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METHOD AND APPARATUS FOR GENERATING AN ACOUSTIC OUTPUT FROM AN IONIZED GAS STREAM

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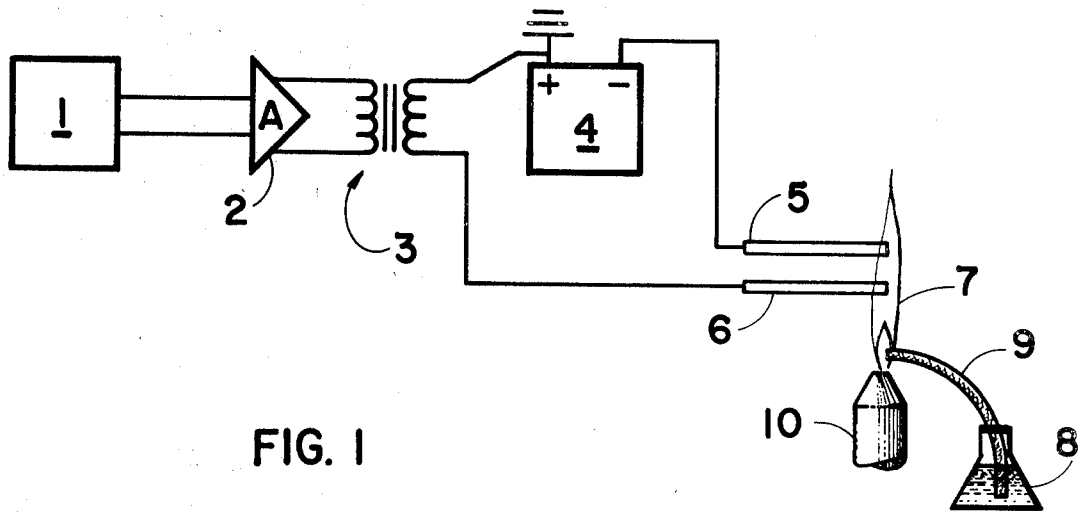


