Sept. 1, 1931. R. B. BOURNE 1,821,688

SILENCER

Filed Dec. 20, 1929

Fig. 1.

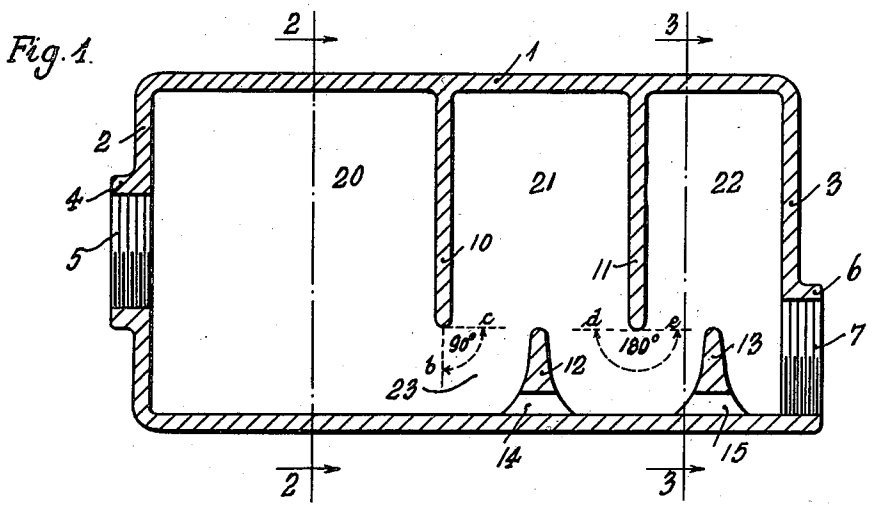


Fig. 2.

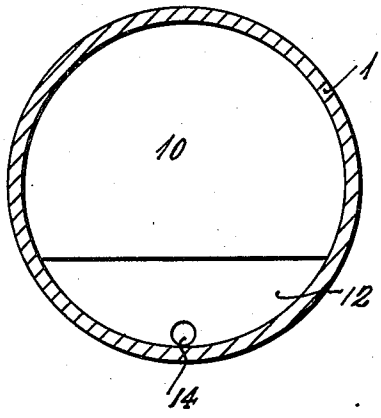
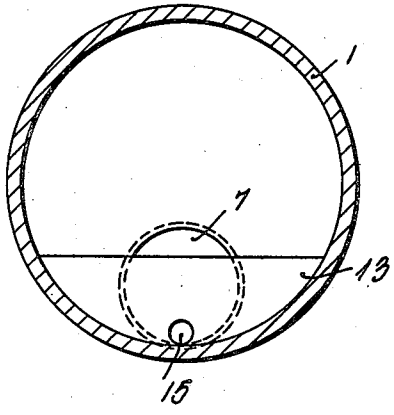


Fig. 3.



INVENTOR.
Roland B. Bourne
BY
Chapin & Neal
ATTORNEYS.

Patented Sept. 1, 1931 1,821,688

UNITED STATES PATENT OFFICE

ROLAND B. BOURNE, OF HARTFORD, CONNECTICUT, ASSIGNOR TO THE MAXIM SILENCER COMPANY, OF HARTFORD, CONNECTICUT, A CORPORATION OF CONNECTICUT

SILENCER

Application filed December 20, 1929. Serial No. 415,576.

This invention relates to mufflers for silencing the exhaust of internal combustion engines and more particularly such engines of small watercraft such as motor boats and the like.

A variety of muffler constructions have been suggested for this purpose, many of them being based on the principle of reducing the discharge energy of the exhaust gases by baffle plates and similar means; others utilizing the interference principle; and still others the diminution of the discharge energy produced by the cooling of the exhaust gases. Practically all of the former mufflers suffer from too great a complexity of the structure; they are difficult to manufacture and consequently expensive; many of them are bulky and heavy in design, not easily installable on small craft; and frequently the question of easy accessibility for cleaning operations has been neglected altogether.

