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EXHAUST SYSTEM

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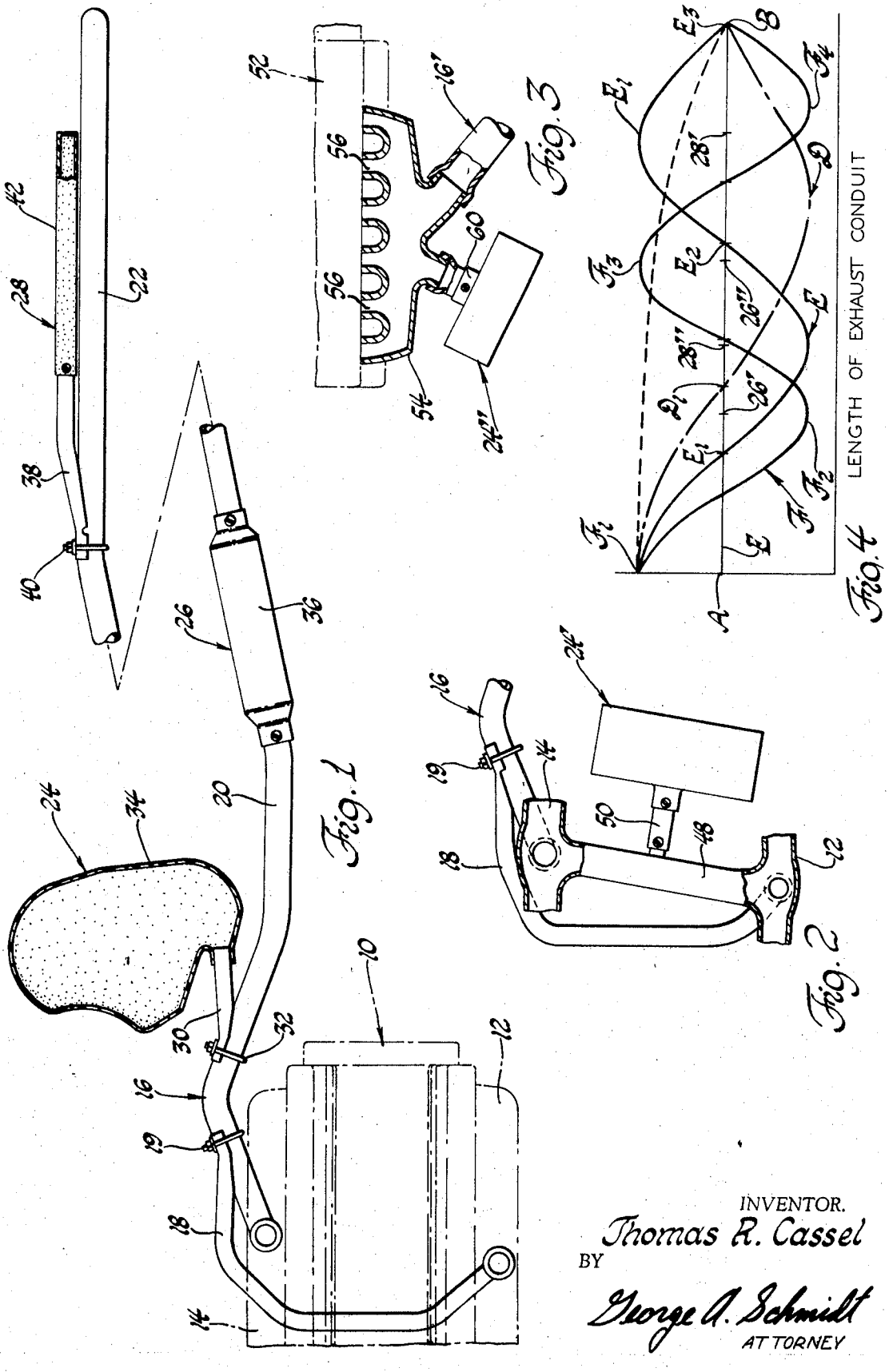


Fig. 1

Fig. 3

Fig. 4

Fig. 2

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EXHAUST SYSTEM

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ABSTRACT OF THE DISCLOSURE

An exhaust system for automotive vehicles or the like having an internal combustion engine, wherein the exhaust system includes a conduit extending from the exhaust means of the engine toward the rear of the vehicle to convey exhaust gasses from the engine, and where sound is attenuated by a plurality of attenuating devices disposed at spaced points along the conduit, each such device being tuned to attenuate sounds in a different range of frequencies. The attenuating devices may be formed of a material permitting them to be formed in irregular shapes for optimum locations along the exhaust conduit and convenient mounting in the under structure of the vehicle.

