(12) UK Patent Application (19) GB (11) 2 120 792 A

(21) Application No **8214671**
(22) Date of filing **20 May 1982**
(43) Application published **7 Dec 1983**
(51) **INT CL^3 G01F 1/28**
(52) Domestic classification **G1R** BE QA **U1S** 1259 G1R
(56) Documents cited **GB 1415109**
(58) Field of search **G1R**
(71) Applicant
Rowland Oliver,
5 Caerleon Drive,
Andover,
Hants
(72) Inventor
Rowland Oliver
(74) Agent and/or Address for Service
Rowland Oliver,
5 Caerleon Drive,
Andover,
Hants

(54) Measuring fluid flow

(57) A flow meter comprises a flexible elongate inelastic ligament 9 fixed at its upper end 18. The other end is wound on to a circular drum 2. The ligament is maintained under tension by a spring 10 acting on the drum via a cam on the drum. The fluid medium acts upon the ligament causing it to bow into the shape of a catenary curve and to unwind from the roller. An index mark is provided on the ligament and is arranged to move over a scale on the meter casing 1. The cam profile is designed to linearise the relationship between ligament wind-off and velocity.

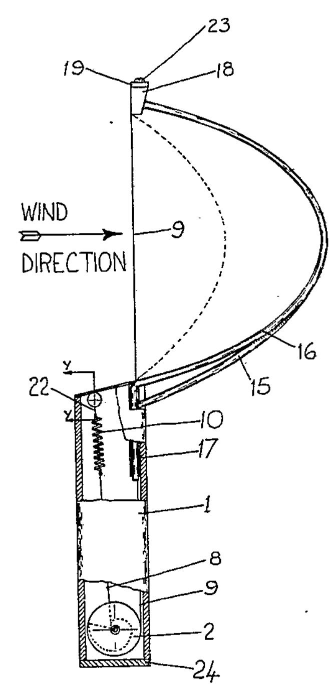

FIG 2

GB 2 120 792 A

2120792

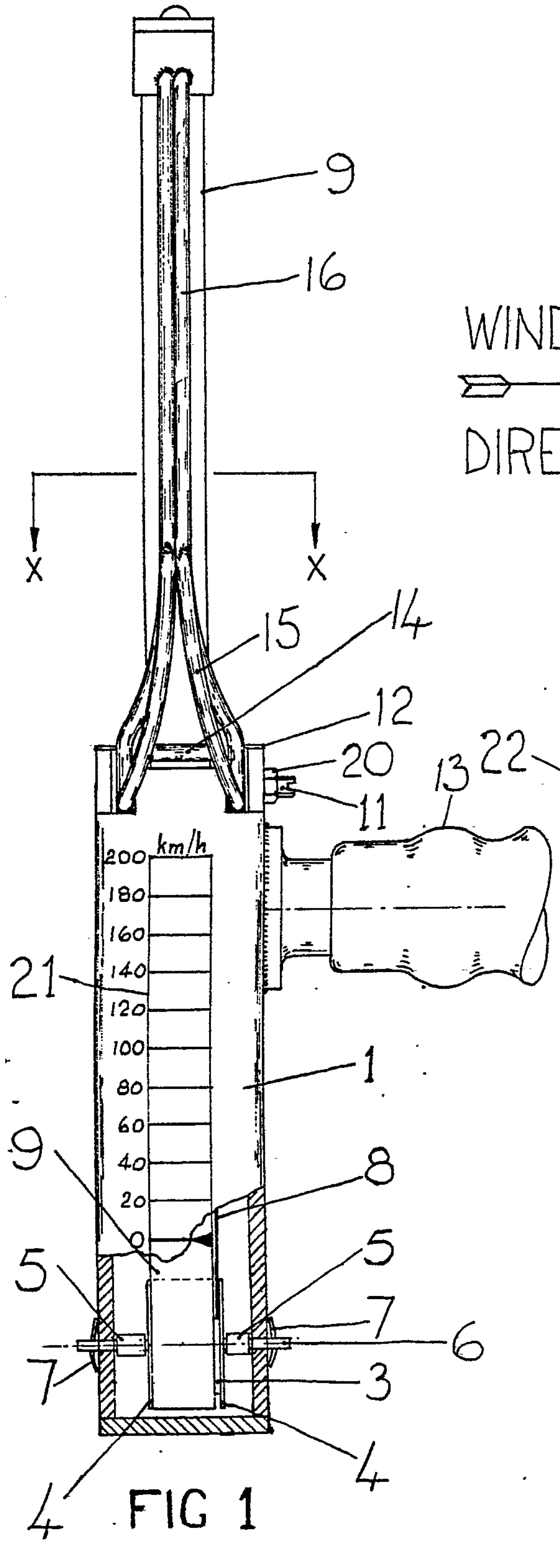

FIG 1

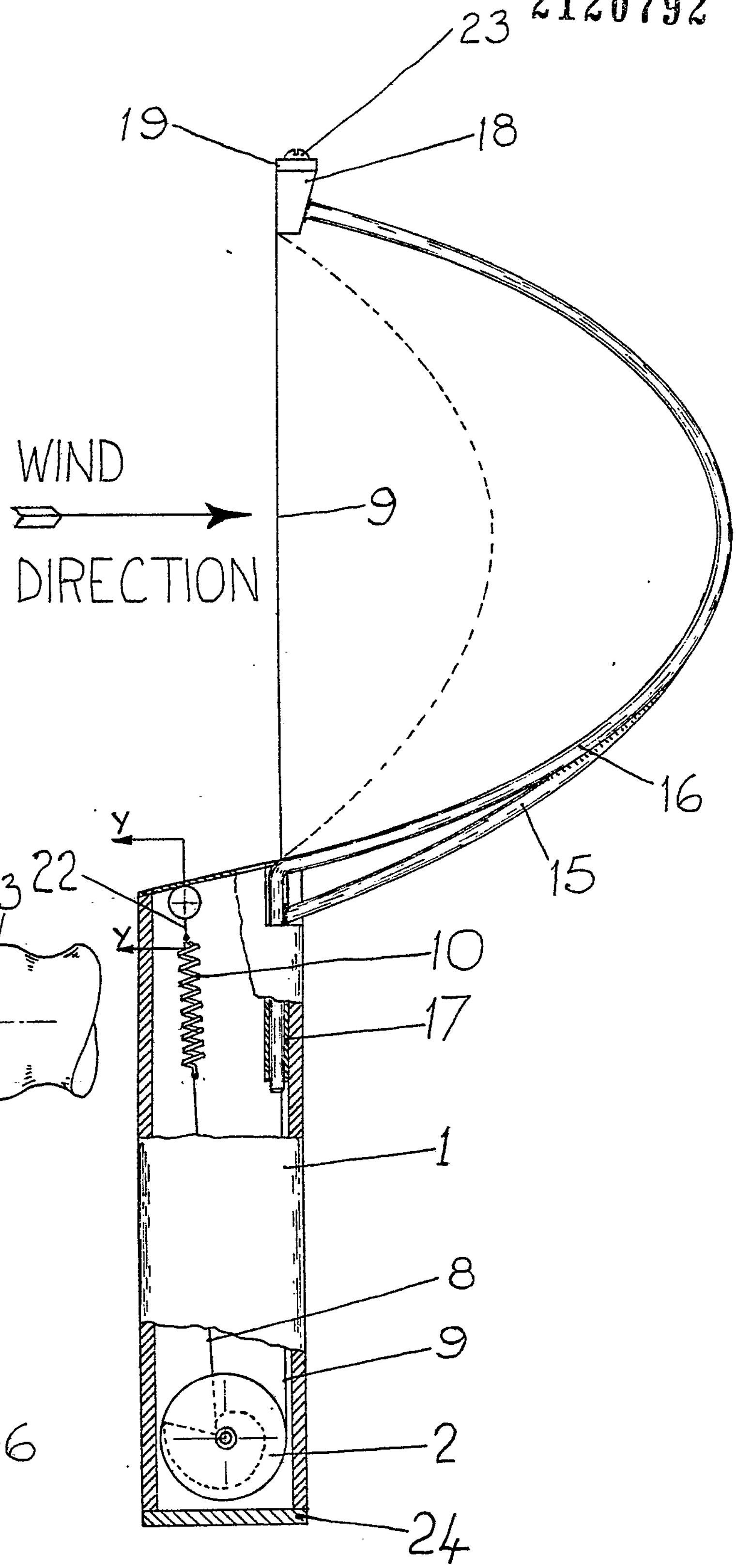

FIG 2

2120792

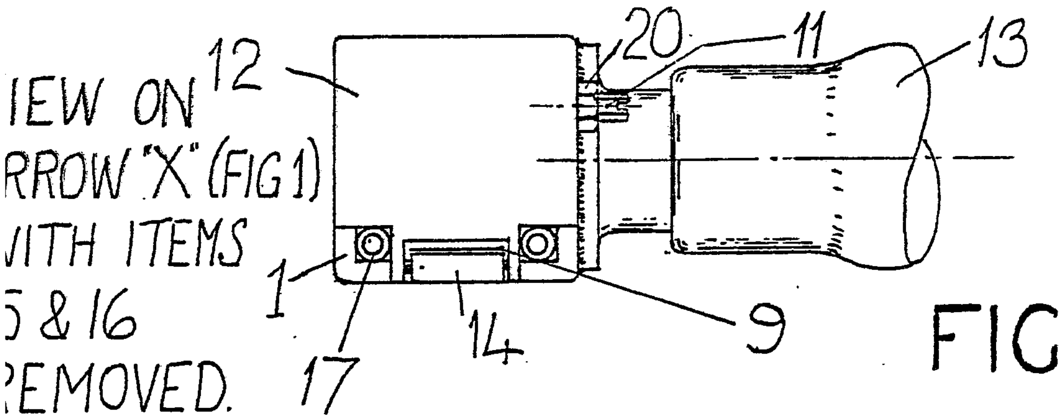

FIG 3

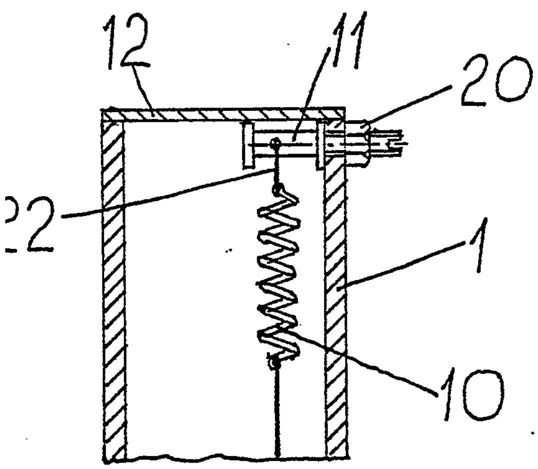

FIG 4 (SECTION Y-Y FIG 2)

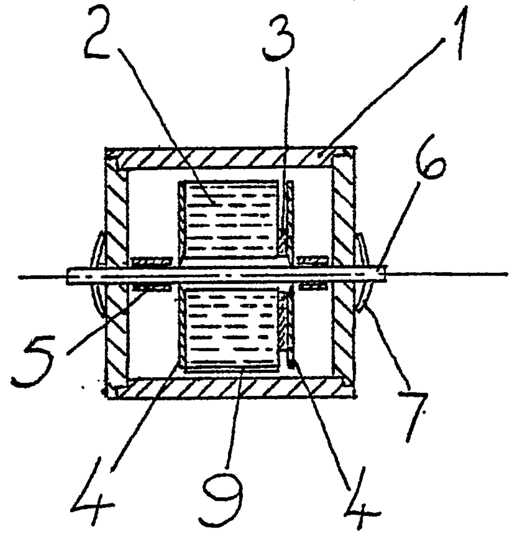

FIG 5 (SECTION Z-Z FIG 1)

