

[54] **SIGNAL GENERATING DEVICE FOR USE WITH A STRUCTURE WHICH IS SUBJECTED TO A RANGE OF VIBRATIONS**

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[58] Field of Search..... **310/8.2, 8.3, 8.8, 310/8.7, 9.1**

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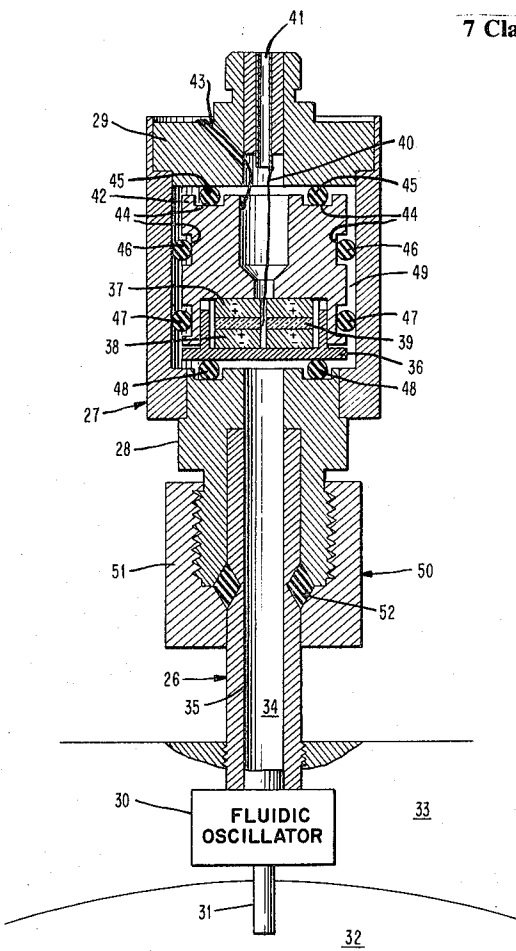
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[57] **ABSTRACT**

The present invention employs a piezo-electric crystal means which is supported by nonrigid material within a housing device. The housing device is adapted to be rigidly held by a vibrating body. The piezo-electric crystal means is coupled to a source of pressure signals which vary in frequency in response to temperature variations and said crystal means is further coupled to an electronic network to provide signals thereto which are converted into pulses whose repetition rate is commensurate with the frequency of said pressure signals. The vibration experience to which the housing and therefore the piezo-electric crystal means is subjected does not cause the piezo-electric crystal means to generate high amplitude electrical signals (noise) because the energy of the vibrations is substantially absorbed by the non-rigid material. In addition the electronic network provides a flat response over a dynamic range that includes the pressure signals generated by the temperatures of the device being monitored. Accordingly, the signals from the pressure source can be readily detected and therefore are readily usable for their intended purpose.

