Feb. 6, 1940. R. L. LEADBETTER 2,189,424

SURGE FILTER FOR PULSATING GASES

Filed Aug. 31, 1938 3 Sheets-Sheet 1

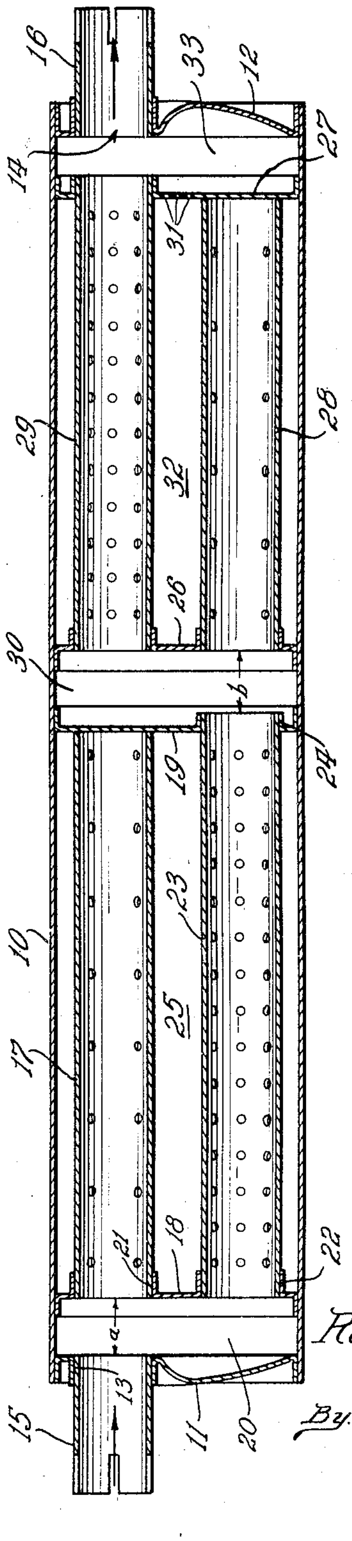

Fig. 1.

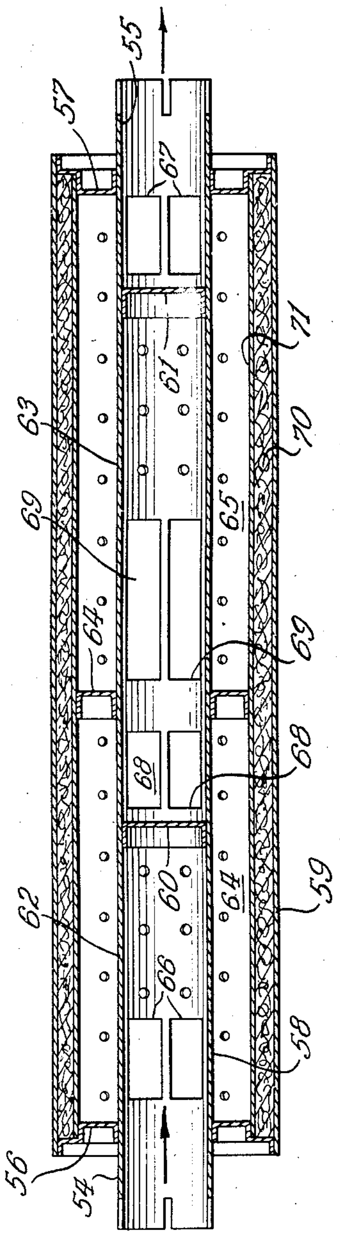

Fig. 6.

