



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

Langley



DEC 21 1978

REPLY TO
ATTN OF: GP

TO: NST-44
~~XXX~~/Scientific & Technical Information Division
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 4,122,712

Government or
Corporate Employee : U.S. Government

Supplementary Corporate
Source (if applicable) : _____

NASA Patent Case No. : LAR-11,729-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

YES NO

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "...with respect to an invention of ..."

Bonnie L. Henderson

Bonnie L. Henderson

Enclosure



(NASA-Case-LAR-11729-1) FLUID VELOCITY N79-12359
MEASURING DEVICE Patent (NASA) 9 p
CSCL 20D

Unclas
00/34 39464

United States Patent [19]

Thomas, Jr. et al.

LAR-11,729-1

[11] 4,122,712

[45] Oct. 31, 1978

[54] **FLUID VELOCITY MEASURING DEVICE** 3,645,132 2/1972 Rasmussen 73/189
3,720,104 3/1973 Zanker 73/194
[75] **Inventors:** David F. Thomas, Jr.; Leon A. Williams, Jr., both of Hampton, Va. 3,785,203 1/1974 Mull 73/170
3,797,309 3/1974 Joy et al. 73/194

[73] **Assignee:** The United States of America as represented by the United States National Aeronautics and Space Administration, Washington, D.C.

Primary Examiner—Herbert Goldstein
Attorney, Agent, or Firm—Wallace J. Nelson; Howard J. Osborn; John R. Manning

[21] **Appl. No.:** 856,461
[22] **Filed:** Nov. 30, 1977

[51] **Int. Cl.²** G01F 1/32
[52] **U.S. Cl.** 73/189; 73/194 VS
[58] **Field of Search** 73/189, 194 VS, 194 B

[57] **ABSTRACT**
A fluid velocity measuring device which when placed in a freestream fluid flow causes vortices to be formed at a frequency proportional to the flow rate of the fluid. Sensors on the device generate electric signals with frequency proportional to the rate of vortex creation and with relative mean amplitudes indicative of fluid flow direction. Electric circuitry translates the electric signals into indications of fluid speed and direction.

