Dec. 21, 1948. C. B. HORSLEY 2,456,706

ACOUSTIC CHAMBER

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Fig. 1.

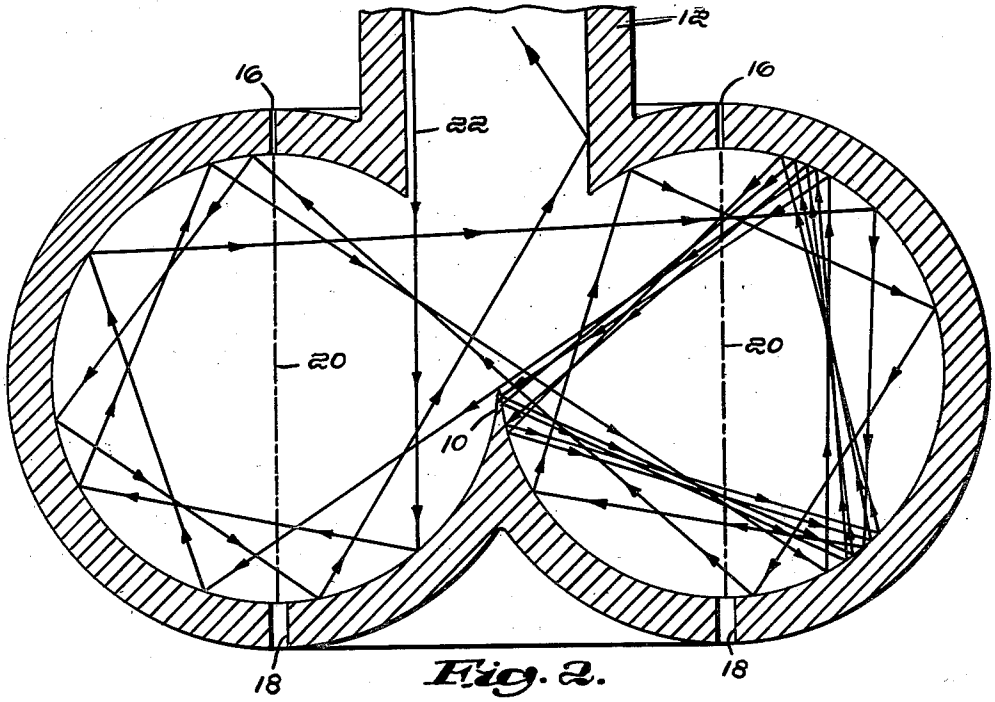
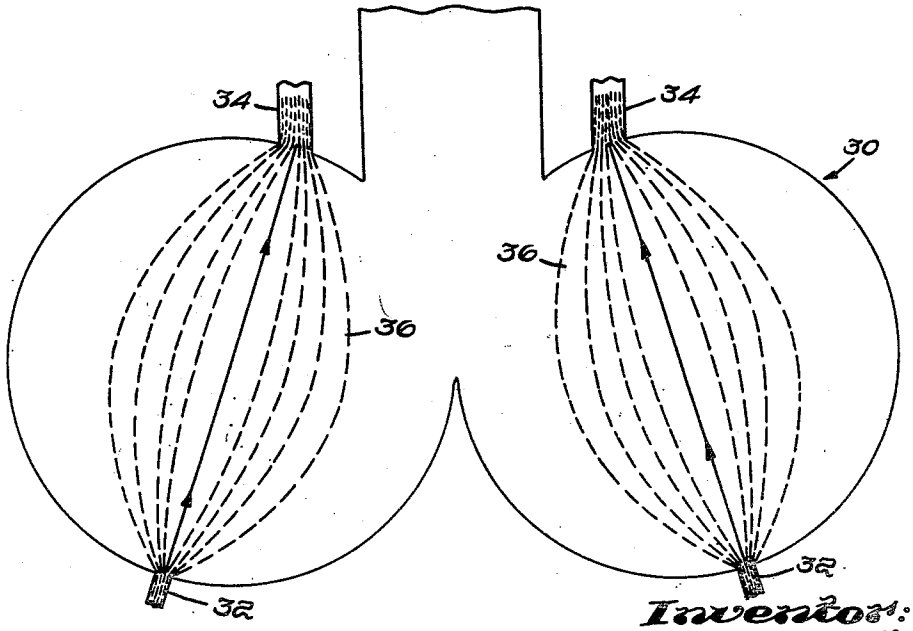


Fig. 2.



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ACOUSTIC CHAMBER

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Fig. 3.

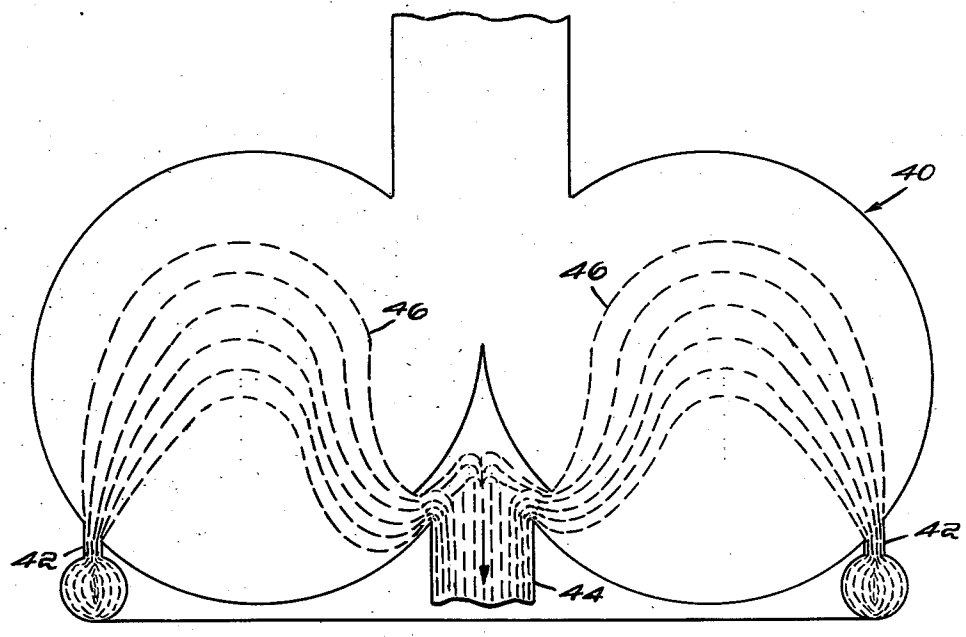
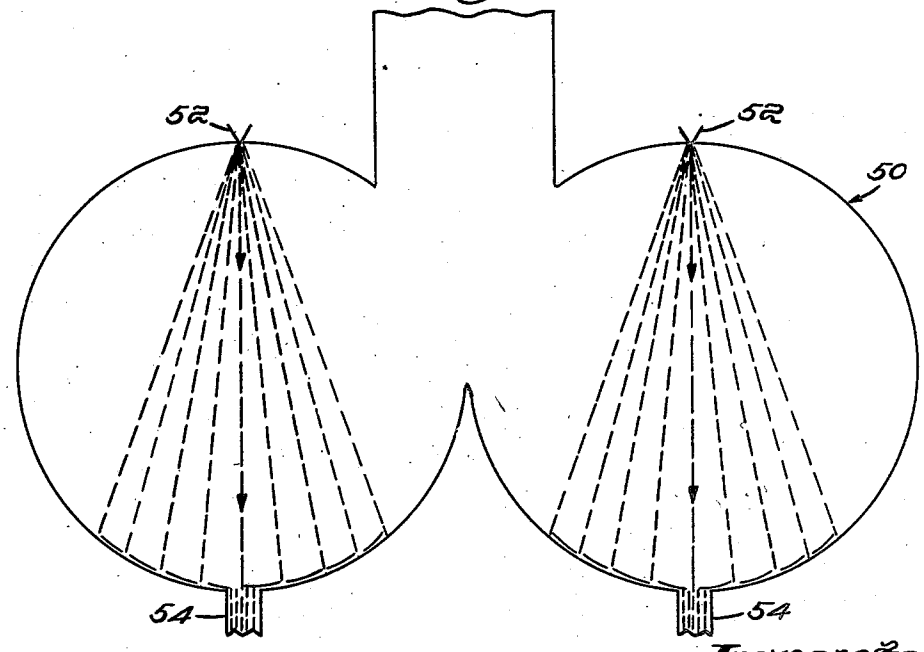