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SURGE FILTER FOR PULSATING GASES

Filed Aug. 31, 1938 3 Sheets-Sheet 2

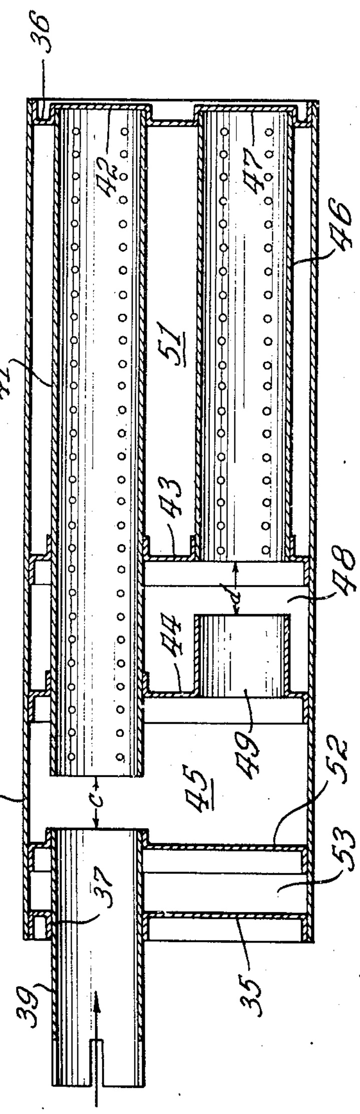

Fig. 2.

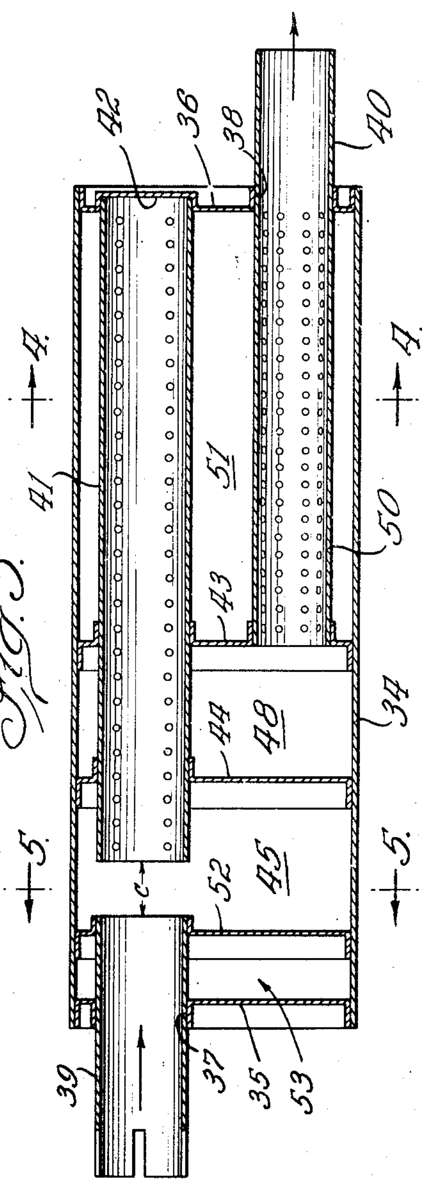

Fig. 3.

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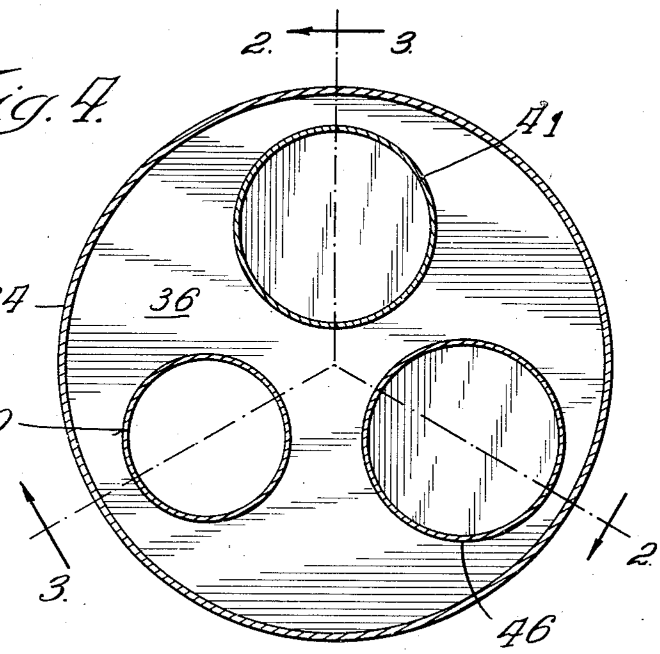
Fig. 4.