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,452,594 7/1969 Dale 73/194

7 Claims, 6 Drawing Figures

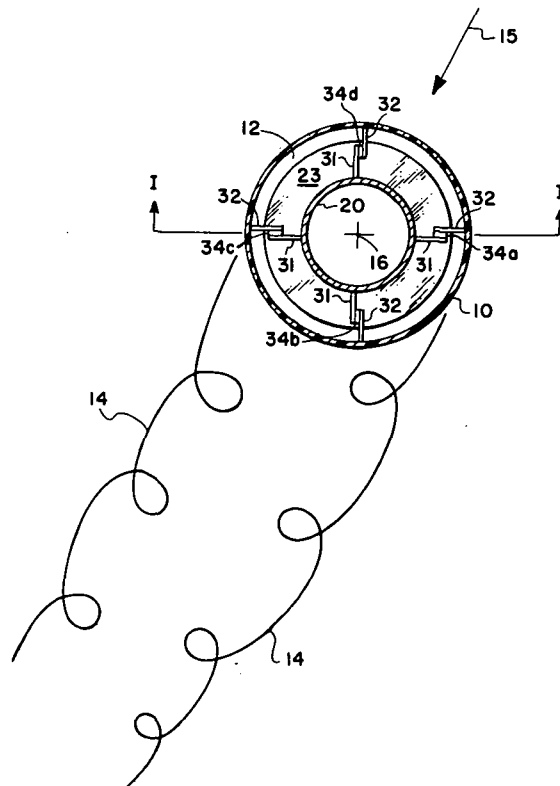


FIG. 1

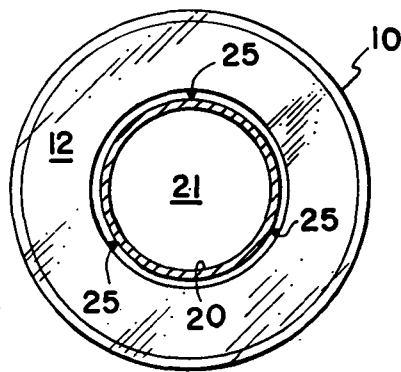
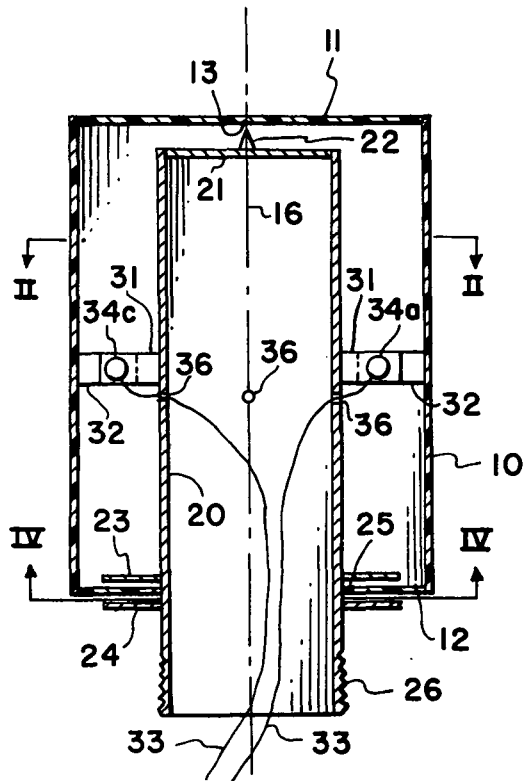