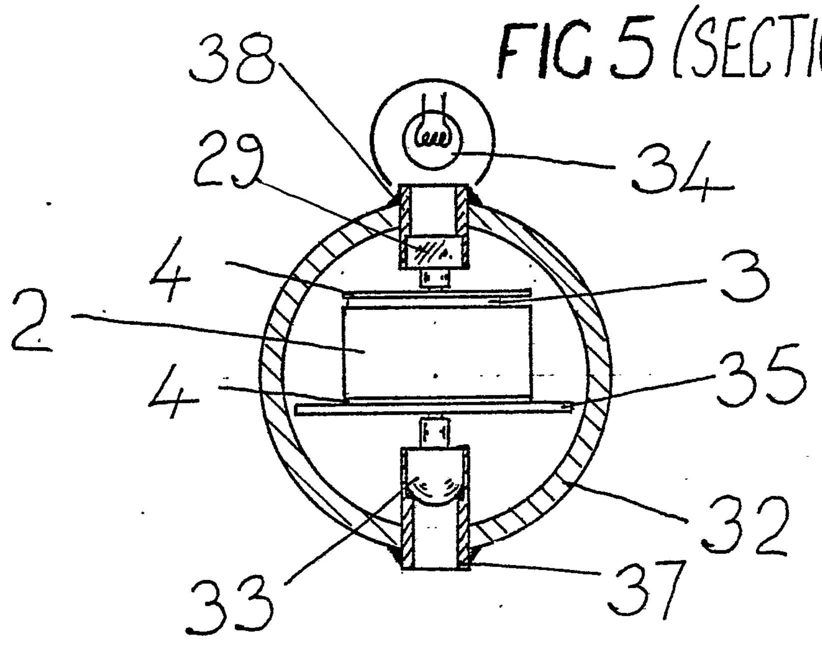

FIG 6 (SECTION A-A FIG 7)

