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Roe et al.

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[54] **EXHAUST SILENCERS**

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[73] Assignee: **Norton Villiers Limited**, Staffordshire, England

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[52] **U.S. Cl.** **181/53**

[51] **Int. Cl.** **F01n 1/08**

[58] **Field of Search** 181/53–57

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Assistant Examiner—John F. Gonzales
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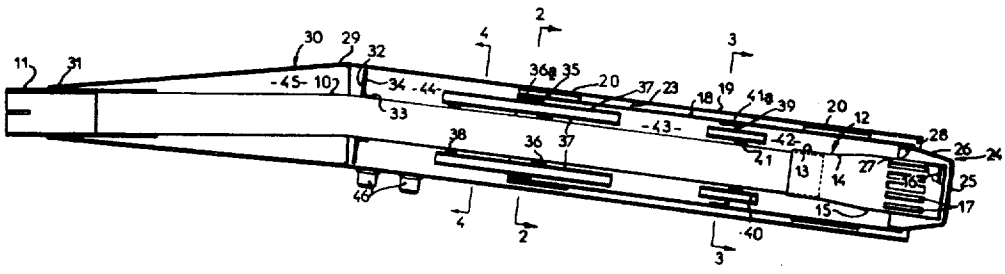
[57] **ABSTRACT**

An exhaust silencer comprises a body which includes inner, intermediate and outer coaxial tubes. The outlet is formed as a slot and immediately upstream of the outlet in the direction of gas flow is a passage between the intermediate and outer tubes, the height of the passage being such as to attenuate the sound of the gas flowing through the passage. Between the inner and intermediate tubes is one or more resonator chambers and the exhaust gas flows through the inner tube and the passage in one direction and through the chambers in the opposite direction.

