United States Patent

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[45] Patented **June 22, 1971**

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[54] **MUFFLER WITH SEQUENTIAL EXPANSION CHAMBERS**
10 Claims, 10 Drawing Figs.

[52] **U.S. Cl.** **181/57,** 181/58, 181/61, 181/63
[51] **Int. Cl.** **F01n 1/02,** F01n 1/08, F01n 1/12
[50] **Field of Search** ..... 181/33, 35, 33.04, 35.3, 47, 49, 43, 51, 61—63, 72, 57, 58, 48, 59

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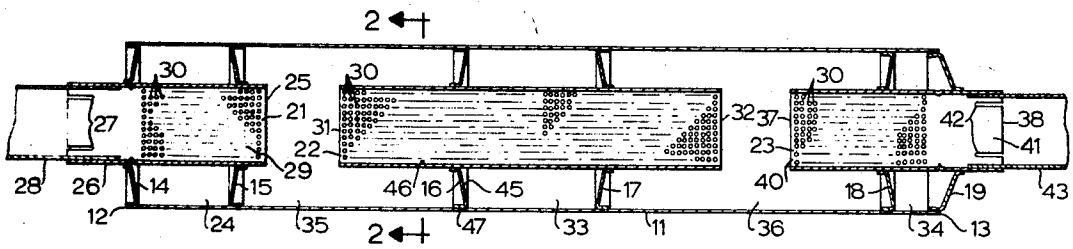
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ABSTRACT: A muffler able to greatly reduce the exhaust sound of powerful truck engines without too greatly increasing the back pressure. The large shell is concentric with first, second and third inner pipes that are axially aligned, and are spaced apart by a distance approximately equal to their diameter. The central inner pipe is much longer than the other two and, within the shell, all are perforated. Each one is supported by two annular baffle-support members. The central innner pipe has its baffles spaced in about one-third of the distance from each end. The axially inner members of each of the two end pairs of baffles are spaced different distances from the axially inner end of their respective inner pipes, that of the third inner pipe being much closer to the end of the shell than the corresponding baffle for the first inner pipe. As a result, the distance between the axially inner baffle of the first pair is closer to its adjacent baffle of the second pair than is the axially inner baffle of the third pair to its adjacent baffle of the second pair. Hence a series of chambers of different sizes are formed. Further reduction of sound is achieved by dividing the inner pipes into radial sectors or by introducing the exhaust gases in a swirl, or by placing a flow restriction at the entrance end to the second pipe.



