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(54) Vortex Shedding Fluid Flowmeter

(57) In order to improve the signal-to-noise ratio of the meter a bluff vortex shedding body (8) is provided with a concave upstream surface (20). The vortex sensors may be capacitance monitors comprising flexible metal plates (26), (27), mounted on side walls (21), (22) of the body adjacent to fixed plates (28), (30). Alternatively temperature sensitive or pressure sensitive sensors may be provided. The ratio of the radius (R) of curvature of the concavity to the width (*d*) of the body lies preferably between 1.4 and 2.5.

Fig 2

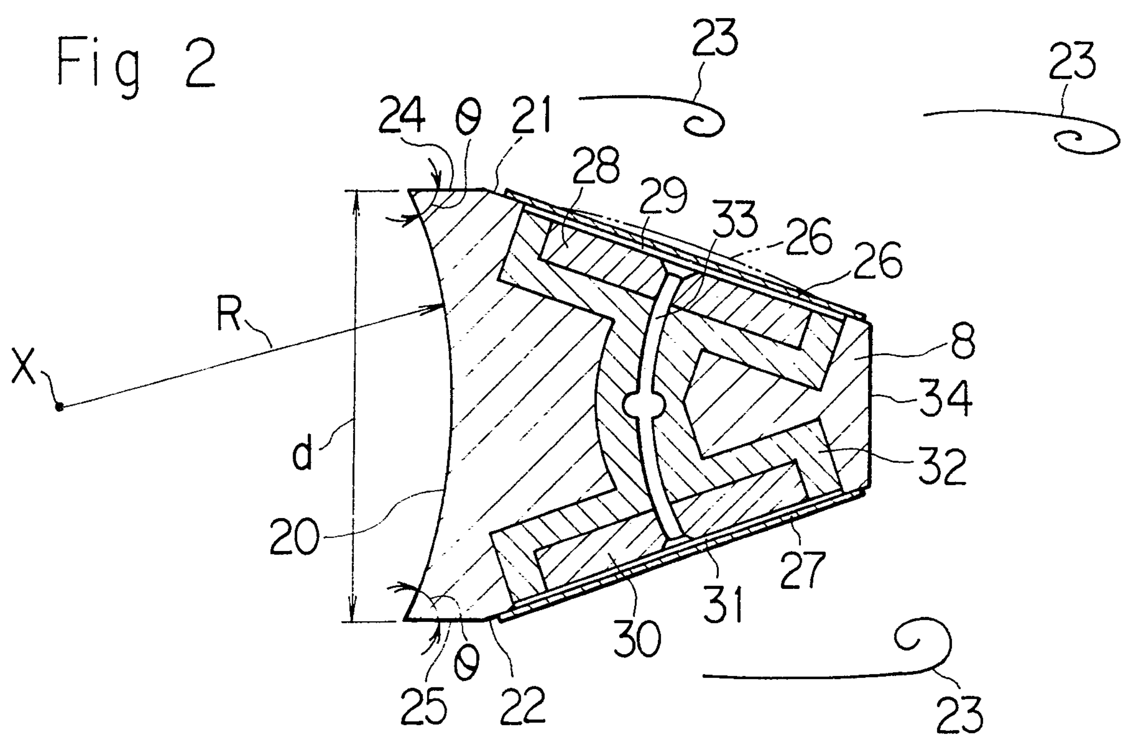

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Fig 1

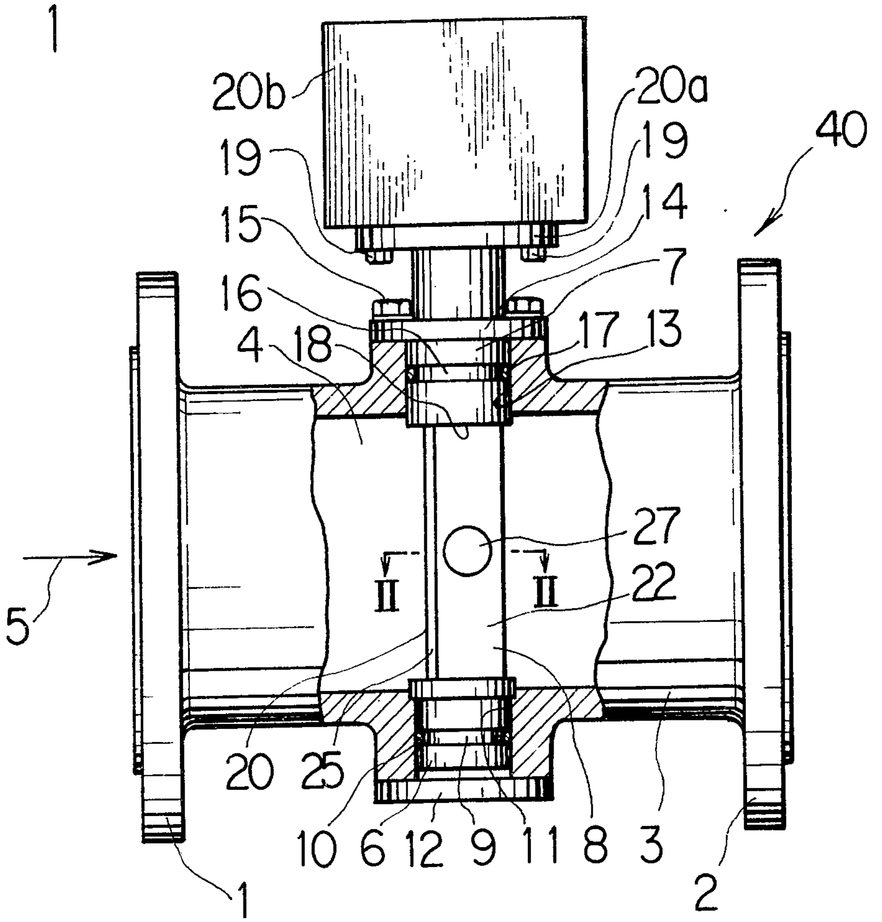

20b
20a
19
19