Fig. 4.



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ACOUSTIC CHAMBER

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Fig. 5.

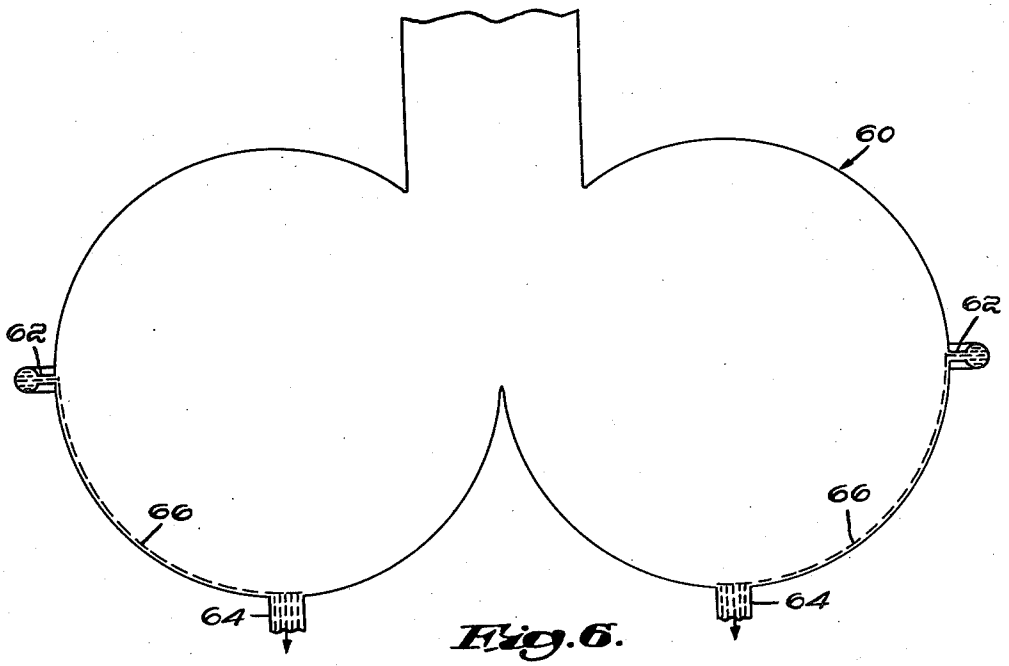
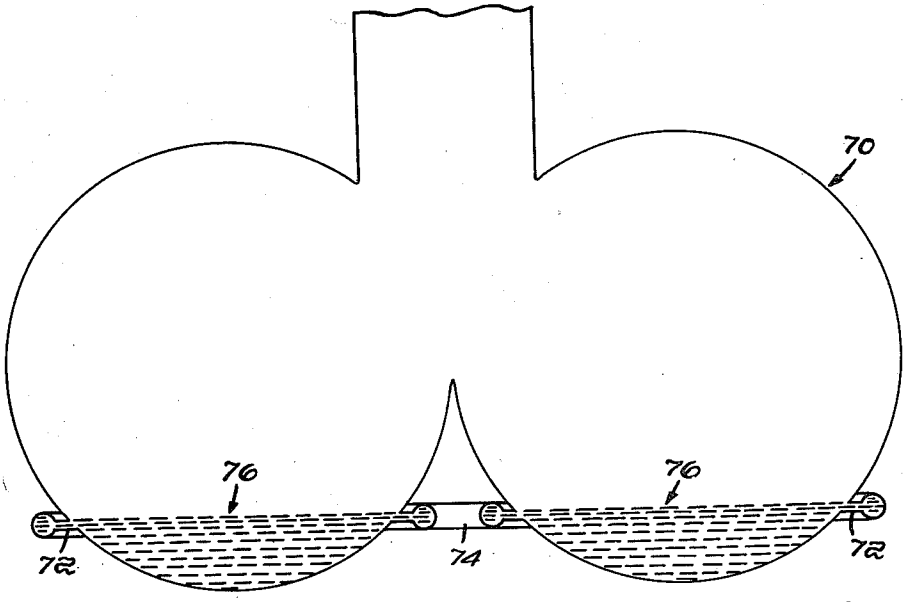


Fig. 6.



