(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 June 2013 (27.06.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/095205 A1

(51) International Patent Classification:
F01N 13/20 (2010.01) *F0IN 13/08* (2010.01)

(21) International Application Number:
PCT/SE201 1/000239

(22) International Filing Date:
22 December 201 1 (22. 12.201 1)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available):* AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available):* ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

WO 2013/095205 A1

(54) Title: EXHAUST COLLING APPARATUS

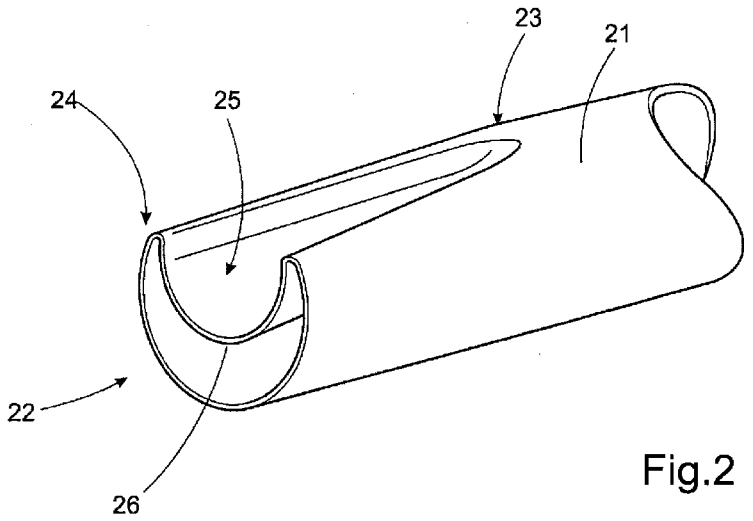


Fig.2

(57) Abstract: The invention relates to an apparatus for cooling exhaust gases from an internal combustion engine, the apparatus comprising: an exhaust tailpipe (21 ; 31; 51) having a proximal end (23; 33; 53) and a distal end (24; 34; 54), the proximal end configured to receive exhaust gases from the engine, and the distal end configured to expel the exhaust gases into the atmosphere. The proximal end (23; 33; 53) has a circular cross-section and the distal end (24; 34; 54) has a C-shaped cross-section, where the change in cross- section occurs at a predetermined rate along a predetermined length $(L_i; L_2 L_3)$ of the tailpipe between the proximal end and the distal end (24; 34; 54).

EXHAUST COOLING APPARATUS

TECHNICAL FIELD

This invention relates to exhaust systems, and more particularly to apparatuses, systems, and methods for cooling exhaust gas as it exits into the ambient atmosphere from an enclosed exhaust stream.

BACKGROUND ART

Environmental regulations are becoming increasingly strict with regard to engine exhaust emissions such as nitrogen oxides (NOx) and particulate matter. New, more stringent, environmental regulations with regard to diesel engine particulate emissions has occasioned the need for diesel particulate filters and/or other exhaust treatment devices such as NOx adsorbers to be placed in the exhaust stream before the exhaust is permitted to enter the atmosphere. In most cases, an exhaust treatment system must initiate regeneration of particulate filters, NOx adsorbers, and other exhaust treatment devices from time to time as the devices fill up with soot, NOx, or the like. In the case of a particulate filter, as one example, this is done by increasing the temperature of the filter to a level where the soot is oxidized, above 400-600 °C, and maintaining that temperature for several minutes or longer, depending on circumstances including the size of the filter, the amount of soot on the filter, the uniformity level of the soot and other pollutants.

The high filter temperatures required for regenerations of this type increase the temperature of the exhaust, particularly at stationary or low-speed operation, meaning the exhaust leaves the tailpipe of the vehicle at a much higher temperature than it would during normal operation. The temperature of the exhaust leaving an unobstructed tailpipe with a nominal outer diameter of 120-155 mm may expel a hot, pointed exhaust gas flow at a temperature of

about 200-500 °C over a distance in excess of one metre. This creates a potential safety hazard with regard to the heat of the exhaust gases leaving the tailpipe and creating discomfort or injury to humans, animals, or plants in proximity. It also increases the surface temperature of exhaust components.

The general problem of heat reduction as the exhaust enters the atmosphere has been solved in different ways in the past, for instance by equipping the exhaust outlet with a water spray device for exhaust cooling, but such a solution is limited to a situation where there is a ready water supply available on the vehicle.

An alternative solution is shown in US 2008/099276, in which an exhaust diffuser is disclosed for coupling to an exhaust system of a vehicle that, when in one orientation, is designed to expel exhaust gasses laterally and downwardly from the exhaust diffuser. A problem with this solution is that a diffuser of this type does not provide full control of the direction of the exhaust gas, which is especially important when exhaust gases are expelled under the vehicle, e.g. when the chosen exhaust direction is rearwards. Although the turbulence generated by the diffuser assists in cooling the exhaust gas, local hot-spots can be created when the direction of the flow is uncontrolled.

US 2007/163249 discloses a lobed exhaust diffuser apparatus configured to cool exhaust gases from an internal combustion engine. A diffuser is provided with a plurality of lobes disposed on the distal end of the tailpipe so that at least a portion of the exhaust gases pass through the lobes, in order to increase the interaction surface area between the exhaust gases and the atmosphere. This allows for diffusion and entrainment between exhaust gases and atmospheric gases, resulting in a cooling of the exhaust gases. A problem with this solution is that the diffuser only handles a portion of the exhaust gases, wherein a major portion of the hot exhaust gases leave the centre of the diffuser with little or no added cooling.