40
15
14
16
7
4
18
17
13
27
5
II
II
22
20
25
10
6
12
9
11
8
3
1
2

Fig 2

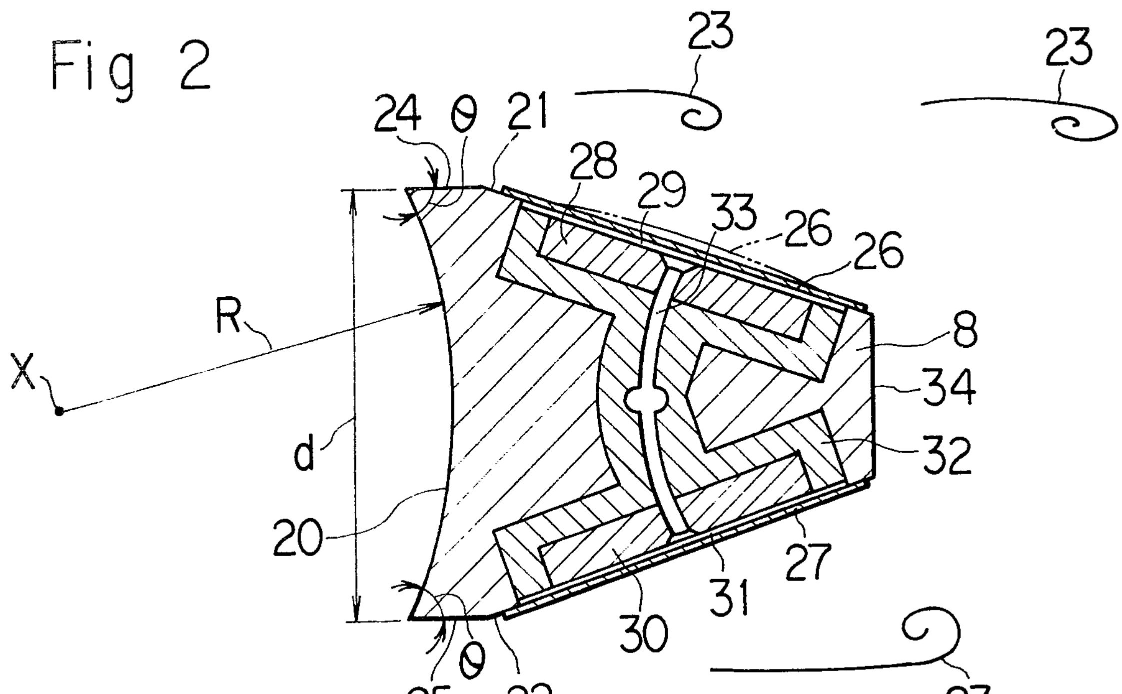

23
23
24
θ
21
28
29
33
26
26
8
R
X
34
d
32
20
27
31
30
θ
25
22
23

Fig 3

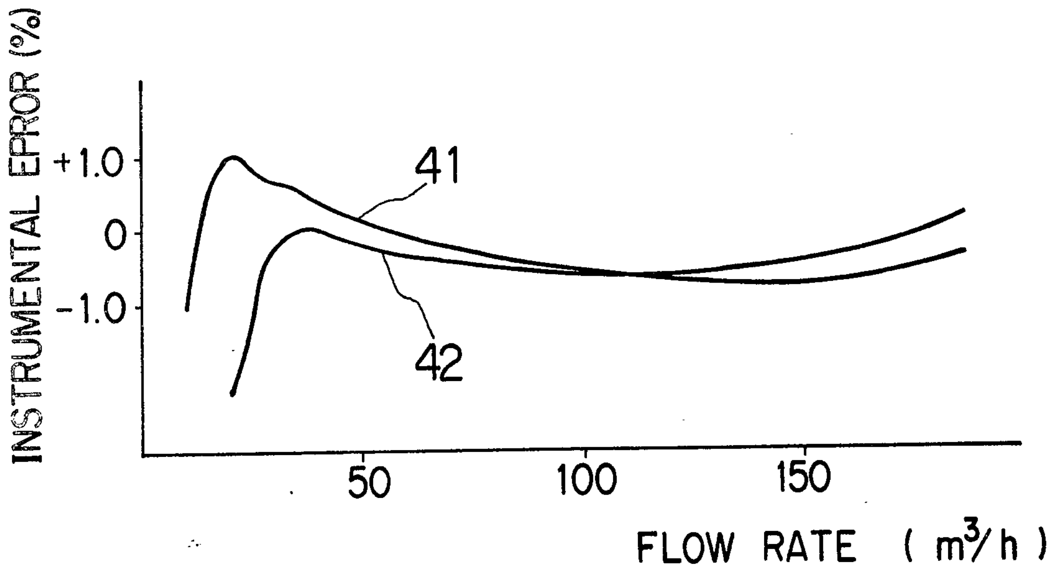

INSTRUMENTAL ERROR (%)
+1.0
0
-1.0
41
42
50
100
150
FLOW RATE (m3/h)

Fig 4

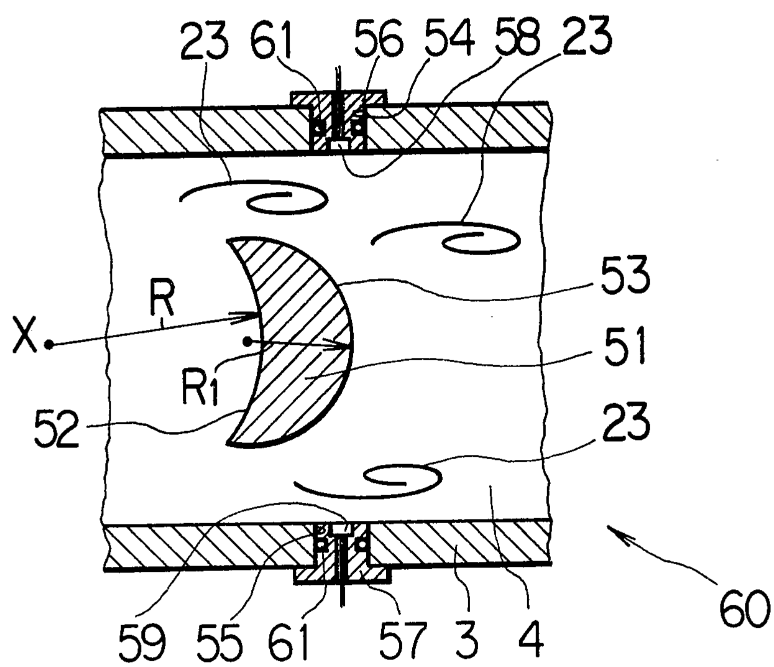
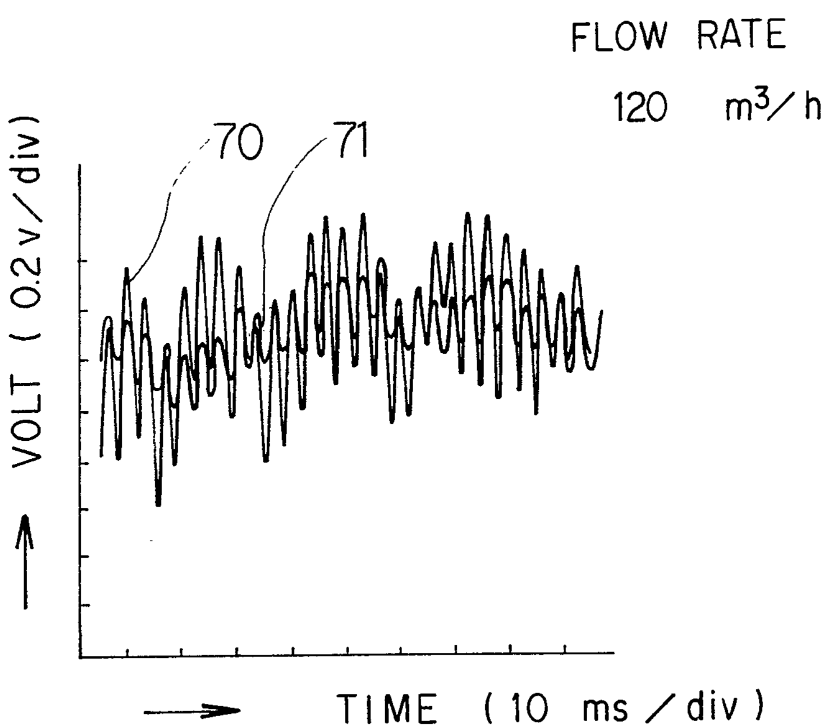