7 Claims, 3 Drawing Figures



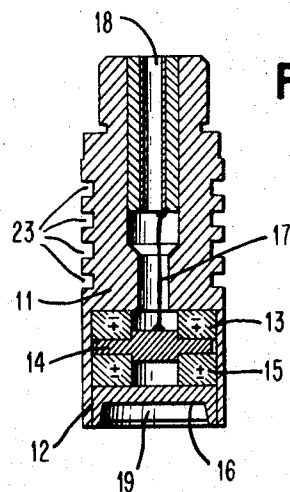


FIG. 1

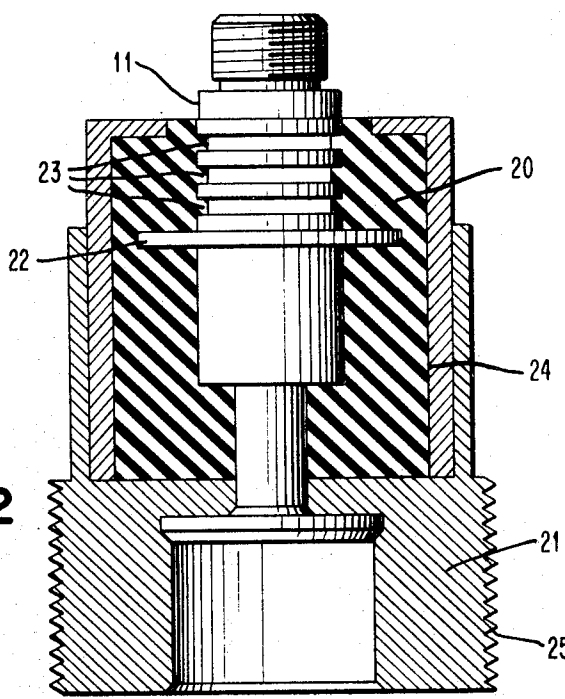


FIG. 2

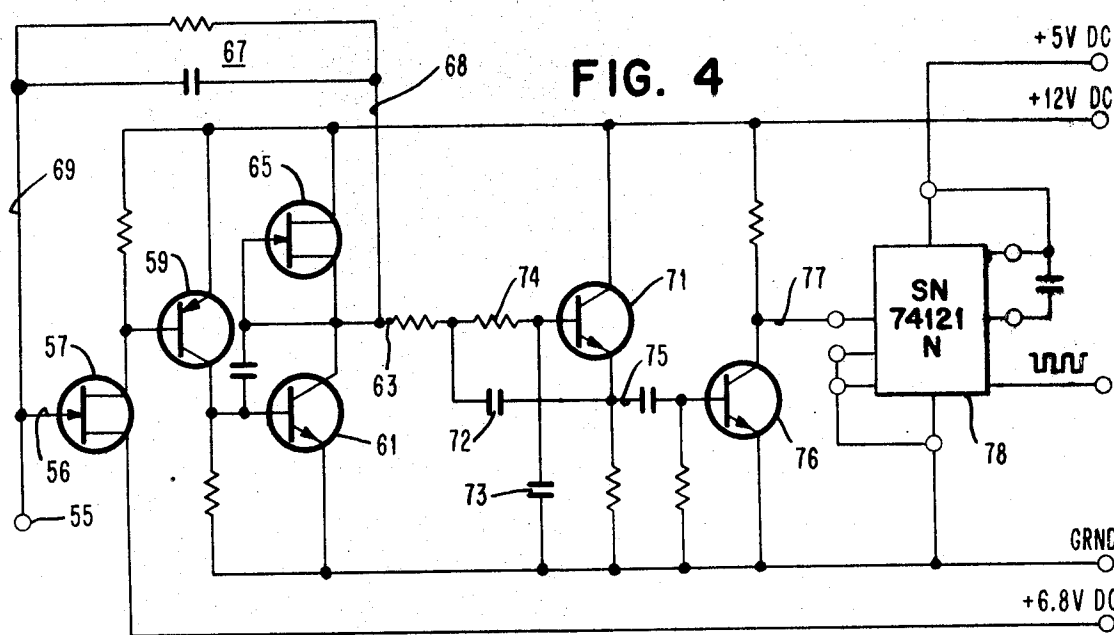
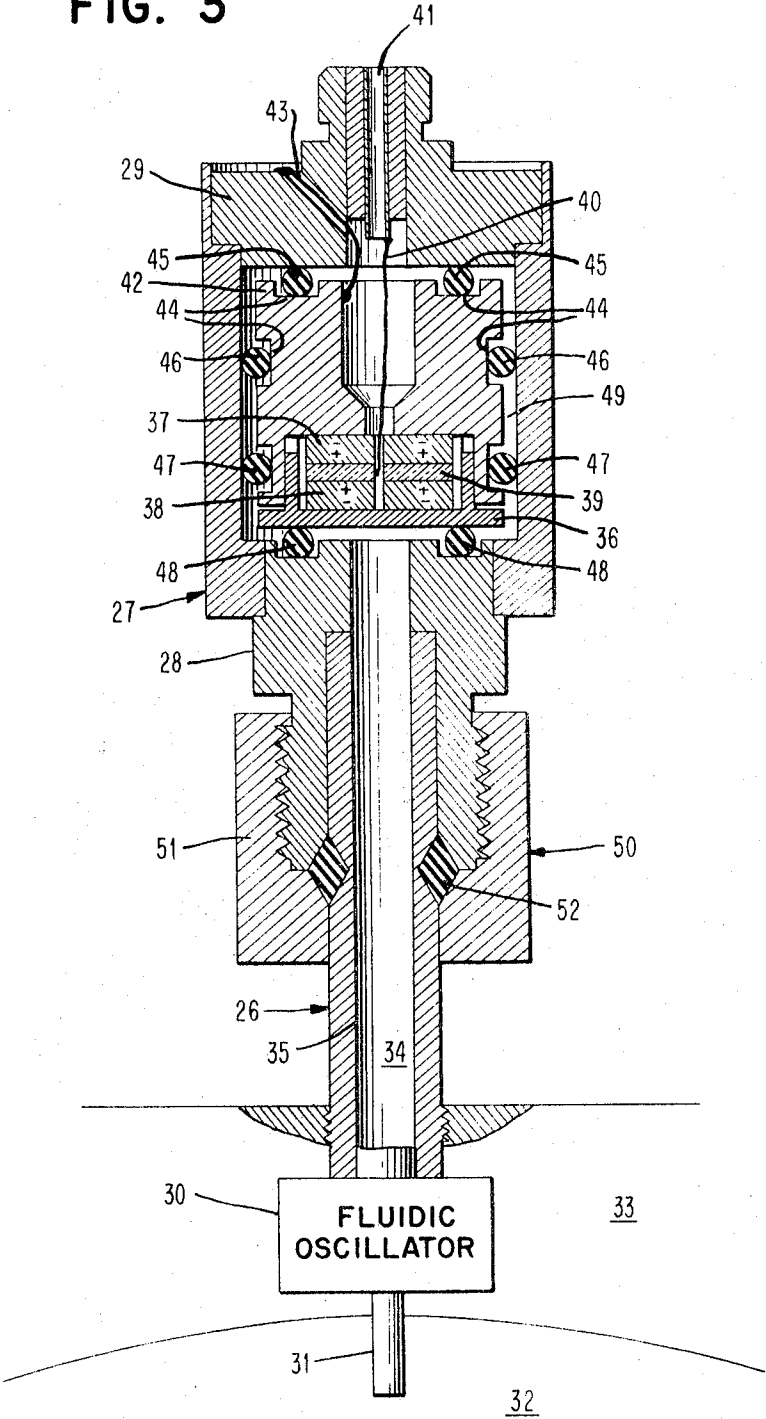


