

[54] **FLUID ACTUATED ELECTRIC
GENERATOR**

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[51] Int. Cl. **H01v 7/00**

[58] Field of Search **322/3; 310/8.1, 8.2, 8.5, 8.6,
310/8.8; 137/81.5; 102/70.2 G**

[56] **References Cited**

UNITED STATES PATENTS

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[57] **ABSTRACT**

A fluid actuated electric generator embodying an edge-tone acoustic oscillator involving a jet of fluid directed upon a knife-edge from a nozzle in communication with a source of fluid under pressure to establish a source of acoustic energy, a resonant cavity for stabilizing the acoustic energy, a coupling device including a second resonant cavity proximate to the source of acoustic energy for coupling the acoustic energy to a transducer responsive to acoustic actuation to produce electrical energy, and an acoustic opaque exhaust arrangement for dissipating exhaust fluid with minimal acoustic dissipation.

12 Claims, 2 Drawing Figures

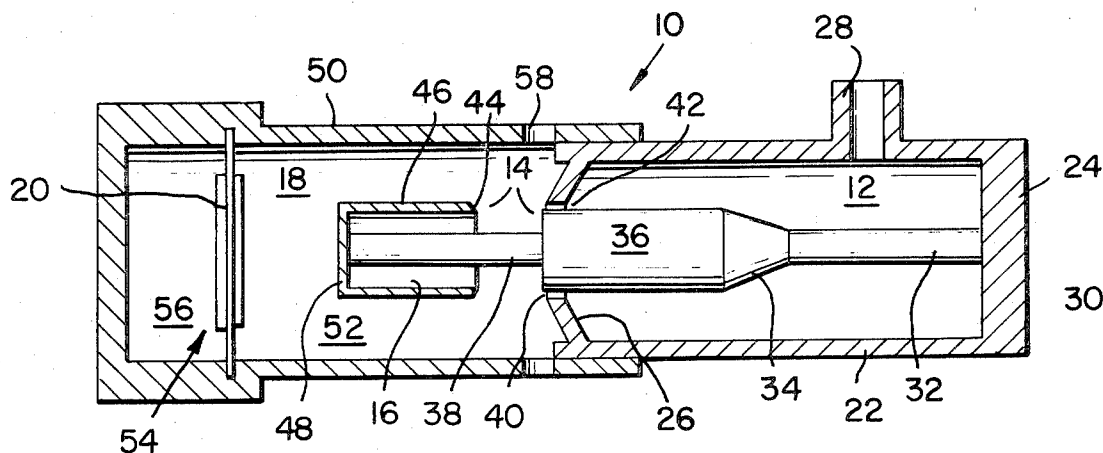


Fig. 1.

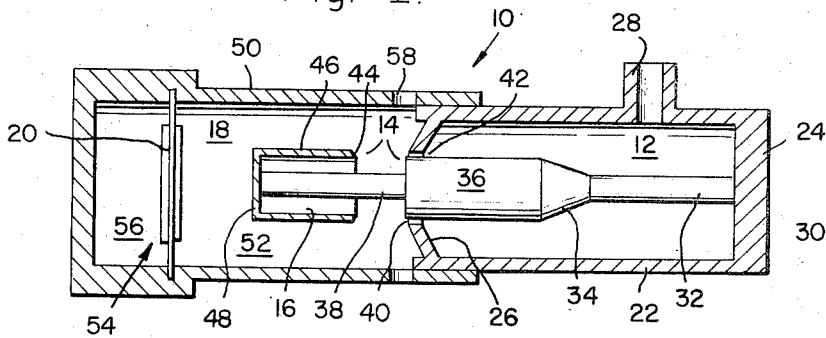
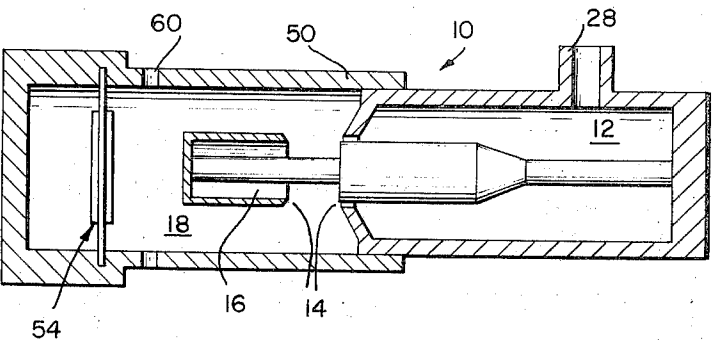


Fig. 2.