This invention relates to exhaust systems for internal combustion engines or the like, and more particularly to an exhaust system having sound attenuating means therein for attenuating sounds emanating from the exhaust manifold of the engine.

The present invention is particularly applicable for use in automotive vehicles and will be described with particular reference thereto. However, it is to be appreciated that the invention has much broader application and may be used in various installations where exhaust systems and noise problems are present.

In the design and manufacture of automotive vehicles using internal combustion engines, it is common to provide an exhaust system to convey exhaust gasses from the engine to the rear of the vehicle for discharge of the gasses to the atmosphere. Normally, there are provided sound attenuating means in the exhaust system to attenuate sounds produced by the firing of the engine and which travel through the exhaust system through the exhaust gasses. It is well known that the basic engine sound is at a fundamental frequency for each vehicle, such fundamental frequency being a function of the firing frequency in the engine and the length of the exhaust system. In addition to the fundamental frequency sound waves, various harmonic frequencies are also present and must be attenuated. It has also been known that there are optimum points along the length of the exhaust system at which to locate sound attenuating devices for most efficient operation. However, numerous problems are presented in optimum location, since the optimum points for the various freqeuncies of the sound waves do not fall at the same points for each of the harmonic frequencies of the fundamental frequency.

Numerous devices have been provided in the past for attenuating or muffling sound in an exhaust system. However, it has been thought necessary to combine all of the sound attenuation means into a single device and to locate such device in the exhaust system at some compromise point to provide at least partial attenuation for all frequencies. Unfortunately, this does not provide complete attenuation, since the single device, by its nature, cannot be located the optimum point for each sound wave

frequency. The formation and use of a single sound attenuating device has been thought necessary because of the complicated under-structure of most automotive vehicles, thus limiting the possible locations of such devices, and because of the attendant costs of manufacturing a plurality of sound attenuating devices and locating such devices at various points along the exhaust system. Present day mufflers are complicated and cumbersome affairs, requiring numerous parts to form resonance and expansion chambers, baffles, inlet and outlet means and the like. These have all been necessary in order to provide as great attenuating coverage as possible in a single location in the exhaust system.

The exhaust system in which this invention is embodied comprises, generally, an exhaust conduit extending from the exhaust manifold of an internal combustion engine to a point rearwardly of an automotive vehicle and beneath the under-structure of the vehicle. A plurality of spaced sound attenuating devices are secured to, and communicate with the interior of, the exhaust conduit and are so constructed, formed and tuned as to be mountable at the optimum locations along the exhaust conduit to provide the most efficient sound attenuation for the various frequencies of the sound passing through the system. The sound attenuating devices may be manufactured of a plastic material and, as such, may be formed to any desired shape, whether regular or irregular, to accommodate the under-surface of the vehicle and permit mounting at any desired point along the conduit. One sound attenuating device is tuned and formed to attenuate sounds in the low frequency range, and may be mounted as close to the exhaust manifold as possible. Another sound attenuating device may be tuned and formed to attenuate sounds in the high freqeuncy range, and may be located along the exhaust conduit at the point where such high frequency sound waves have a maximum pressure point. Yet another sound attenuating device is formed and tuned to attenuate intermediate frequency sound waves and is located in a position spaced from both the first and the second sound attenuating devices, and again at a point to provide the most efficient operation.

An exhaust system so constructed permits optimum sound attenuation of the objectionable sound wave frequencies within the exhaust system by permitting optimum location of the devices for the frequencies they are tuned to muffle. A great flexibility in the design of the exhaust system is permitted, since the various attenuating devices may be made of plastic material and formed into any shape to accommodate the under-structure of the vehicle. The system is extremely economical, in that the numerous parts and forming requirements are eliminated, as compared to present sound attenuating devices, and the entire system is extremely efficient because of the optimum locatability of the parts.