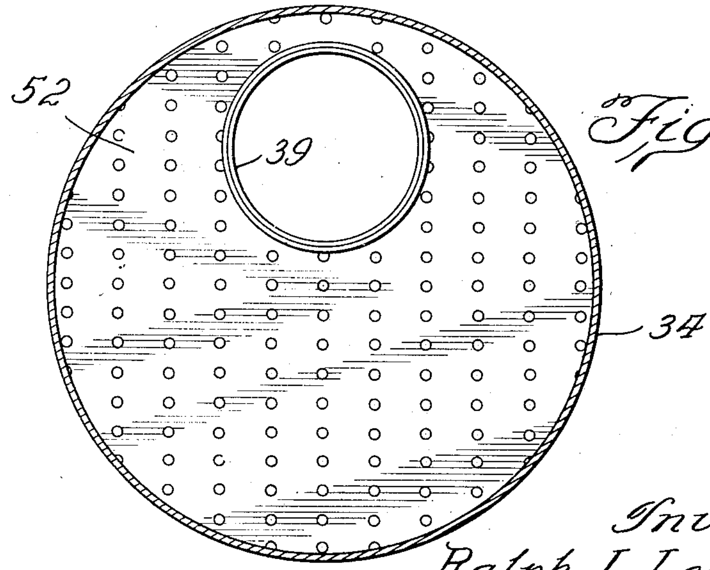


Fig. 5.

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UNITED STATES PATENT OFFICE

2,189,424

SURGE FILTER FOR PULSATING GASES

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Application August 31, 1938, Serial No. 227,655

15 Claims. (Cl. 181—54)

This invention relates to surge filters for flowing, pulsating gases, such as the exhaust gases of internal combustion engines, or, as the terms are loosely used, to improvements in mufflers and silencers for such pulsating gas systems.

This application is a continuation in part of my application Serial No. 156,310, filed July 29, 1937.

Although the invention is useful for the prevention of noise caused by pulsating gases generally, including, for example, the intake and delivery of air compressors, the most severe conditions are met in the prevention of noise caused by the exhaust of internal combustion engines and for this reason the invention will be illustrated and described as applied to this particular problem.

A large variety of constructions have heretofore been employed for the attenuation of noise resulting from the operation of internal combustion engines. Whether such mufflers employ baffles, resonating chambers, or equalizing or expansion chambers, an analysis of their operation discloses that their function depends entirely upon pressure fluctuations of the gas stream and thus their effectiveness depends upon their proximity to points of maximum pressure change in the exhaust system. Thus, a resonating chamber tuned to attenuate a particular frequency is inoperative when located at a (velocity) antinode of that particular sound wave which it is designed to attenuate. It will be seen from the following detailed description that the present invention constitutes a radical departure from mufflers and silencers heretofore known for the reason that it operates by virtue of the inertia imparted to the gases upon being ejected from the engine cylinder into the exhaust system. The invention operates as a velocity smoothing device and depends upon pressure only in the remote sense that the inertia of the exhaust gases depend upon a pressure in the engine cylinder at the time the exhaust valve is opened.

The fundamental distinction indicated in the preceding paragraph will become more apparent as the description of the invention proceeds.

The object of this invention is to prevent noise caused by flowing, pulsating gases by means of a device that may be located with equal effectiveness at any point in the conduit carrying the gas stream and to reduce back pressure and eliminate so-called "period" noises.

