April 14, 1959

A. G. BODINE
ACOUSTIC ATTENUATION OF ENGINE
DETONATION SHOCK WAVES

2,881,751

Filed Dec. 20, 1957

4 Sheets-Sheet 1

FIG. 1

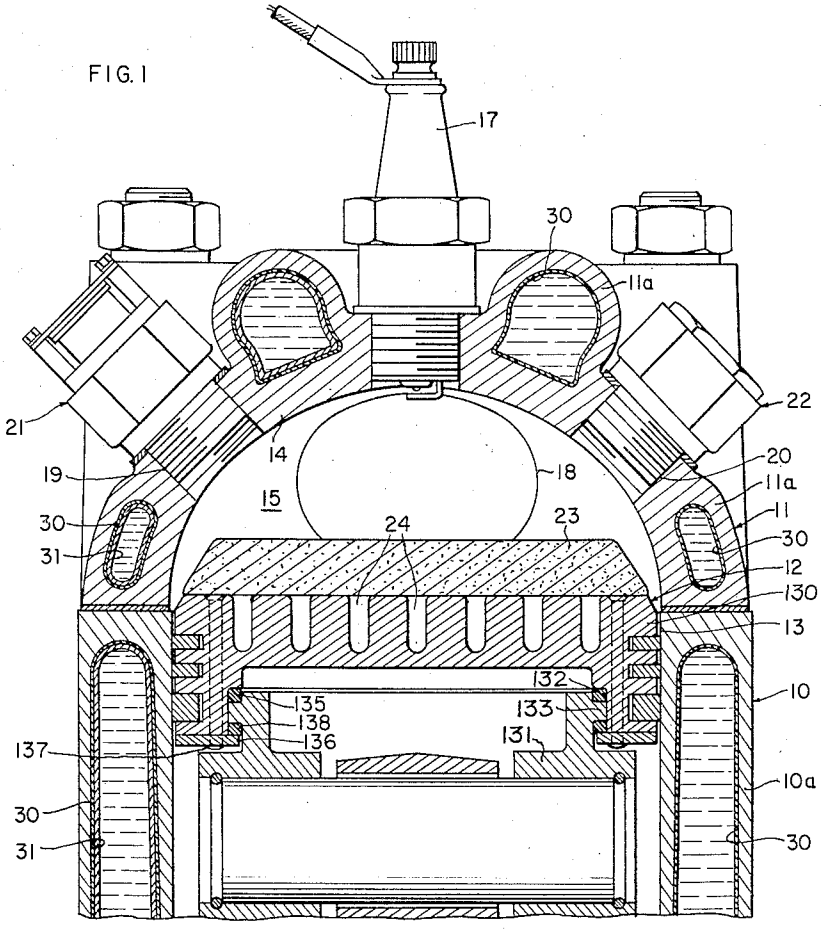
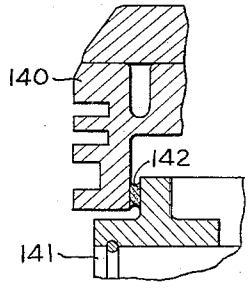