FIG. 4

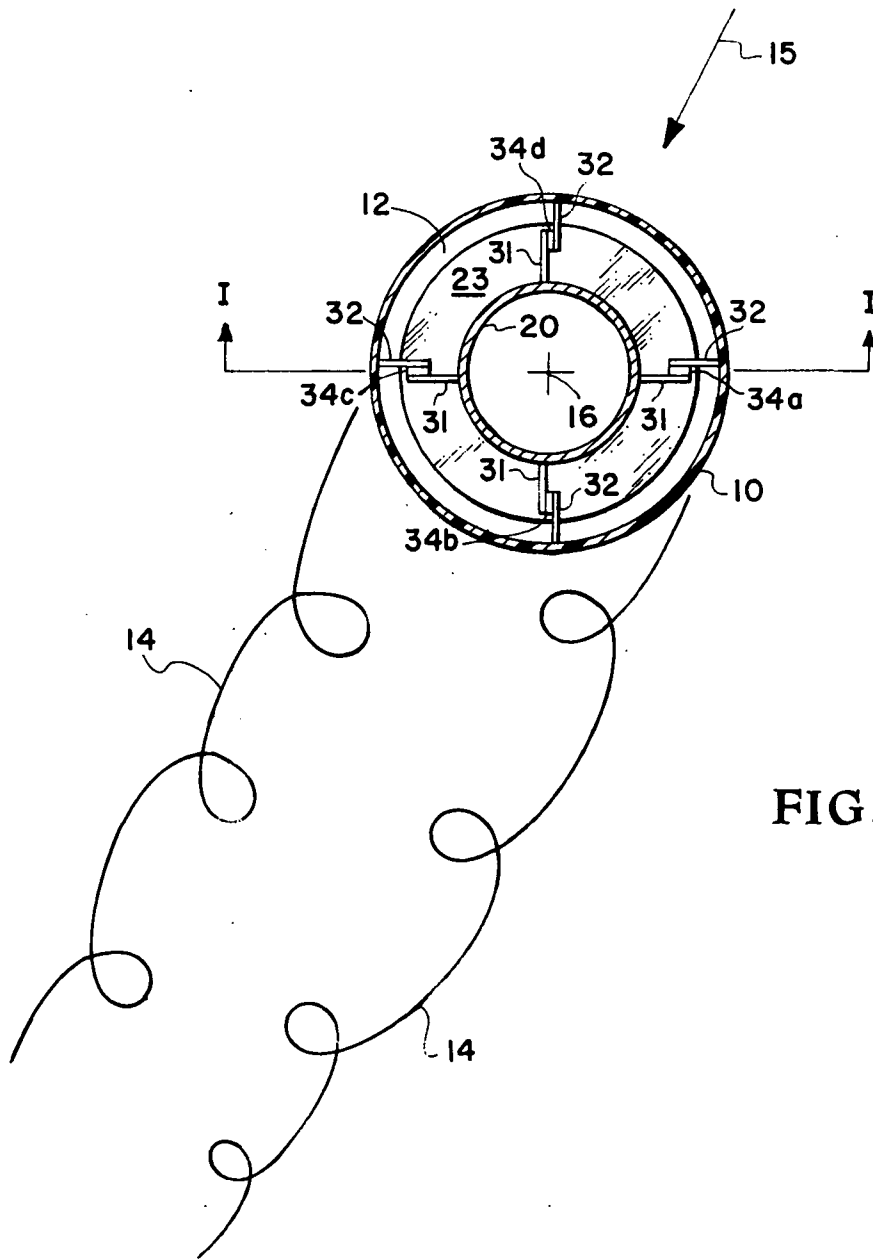


FIG. 2

FIG. 3

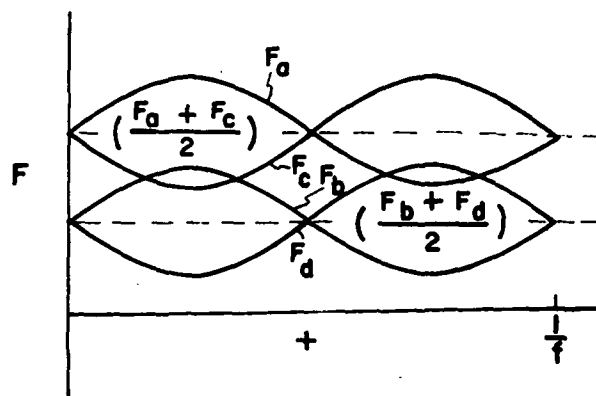
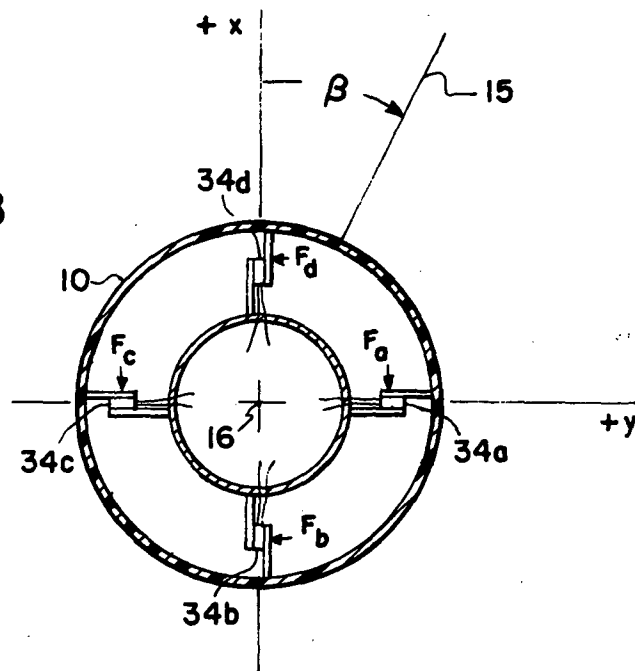