FIG. 4

FIG. 3



SIGNAL GENERATING DEVICE FOR USE WITH A STRUCTURE WHICH IS SUBJECTED TO A RANGE OF VIBRATIONS

BACKGROUND

The present invention is described as a device to be used with a jet engine of an aircraft. The safe-life of a jet engine can be affected by the temperature in the combustion chamber of the engine. For instance, consider that in a typical turbine type engine it is preferable to operate the combustion chamber in the range of 2,500°F. to 3,000°F. Further, consider that if the temperature of the combustion chamber exceeds 3000°F. for any substantial period of time, it will very often cause a failure of the engine. As a result, the engine must be rebuilt. Accordingly, the manufacturers of aircraft jet engines have attempted to monitor or control the temperature of the combustion chambers of their respective products. Since very often the temperature of the combustion chamber can be controlled or regulated, it follows that the safe-life of such jet aircraft engines can be regulated for some optimum period. It should be understood that the temperature values of another engine could vary and/or this invention could be used to monitor devices other than jet engines, for instance a heat source such as a furnace.

Heretofore the attempt to monitor the combustion chamber in an aircraft engine has been unreliable. Since the sensor or probe element is subjected to high temperatures, it can literally burn out. In the course of considering this problem it was determined that hot gases passing from the combustion chamber produce a high frequency sound signal and this high frequency sound signal could be detected if the proper transducer were available. A transducer was developed for this purpose which is generically called a fluidic oscillator and one version of such a transducer is manufactured by Avco Corporation, of Stratford, Conn. This fluidic oscillator produces a pressure signal whose frequency is approximately 15 cycles/second/1°F. For instance, if the temperature of the hot gases rushing from the combustion chamber in our illustrative engine is 3,000°F. then the signal produced by the fluidic oscillator is 45kc. The fluidic oscillator can withstand high temperatures of the combustion chamber and hence in many respects is an excellent transducer from temperature conditions to pressure signals.

