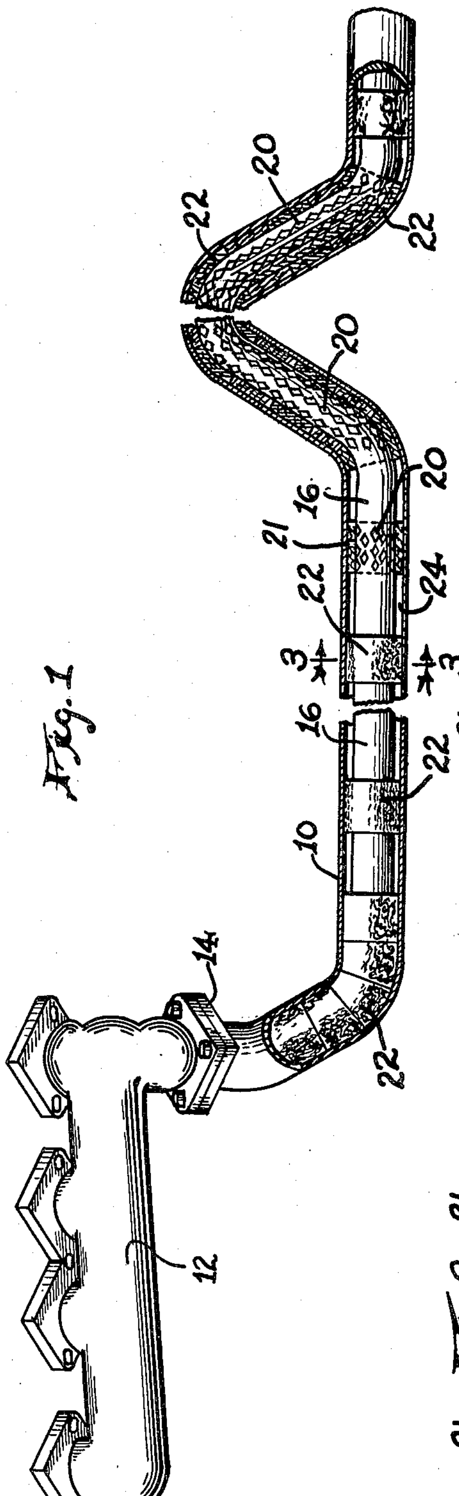
Sept. 24, 1963

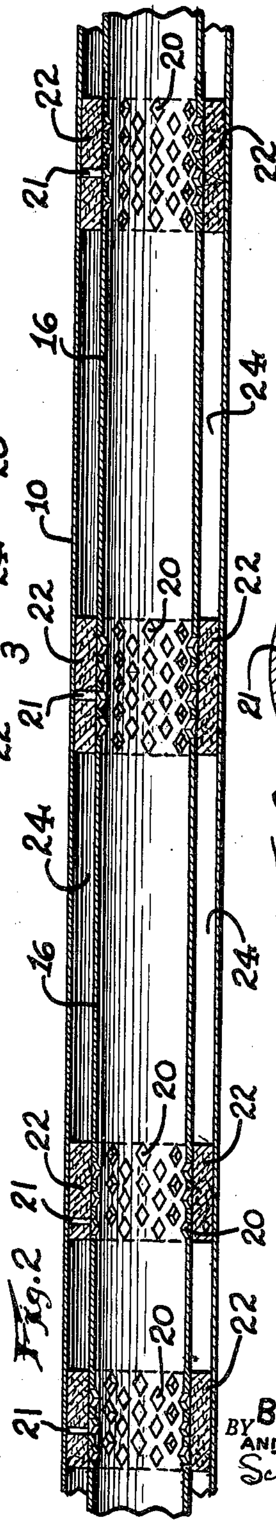
E. LUDLOW ETAL

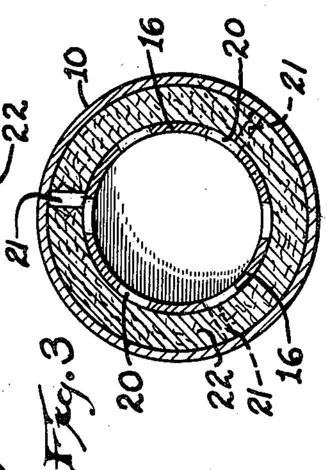
3,104,732

ACOUSTICALLY TREATED GAS PIPE

Filed Nov. 7, 1960







INVENTORS.
EDMUND LUDLOW,
BY BENJAMIN H. IRWIN
AND JOHN C. BRIGHTON

Schley, Trask & Jenkins

ATTORNEYS.

United States Patent Office 3,104,732
Patented Sept. 24, 1963

3,104,732

ACOUSTICALLY TREATED GAS PIPE

Edmund Ludlow, Benjamin H. Irwin, and John C. Brighton, all of Columbus, Ind., assignors to Arvin Industries, Inc., Columbus, Ind., a corporation of Indiana

Filed Nov. 7, 1960, Ser. No. 67,527
9 Claims. (Cl. 181—48)

This invention relates to an acoustically treated gas pipe, and more particularly to a pipe for use in association with internal combustion engines for conveying the exhaust gases therefrom and for attenuating the noise level of said gases.

It is an object of our invention to provide a gas pipe which in addition to providing a means for conveying the exhaust gas emanating from an internal combustion engine will attenuate the noise level of such exhaust gases, which will effect such sound attenuation over a wide range of frequencies, which will have limited space requirements, and which will provide an effective thermal insulation for hot exhaust gases.

In carrying out our invention in its preferred form, we provide an outer pipe having a coaxially aligned inner pipe carried within it and forming the main gas-flow passage. The inner pipe is provided with a plurality of axially spaced groups of perforations, each of said groups of perforations extending circumferentially around said inner pipe. A fibrous acoustical liner is interposed between each of the perforated areas of the inner pipe and the inner walls of the outer pipe. Each of these acoustical liners has an axial extent corresponding to that of the group of perforations about which it is mounted whereby each of said liners forms a sound attenuating medium in communication with the main gas-flow