FIG. 1

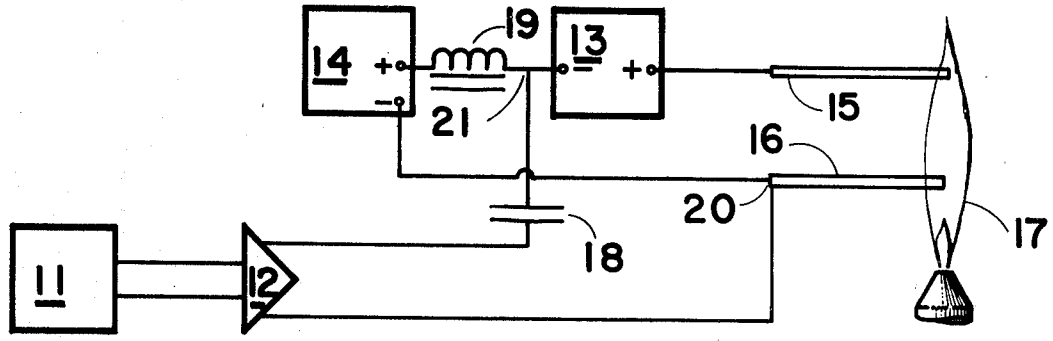


FIG. 2

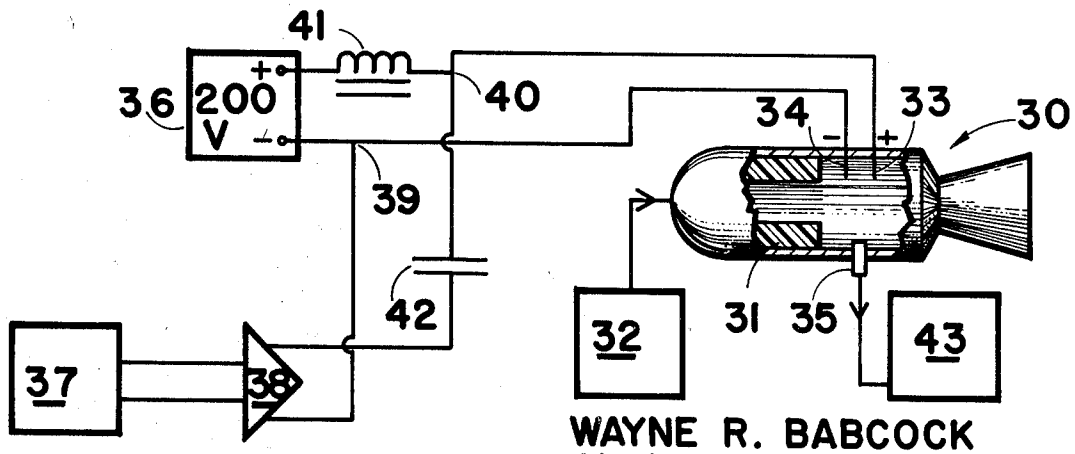


FIG. 3

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METHOD AND APPARATUS FOR GENERATING AN ACOUSTIC OUTPUT FROM AN IONIZED GAS STREAM

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ABSTRACT OF THE DISCLOSURE

An ionized gas stream is passed across spaced electrodes. A D.C. bias is maintained between the electrodes, and the intensity of the bias current is modulated in a predetermined manner. Acoustic waves corresponding in frequency to the frequency of the modulation of the bias current are generated by the gas stream. The invention is useful in a wide variety of applications ranging from entertainment to the testing and control of rocket motors.

BACKGROUND OF THE INVENTION

In the development of high pressure reaction vessels and combustion chambers, it is necessary to determine if unstable conditions can be generated within the chamber. While the mechanisms of instability are not completely understood and may be attributed to many parameters, it is known that certain forms of instability occur as a result of resonant vibrations in the pressurized gas within the chamber. The present method of testing for instability can literally be described as the "shotgun" approach. According to this method, a blank shotgun shell is discharged into the combustion chamber of an operating rocket motor and variations in chamber pressure are measured. This method indicates whether the design is unstable, but does not yield any meaningful information as to the cause of the instability. According to one application of this invention, means are provided for causing the pressurized gas to vibrate at known frequencies, whereby both the presence of instability and the resonant frequency of the instability can be determined.

In another aspect of this invention, the pressure within the combustion chamber can be made to vary in a predetermined manner. If pressure sensitive propellants are employed, the chamber pressure variations may be amplified and thrust variation of the same frequency may be obtained.

Another, less esoteric, but nevertheless important aspect of this invention resides in the use of this invention as a "flame loudspeaker." It has been discovered that audible signals of acceptable volume and fidelity can be generated by a flame without the use of any auxiliary loudspeakers by means of this invention.

It is accordingly an object of this invention to acoustically modulate an ionized gas stream.

It is another object of this invention to provide a means for determining combustion instability in a combustion chamber.

It is another object of this invention to produce predetermined pressure fluctuations in a combustion chamber.

It is another object of this invention to audibly reproduce electromagnetic signals without employing a conventional loudspeaker.

DESCRIPTION OF THE INVENTION

These and other objects of this invention will be readily apparent from the following description with reference to the accompanying drawings wherein:

FIG. 1 is a schematic representation of an embodiment of this invention,

FIG. 2 is a schematic representation of another embodiment of this invention, and

FIG. 3 is a schematic representation of a rocket motor employing an embodiment of this invention.

Briefly stated, the invention contemplates flowing a direct current through an ionized gas stream and modulating the intensity of the current at the frequency or frequencies desired to be reproduced acoustically by the gas stream. Various means can be used to modulate the intensity of the direct current and include means for varying the resistance or voltage of the direct current circuit as well as means for imposing a varying current on the direct current. The latter approach is preferable and is employed in the embodiments hereinafter described, it being recognized that the invention is not limited thereto.

Referring now to FIG. 1, an embodiment of this invention comprises a source of the signal which is to be acoustically reproduced and an amplifier 2 connected thereto. Any suitable source may be employed and include without being limited to an oscillator, tape recorder, or radio receiver, for example, depending upon the signal it is desired to reproduce.

A source of D.C. current 4 is connected to a pair of heat resistant electrodes 5 and 6 which are maintained in spaced relationship in an ionized gas stream 7. In this embodiment the ionized gas stream is the flame of an oxy-acetylene torch which is seeded with potassium ions from an aqueous KNO_3 solution 8 by means of wick 9. The D.C. circuit is coupled to the output of amplifier 2 by an inductive linkage 3 thereby modulating the current flowing in the D.C. circuit. In operation, the flame 7 acts as a loudspeaker and audible sound of good fidelity corresponding to the output of amplifier 2 has been produced by flame 7. Excellent reproduction of music and speech, for example, has been obtained.