However, when such a transducer is employed, it becomes necessary to convert the pressure signals into electronic signals if the system is going to be monitored by a pilot or a recorder of some type. The present invention provides a means to translate the pressure signals into electronic signals so that the temperature can be readily determined.

SUMMARY

The present invention in the preferred embodiment includes a pair of piezo-electric crystals which are particularly polarized so that a common collector for the pair can be used. The combination of the piezo-electric crystals and the collector is mounted in a rigid housing. The rigid housing has an aperture therein with a diaphragm mounted across the aperture. One surface of the diaphragm is in abutment with the piezo-electric crystals so that any forces applied to the diaphragm will result in electric signals being generated by the piezo-electric crystals. The collector and the rigid housing

have wires connected thereto which provide circuit paths for the generated signals. The rigid housing in one embodiment is supported within a second rigid housing by a plurality of silicon rubber O-rings while in a second embodiment the first rigid housing is imbedded in a nonrigid material which nonrigid material is further disposed within a second rigid housing. Accordingly, in both of the last described embodiments when the second rigid housing is mounted on the frame of the jet aircraft engine, the vibrations to which it is subjected cannot create any great effect on the first rigid housing because the aircraft engine vibrations are at a higher frequency than the resonant frequency of the first rigid housing (as mounted in the O-rings or the nonrigid material). Hence the first rigid means as mounted in the silicon rubber O-rings or the nonrigid material is virtually non-responsive to the vibrations of the aircraft engine above the resonant frequency. If the first rigid body were not supported by the silicon rubber O-rings or by the non-rigid material, it would be responsive to the vibrations of the aircraft engine and the piezo-electric crystal means would not recognize whether it was being flexed by vibrations of the aircraft or by pressure signals which are to be monitored. Hence there would be output signals from the piezo-electric crystals resulting from the aircraft vibrations and such signals would be noise or unwanted output signals.

The unit described herein, by way of example, is characterized by two fundamental natural frequencies. The lower natural frequency is about 7.5K Hz. Since the major structural vibrations of the aircraft exceed 10K Hz, these latter vibrations are ineffective on the unit as described above. The higher natural frequency of the unit described herein is approximately 45K Hz and provides a basis for having the system respond to pressure signals in the range of 15K Hz to above 45K Hz. Since the pressure signal frequencies are commensurate with temperatures of gases being monitored (by a fluidic oscillator), the temperature range being monitored is substantially wide. It should be understood that other high and low natural frequencies may characterize a unit within the spirit of this invention if an application thereof is required.

The apertures in the second and first rigid bodies, as will be described in more detail hereinafter, are coupled through a tube filled with a suitable transmission medium, such as a gas, to the fluidic oscillator which is located at a strategic point within the combustion chamber of the jet engine. However, it should be understood that the aperture could be coupled to some other source of pressure signals. The temperature of the gases which pass in contact with the probe of the fluidic oscillator act as the controlling parameter with respect to the pressure signals generated by this fluidic oscillator. The pressure signals generated by this fluidic oscillator are transmitted through said transmission medium to the diaphragm, previously mentioned, and cause forces to be applied to the piezo-electric crystals. These pressure signals are immediately transformed into electric signals by the piezo-electric crystals. Since the frequency of the signals from the fluidic oscillator change or are controlled by the temperature of the hot gases in the combustion chamber, it follows that the frequency of the signals from the piezo-electric crystals provide a reading of the temperature or changes of temperature of the hot gases.

The objects and features of the present invention will be better understood in accordance with the following description which is to be considered in conjunction with the drawings wherein:

FIG. 1 is a sub-assembly sectional showing the first rigid housing of one embodiment;

FIG. 2 is a partial schematic of the second rigid body showing the sub-assembly of FIG. 1 imbedded in non-rigid material; and

FIG. 3 is a sectionalized view of a second form of the first rigid body held within the second form of the second rigid body by the silicon rubber O-ring seals and with the second rigid body schematically connected to the combustion chamber of the jet aircraft engine.