passage, and acts in combination with a pair of adjacent liners to define a pair of axially spaced resonating chamber volumes interposed between the inner and outer pipes. The porous nature of the liners further permits them to function as volume throats operatively interconnecting the resonating chamber volumes with said main gas-flow passage whereby said volumes act in combination with the liners to attenuate the noise level of the exhaust gases passing through said inner pipe.

Preferably, additional attenuation is effected by perforating the inner pipe substantially continuously along its bent portions and interposing an acoustical liner between said perforated areas and the outer pipe.

Other objects and features of our invention will become apparent from the more detailed description which follows and from the accompanying drawing, in which:

FIG. 1 is a fragmentary view partially in section showing an exhaust pipe embodying our invention;

FIG. 2 is an enlarged fragmentary longitudinal section of the exhaust pipe shown in FIG. 1; and

FIG. 3 is an enlarged vertical section taken on the line 3—3 of FIG. 1.

In the operation of a conventional internal combustion engine in an automobile, the combustion of fuel within the cylinders produces a substantial volume of hot exhaust gases which are discharged with substantial noise into one or more exhaust manifolds in communication with the exhaust ports of the several engine cylinders. The frequencies of the sound waves in such exhaust gases extend over a wide range, such as for example from about 30 cycles per second to about 5,000 cycles per second, and in many exhaust systems it is the lower range of frequencies, i.e., frequencies below 200 cycles per second, that are the most difficult to attenuate or silence. This low range of frequencies below 200 cycles per second is the most difficult to attenuate because the firing fre-

quency of the engine falls in this range as does the natural resonance frequency of the exhaust system itself.

