United States Patent

[11] 3,576,191

[72] Inventor Gary L. Innes
Brooklyn Park, Minn.
[21] Appl. No. 801,429
[22] Filed Feb. 24, 1969
[45] Patented Apr. 27, 1971
[73] Assignee Honeywell Inc.,
Minneapolis, Minn.

[54] **TEMPERATURE-RESPONSIVE SONIC OSCILLATOR**
10 Claims, 6 Drawing Figs.

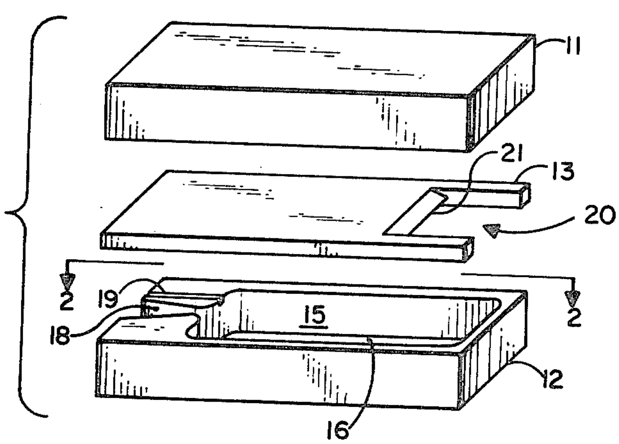
[52] U.S. Cl. 137/81.5
[51] Int. Cl. F15c 1/08, F15c A/00
[50] Field of Search 137/81.5

[56] **References Cited**
UNITED STATES PATENTS

3,294,103	12/1966	Bowles	137/81.5
3,398,758	8/1968	Unfried	137/81.5
3,451,411	6/1969	Johnson	137/81.5
3,468,331	9/1969	O'Neal	137/81.5

Primary Examiner—William R. Cline
Attorneys—Charles J. Ungemach and Charles L. Rubow

ABSTRACT: A temperature sensor of the fluidic oscillator type comprising a housing enclosing a chamber having an inlet aligned with an axis and an outlet configured to facilitate choked flow therethrough. The sensor includes a divider element separating the chamber into two subchambers, each having its maximum dimension substantially parallel to the inlet axis. The divider element is provided with a knife edge oriented toward and separated from the inlet. Means may also be included for directing a portion of the fluid whose temperature is to be measured along outside surfaces of the housing to provide improved transient response.



