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ACOUSTIC GENERATOR OF THE SPARK DISCHARGE TYPE

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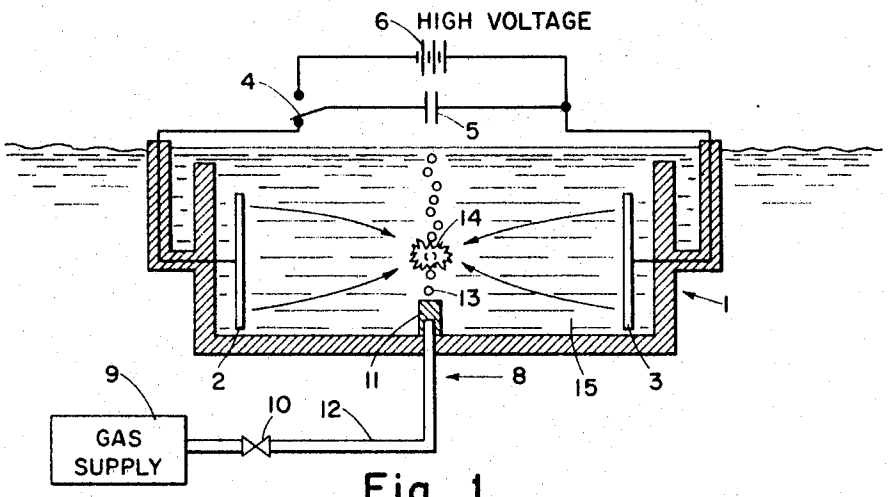


Fig. 1

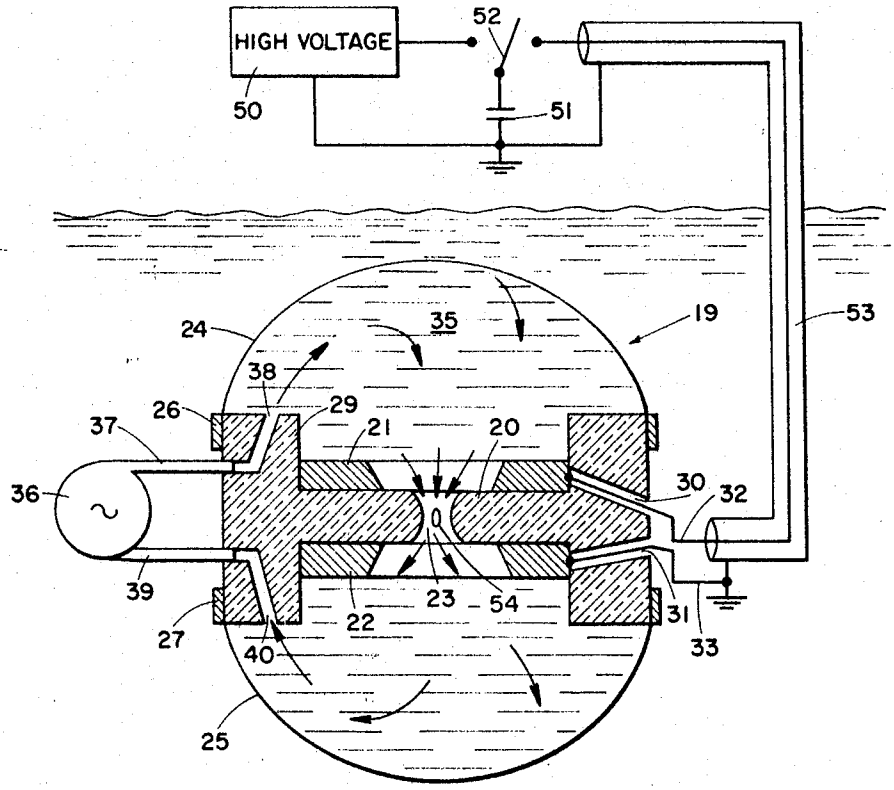


Fig. 2

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ACOUSTIC GENERATOR OF THE SPARK DISCHARGE TYPE

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ABSTRACT OF THE DISCLOSURE

The present invention relates generally to impulse sound generators of the type which employ as the sound producing mechanism an electrical discharge which takes place within a conducting electrolyte. To minimize wear, a gas bubble or bubble screen is introduced into the electrical field at a location remote from the electrical and mechanical components. Ignition of the electrical discharge takes place across the bubble and never reaches the electrodes.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

Impulse sound generators have been successfully employed in the past in geophysical exploration and sonar systems because of their ability to provide improved classification of the nature of the reflecting objects. In this class of acoustic apparatus, the sound pulse may be generated by high explosives, underwater electrical sparks or electromechanical apparatus. Each of these arrangements, however, has associated disadvantages. High explosives, for example, present a handling and safety problem, while mehanical devices are deteriorated by cavitational pitting and electrical spark devices experience erosion of their electrodes as a result of repeated discharges. The latter phenomenon seriously shortens the operational lifetime of the generator and additionally degrades its ability to generate a reproducible output pulse.