The object of this invention is to provide a muffler or silencing device for the purpose stated, which device is very effective in silencing the exhaust noise by combining for the attenuation of vibratory energy, interference and cooling effects, and which is, at the same time, compact, of light weight, and of very simple and rugged construction. Consequently, it can be made cheaply and, if desired, in a single piece casting of easy accessibility for the purpose of core removal and cleaning. Another object, of particular usefulness in watercraft, is the distribution of the cooling water in the silencer in such a manner that the water will act as a clogging agent for the exhaust at idling or very light loads of the engine and thereby improve the thermal conditions of the engine under such circumstances. The cooling water will be supplied to the muffler continually by any one of the usual means in engines of this character.

The manner in which these various objects and still others have been achieved will appear from the subsequent description and the accompanying drawings, in which:

Fig. 1 is a vertical section on the longitudinal axis of the silencer;

Fig. 2 is a vertical section at right angles to Fig. 1 on line 2—2 of Fig. 1; and

Fig. 3 is another section at right angles on line 3—3 of Fig. 1.

Referring to Figs. 1 to 3, it will be noted that the general shape of the muffler is a cylinder closed at both ends by apertured headers. I prefer the cylindrical form because it provides larger volumes for a given surface of the shell. Apart from this reason, I might just as well use a prismatic shape. The cylinder 1 and the headers 2 and 3, the former of which is provided with the internally threaded inlet flange 4 and inlet opening 5 and the latter with the internally threaded outlet flange 6 and outlet opening 7, are shown as consisting of a single-piece casting. However, where very light weight is desired and where corrosion is a matter of subordinate importance, the cylinder and the headers may be made from separate pieces of sheet steel welded together or held by bolts and similar means.

The partitioning walls in the interior of the cylinder which, in this case, are cast integral with the shell and the headers, comprise upper depending long segmental walls 10 and 11 and lower upstanding short segmental walls or wiers 12 and 13. The upper and lower segments are spaced apart in staggered relation and the free edges of the upper and the lower segments preferably lie in one and the same horizontal plane; in other words, they lie flush so that the sum of the surface of an upper segment and the surface of a lower segment equals the cross-sectional area within the cylinder. This condition is clearly to be seen from Figs. 2 and 3.

Fig. 1 shows the longitudinal or axial spacing of the upper segments with respect to the lower segments. The location occupied by the lower segment 12 is midway between the positions of the neighboring upper segments 10 and 11 and the location of the lower segement 13 is again midway between the neighboring upper segment 11 and the header 3.

The exhaust gases and the cooling water enter the silencer jointly through the inlet opening 5 and leave the silencer jointly through the outlet opening 7. On their way through the muffler, the exhaust gases enter first the spacious fore-chamber 20 which occupies about half the volume of the cylinder. Then they undulate under and over the edges of the upper and lower segments, thus forming a sinuous current which finally leaves the cylinder through the outlet opening 7. In its curved flow the current of exhaust gases will, to a small degree, also extend into the spaces of the chambers 20, 21 and 22, formed between the upper segments and cylinder walls. In the main, however, the upper portions of the gas volumes in those chambers will be in a condition of non-flow with only minor disturbances provoked by eddies detached from the passing-by current of exhaust gases and thus constitute in effect acoustic side chambers for the main passage through the casing.

The entering cooling water falls to the bottom of the fore-chamber where it collects until its level has risen high enough to be dragged along by the stream of exhaust gases passing through the orifice 23 as formed by the upper segment 10 and the lower segment or weir 12. Due to the tapering form of the lower segments or weirs, whose faces gradually merge into the lower wall portions of the cylinder, and because of the rapid motion of the exhaust gases in the orifice, the rush of water in the orifice is very rapid. When the engine is operating under normal load conditions, the water will be thrown up across the stream face of the weir 12 into the chamber in the form of a flat spray, the scattered particles of which will then drop to the bottom wall between the lower segments 12 and 13 in order to undergo the same spray effect once more by traveling up the sloping face of weir 13. Finally, the water is carried along through the outlet opening.

As will be noted from Fig. 1, there are provided small axial holes 14, 15 in the lower segments 12 and 13. The opening of these holes is sufficiently wide to permit the drainage of bottom water from the muffler through the outlet opening by slightly raising the inlet end of the muffler. However, these holes are not large enough to materially influence the operating conditions in the silencer as described before. It will furthermore be seen from Fig. 1 that the volume of chamber 21 is larger than the volume of chamber 22. While this is my preferable construction, it is not deemed necessary in all cases and this feature will be dealt with more particularly later on.