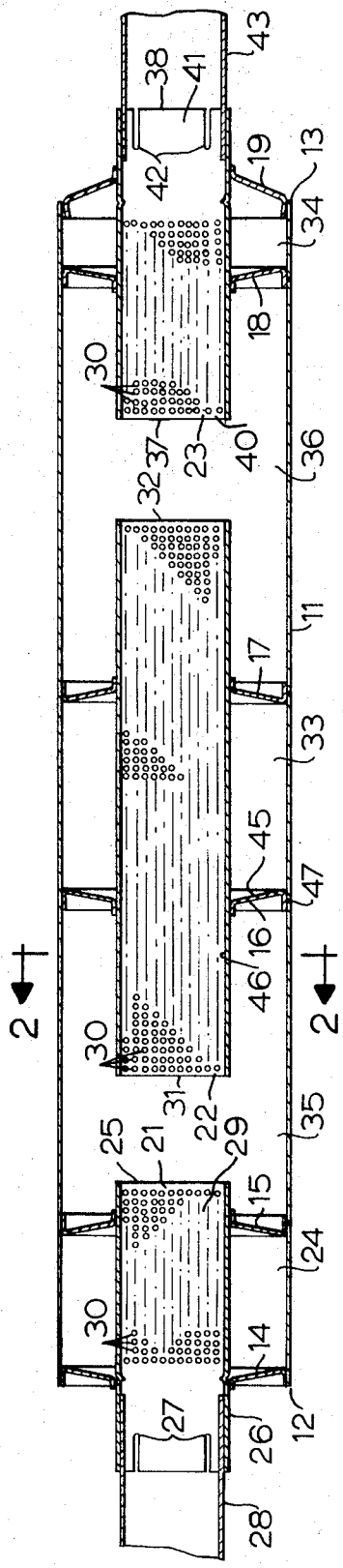


FIG. 1

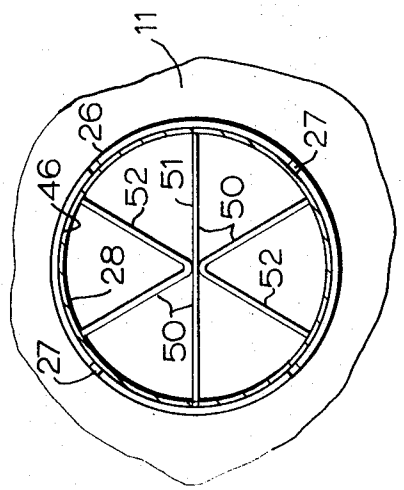


FIG. 5

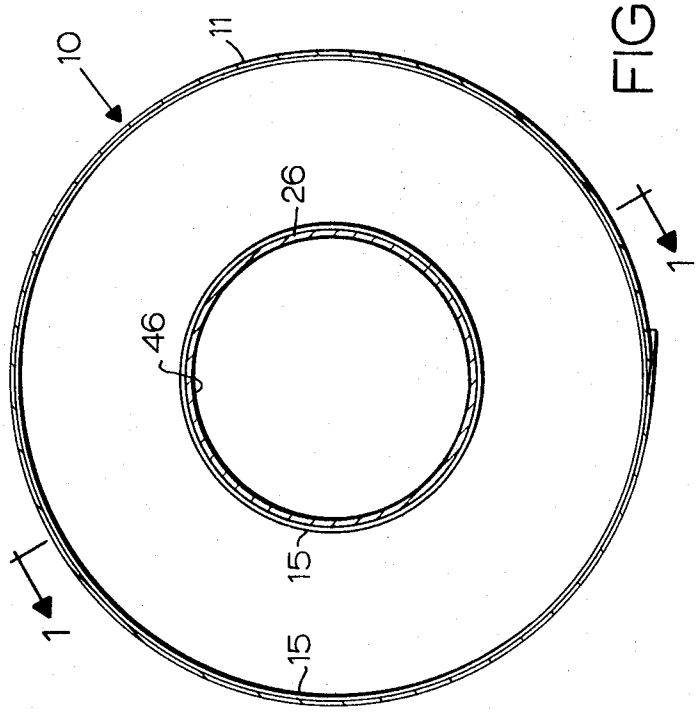


FIG. 2

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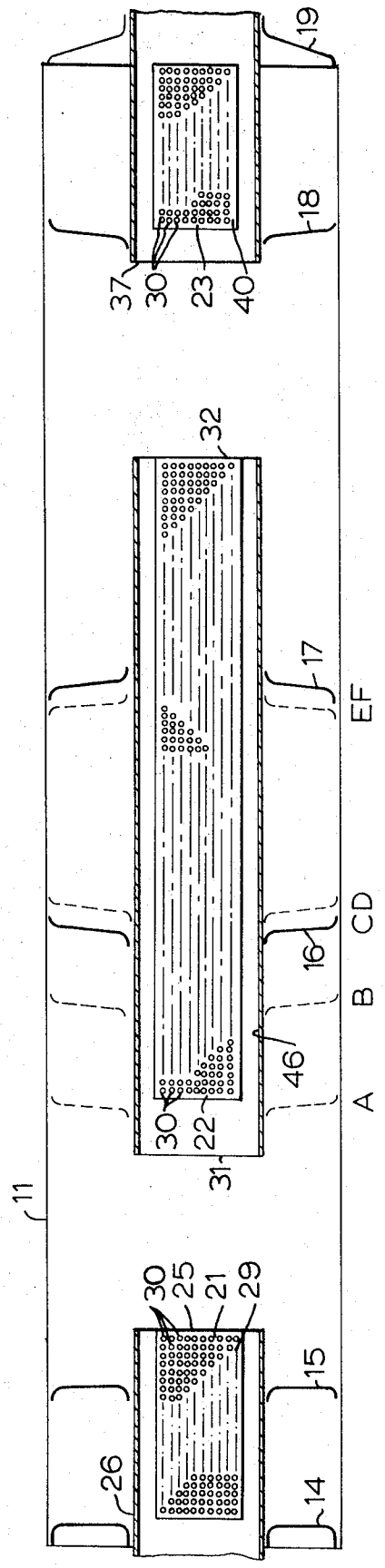