PATENTED APR 27 1971

3,576,191

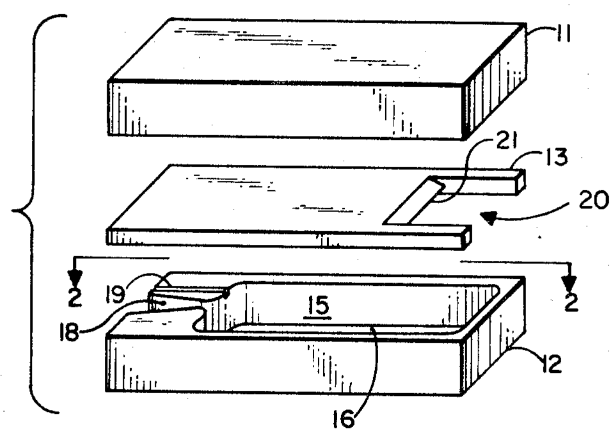


FIG. 1

FIG. 2

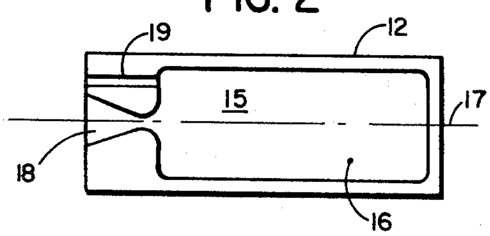


FIG. 3

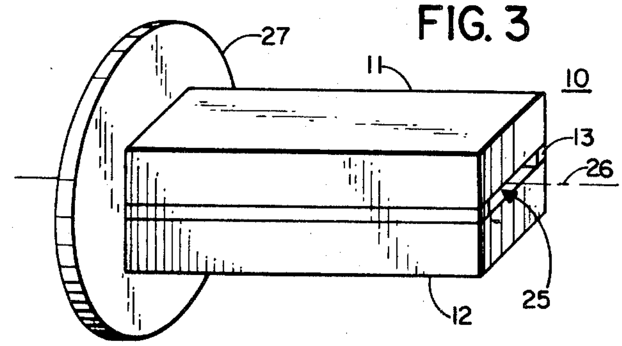


FIG. 4

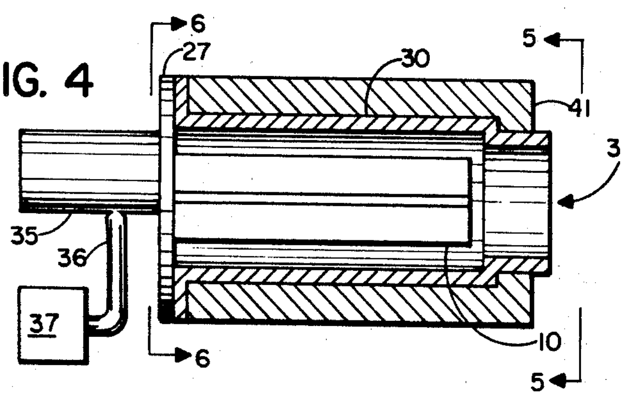


FIG. 6

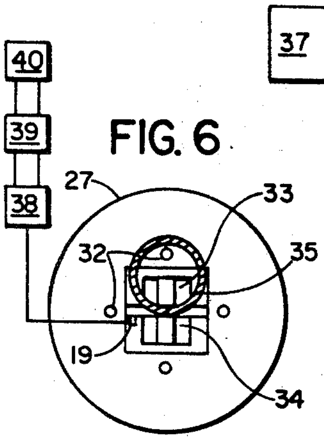
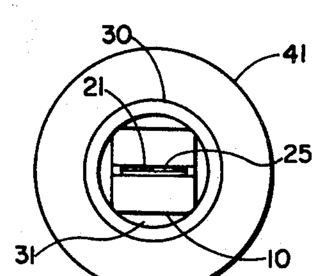


FIG. 5



INVENTOR.
GARY L. INNES

BY Ronald T. Reiling

ATTORNEY

TEMPERATURE-RESPONSIVE SONIC OSCILLATOR

BACKGROUND OF THE INVENTION

This invention relates generally to fluid-handling apparatus, and more specifically, to fluidic devices responsive to temperature.

Temperature-sensitive fluidic oscillators, particularly of the sonic oscillator type, have recently provided great improvements in the art of rapidly and accurately measuring very high temperatures. For the purpose of this specification, a sonic oscillator will be defined as one which operates on the edge-tone effect. Such an oscillator typically comprises a nozzle for issuing a fluid jet which impinges on a knife edge. If the nozzle-knife edge arrangement is properly dimensioned, the fluid stream will oscillate about the knife edge at a frequency dependent on the properties (temperature) of the fluid in the stream. Resonant chambers may be provided on one or both sides of the knife edge to enhance the oscillation.

One of the more serious problems with existing fluidic temperature sensors relates to transient response. It has been found that the transient response of a device of this type reflects two time constants. The first time constant is dependent on the time required to exchange the fluid within the sensor. The second is dependent on the time required to bring the sensor housing to its final steady state temperature. The resonant frequency of the resonant chamber or chambers is dependent on dimensions of the chambers and the properties (temperature) of the fluid therein. The time required for the resonant frequency to change is affected by the purging (exchange) time of the chambers, the thermal inertia of the sensor body and the rate of heat transfer therefrom. In prior-art fluidic temperature sensors, the first and second time constants typically have values of 10 milliseconds and 1 minute respectively. Upon application of a step temperature input, the indicated temperature will reach approximately 60 percent of its steady state value in about 40 milliseconds (four time constants). Thereafter, the indicated temperature will require approximately 3 minutes to come within a few percent of its final steady state value.

Another problem with prior-art fluidic temperature sensors relates to sensor size. A controlling dimension in sensors of this type is the distance between the inlet nozzle and the knife edge. This dimension cannot be reduced to less than some minimum value for optimum operation. Further, the mean operating frequency of the sensor is a function of the dimensions of the resonant chambers. For typically required operating frequencies, a characteristic dimension of each chamber (length) is substantial (for example, 1 inch). In the more satisfactory prior-art sensors, the resonant chambers have been axially aligned on opposite sides of the nozzle-knife edge arrangement. Thus, all of the outer sensor dimensions have fixed minimum values. These dimensions have been found too large for many applications, as for example, temperature probes for insertion into the combustion chamber of certain gas turbine engines.

A further problem with prior-art fluidic temperature sensors relates to difficulty of construction from high-temperature materials. Even though these sensor configurations are relatively simple, they are sufficiently complex that the cost of fabrication from high-temperature materials, such as silicon carbide, is not attractive.