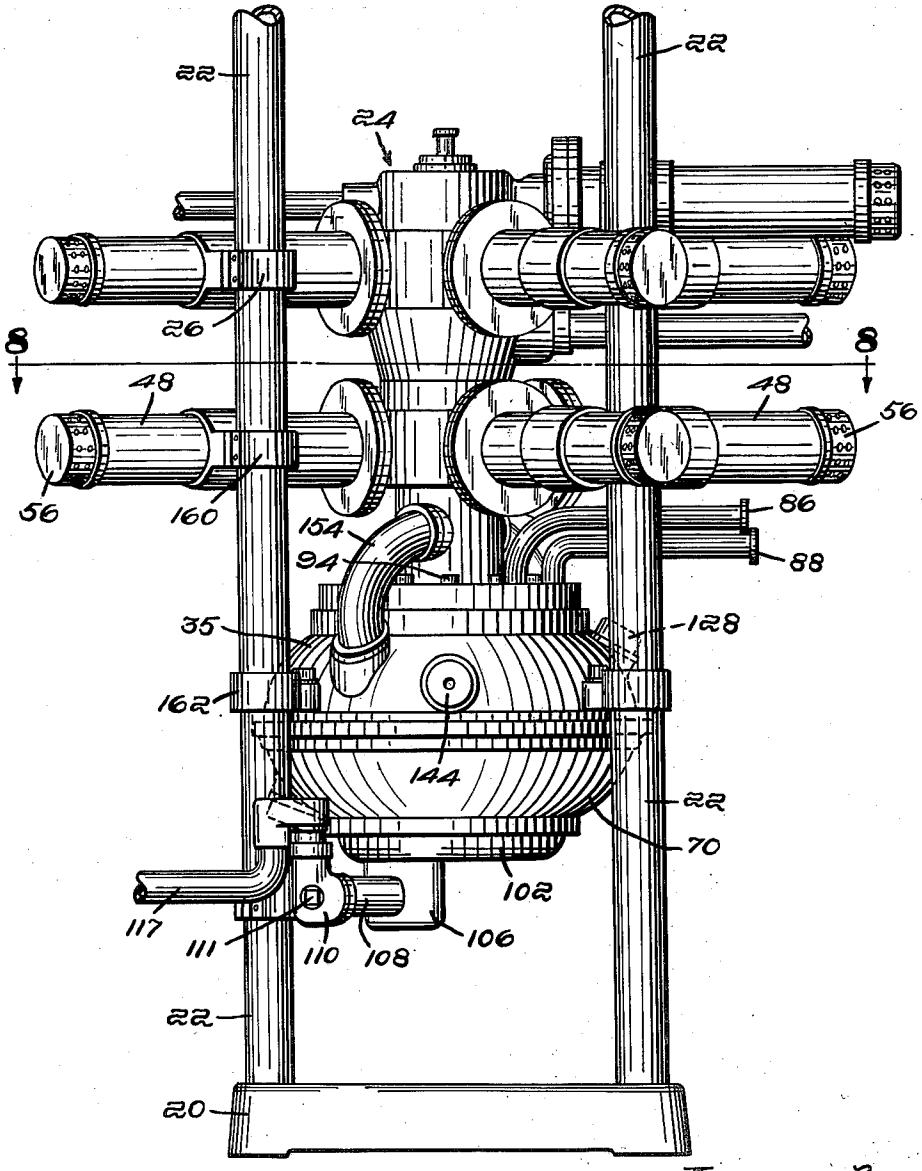
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Dec. 21, 1948. C. B. HORSLEY 2,456,706

ACOUSTIC CHAMBER

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Fig. 2.



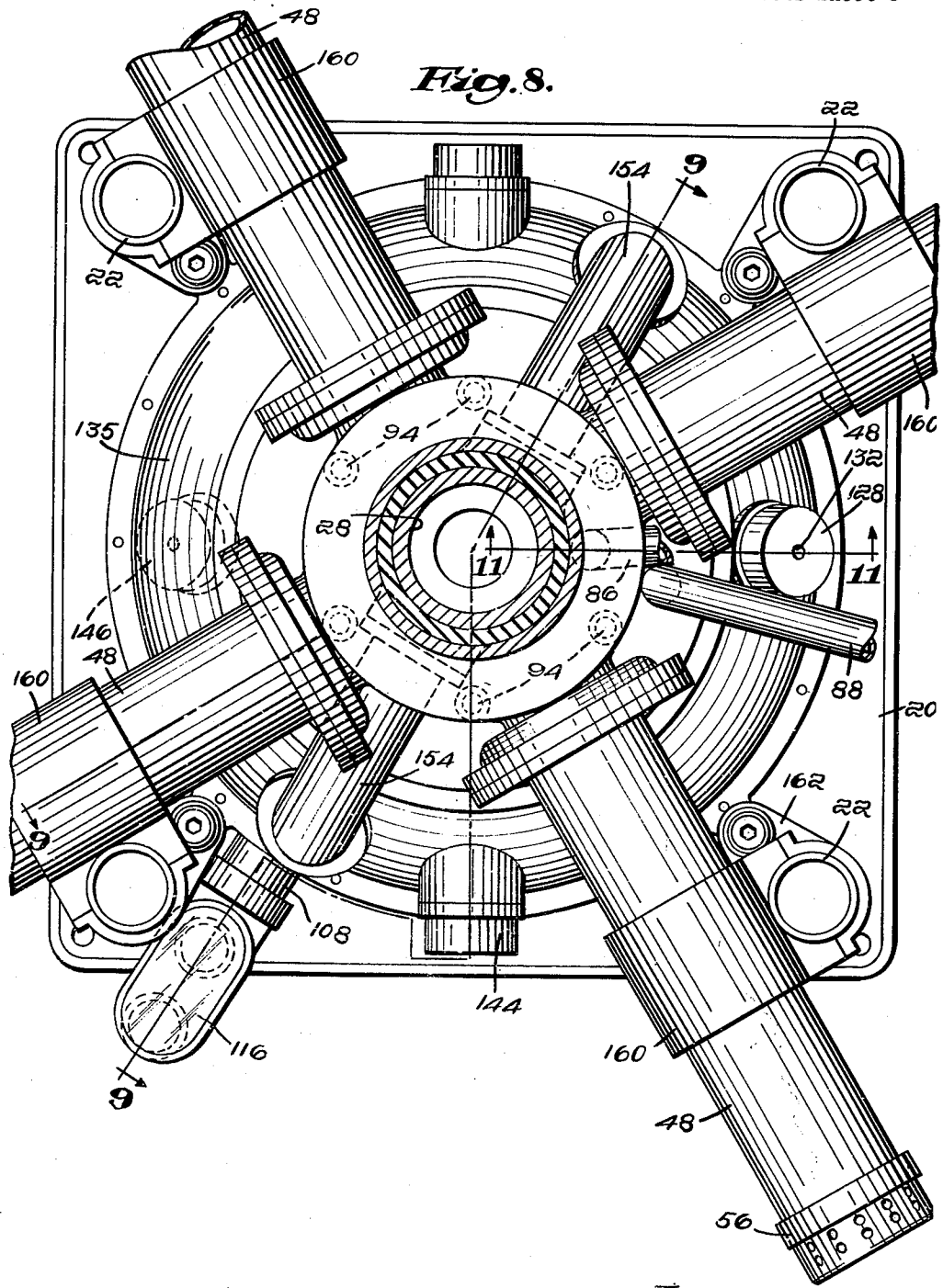
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Dec. 21, 1948. C. B. HORSLEY 2,456,706

ACOUSTIC CHAMBER

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Fig. 8.



