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[54] **SILENCER FOR INTERNAL COMBUSTION ENGINES**

[75] Inventor: **Leszek Bonikowski,** Krakow, Poland

[73] Assignee: **Wytwornia Silnikow Wysokopreznych Prezedsie-biorstwo Panstwowe,** Andrychow, Poland

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[51] **Int. Cl.** **F01n 1/10**

[58] **Field of Search** ..... 181/33 L, 41, 42, 44–46, 181/48–50, 53, 54, 56, 58, 59

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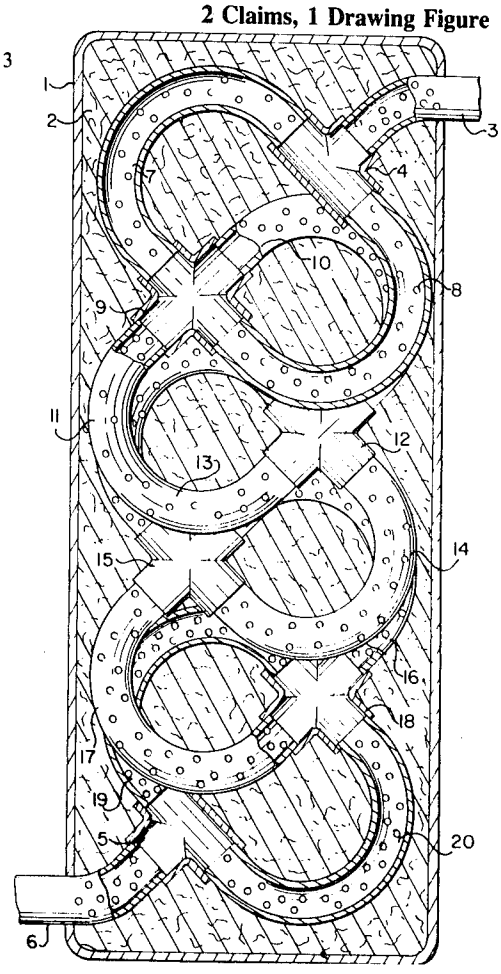
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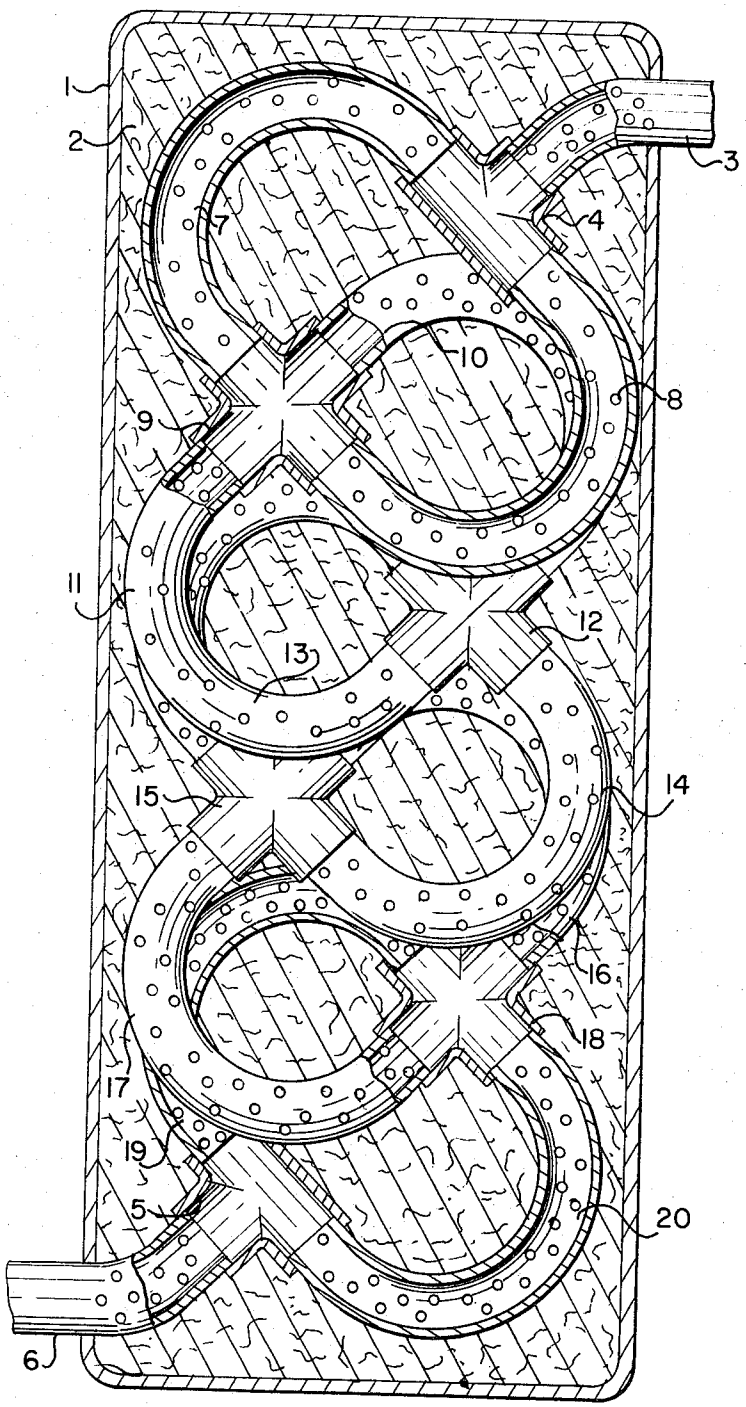
Primary Examiner—Richard B. Wilkinson
Assistant Examiner—John F. Gonzales
Attorney, Agent, or Firm—Irvin A. Lavine