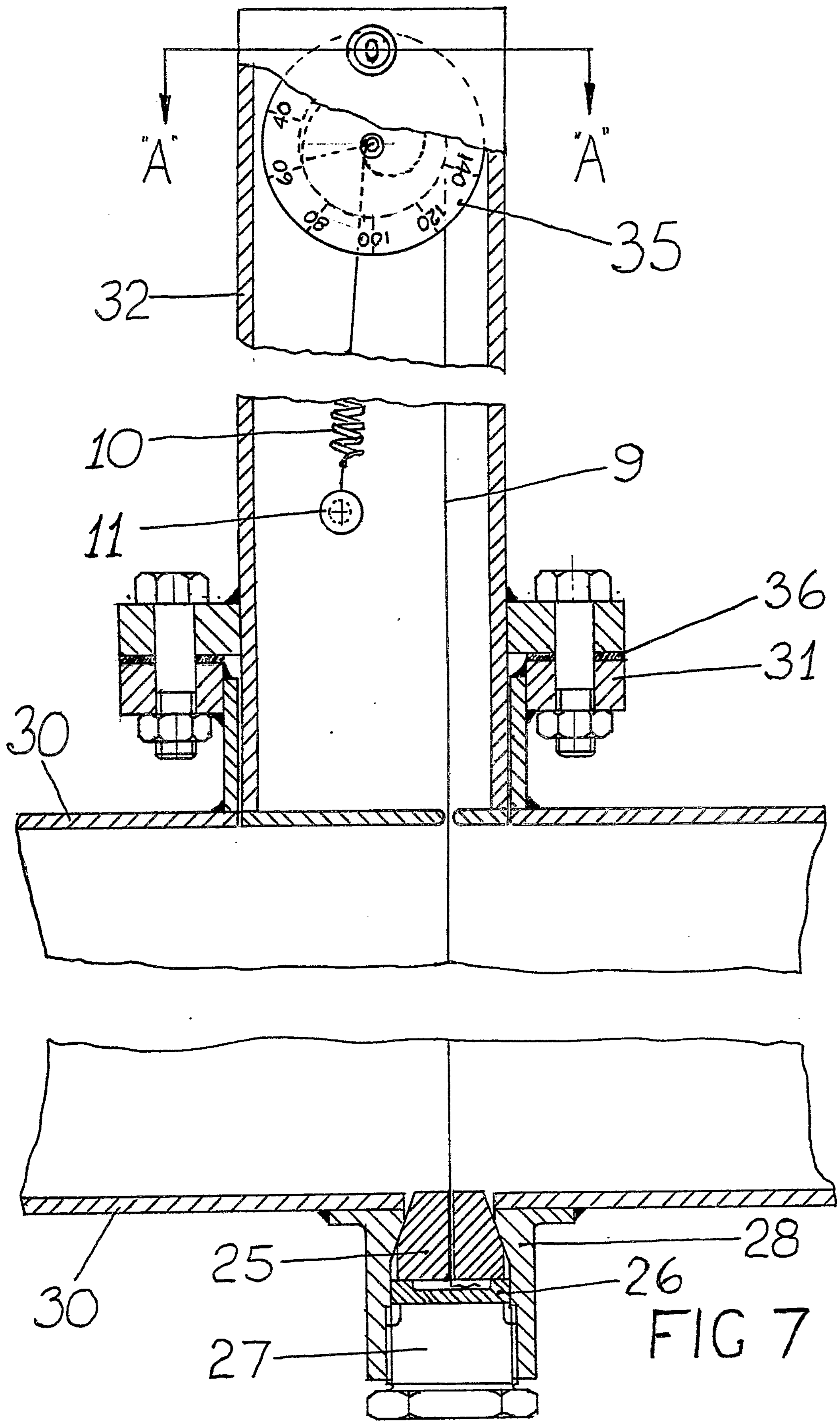

FIG 7

SPECIFICATION

Flexible ligament flowmeter

This invention relates to the field of flow measurement. Fluids may flow in pipes, in totally or partially enclosed ducts or freely as in the open air. Flow of water in a river can be likened to flow in a partially enclosed duct of varying cross section.

The flow rate of a fluid in a pipe is the integrated velocity of the individual stream-lines which make up the total velocity profile across the pipe. As the velocity profile changes with Reynolds number, the accuracy of measurement depends both on the ability of the flowmeter to effectively integrate the velocity profile and on the nature of the flowing conditions.

Because the nature, composition and condition of fluids can vary widely, numerous flow measuring techniques have been devised, each technique having particular benefits and limitations. The selection of the most suitable device for a particular application, therefore, demands not only a clear specification of the objectives and requirements, but also an understanding of the limitations of each device.

Fluid flow is generally taken to mean the flow of gases or liquids, which generally behave according to the so called Newton formulation of the Shear stress $\tau=\mu\partial v/\partial \gamma$, but may also encompass the flow of non-Newtoman fluids such as molasses and other viscous media or of slurries composed of solid particles suspended in a liquid medium.

Flowmeters can be conveniently split into the following categories:

a. Those which are predominantly used for the measurement of flow volume such as positive displacement flowmeters (rotary piston, oval gear, sliding vane, reciprocating piston or flexible bellows meter) or mechanical inferential flowmeters (vane, fan or paddle rotors to turn an output shaft coupled to a mechanical counter).

b. Those which are predominantly used for the measurement of flow rate such as differential pressure devices (orifice plates, venturis, dall tubes, variable area meters etc.).

c. Those which are widely used for both flow rate and flow volume measurement. These devices are uaually flow rate devices which maintain an essentially linear output within a small error deviation over a sufficiently wide flow range to permit accurate measurement of flow volume. Typical dual function devices are electromagnetic, turbine or Pelton wheel, vortex and ultrasonic flowmeters.

This invention would come under category c. above. Most inventions of flow indicating devices using deflection of a member, relate to the deflection of a metal cantilever in a flowing fluid with various ways of relating deflection to fluid velocity. Such devices are described in Patent Specifications 1252433, 1194187, 830211, 988822, 1099451 and 1241389.

This invention relates to the indication and measurement of fluid flow, particularly, but not exclusively, to the measurement of wind velocity in the open air but other uses envisaged are for the measurement of fluid velocity in flow passages such as ducts or pipes. The present invention comprises a flexible elongate inelastic element or ligament fixed at one end, its other end being attached to a drum mounted on a spindle carried in a housing means and interposed between the fixed end and the drum, a fixed roller over which the ligament is free to move lengthways so that when the portion of the ligament between the fixed end and the fixed roller is subjected to a flow such that it is deflected by the dynamic pressure thereof, the deflection causes rotation of the drum thus bringing the biassing and resisting means into action until equilibrium is reached. Equilibrium occurs when the torque exerted by the tension in the ligament about the centre of rotation is balanced by an equal and opposite torque exerted by the biassing and resisting means. A mark on the ligament aligned with a zero mark on a fixed scale on the housing means at zero flow, will move along the scale as the fluid velocity increases, each equilibrium position representing a unique velocity.

The terms flexible elongate inelastic element or ligament are being used broadly to cover elements of twisted natural or synthetic fibres, monofilaments, narrow bands or tapes and fine chains. The ligament nust be light and strong, polyester film being the most obvious choice of material for general use in this device.