From the description it will appear that my design provides a silencer of very simple and inexpensive construction. There are no narrow, tortuous passages in the construction which would cause the accumulation of obstructive deposits from the gases and, if a cleaning of the muffler after prolonged use should be deemed advisable, it can be done without difficulty. If the muffler is made up from several parts of sheet metal, the assembling and disassembling of the same can also be very easily accomplished for cleaning purposes.

I offer the following brief explanation of the operating principles of this silencer without intending that the invention shall be in any way restricted by the proposal of such theoretical explanations. It should be understood at the outset that the various volumes in the silencer represent an extremely complex acoustic system which is hardly within reach of mathematical treatment. All explanations must, therefore, be confined to considerations of qualitative character.

It is a well known fact that volumes branched off sidewise from a stream of gas (viz., acoustic side chambers) which also contain vibratory energy are able to produce by interference counter-vibromotive forces in the stream which attenuate or even entirely extinguish the original vibromotive forces in the stream. To what extent this phenomenon of sound extinction by interference takes place depends on the acoustic characteristic of the system as a whole, the chiefly determining factors being acoustic resistances, inductances, capacitances and their relative configuration in the system, also collectively spoken of as the distribution of acoustic impedances in the system.

From what has been said before as to the behavior of the gas current in the chambers, it follows that the more remote or upper portions of the volumes in the chambers 20, 21 and 22 represent side-branched volumes of different size. Acoustically speaking, they may be said to be impedances branched off from the impedance of the main line or conduit, as represented by the passing stream of exhausting gases. This main conduit may itself be thought of as consisting of a number of acoustic impedances connected in series. The first section extends from the inlet opening 5 to the first orifice 23; the second section is formed by the path in that first orifice. This will be understood by reference to Fig. 1 where the mean path in the orifice 23 is indicated by the 90 degree arc *b*—*c*. The third impedance section is the curved path *c*—*d* in chamber 21; the next section the 180 degree arc *d*—*e* between the two lower segments and so forth. It will be observed that the communicating passage indicated at *b*—*c* between the first chamber 20 and the second chamber 21 is shorter than the communi-

cating passage *d*—*e* between the second chamber 21 and the third chamber 22.

It is obvious to any one versed in the acoustic art that the more remote, stationary volumes in the side chambers will take part in the vibrations of the main line or gas current and react not only directly on the vibromotive forces in this current, but also among each other maintain communicative interference with the result that not only a definite frequency but a wide range of frequencies is attenuated without producing back pressures against the free outflow of the gases. The occurrences in the side chambers are, of course, of very complex nature, since even the shape of the entering wave front is quite irregular and neither plane nor spherical. The reflections which produce the interferences are of correspondingly very complex character. Further complexities are introduced by the presence of the water and the water sprays.

However, I have found from tests with silencers built according to this invention that, though I provide only three chambers, the silencing qualities of this structurally very simple but acoustically very complex arrangement are excellent and very appreciably better than those of prior much more complicated structures which, moreover, frequently impede the outflow of the gases materially by baffle plates, etc. I have furthermore observed that with three chambers, the silencing effect is better if the impedances of the various chambers and sections in the main conduit differ from each other and among each other. For this reason, I prefer dimensions nearly corresponding to those illustrated. I do not mean to specify exact dimensional relations between the various acoustic elements of the silencer. But the silencing effect with a small number of side chambers may be improved by having the side chambers vary in size, preferably in progressively decreased size in the direction of flow as illustrated in the drawings. The impedance sections in the main conduit differ, due to the general arrangement of the segments, and this dissimilarity will be still more pronounced with uneven dimensions of the chambers.