FIG. 5

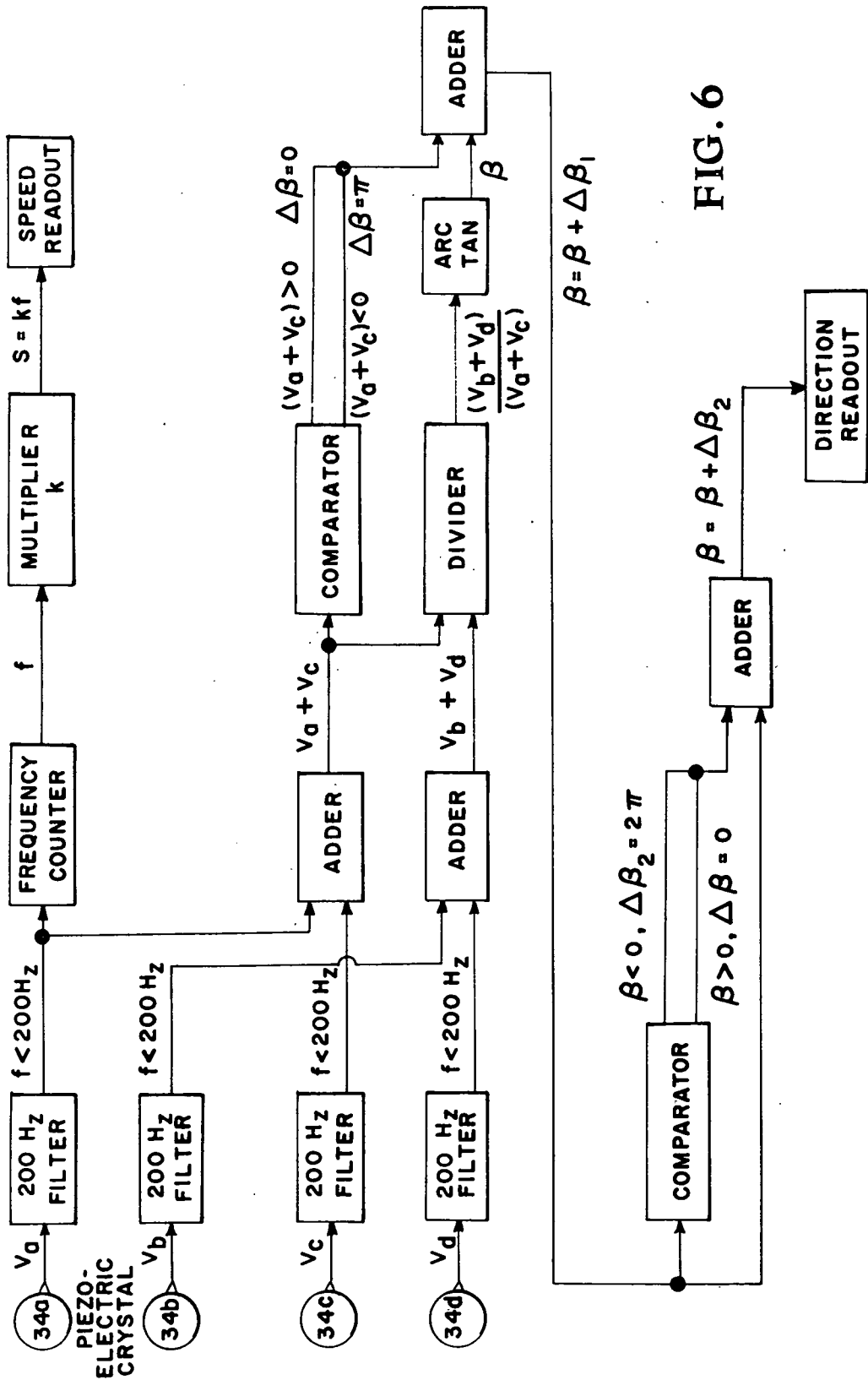


FIG. 6

FLUID VELOCITY MEASURING DEVICE

ORIGIN OF THE INVENTION

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the government for governmental purposes without payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention relates to a fluid velocity measuring device. More particularly, it relates to a fluid velocity measuring device wherein oscillating rotary forces on the device arising from the shedding of vortices created by the passing of a freestream of fluid around the device and translational drag forces on the device are detected by piezoelectric sensor crystals which create electric signals from which fluid velocity components of speed and direction are deduced by an electric circuit. Previously, the measurement of freestream fluid flow velocity was accomplished by the utilization of two separate instruments: one to measure flow speed, e.g. pitot-static tube, venturi tube, bridled pressure plate; and the other to measure flow direction, e.g. directional vane (wind vane, weather vane). The present invention measures freestream flow velocity with a single device.

The utilization of the vortex street phenomenon as an indication of fluid speed is well known in the prior art. When a body is placed in a stream of fluid flow with a Reynolds number between 10^2 and 10^5 , vortices are shed alternately from either side of the body at a frequency proportional to the speed of fluid flow.

