2000
			EP 0835160 A1	15-04-1998
			ES 2147925 T3	01-10-2000
			JP 10511038 T	27-10-1998
			TW 416865 B	01-01-2001
			US 6444177 B1	03-09-2002

EP 0558452	A1	01-09-1993	AT 121966 T	15-05-1995
			CA 2088713 A1	25-08-1993
			DE 59300175 D1	08-06-1995
			DK 558452 T3	02-10-1995
			ES 2074921 T3	16-09-1995
			JP 6007643 A	18-01-1994
			US 5431893 A	11-07-1995

US 3741730	A	26-06-1973	NONE	

US 2005210865	A1	29-09-2005	DE 102005008579 A1	27-10-2005