Although I have mentioned the dissimilarity of the various impedances as a favorable feature, I do not wish the invention limited thereto for in its broader aspect it does not require any precise specifications for relative proportions of the chambers nor of the sections of the main line. Peculiar and distinguishing features of my silencer dimensions are, however, that the side chambers are not narrowed at their junction with the main conduit and that their lateral extension from the gas current is considerably greater than the average thickness of the gas current itself. This latter statement amounts to saying that the lower segment must not extend too far into the side chamber because, then, almost the entire volume in the chamber would become part of the current and thus lose its character as a side-branched volume. On the other hand, the free edges of the upper and lower segments need not necessarily lie flush as shown in the figures but may overlap slightly. I prefer the disposition shown especially for smaller-capacity silencers in order to render the cleaning more convenient.

As I have pointed out already at the outset, the present invention utilizes combined interference and cooling effects. It is known from experience that in cooling a current of gas which also contains vibratory energy the cooling will not only reduce the intrinsic and kinetic energy of the current but also its vibratory energy.

In my arrangement, the water behaves differently under different load conditions of the engine. I shall now point out these differences and, at the same time, take up the discussion of the cooling and other effects of the water current. When the engine is idling or only slightly loaded, the pressure and the velocity of the exhaust gases are also low. This condition will permit the accumulation of more bottom water in the silencer and reduce the rapidity of flow in the water stream so that the top edges of the lower segments will act more like weirs. The damming back and more gentle overflow produced under these circumstances constricts the cross-section of the orifices and may, temporarily, even clog them entirely so that the gas current becomes discontinuous. In any event, a back pressure will be created in the muffler when the engine works at or near idle load.

This back pressure or clogging effect is particularly desirable in boat engines. Such engines are usually cooled by water taken from and discharged into the surrounding water. With this kind of water circulation, any change in the engine load will be quickly reflected on the temperature of the cylinder walls and with low or idling loads the engine cylinder may assume too low a temperature and thus produce fogs in the mixture, followed by irregular ignition and combustion. By raising the exhaust back pressure under such conditions, the end temperature of discharge will be raised in the engine cylinder and, consequently, also the end temperature of compression and the mean temperature of the cylinder walls. In this way the unfavorable influence of the cooling water on ignition and combustion is counteracted.

With increasing engine loads, the clogging effect will almost entirely cease, because then the highly energized gases will disintegrate into a number of fine particles

any masses or sheets of water opposing their way. The water sprays thus produced present a very extended cooling surface to the gases so that energy is quickly withdrawn from the gas current. I have found that the annihilation of vibratory energy by the combined action of interference and cooling effects in the manner described makes it possible not only to obtain excellent silencing effects but also to get such effects with comparatively small, simple and inexpensive apparatus.

It will now be clear that I obtain from the present design of silencer effects which differ materially from those of former constructions. At full and normal partial loads with correspondingly high vibratory energy in the exhaust, both silencing agencies, that is interference and cooling, will exert their full efficacy. At idling and low loads where the vibratory energy or noise produced is much less, the interference effect alone will be sufficient to cause the substantial extinction of the low load noise and in addition the silencer will automatically develop a desirable back pressure. In former constructions employing baffle plates and the like, the back pressure went up with increasing engine load and thus detracted materially from the engine efficiency. In my arrangement, the engine efficiency will be unaffected at higher loads and be bettered at idling and very low loads in virtue of the general improvement of the thermal conditions in the engine cylinder in the low-load range.

What I claim is:

1. A muffler for silencing internal combustion engine exhaust noises, comprising an oblong casing having an inlet opening at one end and an outlet opening at the opposite end for the joint passage therethrough of the exhaust gases and cooling water, said casing having depending from its upper side relatively long depending partition walls spaced apart to form a series of acoustic side chambers, the lower side of said casing having upstanding therefrom relatively short walls serving as weirs for the flow of water thereover, and spaced apart in staggered relation to said partition walls, the upper free edges of said short walls being substantially in the same plane as the lower free edges of said long walls, whereby communicating passages are provided between said chambers the walls of which cause a deflection of the main stream of exhaust gases and water in and out of said chambers, the extent of said main stream deflection being slight as compared with the height of said chambers.