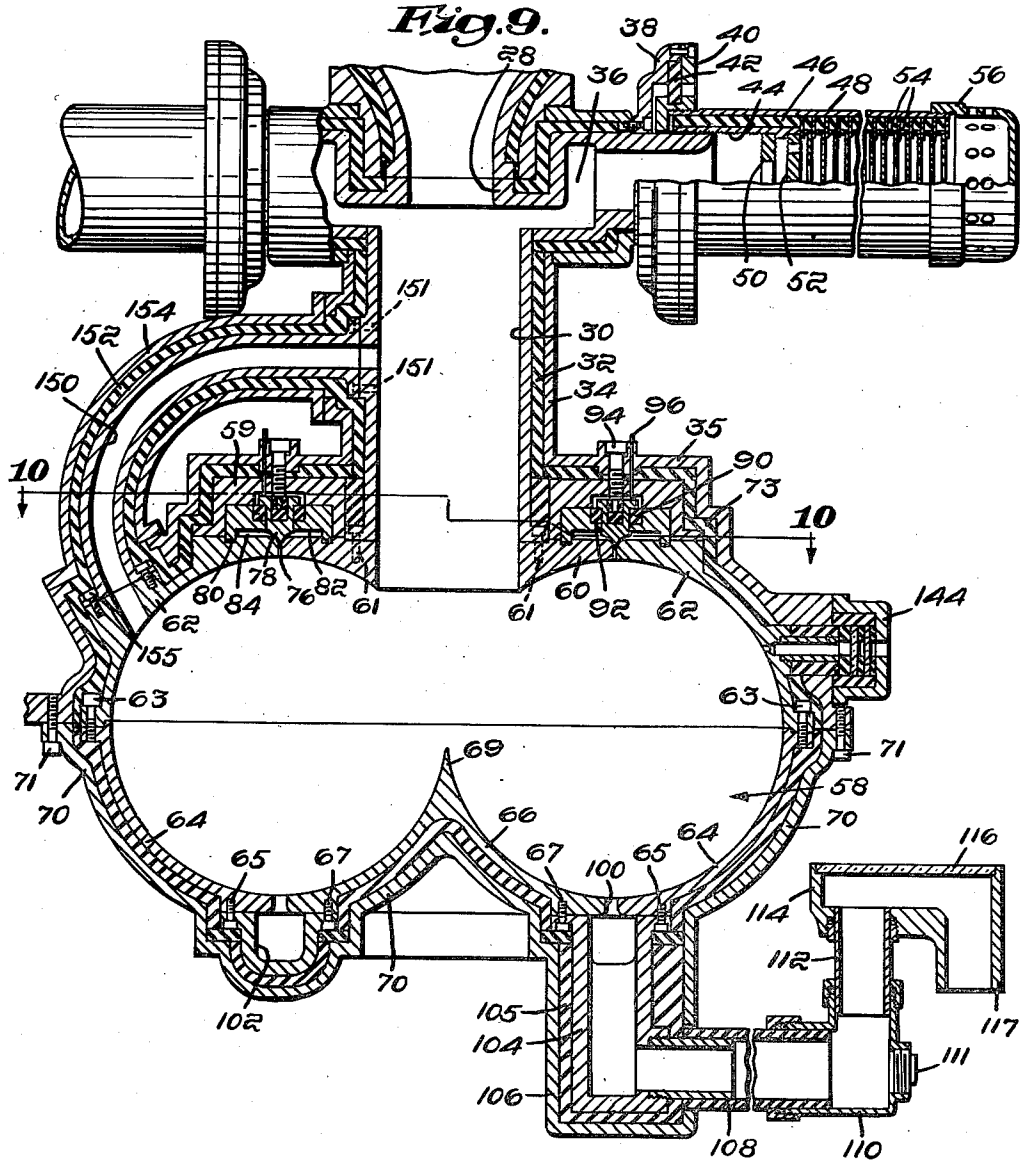
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Dec. 21, 1948. C. B. HORSLEY 2,456,706

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Fig. 9.



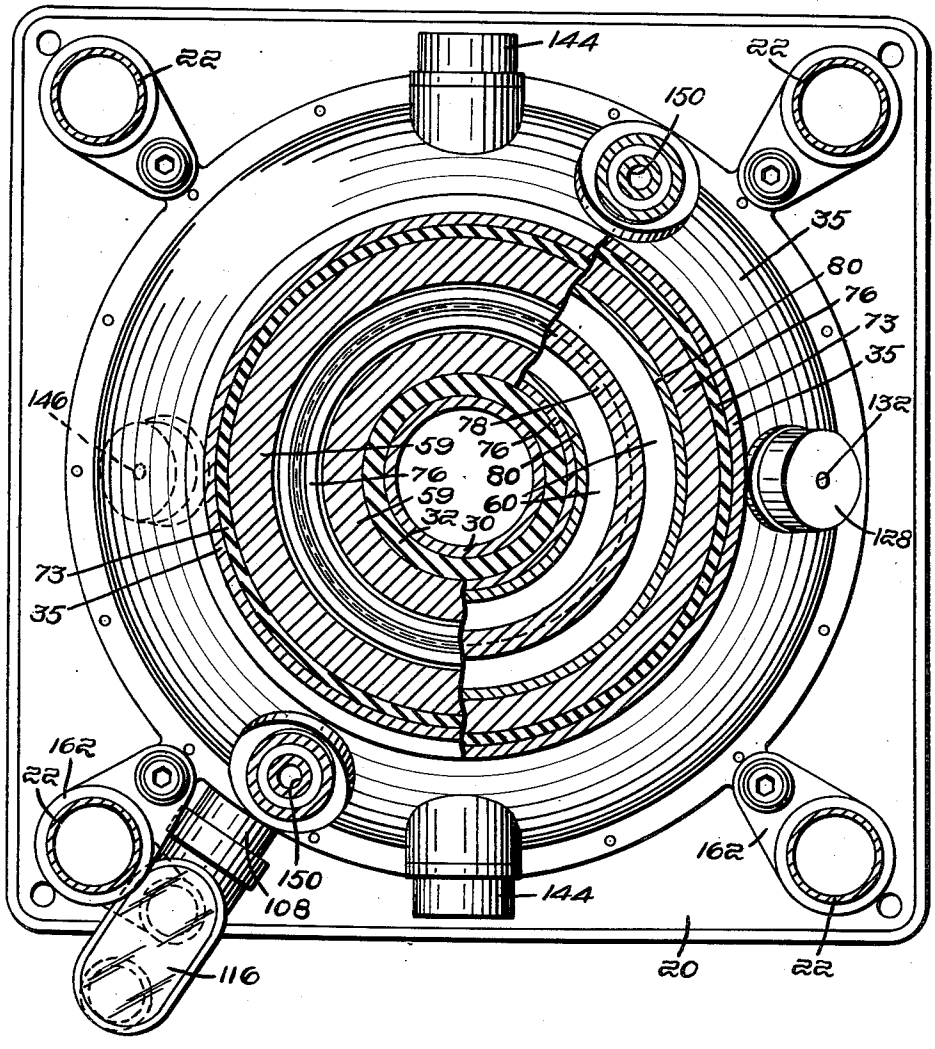
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Dec. 21, 1948. C. B. HORSLEY 2,456,706

ACOUSTIC CHAMBER

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Fig. 10.