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FIG. 3

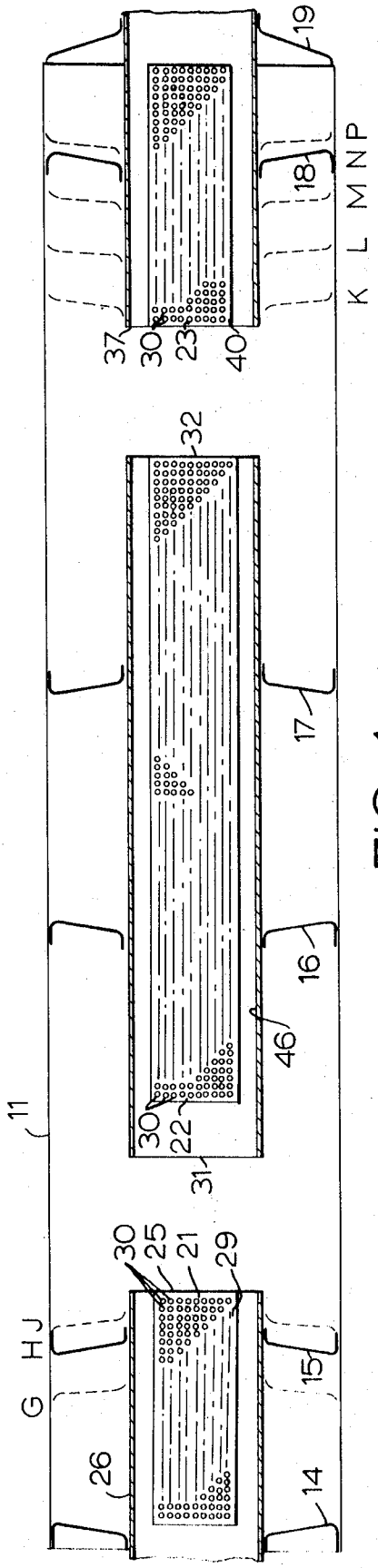

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FIG. 4

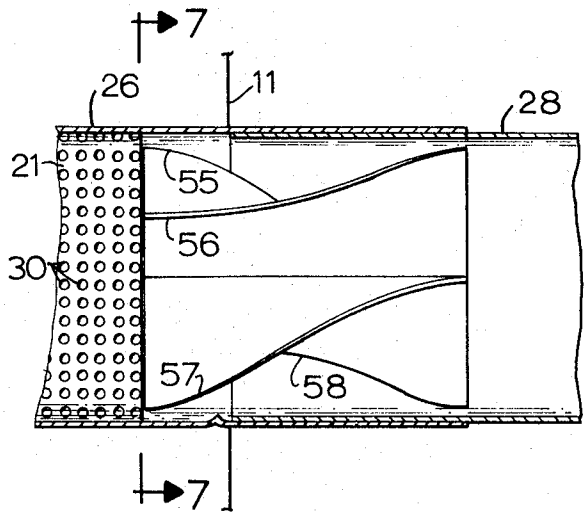


FIG. 6

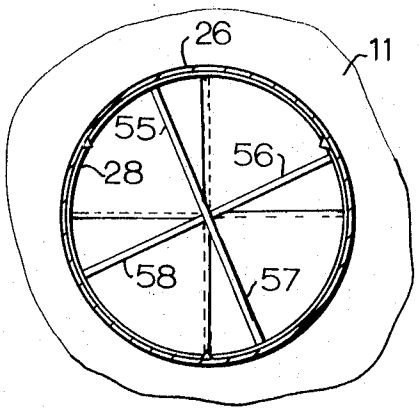


FIG. 7

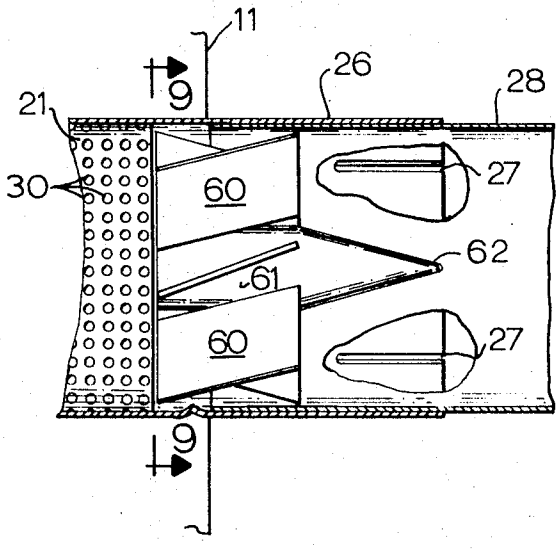


FIG. 8

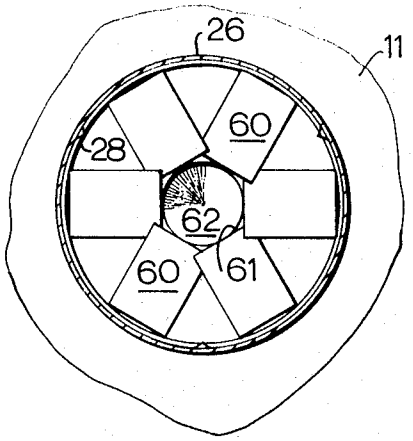


FIG. 9

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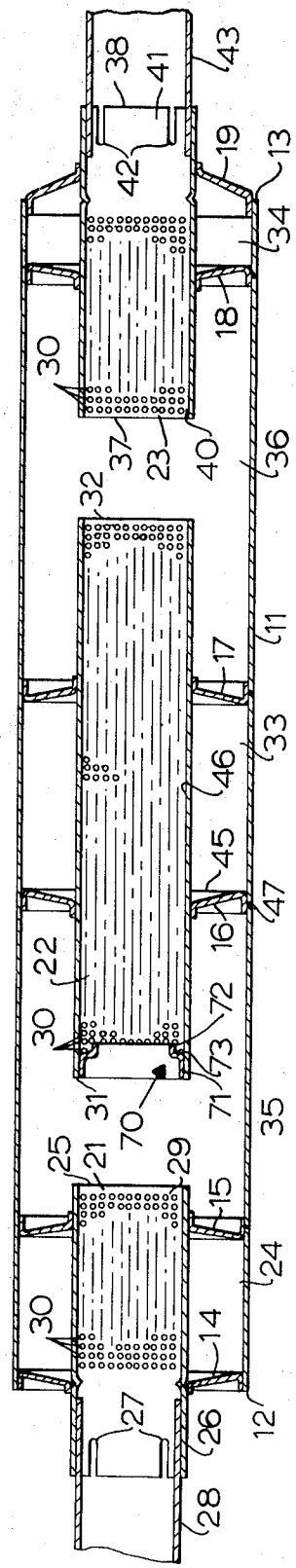


FIG. 10

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MUFFLER WITH SEQUENTIAL EXPANSION CHAMBERS

This invention relates to an improved muffler of the type used in the exhaust system of an engine, especially automotive engines.

The problem of muffling the noise produced by internal combustion engines has become more and more severe as the engines have increased in power.

The powerful diesel engines used in very large trucks illustrate the severity of the problem, for they have been so loud that mufflers have heretofore been unable to reduce the noise level to an acceptable value, for certain engines without creating other unacceptable conditions. For example, California law presently requires that the noise level of trucks not exceed 88 decibels at 50 feet, but prior-art muffler structures could not reach that level of quietness without increasing the exhaust back pressure to an intolerable amount. Cost and size have also been factors, for purchasers of the trucks want to utilize as much as possible of the available space for payloads, rather than to accommodate mufflers, and complicated, expensive structures are undesirable.

The present invention provides a muffler that can be identical in size to the currently used unsatisfactory mufflers, and it is comparable to them in cost. Yet it can meet the legal and prescribed standards when used on many large diesel truck engines, and it does not bring about an excessive back pressure.

We have found that to maintain back pressure within acceptable limits demands small gaps between successive inner pipes and that noise level can be reduced by making the inner pipe in three successive, axially aligned and spaced-apart perforated portions, while providing certain proportions between these inner pipe portions and between their supporting baffles. These relationships are quite important and will be explained below in the detailed description of some examples of preferred embodiments. The operation of the muffler can be further improved, we have found, by combining these principles with means for introducing the gas to the muffler in a swirling stream and by constructing inner pipe with radial sectors, or by placing a flow restriction at the entrance end to the second pipe.