The prior art, however, limits the application of the vortex street phenomenon to flow inside a conduit with the relationship between vortex creation frequency and fluid speed being dependent upon the conduit diameter. The present invention imposes no such requirement and may be mounted in a freestream of fluid such as the air for measuring wind velocities, or in a wind tunnel for measuring air stream perturbations created by aircraft wings and fuselages, or in the ocean or river for measuring water current velocities. The present invention measures vortex creation frequency at the point of creation whereas prior art devices counted the vortex creation frequency at a remote spot somewhat downstream. Downstream counting may lead to unacceptable accuracy since extraneous currents may induce error. Furthermore, downstream counting is impractical in a freestream since the counter would require repositioning for each change in fluid flow direction. One known device which utilizes temperature sensors to determine vortex creation frequency at the point of creation requires precision aligning and it is impractical for use in a freestream fluid. Some advantages of the present invention are, firstly, the consolidation of the functions of both of these types of instruments into one simple solid state device with no moving parts, and secondly, that both flow speed and flow direction can be measured at the same time at the same place.

An object of the present invention is a fluid velocity measuring device adapted to accurately measure freestream fluid flow speed and direction utilizing translational drag and vortex formation phenomenon.

A further object of this invention is a fluid velocity measuring device which yields the foregoing advantages and which also measures fluid flow speed and direction at the same time and at the same place.

A further object of this invention is a fluid velocity measuring device which yields the foregoing advantages and which is simply constructed and easy to operate.

Other objects and advantages of the present invention will be readily apparent from the following description and drawings which illustrate a preferred embodiment of the present invention.

SUMMARY OF THE INVENTION

The present invention involves a fluid velocity measuring device, positionable in a freestream of fluid flow to cause vortices to be created at a frequency proportional to the rate of flow, utilizing sensors to generate signals representative of fluid velocity, the frequencies of which are proportional to fluid flow speed and the amplitudes of which are indicative of fluid flow direction.

The device includes a housing mounted around a spindle fixed at one end to some reference structure. Bearings provide a low friction contact and alignment between the housing and the mounting spindle. Sensors are mounted between the housing and the mounting spindle to measure rotational forces caused by vortex creation and translational drag forces relative to the reference structure. The sensors generate electric signals which are translated into indications of fluid flow speed and direction by additional electric circuitry.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational sectional view of a fluid velocity measuring device as viewed along the line I—I of FIG. 2;

FIG. 2 is a plan sectional view taken along the line II—II of FIG. 1;

FIG. 3 is a plan view similar to FIG. 2 showing the direction of forces incurred by flow from angle β on force sensors;

FIG. 4 is a sectional view taken along line IV—IV of FIG. 1;

FIG. 5 is a graph of the relative magnitude of the forces of FIG. 3 as a function of time; and

FIG. 6 is a schematic diagram of the electrical circuit employed in the present invention and capable of interpreting electric signals into secondary signals proportional to the fluid velocity components of speed and direction.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring to FIG. 1, a fluid velocity measuring device includes a hollow cylindrical housing shell 10 enclosed on the top by an upper cover 11 and enclosed on the bottom by a lower cover 12 and positioned concentrically about a hollow cylindrical mounting spindle 20 having threads 26 for fixing to a reference structure and enclosed on the top by a spindle cover 21. The spindle 20, the shell 10, upper cover 11, lower cover 12, and spindle cover 21 share a common axis of symmetry 16. A pivot bearing 22 affixed to the upper surface of spindle cover 21 at the axis of symmetry 16 is accommodated by dimple 13 located on the bottom surface of upper cover 11 at the axis of symmetry 16.

Three point bearings 25 provide a low friction contact between spindle 20 and lower cover 12.

As shown more particularly in FIG. 4, the three point bearings 25 of the preferred embodiment are spaced at 120 degree intervals about spindle 20.

Substituting equations (3) and (4) into equations (9) and (10)

$$F_a + F_c = F_{TDa} - F_{VS_c} + F_{TD_c} + F_{VS_c}$$

or,

$$F_a + F_c = F_{TDa} + F_{TD_c} \quad (11)$$

and,

$$F_b + F_d = F_{TD_b} - F_{VS_d} + F_{TD_d} + F_{VS_d}$$

or,

$$F_b + F_d = F_{TD_b} + F_{TD_d} \quad (12)$$

Substituting equations (1) and (2) into equations (11) and (12) respectively,

$$F_a + F_c = 2F_{TD} \cos \beta \quad (13)$$

$$F_b + F_d = 2F_{TD} \sin \beta \quad (14)$$

Dividing equation (14) by equation (13),

$$\frac{F_b + F_d}{F_a + F_c} = \frac{2F_{TD} \sin \beta}{2F_{TD} \cos \beta}$$

or,

$$\frac{F_b + F_d}{F_a + F_c} = \frac{\sin \beta}{\cos \beta} = \tan \beta \quad (15)$$