Normally in a jet aircraft engine the combustion chamber is located in the mid-portion of the engine housing. The engine is further disposed within some form of cowling mechanism which serves to keep the engine protected. In accordance with the utility of the present invention for monitoring the temperature of the combustion chamber of a jet aircraft engine, the fluidic oscillator (and therefore the probe of the fluidic oscillator) is located within the engine housing with the probe actually being inserted within the combustion chamber. It can be seen in FIG. 3 that the fluidic oscillator is secured to the engine housing with the probe penetrating into the combustion engine. The second rigid housing is shown as being threaded into the engine housing, but it should be understood that other forms of securing means can be employed. The fluidic oscillator is located in such a position that there is a tube readily connected from the fluidic oscillator to the second rigid housing. Bearing in mind this arrangement, consider FIG. 1.

In FIG. 1 there is shown a housing 11 in sectional form. Within the housing 11 there is formed a cavity 12 within which there is disposed a top piezo-electric crystal 13, a collector 14 and a lower piezo-electric crystal 15. The collector 14 is simply a disc shaped device with a flange which is composed of good electrically conducting material. In the preferred embodiment the collector is made of stainless steel. The piezo-electric crystals 13 and 15 are disc shaped devices with a hole in the middle, or doughnut shaped structures. It will also be noted in FIG. 1 that there is a diaphragm 16 which is fabricated from stainless steel. It will be noted that the diaphragm 16 is in abutment with the lower piezo-electric crystal 15.

It will also be noted that in FIG. 1 that the polarities of the piezo-electric crystals 13 and 15 are such that when a force is applied to the diaphragm 16 there will be a voltage generated by the piezo-electric crystals as shown. In accordance with the voltage generated, the collector 14 will be connected to the positive voltage side of the piezo-electric crystals and hence will conduct a signal along the line 17 to the socket 18, while the negative sides of the piezo-electric crystals are connected to the electrically conducting housing 11 thus providing the other side of the circuit. Hence, when a proper type connector is fitted over the upper portion of the housing 11 with a jack, or a suitable prong insert, the signals which are being generated by the piezo-electric crystals 13 and 15 can be detected for use at some further point in the system.

In FIG. 1 it will be noted that the housing 11 has an aperture 19 therein which permits the pressure signal transmission medium to come into contact with the dia-

phragm 16 and therefore enables the pressure signals to apply forces against the diaphragm 16.

The notches which are cut into the side of the housing 11 serve to imbed this particular housing into the nonrigid material as can be seen in FIG. 2.

In FIG. 2 there is shown the housing 11, nonsectionalized, with the grooves formed therein which are imbedded into the nonrigid material 20. The nonrigid material 20 can be silicone rubber or elastic epoxies or any other suitable nonrigid material which will act to absorb the vibrations of the second rigid housing 21. When the housing 11 is disposed or located within the nonrigid material 20 there is a split disc 22 which slips into one of the grooves 23 to firmly support the housing 11 within the nonrigid material 20.

The nonrigid material 20 is located within the cavity 24 of the second rigid housing 21. The second rigid housing 21 is formed to be held onto the frame of the aircraft by some suitable means such as the threads 25 or simply by a rigid tube 26 (see FIG. 3). As was explained earlier when the second rigid housing 21 vibrates in accordance with the vibrations of the aircraft which is directly proportional to the vibrations of the jet aircraft engine these vibrations will be absorbed by the nonrigid material 20 and hence the first rigid body or housing 11 will be subjected to very little vibration. The vibrations of the aircraft exceed the resonant frequency of the first rigid body as it is held in the nonrigid material. Accordingly, there will be very little in the way of forces applied to the piezo-electric crystals 13 and 15 as a result of the vibrations of the aircraft. On the other hand, as will be explained more fully hereinafter, when there are signals or forces generated by the fluidic oscillator, these forces will be applied to the piezo-electric crystals through the diaphragm and will generate a signal which will be readily detectable.

Consider FIG. 3 which shows a second embodiment of the invention and a schematic relationship of the invention with a jet aircraft engine. It should be understood that the drawing is very much diminished with respect to the size of the combustion chamber and the engine. The stainless steel tubing 26 can provide the support for the second rigid housing 27 which includes a threaded adapter 28 and a connector cap 29.