The solution according to the invention aims to provide an improved arrangement for cooling exhaust gas as it exits into the ambient atmosphere from an enclosed exhaust stream by overcoming the above problems.

DISCLOSURE OF INVENTION

The above problems are solved by an apparatus for cooling exhaust gases according to the appended claims.

In the subsequent text, the term "longitudinal" is used to denote a direction in the main direction of the exhaust pipe. A central axis is defined as the axis through the geometric centre of a circle or a partial circle in a plane a right angles to the longitudinal axis of the exhaust pipe. A plane of symmetry is defined as an imaginary plane coinciding with said longitudinal axis, which plane divides an object into two halves which are identical and mirrored images of each when viewed in a cross-section at right angles in the plane of symmetry. An axis in the plane of symmetry about which the mirrored halves of the object can be turned is termed the axis of symmetry. This axis is located in the intersection between the plane of symmetry and the plane of the cross-section.

The invention relates to an apparatus for cooling exhaust gases from an internal combustion engine. The apparatus comprises an exhaust tailpipe having a proximal end and a distal end, where the proximal end is configured to receive exhaust gases from the engine and the distal end is configured to expel the exhaust gases into the atmosphere. The proximal end has a circular cross-section and the distal end has a general horseshoe or C-shaped cross-section taken at right angles to the longitudinal axis of the tailpipe. In the subsequent text, the proximal end is defined as the point on the tailpipe where the cylindrical tailpipe transitions into the initial portion of the C-shaped cross-section. The distal end is defined as the outer end of the tailpipe. The change in cross-sectional shape occurs at a predetermined rate along a predetermined length of the tailpipe between the proximal end and

the distal end. The C-shaped cross-section is formed by a channel or flute extending gradually deeper into the outer periphery of the tailpipe. The innermost portion of the channel or flute is curved and preferably has a part circular or part oval cross-section and is arranged to extend radially into the tailpipe along an axis of symmetry in the plane of the cross-section.

The apparatus will act as a combined ejector and diffuser, where the exhaust gases and atmospheric gases, resulting in a cooling of the exhaust gases.

A conventional ejector uses the Venturi effect of a converging-diverging nozzle to convert the pressure energy of a moving fluid to velocity energy which creates a low pressure zone that draws in and encloses a suction fluid. After passing through the throat of the injector, the mixed fluid expands and the velocity is reduced which results in recompressing the mixed fluids by converting velocity energy back into pressure energy.

The Venturi effect also applies to the operation of the apparatus according to the invention. Exhaust gas under pressure is converted into a high-velocity jet at the throat of the convergent C-shaped portion of the tailpipe, which creates a low pressure at that point. The low pressure draws ambient air into a flute extending into the side of the tailpipe towards said convergent part of the tailpipe formed by the C-shape at the distal end where said ambient air mixes with the exhaust gas. This eliminates said core of the hot exhaust gas flow, as the flow leaving the exhaust outlet is a relatively thin C-shaped jet surrounded by ambient air on all sides. The distal end of the tail pipe is used as a diffuser to enhance mixing of the ambient air and the exhaust gas immediately after the distal end. This can result in a gas flow where the temperature is reduced from 400-600 °C to a temperature below 200 °C over a distance of less than 3-5 times the nominal diameter of the tailpipe from the end of the exhaust outlet.

The exhaust gas leaving the combustion engine flows through an exhaust conduit having a predetermined diameter towards the tailpipe. The proximal end of the tailpipe has a circular cross-section with a predetermined first

diameter, which is preferably the same as that of the preceding exhaust conduit. The distal end of the tailpipe has a C-shaped cross-section inscribed within a predetermined second diameter, so that the portion of the distal end that is not a part of the fluted channel has a substantially circular shape conforming to the second diameter.

Preferably, the hydraulic diameter of the tailpipe is reduced towards the distal end, which results in in a relatively large outer periphery combined with a relatively small area. The hydraulic diameter, D_H, is a commonly used term when handling flow in non-circular tubes and channels. Using this term it is possible to calculate many properties in the same way as for a circular tube. The definition of D_H is:

$$D_H = \frac{4A}{P} \quad (1)$$

where A is the cross-sectional area and P is the wetted perimeter of the cross-section. In this example, the wetted perimeter is the part of the perimeter in contact with the exhaust gas.

According to one example, the first diameter is equal to or less than the second diameter. The first and second diameters of the tailpipe can increase the counter pressure in the vehicle exhaust system, as the counter pressure is dependent on the cross-sectional area at each point along the exhaust system. Hence the first and second diameters are selected to minimise the effect on the counter pressure for each application. For instance, the first and second diameters used for the tailpipe for one type of engine and/or exhaust system can cause an undesired increase of the counter pressure for another type of engine and/or exhaust system. The first and second diameters will therefore have to be increased to reduce the counter pressure to an acceptable level.

According to an alternative example, the second diameter is greater than the first diameter. This can be achieved by providing a section of the tailpipe near the distal end with an enlarged diameter. In this case, the counter pressure

may be increased above a desired level at an end section of the tailpipe, as the channel reaches it largest extension into the tailpipe. The counter pressure can then be maintained at an acceptable level by enlarging the second diameter at this end section. In both the above examples, the first and second diameters can be determined on a case-to-case basis.

The total circumference of the C-shaped distal end is greater than the circumference of the circular proximal end, and the cross-sectional area of the distal end is smaller the cross-sectional area of the proximal end.