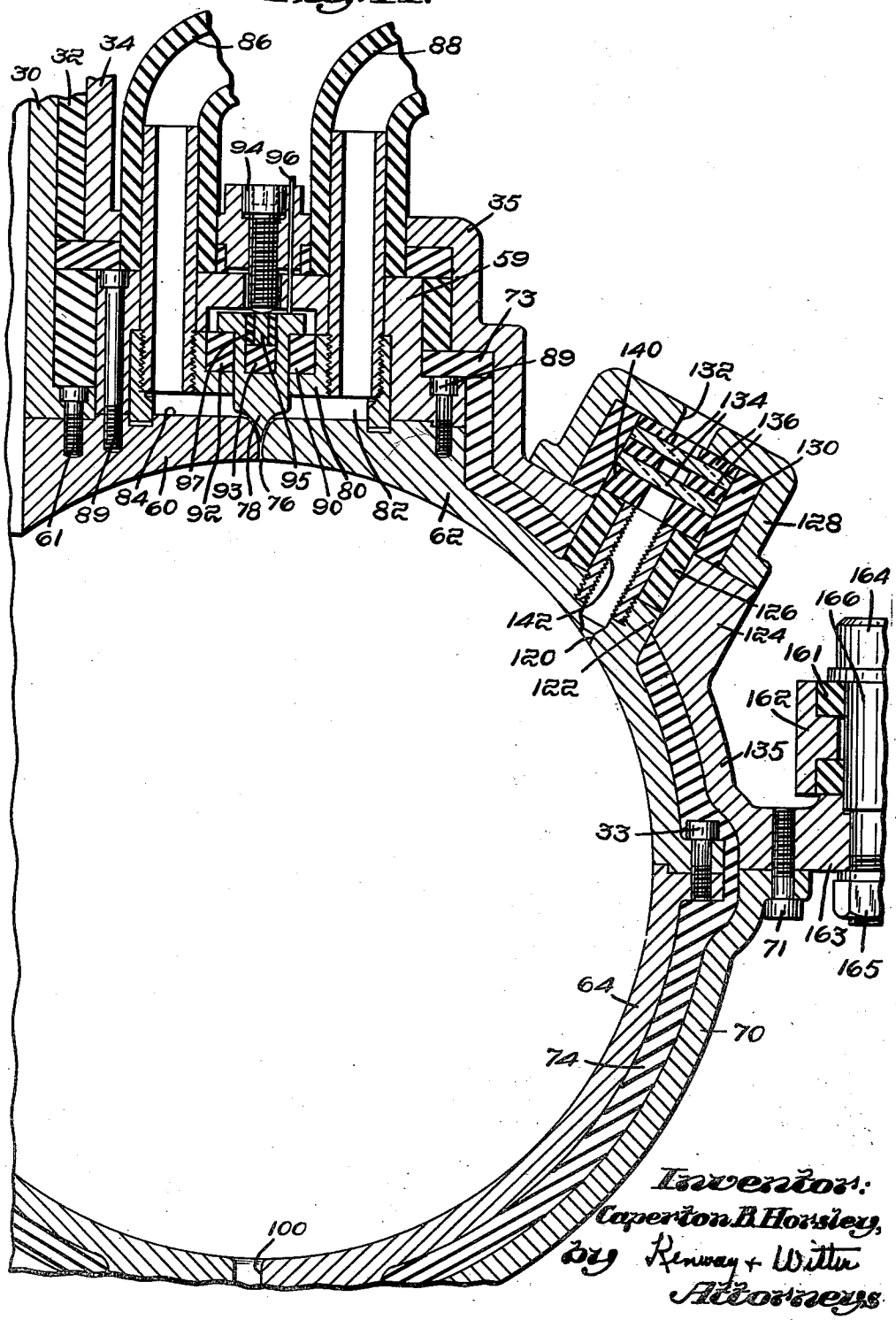
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ACOUSTIC CHAMBER

Filed Feb. 2, 1946 8 Sheets-Sheet 8

Fig. 11.



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Patented Dec. 21, 1948

2,456,706

UNITED STATES PATENT OFFICE

2,456,706

ACOUSTIC CHAMBER

Caperton B. Horsley, Stamford, Conn., assignor to Ultrasonic Corporation, Boston, Mass., a corporation of Massachusetts

Application February 2, 1946, Serial No. 645,224

7 Claims. (Cl. 259—1)

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My invention relates to the art of treating materials with compression waves and, more particularly to an acoustic chamber into which various materials may be introduced for such treatment.

Many valuable and beneficial results may be accomplished by passing compression waves through various media. For example, oil and water may be emulsified by the action of compression waves at suitable frequencies. Waves of a different series of frequencies may be used to separate finely emulsified oil from sea water. Other examples of the application of compression waves are to be found in the sterilization and homogenization of milk, the casting of various metals, and the treatment of aerosols. Although many of the principles involved have been known for some time, it is only in recent years that attempts have been made to apply theoretical knowledge to commercial practice. Various names have been applied to the art such as "sonics," "supersonics," and "ultrasonics," and as used herein such terms refer to waves of any frequency comprising alternate series of positive and negative pressure regions traveling through a material. To avoid unnecessary limitations connoted by other terms I prefer the expression "compression waves."

In order to produce commercially acceptable results from the action of compression waves three primary problems must be solved. In the first place it is necessary to provide apparatus for generating compression waves at various frequencies with energies sufficiently high to accomplish large scale results. One preferred generating apparatus is shown in a co-pending abandoned application Ser. No. 624,504, filed October 25, 1945, by Richard E. Young and myself.

The second important problem is to provide means for rapidly modulating or varying the frequency of compression waves over a wide range. A modulator designed for such use is disclosed in my co-pending application Ser. No. 636,038, filed December 19, 1945, now Patent No. 2,424,357.

The third problem, the solution to which forms the primary object of my present invention, is to provide continuously operating apparatus for receiving compression waves and the material to be treated and for transmitting the compression waves through the material to be treated.

One specific object of my invention is to increase the yield, or desired result produced, per unit of work expended in the generation and modulation of the waves.

Another object of the invention is to provide

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an acoustic treating chamber wherein the material to be treated is, prior to treatment, put in a condition rendering it markedly responsive to the action of compression waves.

In one aspect my invention comprises a chamber containing means for the promotion of reflection and re-reflection of compression waves therein and for inhibiting the escape of reflected waves.

In another aspect my invention comprises a chamber having a valved, annular inlet arranged to project through the chamber a plurality of liquids in a laminar film of controlled thickness, or a single liquid film.