FIG. 1a



INVENTOR.
ALBERT G. BODINE
BY Ernest J. Lilley
ATTORNEY

April 14, 1959

A. G. BODINE
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4 Sheets-Sheet 2

FIG. 2

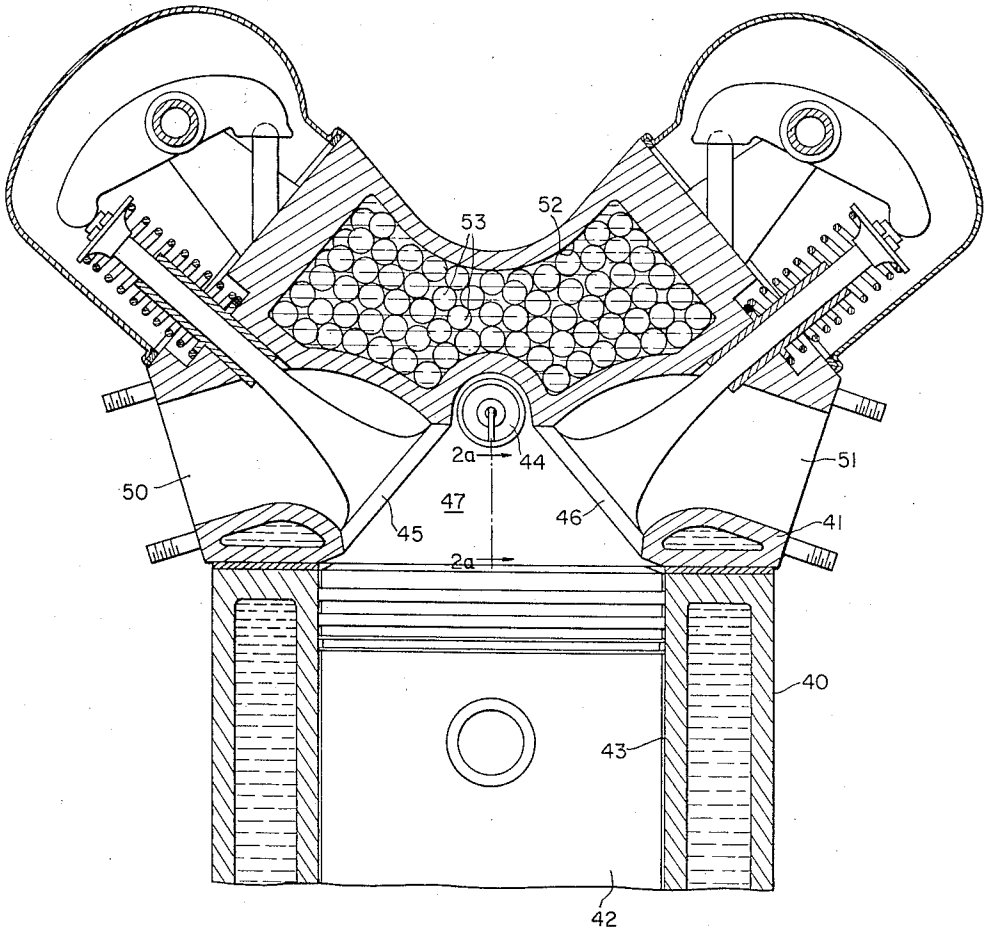


FIG. 2a

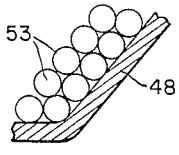
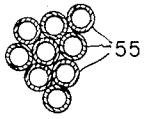


FIG. 2b



INVENTOR.
ALBERT G. BODINE
BY Forrest Hilley
ATTORNEY

April 14, 1959 A. G. BODINE 2,881,751

ACOUSTIC ATTENUATION OF ENGINE DETONATION SHOCK WAVES

Filed Dec. 20, 1957 4 Sheets-Sheet 3

FIG. 3

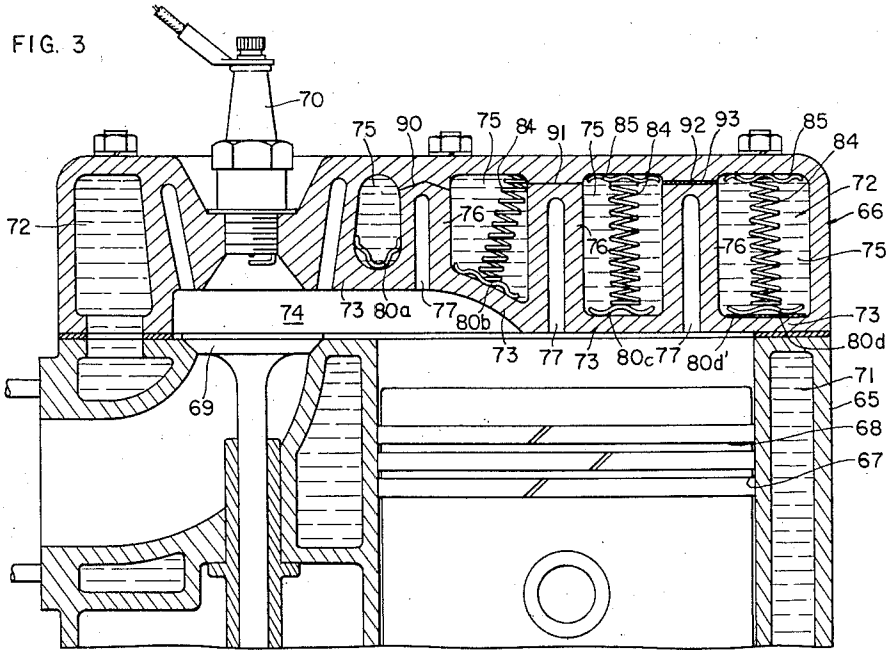
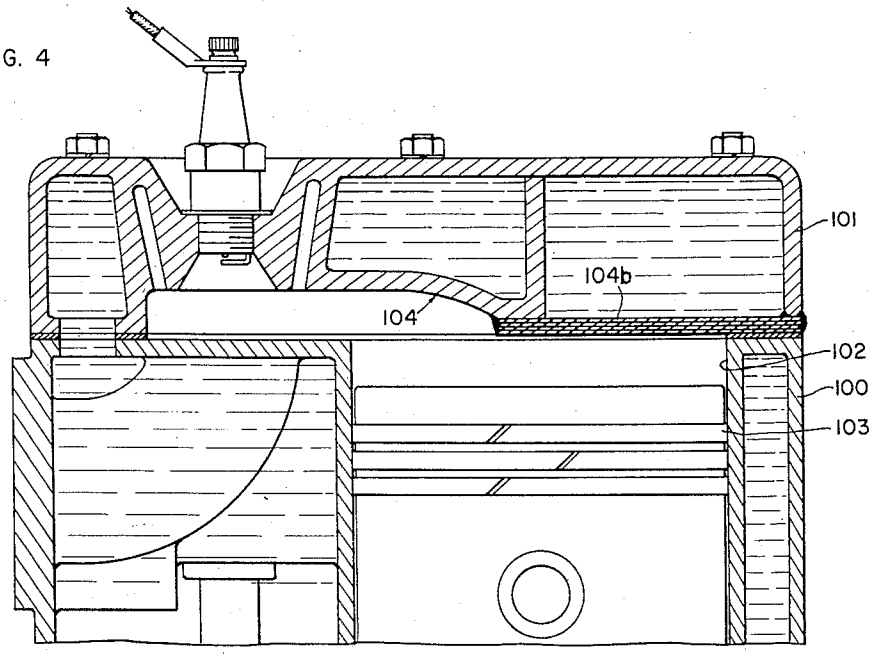