The distal end is inscribed within said second diameter, wherein an inner part-circular portion of the C-shaped cross-section is inscribed within a third diameter. The third diameter is arranged to inscribe the fluted channel in the same way as the distal end of the tailpipe is inscribed within said second diameter. The third diameter is selected in the range: $0{,}2\ D_2 \leq D_3 \leq 0{,}8\ D_2$, where D_2 is the second diameter and D_3 is the third diameter.

The distance between the geometrical centres of the second diameter and the third diameter, termed the centre distance (c) is selected in the range: $0 \leq c \leq 0{,}3\ D_2$. This distance c is measured along the axis of symmetry in either direction from the centre of the second diameter D_2. When c=0 then the second and third diameters are concentric.

The predetermined length (L) of the tailpipe between the proximal end and the distal end is selected equal to or greater than half the second diameter (D_2), preferably equal to or greater than twice the second diameter (D_2).

As stated above, the distal end is an ejector arranged to create a pressure drop at the centre of the exhaust flow leaving the C-shaped cross-section in order to provide a central core of ambient air flowing through said distal end.

According to one example, a line along the inner portion of the channel extending radially into the C-shaped tail pipe between the proximal and distal ends in the plane of symmetry forms a curve. The curved line can be part circular or have the shape of a polynomial curve, such as a parabolic or a hyperbolic curve. Such a curved inner portion is preferably, but not

necessarily, used for tailpipes where the available length between the proximal and distal ends is relatively short and/or when this portion of the tailpipe is curved, that is, when the longitudinal axis of the tailpipe is curved. An advantage with a tailpipe having this shape is that a tangent to the channel or flute in the longitudinal direction can be made parallel to the outer surface of the tubular tailpipe. For a curved tailpipe, the axis of symmetry of the channel intersects the inner radius of the tailpipe between the proximal and distal ends. A tailpipe with an inner portion having such a curved line will be more complex, but will have better aerodynamic properties when the flow is shaped over a relatively short distance.

Alternatively, a tangent along the inner portion of the channel extending radially into the C-shaped tail pipe between the proximal and distal ends in the plane of symmetry forms a straight line. Such a straight inner portion is preferably, but not necessarily, used for tailpipes where the available length between the proximal and distal ends is relatively long and/or when this portion of the tailpipe is straight. A tailpipe with an inner portion having a straight line will be relatively simple. The aerodynamic properties will be sufficient for the intended purpose when the flow is shaped over a relatively long distance.

In this case, the predetermined change in cross-section is preferably formed by an at least part-cylindrical or part oval channel or flute. For a part-cylindrical channel, a cylinder having a predetermined third diameter is inscribed within a circle conforming to said part-cylindrical flute. A cylinder having a cylindrical or oval cross-section conforming to the inner portion of the channel or flute can be located at a predetermined angle relative to the main axis of the exhaust tail pipe.

In both cases, the part circular or part oval inner portion is joined to a pair of parallel, diverging and/or converging walls extending outwards from said inner portion towards the outer periphery of the tailpipe. For instance, in a cross section adjacent the proximal end the walls are diverging outwards. In a cross-section at the distal end the walls can be parallel or converging,

depending on the desired shape of the channel. As the walls approach the tailpipe, a transition in the form of an arc or an angle joins said walls to the periphery of the tailpipe. The shape of the transition will be dependent on the method of manufacture of the channel.

The channel or flute extending into the tailpipe can be manufactured by pressing or stamping, hydroforming or hot working the tailpipe. Alternatively it can be manufactured by having a pre-formed channel component that is mounted in a cut-out in the tailpipe by welding, soldering or a similar suitable method.

BRIEF DESCRIPTION OF DRAWINGS

The invention will be described in detail with reference to the attached figures. It is to be understood that the drawings are designed solely for the purpose of illustration and are not intended as a definition of the limits of the invention, for which reference should be made to the appended claims. It should be further understood that the drawings are not necessarily drawn to scale and that, unless otherwise indicated, they are merely intended to schematically illustrate the structures and procedures described herein.

Figure 1 shows a vehicle provided with an apparatus for cooling exhaust gases according to the invention;

Figure 2 shows a tailpipe with an apparatus for cooling exhaust gases according to a first example of the invention;

Figure 3 shows a tailpipe with an apparatus for cooling exhaust gases according to a second example of the invention;

Figure 4A shows a common end view of the tailpipes of Figures 2 or 3;

Figure 4B shows a cross-section through the plane of symmetry of the tailpipe in Figure 2;

Figure 4C shows a cross-section through the plane of symmetry of the tailpipe in Figure 3;

Figure5A shows an end view of a tailpipe with an apparatus for cooling exhaust gases according to a third example of the invention;

Figure5B shows a cross-section through the plane of symmetry of the tailpipe in Figure 5A; and

Figure 5C shows a perspective view of a tailpipe according to the Figures 5A and 5B.

EXAMPLES OF THE INVENTION

Figure 1 shows a vehicle 11 provided with an apparatus for cooling exhaust gases according to the invention. In the example shown in the figure, an exhaust conduit 12 comprising a silencer 13 and a tailpipe 14 is located along the lower left side of the vehicle frame 15. This is a common arrangement for this type of vehicle adapted for right-hand traffic, where the tailpipe 14 is directed away from objects and persons located on the side of the road or on a pavement. The end 16 of the tailpipe 14 is provided with an apparatus for cooling exhaust gases.

Although the vehicle shown in Figure 1 has an exhaust conduit with a tailpipe located at a lower portion on one side of the vehicle, the invention is also applicable to exhaust conduit with a tailpipe located in alternative positions, such as a vertical tailpipe mounted to one side of the vehicle cab.

