Feb. 16, 1965 S. R. RICH 3,169,508

ELASTIC WAVE GENERATOR

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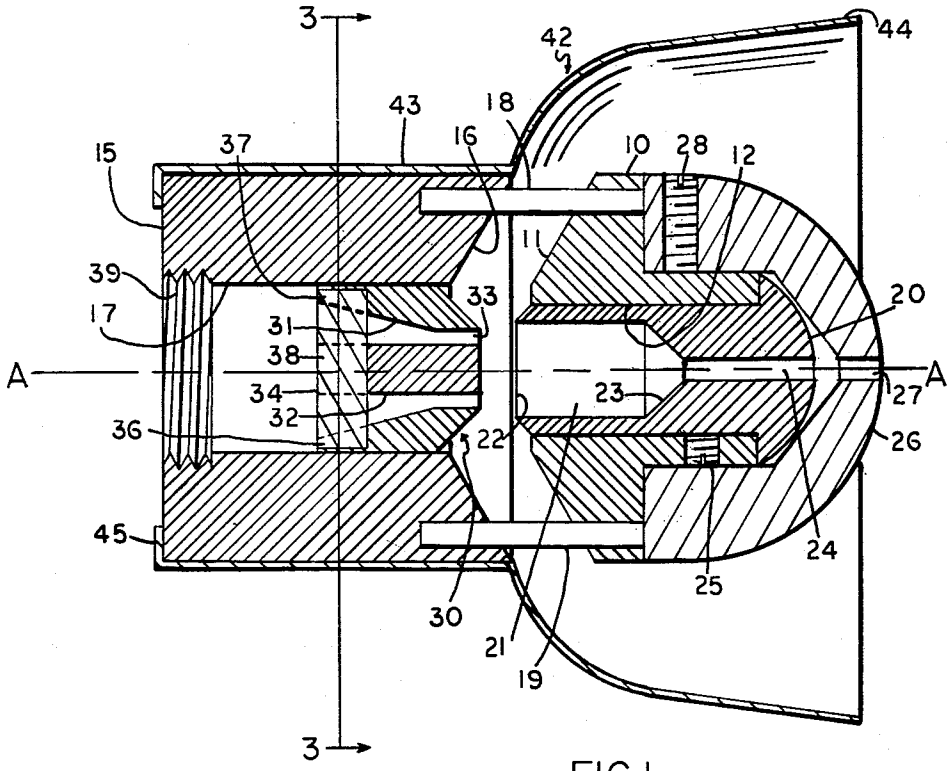


FIG. 1

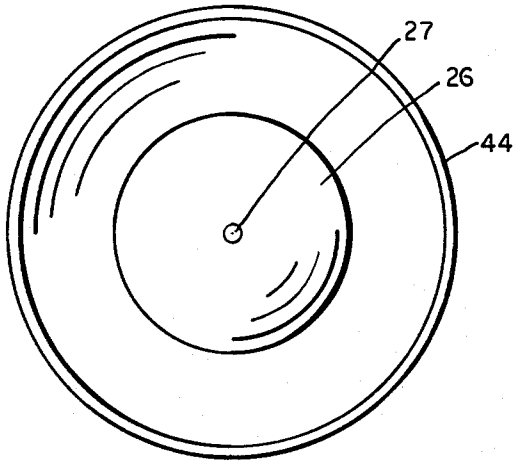


FIG. 2

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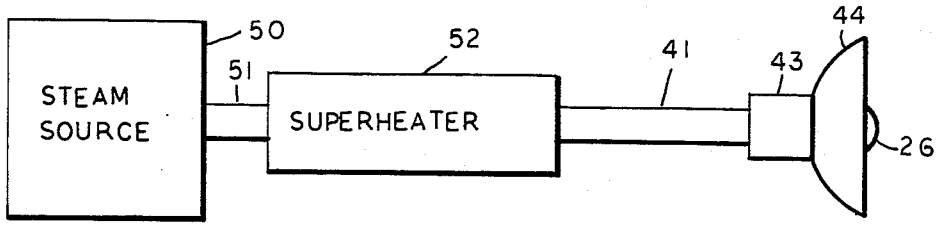