The applicant has provided a unique fluidic oscillator temperature sensor configuration which overcomes the above-described problems associated with prior-art fluidic temperature sensors. Specifically, the applicant's unique temperature sensor is of very simple construction, is small in size, and provides greatly improved transient response.

SUMMARY OF THE INVENTION

Briefly, the applicant's invention comprises a temperature-sensitive fluidic oscillator including an inlet nozzle for issuing a fluid stream which impinges on a knife edge and a pair of chambers on opposite sides of the knife edge, each chamber having its maximum dimension substantially parallel to the axis with which the nozzle-knife edge is aligned. Nozzle means configured to promote choked flow is provided for exhausting fluid from the chambers. Means may also be included for directing a portion of the fluid whose temperature is to be measured along outside surfaces of the sensor housing to improve transient operation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an exploded view of the applicant's unique temperature sensor showing its basic elements;

FIG. 2 is a plan view of a component part of the applicant's sensor taken along lines 2–2 in FIG. 1;

FIG. 3 illustrates one embodiment of the applicant's unique temperature sensor as assembled from the parts shown in FIG. 1;

FIG. 4 illustrates an embodiment of the applicant's unique temperature sensor including an insulated jacket, pickoff means and fluid signal utilization means;

FIG. 5 is an end view of the sensor embodiment of FIG. 4 taken along lines 5–5; and

FIG. 6 is an end view of the sensor embodiment shown in FIG. 4 taken along lines 6–6, showing alternate pickoff means and a simplified circuit responsive to the pickoff output.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 3, reference numeral 10 generally identifies one embodiment of the applicant's unique temperature sensor. Sensor 10 basically comprises a pair of housing members 11 and 12 and a divider element 13. FIG. 1 is an exploded view of these parts in which they are identified by the same reference numerals. A plan view of member 12 is shown in FIG. 2 which, taken in combination with FIG. 1, clearly illustrates its interior details.

Members 11 and 12 are of identical geometry. Therefore, only member 12 will be described in detail. Member 12 basically comprises a shell having a cavity 15 therein. Cavity 15 includes a first portion 16 which is shown as a cylindrical hollow of rectangular cross section aligned with an axis 17. Cavity 15 further includes a second portion 18 also shown as having a rectangular cross section and aligned with axis 17. Portion 18, however, is of converging-diverging geometry along axis 17. Member 12 also includes a channel 19 which extends from portion 16 of cavity 15 to the outside of member 12.

Divider element 13 basically comprises a flat plate of sufficient length and width to cover the cavity and channel in member 12. Divider element 13 is provided with an opening 20 therethrough at one end. The wall bounding opening 20 opposite its open end is formed into a knife edge 21.

As shown in FIGS. 1 and 3, member 12 and member 11, which is identical to member 12, are assembled with their open sides oriented one toward the other. Thus, member 11 and 12 basically define a cylindrical chamber. Divider element 13 is sandwiched between members 11 and 12 with the opening therein positioned away from portion 18 of cavity 15. Members 11 and 12 and divider element 13 cooperate to form an inlet nozzle 25 aligned with a central axis 26. Although not shown in FIG. 3, it is apparent that knife edge 21 forms a splitter element also aligned with and intersecting axis 26. Divider element 13 further separates the cylindrical chamber defined by members 11 and 12 into two substantially equal cylindrical subchambers, each having its maximum dimension substantially parallel to axis 26. Portion 18 of cavity 15, and the corresponding portion in member 11 form converging-diverging outlet nozzles communicating with the subchambers in members 11 and 12. Channel 19, when covered by divider element 13, forms a signal pickoff passage for use with nonfluidic (no flow) pressure transducers.

For reasons which will hereinafter be discussed, it is desirable to make the walls of members 11 and 12 as thin as possible. For simplicity, members 11 and 12 are shown having basically rectangular cross sections. Further, they are shown as having identical geometries. Accordingly, when members 11 and 12 and element 13 are assembled, two identical subchambers, each having an outlet nozzle, are formed. This particular configuration is not essential to the applicant's invention. For example, the sensor cross section may be round and/or the subchambers need not be identical. Further, it is not essential that an outlet nozzle be provided for each chamber. For purposes of the applicant's invention, it is however important that the amount of material in the sensor housing be minimized, that the rate of heat transfer therefrom be maximized and that the maximum dimensions of the subchambers be substantially parallel to the inlet nozzle-knife edge axis.