In a conventional automobile exhaust system, all of the silencing of the gases occurs in a muffler connected between an exhaust pipe joined to the exhaust manifold and a tail pipe leading from the muffler to a gas discharge point. Such mufflers conventionally comprise a large outer shell having a cross-sectional area several times larger than the cross-sectional area of the exhaust pipe, and having a relatively small number of tuned resonator chambers adapted to attenuate the noise level of the exhaust gases passing therethrough. In order for the muffler to achieve maximum silencing it is necessary that a pair of these chambers with large volumes be tuned to attenuate the narrow bands of the wave frequencies of the first overtones of the standing waves of the exhaust and tail pipes. All of the resonator chambers are baffled from one another, and are arranged within the outer muffler shell in staggered patterns which, combined with the large volumes of the chambers for the exhaust and tail pipes, results in the muffler being rather large and difficult to mount within the limited space available on the underside of an automobile.

Our invention is adapted to attenuate the noise level of the exhaust gases over a wide range of frequencies by passing said gases through an exhaust pipe construction containing a series of coaxially aligned acoustical liners carried within an outer pipe. In our invention there is provided a large number of small sound attenuating units disposed along the length of the exhaust system. These units are adapted to attenuate different, and overlapping, bands of wave frequencies so that the combinative effect of all of the units is an attenuation of the entire range of frequencies of the sound waves in the exhaust gases. While our invention effects such an attenuation of the exhaust gas noises alone, it may, if desired, also be used in combination with a conventional muffler, or in combination with a series of in-line air-type resonators, such as is described in copending application Serial No. 67,756, filed November 7, 1960.

As shown in FIG. 1, our invention comprises an outer pipe **10** adapted to be connected to a conventional exhaust manifold **12** of an internal combustion engine by means of a conventional flanged joint **14**. When our invention is used as the sole means for attenuating the noise level of the exhaust gases, or when it is used in combination with the in-line type resonators such as shown in copending application Serial No. 67,756, filed November 7, 1960, the pipe **10** extends away from the manifold for discharging the exhaust gases to the atmosphere. A second or inner pipe **16** is axially disposed within the pipe **10** and throughout its extent within the outer pipe constitutes the main gas-flow passage for the gases moving through the system. The pipe **16** is provided along its length with axially spaced groups of elongated openings **20**, the openings in each of said groups extending circumferentially around the pipe **16**. In the areas of the openings, the pipe sidewalls are at least 30% open, while the pipe stretches axially interposed between said groups of openings are imperforate.

The pipe **10**, and thus the pipe **16**, extend along the undercarriage of the vehicle upon which they are mounted, and because of the construction of such undercarriage, it is necessary that both of the pipes **10** and **16** be bent at various positions along their lengths in order that they may fit in between the various contours on said undercarriage. To facilitate such bending, the openings **20** are diamond-shaped with their longitudinal axes extending parallel to the axis of the pipe **16**. This configuration and orientation of the openings permits both of the pipes **10** and **16** to be bent into any desired configuration without the inner pipe **16** wrinkling or splitting.

As shown in FIG. 2, the pipes 10 and 16 are held in spaced concentric relationship by a plurality of ears 21 projecting outwardly from the inner pipe and engaging the inner walls of the outer pipe. A plurality of axially spaced, sound absorbing liners are disposed about the inner pipe with their outer faces abutting the inner wall of the outer pipe 10. The liners 22 are mounted on the inner pipe in axially spaced positions of alignment with the groups of openings 20 and have axial lengths slightly longer than the axial lengths of said groups of openings to thus cover said openings and dispose the liners in operative communication with the main gas-flow passage for attenuating the noise level of the gases passing therethrough. Conveniently, the ears 21 are formed in the areas of the groups of openings 20 and thus extend through the liners 22 to hold them in their positions of alignment with said groups of openings.

The sound absorbing liners 22 comprise porous (pervious), heat stable, corrosion resistant mats, and may be formed from a porous mat of fibers, such as asbestos, glass, stainless steel, beryllium, molybdenum, tungsten, or the like. Such fibers may be of any desired length or diameter, but they must, of course, have a sufficient length to permit them to be intermingled and interconnected so that they will not pull or fall out of the liners 22.