FIG. 4

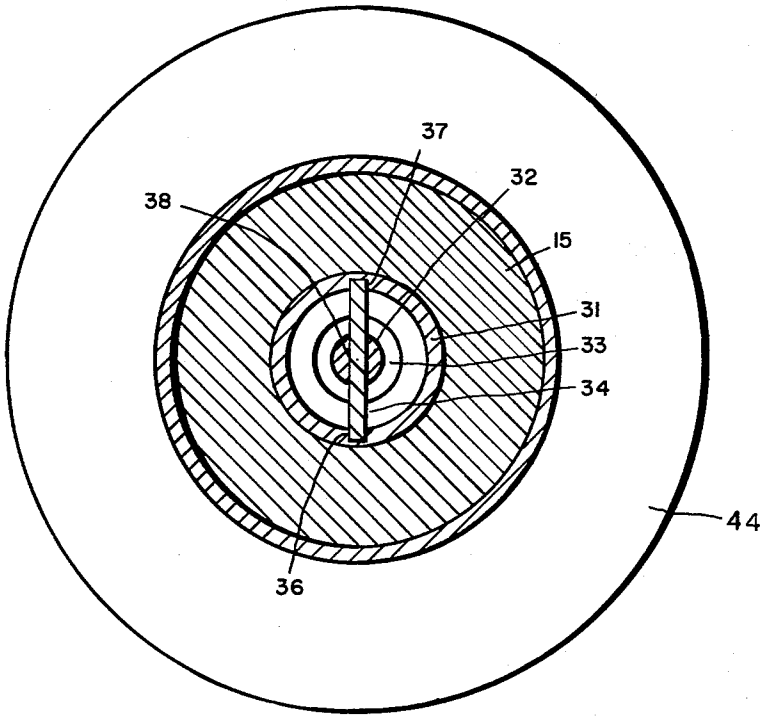


FIG. 3

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ELASTIC WAVE GENERATOR

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7 Claims. (Cl. 116—137)

This invention relates in general to apparatus for generating high intensity elastic waves in a gaseous medium for industrial purposes, and more particularly to the class of such apparatus which depends for its operation upon fluid dynamics in a structure having parts fixed relative to one another, rather than upon relative motion between parts of a structure having relatively movable parts.

Apparatus of the class to which the invention relates is generally characterized by a hollow acoustic resonator having an opening thereinto, and a gas nozzle confronting the opening for propelling a stream of gas toward the opening to generate elastic wave energy. While such apparatus is now available for continuous use over long periods of time with dry air or other gas, attempts to use a wet gas, such as saturated or wet steam, have not met with the same success because liquid collecting in the resonator interrupts the operation. The problem is not the same as is encountered with steam whistles which are intended only for intermittent operation, and can be mounted so that their resonators have their open sides or ends at the bottom, and which, moreover, are designed for audible sound generating only, and are consequently relatively large as compared with generators to which the present invention relates. The latter generators are preferably designed to operate in the superaudible regions, or in the upper audible regions (e.g., 8 kc./sec. or higher), and consequently have resonators which are quite small as compared with audible whistles. Furthermore, gas-borne elastic wave generators for industrial purposes should preferably be able to be mounted in any conceivable position or orientation, and in many cases must be mounted with their resonators open at the top. These considerations, taken together with the requirement for the ability to be operated continuously for long periods of time, have heretofore substantially prevented the use of steam as the driving gas for the gas-driven fluid-dynamic class of generators of gas-borne elastic wave energy for industrial purposes.