These and other advantages will become apparent from the following description used to illustrate a preferred embodiment of the invention, when taken with the accompanying drawing in which:

FIG. 1 is a plan view, with parts broken away and in section, of an exhaust system embodying the present invention;

FIG. 2 is a partial plan view, with parts broken away and in section, of an exhaust system that is a modification of the system illustrated in FIG. 1;

FIG. 3 is a partial plan view, with parts broken away and in section, of another modification of the system of FIG. 1;

FIG. 4 is a graph showing the sinusoidal shape of the various sound waves in the exhaust system of FIG. 1 and plotted as a function of the length of the exhaust conduit.

Referring more particularly to the drawing, where the showings are for the purpose of illustrating a preferred embodiment of the invention only, and not for the purpose of limiting same, reference is first to be had to FIG. 4 where the sinusoidal shape of the sound waves in a typical exhaust system are illustrated. In FIG. 4 the sound waves are plotted as a function of the length of the exhaust conduit, wherein point A represents the location of the exhaust manifold of an internal combustion engine and B is the rearward end of the exhaust conduit. A first curve C is a depiction of the fundamental frequency of the engine sounds, which is a function of the firing frequency in the engine and a function of the length of the exhaust system. In most V–8 engines, and with normal vehicle size, the frequency of sound wave C will be in the neighborhood of 20 cycles per second (hereinafter, c.p.s.) Since the exhaust conduit is an open pipe, the sound waves passing therethrough will have an anti-node, or point of maximum pressure, at the exhaust manifold, and a node, or point of minimum pressure, at the rearward end of the exhaust conduit. This is represented in FIG. 4 by an amplitude peak of curve C at A and a zero amplitude at point B.

Along with the fundamental frequency sound wave C, various harmonics and resonant frequencies are generated by the engine and travel through the exhaust system. These frequencies must also be attenuated. For example, the third harmonic frequency, indicated in FIG. 4 by the sine curve D, is a sound wave having a frequency three times as great as the fundamental frequency C, and thus in the neighborhood of 66 c.p.s. The fifth harmonic frequency, indicated at E, is likewise a sound wave having a frequency five times that of the fundamental frequency, or somewhere in the neighborhood of 110 c.p.s. The seventh harmonic frequency, indicated at F has a frequency seven times greated than the fundamental frequency C, and in the neighborhood of 154 c.p.s. Each of these sound waves, C, D, E and F are present in the exhaust conduit during the operation of the engine and each of these sound waves must be attenuated in order to avoid objectionable noise in the operation of the vehicle.

It is known that the optimum point of sound attenuation is at an anti-node, or point of maximum pressure, of the sound wave. In the sinusoidal depiction of the sound waves in FIG. 4, the points of maximum amplitude of the various sine curves indicate the anti-nodes. For example, the seventh harmonic wave F is shown to have anti-nodes at points F_1, F_2, F_3 and F_4. Similarly, the points of minimum amplitude, or nodes, are points of minimum pressure, such as indicated at E_1, E_2 and E_3 on the fifth harmonic sine curve E. For proper attenuation of the sound wave F, a sound attenuating device, properly tuned, can best be located at any one of the anti-node points F_1–F_4.

It should be noted that to provide some tolerances in the positioning of a sound attenuating device, the device may be positioned within 45° of the anti-nodal point, and on either side thereof, in order to provide acceptable sound attenuation. Placement of the device within this range provides some attenuation, but the closer the device is located to the anti-node point, the more efficient it will be in attenuating sounds at that frequency. Since the distance between the anti-nodal point and the next nodal point of any of the sinusoidal waves represents 90° of the sine curve, it will be apparent that 45° represents one-half of this distance. For example, with the third harmonic wave D, an anti-nodal point is at A and the first nodal point falls at a distance of one-third of the length of the conduit from point A, or at point D_1. This is a distance of 90° on the sine curve and a point one-half the distance between A and D_1 would be at 45°. Thus, location of a sound attenuation device within the first one-sixth of the length of the exhaust system from A will be within the acceptable range. Since the fundamental frequency sound wave C covers one-quarter of its distance over the entire length of the exhaust system, the location of a sound attenuating device within the first one-sixth of the length of the system to satisfy the third harmonic frequency D will also be effective to attenuate frequency C.