Figure 2 shows a tailpipe with an apparatus for cooling exhaust gases according to a first example of the invention. Figure 2 shows a tailpipe 21 with an end section 22 where a first, proximal end 23 has a circular cross-section and a second, distal end 24 has a general horseshoe or C-shaped cross-section taken at right angles to the longitudinal axis of the tailpipe. The change in cross-sectional shape occurs at a predetermined rate along a predetermined length of the tailpipe between the proximal end and the distal end. The C-shaped cross-section is formed by a channel 25 extending gradually deeper into the outer periphery of the tailpipe. The innermost portion 26 of the channel is curved and preferably has a part circular or part

oval cross-section and is arranged to extend radially into the tailpipe along an axis of symmetry Y (Figure 4A) in the plane of the cross-section. A cross-section through this tailpipe 21 is shown in Figure 4B.

Figure 3 shows a tailpipe with an apparatus for cooling exhaust gases according to a first example of the invention. Figure 3 shows a tailpipe 31 with an end section 32 where a first, proximal end 33 has a circular cross-section and a second, distal end 34 has a general horseshoe or C-shaped cross-section taken at right angles to the longitudinal axis of the tailpipe. The change in cross-sectional shape occurs at a predetermined rate along a predetermined length of the tailpipe between the proximal end and the distal end. The C-shaped cross-section is formed by a channel 35 extending gradually deeper into the outer periphery of the tailpipe. The innermost portion 36 of the channel is curved and preferably has a part circular or part oval cross-section and is arranged to extend radially into the tailpipe along an axis of symmetry Y (Figure 4A) in the plane of the cross-section. A cross-section through this tailpipe 31 is shown in Figure 4C.

Figure 4A shows a common end view of the tailpipes of Figures 2 or 3. The total circumference or perimeter P of the C-shaped distal end (Figure 4B, "24"; Figure 4C, "34") is greater than the circumference of the circular proximal end (Figure 4B, "23"; Figure 4C, "33"). In this example, the first and second diameters Di, D_2 of the proximal and distal ends, respectively, have the same external diameter and the cross-sectional area A_2 of the distal end is smaller the cross-sectional area A_1 of the proximal end.

The distal end is inscribed within said second diameter D_2, wherein the inner part-circular portion 26; 36 of the C-shaped cross-section is inscribed within a smaller, third diameter D_3. The internal third diameter D_3 is arranged to inscribe the inner portion of the fluted channel (25; 35) in the same way as the distal end of the tailpipe is inscribed within said second diameter D_2. At the distal end the third diameter D_3 is selected in the range: $0{,}2\ D_2 \leq D_3 \leq 0{,}8\ D_2$.

The distance between the geometrical centres of the second diameter D_2 and the third diameter D_3, termed the centre distance C is selected in the range: $0 \leq c \leq 0{,}3\ D_2$. This distance c is measured along the axis of symmetry Y in either direction from the centre of the second diameter D_2. When c=0 then the second and third diameters are concentric.

The tailpipe has a predetermined length L_1 (Figure 4B); L_2 (Figure 4C) between the proximal end and the distal end. The lengths L_1 and L_2 are selected equal to or greater than half the second diameter D_2, preferably equal to or greater than twice the second diameter D_2.

As stated above, the distal end is an ejector arranged to create a pressure drop at the centre of the exhaust flow leaving the C-shaped cross-section in order to provide a central core of ambient air flowing through said distal end.

Figure 4B shows a cross-section through the plane of symmetry of the tailpipe in Figure 2. In this case, the plane of symmetry coincides with the axis of symmetry Y shown in Figure 4A. A tangent along the inner portion 26 of the channel 25 extending radially into the C-shaped tail pipe 21 between the proximal and distal ends 23, 24 in the plane of symmetry forms a straight line. Such a straight inner portion is preferably, but not necessarily, used for tailpipes where the available length L_1 between the proximal and distal ends 23, 24 is relatively long and/or when this portion of the tailpipe is straight.

In this case, the predetermined change in cross-section is preferably formed by an at least part-cylindrical channel 25. For a part-cylindrical channel 25, a cylinder having a predetermined third diameter D3 is inscribed within a circle conforming to said part-cylindrical channel. A cylinder having a constant cylindrical cross-section conforming to the inner portion 26 of the channel 25 is located at a predetermined angle α relative to the main axis X of the exhaust tail pipe 21.

Figure 4C shows a cross-section through the plane of symmetry of the tailpipe in Figure 3. In this case, the plane of symmetry coincides with the axis of symmetry Y shown in Figure 4A. According to this example, a line 37

along the inner portion 36 of the channel 35 extending radially into the C-shaped tail pipe 31 between the proximal and distal ends 33, 34 in the plane of symmetry forms a curve. The curved line 37 can be part circular or have the shape of a polynomial curve, such as a parabolic or a hyperbolic curve. Such a curved inner portion 36 is preferably, but not necessarily, used for tailpipes where the available length l_2 between the proximal and distal ends 33, 34 is relatively short and/or when this portion of the tailpipe is curved, that is, when the longitudinal axis of the tailpipe is curved (not shown). An advantage with a tailpipe having this shape is that a tangent T to the channel 35, at its inner portion 36 and at the distal end 34, in the longitudinal direction can be made parallel to the outer surface of the tubular tailpipe in the longitudinal direction parallel to the longitudinal axis X.

For a tailpipe having a curved end between the proximal and distal ends (not shown), the axis of symmetry of the channel would intersect the inner radius of the tailpipe between the proximal and distal ends. A tailpipe with an inner portion having such a curved line will be more complex, but will have better aerodynamic properties when the flow is shaped over a relatively short distance.