The fluidic oscillator 30 has a probe 31 which fits into the combustion chamber 32 of the engine 33. The fluidic oscillator and its operations are not part of this invention and thus it suffices to say because of the arrangement of the fluidic oscillator and the probe 31 there are generated high frequency pressure signals which are transmitted through a gas or fluid 34 located in the aperture 35 of the stainless steel tube 26. Normally the air which finds its way into the cavity 35 of the tube 26 is trapped therein and hence the pressure signals which are generated by the fluidic oscillator 30 are transmitted to the diaphragm 36 by the trapped air or other trapped gases. It should be understood that since there is no flow of gases in the tube 26 it is possible that some of the hot gases from the combustion chamber will also become trapped in the cavity 35 if for some reason there has been some leakage of the air normally trapped therein. In any event the gases that eventually become trapped in the chamber 35 act as the medium to transmit the signals from the fluidic oscillator 30 to the diaphragm 36 and since there is no transmission of gases through this tube the tube does not act as a conduit for heat conduction.

Located within the housing 27 are a pair of piezo-electric crystals 37 and 38 in between which there is located a common collector 39. The piezo-electric crystals 37 and 38 are polarized as shown and are similar to the polarization of the crystals 13 and 15 shown in FIG. 1 and operate in the same fashion. Hence there need be no further discussion thereof. It will be noted that the common collector 39 is connected by the wire 40 to the conducting socket 41. It will further be noted that the insert housing 42 which holds the piezo-electric crystals 37 and 38 as well as the common collector 39, is electrically connected to the connector cap 29 by virtue of the wire 43. Hence then circuit connection can be made to both sides of the circuit by a connector device mounted on the outside of the housing.

It should be noted in FIG. 3 that the insert housing 42 has a number of notches 44 formed therein and that these notches 44 have O-rings 45 through 48 located therein. The O-rings 45 through 48 serve to suspend or support the insert housing 42 within the cavity 49. The role of the O-rings 45 through 48 is similar to the non-rigid material 20 in FIG. 2 but they have the added advantage that they are very easy to assemble and therefore make the fabrication of the overall assembly quite economical.

We have found that if we use silicon O-rings for mounting the insert housing (or first rigid body), the resonant frequency for the insert housing so mounted is about 7,500 Hertz and there is a very narrow bandwidth to which the insert housing is responsive. Accordingly the insert housing 42, mounted by the O-rings, is insensitive to vibrations in excess of 10,000 Hertz.

Further, in FIG. 3, it will be noted that the housing assembly 27 is mounted on the stainless steel tube 26 by virtue of a Swagelok fitting 50. The Swagelok fitting 50 includes a fitted cap 51 which is threaded up onto the threaded adapter 28 and a compression ferrule 52 which is squeezed or pushed into both the stainless steel tubing 26 and the threaded adapter 28 in response to the cap 51 being threaded up onto the adapter 28. In this way the housing assembly 27 is mounted onto the stainless steel tubing 26.

In the discussion thus far, we have considered the mechanical aspects of the present transducer system and have determined that electrical signals are generated in response to forces exerted against the diaphragm 36 (FIG. 3) by the pressure signals from the fluidic oscillator 30. The frequencies of those pressure signals are representative of the temperatures of gases in the combustion chamber 32 and hence the electrical signals are representative of the temperatures of the gases in the combustion chamber 32. However, the electrical signals thus generated by the piezo-electric crystals are unrefined signals. In other words, these signals may well include many harmonics and other forms of noise. In addition, the resonant frequency of the piezo-electric crystals may well be within the frequency range of the fluidic oscillator output signals. Hence the signals generated when the piezo-electric crystals are at their resonant frequency provide another source of output signal distortion with which the system must deal.

It should also be understood that ultimately the signals must be converted to some form that can be readable by a human, if the system is to be monitored by an

operator, or to a form that can be readable by an automatic control means.

The present system employs circuitry which accepts the unrefined signals from the piezo-electric crystals, filters these signals to provide a flat response over the pressure signal frequency range which represent the operating combustion chamber temperatures of the aircraft and converts the signals into pulses which can be counted and whose repetition rate is commensurate or representative of the frequency of the pressure signals.