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FLUID ACTUATED ELECTRIC GENERATOR

BACKGROUND OF THE INVENTION

This invention relates to an acoustically actuated electric generator and more particularly to an acoustically actuated electric generator incorporating separate acoustic stabilization and acoustic coupling arrangements.

As stated in Applicant's copending application, Ser. No. 529,895, filed Nov. 10, 1965, entitled "Fluid Operated Electric Generator," fluid actuated electric generators find wider application and provide more reliable operation than other sources of electrical energy, such as electrochemical storage batteries or reserve cells, thermal batteries, radioactive batteries and rotary electric generators when used in conjunction with vehicles and devices, such as projectiles, capable of moving through the earth's atmosphere. The desirability of fluid actuated electric generators is predicated upon their immunity to deterioration when subjected to extremely long inactive storage periods, and their resistance to shock damage and dependability of operation upon the launching of the vehicles or projectiles in which they are embodied.

When it is required to incorporate an acoustic actuated electric generator in a vehicle or projectile affording restricted structural space, the stability of the acoustic oscillator forming a part of the generator is adversely affected due to the spatial limitations imposed upon the location of fluid exhaust ports. Additionally, in such a restricted spatial involvement, the transformation of acoustic energy to mechanical to electrical transducers embodied in such generators is tremendously interfered with when conventional exhaust configurations and locations are utilized.

SUMMARY OF THE INVENTION

Briefly described, the improved fluid actuated electric generator of the present invention comprises an edge-tone acoustic oscillator embodying a fluid nozzle directing a jet of fluid upon a knife-edge surface to produce acoustic oscillations and a resonant cavity proximate to the knife-edge surface for stabilization of the acoustic oscillations, a second resonant cavity coupling the stabilized acoustic oscillations to a piezoelectric element responsive to the acoustic oscillations to produce electric energy, and in one modification to be presented an acoustically opaque exhaust port arrangement for discharging the spent fluid.

Accordingly, it is an object of the present invention to provide an improved type of fluid actuated electric generator including a novel arrangement for coupling acoustic energy to a transducer.

A further object of the present invention is to provide an improved type of fluid actuated electric generator incorporating separate acoustic stabilization and acoustic coupling arrangements.

Another object of the present invention is to provide an improved type of fluid operated piezoelectric power source including a novel arrangement of a plurality of resonant cavities positioned co-axially with respect to the nozzle of an acoustic oscillator.

A still further object of the present invention is the provision of a fluid operated power source including a transducer responsive to acoustic energy to produce electric energy and an acoustically opaque exhaust arrangement to discharge the spent fluid.

These and other objects and advantages of this invention will become apparent from the following description taken in accordance with the specification and considered in conjunction with the accompanying drawings throughout which like reference characters represent like parts and in which:

FIG. 1 is a diagrammatical representation in cross section of one embodiment of a fluid actuated generator constructed in accordance with the principles of the present invention; and

FIG. 2 is a diagrammatical representation of a cross section of another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiment of the improved fluid actuated generator 10 depicted in FIG. 1, is composed of five primary elements arranged to form a unitary tubular structure. Basically, these five elements are formed by an input plenum or pressure chamber 12, an acoustic edge-tone oscillator 14, an acoustic oscillation stabilizing resonant cavity 16, an acoustic coupling or matching Helmholtz resonator cavity 18 and a mechanical-to-electrical transducer element 20.

Structurally, the plenum chamber 12 is formed by a hollow tubular housing 22 provided with a closed end wall 24, a contracted end wall 26 and a fluid entrance duct 28 disposed in the side wall of the tubular housing. Internally of the plenum, a coaxially disposed central core member 30 extends from the closed end wall 24 having a first section 32 of small diameter, a tapered section 34 joining to a second section 36 of large diameter and an additional section 38 of small diameter which protrudes beyond the contracted end 26 of the plenum chamber. The adjacent surfaces of the contracted end 26 and the confronting outer surface of the large diameter section 36 of the core member define an annular discharge orifice 40 of a nozzle 42 forming a part of the acoustic edge-tone oscillator 14.

The remaining structure of the edge-tone oscillator 14 is formed by an annular knife-edge surface 44 positioned in uniform spaced relation of the nozzle orifice 40. As may be seen in FIG. 1, the knife-edge surface 44 is an integral open end surface of a tubular housing 46 coaxially suspended from the core section 38 by an end wall 48 which together with the tubular housing 46 forms the stabilizing resonant cavity 16.