In applicant's copending application, Ser. No. 637,033, filed Apr. 27, 1967, now Patent No. 3,403,375, there is disclosed an arrangement for solving the problem of electrode deterioration in spark generators. More specifically, the acoustic generator utilizes electrodes which have a sufficiently large area so that the current density at their surfaces is below the sparking level. Between the electrodes is a dielectric barrier having a constricted aperture formed therein. When the generator is excited, the discharge occurs through the aperture between volumes of the electrolyte on opposite sides of the barrier. The electrolyte consequently acts as the electrodes and, although there may be some "erosion" of these electrodes, each element is, in effect, continuously replenished from the readily available electrolyte supply.

A critical element of the above generator is the dielectric barrier and the shape of the aperture formed therein. This aperture is configured so as to result in a virtual discontinuity in the rate of power dissipation in the spark at an instant in time near the midpoint of the discharge. While this apparatus does not suffer from electrode erosion, the problem of material failure is to some extent transferred from the electrodes to the dielectric plate. It is, therefore, desirable to remove the ignition point of the discharge from the immediate vicinity of the aperture in the dielectric barrier.

It is accordingly a primary object of the present invention to provide an arrangement for controlling the point of ignition of an electrical discharge used as the sound producing mechanism in an acoustic generator.

Another object of the present invention is to provide an acoustic generator of the spark discharge type where the point of ignition of the spark may be controlled so as to be removed from the electrical and mechanical components of the generator.

A still further object of the present invention is to provide an acoustic generator of the electrical discharge type wherein the electro-acoustic efficiency is increased by means of a gas bubble or gas bubble screen introduced into the electrical field.

Briefly and in somewhat general terms, the above objects of invention are realized by making use of the fact that when a gas bubble is introduced between two energized electrodes which are immersed in a conducting electrolyte, the electrical discharge, when it occurs, takes place across the gas discontinuity. The ignition of the electrical discharge at the gas bubble is the result of several factors working in consort. For example, the dielectric strength of most gases is much less than that of most conducting electrolytes. Consequently, the application of an increasing voltage gradient to a mixture of gas and water will result in an electrical breakdown in the gas. Moreover, prior to this breakdown, the specific resistance of the air is significantly greater than the water. Since the external electrical circuit exposed to the voltage gradient is made up of the electrode-electrolyte-gas-electrolyte-electrode, in series, essentially all of the voltage will immediately appear across the poorly conducting gas. The third effect which contributes to the ignition of the electrical discharge at the bubble is due to the fact that the gas-electrolyte interface of a three-dimensional gas bubble which is exposed to an electric field crosses equipotential lines and presents a breakdown surface which will fail at voltage gradients significantly less than the breakdown strength for either medium.

Not only does the present invention overcome the material erosion problem encountered in prior art devices but, additionally, it may result in an increase in the electro-acoustic efficiency of the generator. One reason for this is that the electrical discharge starts from a preformed bubble. Hence, the electrical energy necessary to expand the electrical discharge from a nucleus to this bubble size need not be expended. Also, when the bubble breaks down and ionization results, there is a sudden increase in the rate of power consumption, and this generates large acoustic pressures.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings wherein:

FIG. 1 is a schematic diagram illustrating the principle of operation of the present invention; and

FIG. 2 shows the application of the gas bubble feature to an acoustic generator of the type employing an apertured dielectric barrier between the electrodes.

The principle of operation of the present invention may perhaps best be understood by referring now to the schematic showing of FIG. 1. It will be seen that the simplified acoustic generator includes an open-ended housing **1**, made of an electrically nonconducting material and adapted to support a pair of aligned, metallic electrodes **2** and **3**. These electrodes may be energized by a suitable control switch **4**. In the position shown, this switch connects the electrodes across a capacitor bank **5**. In its alternative upper position, it connects this capacitor bank across a high voltage, DC charging source **6**. The apparatus so far described is, of course, conventional. However, the present invention adds to it a gas bubble generator **8** which comprises a gas supply **9**, control valve **10** and bubble forming device **11**. It will be appreciated that when valve **10** is opened gas flows from supply source **9** through tube **12** into the bubble-form-

ing device 11 and a bubble or screen of bubbles, such as 13 and 14, appear and travel upwardly, in the illustration shown, through the conducting electrolyte 15.