FIG. 4



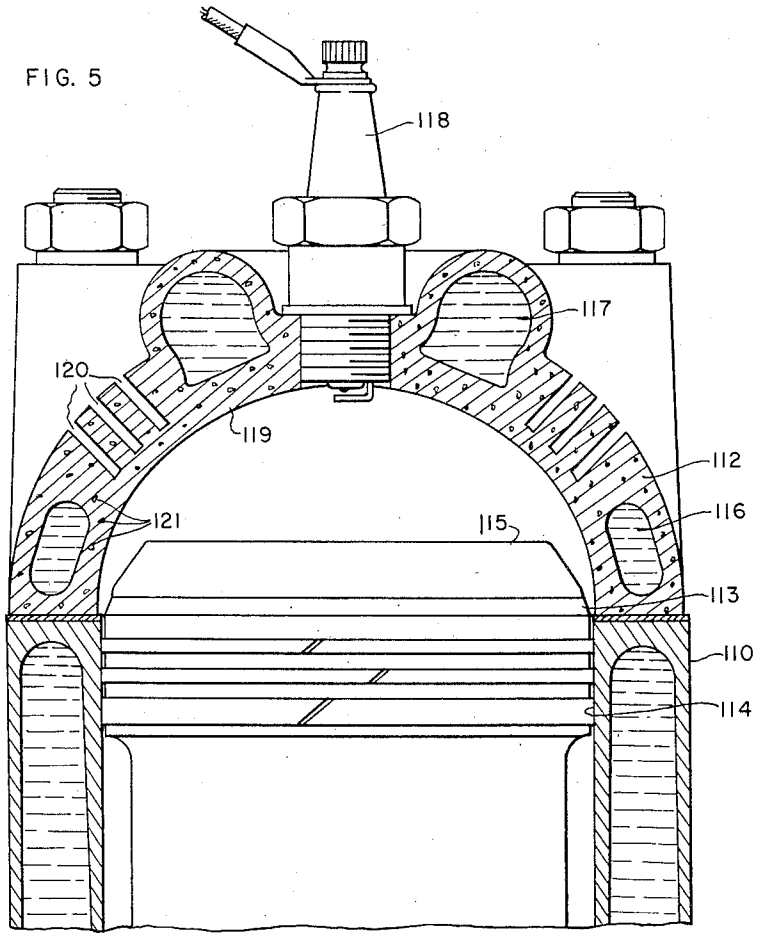
INVENTOR.
ALBERT G. BODINE
BY Forrest J. Hiller
ATTORNEY

April 14, 1959 A. G. BODINE 2,881,751

ACOUSTIC ATTENUATION OF ENGINE DETONATION SHOCK WAVES

Filed Dec. 20, 1957 4 Sheets-Sheet 4

FIG. 5



INVENTOR
ALBERT G. BODINE
BY
ATTORNEY

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2,881,751

ACOUSTIC ATTENUATION OF ENGINE DETONATION SHOCK WAVES

Albert G. Bodine, Sherman Oaks, Calif.

Application December 20, 1957, Serial No. 704,033

16 Claims. (Cl. 123—191)

This invention relates generally to the art of acoustic attenuation along the transmission paths radiating from the source of the manifestations of detonation or combustion roughness in internal combustion engines.

In my prior Patent No. 2,573,536, as well as in a number of subsequent patents, I have disclosed the principle of acoustic suppression of detonation in both piston and continuous combustion or jet engines. These patents have disclosed a number of specific means or devices for combatting detonation, whether in carburetor engines, manifold injection engines, or cylinder injection engines, including diesels. Reference to the aforementioned patent is made for a full disclosure of the principle of acoustic detonation suppression and various techniques for applying the same. In connection with that fundamental teaching, it must be recognized that this invention is not concerned with suppression of the detonation phenomena.

I have noticed in my experimental work with various applications of acoustic detonation suppression that the repeated cycle engine, such as the piston engine, has the significant characteristic that the combustion cycle is repeated in successive totally independent cycles. Thus there is repeated the initiation of various transient phenomena, to a much greater extent than is the case with the continuous combustion family of engines. In the latter the fuel and air mixture is ignited when the engine is started, and combustion is maintained more or less constant, with the only qualification that the combustion becomes undesirably undulatory, thus requiring acoustic treatment.

In the case of piston engines, however, the ignition and subsequent fuel combustion steps are necessarily a series of separated or discretely repeated events. I have noted that with some engines the phenomena of detonation frequently involves an initial transient of shock nature. Referring again to my above-mentioned Patent No. 2,573,536, and particularly to Figure 8*a* thereof, there is shown at A the initial shock which very often precedes detonation phenomena. As has been explained, there are variations of this condition wherein the initial shock is the cycle of greatest amplitude, and the repeated cycles thereafter are of gradually decaying amplitude.