The essential element of a muffler embodying this invention is a receptacle or "snubber tube" into which the exhaust gases are projected at high velocity from the exhaust ports of the engine. Part of the exhaust gases is conducted directly to the muffler outlet via a substantially unrestricted passageway without entering the snubber tube. Only that portion of each pulsation having sufficient inertia to cause it to jump a gap rather than deviate in its course to follow the line of least pressure resistance enters the snubber tube. The velocity of the gases entering the snubber tube is arrested and the gas pressure caused thereby dissipated through perforations in the walls of the snubber tube.

Several embodiments of the invention are illustrated in the accompanying drawings in which:

Fig. 1 is a longitudinal, sectional view of one form of muffler embodying the invention;

Fig. 2 is a longitudinal, sectional view on 2—2 of Fig. 4, showing a different species of the invention;

Fig. 3 is a longitudinal, sectional view on 3—3 of Fig. 4;

Fig. 4 is a transverse, sectional view taken at 4—4 of Fig. 3;

Fig. 5 is a transverse, sectional view taken at 5—5 of Fig. 3; and

Fig. 6 is a longitudinal, sectional view illustrating a modified form of muffler embodying the invention.

The exhaust of an internal combustion engine consists largely of a series of rapidly traveling pulses of high pressure gas known to the art as "slugs." A high velocity peak, or slug, is formed each time an exhaust valve opens. Sound waves are thought to be caused by high velocity impact of these slugs with the atmosphere. These are the sharp cracks characteristic of the exhaust when not properly muffled. A low pitched rumble is maintained between explosions. These noises may be eliminated by dissipating the velocity peaks to smooth out the flow of the gases through the exhaust system before exhausting to the atmosphere at a relatively uniform velocity. In addition to these noises, period noises are caused at certain firing frequencies of the engine. These periods occur when the firing frequency substantially coincides with the natural resonant frequency of the exhaust system or a harmonic thereof, the timed recurrence of the pulsations tending to set the exhaust system in vibration. Periods may also occur when the exhaust slugs reinforce every second, or every third, etc., sound wave condensation without intervening neutralizing slugs. Resonance of the exhaust system depends largely upon reflection of the atmosphere impact into the system. The muffler of this invention is effective in preventing such impacts and thus in preventing both direct and period noises.

All of the mufflers are illustrated in their preferred forms, that is, contained within a single enveloping shell. The muffler of Fig. 1 employs a shell 10 which may be circular or elliptical in cross-section, the ends being closed by flanges 11 and 12 having inlet opening 13 and outlet opening 14, respectively. Inlet snout 15 is mounted in inlet opening 13 and outlet snout 16 is mounted in outlet opening 14. These snouts are provided for convenience in mounting the muffler in the exhaust line. Two snubber units are arranged in series within the muffler. The primary snubber unit consists of a perforated snubber tube 17 mounted between partitions 18 and 19. Partition 18 is spaced from end flange 11 to form primary by-pass chamber 20 and is provided with openings 21 and 22, the former opening being concentric with opening 13 in flange 11 and the latter opening being in non-alignment with opening 13. The mouth of the snubber tube 17 is mounted on partition 18 at opening 21, the remote end of the snubber tube being closed by partition 19. The ends of inlet snout 15 and/or snubber tube 17 may extend into by-pass chamber 20, but a gap "*a*" between contiguous ends of these two members not substantially less than one-fourth of the diameter of snout 15 must be provided. In other words, the cylindrical area forming the gap between the snout 15 and snubber tube 17 should not be substantially less than the cross-sectional area of the exhaust pipe of the engine. Substantially unrestricted flow of gases through snout 15 and by-pass chamber 20 to opening 22 is thus provided with the result that back pressure due to restriction within the muffler is practically nil.

Perforated conduit 23 is mounted in openings 22 and 24 to carry the gases from primary by-pass chamber to the secondary snubber unit. Conduit 23 is perforated so that gases dissipated from snubber tube 17 through the perforations therein may enter conduit 23. Space 25 operates as an expansion chamber to attenuate the high frequency sound waves and pulsations in conduit 23.