23 61 56 54 58 23
53
R
X
51
R1
52
23
60
59 55 61 57 3 4

Fig 5



SPECIFICATION

Detector for use in Measurement of Flow Speed or Flow Rate of a Fluid

This invention relates to a detector for use in measuring the flow speed or flow rate of a fluid in a flow channel based on the detection of the frequency or the number of Karman's vortex streats shed by a bluff body disposed in the flow channel.

A flowmeter for measuring the flow speed or flow rate of the fluid by the detection of Karman's vortex streets have been known. The flowmeter of this type is provided with a detector, as a sensor, comprising a bluff body disposed within a tubular member and a vortex detection device, for example, a temperature-sensitive element or pressure-sensitive element provided to the bluff body. It is required for such a detector that it can detect the vortex exactly for a long period whether the fluid to be measured is liquid or gas.

In a case where the fluid to be measured is a gas, effects given by the gas vortexes on the detection device are generally small, so that no sufficient signal to noise ratio can be obtained in a detector using a pressure-sensitive element or a movable electrode plate that directly senses the mechanical effects caused by the vortexes.

In addition, since the vortex detection element is mounted to the bluff body in direct contact with the fluid to be measured, dusts or the likes present in the flow channel are liable to be deposited to the vortex detection element. Such deposition of dusts may result in gradual reduction in the vortex-sensing performance of the vortex detection element, failing to obtain required signal to noise ratio long use.

Furthermore, the conventional bluff body can not shed so effective vortexes since they are formed, simply, in a prismatic, cylindrical or square post configuration, and the detector having such a bluff body can not obtain sufficient signal to noise ratio as well.

An object of this invention is to provide a vortex detector capable of obtaining detection signals at a desirable signal to noise ratio.

Another object of this invention is to provide a vortex detector capable of generating intense Karman's vortex streets and thus obtain accurate detection signals for the measurement of the flow speed or flow rate of gas or liquid.

Another object of this invention is to provide a vortex detector capable of obtaining detection signals with a level above a certain value for a long time.

A further object of this invention is to provide a vortex detector capable of decreasing the effects resulted from dusts or the likes and thus substantially eliminating the requirement for the maintenance works.

A still further object of this invention is to provide a vortex detector capable of improving the instrumental error characteristics and obtaining detection signals substantially exact over a wide range from low flow rate region to high flow rate region.

This invention is to be explained by way of preferred embodiments in conjunction with the accompanying drawings, by which these and other objects and features of this invention will be made more clear. However, this invention is no way limited only to those embodiments but those skilled in the art can take various modifications and changes within the scope of the appended claims, which are also encompassed in this invention.