When held upright in still air the ligament is straight due to a slight residual tension exerted by the resisting means, but when the wind blows the ligament is deflected into a curved shape approximating a catenary. The deflection is proportional, though not linearly, to the fluid (wind) velocity. The measurement of fluid (wind) velocity relies upon the fact that the ligament is deflected, or, more precisely upon the difference between the length of the straight ligament under zero flow condition and the length of the curved ligament under flow conditions.

The additional length of ligament necessary to allow for this curving or bowing is wound onto the drum and attached to the biassing and resisting means, the assembly rotating freely on the spindle. The resisting means may take several forms but here is in the form of a coil spring attached to the biassing means by a strong thread, so as to apply an opposite torque about the centre of rotation to that applied by the ligament. The amount of deflection of the ligament due to its bowing under fluid pressure is measured by the movement of a mark made on the straight part of the ligament over a stationary scale marked on a transparent wall of the housing means. The force exerted by the flowing fluid on the ligament is approximately proportional to the square of the fluid velocity. By applying this force to a catenary curve and obtaining an expression for equilibrium with the resisting means it is possible to design a biassing means so that the vertical scale on the casing can be calibrated linearly. The biassing means therefore, in this invention, takes the form of a cam whose profile is generated from the same centre of rotation as for the drum, the maximum radius of cam being arranged to be diametrically opposite the point of attachment of ligament to the drum.

In the example of the invention described here, it is necessary to provide the fixed support for the remote end of the ligament by attaching a frame to the housing means or body of the device, in order that the whole device may be self contained but most cases, where fluid velocity is required to be measured, occur in pipes or ducts so that the wall of the pipe or duct may provide the support required for the end of the ligament.

The advantages of this invention are as follows:—

a) by suitable choice of coil spring rate for the biassing means and by varying the width of ligament, a large range of flows of fluids of different properties can be measured.

b) the active length of ligament in the self contained device can be varied to suit various applications. For measurement of flow rate in a pipe or duct, however, the active lenght of ligament will normally correspond with the pipe diameter or depth of duct.

c) the device will cause a very low pressure loss in the flowing fluid unlike orifice plates which cause relatively large pressure drops and which therefore cannot be used where fluid pressure cannot be sacrificed.

d) the device integrates turbulent velocity profile across the diameter of the pipe or duct thus giving bulk mean velocity, as compared with insertion turbine meters in large pipes, which measure only the velocity on a stream line.

e) The velocity or volume flow can be read directly from the position on the ligament relative to the fixed scale on the housing means. Direct measurement of velocity is not possible with orifice plates, venturi-meter or dall tubes. It is only possible with vortex and ultrasonic flowmeters to obtain direct measurement of velocity by means of sophisticated electronics whereas the present invention is a simple mechanical device.

f) The device can be produced relatively cheaply.

g) Installation of the device into an existing pipe or duct can be readily and cheaply effected by attaching small metal pads to diametrically opposite sides of the pipe, threading the ligament across the pipe, screwing the housing means into a pad and finally attaching the remote end of the ligament to the opposite pad. The very least that is required by other devices is the fitting of two flanges to the pipe and interposing the device between the flanges.

h) Calibration and adjustment of the device initially and during service is straightforward, simply by holding the device horizontally and placing a pre-determined weight on the centre of the active part of the ligament to produce a mid-scale deflection, or adjusting the resisting means until mid-scale deflection is obtained. For pipe applications a dummy remote support would be needed for calibration purposes.

i) By suitable design of the housing means and the method of scale reading, the device can be used for a large range of fluid pressures.

The invention may be carried into practice in various ways, and one embodiment will now be described by way of example, with reference to the accompanying drawings, of which:—

Figure 1 is the rear elevation of the device, partially sectioned to show internal details.

Figure 2 is the side elevation of the device also partially sectioned to show internal details.

Figures 3, 4 & 5 are auxiliary views to clarify the various details not shown in figures 1 & 2.