The secondary snubber unit is constructed the same as the primary unit except that the snubber tube may be somewhat shorter. Partitions 26 and 27 support snubber tube 28 and conduit 29. A gap "*b*" is provided subject to the limitation above set forth whereby the gases from conduit 23 may enter secondary by-pass chamber 30 and pass through conduit 29 to the muffler outlet. The snubber tube 28 and conduit 29 are perforated as above described. Perforations 31 may be provided in partition 27, if desired, to permit direct escape of gases from space 32 to chamber 33 at the outlet end of the muffler. Chamber 33, as well as space 32, operate as expansion chambers to further attenuate the sound waves and gas pulsations, but this chamber 33 may be dispensed with and snubber tube 28 and conduit 29 mounted directly in end flange 12. In this case outlet snout 16 may be integral with conduit 29.

The engine exhaust gases enter the muffler through snout 15 and opening 13. The inertia of the slug causes a portion of the gases forming the slug to jump the gap "*a*" and project into primary snubber tube 17 wherein the velocity energy is transformed into static pressure which is dissipated through the perforations of the snubber tube. The snubber tube must be of sufficient volume and sufficiently perforated to accommodate the velocity peak portion of the slug but must not be so extensively perforated that the slug will be permitted to project through the walls of the snubber tube without undergoing the transformation described. The portion of the gases of the pulsation which do not have sufficient inertia to jump the gap and enter the snubber tube follow the path of less resistance and flow through by-pass chamber 20 into conduit 23. A primary smoothing has been accomplished by the operation of the primary snubbing unit functioning as a surge filter and the gases are delivered to the secondary snubbing unit by conduit 23 and are there operated upon in a manner similar to that above described. The gases finally emerge from the muffler in a relatively smoothly flowing stream. The velocity peaks of the slugs entering the primary snubber tube are of relatively large magnitude, the peaks of the slugs entering the secondary snubber tube are greatly modified and the peaks are inconsequential as the gases leave the device. Although the velocity of the gases leaving the muffler may still gradually rise and fall, there is no sound produced because there is no impact of the moving gases with the atmosphere.

In a particular commercial muffler of the type illustrated in Fig. 1 designed for a single cylinder four cycle gasoline engine of 2 horse power and having a 1 inch diameter exhaust pipe, the primary snubber tube is 8 inches long, sufficiently perforated with $\frac{3}{32}$ inch holes to render it 4% open, gap "*a*" being 1½ inches. Gap "*b*" is one inch and the secondary snubber tube is 7 inches long and perforated as specified for the primary snubber tube. In this particular muffler the primary snubber tube is 1½ inches in diameter and the secondary snubber tube is one inch in diameter.

The muffler illustrated in Figs. 2 to 5 is similar to that above described in that two snubbing units are enclosed within the shell 34. End flanges 35 and 36 are provided with openings 37 and 38, respectively in which inlet snout 39 and outlet snout 40 are mounted. Primary snubber tube 41 abuts outlet end flange 36 at 42 and passes through openings in partitions 43 and 44, opening into primary by-pass chamber 45 leaving a gap "*c*" between the end of inlet snout 39 and the open mouth of snubber tube 41. A secondary snubber tube 46 is arranged between end flange 36 which it abuts at 47, and partition 43, the snubber tube opening into secondary by-pass chamber 48. The primary snubber tube is in substantially axial alignment with inlet snout 39 and the secondary snubber tube is in substantially axial alignment with a nozzle or gas directing member 49 associated with an opening in partition 44. A gap "*d*" is provided as shown. Gases are conducted from the muffler by means of perforated conduit 50 illustrated as integral with outlet snout 40.

In the operation with this form of the muffler the exhaust slugs are filtered successively by the primary and secondary snubber tubes as above described. However, the pressure generated in primary snubber tube 41 dissipates by flow of gases through the perforations in the walls of the snubber tube directly into secondary by-pass chamber 48 and space 51. The operation thus differs from that of the muffler shown in Fig. 1 in that in that particular form all of the gases operated upon by the primary snubber unit are collected for projection into the secondary unit.

Each form of muffler has advantages for particular installations.