Fig. 1 is a cross sectional view for a preferred embodiment according to this invention,

Fig. 2 is a cross sectional view of the preferred embodiment taken along line II—II in Fig. 1,

Fig. 3 is a graph showing the comparison for the instrumental error characteristics between the preferred embodiment shown in Fig. 1 and a conventional detector,

Fig. 4 is a cross sectional view for another preferred embodiment according to this invention, and

Fig. 5 shows electric signals obtained by the embodiment of Fig. 1 and conventional detector.

In Fig. 1 and Fig. 2, a circular tube housing 3 having flanges 1 and 2 on both ends defines a flow channel or a flow passage 4 therein and liquid or gas as a fluid to be measured flows in the direction of an arrow 5 within the flow channel 4. A bluff body for shedding Karman's vortex streets is generally of a prismatic configuration and supported to the housing 3 at both ends 6 and 7 thereof, respectively. An o-ring 10 is fitted into an annular recess 9 formed around the end 6 of the body 8. An aperture 11 formed in the housing 3, into which the end 6 is inserted, is closed bv a cover 12 attached to the housing 3 and the seal ring 10 closes the aperture 11 in a liquid- and gas-tight manner. The end 7 is passed through another aperture 13 formed in the housing 3, and a flange 14 clamped by bolts 15 to the housing 3 secures the body 8 to the housing 3 so that the body 8 may not be detached out of the housing 3. The end 7 is formed with an annular recess 16 in which an o-ring 17 is fitted, and the aperture 13 is closed in liquid- and gas-tight manner by the seal ring 17. A casing 20b is attached by bolts 19 to the flange 20a of the hollow end 7 whose lower surface 18 is closed, and the casing 20b contains electronic circuits comprising a bridge circuit, a differential amplifier or the like.

The body 8 passing through the axial center of the housing 3 across the flow channel 4 and extending in the diametrical direction thereof has a surface 20 which opposes to the upstream of the flow channel 4 and crosses in perpendicular to the direction of the arrow 5, and two surfaces 21 and 22 which oppose to the downstream of the flow channel 4 and cross slantwise to the direction of the arrow 5. The body 8 sheds Karman's vortex streets 23 in the fluid to be measured downstream of the surface 20 when the fluid flows in the direction of the arrow 5 in the flow channel 4. The surface 20 is concaved in II—II cross section, that is, in the transverse cross section, shown in Fig 1, and intense vortexes 23 are preferably shed in the case where the ratio R/d between the radius of curvature R of the concaved surface 20 to the center X and the lateral width d of the concaved surface 20 is within the range from 1.4 to 2.5. The surface 20 has substantially the same radius of curvature R in its transverse cross sectional over the entire longitudinal length. The lateral width d of the body 8 disposed in the housing 3 is shortended toward the downstream, that is, the width d of the body 8 in the transverse cross section is gradually narrowed from the upstream to the downstream.

The side surfaces 24 and 25 of the body 8 in continuous to the concaved side surfaces 20 are in parallel with the direction of the arrow 5 and each of them opposes to the inner surface of the housing 3. Each of the intersecting angle θ made between the surface 20 and 24 and the intersecting angle θ made between the surface 20 and 25 in the body 8 forms an acute angle since the surface 20 is a concaved surface. The surfaces 21 and 22 in continuous to the surfaces 24 and 25 respectively are mounted with metal diaphragms 26 and 27 as movable electrode plates respectively. The diaphragm 26 defines a chamber 29 in association with an opposing stationary electrode 28 and the diaphragm 27 defines a chamber 31 in association with an opposing stationary electrode plate 30. The electrode plates 28 and 30 are embedded in an electrical insulation member 32 which is secured to the body 8, and the electrode plates 28 and 30 are electrically insulated by the insulation member 32 from each other and from the body 8. Disc-like plates 26 and 28 form a capacitor and another disc-like plates 27 and 30 form another capacitor.