Other objects and advantages of the invention will appear from the following description of some preferred embodiments.

In the drawings:

FIG. **1** is a view in longitudinal section taken along the line **1–1** in FIG. **2** of a muffler embodying the principles of the invention.

FIG. **2** is a view in section taken along the line **2–2** in FIG. **1**.

FIG. **3** is a view similar to FIG. **1** of a somewhat modified form of the invention, showing in broken lines some possible positions for the baffles for the central inner pipe, none of which give as good results as the positions shown in solid lines.

FIG. **4** is a view similar to FIG. **1** showing in broken lines some possible positions for the axially inner baffles of the two axially outer inner pipe sections, none of which gives as good results as the solid-line positions.

FIG. **5** is a view similar to FIG. **2** of a modified form of the invention with the inner pipe sections radially sectored.

FIG. **6** is a view in side elevation of a swirler for use with the muffler of FIG. **1**, shown adjacent the inlet end thereof.

FIG. **7** is a view in section taken along the line **7–7** in FIG. **6**.

FIG. **8** is a view in side elevation of a modified form of swirler.

FIG. **9** is an end view of the device of FIG. **8**.

FIG. **10** is a view similar to FIG. **1** of a modified form of the invention showing a flow restrictor placed at the entrance to the second pipe.

A muffler **10** embodying the principles of the invention is shown in FIGS. **1** and **2**. It has a cylindrical metal shell **11** with ends **12** and **13**. Three pairs of baffle-and-support members, **14**, **15** and **16**, **17**, and **18**, **19** support three successive, axially aligned and spaced-apart inner pipes **21**, **22**, and **23**.

Between the first pair of baffles **14** and **15** is an annular chamber **24**, the baffle **15** being spaced away from the axially inner end **25** of the first pipe **21**, toward the baffle **14**, but the chamber **24** is about two-thirds or more as long as the first inner pipe **21**. The first inner pipe **21** is relatively short and it has an axially outer imperforate portion **26** that has axial slots **27** enabling a snug press fit with the exhaust pipe **28** which conducts the exhaust gases from the engine to the muffler **10**. The axially inner portion **29** of the pipe **21** is perforated by conventionally sized holes **30**.

The first inner pipe **21** is spaced apart from the second inner pipe **22** by a gap which preferably is small, for we have found that the back pressure can be kept low by having these gaps small. We have found that it is desirable for the gap to be about the same length as the diameter of the inner pipes, and that it can vary from this with some increase in noise or back pressure, by about plus or minus 10 percent. The gap between the second inner pipe **22** and the third inner pipe may be identical or approximately so.

The second inner pipe **22** is preferably perforated fully between its ends **31** and **32**, or substantially so, by the holes **30**, for best performance. The baffle **16** is spaced in from the end **31** by about one-third the length of the pipe **22**, and the baffle **17** is spaced in from the end **32** by about the same distance, so that the baffles **16** and **17** define between them an annular chamber **33** that encircles the center third of the pipe **22**, or approximately that much.

The third pair of baffles **18** and **19** surround the third inner pipe **23**, and define between them an annular chamber **34**. Like the baffle **14**, the baffle **19** closes one end of the muffler **10** around the inner pipe. THe baffle **18** is substantially closer to the baffle **19** than the baffle **14** is to the baffle **15**; so the chamber **34** is shorter than the chamber **24**; in fact the chamber **34** is only about half as large. As a result, the distance between the baffles **15** and **16** which define ends of a chamber **35**, is somewhat shorter than the distance between the baffles **17** and **18**, which define ends of a chamber **36**.

The third inner pipe **23** has ends **37** and **38**. An axially inner portion **40** of the third inner pipe **23** is perforated by the perforations **30**, while an outer portion **41** has axially extending slots **42** that enable a snug press fit around an exhaust pipe section **43** that conducts the exhaust gases away from the muffler **10**.

The baffles **14**, **15**, **16**, **17**, **18** and **19** may be standard muffler baffles and each may have a dished generally radial wall **45** between inner and outer axially extending flanges **46** and **47**. They may be welded in place.