After valve 10 is operated, switch 4 may be moved to the position shown. With capacitor bank 5 previously charged, the voltage available across electrodes 2 and 3 develops a high electric field within the electrolyte solution. If the electrical characteristics of the external circuit between electrodes 2 and 3 is examined, it will be seen that this circuit includes the series combination of a relatively low impedance, consisting of the volume of electrolyte from one of the electrodes to the electrolyte-bubble interface, a relatively high impedance due to the gas medium within the bubble and a second relatively low impedance consisting of the other volume of electrolyte between the electrolyte gas interface of the bubble and the second electrode. Because of this impedance relationship, a large proportion of the high voltage immediately appears across the gas bubble. Since the dielectric strength of the gas is less than that of most conducting electrolytes and due to the configuration of the gas bubble itself, the gas bubble serves as the origin of the resulting electrical spark discharge.

Depending upon the size and separation and spacing of the electrodes, this discharge will either be completely confined within the electrolyte fluid or expand until it bridges the electrodes. If the area of the electrodes is made sufficiently large so that the current density at their surfaces is below the point of sparking, this discharge will occur completely within the electrolyte and not cause electrode deterioration. Since the gas bubble is introduced at a location remote from the other mechanical components of the generator, the discharge likewise does not cause mechanical breakdown of the apparatus.

Besides prolonging the electrical and mechanical life of the generator, the bubble feature as alluded to hereinbefore has the further potential of increasing its electroacoustic efficiency. The reason for this is that the presence within the electric field of the gas discontinuity eliminates the expenditure of electrical energy to expand the electrical discharge from microbubble size to the size represented by the injected bubble. In other words, by having a bubble available, the system, so to speak, always starts from a finite discharge.

In applicant's copending patent application, the electrical discharge takes place between volumes of electrolyte solution on opposite sides of a dielectric barrier fabricated with a so-called "discontinuous aperture" that has a bell-shaped configuration. The relatively high impedance of the aperture results in a large proportion of the high voltage being initially impressed across this portion of the external circuit. Hence, the electrical discharge takes place through the aperture remote from the electrodes. While this mode of operation does successfully eliminate electrode erosion, it does unfortunately impose severe requirements from the mechanical and electrical properties of the dielectric barrier. These barriers therefore have been formed from plastic-based composites and refractory ceramics. Even so, the lifetime of the acoustic generator is still, in most cases, determined by the cracking or gradual thermal or mechanical erosion of this barrier. The bubble feature of the present invention may be employed to minimize this problem by again removing the point of ignition of the electrical discharge from the lip of the discontinuous aperture.

Referring now to FIG. 2 of the drawing which illustrates one preferred embodiment of the invention, the spark discharge sound generator 19 includes a dielectric barrier or spacer 20 which separates two ring electrodes 21 and 22. Barrier 20 has a central aperture 23 formed therethrough. This aperture is constricted at its midpoint, and this restriction, as will be seen hereinafter, results in the development of air bubbles at this site when the conducting electrolyte flows through this passageway.

Two relatively thin dielectric housings or boots 24 and 25 of generally hemispherical shape are sealed to a rim extension 29 of dielectric spacer 20 by means of clamps 26 and 27. Boots 24 and 25 form an enclosure for the conducting electrolyte 35 which completely fills the interior of spark discharge generator 19. These boots should be made of a material that is transparent to acoustic energy so that the sound pulses generated in response to the triggering of the apparatus may pass into the fluid medium with a minimum of attenuation.

Rim extension 29 has a pair of passageways 30 and 31 formed therein for accommodating conductors 32 and 33 which serve as the electrical energization means for the ring electrodes. These conductors may be secured to the electrodes in any suitable manner, and passageways 30 and 31 thereafter may be filled with any appropriate sealing material to electrically isolate the electrodes from the surrounding field medium.

In order to form a gas bubble at the waist of aperture 23, that is, at its narrowest dimension, electrolyte 35 is saturated with a dissolved gas, such as air, and this fluid, in the illustration shown, is forced downwardly through the aperture by means of pump 36. This pump has its output and input sides 37 and 39 respectively connected to inlet and outlet passageways 38 and 40 formed in the rim extension of dielectric spacer 20. When pump 36 is operated, the conducting electrolyte will therefore circulate through the system, following the path generally indicated by the arrows.

If aperture 23 is properly configured, the velocity of flow of the electrolyte will be greatest at its waist portion. Thus, the pressure at this location will be a minimum. This reduced pressure and the saturated or nearly saturated condition of the electrolyte will cause a succession of gas bubbles to appear at the midpoint of the aperture, and these bubbles will exist in a quasi steady-state condition.