2. A muffler for silencing internal combustion engine exhaust noises, comprising an oblong casing having an inlet opening at one end and an outlet opening at the opposite end for the joint passage therethrough of the exhaust gases and cooling water, said casing having depending from its upper side relatively long depending partition walls spaced apart to form a series of acoustic side chambers, the lower side of said casing having upstanding therefrom relatively short walls serving as weirs for the flow of water thereover, and spaced apart in staggered relation to said partition walls, the upper free edges of said short walls being substantially in the same plane as the lower free edges of said long walls, whereby communicating passages are provided between said chambers the walls of which cause a deflection of the main stream of exhaust gases and water in and out of said chambers, the extent of said main stream deflection being slight as compared with the height of said chambers, the upstream faces of said weirs being so sloped as to produce, at lower velocities of the exhaust gases, a constriction of the said communicating passages by water damming and, at higher velocities of the exhaust gases, a water spray within said chambers.

3. A muffler for silencing internal combustion engine exhaust noises, comprising an oblong casing having an inlet opening at one end and an outlet opening at the opposite end for the joint passage therethrough of the exhaust gases and cooling water, said casing having depending from its upper side relatively long depending partition walls spaced apart to form a series of acoustic side chambers, the lower side of said casing having upstanding therefrom relatively short walls serving as weirs for the flow of water thereover, and spaced apart in staggered relation to said partition walls, the upper free edges of said short walls being substantially in the same plane as the lower free edges of said long walls, whereby communicating passages are provided between said chambers the walls of which cause a deflection of the main stream of exhaust gases and water in and out of said chambers, the extent of said main stream deflection being slight as compared with the height of said chambers, the upstream faces of said weirs being so sloped as to produce, at lower velocities of the exhaust gases, a constriction of the said communicating passages by water damming and, at higher velocities of the exhaust gases, a water spray within said chambers, the bottom portions of the weirs having water passages wide enough for draining the casing, but too narrow to interfere with said operation of the weirs.

4. A muffler for silencing internal combustion engine exhaust noises, comprising an oblong casing having an inlet opening at one end and an outlet opening at the opposite end for the joint passage therethrough of the exhaust gases and cooling

water, said casing having depending from its upper side relatively long depending partition walls spaced apart to form a series of chambers decreasing in size toward the outlet end of said casing, the lower side of said casing having upstanding therefrom relatively short walls serving as weirs for the flow of water thereover, and spaced apart in staggered relation to said partition walls, the upper free edges of said short walls being substantially in the same plane as the lower free edges of said long walls, whereby communicating passages are provided between said chambers the walls of which cause a deflection of the main stream of exhaust gases and water in and out of said chambers, the extent of said main stream deflection being slight as compared with the height of said chambers.

5. A muffler for silencing internal combustion engine exhaust noises, comprising an oblong casing having an inlet opening at one end and an outlet opening at the opposite end for the joint passage therethrough of the exhaust gases and cooling water, said casing having relatively long depending partition walls spaced apart to form a series of at least three successive chambers, the lower side of said casing having upstanding therefrom relatively short walls serving as weirs for the flow of water thereover, and spaced apart in staggered relation to said partition walls, the upper free edges of said short walls being substantially in the same plane as the lower free edges of said long walls, whereby communicating passages are provided between said chambers the walls of which cause a deflection of the main stream of exhaust gases and water in and out of said chambers, the extent of said main stream deflection being slight as compared with the height of said chambers, the communicating passage between the first and second chambers being of shorter length than the communicating passage between the second and third chambers.

6. A muffler for silencing internal combustion engine exhaust noises, comprising an oblong casing having an inlet opening at one end and an outlet opening at the opposite end for the joint passage therethrough of the exhaust gases and cooling water, said casing having depending from its upper side relatively long depending partition walls spaced apart to form a series of at least three successive chambers decreasing in size toward the outlet end of said casing, the lower side of said casing having upstanding therefrom relatively short walls serving as weirs for the flow of water thereover, and spaced apart in staggered relation to said partition walls, the upper free edges of said short walls being substantially in the same plane as the lower free edges of said long walls, whereby communicating passages are provided between said chambers the walls of which cause a deflection of the main stream of exhaust gases and water in and out of said chambers, the extent of said main stream deflection being slight as compared with the height of said chambers, the communicating passage between the first and second chambers being of shorter length than the communicating passage between the second and third chambers.

In testimony whereof I have affixed my signature.

ROLAND B. BOURNE.