One feature of the invention resides in a chamber so constructed and proportioned that compression waves entering it are reflected in such fashion that a curtain of material flowing through the chamber is bombarded from all angles.

Another feature of my invention consists in an arrangement whereby compression waves are generated in and transmitted through a gaseous medium before being directed against a liquid or other material to be treated.

Still another feature of the invention is the provision of means for flowing through the chamber a curtain of material having a thickness either a multiple of a quarter wavelength of the average compression wave in the chamber, or having a weight of a column of air of the same cross-sectional area as the curtain and a thickness of one-fourth the average wavelength in air at the frequencies employed in the chamber. In the former case standing waves are set up in the material of the curtain. In the latter case the curtain acts as a diaphragm. Both arrangements enhance the effect of the compression waves.

Another feature of the invention resides in a protective layer of absorbent material surrounding all of the apparatus and in turn encased in a steel jacket. The effect of this sandwich arrangement is to suppress noise from compression waves at audible frequencies and to eliminate the deleterious effects of supersonic waves upon surrounding equipment and workers.

These and other objects and features of my invention will be more readily understood and appreciated from the following detailed description of preferred embodiments thereof selected for purposes of illustration and shown in the accompanying drawings, in which:

Figs. 1–6 are diagrammatic views in cross-section through acoustic chambers suggestive of several embodiments of the invention,

Fig. 7 is a view in side elevation of a preferred embodiment of the invention,

Fig. 8 is a view in cross-section along the line 8—8 of Fig. 7,

Fig. 9 is a view in cross-section along the line 9—9 of Fig. 8,

Fig. 10 is a view in cross-section along the line 10—10 of Fig. 9, and

Fig. 11 is a view in cross-section along the line 11—11 of Fig. 8.

Before proceeding to a detailed account of the construction and operation of one embodiment of my invention, I shall first discuss the subject in general and refer to the diagrams in Figs. 1–6. In constructing a chamber according to the invention there are three chief factors to be considered. In the first place, the construction must be such that the air or other fluid atmosphere in the chamber is not bodily agitated. To obtain this effect I provide a system of exhaust mufflers arranged adjacent the entrance to the chamber for removing air coming from the generator or modulator. The result is that the compression waves travel through a relatively static medium within the chamber.

Secondly, means must be provided to minimize the reflection of waves toward the entrance of the chamber. As will appear in Fig. 1 the body of the chamber is of toroidal or doughnut form. At the bottom is a centrally located conical projection 10 axially aligned with an upper entrance tube 12. In cross-section the chamber presents two adjacent circles tangent to each other at their inner peripheries and interrupted by the entrance tube at the top connected at its upper end to a suitable source of compression waves. The geometry of the interior of the chamber is such that the entering compression waves are reflected back and forth through the chamber instead of back toward the entrance.

The manner in which the material to be treated is introduced into the chamber depends upon the physical form of the material as well as the result desired. I prefer to introduce a liquid in the form of an annular curtain dropping through the maximum vertical diameter of the chamber. At the top of the chamber there is formed a narrow annular opening 16 through which a controlled flow of liquid or liquids is admitted to the chamber. A larger annular opening 18 at the bottom of the chamber is connected to a sump (not shown) in which the treated liquid is collected. The broken lines 20 represent the continuously flowing liquid curtain or film.

The full line 22 represents the path of a point on a wave front, selected at random to illustrate the reflection of compression waves in the chamber. It will be seen that the point 22 is reflected twenty-eight times before it is directed toward the entrance tube 12 and that it has passed twenty times through the curtain 20. By this time the wave 22 will have expended the greater part of its energy in useful work.

I have discovered that the thickness of the curtain 20 has a definite effect on the efficiency of the chamber. Every material moves when transmitting compression waves by an amount which varies directly with the amplitude and inversely with the frequency of the waves in any given material. Furthermore the acceleration of any one portion of the material is proportional to the movement, or particle displacement, of the material times the square of the frequency. I prefer to employ a curtain thin enough to move as a diaphragm, thus imparting more acceleration to the material than would be obtained by the use of the same energy in a large quantity of liquid, since maximum acceleration may be required for optimum results. In order to obtain the diaphragm effect I employ a curtain which weighs not appreciably more than one hundred times the weight of a column of air having the same cross-sectional area as the curtain and a thickness of one fourth the average wavelength in air at the frequencies to be employed in the chamber.

Where for any reason such thin films or curtains are impractical the efficiency of the treatment may still be enhanced over that obtained by using curtain thicknesses selected at random. By making the thickness of the curtain approximately equal to a quarter the average wavelength in the liquid, or a multiple thereof, standing waves are set up in the curtain, and the effect of the compression waves in the chamber is amplified.

It is to be understood that my invention includes acoustic chambers for a host of different treating processes. In Figs. 2–6 I have suggested additional embodiments showing chambers adapted to treat various solids, liquids, gases, or aerosols.

In Fig. 2 there is shown the outline of a chamber 30 provided in the bottom with an annular inlet 32 for smoke or gas, and an exhaust outlet 34 at the top. Compression waves at proper frequencies will agglomerate smoke particles and cause them to settle out rapidly. By drawing smoke through the chamber 30 along the paths illustrated generally by the broken lines 36 while compression waves are introduced at the top, the smoke particles are agglomerated and will rapidly settle out in a tank or conventional separator (not shown) into which the smoke may be led when it leaves the chamber 30.

In Fig. 3 there is shown a variation of a chamber equipped for handling gas or smoke. An annular inlet 42 leads into the bottom of a toroidal chamber 40, and an exhaust outlet 44 is disposed in the bottom central portion of the chamber. Compression waves are introduced at the top as before, and the path of the smoke or gas is shown generally by the broken lines 46.

In Fig. 4 I have shown a chamber 50 provided at its top with an annularly disposed series of spray nozzles 52; an annular outlet 54 is shown at the bottom of the chamber. It should be pointed out that solid material in powder form may be sprayed into the chamber. By way of example organisms present in flour may be destroyed by passing the flour in a stream or streams through the chamber and subjecting it there to the action of compression waves varying over a suitable range of frequencies.

In Fig. 5 I have shown a chamber 60 equipped with an annular inlet 62 and a bottom outlet 64. The inlet is disposed halfway up the side of the chamber and may be employed for the introduction of liquid or powdered material into the chamber. In this embodiment of the invention the material flows along the interior wall of the chamber as shown by the broken line 66.

The chamber 70 shown in Fig. 6 is adapted for the treatment of a circulating liquid and is provided adjacent the bottom of each half with annular orifices 72 connected to a pipe or header 74 through which the liquid is circulated. The liquid accumulates in the bottom of the chamber as shown at 76 and is pumped in and out by any suitable pumping system (not shown).