In order to reduce distortion of the acoustic signal generated by ionized gas stream 7, certain general guidelines should be observed in selection of bias voltage and current both in the embodiment of FIG. 1 and in other embodiments of the invention. The D.C. bias voltage should be selected such that it is at least one half of the peak-to-peak output voltage of the amplifier 2 and is preferably higher than this value. This prevents any change in the direction of current flow in the D.C. circuit. The D.C. voltage, however, must be kept below that which will create an arc discharge between electrodes 5 and 6. The current flow in the D.C. circuit is preferably maintained at least .3 ampere. Below this value of current flow reduction in volume and distortion of the acoustic signal are quite noticeable. At and above this value there is relatively little distortion and large increases in current flow produce relatively small charges in the level of distortion. The spacing of the electrodes in the ionized gas and the degree of ionization of the flame are selected such that the resistance in this portion of the circuit is compatible with the aforementioned voltage and current parameters. In the above described embodiment, the system was operated satisfactorily at various electrode spacings and the flame was seeded to produce a resistance of from 2000 to 3000Ω across the gap between electrodes 5 and 6. A 500 volt D.C. source was employed as the source of bias voltage 4.

Referring now to FIG. 2, a more sophisticated embodiment of the invention is illustrated which employs a direct linkage between the A.C. signal and the D.C. bias circuit and has means for isolating the A.C. output, means for preventing negative current excursions and means for preventing the A.C. current from flowing through the D.C. bias source. The system comprises a signal source 11

coupled to amplifier **12** which is tapped into the D.C. circuit at points **20** and **21**. Capacitance **18** is inserted into the A.C. circuit to isolate output amplifier **12** from the D.C. circuit. The D.C. bias circuit comprises, in series, a D.C. bias voltage source **14**, a choke **19**, an auxiliary source of D.C. voltage **13**, and spaced electrodes **15** and **16** inserted in the ionized gas stream **17**. The D.C. voltage of the bias voltage source is selected to be greater than the peak negative voltage of output amplifier **12** thereby preventing any change in direction or interruption of the current flowing between electrodes **15** and **16**; the auxiliary D.C. source further insures that the voltage level in the flame remains above a minimum level, below which distortion of the signal becomes significant. The choke **19** prevents the output current from amplifier **12** from flowing through bias voltage source **14**. In operation with an output signal from amplifier **12** having a negative peak voltage of −100 volts, a 500 volt D.C. source **14**, a 200 volt D.C. source **13**, a 10 henry choke **19** and a 40 microfarad, 1000 v. capacitor produced excellent acoustic reproduction of music and voice by ionized gas stream **17**, which was seeded to produce about 2500Ω resistance between electrodes **15**.

Referring now to FIG. 3, a system for generating acoustic waves in a combustion chamber is shown. This system will be illustrated with respect to a hybrid rocket motor, but it should be understood that the invention is useful with respect to other types of high pressure chambers. When the hot gas stream is generated by combustion of a solid material as in hybrid and solid propellant rocket motors, the solid material is seeded with a readily ionizable material such as a potassium salt if it does not itself contain adequate ionizable material. If the system employs only fluid components as in fluid mono and bipropellant rocket motors, the ionizable material may be dissolved or suspended in one of the fluid components or introduced separately into the combustion chamber. This embodiment comprises a conventional hybrid rocket motor **30** operating with a solid fuel grain **31** seeded with KNO_3 and a fluid oxidizer such as liquid oxygen from a suitably pressurized source **32**. Spaced electrodes **33** and **34** extend in a sealed manner through the wall of motor **30** into the combustion or mixing chamber. A pressure transducer **35** is likewise provided within motor **30** and supplies signals to recorder **43**. A D.C. bias voltage is maintained across spaced electrodes **33** and **34** by means of D.C. source **36** and the D.C. circuit is modulated with an audio signal from signal generator **37** and amplifier **38**, which is tapped into D.C. circuit at points **39** and **40**. Choke **41** and capacitance **42** perform the same functions as in the embodiment of FIG. 2.