The chamber 29 and 31 communicated with each other by way of a passage 33 passing through the insulation member 32 and the electrode plates 28 and 30 and liquid is filled within the passage 33 and the chambers 29 and 31. When one of the diaphragms exposed to the flow channel 4, for example, the diaphragm 26 is deformed outwardly so as to increase the volume of the chamber 29 by the generation of the vortex streets 23, as shown by the dotted line in Fig. 2, the deformation is transmitted by way of the liquid filled in the passage 33 to the chamber 31, whereby the other diaphragm 27 exposed to the flow channel 4 is deformed in the direction opposite to the deforming direction of the diaphragm 26 so as to decrease the volume of the chamber 31. In this way, the diaphragms 26 and 27 are subjected to different deformations alternately by the generation of the vortex streets 23 repeatedly, in which the deformations in the diaphragm 26 causes the electric capacitance to be changed between the diaphragm 26 and the electrode plate 28 and, on the other hand, the deformation in the diaphragm 27 causes the electric capacitance to be changed between the diaphragm 27 and the electrode plate 30. Thus, the diaphragm 26 and the electrode plate 28, as well as the diaphragm 26 and the electrode plate 30 detect the generation of the vortex streets 23 as the changes in the capacitance respectively. The diaphragms 26, 27 and the electrode plates 28, 30 are respectively connected with each of the ends of the lead wires electrically, and the lead wires are introduced through the inside of the body 8 and the end 7 into the casing 20b and connected through the bridge circuit to the differential amplifier provided in the casing 20b. The electronic circuit for obtaining the changes in the capacitance as voltage signals or current signals by means of such bridge circuit and differential amplifier is well-known per se. The rear surface 34 of the body 8 in continuous to the surfaces 21 and 22 opposes the downstream crossing in perpendicular to the direction of the arrow 5.

In the detector 40 having the foregoing constitution, when a fluid flows in the direction of the arrow 5 in the flow channel 4, the Karman's vortex streets 23 are shed in the fluid by the body 8. The diaphragms 26 and 27 are deformed by the vortexes 23, and each of the vortexes 23 is detected as the changes in the electric capacitance between the diaphragm 26 and the electrode plate 28, and as the changes in the electric capacitance between the diaphragm 27 and the electrode plate 30. The changes in the capacitance are converted into voltage signals or current signals by the electronic circuit in the casing 20b. By the way, since the front surface 20 of the body 8 is concaved, the shedding of the vortexes 23 is ensured and the shed vortexes 23 are made powerful to provide greater deformation in the diaphragms 26 and 27 and, accordingly, make the changes in the capacitance relatively greater. As the result, the level of the amplitude of the voltage signals or the current signals corresponding to the generation of the vortexes 23 is made greater to improve the signal to noise ratio in the detection signals. Moreover, electrical detection signals having desired signal to noise ratio can be obtained even if the fluid to be measured is a low density fluid such as gas, since the vortexes 23 can surely be shed and are strong in the detector 40.

Further, the instrumental error in the low flow rate region can be decreased in the detector 40 as shown in Fig. 3. In Fig. 3, a curve 41 represents an instrumental error for the detector 40 and a curve 42 represents an instrumental error for a conventional detector, in which the instrumental error for the detector 40 is within $\pm 1.0\%$ even in the low flow rate region as compared with the conventional detector. The advantage referred to above is more enhanced by taking the R/d ratio within the range from 1.4 to 2.5. Additionally, since the diaphragms 26 and 27 of the detector 40 are attached to the side surface 21 opposing to the downstream, deposition of dusts or the likes on the diaphragms 26 and 27 can be decreased.

While the body 8 for shedding the Karman's vortex streets if formed as a prismatic configuration in the foregoing embodiment, the bluff body can alternatively be formed in the shape of a semi-circular post, that is, of a crescent post as shown in Fig. 4. In Fig. 4, a bluff body 51 disposed in the housing 3 has a concaved surface 52 with a radius of curvature R opposing to the upstream of the flow channel 4 and a convexed surface 53 with a radius of curvature R1 which is smaller than the radius of curvature R, the surface 53 opposing to the downstream of the flow channel 4.

The detection means may be provided, instead of to the bluff body, to the housing 3 as shown in Fig. 4. In the detector 60 shown in Fig. 4, cylindrical members 56 and 57 are inserted into apertures 54 and 55 formed in the housing 3 respectively, and pressure-sensitive elements 58 and59 comprising, for example, piezoelectric elements are mounted to the inner faces of the member 56 and 57 that oppose to the flow channel 4 respectively. The pressure-sensitive elements 58 and 59 disposed opposing to each other detect Karman's vortex streets 23 shed by the body 51 in the fluid as the changes in the pressure, which are then converted into electrical signals.

Instead of the pressure-sensitive elements referred to above, the detection elements 58 and 59 may be temperature-sensitive elements, for example, thermistors. In the use of the temperature-sensitive elements, the amount of heat dissipated from the elements which are previously heated and set to a predetermined temperature is changed by the generation of the vortexes, and the changes in the dissipation heat cause the temperature of the elements per se and, thus, the electrical internal resistance of the elements to be changed. The changes in the internal resistance are converted into electrical signals.