As set forth in said patent, I have found that acoustic wave suppression means incorporated in connection with the combustion chamber of an engine will greatly reduce the mean effective amplitude of the overall acoustic phenomena. The result is that the overall energy represented by the acoustic phenomena is very greatly reduced. This energy factor is of primary importance to engine durability. Accordingly, from the pure engineering standpoint, it is true that totally satisfactory results in all respects can be accomplished by acoustic suppression of the repeated wave phenomena within the combustion chamber. However, there is still an important factor, which may be thought of more as a matter of personal psychology than a matter of satisfactory engine operation and durability, associated with the initial shock type "spike" involved in some forms of detonation. In this

connection, it is to be recalled that the initial shock or spike here spoken of, which is a transient condition that initiates the detonation cycle, is not necessarily or always removed by the detonation suppression means and methods disclosed in my aforementioned patents. Instead, this initial shock may initiate the process, and the process is then immediately suppressed or snuffed out.

The initial shock or spike which thus may remain even during the practice of acoustic detonation suppression may be noticeably audible even though its energy content is for all practical purposes nil. It can be somewhat disturbing to sensitive people, especially under conditions of otherwise very low background noise from other sources. Thus, to illustrate further, while the acoustic suppression of detonation waves within the combustion chamber is in most cases adequate to meet all requirements, there still remain a few isolated special situations, typified by an acoustically treated luxury passenger car climbing a long difficult mountain in the quiet countryside. Here the least "tinkle" owing to detonation can still be detected by the discriminating person, notwithstanding use of acoustic detonation suppression practices. By the term "detonation" I intend to include the whole family of combustion vibration or combustion roughness phenomena.

Accordingly, it is the primary object of this invention to reduce the transmission of the particular kind of sound waves spoken of above from the combustion gases through the mechanical wall structure of the engine, whereby to eliminate radiation of detonation sound at audible levels.

It is an object of this invention to reduce the detonation shock frequency acoustic transmission properties of the combustion chamber walls, water jacket body, water jacket walls, pistons, and other associated mechanical structure. That is to say it is an object of the invention to reduce the acoustic "Q" of the engine structure outside the combustion chamber for detonation shock frequencies. The invention is illustratively carried into effect by any combination of techniques and devices to be presently set forth. These are all to be distinguished from such acoustic wave suppression devices as are disclosed in my aforementioned patent and others related thereto, in that the latter devices are in gaseous or immediate sound wave communication with the combustion chamber of the engine. They react on the acoustic wave processes inside the combustion chamber. The sound wave attenuating devices of the present invention, are, by contrast, in a wave transmission path in the engine structure located outside the chamber. They are removed from immediate acoustically coupled relations with the combustion chamber, and do not react on or have any attenuative effect on the acoustic wave phenomena existing within the combustion chamber. Acoustic attenuator pockets or elements in the combustion chamber walls, in communication with the combustion chamber, are to be distinguished from the present invention in this respect.

Practice of the invention may involve reduction of the flexural vibration of engine walls, and/or the reduction of longitudinal transmission of waves through the engine wall structure, by reduction of the acoustic "Q" of the metal itself, or its structural form.

One preferred practice of the invention is to reduce the acoustic "Q" of the engine structure for detonation frequencies by applying a coating of viscous material on surfaces of the structural parts that tend to transmit detonation noise. I may, for example, apply such a layer of viscous material on the wall surfaces of the water jacket space. This can be accomplished by pouring into the jacket ports a material such as molten tar, or other viscous material which has been made temporarily fluid by combination with a volatile solvent. After the material sets up, there results a thick coating of viscous material on the internal water jacket surface.

It is essential in this connection to use a material which, in relation to the particular stiffness of the underlying wall structure, has an energy absorbing frequency response for the detonation frequency, particularly the frequency content of the initiating shock phenomena above described. A further important improvement resides in applying a relatively stiff or rigidly setting coating material over the layer of viscous material. This added stiff coating over the underlying viscous layer greatly enhances the acoustic damping of the sound wave within the viscous material. In particular, the effect is to damp shear phenomena within the viscous substance. It will be seen that this form of my invention, i.e., a layer of viscous material, preferably with an additional layer of a stiff substance coated thereover, may be applied to any vibrating wall surface, and in fact, this particular acoustic wave attenuator means has a wider application than to the limited field of acoustic engine treatment. Used inside the water jacket of the engine, however, this practice of the broad invention is particularly easily applied and particularly useful.

A further practice of the invention is to provide discontinuities in the sound wave transmission through the engine structure, which discontinuities function either as a substantial change in acoustic reactance, at detonation frequencies, so as to cause the wave energy to be reflected back toward the combustion chamber, or to be present in an attenuative wave path which gradually and progressively absorbs the wave.

A further practice of the invention is the use of loose or unattached inertia bodies in contact with wave transmitting wall surfaces, such as undergo or cause out-of-phase reflections at detonation frequencies and resulting damping of the wave.

Various other objects, features and variational forms of the invention will appear and be described in the course of the following detailed description of a number of illustrative embodiments thereof, reference for this purpose being had to the accompanying drawings in which:

Figure 1 is a vertical sectional view through an engine incorporating acoustic attenuating means in accordance with the invention;

Figure 1*a* is a fragmentary view showing a modification of a portion of Figure 1;

Figure 2 is a view similar to Figure 1 but showing a modified species of the invention;

Figure 2*a* is a detailed section taken on line 2*a*—2*a* of Figure 2;

Figure 2*b* is a view similar to Figure 2*a* but showing a modification; and,

Figures 3, 4 and 5 are transverse vertical sections of engines showing further modified forms of the invention.