In a particular commercial muffler of this type designed for a six cylinder engine having a cylinder bore of 3¼ inches, stroke 4⅜ inches (displacement 217.8 cubic inches) and 87 brake horse power at 3600 revolutions per minute, the shell is 24 inches long between end flanges and is 6½ inches in diameter. The primary snubber tube is 19 inches long by 2 inches in diameter and the secondary snubber tube is 15 inches long by 2 inches in diameter. Both by-pass chambers are 4 inches deep. Spacing "*c*" may be ¾ inch and "*d*" ½ inch. The outlet conduit **38** is of the same diameter as the tail pipe of the exhaust system, about 1⅝ inches.

Perforated partition **52** is not an indispensable element of the muffler but is useful for supporting inlet snout **39** and provides expansion chamber **53** for the better attenuation of high frequency waves.

The modified embodiment shown in Fig. 6 is of a simpler construction than the forms above described. A number of modifications shown are adaptable to the mufflers above described. Intake snout **54** and exhaust snout **55** are provided in openings in end flanges **56** and **57**, respectively, and tube **58**, which may be an extension of the concentrically located intake and exhaust snouts, extends through the muffler shell **59**. Partitions **60** and **61** are provided in the tube to form primary snubber tube **62** and secondary snubber tube **63**. A partition **64** divides the interior of the muffler shell into two compartments, **64** and **65**. Openings **66** and **67** are provided in the walls of tube **58** near the inlet and outlet ends of the muffler, respectively. Openings **68** and **69** extend a short distance on either side of partition **64**, but do not extend beyond partition **60**.

Openings **66** and **69** are equivalent to the gaps provided in the other forms of the muffler disclosed. These openings must be sufficiently open to allow substantially unrestricted flow of gases through them into the spaces surrounding the snubber tubes.

The exhaust gas pulsations are filtered or attenuated by the muffler shown in Fig. 6 by the compound snubber action described above. A slug projects successively into primary snubber tube **62** and secondary snubber tube **63**, the gases passing from the exhaust line through openings **66** into chamber **64** again re-entering the tube through opening **68**, passing into chamber **65** and leaving the muffler through openings **67** and the muffler tail pipe attached to exhaust snout **55**. A large portion of the gases of each slug is dissipated from the snubber tubes through the perforations therein.

If desired, shell **59** may be lined with sound-absorbing material **70** of substantial thickness, a perforated wall **71** being provided to maintain the sound-absorbing material in place; or perforated membrane **71** may be used without the sound-absorbing material to provide an expansion chamber. Attenuation, especially of the high frequency sounds, is improved when either of these devices is used.

The shells of the mufflers described may be double-wrapped or they may be wrapped with asbestos to prevent "shell noise".

As above stated, an internal combustion engine emits a series of timed pulsations into the exhaust system. At certain engine speeds the frequency of these pulsations may coincide with the fundamental or a harmonic of the natural resonant frequency of the exhaust system. At this time a standing wave pattern forms in the pipe. A column of gas, although traveling at high velocity, breaks into violent longitudinal oscillation causing period noises, and, when the exhaust system is connected with the body of a vehicle, as an automobile for example, the body of the vehicle responds to these vibrations. In an exhaust system in which one of the above described mufflers is inserted, each slug impinges against the closed ends of the successive snubber tubes in quick succession before it is exhausted from the muffler. The first impact of the succeeding slug follows after a time interval. It is apparent that when the snubber tubes are properly disposed relatively to each other, the succession of impacts occur at irregular intervals. While regularly recurring impacts might be undesirable at certain frequencies since such blows would aggravate longitudinal vibration of the exhaust system, the snubber tube muffler having a plurality of snubber units would have no such undesirable effect, the tendency being rather to interfere with such vibration and reduce the amplitude thereof.

The mufflers described herein, which have come to be known as snubbers, may be inserted at any point of the pulsating gas system. It may be used in appropriate sizes for the muffling of exhausts of all types of engines, including large size Diesel engines. Since back pressures increase with the velocity of the gases traveling through a conduit, and since the snubber tube muffler substantially reduces peak velocities, the back pressures are accordingly greatly reduced by the device.