The perforations **30** and their disposition along substantially the full length of the second inner pipe **22** and along substantially the full length of those portions of the first and third inner pipes **21** and **23** that lie inside the shell **11** are important. Omitting them or substantially shortening the length of the perforated portions by making most or all of any of the pipes imperforate raises the noise level. Note that the perforations do not lie only in the chambers **24**, **33**, and **34** but also beyond them, and we have found that this structure contributes substantially to the needed reduction in noise level.

The location of the baffles **15**, **16**, **17**, and **18** is likewise of considerable significance, as will now be shown. A typical embodiment of the invention, where the exhaust pipes **28** and **43** and the three inner pipes **21**, **22**, and **23** are four inches in diameter will serve to illustrate the principles involved. The muffler shell **11** is 9 inches in diameter and about 44 inches long. The perforations may be one-eighth inch in diameter, and they may be located about one-half inch from each other axially and circumferentially. About 10 percent of the surface of the second inner pipe **22** is open area, for example. THe pipe **22** is preferably spaced about four inches apart from each of the pipes **21** and **23**, and the pipe **22** is preferably about 21 inches long with the baffles **16** and **17** each 7 inches apart and 7 inches from each end **31** and **32**, in this example (which is offered only as an example, not a limitation of the invention). The pipe **21** may be about 11 inches long with the inner 7

inches perforated, and the baffles 14 and 15 may be about 6 inches apart, at their centers or 5 inches at their outer closest-together parts. The pipe 23 may be about 12 inches long, with its inner 8 inches perforated, and the baffles 18 and 19 may be about 2½inches apart at their closest points. All this is by way of example only of one very satisfactory construction.

Now consider FIGS. 3 and 4. FIG. 3 shows a muffler in which the inner pipes 21 and 23 are a little shorter than in FIGS. 1 and 4, so that the gaps are a little longer, but the structure is otherwise quite similar. Experiments were run on the structure of FIG. 3 in which nothing was changed but the positions of the baffles 16 and 17. The baffle 16 occupied at different times the positions A, B, C, and D, the preferred position C being shown in solid lines while the positions A, B, and D shown in broken lines gave less satisfactory results. The baffle 17 similarly was sometimes at position E and sometimes at its preferred position F. The results of the tests, which tested both the sound level in decibels from the same large diesel engine and the back pressure are as follows:

TABLE I

Position of baffles		Sound level, decibels at 50'	Total exhaust system back pressure, inches mercury
16	17		
A	E	89.0	2.6
B	E	88.0	2.6
D	E	88.0	2.5
C	F	87.8	2.45

In FIG. 4, substantially the structure of FIG. 1 is shown. In this instance, the optimum positions of the baffles 16 and 17 obtained from table I were used (at C and F in FIG. 3) and only the baffles 15 and 18 were moved. The baffle 15 was moved between positions G, H, and J, position H being determined thereby to be the best one. The baffle 18 was tried in positions K, L, M, N and P, and position N turned out to be the best one in this experiment, as shown in the following table.

TABLE II

Position of baffles		Sound level, decibels at 50'	Total exhaust system back pressure, inches mercury
15	18		
J	K	90.6	2.4
H	K	89.5	2.4
G	K	90.0	2.4
H	L	89.0	2.4
H	M	88.0	2.3
H	N	87.2	2.3
H	P	87.6	2.3

We have found also that the noise level can be reduced about one decibel further, without raising the back pressure too much by using the structure shown in FIG. 5 for providing each of the inner pipes 21, 22, and 23 throughout the length of each with radial compartment walls 50. There can be four or, better, six such walls 50, and these walls can be made from a flat strip 51 to which are welded two 60° angles 52, each bent from a similar strip.

Further noise reduction with only minor increase in back pressure can be obtained by causing the exhaust gas to enter the muffler 10 in a swirling manner. The structure of FIGS. 6 and 7 employs four helical segments 55, 56, 57, and 58 at the entrance to the muffler 10, in or just before the first inner pipe 21. THe structure of FIGS. 8 and 9 uses a series of flat vanes 60 welded to a cylindrical member 61 that follows an upstream cone 62. The vanes are welded at an inclination to impart the swirling. Other similar structures may be used.

FIG. 10 shows a muffler similar to that of FIG. 1 but having a flow restriction at the entrance end to the second pipe 22. The restriction may be provided by a tubular member 70 having a wide portion 71 and a narrower portion 72 joined to the wide portion by a step portion 73. This expedient helps to reduce sound and is an alternate to the expedients shown in FIGS. 6—9.