In an operable embodiment of this invention, the fuel grain **31** would be seeded with sufficient readily ionizable material to produce ionized combustion gases having a resistance of from 150–300Ω between electrodes **34** and **35** afte rignition of the motor. A convenient spacing of the electrode is from one to two inches. A signal of predetermined frequency is generated by signal generator **37** and in the absence of instability recorder **43** will produce a pressure trace from transducer **35** in which the frequency of the signal is superimposed on the motor pressure and its amplitude corresponds to the signal strength. If instability of the motor exists at the frequency of the imposed signal, resonance will occur and will be observed as a greatly increased amplitude. The increase in amplitude could, if desired, be used to automatically initiate shutoff of the oxidizer flow to prevent damage to the apparatus and permit later measurement of the grain geometry which let to instability. An alternative approach is to employ as a signal generator a variable oscillator capable of scanning a large range of frequencies. Such a system is particularly useful with liquid propellant rockets which do not encounter a change in internal geometry during firing, thereby permitting the investigation of a wide range of frequencies in one firing.

Another application of this invention is in modulating the thrust of a rocket motor employing a pressure sensitive propellant. In this embodiment, the acoustic waves generated within the rocket motor, corresponding to the input signal from source **37** will cause small pressure fluctuations which are multiplied by their effect on the burning rate of the propellant. The net result would be large thrust fluctuations corresponding in frequency to that of the input signal.

While this invention has been described with respect to several embodiments of this invention, it should not be construed as limited thereto. Various modifications will suggest themselves to workers skilled in the art and can be made without departing from the scope of this invention, which is limited only by the following claims.

We claim:

1. Apparatus for generating acoustic waves in an ionized gas stream comprising:
- (a) a pair of spaced electrodes,
- (b) direct current circuit means for causing a direct current to flow continuously between said electrodes when said electrodes are introduced into an ionized gas stream, and
- (c) means for modulating the direct current flowing between said electrodes.

2. The apparatus of claim **1** wherein said means for modulating the direct current comprises output means producing an electrical signal of varying voltage and means for impressing said signal on said direct current.

3. The apparatus of claim **2** wherein said means for impressing said signal comprises an inductive linkage of said signal with said direct current circuit means.

4. The apparatus of claim **2** wherein said means for impressing said signal comprise a direct linkage of said output means to said D.C. circuit means.

5. The apparatus of claim **2** further comprising means for preventing the D.C. current from flowing through said output means.

6. The apparatus of claim **5** further comprising means for preventing said signal from flowing through the source of D.C. voltage.

7. The apparatus of claim **6** further comprising means for preventing the reversal of the direction of current flow in said D.C. circuit.

8. Apparatus comprising in combination:
- (a) a combustion chamber,
- (b) means for generating an ionized gas stream,
- (c) means for flowing said gas stream through said combustion chamber, and
- (d) means for generating acoustic waves of predetermined frequency in said ionized gas stream comprising:
  - (i) a pair of spaced electrodes disposed in the path of said ionized gas stream,
  - (ii) D.C. bias means for maintaining a flow of direct current through the ionized gas between said electrodes, and
  - (iii) modulating means for varying the flow of D.C. current between said electrodes at a frequency corresponding to the frequency of the acoustic wave to be generated.

9. The combination of claim **8** further comprising pressure sensing means for sensing the pressure within said combustion chamber.

10. The combination of claim **8** wherein said modulating means comprises output means for generating an A.C. signal of predetermined frequency and means coupling said A.C. signal to said bias means.

11. A method for generating acoustic waves in an ionized gas stream which comprises continuously flowing a direct current through an ionized gas stream and varying the intensity of said current whereby acoustic waves corresponding in frequency to the frequency in which the intensity is varied are generated.

12. The method of claim **11** wherein the D.C. current is maintained at a value greater than 0.3 ampere.

13. A method for determining combustion instability in a combustion chamber which comprises generating combustion gases in said combustion chamber, generating an acoustic wave of predetermined frequency in said combustion gases and sensing the pressure within said combustion chamber.

14. A method for producing fluctuations in the chamber pressure of a reaction motor said fluctuations having a predetermined frequency which comprises generating a pressurized gas within said reaction motor and generating acoustic waves of predetermined frequency in said pressurized gas within said reactor motor.

15. Apparatus for generating accoustic waves in an ionized gas stream comprising:

(a) a pair of spaced electrodes,

(b) means for passing an ionized gas stream between spaced electrodes,

(c) direct current means for flowing a direct current continuously between said spaced electrodes and through said ionized gas stream, and

(d) means for modulating the direct current continuously flowing between said spaced electrodes and through said ionized gas stream.

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