[57] **ABSTRACT**

A silencer for an internal combustion engine comprising at least one set of two bowed, perforated pipes enclosed in sound absorbing material within a housing: at least one connector is provided having arms extending in opposite directions, an inlet of each pipe being axially connected to an arm of the connector. Entrance to the connector is provided by one or more arms transverse to the oppositely extending arms. Preferably, a plurality of sets of pipes are connected by a plurality of such connectors, the discharge from one set providing the inlet to the succeeding set, with collision of exhaust gas streams occurring in the connectors.

2 Claims, 1 Drawing Figure




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SILENCER FOR INTERNAL COMBUSTION ENGINES

This is a continuation of U.S. Pat. application Ser. No. 28,470, filed Apr. 14, 1970 now abandoned.

The present invention relates to a silencer for internal combustion engines designed for reducing the noise of the combustion exhaust gases.

The present invention may also be employed in cases where a necessity arises for miniaturization and mounting on an engine without the intermediary of an exhaust pipe.

The interference silencers now known are designed in a way so as to enable a superposition, due to a differentiation of lengths of flow paths, of the waves travelling in the same direction as the exhaust gas stream.

The operation of the known interference silencers consists of a distribution of a single pressure pulse into a number of smaller pulses which are finally joined together at the outlet of the silencer, with a corresponding phase shift, into one continuous pulse.

Such a silencer does not reduce the variable frequencies of the sounds. Besides, it has been stated that the flow of exhaust gas stream through a silencer of this type does not fulfill the relative assumptions due to different flow resistances which oppose the flow of the exhaust gases in particular branches of the silencer.

The absorption silencer now known consists of through conduits enclosed within a housing filled with noise-absorbing material.

The operation of an absorption silencer provides for the transformation of the energy of vibrations of high frequency of the exhaust gases flowing through the silencer into heat.

Due to the sound absorption effectiveness of absorption materials, the silencers of this type are efficient only for sounds with frequencies above 500 cycles per second. Therefore, they are not suited for absorption of fundamental frequency, which is the dominant noise characteristic, and which in engines being generally used, amounts to about 200 cycles per second.

In silencers now in general use there exists a dependence of the sound absorption and engine parameters on the volume of the silencer.

The volume of the silencer needed for an average engine, e.g. four-stroke, four-cylinder engine, with displacement 91.5 cu. in. and rotational speed of about 4000 R.P.M., amounts to 610 cu. in.

This condition, practically, makes it impossible to design efficient exhaust systems as light and compact structures. It makes it necessary to employ at least two silencers, in which different principles of sound absorption for particular bands of frequencies occurring in the characteristic sound level are employed.