In each case it will be seen that compression waves are generated in and transmitted through

a gaseous atmosphere before reaching the material to be treated. This contrasts with the generally accepted mode of operation in which the waves are generated in the material undergoing treatment. Furthermore the gaseous atmosphere may be varied to produce beneficial results in specific processes. For example the chamber may be filled with chlorine at any desired pressure for the chlorination of liquids.

Furthermore the compression waves in the chamber are directed against the material to be treated at a multiplicity of angles. In the breaking up of organisms or globules of material the angle at which the wave hits the target as well as the dimensions thereof may determine the frequencies which will have lethal or destructive effect. Consequently the modulation of frequency and the multiplicity of angles at which the waves strike the target are factors which may tremendously increase the efficiency of the treating process. It is unlikely that a particle, globule, or organism can progress entirely through the chamber without encountering a series of waves at the most effective frequency and angle.

After the foregoing general discussion of several embodiments shown diagrammatically there will follow a detailed description of one preferred embodiment of the invention shown in detail in Figs. 7 to 11 and based, in principle, on the diagram shown in Fig. 1.

As shown in Fig. 7 the apparatus of my invention is organized about and supported by a heavy rectangular base **20** which serves as an anchorage for the lower ends of four vertical supporting rods or standards **22**. At the top of the apparatus is mounted a compression wave generator **24** constructed according to the disclosure of the copending application Ser. No. 624,504, filed by Richard E. Young and myself on October 25, 1945, and to which reference is made for details. It is sufficient to say that the generator is held in a central position among the rods **22** by means of a plurality of straps **26** secured to the mufflers of the generator. At its lower end the generator terminates in a nozzle or outlet passage **28** axially aligned with a vertical tube or conduit **30** surrounded by a layer of sponge rubber, fiber glass, or other suitable material and encased in an outer shell **34**. Leading laterally from the vertical axis and disposed beneath the nozzle **28** are four restricted passages **36** terminating in four circular flanges **38** disposed at 90° intervals about the conduit **30**. Bolted to each flange **38**, with an intervening rubber gasket **42**, is a corresponding flange **40**. A muffler is connected to each of the flanges **40** and comprises essentially an inner cylindrical shell **44**, a surrounding protective layer **46** of sponge rubber and an outer metal casing **48**. Each passage **36** leads to the interior of a muffler provided with a first annular baffle **50** having a centrally located aperture and backed up by a second baffle **52** having marginal apertures offset from the central aperture of the baffle **50**. Outwardly disposed of the baffle **52** and in spaced relation within the muffler is a plurality of baffle plates **54**. Each of the baffle plates **54** is apertured, but the apertures in adjacent plates are offset. The outer end of each muffler is provided with a perforated cap **56**. The mufflers provide an exhaust system for air delivered from the generator.

The lower end of the conduit **30** is outwardly flanged and fitted against an annular casting **60** which forms the upper central portion of the toroidal acoustic chamber **58** and is secured to

the flange on the conduit **30** by a plurality of peripherally arranged bolts **61**. A segmental annular casting **62** is arranged contiguously with the casting **60** to form the major portion of the upper part of the toroidal chamber and is secured by a series of bolts **63** to a second segmental annular casting **64** forming the outer and lower portion of the toroidal chamber. The bottom central portion of the chamber is formed by a casting **66** having a conical central upwardly extending projection **69**. The castings **60**, **62**, **64** and **66** together form the toroidal chamber **58** for which the tube **30** serves as an upper inlet.

At the bottom of the chamber **58** there is provided an annular trough or drain **102** secured by bolts **65** to the casting **64** and, by another series of bolts **67**, to the casting **66**.

The outer shell **34** for the conduit **30** merges into an outwardly and downwardly extending portion **35** secured in turn to a lower shell member **70** by a series of peripheral bolts **71**. The casing **35** encloses the castings **60** and **62**, and the lower shell **70** encloses the castings **64** and **66**. In each case there is provided an intermediate protective layer of sponge rubber or other suitable sound-absorbing material disposed between the outer casing and the inner casting. Thus a layer of sponge rubber **73** is interposed between the shell **35** and the castings **60** and **62** while a similar layer is interposed between the shell **70** and the castings **64** and **66**. It will be observed from an inspection of the drawings that the entire chamber and appurtenance are protected by this sandwich construction comprising an inner casting or tube, a layer of sponge rubber, and an outer shell or casing. The purpose of this construction is to prevent the radiation of compression waves outside the chamber, to prevent noise, and to protect operators of the equipment from the physiological effects of compression waves. While I have found that sponge rubber is satisfactory for this purpose, I have no doubt that other materials are equally well fitted for such use. It is to be understood that the purpose of the outer shell is not only to confine the sponge rubber in position but also to reflect inwardly any compression waves which manage to penetrate the sponge rubber.

The castings **60** and **62** are so disposed that there is left between them a narrow annular inlet **76**. Between the sponge rubber layer **73** and the inlet **76** there is disposed an annular bar **59** having, in cross section, substantially the shape of an inverted U and enclosing a pair of annular guide rings **80** between which is interposed an annular knife-edged valve member **78**. It is to be understood that the valve **78** slides vertically between the guide bars **80** which are hollowed to form flat annular inner and outer channels **82** and **84** on either side of the valve member **78**. The guide bars **80** are fitted with annular gaskets **90** and **92** which support an overhanging flange on the upper end of the valve member **78** which is recessed to receive a third gasket **93**. Bearing on the gasket **93** is a metal ring **95** held in place between two rubber rings **97**. A series of bolts **94** are threaded into the casing **35** and extend through the member **59** in position to bear upon the ring **95**. Adjacent each of the bolts **94** is a vertically disposed pin **96** resting at its lower end on the valve member **78** and extending to the exterior of the apparatus. I contemplate graduating the pins **96** (graduations not shown) in order to be able to determine whether the opening beneath the valve member **78** is uniform through-

out. The parts are so dimensioned that the valve 78 is normally raised to permit liquid to flow from the channels 82 and 84 into the chamber 58 through the inlet 76. By turning the bolts 94 in clockwise direction, the valve member 78 is depressed to close the inlet 76, the downward movement of the valve member being accommodated by compression of the rubber rings 90, 92 and 93.

The apparatus of my invention is designed to treat either a mixture of liquids or a single liquid. For example when the apparatus is to be used to emulsify oil and water, oil will be introduced into one of the channels 82 and 84 and water into the other. To this end I provide conduits 86 and 88 leading to the channels 84 and 82 respectively. The liquid or liquids to be treated may be pumped through the conduits 86 and 88 by any suitable means (not shown). At the bottom of the chamber 58 the castings 54 and 56 are so disposed that there is left between them an annular outlet 100 which is substantially wider than the inlet 76 and leads to the trough 102 previously described as secured to the bottom of the chamber and leading to a small sump tank 104 protected by a layer of sponge rubber 105 and by an outer metal shell 106. A rubber tube 108 leads from the bottom of the sump to a metal header 110 provided in one wall with a drain plug 111 and connected by means of a pipe 112 to an upper header 114 covered by a glass plate 116 and having an outlet pipe 117. Through the glass plate 116 the character of the treated liquid may be observed.