The density and thickness of the liners may vary with the material used to form such liners. In this regard, we have achieved excellent results by employing liners of asbestos having a wall thickness in the range of from about one-sixteenth inch to about one-half inch, and a density in the range of from about 10% to about 50%.

The axial positioning of the groups of openings 20 along the pipe 16 and thus the axial positioning of the liners will vary from one design to another depending on the frequency distribution of the sound power to be attenuated. The spaced liners 22 along the pipe 16 segment the air space between the inner and outer pipes into a plurality of resonating chamber volumes 24 in the form of extended annuli. And, because of their porosity, the liners 22 at the ends of the volumes 24 constitute volume throats joining said volumes with the main gas-flow passage of the inner pipe 16.

It is well established in the field of resonator design that a resonator volume having a long volume throat, will attenuate a lower sound wave frequency than a corresponding volume having a short throat. Therefore, in our present invention, the liners having the greater densities and/or longer axial lengths will provide longer throats interconnecting the volumes 24 with the main gas-flow passage so that the volumes joined to said throats act upon the lower sound wave frequencies. It is further established in the field of resonator design that a pipe of about 2 inches in length will have a standing wave frequency of about 3,500 cycles per second, while a pipe of about 180 inches in length will have a standing wave frequency of about 30 cycles per second. It is thus critical to the maximum utility of our invention that the liners 22 be axially spaced along the pipe 16 to provide resonating chamber volumes 22 of different lengths in order to effect a sound attenuation of the exhaust gases over a wide range of sound wave frequencies. We have found that if the liners 22 and openings 20 are disposed in a continuous manner throughout the entire length of the pipes 10 and 16, excellent sound attenuation is obtained at frequencies above 1,000 cycles per second and relatively poorer attenuation occurs at frequencies below 1,000 cycles per second. However, attenuation over a broad range of frequencies can be achieved by providing a plurality of resonating chamber volumes having axial lengths of 2 inches, 6 inches, and 12 inches employed in combination with liners 22 having axial lengths of 1½ inches, 2 inches, and 4½ inches, respectively. By employing the shorter of these dimensions in combination, the frequencies above 200 cycles per second will be preferentially attenuated to the greater extent; and by employing the longer of these dimensions in combination, the frequencies below 200 cycles per second will be preferentially attenuated to the greater extent. Thus, our exhaust pipe may be tuned to attenuate the noise level of a wide range of frequencies by the axial positioning of adjacent groups of openings 20 and liners 22, the axial and wall thickness dimensions of the liners, and the density of said liners, with the liners serving both as sound attenuating members per se and as throats for a plurality of resonator volumes.

The exhaust system illustrated in FIG. 1 may be produced by forming the openings 20 in the pipes 16 and then disposing the plurality of liners 22 in axially spaced relation around the pipe 16 in alignment with said groups of openings. The outer pipe 10 is then positioned around the inner pipe 16 with the opposed inner and outer walls of said liners abutting the inner and outer pipes, respectively, in face-to-face contact. The pipe assembly may then be placed in a conventional pipe bending machine and bent into the desired contours, the configuration and orientation of the openings 20 in the inner pipe permitting said pipe to be bent into smooth curves in the absence of any wrinkling or splitting.

As shown in FIG. 1, the openings 20 may extend substantially continuously along the bent portions of the inner pipe 16 and an elongated acoustical liner 22 is interposed between those bent portions of the inner pipe 16 and the corresponding portions of the outer pipe 10. Such elongated liners along the bent portions of the inner pipe 16 have a length several times as long as the other liners employed, and we have found that they are particularly well adapted for attenuating the noise level of the higher frequency sound waves in the exhaust gases, i.e., those frequencies above 200 cycles per second. Thus, with the elongated liners along the bent stretches of the pipe 16 and the shorter liners in the straight stretches acting in combination with the resonating chamber volumes 24, a sound attenuation over a wide range of frequencies is achieved by our system.