In Figure 1 is shown a valve-in-engine, equipped with certain acoustic detonation wave suppression means in accordance with the invention disclosed by my Patent No. 2,573,536, and equipped also with illustrative forms of shock wave attenuator means in accordance with the present invention. The engine is shown to have a water-cooled block **10**, water-cooled head **11** fastened to block **10**, and piston **12** reciprocable in cylinder **13** in block **10**. Head **11** comprises a generally domed combustion chamber wall **14** defining a combustion chamber **15**. Block **10** and head **11** have coolant jackets **10***a* and **11***a*, respectively. In the center of head wall **14** is a threaded port to receive spark plug **17**. Intake and exhaust valves open to combustion chamber **15** through wall **14**, an exhaust valve being indicated at **18**, and the intake valve, not shown, being understood to be located forwardly of the plane of the drawing.

Formed in the generally hemispheric wall **14** of engine head **11** are threaded ports **19** and **20** to receive acoustic detonation attenuators **21** and **22**, respectively. These attenuators **21** and **22** may be of the nature shown in Figure 21 of my Patent No. 2,573,536, and a detailed disclosure thereof will not be necessary herein.

Figure 1 shows also, as a further means for suppressing detonation sound waves within the combustion chamber, a porous pad **23** is mounted on the top end of the piston **12**. Also, the top of the piston, beneath the pad **23**, is shown as formed with resonant absorber cavities **24**, also as described in my aforementioned patent.

The attenuator devices so far described in connection with Figure 1 will be understood to operate in communication with the combustion chamber to attenuate the full acoustic wave pattern associated with detonation, with the exception of the initial shock or "spike" with which the detonation pattern is initiated, and various means in accordance with the invention for preventing transmission through the combustion chamber walls of a sound wave resulting from the initial detonation shock wave or spike will next be set forth.

The interior surfaces of water jacket **10***a* and head jacket **11***a* have applied thereto a relatively thick layer of a viscous acoustic damping material. Such a layer is shown at **30** in jackets **10***a* and **11***a*. It can be applied by pouring a temporarily fluid, but essentially viscous material, into the water jacket space and then tipping the part about until the surfaces are adequately coated. For example, a material such as molten tar, or a viscous material made temporarily fluid by combination with a volatile solvent, is poured into the jacket ports. When the material thus coated onto the interior surfaces has set up, a thick coating of the viscous material adheres to the internal jacket surfaces. Such a coating of viscous material is effective to absorb and attenuate sound waves otherwise transmitted through the wall structure of the engine, it being noted, however, that a material should be used which, in combination with the particular elastic stiffness of the wall structure, has an energy absorbing frequency response for the particular frequency content of the shock wave phenomena desired to be subdued. The section of an appropriate material in any given case is within the skill of those versed in the acoustics art.

A further improvement, as shown in the left half of Figure 1, consists in applying over the thick viscous layer **30**, a second or outside layer **31** of a stiff or rigidly setting coating material. Such a material, an example of which is a phenolic varnish, may be introduced and applied over the initial layer **30** after the latter has set up. This stiff outside layer greatly increases the acoustic shear wave damping phenomena within the underlying viscous material.

In Figure 2 I have shown a valve-in-head type engine having a water-cooled block **40**, water-cooled head **41** secured thereto, and piston **42** reciprocable in cylinder **43**. A spark plug **44** is mounted in head **41**, and intake and exhaust valves are shown at **45** and **46**, respectively. Combustion chamber **47** defined by head wall **48** is provided over cylinder **43**. The intake and exhaust valves control fluid mixture intake and exhaust gas passages **50** and **51** opening into the combustion chamber. The valves are shown provided with suitable guides and valve actuating mechanism, not necessary to describe herein.

The two valves **45** and **46** may be provided with acoustic detonation suppressing attenuators of the type shown in Figure 26 of my aforesaid Patent No. 2,573,536, and the engine may be provided with any other detonation suppression means, as desired.

The water jacket cavity of head **41** is indicated generally by numeral **52**, and in accordance with the practice of the invention under consideration, this cavity is filled with or contains a multiplicity of loose bodies, such as balls **53**. These separate bodies or balls, which may be typically of approximately marble size, may be composed of any suitable material such as steel, glass, ceramic or plastic. Ordinary glass marbles can serve the purpose very well. These separate bodies provide free passage of the water jacket fluid through the spaces therebetween.

The dissipation of the acoustic, shock-type "spike" with which an acoustic detonation wave is generally initiated may be considered under two heads. Notwithstanding the acoustic suppression of the wave pattern following the initial "spike" by practices taught in my Patent No. 2,573,536, this "spike" or peaked half-wave, starts a vibration of the combustion chamber wall **48**, and one mode of attacking the problem consists in heavily damping this wall vibration. Second, the half-wave spike itself may be attacked directly by methods or means designed to disperse it through random multiple reflections. The particular action applied or realized in any given case depends largely on the type of ball or other body **53** that is used.