To those skilled in the art to which this invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the spirit and scope of the invention. The disclosures and the description herein are purely illustrative and are not intended to be in any sense limiting.

We claim:

1. A muffler for connection between first and second exhaust pipe sections of an engine, including in combination:
a tubular shell about twice the diameter of said exhaust pipe sections,
first, second, and third inner pipes substantially identical in diameter to said exhaust pipe sections and axially in line with each other, in and concentric with said shell imperforate end portions of said first and third inner pipes projecting beyond the ends of said shell for connection respectively to said first and second exhaust pipe sections, said second inner pipe and the portions of said first and third inner pipes that lie axially within said shell being perforated, said inner pipes being spaced apart from each other successively by first and second gaps, each about as long as the diameter of said inner pipes, and
first, second, and third pairs of annular baffle and support members secured to both said shell and, respectively to said first, second, and third pipes to hold them in position in said shell and to provide annular chambers therearound and to divide said chambers from each other,
the axially outer members of said first and third pairs closing the space between said shell and said first and third inner pipes at the ends of said shell, the axially inner members of said first and third pairs being spaced away from the axially inner ends of said first and third inner pipes toward said outer members, the inner member of said third pair lying substantially closer to the outer member of said third pair than the inner member of the first pair lies to the outer member of said first pair,
said first inner pipe and said third inner pipe being approximately of the same length, while said second inner pipe is approximately twice as long as the portions of said first or third inner pipes that lie axially within said shell,
said second pair of baffle and support members each lying at about one-third of the length of said second inner pipe, so that between them they define a chamber around the middle third of said inner pipe, said members of said second pair lying at different distances from said inner members of said first and third pairs, to define end walls of chambers of different length.

2. The muffler of claim 1 wherein said inner pipes are each divided into a plurality of sectors by generally radially extending partitions.

3. The muffler of claim 1 having means for causing the exhaust gases from said first exhaust pipe section to enter into said first inner pipe with a swirling motion.

4. The muffler of claim 3 wherein said means for causing comprises inclined radially extending vanes.

5. The muffler of claim 3 wherein said means for causing comprises generally helically twisted vanes.

6. The muffler of claim 1 wherein the entrance to the second pipe is made smaller by partial obstructions at that point.

7. A muffler for connection between first and second exhaust pipe sections of an engine, including in combination:
a tubular shell about 2.5 times the diameter of said exhaust pipe sections,
first, second, and third inner pipes substantially identical in diameter to said exhaust pipe sections and axially in line with each other, in and concentric with said shell, imperforate end portions of said first and third inner pipes projecting beyond the ends of said shell for connection respectively to said first and second exhaust pipe sections, said second inner pipe and the portions of said first and third inner pipes that lie axially within said shell being

perforated, said inner pipes being spaced apart from each other successively by first and second gaps, each within 10 percent as long as the diameter of said inner pipes, and

first, second, and third pairs of annular baffle and support members secured to both said shell and, respectively to said first, second, and third pipes to hold them in position in said shell and to provide annular chambers therearound and to divide said chambers from each other

the axially outer members of said first and third pairs closing the space between said shell and said first and third inner pipes at the ends of said shell, the axially inner members of said first and third pairs being spaced away from the axially inner ends of said first and third inner pipes toward said outer members, the inner member of said third pair lying substantially closer to the outer member of said third pair than the inner member of the first pair lies to the outer member of said first pair,

said first inner pipe and said third inner pipe being approximately of the same length, while said second inner pipe is

approximately 2.3 times as long as the portions of said first or third inner pipe that lie axially within said shell,

said second pair of baffle and support members each lying at about one-third of the length of said second inner pipe, so that between them they define a chamber around the middle third of said inner pipe, said members of said second pair lying at different distances from said inner members of said first and third pairs, to define end walls of chambers of different length.

8. The muffler of claim **7** wherein said inner pipes are each divided into a plurality of sectors by generally radially extending partitions.

9. The muffler of claim **7** wherein the entrance to the second pipe is made smaller by partial obstruction at that point.

10. The muffler of claim **7** wherein the partial obstruction comprises an annular member reducing the diameter of the passage therethrough.