The third, fifth, seventh and ninth harmonic frequencies are the sound waves most commonly dealt with in sound attenuation of exhaust systems, as these are in the objectionable noise range. Attenuation of these frequencies will also include attenuation of the higher harmonic frequencies, since anti-nodal points occur at substantially the same points along the length of the exhaust system. For example, the ninth harmonic frequency, in the range of 198 c.p.s., would have anti-nodal points coinciding with the anti-nodal points of the third harmonic frequency curve D, although the ninth harmonic frequency would have a number of other anti-nodal points as well. Nevertheless, the location of a sound attenuating device at the anti-nodal point of sound wave D will also attenuate sounds in the ninth harmonic frequency of the fundamental frequency C. Beyond the ninth harmonic frequency, the sound waves become less and less objectionable, and in fact, will probably not be heard over other extraneous noises in normal vehicle operation, such as wind flow and the like. Thus, optimum sound attenuation in the exhaust system quite properly deals with sound waves in the range of frequencies of from 20 c.p.s. to 200 c.p.s., and the system is tuned to these frequencies.

With reference now to FIG. 1, an internal combustion engine, indicated by dashed and dotted lines **10**, may be of the V–8 type having exhaust manifolds **12** and **14** located on opposite sides thereof, and communicating with the engine cylinders. A main exhaust conduit, indicated generally by the numeral **16**, is properly connected to the exhaust manifold **14** and a cross-over conduit **18** is connected at one end to the exhaust manifold **12** and at the opposite end to the exhaust conduit **16**. Any suitable connection may be made, such as U-bolt **19**, so long as the connection is positive to prevent gas leakage. Thus, the exhaust gasses from both manifolds **12** and **14** will be conveyed to the exhaust conduit **16** for passage to the rear of the vehicle.

Exhaust conduit **16** includes a first exhaust pipe section **20** and a second section **22**, commonly referred to as a tail-pipe. Tail-pipe **22** terminates at the rearward end of the vehicle for emission of the exhaust gasses to the atmosphere. The unusual shape of the conduit **16** is dictated by the under-structure of the vehicle, the conduit being formed to avoid obstructions and the like between the front and rear of the vehicle.

Secured on the exhaust pipe **20**, and at a point near the engine exhaust manifold **14**, is a first sound attenuating device, indicated generally by the numeral **24**, and which will be described hereinafter with more particularity. Device **24** is intended to attenuate low frequency sounds in the exhaust system, such as the fundamental frequency wave C and the third harmonic wave D illustrated in FIG. 4. Sound attenuating device **24**, in order to perform the necessary function, is best located near the anti-nodal point of these sound waves, which is shown in FIG. 4 to be at the engine manifold. However, with reference to the 45° range limitation previously discussed, device **24** may be located anywhere within the first one-sixth of the length of the conduit **16** and still provide acceptable, though less efficient, sound attenuation. Thus, the under-structure of the vehicle may be accommodated.

Disposed between the exhaust pipe **20** and the tail-pipe **22** in the exhaust conduit **16** is a second sound attenuating device, indicated generally by the numeral **26**, and which will be described hereinafter with more particularity. Attenuating device **26** is intended to attenuate sounds in the high frequency range, such as the seventh harmonic frequency F, illustrated in FIG. 4. Again, locating the attenuating device **26** at an anti-nodal point, such as F_2, F_3 or F_4, will provide optimum sound attenuation of these sound waves. The seventh harmonic fre-

quency, as noted in FIG. 4, locates, the anti-nodal points at two-sevenths, four-sevenths and six-sevenths of the distance along the conduit **16** from the exhaust manifold, and placement of the sound attenuating device **26** at any one of these points will provide optimum sound attenuation. By the same token, the 45° variance on either side of the anti-nodal points is a limit of acceptable sound attenuation, giving some flexibility in the location of the device **26** relative to the understructure of the vehicle.

Secured in the tail-pipe **22** of the exhaust conduit **16** is a third sound attenuating device, indicated generally by the numeral **28** and which will be hereinafter described with more particularity, the device being intended to attenuate sounds in the intermediate range of frequencies, such as the fifth harmonic sound wave frequency E of FIG. 4. The anti-nodal points of the fifth harmonic frequency occur at the points of maximum amplitude, at two-fifths and four-fifths of the distance along the exhaust conduit **16** from the manifold **14**. Locating the sound attenuating device **28** at the rearward anti-nodal point provides optimum sound attenuation for this frequency and avoids interference in location with the sound attenuation device **26**. A certain degree of flexibility is provided by the 45° range on either side of the anti-nodal points, thus accommodating the under-structure of the vehicle in the placement of the device **28**.