Assume first the use of heavy balls, roughly of marble size, composed, e.g., of steel or iron. The acoustic damping action of these balls arises from their being in contact with the water jacket side of the combustion chamber wall. Acoustic flexural modes of vibration of this wall are opposed by the loose balls in engagement therewith, and the wall is thereby heavily damped. The balls are caused to vibrate in out-of-phase relation to the combustion chamber wall and to one another, because of acoustic impedance mismatch at detonation frequencies throughout the entire combination of flexural wall, ball mass, and intervening water. There results a very attenuative condition, acoustic energy being absorbed by friction between the moving balls and the combustion chamber wall, and between one another, by non-linear impacts, which tend to convert basic frequency to random frequencies, by internal friction within the balls, and by acoustic wave dispersion owing to random reflections from the surfaces of the balls. The damping will be seen to be cumulative through the mass of loose bodies.

As stated above, steel, iron, or other heavy metallic balls exert a heavy damping action on the combustion chamber walls, and thereby greatly reduce transmission of detonation sound from the combustion chamber through the engine structure.

The balls may alternately be composed of non-metallic materials, such as glass, ceramic, or plastics, which offer less mass reaction, but which consume more acoustic energy internally by internal damping.

It is in all cases important that the bodies in contact with the combustion chamber wall and with each other must meet the structural requirement of having an attenuative frequency response for the detonation frequencies to be combatted, particularly the frequency content of the shock phenomena above described.

In a modification of the invention, the bodies used in the water jacket may be hollow plastic balls, made like Ping Pong balls, and can be smaller, e.g., of common marble size. A group of such balls **55** is shown in Figure 2*b*, and it will be understood that these may be installed in the water jacket of the engine, as in Figures 2 and 2*a*. These hollow or gas-filled balls greatly enhance sound wave dispersion by reason of great impedance mismatch at the boundaries between the balls and the combustion chamber wall and at the boundaries between the balls and the surrounding water. The sound waves radiated by the combustion chamber wall, upon encountering such balls, are partially transmitted and partially reflected at each wall-to-ball interface, at each water-to-ball interface, and at each interior wall surface-to-gas interface. These reflections rapidly degrade and disperse the sound wave, and transmission entirely through the mass of balls is comparatively slight. Any remaining transmission is of a much lower order than the transmission that can otherwise take place through water in the water jacket.

In Figure 3 is shown an engine embodying another form of the invention. At **65** is shown an L-head water-cooled block, to which is fastened water-cooled head **66**, block **65** having cylinder **67** in which works a piston **68**.

An exhaust valve is indicated at **69**, and a spark plug at **70**. It will be understood that, as in conventional L-head engines, an intake valve (not shown) will be located alongside exhaust valve **69**, such valve being, of course, out of the plane of the drawing. Block **65** and head **66** have coolant jackets **71** and **72**, respectively, and head **66** has a combustion chamber space **74** over the cylinder and valves, as indicated. The water jacket **72** is divided into compartments or passages **75** by vertical webs **76**, the compartments **75** being understood to be interconnected around or behind said webs; and the webs **76** are here shown as breached by a substantial number of acoustic "spoiler" cavities, here in the nature of pipe resonators consisting of straight cylindrical bores **77** opening inside the combustion chamber. Such spoiler cavities and their function in suppressing the detonation wave is fully set forth in my said Patent No. 2,573,536, and need not be repeated herein.

The several combustion chamber wall portions **73** intervening between the water jacket compartments and the combustion chamber are contacted, within the water jacket compartments, by metal bridge plates such as **80***a*, **80***b*, **80***c* and **80***d*. These plates **80***a*–**80***d* are designed to contact the adjacent wall surfaces at spaced points, as shown, and to introduce a frictional sliding action at such points. The spacing distance is determined with references to the wave length for the lateral wave existing in or being transmitted through the adjacent combustion chamber wall as a result of the detonation phenomena, as earlier explained. Thus, the combustion chamber wall portions **73**, as a consequence of detonation shock are set into a flexural, lateral vibration of characteristic frequency. Such vibration often occurs in definite acoustic patterns, with spaced nodal and antinodal regions. The antinodal regions are of course those at which vibration amplitude is maximized and the nodal regions are those at which vibration amplitude is minimized. Accordingly, the plates **80***a*–**80***b* are preferably designed with such spacing between contact points as will assure that the antinodal regions will not all be bridged. In other words, the plates **80***a*–**80***d* should each contact one or more velocity antinodal regions. This is assured if the wave frequency of interest is ascertained, the corresponding wave length in the combustion chamber wall is then found, and the spacing distance between contact points on the plates **80***a*–**80***d* is then made such as will assure at least one antinodal region being contacted. Clearly, as one example, a one-quarter wave length spacing of the contact areas on the plates will assure some degree of contact with the vibrating antinodal regions of the walls. It is also important that the spacing distances between contact points not be very much smaller than a quarter wave length, since in such case, frictional sliding action is materially reduced.

The metal plates **80***a*–**80***d* are preferably held against the adjacent combustion chamber wall surfaces by spring pressure. In the case of plate **80***a*, the plate itself is somewhat resilient, and is so bent as to engage not only the bottom but the sides of the corresponding coolant compartment. It is resilently deformed upon installation, and is thereafter spring actuated to engage the wall surfaces opposite.

Plates **80***b*, **80***c*, and **80***d* are provided with coil compression springs **84** holding them against the adjacent wall surfaces. In the case of plates **80***c* and **80***d*, the corresponding springs **84** are also provided at the top with additional plates **85**, engaging the underside of the top wall of the water jacket.