The outer wall of the Helmholtz resonator cavity 18 is formed by a closed end tubular member 50 which is telescopically joined to the plenum housing 22 and extends to the left, as viewed in FIGS. 1 and 2. The Helmholtz resonator 18 is further defined by the coaxial annular space 52 between tubular wall member 50 and the tubular housing 46 of the stabilizing cavity 16, the end wall 48 of the stabilizing cavity 16 and an end surface which is formed by a multi-disc piezoelectric element 54 which constitutes the transducer element 20. The closed space or chamber 56 between the piezoelectric disc 54 and the end wall of the tubular member 50 defines a volume of entrapped fluid, for example, air, to provide containment of the energy emanating from the rear face of the piezoelectric disc, known as a back-wave, without dissipation or amplification of its energy content to thereby eliminate attenuation of the vibratory energy acoustically imparted to the disc from the Helmholtz resonator. Additionally, the space 56

serves to isolate the piezoelectric disc from extraneous vibratory energy emanating from adjacent areas that may disrupt or interfere with the normal function of the disc.

Functionally, the plenum chamber 12 serves to connect, filter, cool and regulate the input fluid or air entering the entrance duct 28. The particular configuration of the entrance duct 28 and the plenum chamber 12 is dependent upon the velocity and configuration of the particular vehicle or device utilizing the generator 10. As described in Applicant's previously cited copending application, the source of fluid normally encountered is the ram air associated with the vehicle or projectile utilizing the generator 10 as it moves through the earth's atmosphere. While this particular source of operated fluid in combination with the plenum chamber has been shown and described, it should be understood that this is for illustration only since other fluids and sources thereof may be used without varying from the scope of this invention. As an example, the fluid may be derived from a pneumatic acoustic system having a portion thereof connected to the entrance duct 28.

With reference to Applicant's above mentioned copending application, the acoustic edge-tone oscillator 14 is dependent in its operation, upon a jet of fluid derived from the plenum chamber 12 issuing through the nozzle orifice 40 to impinge upon the knife-edge surface 44 thereby establishing a source of acoustic oscillations. The theory of operation of such an edge-tone oscillator is set forth in the specification of Applicant's copending application starting with the last paragraph of page 5 through line 21, page 7.

Stabilization of the acoustic oscillations generated by the knife-edge surface 44 is affected by the resonant cavity 16. This stabilization is attempted by making the acoustic depth of the cavity 16 equal to $\frac{1}{4}$ the wavelength of the operating frequency of the edge-tone oscillator 14. The physical depth of the cavity 16 does not correspond to the acoustic depth. This is because the wavelength depth of the resonant fluid or plasma in such a resonator will extend an appreciable distance beyond the entrance of the cavity.

It is to be noted, in the case of the generator embodiment shown in FIG. 1 that the resonant cavity 16 serves only the function of stabilizing the acoustic oscillations generated by the knife-edge surface and does not perform acoustic coupling of the acoustic oscillations to the piezoelectric disc 54. This latter function is performed by the Helmholtz resonator cavity 18.

The coupling action of the Helmholtz resonator 18 is highly efficient because in such a resonator the maximum acoustical pressure occurs within and throughout the body chamber which in this case is in direct communication with the conversion surface of the piezoelectric element 54.

The embodiment of the fluid actuated electric generator shown in FIG. 1 further includes a plurality of circumferentially spaced exhaust ports 58 disposed in the Helmholtz resonator 14.

The primary consideration in selecting the configuration of the piezoelectric disc 54 is a need to minimize the impedance mismatch with the air column of the Helmholtz resonator 18. This mismatch is reduced by using a piezoelectric element that has a high compliance, e.g., high flexibility. A laminated disc form provides the necessary compliance. As shown in FIG. 1, a

laminated element formed of two piezoelectric ceramic discs is one type of piezoelectric element that has proved satisfactory, however, this invention is not so limited. Such an element may be fabricated by bonding one or two piezoelectric discs on a brass or beryllium copper disc with a silver filled epoxy cement.

The choice of the piezoelectric material requires several interrelated parameters, among these being the electro mechanical coupling coefficient, dielectric constant, piezoelectric constant, frequency constant, mechanical Q, and the depolarization level. Each of these parameters has an effect on the selection of the proper material and it has been found that several lead zirconate-titanate crystal materials meet these parameter requirements. Such commercial materials are Type HST-41, manufactured by Gulton Industries, Inc., Metuchen, New Jersey, and Clevite Type PZT-5, manufactured by Piezoelectric Division of Clevite Corporation, Bedford, Ohio.