Referring again to FIG. 3, sensor 10 is provided with a mounting flange 27 to facilitate its mounting directly in any desired installation, or in an insulated jacket as will hereinafter be described. Since sensor 10 is particularly applicable to sensing very high temperatures, it must be specially constructed to prevent bending and warpage of the sensor housing due to large thermal gradients therein. Conventional construction techniques, such as bolting, riveting and welding have proven unsatisfactory under extreme temperature conditions. Such construction techniques are further unsatisfactory in view of the thin housing walls. Diffusion bonding may, however, be employed to fuse the separate portions of the housing into a single structure.

It should further be noted that sensor 10 can basically be fabricated from three geometrically simple parts, two of which may be identical. The parts may have rectangular cross sections to simplify machining or other forming operations in high-temperature materials.

Since the minimum transverse dimensions of the housing are not limited by the minimum allowable spacing between the inlet nozzle and the knife edge, the housing may have relatively small transverse dimensions. This configuration allows the sensor housing to be made from a minimum amount of material, thus minimizing its thermal inertia. Further, the small size of the sensor permits it to be built into a probe which can, for example, be easily inserted into the combustion chamber of a gas turbine engine. In such an installation, the gas whose temperature is to be measured flows both outside and inside the sensor housing, thus substantially increasing the rate of heat transfer therefrom. Reducing the amount of material in the sensor housing and increasing the rate of heat transfer therefrom substantially decreases the second time constant in the transient sensor response. For example, whereas the second time constant associated with a typical prior-art fluidic temperature sensor is in the order of 1 minute, the second time constant associated with the applicant's present temperature sensor is in the order of 6—8 seconds. Accordingly, the applicant's temperature sensor offers greatly improved transient performance.

In applications where internal installation is not feasible or desirable, the fluid whose temperature is to be measured may be brought to the sensor, and alternate means provided for directing a portion of the fluid along outer surfaces of the sensor housing. Such means for improving the sensor transient response is shown in FIGS. 4, 5 and 6 in which the elements of the sensor shown in FIGS. 1, 2 and 3 are identified by like reference numerals. In FIG. 4, reference numeral 30 identifies a tubular jacket surrounding sensor 10 and mounted on mounting flange 27. Jacket 30 includes a fluid inlet 31 which is aligned with inlet nozzle 25. Fluid outlets 32 outside housing members 11 and 12 are provided in mounting flange 27. Jacket 30 is spaced from the housing of sensor 10 so as to provide fluid flow paths between inlet 31 and outlets 32 along surfaces of the sensor housing.

It will be noted that outlets 32 are relatively small. This provides for a positive pressure on the outside of the sensor housing. A slight positive pressure on the outside of the sensor housing is desirable, particularly if the housing walls are very thin, to prevent distortion of the housing and/or rupture of the bonded joints which would introduce errors into the sensor output signal.

A portion of the fluid entering inlet 31 also enters inlet nozzle 25. The fluid entering inlet nozzle 25 impinges on knife edge 21 and thereafter flows through the subchambers and exhausts through exhaust nozzles 33 and 34. Nozzles 33 and 34, which are formed by portion 18 of cavity 15 in housing member 12 and the corresponding cavity portion in housing member 11, are configured so as to provide choked flow therethrough with a minimum total pressure differential across the sensor. Choked flow through exhaust nozzles 33 and 34 is desirable because the pressure ratio across the inlet nozzle 25 is then constant and the sensor is thereby made insensitive to variations in the total pressure differential thereacross. The frequency of the sensor output signal is thus relatively independent of variations in pressure in the fluid supplied thereto.

It is frequently desirable to use sensor 10 directly in a fluidic system comprising conventional fluidic devices. Such devices require fluid signals having controlled low means pressure levels. Further, the oscillating signal must be extracted from sensor 10 without creating flow parallel to the exhaust nozzle flow since such parallel flow would disrupt the choked flow operation. This function may be accomplished by means of a quarter wave resonator 35 which communicates with exhaust nozzle 33 and is shown attached to mounting flange 27. Resonator 35 is tuned to the same frequency as the subchambers within sensor 10 and serves to enhance the oscillating signal transmitted thereinto. It will be noted that one of outlets 32 also terminates within resonator 35. This serves to maintain the fluid in resonator 35 at a temperature which approximates the temperature of the fluid entering sensor 10. Accordingly, the resonant frequency of resonator 35 is maintained near the resonant frequency of the subchambers for all temperatures of the fluid entering sensor 10.