It is the principal object of the present invention to provide new and improved apparatus of the fluid-dynamic class for generating elastic waves in a gaseous medium, which can be operated continuously for long periods of time with steam or other wet or liquid-bearing gas, as well as with any of the dry gases heretofore useful. Another object is to provide such improved apparatus which can be made to operate in the ultrasonic frequency range. Additional objects are to provide such improved apparatus which is self-cleaning, which does not have severe dimensional tolerances, which can be operated in any position or attitude, which will be economical to build and operate, and rugged in construction, which will require little or no maintenance, which will resist contamination during operation with foams, for example, which will be easily cleaned, assembled and put into use, and which can be adapted to all types and kinds of gas-phase applications of elastic wave power.

According to the invention in one of its more general aspects, there is provided a new and improved apparatus for generating elastic waves in a gaseous medium comprising a hollow acoustic resonator having an opening thereinto, means to propel a stream of gas at said opening for generating said waves, and means comprising a

separate passage from said resonator to drain liquid from said resonator. The separate train passage is so dimensioned relative to the wavelength of elastic waves in the apparatus at the operating frequency that substantially no elastic wave energy can propagate through it, but is sufficiently large to permit the escape of liquid continuously, so that the resonator remains substantially free of liquid at all times during operation of the apparatus.

According to the invention in one of its more particular aspects, there is provided, in one embodiment, an apparatus for generating elastic waves in a gaseous medium comprising a hollow acoustic resonator having an opening thereinto, means to propel a stream of gas at said opening for generating said waves, means providing an annular passage the cross-sectional area of which progressively increases substantially with the radius thereof coupled at its smaller end to said opening for exhausting the gas of said stream and guiding said waves to an ambient region, wave director means in register with the larger end of said passage to direct said exhaust gas and waves in a common direction, and means comprising a separate passage from said resonator to drain liquid from said resonator substantially toward said common direction.

This apparatus may conveniently be realized in a circular or cylindrical form which is particularly easy to manufacture and assemble.

According to another aspect of the invention, the resonator may be realized in a separate part, which can be exchanged in a particular apparatus, so that a desired operating frequency can be chosen without changing the entire apparatus, and this part can include the drain means for the particular resonator it embodies.

According to still another aspect of the invention, there is provided a system for generating elastic waves in a gaseous medium comprising in combination, a hollow acoustic resonator having an opening thereinto, a source of steam under pressure, means connected to said source to propel a stream of steam at said opening for generating said waves, and means comprising a separate passage from said resonator to drain liquid from said resonator.

The invention is particularly useful for generating high intensity elastic wave energy in a gaseous medium, using either wet or dry gas as the source of driving energy. By the term "high intensity" is meant elastic wave energy in a gaseous medium (e.g., "sonic" or "ultrasonic" energy) at an intensity level up to about 160 db (1 watt/cm.^{2}) or more. By the term "gas" it is meant to include steam, air, nitrogen, carbon dioxide, and the like, without limitation.

The invention will now be described with reference to the accompanying drawings, wherein:

FIG. 1 is an axial section through a generator according to the invention;

FIG. 2 is an end view, on a reduced scale, of FIG. 1 as seen from the right-hand end of FIG. 1;

FIG. 3 is a cross-section on line 3—3 of FIG. 1; and

FIG. 4 is a system incorporating a generator according to FIGS. 1–3, inclusive.

Referring to FIGS. 1–3, inclusive, a first cylindrical body **10**, having a convex conical surface **11** and first axial bore **12** passing through it, confronts a second cylindrical body **15** having a concave conical surface **16** and a second axial bore **17** passing through it. These two bodies are mounted one to the other by stand-off posts **18, 19**, which may be welded or otherwise fastened in place, so that the convex and concave surfaces **11** and **16**, respectively, are spaced apart and parallel to each other, and the bores **12** and **17** are collinear on the common axial A—A of the apparatus. The apparatus of FIG. 1 is a figure of revolution about the axis A—A, as is apparent from FIGS. 2 and 3.