Figure 5A shows an end view of a tailpipe with an apparatus for cooling exhaust gases according to a third example of the invention. According this example, the second diameter D_2 is greater than the first diameter Di. This has been achieved by providing a final section 58 of the tailpipe 51 near the distal end (Figure 5B, "54") with an enlarged diameter. In this case, the counter pressure would have been increased above a desired level at the end section of the tailpipe, if the second diameter D_2 had been selected equal to the first diameter D-|. In the example shown in Figure 5A, the counter pressure is maintained at an acceptable level by enlarging the second diameter D_2 at this end section.

In the same way as in Figure 4A, the total circumference or perimeter P of the C-shaped distal end (Figure 5B, "54") is greater than the circumference of

the circular proximal end (Figure 5B, "53"). In this example, the cross-sectional area A_2 of the distal end is smaller than the cross-sectional area A_1 of the proximal end, even though the second diameter D_2 of the proximal end 53 is greater than the first diameter D_1 of the distal end 54.

The distal end is inscribed within said second diameter D_2, wherein the inner part-circular portion 56 of the C-shaped cross-section is inscribed within a smaller, third diameter D_3. The internal third diameter D_3 is arranged to inscribe the inner portion of the fluted channel 55 in the same way as the distal end of the tailpipe is inscribed within said second diameter D_2. At the distal end the third diameter D_3 is selected in the range: $0{,}2\ D_2 \leq D_3 \leq 0{,}8\ D_2$.

The distance between the geometrical centres of the second diameter D_2 and the third diameter D_3, termed the centre distance c is selected in the range: $0 \leq c \leq 0{,}3\ D_2$. This distance c is measure along the axis of symmetry Y in either direction from the centre of the second diameter D_2. When c=0 then the second and third diameters are concentric.

The tailpipe has a predetermined length L_3 (Figure 5B) between the proximal end 53 and the distal end 54. The length L_3 is selected equal to or greater than half the second diameter D_2, preferably equal to or greater than twice the second diameter D_2.

Figure 5B shows a cross-section through the plane of symmetry of the tailpipe in Figure 5A. In this case, the plane of symmetry coincides with the axis of symmetry Y shown in Figure 5A. According to this example, a line 57 along the inner portion 56 of the channel 55 extending radially into the C-shaped tail pipe 51 between the proximal and distal ends 53, 54 in the plane of symmetry forms a curve. The curved line 57 can be part circular or have the shape of a polynomial curve, such as a parabolic or a hyperbolic curve. Such a curved inner portion 56 is preferably, but not necessarily, used for tailpipes where the available length L_3 between the proximal and distal ends 53, 54 is relatively short and/or when this portion of the tailpipe is curved, that

is, when the longitudinal axis of the tailpipe is curved (not shown). An advantage with a tailpipe having this shape is that a tangent T to the channel 55, at its inner portion 56 and at the distal end 54, in the longitudinal direction can be made parallel to the outer surface of the tubular tailpipe in the longitudinal direction parallel to the longitudinal axis X.

Figure 5C shows a perspective view of a tailpipe according to the Figures 5A and 5B. Figure 5C shows a tailpipe 51 with an end section 52 where a first, proximal end 53 has a circular cross-section and a second, distal end 54 has a general horseshoe or C-shaped cross-section taken at right angles to the longitudinal axis of the tailpipe. The change in cross-sectional shape occurs at a predetermined rate along a predetermined length of the tailpipe between the proximal end and the distal end. The C-shaped cross-section is formed by a channel 55 extending gradually deeper into the outer periphery of the tailpipe. The innermost portion 56 of the channel is curved and preferably has a part circular or part oval cross-section and is arranged to extend radially into the tailpipe along an axis of symmetry Y (Figure 5A) in the plane of the cross-section. A cross-section through this tailpipe 51 is shown in Figure 5B.

The invention is not limited to the above examples, but may be varied freely within the scope of the appended claims.

CLAIMS

1. An apparatus for cooling exhaust gases from an internal combustion engine, the apparatus comprising: an exhaust tailpipe having a proximal end and a distal end, the proximal end configured to receive exhaust gases from the engine, and the distal end configured to expel the exhaust gases into the atmosphere, characterized in that wherein the proximal end has a circular cross-section and the distal end has a C-shaped cross-section, where the change in cross-section occurs at a predetermined rate along a predetermined length (L) of the tailpipe between the proximal end and the distal end.

2. The apparatus according to claim 1, characterized in that the proximal end has a circular cross-section with a predetermined first diameter (Di) and that the distal end has a C-shaped cross-section inscribed within a predetermined second diameter (D_2).

3. The apparatus according to claim 2, characterized in that the first diameter (D^ is equal to or less than the second diameter (D_2).

4. The apparatus according to claim 2, characterized in that the second diameter (D_2) is greater than the first diameter (D^.

5. The apparatus according to any one of the above claims, characterized in that the total circumference of the distal end is greater than the circumference of the proximal end, and the cross-sectional area of the distal end is smaller the cross-sectional area of the proximal end.

6. The apparatus according to any one of the above claims, characterized in that the distal end is inscribed within said second diameter (D_2), wherein an inner part-circular portion of the C-shaped cross-section is inscribed within a third diameter (D_3), wherein the third diameter (D_3) is selected in the range : $0,2\ D_2 \leq D_3 \leq 0,8\ D_2$.

7. The apparatus according to claim 6, characterized in that the centre distance (c) between the centre of the second diameter (D_2) and the centre of the third diameter (D_3) is selected in the range : $0 \leq c \leq 0{,}3\ D_2$.