The flow resistance encountered in silencers now, properly selected with regard to the loudness, causes an excessive counterpressure, which disturbs the process of charge change in the engine.

The purpose of the present invention is to reduce the noise level due to the exhaust of combustion gases in the whole range of frequencies resulting from the different rotational speeds of an engine, without impairing the engine operating parameters, by means of a silencer of reduced size and simplified design.

This aim has been fulfilled by utilization of an interference - absorption set, whose construction and geometrical dimensions cause the generation of standing

waves with constant exhaust gas vibration frequency elevated to such a height as to enable a transformation of their energy into heat in a sound absorbing material.

The interference - absorption set of the silencer, according to the invention, consists of perforated pipe conduits enclosed in a housing, forming a connected system of pipes and located in absorbing material.

These conduits are formed by symmetrical bowed pipes connected by connector joints where exhaust gas streams collide and are again divided.

The bow-like shape of symmetrical halves of a pair of pipes causes such a conducting of the exhaust gas stream that these exhaust gases flowing from opposite directions, collide in the cross connectors of the pipes, thus causing a generation of standing waves.

These waves are generated from two plane waves being superposed one upon another with opposite displacement speed directions with the same amplitudes.

In order to obtain a plane wave, the diameter of the pipe conduit in the silencer, according to invention, is at least fourfold smaller than the length of a single bowed pipe.

The distances between places of succeeding collisions of exhaust gas streams in the connected system of pipes are spaced in such a manner that the proportions of these distances, being the lengths of single bowed pipes and the speeds of wave displacement in exhaust gas streams flowing through these pipes are maintained at constant values. Stated another way, equal distance proportions are maintained in the system of pipes between successive collision points of the exhaust gases, determined by the pipe lengths, and the velocities of wave propagation in the streams flowing through these pipes.

This distance is many times smaller than the smallest length of a sound wave being determined, as a result of rotational speed of the engine, by the frequency of the fundamental component of noise characteristic.

Thus, an elevation and stabilization at equal height of vibration frequencies of waves being formed, are maintained at the same level in all branches i.e., in all branches the wave vibration frequencies are equal.

This frequency is independent of the frequency of waves flowing from the engine and is stabilized by geometrical dimensions of the pipes of the connected system of the silencer, according to the invention.

The vibration frequency of the waves is raised to a value corresponding to the maximum value of the coefficient of energy absorption, the energy absorption being due to the transformation of the sound energy into heat in the sound absorbing material being used. To this frequency are adapted the form, proportion, and volume of the housing of the silencer, which is a known acoustic reflection filter.

This stabilization of the vibration frequency of waves generated in the silencer, according to the invention, in the whole range of frequencies resulting from the rotational speeds of the engine, and a simultaneous raising of these frequencies to a value corresponding to the maximum value of the coefficient of sound absorption by the absorbing material being used enables the efficient absorption of sounds.

The silencer, according to the invention, whose construction causes the absorption of the wave movement without limiting the flow of exhaust gases, enables a

choice of a most advantageous flow resistance on which the improvement of the charge exchange in the engine depends, without impairing the engine parameters.

The application of the silencer, according to the invention, to a Diesel engine with a displacement of 397 cu. in. and with fourfold volume as calculated for known silencers, has made possible, by way of example, at 1500 rpm, a lowering of the loudness level dominating in the noise characteristic of the fundamental frequency band, by 34 dB, without any negative influence of the operating parameters of the engine.

The increase of the wave vibration frequency tantamount to the decrease of their length, limits the range of spreading of these waves, since the high tones do not spread as wide as the low tones.

The construction of the silencer, according to the invention, enables its assembling from prefabricated elements, is simple and economic, and provides a possibility of a choice of an appropriate number of pipes, depending on the degree of sound absorption required.

In the silencer, according to the invention, the efficiency of sound absorption is independent of the pressure of exhaust gases at the beginning of the cycle of the outlet, due to the superposition of waves with the same parameter, spreading in opposite directions.

The sound absorption method used in the silencer, according to the invention, is based on the phenomenon of the generation of standing waves and the accompanying dynamic effects, an absence of disturbing transverse waves, making it possible to determine the design parameters of silencers for various types of internal combustion engines, by calculation and tests on motorless stands, as well, and eliminates a fortuitous choice of silencers as is presently practiced.