A cylindrical elongated resonator part **20** is located in the bore **12** of the first body **10**. The resonator part has at one end a resonator cavity **21**, of which one end **22** confronting the second body **15** is open; the other end **23** is closed except for a vent passage **24** of smaller diameter than the resonator cavity which extends from the closed end **23** through the remainder of the resonator part **20**. The resonator part **20** is held in the bore **12** by a set screw **25**. A somewhat hemispherical cover **26** is fitted over the right-hand ends of the first body **10** and the resonator part **20**, for streamlining purposes. This cover has a vent passage **27** through it in axial register with the vent passage **24** from the resonator **21**, and is held in place by a second set screw **28**.

The bore **17** in the second body **15** is fitted with a gas nozzle **30** confronting the open end **22** of the resonator cavity **21**. This nozzle comprises a hollow cylindrical part **31** which fits tightly into the bore **17**, and has its inner cross-section tapered to a smaller diameter as it approaches the resonator cavity **21**, and a solid cylindrical part **32** axially disposed within the hollow part to provide an annular gas passage **33** confronting the resonator cavity. The outer diameter of the gas passage is approximately the same as, or slightly smaller than, the diameter of the open end **22** of the resonator cavity. The nozzle parts **31** and **32** are held together by a spanner bar **34** which is fitted into two diametrically-opposite slots **36**, **37** in the end of the hollow member **31** remote from the resonator cavity **21**, and in a slot **38** at the corresponding end of the solid part **32**. The region at the end **39** of the bore **17** most remote from the first body **10** may be internally threaded, for attachment to a feed pipe **41** for gas or steam (as shown in FIG. 4).

A wave director **42**, having a cylindrical collar part **43** and an integral bell part **44** holds the second body **15** in the collar part. The base **45** of the collar part is apertured for passage of a gas feed pipe (not shown in FIG. 1). The bell part **44** has its inner surface at the collar part **43** in register with the concave surface **16** of the second body **15**, from which the bell part flares outward from the axis A—A and projects forward to envelop the first body **10** and its contents.

The generator apparatus of the present invention may be operated in a system as illustrated in FIG. 4. A source of steam **50** may be connected by a pipe **51** to a superheater **52** and thence via another pipe **41** to the generator. With a generator according to the present invention the superheater **52** is optional, since the generator can be operated with wet steam. Practical embodiments of the generator shown in FIGS. 1–3, inclusive, use ½ to ¾ pound of steam per minute at 30 to 40 p.s.i. (gauge).

In operation, the driving gas from the nozzle passage **33** cooperates with the resonator cavity **21** to produce gas-borne elastic wave energy in a known manner. Exhaust gas and the generated elastic wave energy pass through the annular passage defined by the conical walls **11** and **16** to the bell part **44** of the wave director, which directs both forward over the first body **10** and the cover **26**.

Any liquid which enters the resonator cavity **21** can readily and without delay escape via the liquid drain vent passages **24** and **27**. The bottom **23** of the resonator cavity is desirably tapered toward the vent passage **24**, to facilitate the escape of liquid. The diameter of the vent passage **24** is so small, relative to the wavelength of elastic wave energy in air at the operating frequency, typically about 0.060 inch at frequencies up to about 25 kc./sec., for example, that the elastic wave energy cannot propagate through the vent passage, while liquid and gas can escape through it. The vent passage may be regarded as a vent which is so small relative to the bore of the resonator cavity **21** that it functions as an acoustic inductance of which the reactance, $j\omega M$, is large compared with the acoustic impedance of the resonator cavity. In this expression,

"ω"$=2\pi f$;
"M"=mass of air (or other gas) in the vent column; and
"f"=the operating frequency.

The length of the vent passage **24** does not appear to be critical; however, it can readily be made to be $\lambda/4$ relative to the wavelength of the elastic wave energy being generated, if desired.