8. The apparatus according to any one of the above claims, characterized in that the predetermined length (L) of the tailpipe between the proximal end and the distal end is selected equal to or greater than half the second diameter (D_2), preferably equal to or greater than twice the second diameter (D_2).

9. The apparatus according to any one of the above claims, characterized in that the distal end is an ejector arranged to create a pressure drop at the centre of the exhaust flow leaving the C-shaped cross-section in order to provide a central core of ambient air flowing through said distal end.

10 The apparatus according to any one of claims 1-9, characterized in that a cross-section through the an inner portion of the C-shaped tail pipe between the proximal and distal ends, in the plane of symmetry of the C-shaped distal end, forms a curved line.

11. The apparatus according to claim 10, characterized in that the curved line is part circular.

12. The apparatus according to claim 10, characterized in that the curved line is a partial polynomial curve.

13 The apparatus according to any one of claims 1-9, characterized in that a cross-section through the an inner portion of the C-shaped tail pipe between the proximal and distal ends, in the plane of symmetry of the C-shaped distal end, forms a straight line.

14. The apparatus according to claim 13, characterized in that the predetermined change in cross-section is formed by an at least part-cylindrical flute, wherein a cylinder having a predetermined second diameter is inscribed within a circle conforming with said part-cylindrical flute.

15. The apparatus according to claim 14, characterized in that said cylinder is located at a predetermined angle relative to the main axis of the exhaust tail pipe.

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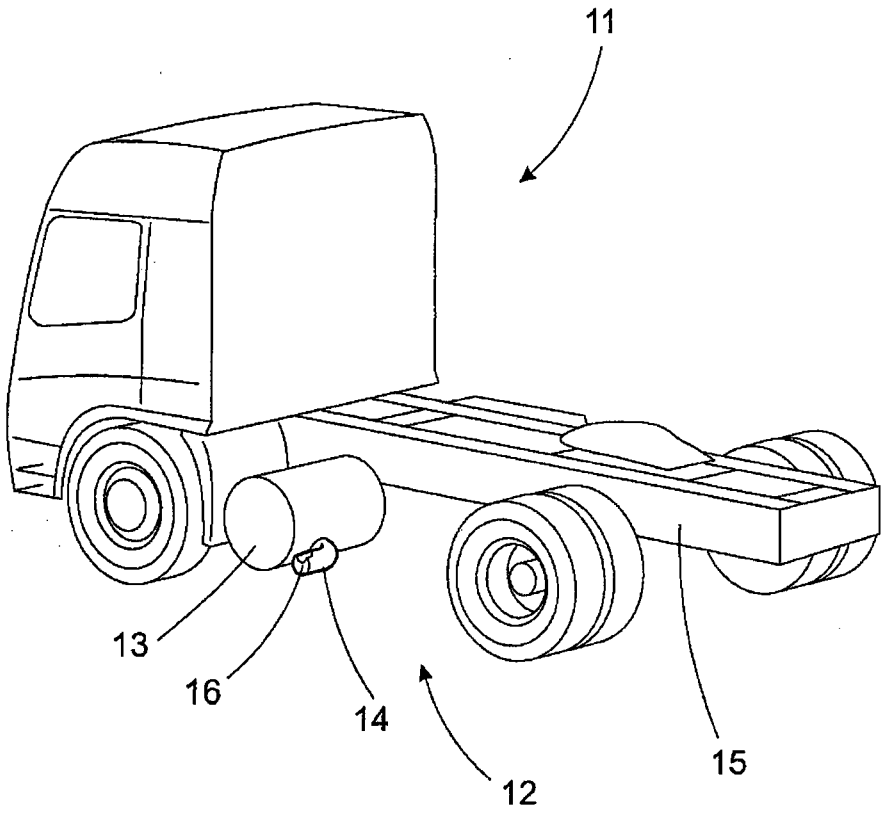