4 Claims, 5 Drawing Figures



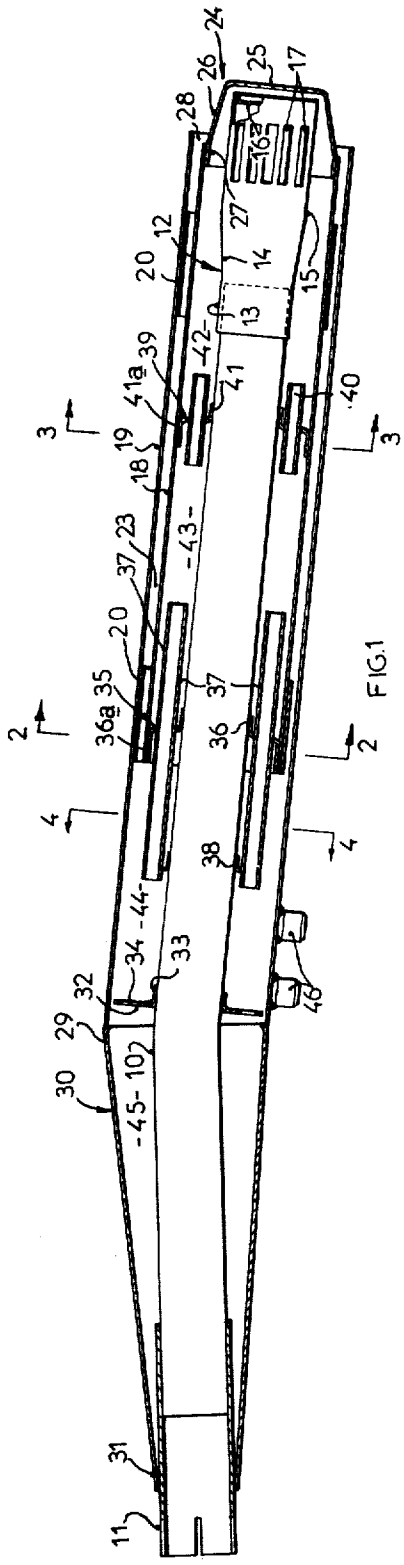

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FIG.1

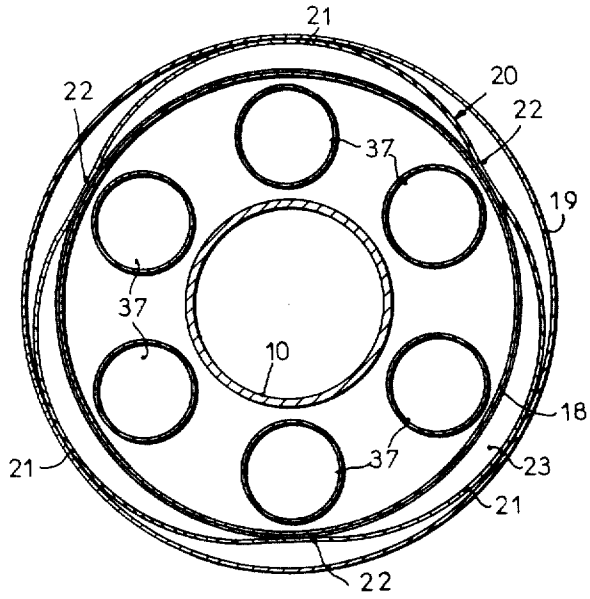

FIG. 2

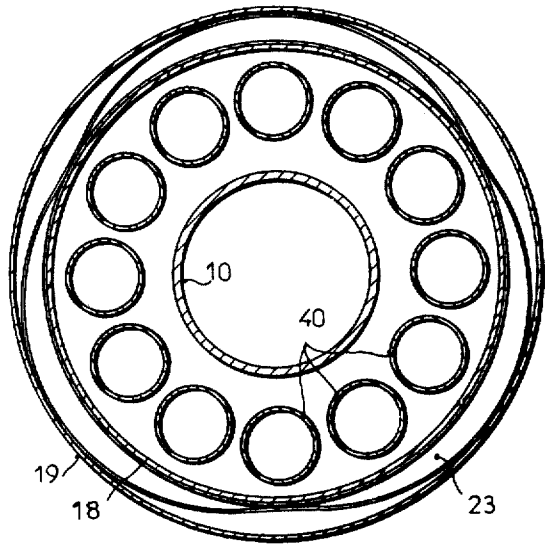

FIG 3

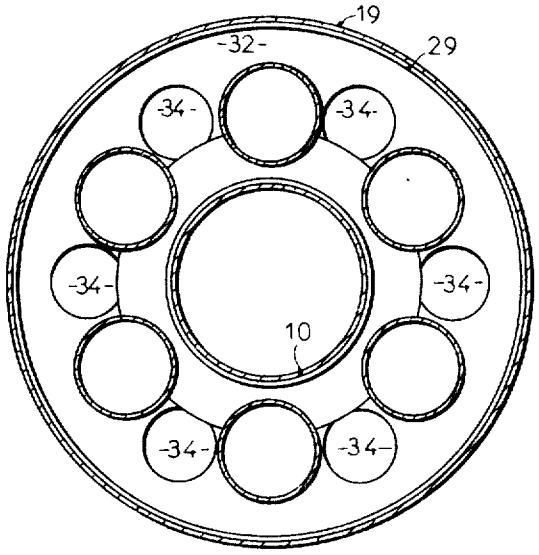
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FIG. 4

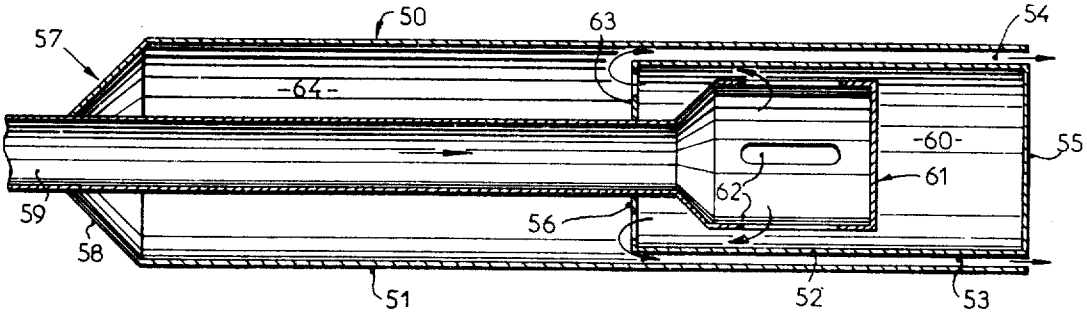
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FIG. 5

EXHAUST SILENCERS

This invention relates to exhaust silencers for use in association with internal combustion engines to reduce the noise level of the exhaust without effecting the power output of the engine to an unacceptable extent.

The exhaust noise from an internal combustion engine encompasses a band of frequencies and the noise level normally peaks over a compact range of frequencies within the band. Silencers are designed to attenuate the noise within the range of frequences where the noise peaks, thus to reduce the overall level of the noise.