With reference to the horizontal line G in FIG. 4, which represents the exhaust conduit **16**, it will now be apparent that the sound attenuating device **24** may properly be located somewhere between the manifold A and a point one-half of the distance to the node D_1 on the sine curve D. The closer to the manifold A the device **24** is located, the more efficient it will be in attenuating the low frequency sounds.

Sound attenuating device **26** may best be located at point **26'** on the horizontal line G, which is the anti-nodal point F_2. Should the under-structure of the vehicle be overly cluttered at that point, the sound attenuating device **26** may be located at point **26''**, which is the anti-nodal point F_3.

Similarly, the sound attenuating device **28** may best be located at point **28'** on the horizontal line G, which is the anti-nodal point E_1 of the intermediate frequency sound wave E. Should the understructure of the vehicle require, the device **28** may alternatively be located at point **28''**, that is the anti-nodal point E_2 of the sound wave E.

Low frequency sound attenuating device **24** includes a conduit portion **30**, secured to the exhaust pipe **20** in such manner as to communicate with the interior thereof. A U-bolt, or the like, **32** secures the portion **30** to the pipe **20** in a rigid and positive manner. Portion **30** extends rearwardly of the conduit **16** and is secured to an enlarged closed structure **34** in any suitable manner. Structure **34** is shown to be of irregular shape and is formed of a plastic material so that such irregular shape, or any other irregular shape, may be easily formed to accommodate the under-structure of the vehicle. Any suitable plastic material may be used, so long as it may be formed into some suitable shape, will hold such shape after its formation, and will maintain such shape at ambient temperatures at the location of the device.

By ambient temperature is meant the temperature that the surrounding air may reach in the operation of the vehicle and the climate wherein it is used. Even though exhaust gas temperatures may be in the range of 700°–900° Fahrenheit, the ambient temperature may be in the neighborhood of 150°–200° Fahrenheit. It is the latter temperature that is important in selecting a plastic material for the structure **34**.

Since the structure **34** is a closed volume; that is, its only opening is the communication with the conduit portion **30**, and there is no opening to the atmosphere, there will be no pressure drop across the attenuating device **24** with exhaust gas flow through the conduit **16**. Since there is no pressure drop across the device, there will be no resulting temperature change therein. Thus, the structure **34** may be conveniently made of a plastic material that meets the other qualifications necessary, and it will not be subject to rapid or violent temperature changes.

The volume of the structure **34** may be any convenient volume, taking into consideration the under-structure of the vehicle and the shape in which it is formed. Once such volume is established, the dimensions of the tuning tube **30** may be set. The length and diameter of the tube **30** are proportional to the volume of the structure **34**, for a given frequency attenuation, and may be designed in the manner well known in the art.

Although it is preferred that structure **34** be completely closed to the atmosphere, to prevent temperature changes with pressure changes, condensation within the volume may pose a problem. For this purpose, a very small hole may be made in the structure **34** to permit drainage of such condensation. If such hole is on the order of one-eighth inch in diameter, the resultant pressure drop will not be significant enough to present temperature difficulties. Thus, the structure can be considered to be closed to the atmosphere even though such hole exists.

The high frequency sound attenuating device **26** may be any of a number of well known sound attenuating devices, for example, of the type known as a Helmholtz resonator. This is merely an expansion volume; that is, an outer tubular casing **36** about the conduit **20** as it passes therethrough and the conduit is provided with a plurality of openings communicating with the tubular chamber between the conduit **20** and the casing **36** to permit gas expansion thereinto.

Sound attenuating device **28**, located for attenuating intermediate frequency sound waves, includes a first tubular member **38**, mounted on the tail-pipe **22** in such manner as to communicate with the interior thereof, and being secured thereto in any suitable manner, as by U-bolt **40**. Extending from the tubular portion **38** is a second tube **42** which may be formed of a plastic material similar to the structure **34**, having the same requirements and being closed at its end. Being formed in tubular shape, the element **42** is conveniently disposed adjacent the tail-pipe **22** and accommodates the under-structure of the vehicle. The combination of element **38** and element **42** creates what is known in the art as a quarter-wave tuner, and its length and diameter are thus a function of the length of the sound wave it is intended to attenuate. The tubular portion **42** is closed to the atmosphere, having no openings therein except for the connection to the tubular portion **38** and a possible condensation drain, thus eliminating any temperature variations as heretofore described with respect to structure **34**.