Consider FIG. 4 and consider that the terminal 55 is a jack, or prong, which fits into the conducting socket 41 in FIG. 3. A.C. signals will be generated by the piezo-electric crystals as explained above and these signals will be transmitted through the terminal 55 to the base 56 of the field effect transistor 57. The field effect transistor 57, the PNP transistor 59 and the NPN transistor 61 are three stages of amplification to provide an amplified A.C. signal on line 63. The field effect transistor 57 acts as the load for transistor 61 and provides a constant current source thereto. The R-C circuit 67 which is connected by lines 68 and 69 comprises a feedback circuit which acts in conjunction with the amplifiers 57, 59 and 61 to reduce the gain of the signals at the lower frequencies.

The partially filtered A.C. signal is transmitted to the NPN transistor 71 which has an A.C. feedback through the capacitor 72. The transistor 71 acts in conjunction with the capacitor 73, resistor 74 and feedback capacitor 72 as a low pass filter. The parameters of the circuit are chosen such that there will be a substantially flat response to signals in the range of 27 kc to 48 kc for the particular engine in our example.

Other parameter values of course can be chosen for engines which operate at different temperature values.

The filtered signals are transmitted on line 75 to the base of the NPN transistor 76 which acts as a rectifier (only responding to the positive portions of the signal). When transistor 76 is conducting there is a negative signal on line 77 which is fed to the monostable multivibrator 78. The monostable multivibrator 78 provides an output pulse each time it is turned on and this output pulse is of negative polarity and has a width of 5 microseconds. The pulse output can be simply connected to a pulse counter which will count the repetition rate of the pulses to convert such information into a temperature display or to a control signal or to both.

Field effect transistor 57 can be an ITE 4868; transistor 59, 61, 71 and 76 can all be 2N3903's; and the monostable multivibrator can be a commercially-available integrated circuit SN74121N.

We claim:

1. A signal generating device which generates signals in response to pressures applied thereto and which is employed with a structure having hot gases pass there-through and which is subjected to a range of vibrations comprising in combination: piezo-electric crystal means; first rigid means having a diaphragm at one end thereof and having a cavity therein, said piezo-electric crystal means disposed in said cavity of said first rigid means and in abutment with said diaphragm; second rigid means having a cavity therein and having first and second apertures, said first rigid means disposed in said cavity of said second rigid means, said first and second apertures extending from said cavity to respectively first and second outer positions of said second rigid means, said first aperture further disposed to lie in

close proximity to said diaphragm and adapted to provide pressure signals thereto; nonrigid means disposed in said cavity of said second rigid means to support said first rigid means located therein, said non-rigid means characterized by having the capacity to absorb the vibrations to which said second rigid means is subjected over said range of vibrations, whereby said first rigid means has virtually no vibrations in response to said range of vibrations of said second rigid means; fluidic oscillator means having a sampling probe and capable of transmitting signals having frequencies representative of the temperatures of said hot gases and coupled to said first aperture to transmit pressure signals there-through to said diaphragm in response to said hot gases being passed over said sampling probe; and electrical signal conducting means connected to said piezo-electric crystals to transmit signals generated thereby in response to pressure signals applied through said first aperture.

2. A signal generating device according to claim 1, wherein said nonrigid means is a plurality of O-rings.

3. A signal generating device according to claim 1, wherein said nonrigid means is a mass of silicon rubber.

4. A signal generating device according to claim 1,

wherein said piezo-electric crystal means includes two donut-shaped piezo-electric crystals mounted in abutment on opposite sides of a common collector and respectively poled whereby each of the ends of said piezo-electric crystals which are in abutment with said common collector develop the same voltage polarity signals in response to pressure signals applied to said diaphragm.

5. A signal generating device according to claim 1, wherein there is further included circuitry means connected to said electrical signal conducting means to receive signals therefrom and filter said signals to provide a flat signal response over a predetermined bandwidth of pressure signals applied to said diaphragm.

6. A signal generating device according to claim 5, wherein said circuitry means further includes means to convert said filtered signals into pulse signals whose repetition rate represents the frequency of pressure signals applied to said diaphragm.

7. A signal generating device according to claim 1, wherein said second rigid means is formed to be secured to a structure which is being subjected to a range of vibrations.

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