It is known to employ for this purpose a number of resonators or acoustic filters which are tuned to respond to different frequences in the range. Standing waves are thus formed and the supply of energy required to keep these standing waves in existence attenuates the noise level within said range and thus the peak noise level of the exhaust.

The object of the invention is to provide an improved silencer using resonating chambers.

According to the invention we provide an exhaust silencer comprising: a body which includes inner, intermediate and outer co-axial tubes; an exhaust gas inlet at one end of the body and in one end of the inner tube; an exit opening at the other end of the inner tube; an outlet at the other end of the body in the form of a slot; a passage between the intermediate and outer tubes immediately upstream of said slot in the direction of flow of the exhaust gas, the passage having an inlet and terminating in the slot; the walls of the passage being imperforate and spaced apart by a distance such that the height of the passage between the walls is such as to cause attenuation of the noise of gas flowing through the passage while the area of the slot and of the cross section of the passage transverse to the direction of flow of gas therethrough is at least as great as the cross-sectional area of the inlet transverse to the general direction of flow of exhaust gases through the inlet; the passage having a length equal to at least 15 times the height of the slot; there being no part of the flow path of the gas between the inlet and the outlet which has a cross-sectional area perpendicular to the general direction of gas flow which is less than said cross-sectional area of the inlet; and there being one or more chambers between the exit opening of the inner tube and the inlet to the passage and arranged so that the direction of flow of exhaust gases through the chamber or chambers is in a direction generally opposite to the direction of flow of exhaust gases through the inner tube and the passage.

We have found that by having an outlet in the form of a slot and a passage upstream of the slot and having imperforate walls, the noise level of the exhaust is attenuated to a greater extent than in exhaust silencers using resonators or acoustic filters as heretofore provided. We do not wish to be bound by an explanation as to why this attenuation is obtained but we believe that it is obtained because of interference and damping which takes place between the pressure waves in the gas as the waves travel along the passage to the outlet slot.

The exit opening of the inner tube may lead to a diffuser from which the gas passes to the chamber or chambers between the inner and intermediate tubes.

The slot can be continuous, for example, circular, oval, rectangular or of sinuous shape. Alternatively, the slot can be finite and may be straight or arcuate. In any event, the slot is preferably of a constant width along its length. The cross-sectional shape (and hence the height) of the passage is preferably the same as that of the slot and the passage is preferably of a length greater than fifty times the height of the slot.

The silencer may include, between the inner and intermediate tubes, a number of resonator chambers arranged in series and tuned to different frequencies within the frequency band of the exhaust noise to be silenced. The chambers may be placed in communication by a number of tuned pipes and spaced apart around the inner tube.

In designing the silencer we have found that it is desirable that the height of the slot and of the passage shall not be greater than one-tenth of the shortest wave length of the sound to be attenuated and shall not be less than one-tenth of a quarter of such shortest wave length. The height of the passage is the dimension thereof corresponding to the height of the slot.

It is preferred that the slot be in the form of a sharp-edged orifice but this is not essential.

Two embodiments of the invention will now be described in detail by way of example with reference to the accompanying drawings in which:

FIG. **1** is a longitudinal section through a silencer constituting a first embodiment of the invention;

FIG. **2** is a section on the line **2—2** of FIG. **1**;

FIG. **3** is a section on the line **3—3** of FIG. **1**;

FIG. **4** is a section on the line **4—4** of FIG. **1** and

FIG. **5** is a diagrammatic cross section through a second embodiment of the invention.

Referring now to FIGS. **1** to **4** of the drawings, the silencer there shown comprises an inner tube **10** which at the inlet end, the left hand end in FIG. **1**, is surrounded by a front tube **11** which is adapted to be connected to the exhaust pipe of an engine. At its right hand end the inner tube **10** has an exit opening which leads to a diffuser indicated generally at **12** and connected to the tube **10.** The diffuser has a cylindrical part **13** which fits over the right hand end of the inner tube **10,** a frusto-conical part **14,** a cylindrical part **15** of greater cross-sectional area than the part **13** and an end plate **16.** The end plate **16** is imperforate but the cylindrical portion **15** is provided with a plurality of slots some of which are shown at **17.** The inner tube **10** and the diffuser **12** are so dimensioned that the distance between the end plate **16** and the exhaust ports of the engine is the optimum distance for the generation of engine power.