In some applications, dimensional restrictions may be such that sonic reflections from the exhaust ports disturbs the performance of the edge-tone oscillator. In such a case, the embodiment of the invention of FIG. 2 offers improvement. In this FIGURE the exhaust ports 60 have been opened through the housing 50 in circumferentially spaced positions adjacent the piezoelectric disc 54. In this case, the exhaust ports are sized to be small compared to a wavelength in operating frequency whereby the holes appear to be sufficiently opaque to acoustic energy. If a sufficient number of such ports are provided to freely pass the spent fluid, the exhaust ports perform as a filter permitting escape of acoustically spent fluid with minimal escape of acoustic energy. Accordingly, optimum vibration and, hence, electrical output, of the piezoelectric disc is obtained since the spent fluid does not act to reduce or block entrance of acoustic energy from the acoustic generator into the Helmholtz resonator.

By virtue of the above described construction of the embodiment of FIGS. 1 and 2, the functions of stabilization and acoustic impedance transformation are made separate. This arrangement minimizes the effects of electrical loads on the stability of performance of the disclosed generators. Additionally, the modification shown in FIG. 2 further reduces the affects of sonic reflections on the stability of operation of the edge-tone oscillator. It is contemplated that within the scope of the invention, an electrical resonant circuit (not shown) may be coupled to the piezoelectric element 20 for resonating the capacitance of piezoelectric element 20 and enhancing the electrical signals generated by element 20. Such a circuit coupled to the piezoelectric element is shown and described in my above-mentioned copending application Ser. No. 529,895.

While preferred embodiments of this invention have been illustrated and described, it will be appreciated by those skilled in the art that variations of these embodiments both as to detail and as to organization of such detail may be made without departing from the spirit and scope thereof. Accordingly, it is intended that the foregoing disclosure of the preferred embodiments will be considered only as illustrative of the principles of the invention as described herein and will not be considered in a limiting sense.

What is claimed is:

1. A fluid actuated electric generator comprising:
a fluid coupling means for conveying a flow of fluid;

an acoustic oscillator means including a nozzle communicating with said coupling means, a cooperating element disposed in spaced relation thereto for producing acoustic oscillations, and an acoustic oscillation stabilizer for stabilizing said oscillations; acoustic coupling means including a first resonant cavity resonantly responsive to certain frequencies of said acoustic oscillations; and transducer means coacting with said resonant cavity and responsive to acoustic oscillations for producing electrical energy.

2. The fluid actuated electric generator of claim 1 which further includes:
a substantially acoustically opaque exhaust means for said first cavity.

3. The fluid actuated electric generator of claim 1 wherein:
said acoustic oscillation stabilizer comprises a second resonant cavity.

4. The fluid actuated electric generator of claim 3 wherein:
said cooperating element of said acoustic oscillator means comprises a knife-edge.

5. The fluid actuated electric generator of claim 4 wherein:
said nozzle and said knife-edge are annular in shape and are coaxially disposed in confronted relationship along a central axis of said electric generator.

6. The fluid actuated electric generator of claim 5 wherein:
said second resonant cavity for stabilizing said acoustic oscillations is coaxially disposed on said central axis; and
said annular knife-edge is contiguous with said second resonant cavity.

7. The fluid actuated electric generator of claim 6 wherein:
said fluid coupling means and said acoustic coupling means are coaxially disposed on said central axis.

8. The fluid actuated electric generator of claim 7 wherein:
said transducer means comprises a piezoelectric ele-

ment; and
a substantially acoustically opaque exhaust means for said first cavity.

9. The fluid actuated electric generator of claim 8 wherein:
said transducer means comprises a piezoelectric disc cooperating with said first resonant cavity of said acoustic coupling means to close one end thereof.

10. The fluid actuated electric generator of claim 9 wherein:
said acoustic coupling means is coaxially disposed along said central axis in spaced relation from said acoustic oscillator means.

11. A source of electrical power comprising:
an acoustic oscillator including an annular nozzle having a central axis and a first resonant cavity positioned coaxially with said central axis having an annular knife-edge spaced a predetermined distance from said nozzle;
a fluid coupling chamber comprising means for regulating to reduce turbulence and cooling fluid within said chamber for conveying a flow of fluid to said nozzle for producing a jet of fluid from said nozzle directed to impinge upon said knife-edge to generate said acoustic oscillations;
said first resonant cavity having a resonant range to resonate at certain frequencies of said acoustic oscillations to stabilize said certain frequencies;
a second resonator coaxial of said central axis having a resonant range to resonate at substantially said certain frequencies;
a piezoelectric element in said second resonant cavity and responsive to said certain frequencies for generating an alternating electrical output signal.

12. The source of electrical power of claim 11 wherein:
said second resonator is provided with an exhaust means comprising a plurality of exhaust openings sized to freely pass spent acoustic fluid from said second resonator and to be substantially opaque to the passage of acoustic energy of said certain frequencies.

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