Thus, flexural vibration of the combustion chamber engine wall **73** results in a friction action with the spring-pressed metal plate, which friction action is dissipative of detonation sound wave vibration otherwise transmitted through that portion of the engine structure. This frictional dissipation of acoustic energy can be further

increased by introducing a layer **80***d'* of a viscous material, such as between the plate **80***d* and the wall **73**.

Figure 3 shows also a further modification of conventional engine structure giving an acoustic attenuation property in accordance with the invention. In general, there are various webs between the portion of the cylinder head casting which makes up the combustion chamber wall and the remaining portion of the cylinder head casting which makes up the outside defining wall of the water jacket. These webs are primarily compression members which provide stiffness in supportive relationship to the combustion chamber wall. These webs can be cut through and still maintained in contact at the cut, with the result that compressional loading can still be carried, but any vibration being transmitted through the webs is greatly damped if the cut is oriented properly in relation to the sound waves. The webs **76** in Figure 3 are shown with such cuts at **90**, **91**, and **92**. Acoustic damping effect at such a cut results largely from out-of-phase reflections of the wave caused by the discontinuity in the wave transmission path. In addition, the cut can introduce a dissipative resistive impedance at detonation frequencies, especially if an acoustic shear material is embodied or introduced into the cut. For example, the cut **92** at the top of the right hand web **76** in Figure 3 shows an introduced layer **93** of thermo plastic material. It will be seen that longitudinal (vertical) vibrations in the walls **76** are reflected by the cuts or discontinuities **90**, **91**, and **92** oriented at right angles to the direction of transmission of these vibrations, while lateral or flexural vibrations in the walls **76** are dissipated by friction between opposed sliding surfaces at the cuts **90**, **91**, and **92**, or by shear friction of a substance introduced into a cut, as at **93**.

Figure 4 shows an engine generally similar to that of Figure 3, again made up of a block indicated at **100**, and a water-cooled head **101**, block **100** having a cylinder **102** for piston **103**, and head **101** providing an L-head type combustion chamber head wall generally indicated at **104**. The combustion chamber head wall is in this case made up in two parts, an elevated part **104***a* forming an integral portion of the head casting, and a laminated portion **104***b* overlying a major portion of the cylinder bore immediately at the top end of the latter. These laminations may be integrated to one another by welding at the periphery thereof, and the welded lamination assembly may then be welded in place to the head casting as indicated in Figure 4. Such a laminated wall construction has a substantial acoustic attenuative property for high frequency transmission and, in accordance with the invention, is designed in accordance with known principles to have an acoustic attenuative frequency response for the detonation frequency content desired to be suppressed. The stock type detonation wave pulse is greatly attenuated by such a laminated wall structure, and transmission through the engine structure to the outside is correspondingly reduced.

In Figure 5, I have shown a further modification of the engine made up of cylinder block **110**, cylinder head **112**, and piston **113** working in cylinder **114** in cylinder block **110**. The piston is again shown with a porous pad **115** mounted on its top, designated for detonation wave suppression, and below this pad **115** there may be spoiler cavities similar to those shown in the piston structure of Figure 1. These features of the engine were disclosed in my aforesaid Patent No. 2,573,536 and need not be further described herein.

Head **112** is formed with water circulation passages **116** and **117**, and mounts, at the top, a spark plug **118**. The head **112** is formed to provide a domed combustion chamber head wall **119**. In this particular instance, the purpose is, essentially, reduction of the wave transmission property of the structure of cylinder head **112** at the frequencies involved in the detonation shock phenomena desired to be combatted. In the language of acoustics, the purpose is to reduce the acoustic "Q" of the head structure, whereby acoustic detonation wave transmission therethrough will be materially reduced. To this end, the structure of cylinder head **112** is made somewhat cellular or interrupted as regards wave lengths of the order of the transmitted frequencies to be combatted. This is illustratively accomplished by machining holes or pockets such as indicated at **120** in the wall of the cylinder head. Additionally, or alternatively, a plurality of foreign bodies of material such as indicated at **121** are included in the metal of the head, thereby introducing acoustic discontinuities within the metal structure, whereby the acoustic "Q" of the metal itself is greatly reduced. For example, these foreign materials or bodies may consist of non-alloying inclusions or dispersions introduced into the iron in the molten states, such as higher melting point metals, or ceramics. These bodies introduce substantial variances in acoustic impedance at random locations throughout the head structure, and therefore cause random reflections which are highly dispersive of the detonation frequency sound waves attempting to pass through the head structure. Flexural vibration of flat surfaces of the engine are particularly well subdued by this method of reducing the acoustic "Q" of the metal. The discontinuities or foreign-introduced bodies should, of course, be such as will effect an attenuative frequency response at those frequencies involved in the shock phenomena to be combatted.