It will be recognize that liquid will escape via the vent passage **24** regardless of the orientation or attitude of the generator. If its axis A—A is vertical, liquid will obviously pour out of the resonator cavity **21**. If the axis A—A is horizontal, liquid will be blown out by gas from the nozzle **30**. This will not interfere with or degrade the elastic-wave generator function of the apparatus. Further, there is no need to mate the meeting surfaces of the resonator part **20** and the cover **26** (when the latter is used); since liquid in the space between them has no effect on the generation of elastic wave energy. Liquid in that space readily escapes in any event, due either to gravity or to gas escaping through the passages **24** and **27**.

Apparatus according to the invention has been successfully used repeatedly on an industrial scale with steam, both wet and dry, air under pressure and contaminated with oil, and other liquid-bearing gases.

As is well-known, the frequency of operation is determined essentially by the depth of the resonator cavity **21**. Typical depths for frequencies in the range 8,000 to 24,000 cycles per second, in a cavity ¼ inch in diameter, are:

(*a*) for frequencies of the order of 20 kc./sec.: ⅛ inch
(*b*) for frequencies of the order of 12 kc./sec.: 5/16 inch

These depths are measured to the beginning of the taper in the bottom **23**. As has been indicated above, the diameter of the vent passage **24** may typically be about 0.60 inch.

The apparatus may be made of any suitable material. Stainless steel of the 300 series is preferred.

The embodiments of the invention which have been illustrated and described herein are but a few illustrations of the invention. Other embodiments and modifications will occur to those skilled in the art. No attempt has been made to illustrate all possible embodiments of the invention, but rather only to illustrate its principles and the best manner presently known to practice it. Therefore, while certain specific embodiments have been described as illustrative of the invention, such other forms as would occur to one skilled in this art on a reading of the foregoing specification are also within the spirit and scope of the invention, and it is intended that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

What is claimed is:

1. In apparatus for generating elastic waves in a gaseous medium with an acoustic resonator cavity, an opening at one end of said cavity and means to propel a stream of gas at said opening for generating said waves, the improvement comprising, a conically shaped wall means in said cavity opposite said opening, said wall means providing a vent column of generally uniform cross-section smaller than the cross-section of said cavity and extending away from the wall means in said cavity opposite said opening for draining liquid from said resonator, said cross-section of said vent column being so small that said vent column functions as an acoustic inductance, with respect to said waves, of which the reactance $j\omega M$ is large compared with the acoustic impedance of said resonator cavity, where

"ω"$=2\pi f$;
"f"=the frequency of said waves; and
"M"=mass of gas in said vent column.

2. In apparatus for generating elastic waves in a gaseous medium with an acoustic resonator cavity, an opening at one end of said cavity and means to propel a stream of gas at said opening for generating said waves, the improvement comprising, wall means in said cavity providing a passage extending in the direction away from said opening and tapering generally from said resonator size at one end to a smaller size at the other end more remote from said opening, and means providing a vent column of generally uniform cross-section extending away from said other end of said passage for draining liquid from said resonator, said cross-section of said vent column being so small that said vent column functions as an acoustic inductance, with respect to said waves, of which the reactance $j\omega M$ is large compared with the acoustic impedance of said resonator cavity, where

"ω"$=2\pi f$;
"f"=the frequency of said waves; and
"M"=mass of gas in said vent column.

3. Apparatus according to claim 1 in which said cavity is cylindrical, said opening is at one end of the cylinder and said vent column is at the other end of said cylinder and extends straight on the cylinder axis away from said resonator.

4. Apparatus according to claim 2 in which said cavity is cylindrical, said opening is at one end of the cylinder and said vent column is at the other end of said cylinder and extends straight on the cylinder axis away from said resonator.

5. Apparatus according to claim 3 in which said means to propel a stream of gas at said opening provides an annular stream of gas the outer diameter of which is not larger than the diameter of said resonator.

6. Apparatus according to claim 1 in combination with a source of steam under pressure connected to said means to propel a stream of gas at said opening.

7. Apparatus according to claim 1 in which said source of steam includes a steam superheater.

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