Surrounding the inner tube **10** is an intermediate tube **18** and surrounding the tube **18** is an outer tube **19.** The tubes **10, 18** and **19** are co-axial and are cylindrical as will be clear from FIG. **2.** Two support rings **20** are interposed between the tubes **18** and **19** and are spaced apart longitudinally of the tubes. As shown in FIG. **2,** each support ring has three outer portions **21** which engage the outer tube **19** and three inner portions **22** which engage the intermediate tube **18.** It will be seen that the support rings locate the intermediate tube within the outer tube without substantially obstructing the cross-sectional area of an annular outlet passage **23** between the tubes **18** and **19** and which has an entrance at the left hand end of the intermediate tube **18.**

The right hand end of the tube **18** is closed by an end plate indicated generally at **24.** This end plate has a circular portion **25** opposite to the end plate **16,** a diverging wall portion **26** and a cylindrical portion **27** which fits within, and is secured to, the tube **18.** The outlet from the outlet passage **23** is a slot indicated at **28** and it will be seen that it is formed between the opposed rear ends of the outer tube **19** and the intermediate tube **18.** The length of the outlet passage **23** is thus from the entrance at the left hand end of the tube **18** to the slot **28.**

The left hand end of the outer tube **19** is connected to the larger diameter end **29** of a front cone **30,** the smaller diameter end **31** thereof being connected to the front tube **11.**

An annular front plate **32** surrounds the tube **10** and is secured thereto by a flange **33.** The front plate **32** is located adjacent the left hand end of the outer tube **19** and is provided with a number of equi-angularly spaced apertures **34,** some of which are seen in FIG. **4.**

Between the inner tube **10** and the intermediate tube **18** are mounted front and rear baffles. The front baffle is indicated generally at **35** and is a ring of substantially Z cross section having an inner flange **36** welded to the tube **10** and an outer flange **36***a* welded to the tube **18.** The baffle carries six pipes **37** which, as shown in FIG. **2,** are equi-angularly spaced around the tube **10.** The left hand ends of the tubes **37** are supported by a flanged ring **38** welded to the tube **10.**

In a similar manner, the rear baffle **39** is an annular ring of Z cross-section having an inner flange **41** welded to the tube **10** and an outer flange **41***a* welded to the tube **18.** The baffle **40** carries twelve pipes **40** which are equiangularly spaced as shown in FIG. **3.** It will be noted that the pipes **40** are shorter and smaller in diameter than the pipes **37.**

The baffles **35** and **39** divide the space between the tubes **10** and **18** into two chambers **42** and **43.** A further chamber **44** is provided within the outer tube **19** to the left or forwardly of the front baffle **45** and a dead air space **45** is provided within the front cone **30** around the tube **10.**

Pommels **46** are welded to the outer tube **19** to provide means for mounting the silencer on a support bracket.

In operation, exhaust gas flows from left to right along the inner tube **10.** When the gas reaches the diffuser **12** the gas expands and its velocity decreases and it passes through the slots **17** into the chamber **42.** The gas then passes through the pipes **40** into the chamber **43** and through the pipes **37** into the chamber **44.** The volumes of the chambers **42, 43** and **44** and the lengths and diameter of the pipes **37** and **40** are arranged to provide the desired attenuation characteristics for the silencer. The gas then flows from the chamber **44** along the outlet passage **23** and through the outlet **28.** The gas flow is in contact with the dead air space **45** through the apertures **34** and this gives further attenuation. It will be noted that the chamber **44** has a greater volume than the chamber **43** which has a greater volume than the chamber **42.**

The cross-sectional area of the flow path of the gas is not restricted between the entry to the inner tube **10** and the exit from the outlet **28.** Preferably the cross-sectional area of the outlet is greater than that of the inlet and may be 40 percent greater. The outlet **28** is in the form of a slot which is at the downstream end of the passage **23** whose concentric walls, provided by the tubes **18** and **19,** are imperforate and are a constant distance apart. The cross-sectional area of the outlet **28** can be considered to be defined by the inner surface of the outer tube **19** and the outer surface of the inner tube **18** as it has been found that the exhaust gases emerging from the outlet do not follow the angle of the diverging wall portion **26** unless this angle is less than 8°. The height of the passage **23** and slot **28** is the radial distance between the outer surface of the intermediate tube **18** and the inner surface of the outer tube **19.** The height of the passage is such as to cause attenuation of the noise of the exhaust gas flowing through the passage. The passage has a length equal to approximately 60 times the height of the slot (and also the height of the passage itself) although for this embodiment it could be between 50 and 60 times the height of the slot.