Fig.1

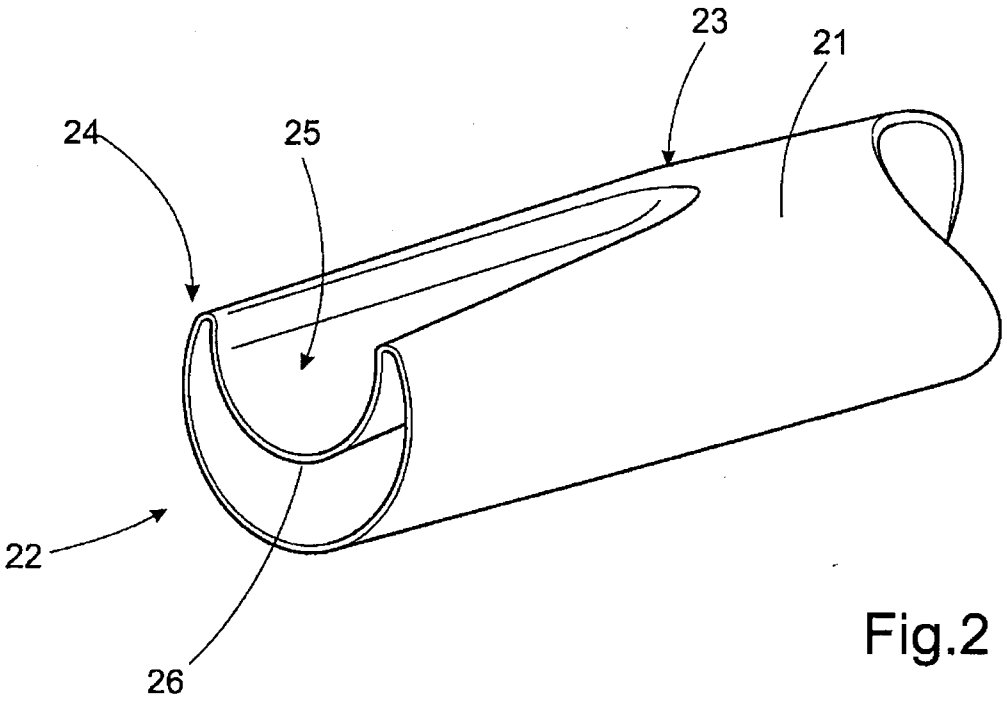


Fig.2

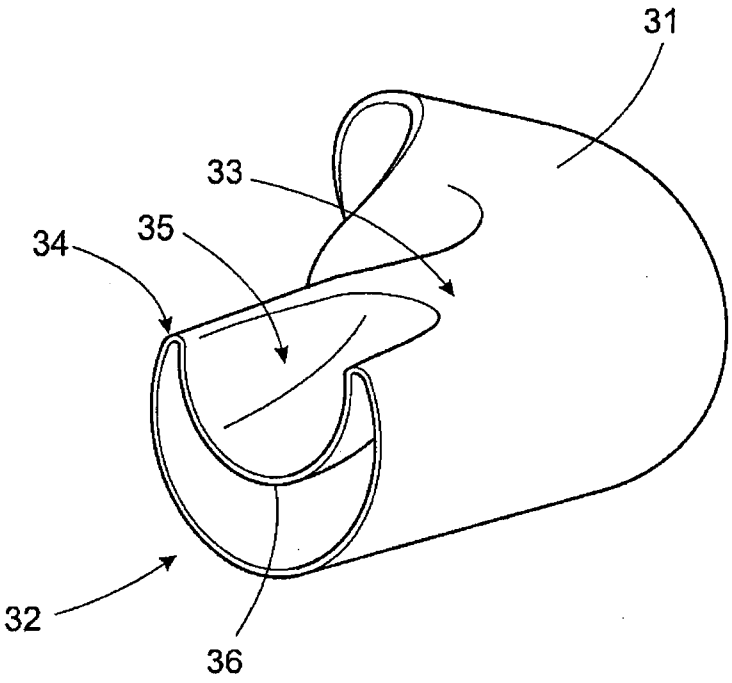


Fig.3

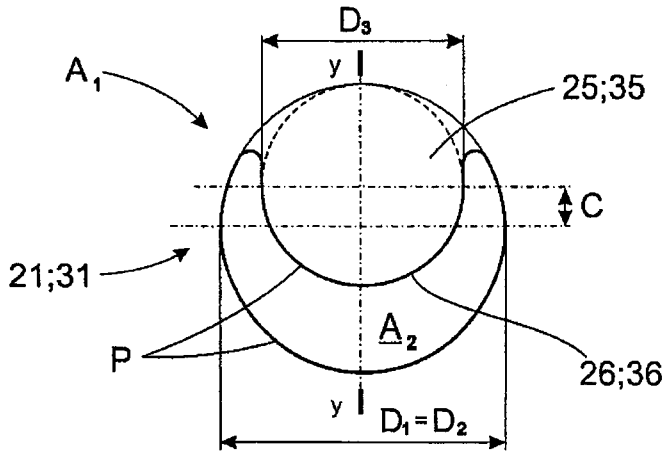


Fig.4A

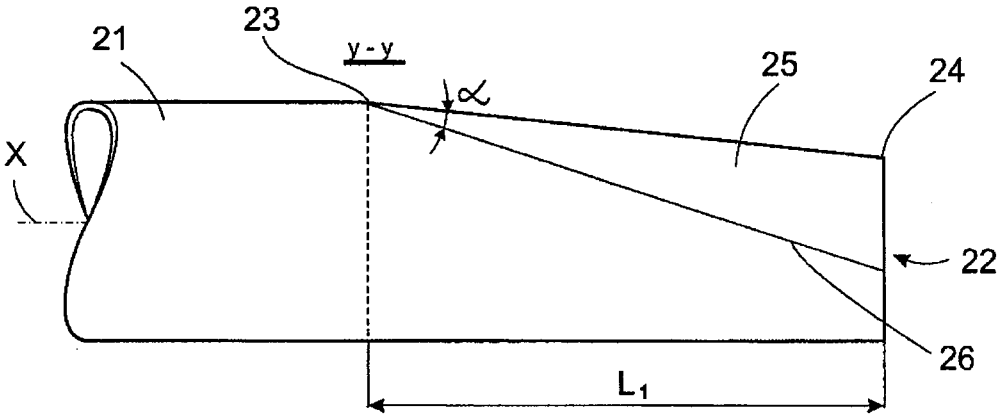


Fig.4B

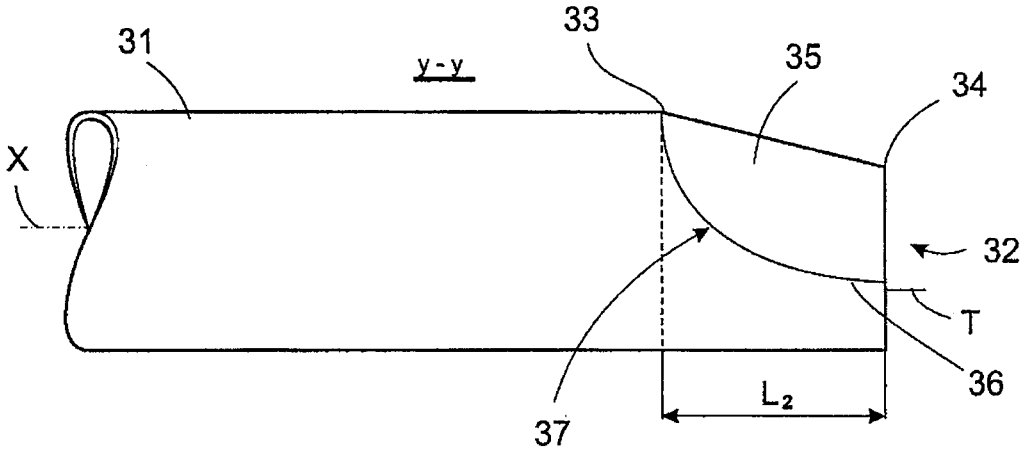


Fig.4C

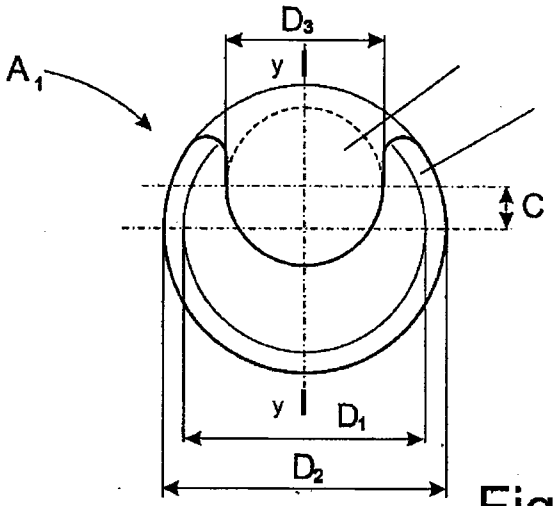


Fig.5A

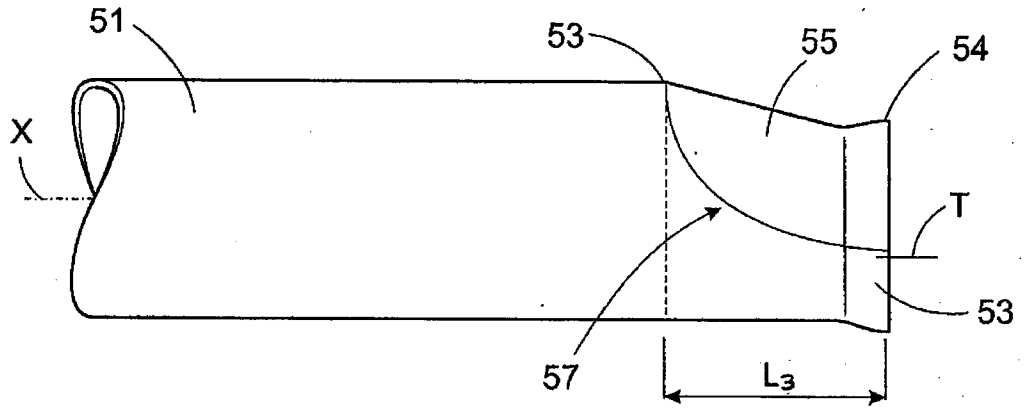


Fig.5B

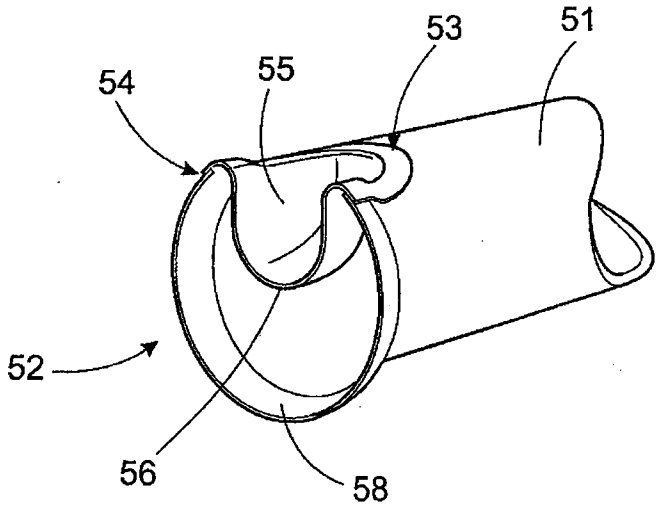


Fig.5C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE201 1/000239

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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: F01 N

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category'*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 621 931 15 U (.), 8 December 1987 (1987-12-08); figure 1 --	1-5, 8, 10-1 5
X	US 2007003931 8 A 1 (KRAJEWSKI JASON T ET AL), 22 February 2007 (2007-02-22); paragraphs [0073], [0083]; figures 1-4 --	1
A	GB 568140 A (JEAN CLEMENT DANINOS), 20 March 1945 (1945-03-20); page 3, line 10 - line 35; figures 1-4 --	1, 9
A	US 20080099276 A 1 (BACH TRAVIS), 1 May 2008 (2008-05-0 1); paragraphs [0003]-[0004]; figures 1-4; Cited in the application --	1-15

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
23-08-201 2	3 1-08-201 2

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE201 1/000239

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 200701 63249 A 1 (CLERC JAMES C ET AL), 19 July 2007 (2007-07-1 9); abstract; figures 2,6-13; Cited in the application --	1-15
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International application No.
PCT/SE201 1/000239

Continuation of: second sheet

International Patent Classification (IPC)

***F01N* 73/20** (2010.01)
***F01N* 73/05** (2010.01)

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Cited literature, if any, will be enclosed in paper form.

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