Taking the arc tangent of both sides of equation (15)

$$\beta = \arctan \left(\frac{F_b + F_d}{F_a + F_c} \right) \quad (16)$$

And, for identical crystals 34a, 34b, 34c, and 34d which generate voltages V_a , V_b , V_c and V_d , respectively, equally proportional to force thereon, equation (16) can be rewritten

$$\beta = \arctan \left(\frac{V_b + V_d}{V_a + V_c} \right) \quad (17)$$

The direction, β , of freestream flow 15 is given by equation (17) in terms of the measurable quantities V_a , V_b , V_c , and V_d . The fluid speed S is proportional to the vortex creation frequency, f , and is determined by the simple relationship

$$S = kf \quad (18)$$

where k is a constant (≈ 0.19).

FIG. 6 is a schematic of a simple electric circuit for performing equations (17) and (18). The force induced crystal voltage signals are first filtered, eliminating all frequencies above 200 cycles per second, to preclude the passage of structural material resonance frequency signals. Fluid speed, S , is calculated by taking any one of the filtered signals (V_a is used for purpose of illustration of FIG. 6), feeding it into a frequency counter and multiplying the resulting frequency signal by a constant,

k , to obtain the fluid speed, $S = kf$. The calculated speed signal is at this point fed to a speed readout.

The fluid direction equation (17) is calculated in the remainder of the circuit of FIG. 6. V_a is added to V_c and V_b is added to V_d . Thus $(V_b + V_d)/(V_a + V_c)$ is taken to find β . Since the arc tangent function only yields values from $+90^\circ$ to -90° an additional test must be performed to determine if a correction must be made to obtain the true angle β . If $(V_a + V_c) > 0$, angle of incidence β is left as calculated, but if $(V_a + V_c) > 0^\circ$, 180° is added to β . The true angle β has been determined at this point. However, it will have a value from -90° to 270° and since it is preferable to have values between 0° and 360° , β is now tested and corrected by adding 360° thereto. The fluid flow direction signal is at this point fed to a direction readout.

The above described fluid velocity measuring device is constructed primarily of metallic material. However, the shell 10, upper cover 11, and lower cover 12 are plastic for the purpose of minimizing material resonance frequency signals in the electric circuit. The use of these materials in the preferred embodiment is not intended to limit the present invention thereto, and any suitable material may be used alternatively.

The above described fluid velocity measuring devices utilizes piezoelectric sensor crystals to sense vortex creation frequency and translational drag force in a freestream of fluid flow. It is understood that other electric sensing devices capable of generating signals having frequency proportional to vortex creation frequency and amplitudes representative of fluid flow direction, including strain gauges and induction coils but not excluding others, may also be employed.

The above description and drawings are only illustrative of one embodiment which achieves the objects, features, and advantages of the present invention, and it is not intended that the present invention be limited thereto. All modifications of the present invention which come within the spirit and scope of the following claims are considered part of the present invention.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A fluid velocity measuring device positionable in a freestream of fluid flow to cause vortices to be shed therefrom at a frequency proportional to fluid flow speed, said device comprising:

a housing mounted on a spindle;
said housing being capable of oscillatory rotary motion about said spindle induced by, and at a frequency indicative of, the periodic shedding of vortices therefrom; said housing being further capable of translational motion relative to said spindle induced by, and indicative of the direction of, said freestream fluid flow;
said spindle fixable at one end to a reference structure and extending into said housing;
bearing means providing low friction contact and alignment of said housing with said spindle;
force sensing means attached between said housing and said spindle capable of generating an electric signal indicative of said vortex creation frequency and indicative of the direction of translational drag force on said housing by said fluid flow; and
electric circuitry for translating said electric signal into a readout of fluid speed and direction.

2. A fluid velocity measuring device as in claim 1 wherein said force sensing means includes four sensors positioned at 90° intervals around said spindle.