While several specific embodiments of the invention are shown, it is obvious that many modifications may be made without departing from the spirit thereof. The snubber tubes may be arranged other than in parallel relation to each other and need not be confined within a unitary muffler shell. More than two snubber units may be used in series, if desired. The lower limit of the "gap" adjacent the mouths of the snubber tubes has been described above, but there is no critical upper limit. The expression "snubber tube" is used for convenience but forms other than tubular may be employed.

I claim:

1. In a device of the character described including a shell, gas-velocity-peak snubbing means comprising a plurality of snubbing units arranged in series within said shell, each of said units comprising: means forming a chamber having an inlet opening and an outlet opening, conduit means arranged in said inlet opening terminating within said chamber, and adapted to conduct gases directly thereinto, a receptacle having apertured walls and a mouth, said mouth of said receptacle being in direct communication with said chamber and in alignment with said conduit means whereby gases conducted into said chamber may project into said receptacle; and means for ingress of gases into and means for egress of gases from said shell, said units being so arranged that the outlet opening of the chamber of one unit is in communication with the inlet opening of the chamber of the next succeeding unit and the outlet opening of the chamber of the last unit of the series is in communication with said shell egress means.

2. A device in accordance with claim 1 characterized in that the passageway from said ingress means to said egress means through said

series of snubbing units is substantially unrestricted to the flow of gases therethrough.

3. In a device of the character described including a shell having means for ingress of gases thereinto and means for egress of gases therefrom, gas-velocity-peak snubbing means comprising a plurality of snubbing units arranged in series within said shell, each of said units comprising: means forming a by-pass chamber having an inlet opening and an outlet opening, a conduit for conducting gases into said by-pass chamber arranged in said inlet opening and terminating within said chamber, an apertured snubber tube having a mouth opening into said by-pass chamber in alignment with said conduit, the end of said conduit within said chamber being spaced from said snubber tube mouth to provide a gap through which gases from said conduit may flow directly to said outlet opening; said units being so arranged that the outlet opening of the chamber of one unit is in communication with the inlet opening of the chamber of the next succeeding unit and the outlet opening of the chamber of the last unit of the series is in communication with said shell egress means.

4. A device in accordance with claim 3 in which the area of the gap between the conduit and the snubber tube mouth in the by-pass chamber of each snubbing unit is not substantially less than the transverse area of said conduit.

5. In a device of the character described comprising a shell having an inlet opening and an outlet opening in the respective ends thereof, a transverse partition within said shell spaced from the inlet end of said shell to form a primary by-pass chamber into which said inlet opening directly opens, a pair of transverse partitions within said shell intermediate the ends thereof and spaced apart to form a secondary by-pass chamber, a primary apertured snubber tube opening into said primary by-pass chamber and a secondary apertured snubber tube opening into said secondary by-pass chamber, a perforated conduit connecting said by-pass chambers, a second perforated conduit connecting said secondary by-pass chamber with said outlet opening, the mouth of said primary snubber tube being in substantial alignment with said inlet opening and the mouth of said secondary snubber tube being in substantial alignment with said perforated conduit connecting said by-pass chambers.

6. The device of claim 5 in which the mouth of said primary snubber tube is spaced from the periphery of said inlet opening a distance not substantially less than one-fourth the diameter of said inlet opening and the mouth of said secondary snubber tube is spaced from the adjacent end of said conduit connecting said by-pass chambers a distance not substantially less than one-fourth the diameter of said conduit.

7. The device of claim 5 in which a transverse partition is arranged within said shell in spaced relation to the outlet end thereof to form an expansion chamber, said expansion chamber being in communication with said conduit connecting said secondary by-pass chamber and said outlet opening.