It should be noted that although a quarter wave resonator is shown employed with sensor 10, other acoustically active control volumes are also equally suitable. For example, an open resonator having a length equal to any odd integral multiple of the quarter wave resonator length may be used. For purposes of this specification, an acoustically active control volume is defined as a volume which, because of its geometric dimensions amplifies a specific frequency spectrum and attenuates other frequencies.

A pickoff tube 36 is provided in communication with resonator 35 and serves to separate the acoustic intelligence, in the form of an oscillating signal, from the bulk fluid flow through the resonator. The oscillating signal in pickoff tube 36 may be transmitted to any suitable utilization device, normally a fluidic network, which is identified by reference numeral 37 in FIG. 4.

In other applications it may be desirable to employ sensor 10 directly with electronic utilization apparatus This can be accomplished as shown in FIG. 6 by making use of channel 19 which leads from the subchamber within member 12 to the outside of the sensor housing A large-magnitude, high-quality signal may be extracted through channel 19 by means of an infinite impedance (zero flow) electrical transducer. Reference numeral 38 identifies such a transducer which converts the oscillating pressure signal into an oscillating electrical signal having the same frequency. The electrical signal is amplified by means of amplifier 39 and transmitted to an electronic counter 40. Counter 40 then displays the frequency of the oscillating pressure signal produced by temperature sensor 10. This frequency is accordingly indicative of the temperature of the fluid within sensor 10. This electronic utilization apparatus is intended to be exemplary only. Many other forms of such apparatus are equally suitable.

It will be apparent that there may be substantial heat loss through jacket 30. If so, the temperature of the fluid flowing along the surfaces of sensor 10 will be lowered, which will in turn lower the housing temperature of sensor 10 and impair the accuracy of the output signal produced thereby. Heat loss through jacket 30 can be reduced by surrounding it with thermal insulation which is identified in FIGS. 4 and 5 by reference numeral 41. Jacket 30 and insulation 41 serve to maintain the excellent accuracy and fast time response of sensor 10 in installations in which the sensor cannot be mounted directly in the source of fluid whose temperature is to be measured.

I claim:

1. Temperature-responsive apparatus of the sonic oscillator type comprising:
housing means defining a substantially cylindrical chamber and an inlet nozzle aligned with a central axis, said housing means including a divider element aligned with a central axis and dividing the chamber into first and second substantially equal cylindrical subchambers longitudinally aligned respectively with first and second axes, the first and second axes each parallel to and spaced from the central axis, the divider element having a knife edge intersecting the central axis, oriented toward the inlet nozzle and spaced from the inlet nozzle by a distance suitable for achieving edge-tone oscillation of a fluid stream from the inlet nozzle about the knife edge, said housing means further defining first and second outlet nozzles configured to promote choked flow therethrough, said first and second outlet nozzles communicating respectively with the first and second subchambers.

2. The apparatus of claim 1 further including signal pickoff means comprising an acoustically active control volume in communication with a subchamber in said housing.

3. The apparatus of claim 1 including transient response improvement means comprising a jacket surrounding said housing means, said jacket having an inlet substantially aligned with said central axis and outlet means remote from said inlet, said jacket being spaced from said housing so as to provide fluid flow paths along outer surfaces of said housing.

4. The apparatus of claim 3 wherein thermal insulation is provided around outer surfaces of said jacket.

5. Fluid-responsive apparatus of the sonic oscillator type comprising:
housing means enclosing a chamber having an inlet nozzle aligned with an axis and an outlet nozzle configured to promote choked flow; and
a divider element located within the chamber and aligned with said axis so as to separate the chamber into subchambers, each subchamber having its maximum dimension substantially parallel to said axis, said divider element having a knife edge oriented toward and spaced from said inlet nozzle by a distance suitable for achieving edge-tone oscillation of a fluid stream from the inlet nozzle about the knife edge.

6. The apparatus of claim 5 including transient response improvement means for directing a fluid whose temperature is to be measured into said inlet nozzle and along outer surfaces of said housing.

7. The apparatus of claim 6 wherein said transient response improvement means comprises a jacket surrounding said housing means, said jacket having an inlet substantially aligned with said axis and outlet means remote from said inlet, said jacket being spaced from said housing so as to provide fluid flow paths along outer surfaces of said housing.

8. The apparatus of claim 5 further including signal pickoff means in communication with a subchamber in said housing and means connected to said signal pickoff means responsive to signals produced thereby.

9. The apparatus of claim 8 wherein said signal pickoff means comprises an acoustically active control volume in communication with a subchamber in said housing.

10. The apparatus of claim 8 wherein said signal pickoff means comprises an electrical pressure transducer in communication with a subchamber in said housing.