Referring now to FIG. **5** this shows another embodiment of the invention in which the silencer comprises an elongated body **50** comprising an outer tube **51** and an intermediate tube **52.** The outer tube **51** is longer than the inner tube **52** and there is an annular passage **53** between the tubes which leads to an annular exit slot **54** similar to the slot **28** in FIG. **1.** The passage **53** corresponds to the passage **23** in the first embodiment and is similarly dimensioned to attenuate the noise of the exhaust gas flowing through it. The tube **52** has a closure **55** at the outlet end of the silencer and has a perforated plate **56** at its other end.

The inlet end of the silencer is indicated at **57** and comprises a cone **58** welded to the outer tube **51** and also to an inner tube **59** which extends into the chamber **60** provided within the tube **52** and is connected at its end to an apertured diffuser **61** which has a number of apertures **62** therein. The length of the passage **53** is at least 15 times the height of the outlet slot **54** and there is no restriction to flow between the inlet to the tube **59** and the slot **54.**

The operation of the silencer of FIG. **5** is as follows. Exhaust gas enters through the tube **59** and flows into the diffuser **61** and from thence through the apertures **62** into the chamber **60** which acts as a resonator and absorbs sound energy. The gas then flows through apertures **63** in the plate **56** into the chamber **64** provided in the outer tube **51** and this chamber **64** also acts as a resonator absorbing further sound energy. It will be understood that the chambers **60** and **64** are tuned to resonate at different frequencies within the range of frequencies required to be attenuated by the silencer. The gas then flows from the chamber **64** along the passage **53** to the outlet slot **54** which is in the form of a sharp edged orifice. The passage **53** which has imperforate walls formed by the tubes **51** and **52** acts in the same manner as the passage **23** of FIGS. **1** to **4** and we have found that the inclusion of such a passage improves the performance of the silencer as compared with those known heretofore.

It is also necessary that there be no restriction in the silencer and therefore the cross sectional area of the slot such as **28** or **54** must be at least equal to the cross sectional area of the tube **10** or **59** respectively. It follows that the cross sectional area transverse to the direction of flow of the gas through the silencer must not, at any position, be less than the cross sectional area of the inlet to the silencer constituted by the tube **10** or the tube **59.**

We claim:

1. An exhaust silencer comprising: a body which includes inner, intermediate and outer co-axial tubes; an exhaust gas inlet at one end of the body and in one end of the inner tube; an exit opening at the other end of the inner tube which is imperforate between its one end and the exit opening; an outlet at the other end of the body in the form of a slot; an outlet passage defined between concentric inner and outer walls provided by the intermediate and outer tubes respectively and being located immediately upstream of said slot in the general direction of flow of the exhaust gas, the outlet passage having an entrance at one end and terminating in the slot at the other end and being arranged so that all the exhaust gas flows therethrough; said concentric walls of the passage being imperforate and spaced apart by a constant distance over the whole of the overlapping lengths of the intermediate and outer tubes; said distance being such that the height of the passage between the walls is such as to cause attentuation of the noise of gas flowing through the outlet passage while the area of the slot and of the cross-section of the outlet passage transverse to the general direction of flow of the gas therethrough is at least as great as the cross-sectional area of the inlet transverse to the general direction of flow of exhaust gases through the inlet; the outlet passage having a length between the entrance and the slot equal to at least 50 times the height of the slot and providing a clear path for gas flow in a direction parallel to the longitudinal axis of the passage between the entrance and the slot; there being no part of the flow path of the gas between the inlet and the outlet which has a cross-sectional area transverse to the general direction of gas flow which is less than said cross-sectional area of the inlet; there being one or more chambers through which the gas flows on emerging from the exit opening of the inner tube and arranged so that the direction of flow of exhaust gases through the chamber or chambers is in a direction generally opposite to the direction of flow of exhaust gases through the inner tube and the passage, and there being a further chamber defined between the inner and outer tubes into which the gas flows on emerging from said first mentioned chamber or chambers, the general direction of flow of gas being reversed in said further chamber from the entrance to which the gas passes directly to the entrance to the outlet passage.

2. A silencer according to claim 1 wherein the exit opening of the inner tube leads to a diffuser from which the gas passes to the chamber or chambers between the inner and intermediate tubes.

3. A silencer according to claim 1 wherein there is a number of the first mentioned chambers between the inner tube and the further chamber, all said chambers acting as resonators, being arranged in series and being tuned to different frequencies within the frequency band of the exhaust noise to be silenced.

4. A silencer according to claim 3 wherein adjacent chambers are placed in communication via tuned pipes spaced apart around the inner tube.

* * * * *