8. In a device of the character described comprising a shell having an inlet opening and an outlet opening in the ends thereof, a partition within said shell spaced from the inlet end thereof to form a by-pass chamber a closed-ended perforated snubber tube extending in substantially axial alignment with said inlet opening and opening into said by-pass chamber, a gap being left between said snubber tube and said partition at said inlet opening, said partition having a vent therein, a second partition within said shell spaced intermediate said first partition and the outlet end of said shell to form a secondary by-pass chamber between said two partitions, a secondary closed-ended perforated snubber tube extending in substantially axial alignment with said vent in said first partition and opening into said secondary by-pass chamber, a gap being left between said secondary snubber tube and said second partition at said vent, and a conduit establishing communication between said secondary by-pass chamber and said outlet opening.

9. The construction of claim 8 and including gas-flow directing means comprising a snout member arranged in said inlet opening in said shell in substantially axial alignment with said snubber tube and a tubular member arranged in said vent in substantially axial alignment with said secondary snubber tube.

10. The construction of claim 8 in which the walls of said conduit are perforated.

11. An exhaust muffler comprising a shell having an inlet opening and an outlet opening in the ends thereof, a perforated partition within said shell spaced from the inlet end thereof, a second partition within said shell spaced interiorly from said first partition to form a by-pass chamber, an inlet snout arranged in said inlet opening and opening into said by-pass chamber at said perforated partition, a closed-ended perforated snubber tube extending in substantially axial alignment with said inlet snout and opening into said by-pass chamber, a vent in said second partition, tubular air-flow directing means arranged in said vent, a third partition within said shell spaced intermediate said second partition in the outlet end of said shell to form a secondary by-pass chamber between said second and third partitions, a secondary perforated closed-ended snubber tube extending in substantially axial alignment with said tubular gas-flow directing means in said second partition and opening into said secondary by-pass chamber, and a conduit having perforated walls establishing communication between said secondary by-pass chamber and said outlet opening.

12. In a surge filter for pulsating gases, cylindrical shell including end closures, a transverse partition within said shell in the middle portion thereof dividing the space therein into a primary enclosure and a secondary enclosure, a second transverse partition within said shell dividing said primary enclosure into a primary by-pass chamber at an end of said shell and a primary expansion chamber, an inlet conduit extending from without said shell and terminating within said primary by-pass chamber, a perforated snubber tube within said primary expansion chamber opening into said primary by-pass chamber and in substantial alignment with said inlet conduit, a third transverse partition within said shell dividing said secondary enclosure into a secondary by-pass chamber and a secondary expansion chamber the latter being at an end of said shell, a perforated tube passing through said primary expansion chamber and connecting said secondary by-pass chamber with said primary by-pass chamber, a secondary perforated snubber tube within said secondary expansion chamber opening into said secondary by-pass chamber and in substantial alignment with said perforated tube, an outlet conduit connecting with said secondary expansion chamber for conducting gases from

said shell, and a secondary perforated tube within said secondary expansion chamber connecting said secondary by-pass chamber with said outlet conduit.

13. In an exhaust muffler comprising a cylindrical shell having an inlet opening and an outlet opening located concentrically in the ends thereof, an inlet snout arranged in said inlet opening, an exhaust snout arranged in said outlet opening in substantially axial relation to said inlet snout, a tube comprising substantially an extension of said snout members passing through said shell, a transverse partition within said shell intermediate the ends thereof said partition having an opening therein through which said tube passes, said tube having openings in the walls thereof in the portions near the inlet and outlet ends of said shell and in an intermediate portion extending a short distance on either side of said partition, a transverse partition within said tube intermediate said openings in said inlet end and said intermediate openings, and a transverse partition within said tube intermediate said intermediate openings and said openings in said outlet end.

14. The construction of claim 13 in which a perforated membrane is arranged concentrically within said shell and spaced therefrom to form an annular chamber between said membrane and said shell, and sound-absorbing material in said annular chamber.

15. The construction of claim 13 in which a perforated membrane is arranged concentrically within said shell and spaced therefrom to form an annular expansion chamber between said membrane and said shell.

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