The members 56 and 57 are respectively fitted with seal rings 61 which close the apertures 54 and 55 in liquid- and gas-tight manner respectively.

The capacitor type detection means utilized in the detector 40 can also be applied to the detector 60, and the detection means such as of pressure-sensitive type, capacitor type and temperature-sensitive type may be provided to the body 51. On the contrary, detection means of the pressure-sensitive type and the temperature-sensitive type may be applied to the detector 40 and, in addition, the detection means may be provided to the housing 3 in the detector 40.

In Fig. 5, a curve 70 represents measuring values of a change in an internal electric resistance in a pair of thermistors taken out as electric signals, the thermistors being mounted as detection means instead of a pair of electrodes on the surface 20 in the detector 40, and the change in the internal electric resistance being caused by a generation of vortexes, a curve 71 represents measuring values of the electric signals issued from the thermistors which are mounted on a plane surface formed by leveling the surface 20 in same detector as the detector 40. As shown in Fig. 5, the detector 40 having a concaved surface 20 is capable of obtaining electric signals with large level in the amplitude.

Furthermore, while a pair of temperature-sensitive elements, a pair of pressure-sensitive elements or a pair of capacitor type detection means have been applied opposing to each other to the detector 40 or the detector 60 in the foregoing embodiments, only a single pressure-sensitive element, single temperature-sensitive or single capacitor type detection means may be provided to the detector 40 or 60. However, the provision of a pair of detection means is preferred since higher signal to noise ratio can be obtained in comparison with the single detection means.

Claims

1. A detector comprising a housing for defining therein a flow channel through which a fluid flows, a bluff body for shedding Karman's vortex streets in said flow channel, said bluff body being disposed within said housing and having a surface opposing to the upstream of said flow channel, said surface being concaved in the transverse cross section of said bluff body, and means disposed opposing to said flow channel for detecting the Karman's vortex streets shed in said fluid by said bluff body.

2. The detector according to claim 1, in which the ratio R/d between the radius of curvature R of said concaved surface opposing to the upstream and the lateral width d thereof of said bluff body is within a range from 1.5 to 2.5.

3. The detector according to claim 1, in which said housing comprises a circular tube.

4. The detector according to claim 3, in which said bluff body traverses said flow channel and extends through the center of said circular tube.

5. The detector according to claim 1, in which said bluff body has a generally prismatic configuration.

6. The detector according to claim 1, in which said surface has substantially the same concaved configuration in the transverse cross section over the entire longitudinal length of said bluff body.

7. The detector according to claim 1, in which the width of said bluff body in the transverse cross section is gradually narrowed from the upstream to the downstream.

8. The detector according to claim 1, in which said detection means is provided to said bluff body.

9. The detector according to claim 1, in which said detection means is provided to said housing.

10. The detector according to claim 8 or 9, in which said detection means comprises a movable electrode and a stationary electrode disposed opposing to said movable electrode, the electric capacitance between said movable electrode and said stationary electrode being caused to change by the displacement in said movable electrode resulted by the Karman's vortex streets.

11. The detector according to claim 8 or 9, in

which said detection means comprises a pressure-sensitive element.

12. The detector according to claim 8 or 9, in which said detection means comprises a temperature-sensitive element.

13. The detector according to claim 1, in which said bluff body has a generally prismatic configuration, said concaved surface being one of side surfaces of said bluff body, said detection means comprises two movable electrodes and two stationary electrodes, each of said movable electrodes being provided respectively to the side surfaces in continuous to said concaved surface, each of said stationary electrodes being provided in said bluff body and opposing to said movable electrodes respectively.

14. The detector according to claim 13, in which one of said movable electrodes and one of said stationary electrodes define first chamber therebetween, another of said movable electrodes and another of said stationary electrodes define second chamber therebetween, said first and second chambers are communicated with each other through a passage provided in said bluff body.

15. The detector according to claim 14, in which said chambers and said passage are filled with liquid.

16. The detector according to claim 1, in which said bluff body has a generally semi-circular post configuration, and said detection means is provided to the housing and opposes on the downstream of the flow channel.

17. A detector substantially as hereinbefore described with reference to and as shown by the accompanying drawings.

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