One further variant of my invention involves the introduction of a frequency responsive attenuation element in an attachment means between two components of the engine. For example, as illustrated in Figure 1, I may use a form of piston wherein the piston crown part **130** is separate from the piston body part **131**, and is acoustically isolated at detonation frequencies from the body portion and the mechanical structure therebeyond. As shown, the crown has an internal cylindrical surface **132**, which is frictionally engaged by an external annular rib **133** on the piston body, the crown having a friction, press fit over the rib **133**. In the pocket between rib **133** and the shoulder **134** above, on the crown **130**, is fitted a ring **135** of low "Q," vibration absorbing material, such as fiber glass, plastic, or tetrafluorethane. A shoulder underlying the rib **133**, afforded by a clamp ring **136** secured to the bottom of crown **30** as by rivet pin **137**, holds a second ring **138** of vibration absorbing material against the lower side of rib **133**. In engine operation, the piston is acted on by the body of burning combustion gases functioning as a compliance, and assuming a proper mass for the piston crown, the crown will tend to vibrate during detonation. The crown accordingly vibrates relative to the piston body, sliding slightly up and down on the body, and acoustic energy is dissipated at the frictional junction between crown and body, as well as within the vibration absorbing rings **135** and **138**. By making the mass of the body portion of the piston proper in relation to the compliance of the connecting rod, the body will also have a frequency response, and increased relative frictional vibration between crown and skirt can be attained.

In Figure 1*a* I have shown a modification, wherein the piston crown **140** and piston body **141** are separated by a plastic insert ring **142**. This insert, which may be a thermosetting phenolic, introduces a viscous shear effect between the two components of the piston. The introduced material should have an attenuative frequency response characteristic for the detonation wave frequencies whose transmission is to be reduced.

I have now shown and described a number of practices of my present invention. Briefly summarizing, the invention introduces an attenuative characteristic into the engine structure, such that shock or other acoustic wave phenomena arising from detonation, and not suppressed inside the combustion chamber, are materially suppressed in course of transmission from the combustion chamber

through the engine structure to outside. The various attenuative devices here shown may be used in various combinations in various portions of the engine structure to assure against escape of material audible sound from detonation. The invention is preferably practiced in combination with my techniques for suppressing the detonation wave pattern inside the combustion chamber. However, my inventions may also be practiced without detonation wave pattern suppression within the combustion chamber, and while in such case the engine is not relieved from the physical shock of detonation, audible manifestations are nevertheless made less disagreeable. It will also be understood that while various forms of the invention have been disclosed herein, numerous other forms are evidently possible, and these are to be considered as coming within the scope of the broader of the appended claims.

I claim:

1. In an internal combustion engine having a combustion chamber wherein detonation may occur, engine walls including wall means defining said combustion chamber and including wall structure whose solid material forms an acoustic wave transmission path leading outwards from said chamber, said wall structure being physically vibratory as a consequence of wave transmission therein owing to detonation within said chamber, and thereby acting as an acoustic radiator, and acoustic attenuating means acoustically coupled into said physically vibratory wall structure in said wave transmission path outside the defining wall surfaces of the combustion chamber, said attenuating means having an attenuative response for the frequency pattern of the accoustic wave transmitted through the solid material of said wall structure from the detonation phenomena within the combustion chamber.

2. The subject matter of claim 1 wherein said acoustic attenuating means comprises a layer of viscous material on at least a portion of said wall structure in said wave transmission path.

3. The subject matter of claim 1 wherein said acoustic attenuating means comprises a layer of viscous material on at least a portion of said wall structure in said wave transmission path, and a layer of relatively stiff material over said layer of viscous material.

4. The subject matter of claim 1 wherein said acoustic attenuating means comprises a layer of viscous material on interior water jacket surfaces of the engine.

5. The subject matter of claim 1 wherein said acoustic attenuating means comprises a layer of viscous material on interior water jacket surfaces of the engine, and a layer of relatively stiff material over said layer of viscous material.

6. The subject matter of claim 1, wherein said acoustic attenuating means comprises a mass of loose bodies positioned in contact with one another and with at least a portion of said wall structure in said wave transmission path.

7. The subject matter of claim 6, wherein said bodies possess substantial inertia whereby to effect a substantial damping of said wall structure against wave transmission therethrough.

8. The subject matter of claim 6, wherein said bodies have substantial internal damping.

9. The subject matter of claim 6, wherein said bodies are ball shaped.

10. The subject matter of claim 6, wherein said bodies are hollow and composed of light material.

11. The subject matter of claim 6, wherein said bodies are spherical, hollow, and composed of light material.

12. The subject matter of claim 6, wherein said engine has a water jacket defined in part by an exterior surface of a combustion chamber wall, and said mass of loose bodies is contained within said jacket, in contact with said exterior surface of said combustion chamber wall.

13. The subject matter of claim 1, wherein said engine wall structure has a wall surface bounding said acoustic wave transmission path, and said acoustic attenuating means includes a plate spring-urged into engagement with said wall surface.

14. The subject matter of claim 1, wherein said engine wall structure has a wall surface bounding said acoustic wave transmission path, and said acoustic attenuating means includes a bridge plate spring-urged in engagement with said wall surface at a plurality of points spaced by a substantial fraction of a detonation shock frequency wave length distance in said wall structure adjacent said bounding wall surface.

15. The subject matter of claim 1, wherein said acoustic attenuating means comprises a multiplicity of non-alloying foreign particles incorporated in the vibratory wall structure in such dispersion and of such material as to introduce substantial variances in acoustic impedance in said wave transmission path and thereby cause random wave reflections and dispersion of acoustic detonation frequency waves attempting to follow said path.

16. In the operation of internal combustion engines, the method of reducing audible detonation induced acoustic wave frequencies initiated in the combustion chamber of the engine, transmitted through the surrounding wall structure of the engine, and radiated from the outer surface of said structure, that comprises attenuating said wave frequencies in course of their transmission through said wall structure of the engine.

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