As will be understood, the volumes 24 and acoustical liners 22 will also serve as thermal insulation for the exhaust gases passing through the inner pipe 16, and further provide a double shell-type construction which materially reduces the direct transmission of high frequency sound from the gas stream through the pipe walls.

While our invention has been described for use in an exhaust system, it may, of course, be used on the intake side of an internal combustion engine for transporting and silencing the gaseous mixtures into the engine, or in any other applications involving the movement and silencing of gases.

We claim as our invention:

1. In an acoustically treated gas pipe for conveying and attenuating the noise level of a moving gas stream, an outer pipe, an inner pipe carried within said outer pipe and forming the main gas-flow passage, said inner pipe having a plurality of axially spaced groups of openings formed therein, means on one of said pipes engaging the other pipe for holding said pipes in spaced relation to each other, and a plurality of porous, corrosion-resistant, fibrous liners mounted on said inner pipe in alignment with said groups of openings in abutting engagement with the adjacent faces of said inner and outer pipes, said liners having axial lengths substantially equal to the axial lengths of said groups of openings to form the end walls of a plurality of axially spaced resonating chamber volumes interposed between said inner and outer pipes and the throats for said volumes.

2. The invention as set forth in claim 1 in which said inner pipe is at least 30% open in the areas of said groups of openings and imperforate between said groups of openings.

3. The invention as set forth in claim 1 in which said openings have an elongated configuration with their long axes parallel to the axes of said inner and outer pipes.

4. The invention as set forth in claim 1 in which said liners have axial lengths longer than the axial lengths of said groups of openings.

5. The invention as set forth in claim 1 in which said means comprises a plurality of outwardly projecting ears formed on said inner pipe and engaging the inner walls of said outer pipe.

6. The invention as set forth in claim 5 in which said ears are formed in the areas of said groups of openings and extend through said liners for retaining said liners in positions of alignment with said groups.

7. In an acoustically treated gas pipe for conveying and attenuating the noise level of a moving gas stream, an outer pipe, an inner pipe carried within said outer pipe and forming the main gas-flow passage, said inner pipe having a plurality of groups of openings formed therein, at least a plurality of said groups of openings having axial lengths in the range of from about 1.5 inches to about 4.5 inches and axial spacings in the range of from about 2 inches to about 12 inches, and a plurality of porous, corrosion-resistant, fibrous liners mounted on said inner pipe in alignment with said groups of openings and abutting the adjacent faces of the inner and outer pipes, said liners having axial lengths substantially equal to the axial lengths of said groups of openings to form the end walls of a plurality of axially spaced resonating chamber volumes interposed between said inner and outer pipes and the throats for said volumes.

8. The invention as set forth in claim 7 in which there is provided at least one additional group of openings and a liner therefor having axial lengths several times as long

as the length of the longest group of openings in said plurality of groups of openings having lengths in the range of from about 1.5 inches to about 4.5 inches.

9. In an acoustically treated gas pipe for conveying and attenuating the noise level of a moving gas stream, an outer pipe, a plurality of axially spaced imperforate pipe sections carried within said outer pipe and forming a substantially continuous main gas-flow passage, and a plurality of gas-pervious, sound absorbing means axially spaced along said imperforate pipe sections bridging the spacing between said pipe sections and abutting the adjacent walls of the pipe sections and said outer pipe whereby said means and the adjacent walls of said outer pipe and pipe sections form a plurality of annular resonating chamber volumes, said means being in operative communication with said main gas-flow passage to form a plurality of volume throats joining said volumes to the main gas-flow passage.

References Cited in the file of this patent

UNITED STATES PATENTS

Re. 22,283	Bourne	Mar. 9, 1943
2,075,263	Bourne	Mar. 30, 1937
2,076,807	Burgess	Apr. 13, 1937
2,101,460	Schmidt	Dec. 7, 1937
2,808,896	Wilman	Oct. 8, 1957

FOREIGN PATENTS

809,206	France	Dec. 3, 1936
317,630	Switzerland	Jan. 15, 1957