Associated with sound generator 19 is a suitable electrical control circuit which includes high voltage DC source 50, capacitor bank 51, control switch 52 and coaxial line 53. Switch 52, like its counterpart in FIG. 1, permits capacitor bank 51 to be charged when it is moved to the left as viewed in this figure. In its alternate position, it connects capacitor bank 51 to coaxial line 53, thereby energizing ring electrodes 21 and 22 and causing activation of the sound generator.

If capacitor bank 51 is connected to coaxial line 53 when charged and if a bubble 54 is present at the narrow throat of aperture 23, then the greatest voltage gradient in the system will appear in the vicinity of the aperture midpoint and electrical breakdown of the gas bubble will occur. Once the spark discharge has been initiated at this site, it will tend to grow about the point of ignition. Thus, the electrical discharge in its early stages takes place at a position remote from the surface of dielectric barrier 20. Consequently, the nascent spark, which may be locally intense, will be less likely to cause erosion of this structure.

A condition of least pressure in the center of aperture 23 exists as a result of lower fluid velocities near the aperture wall due to viscous drag exerted upon the fluid by the wall of the aperture. In opposition to this effect (a) asperities on the walls of the aperture present gas nucleation points, and (b) microbubbles contained in the fluid near the wall flow less rapidly and are exposed therefore to the region of reduced pressure for a longer time so that they are capable of growth to large size. As a result of these conflicting effects, it will probably be necessary to induce some circular flow, or vorticity, to the electrolyte 35 in order to increase the near-wall pressure and cause bubble formation in the aperture center. Vorticity may be induced by horizontally offsetting the intake and outlet ports of passageways 38 and 40 so as to create a circular flow in the plane perpendicular to the longitudinal axis of aperture 23. An alternative method of inducing this vorticity is to include circulation-inducing

structural elements on the upper and lower surfaces of electrodes **21** and **22** or on any other portions of the apparatus. These elements may be small grooves or fences which are canted from the radial direction.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. An impulse sound generator of the electrical discharge type comprising, in combination,

a pair of metallic electrodes immersed in a conducting electrolyte;

a dielectric barrier disposed between said electrodes;

said dielectric barrier having an aperture formed therethrough;

said aperture having a constriction at its midpoint;

means for forming gas bubbles at said midpoint;

and means for applying a high DC voltage across said electrodes whereby electrical breakdown of said gas bubbles occurs, this breakdown serving as the ignition point of the resulting electrical discharge.

2. An impulse sound generator of the spark discharge type comprising, in combination,

first and second ring electrodes, said ring electrodes being in a spaced coaxial relationship;

an insulating barrier positioned between said electrodes and having an aperture formed therein which is positioned along the central axis of said electrodes;

said aperture having a narrow throat portion;

a dielectric housing enclosing said electrodes;

a conducting electrolyte saturated with a dissolved gas filling the interior of said housing;

means for forcing said conducting electrolyte through said aperture at a velocity such that the reduced pressure existing at said narrow throat portion causes gas bubbles to form at this location;

and means for applying a high DC voltage across said ring electrodes whereby electrical breakdown of said gas bubbles takes place, this electrical breakdown serving as the ignition means for the spark discharge.

3. In an arrangement as defined in claim **2** wherein said housing is made of an electrically nonconducting material which is transparent to acoustic energy whereby the acoustic pulse developed by said spark discharge propagates therethrough into the surrounding fluid medium with little attenuation.

4. In an arrangement as defined in claim **2** wherein the surface area of said electrodes that is in contact with said conducting electrolyte is sufficiently large so that the current density at said electrodes when said high DC voltage is applied thereacross is below the sparking level.

5. In an impulse sound generator of the spark discharge type, the combination of

a dielectric spacer having an aperture formed therethrough;

a pair of ring electrodes positioned on opposite sides of said dielectric spacer and symmetrically positioned with respect to the aperture formed in said dielectric spacer;

said aperture being small compared with the inner diameter of said ring electrodes and having a restricted throat portion;

means for enclosing said ring electrodes in a fluidtight compartment;

a conducting electrolyte filling the interior of said compartment;

means for forming a gas bubble at the throat portion of said aperture;

and means for applying a high DC voltage across said ring electrodes whereby electrical breakdown of said gas bubble occurs, this breakdown serving as the ignition means for the electrical discharge which subsequently develops whereby this electrical discharge takes place at a location remote from any surface of said dielectric spacer.

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U.S. Cl. X.R.

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