With reference now to FIG. 2, a modification of the exhaust system illustrated in FIG. 1 is shown, and in which the exhaust conduit **16** is in communication with exhaust manifold leg **14** of the engine and the cross-over pipe **18**, secured to the exhaust conduit **16** as at **19**, is in communication with the exhaust manifold leg **12**. The low frequency sound attenuating device, indicated generally by the numeral **24'**, is shown to be secured in the exhaust system at the optimum point; that is, the anti-nodal point of the sound wave frequencies in the exhaust manifold cross-over **48**. The sound attenuating device **24'** may be of plastic construction, and of any suitable shape to fit within the space available in the vehicle, and is connected to the cross-over passage **48** by a tuning tube **50**, connected to each of the elements in any suitable manner. At the cross-over passage **48** the pressure will be at a maximum, and sound attenuation at this point is most efficient.

With reference now to FIG. 3, the exhaust system is shown to be incorporated in an internal combustion engine of the in-line cylinder type, wherein the engine, indicated by dashed and dotted lines **52**, includes a single exhaust manifold **54** having passages **56** leading from each engine cylinder. The exhaust conduit **16'** is connected to the exhaust manifold **54** in any suitable manner

and extends rearwardly therefrom to the after portion of the vehicle. A low frequency sound attenuating device, indicated generally by the numeral **24**," communicates with the exhaust manifold **54** through a tuning tube **60**, secured thereto in any suitable manner. The attenuating device **58** may be of plastic construction, similar to that heretofore described, and of any suitable shape to fit within the available space. Rearwardly of the exhaust manifold **54** in the exhaust conduit **16'** are located high frequency and intermediate frequency sound attenuating devices, such as illustrated in FIG. 1. Location of the sound attenuating device **58** at the exhaust manifold provides optimum sound attenuation of the low frequency sound waves in the exhaust system.

Thus, an exhaust system is provided that is extremely flexible in location of its components to provide optimum sound attenuation for all frequencies of sounds passing through the exhaust system. Certain of the component parts may be made of plastic materials, thus providing a greater degree of flexibility in the location of the parts relative to the under-structure of the vehicle. Since it is not necessary to combine all the component parts into one large structure, optimum attenuation of various frequencies is readily accomplished. The overall result is an extremely economical and efficient sound attenuating system for an exhaust conduit, and one that may be installed with ease and efficient operation for economical design and manufacture of exhaust systems.

The present invention has been described in connection with certain structural embodiments; however, it is to be appreciated that various changes may be made in the structural embodiments without departing from the intended spirit and scope of the present invention.

Having thus described the invention, I claim:

1. A sound attenuating device for an exhaust system of an automotive vehicle including an exhaust conduit adapted to conduct the high temperature exhaust gas flow from an engine, said device comprising; a sound attenuating chamber adapted for attenuation of selected acoustical frequencies in said gas flow, said chamber comprising a first part having a substantially closed wall defining an opening and a second part including a coupling conduit having one end adapted for connection with the exhaust conduit and the other end connected with said opening in said first part, said chamber being substantially closed to the passage of gas therethrough, said first part being constructed of a first material which is structurally unstable at a temperature limit below the high temperature of said exhaust gas flow and being separated from the exhaust conduit whereby the temperature of said first part is substantially that of the ambient atmosphere, said second part being constructed of a material which can withstand the high temperature of the exhaust gas flow and having a length which is great enough that the temperature at said other end is below the temperature limit of the first material and which is related to the dimensions of the first part so that the chamber will attenuate the desired frequencies.

2. The invention as defined in claim **1** wherein said chamber is a resonator tuned to a selected acoustical frequency and wherein said chamber including said coupling conduit is of a configuration adapted to be accommodated in the space under the vehicle in the vicinity of said exhaust conduit with said coupling conduit adapted for connection to the exhaust conduit near an anti-node in the pressure wave of said acoustical frequency.

3. The invention as defined in claim **2** wherein said first material is plastic which is incapable of maintaining its shape at an ambient temperature in the neighborhood of 200° F.

4. The invention as defined in claim **2** wherein said chamber is a volumetric resonator in which said coupling conduit constitutes the resonator throat and provides a conductance in relation to the volume of the second part of said chamber so that the chamber is tuned to said selected acoustical frequencies.

5. The invention as defined in claim **2** wherein said resonator is a quarter wave tuner in which said first part and said second part have a combined length which corresponds to one-fourth wavelength of said selected acoustical frequency in the gas flow.

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