I contemplate that the apparatus of my invention will be used to a considerable extent in research laboratories as well as in commercial process. Consequently I provide means for viewing the interior of the chamber 58 from a plurality of angles. For this purpose, as will particularly appear in Fig. 11, I form in the casting 62 a boss 122 pierced by a hole 120 and in register with a boss 124 in the casing 35. The boss 124 is apertured internally and provided with a tube 126 of sponge rubber and an internally threaded bushing 142. The boss 124 receives a cap 128 within which is a cylindrical layer of sponge rubber 130 and two lenses or windows 134 separated and seated on rubber gaskets 136 and 140. The cap is apertured as shown at 132 in alignment with the bushing 142 and with the hole 120. Consequently an observer may inspect the interior of the chamber through the viewing system just described. If the operation is such that the viewing is deemed unnecessary, the cap and lenses may be removed and a solid plug threaded into the bushing 142. The threads also serve to break up and disperse compression waves and thus protect the lenses or windows. The viewing system shown in Fig. 11 is so disposed as to afford observation of the interior of the chamber in the vicinity of the outlet 100. I also provide a plurality of viewing systems 144 directed horizontally into the chamber as well as a viewing system 146 disposed so as to provide means for visually inspecting the interior of the chamber at or about the inlet 76. A light source may be introduced into one of the viewing systems in order to illuminate the chamber for an observation made through another viewing aperture.

When the generator is placed in operation, compression waves and a stream of air will flow from the nozzle 28. In view of the long tube 30 and the substantially closed chamber 38, the air leaving the nozzle 28 will very largely flow out

of the apparatus through the four mufflers. Consequently the interior of the chamber will be practically static and not subjected to blasts of air. The compression waves travel through the tube 30 and into the chamber 58 where they are reflected in the manner described in connection with Fig. 1. The liquid or liquids admitted through the inlet 76 drop through the chamber to the outlet 100 as a continuous cylindrical curtain. The flow of liquid, and consequently the thickness of depth of the curtain, is controlled by the bolts 94 operating on the valve member 78. The curtain is subjected to the action of compression waves striking it from an infinite variety of angles. By interposing between the tube 30 and the nozzle 28 a modulator of the sort disclosed in my copending application Ser. No. 636,038, filed December 19, 1945. I may vary the frequency of the compression waves very rapidly over a large range or over a selected narrow range for specific processing. Thus all of the liquid flowing through the chamber is subjected to equal treatment and there is no area or part of the curtain which receives, before it leaves the chamber, a treatment any different from that received by all the rest of the curtain.

After the device has been in operation it may be that the pressure in that portion of the chamber surrounded by the curtain will become greater than that portion lying outside the curtain and the curtain will break and scatter. In order to avoid this event I provide two by-pass tubes 150 which lead from opposite points in the tube 30 to apertured bosses formed in the casting 62. The upper ends of the tubes 150 are flanged and secured to the tube by bolts 151, and the lower ends of the tubes are flanged and secured to the bosses on the casting 62 by means of bolts 155. Each of the tubes 150 is covered by a protective layer or sheet of sponge rubber 152 and by an outer tube or casing 154. The by-pass tubes 150 serve to maintain equal pressure throughout the chamber 58 and prevent the creation of pressure differentials therein. The mufflers 48 are secured to the vertical standards 22 by straps 160. Similarly, the casing 35 has four outwardly extending projections 163 each of which cooperates with a yoke 162 secured to the standards 22 and provided with a pair of rubber rings 161 bearing against a sleeve 166 surrounding a bolt 164 secured in place by a nut 165. When the bolts 165 are tightened the chamber construction is held tightly in place, supported by the standards 22.

The theory of operation of the acoustic chamber just described was considered in conjunction with Fig. 1 and need not be repeated here. Reference to Figs. 2–6 is made to show how the chamber may be modified and the various ways to render it more suitable for different processing operations. Those skilled in the art will doubtless understand at once that additional modifications would be practical. I contemplate, for example, operating the system under pressures greater than atmospheric in order to be able to obtain greater pressure amplitudes of the compression waves or to obtain greater acceleration of the particles in the curtain. It would be necessary in such an event to maintain the liquid under increased pressure both before it reaches the chamber as well as in the sump. In some processes it may be advantageous to operate under reduced pressure. Furthermore any suitable gas may be employed in place of air. For example

the entire system may be operated in an atmosphere of hydrogen or chlorine.

Having thus disclosed my invention what I claim as new and desire to secure by Letters Patent of the United States is:

1. An acoustic chamber comprising walls forming a toroidal chamber, means for flowing material continuously through said chamber, an inlet located in the axis of the chamber for introducing compression waves therein, and a substantially conical projection disposed opposite said inlet for reflecting compression waves from said inlet toward the sides of said chamber.

2. An acoustic chamber comprising walls defining a toroidal chamber, an annular inlet disposed in the top of said chamber, an annular outlet disposed in the bottom of said chamber, valve-controlled means for admitting material to said inlet to form an annular curtain of material dropping through said chamber from the inlet to the outlet, and means for introducing compression waves into said chamber.

3. An acoustic chamber comprising walls defining a toroidal chamber, means for flowing a broad shallow stream of material through said chamber, means for introducing compression waves to said chamber, and a substantially conical reflector disposed opposite said inlet for reflecting the waves from said inlet toward said stream.

4. An acoustic chamber comprising walls defining a chamber, an annular inlet disposed in the top of said chamber, an annular valve member disposed to control said inlet, means for flowing a liquid to each side of said valve member, whereby a curtain of liquid or liquids may be passed through said chamber, and means for introducing compression waves to said chamber.

5. Compression wave-treating apparatus which comprises a tubular conduit, a muffler disposed adjacent one end of said conduit, walls forming a toroidal chamber disposed adjacent the other end of said conduit, said conduit and said chamber being in substantially axial alignment, and a by-pass conduit leading from an intermediate point in said conduit to said chamber.

6. Compression wave-treating apparatus which comprises walls forming a toroidal chamber, an inlet conduit for compression waves connected to the upper central portion of said chamber, an annular inlet disposed at the top of said chamber, a plurality of annular walls forming annular channels leading to said inlet, and a valve controlling the passage of material from said channels to said inlet.

7. Compression wave-treating apparatus which comprises a base, a plurality of vertical standards secured to said base, a compression wave generator secured to said standards, an acoustic chamber secured to said standards below said generator, means connecting said generator and said chamber, and a drain connected to the bottom of said chamber.

CAPERTON B. HORSLEY.

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