The silencer for internal combustion engines, according to the invention, is shown by way of example in the accompanying drawing, in a partial section view, with one half of the housing removed.

The silencer, according to the invention, consists of a system of perforated pipe conduits arranged in pairs, enclosed within housing **1**, contained in an absorbing material **2**, to which system the exhaust gases flow through an inlet pipe **3** and inlet connector **4** and flow out through outlet connector joint **5** and discharge pipe **6**.

The pipes, being the elements of the connected system consist of symmetrical perforated pipes or conduits **7** and **8**, **10** and **11**, **13** and **14**, **16** and **17**, **19**, and **20**, connected in pairs by cross connector joints **9**, **12**, **15** and **18**, and the inlet connector joint **4** and outlet connector joint **5**.

The silencer, with an interference-absorption set, according to the invention, operates in so that an exhaust gas stream flowing in through the pipe **3** fixed in the housing **1** is divided in the inlet connector joint **4** into two streams which flow through oppositely extending pipe conduits **7** and **8**, and then collide in the cross connector joint **9**.

In this connector joint they are divided into two streams flowing through the pipe conduits **10** and **11**, to collide in the cross connector joint **12** and for the third time they divide, flowing into the pipe conduits **13** and **14**.

The streams flowing through the pipes **12** and **14** collide for the third time and are divided for the fourth time in the cross connector joint **15** flowing into the pipe conduits **16** and **17**.

From the latter the exhaust gases flow, colliding for the fourth time and being divided for the fifth time in the cross connector joint **18** and then flow through the pipe conduits **19** and **20**.

The exhaust gas streams flowing in pipe conduits **19** and **20** collide in the outlet connector joint **5** for the fifth time, and then flow out outside the silencer through the exhaust pipe **6** fixed in its housing **1**.

The connectors each have at least one pair of oppositely extending arms to each of which a perforated pipe is connected. Each connector also has either a second pair of arms transverse to the first pair, or a single transverse arm, as in the case of inlet connector **4** and outlet connector **5**.

It is evident that the number of pairs of conduits the silencer, according to the invention, is selected depending on the efficiency of noise absorption connected with the exhaust of combustion gases.

The collisions of streams in connectors joints cause the generation of standing waves with equal vibration frequency independent of the frequency of pulsation of a non-stationary stream of exhaust gases flowing into the silencer.

At the nodes of these waves the speeds of the vibrating points are equal to zero, since the molecules successively approach and move away from the node.

The places of collisions of streams are established at such distances from one another that the standing waves generated in successive branchings of the interference conduits have an equal frequencies of vibrations.

The distance between two successive places of collisions of exhaust gas streams is at least twice smaller than the smallest length of the sound wave as defined by the frequency of the fundamental component of noise characteristics resulting from the highest rotational speed of the engine.

The vibration frequency of standing waves generated in the interference conduits, depending on geometrical dimensions of these conduits and parameters of exhaust gases flowing through is adapted to the most advantageous range of frequency absorption by the absorbing material being applied.

Besides, the geometrical dimensions of the silencer are so selected in relation to the vibration frequency of the exhaust gas stream that it forms an acoustic resonance filter reducing deviations of vibrating molecules due to a dynamic reaction of gases filling the silencer.

I claim:

1. A silencer for an internal combustion engine comprising:

a plurality of sets of pipes, each set comprising two bowed symmetrical pipes each having an inlet and an outlet and being perforated along their lengths,

a connector for the pipe inlets of each set comprising a pair of oppositely extending arms to each of which an inlet of a said pipe is axially connected, and inlet arm means extending transversely of said oppositely extending arms,

a connector for the pipe outlets of each set comprising a pair of oppositely extending arms to each of which an outlet of a said pipe is axially connected, and outlet arm means of said last mentioned con-

nector extending transversely of said arms thereof,

the outlets of the pipes of one set being connected to the inlets of the pipes of a succeeding set by a said connector having two pairs of coplanar oppositely extending arms transverse to each other,

a housing for said pipes and connectors, and sound

absorbing material occupying the space in said housing around said pipes and connectors.

2. The silencer of claim **1**, wherein the diameter of a said bowed pipe is not greater than one-fourth the length thereof.

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