In figures 1 & 2 the elongate element 9 is shown as a broad ligament or tape disposed in a straight line between drum 2 and remote support 18. When the part of the ligament external to the housing means (the active part) is acted upon by the wind, it will bow into a catenary curve shown dotted thus causing the drum to rotate anti-clockwise as viewed in figure 2. Thread 8 which at its lower end is attached to the centre of the cam 3, is attached to coil spring 10 at its upper end, which in turn attaches through a short thread 22 to an anchoring and adjusting pin 11. Pin 11 is attached to the side wall of housing means 1, and locked by nut 20. The cam constitutes the biassing means and the coil spring and anchor pin, the resisting means. As the drum rotates anti-clockwise, thread 8 winds onto the cam until the product of spring force and movement arm about the centre of rotation is exactly equal to the ligament tension multiplied by the drum radius. The mechanism is then in equilibrium and the wind velocity will be registered on transparent scale 21 on the rear face of the housing means 1 shown in figure 1, by the position of the arrow on the ligament relative to the fixed scale.

Two side plates 4 provide ground knife-edges bores shown in figure 5, so that when attached concentrically to drum 3 and cam 4, the assembly will rotate on the spindle 6 with negligible friction. The profile of cam 4 is shown chain dotted inside the drum outline on figure 2. Distance pieces 5 locate the drum centrally between the sidewalls of the casting 1, whilst spring clips 7 lock the spindle in position.

Roller 14 in figures 1 & 3, provides free rolling support for the ligament as it winds on and off the drum, whilst struts 15 and 16 form a rigid structure, attached at their lower ends to the casing by sliding into tubes 17, see figures 2 and 3, and their upper ends being rigidly fixed into the ligament remote support. By means of retention plate 19 and screw 23 the ligament can be fixed at its upper end, and can be adjusted before fixing to give a zero scale at zero flow. Then, adjusting 22 & 8, in order to balance the whole mechanism prior to use. A handgrip 13 is attached to the casing sidewall in order that the complete instrument may be held forward at arms length and the scale reading noted whilst the ligament is bowed by the wind pressure.

Item 12 closes the top of the housing means against ingress of dirt and moisture whilst plate 24 closes the bottom.

The possible applications of this invention are so varied as to make the choise of a best mode very difficult. The embodiment described above is seen as applying specifically to the leisure industry where it could be used by yatchsmen, hang glider pilots, and others, whilst an abvious practical application would be for the measurement of wind speed at weather stations.

However, the most prolific field of flow measurement known to the inventor exists on chemical and petrochemical plant, natural gas pipeline networks, water conservancy and distribution networks and so on. Figure 7 shows a typical example of a pipleine application, where the main mechanism is mounted on the top of the pipe to prevent foreign matter passing along the pipe with the fluid, from collecting in the housing. With the mechanism inverted as shown in figure 7 compared with figures 1 and 2, the weight of the resisting means, spring 10, and the weight of the ligament 9 enter into calculations of torques but can be made by correct design to have negligible affect on the accuracy of the instrument. A split tapered collect 25, sealing washer 26 and securing cap 27 are used to lock the lower end of the ligament into the pipe fitting 28 previously welded to pipe 30. On the diametrically opposite side of the pipe, pad 31 has been welded to the pipe to provide an appropriate mounting face for the housing means 32, which can be retained by two or more nuts and bolts. A different method of reading velocity is proposed since the vertical scale on the housing means in the previous embodiment is not very convenient in a pipe application. The circular face of the drum is therefore used in this embodiment, see figure 6, to indicate velocity by means of back lighting 34 shining through a piece of toughened glass 29 mounted in radially disposed tube 38 welded to the casing.

Diametrically opposite is magnifying lens 33 mounted in tube 37 which is also welded to the casing. The light from 34 shines through translucent disc 35 attached to the drum, the disc being marked with equi-angular graduations to indicate velocity. Glass 29 and lens 33 are sealed in their respective tubes to render the casing 32 pressure tight when attached to the pipe 30.

A sealing washer 36 is interposed between the device and pipe pad 31 to prevent leakage of fluid from the pipe and the design of the housing means with drum spindle, reading lens and back light is such as to allow the device to withstand whatever internal pressure is in the pipe.

It is obvious that there is no limit to the diameter of pipe or duct that can be spanned by a ligament and so a wide variety of near ambient pressure application is envisaged, such as behind filters used in the air intakes of large centrifugal/axial compressors in order to sense when the filters become dirty and the velocity behind the filter therefore falls. By correct choice of ligament material the device can be used to measure velocity along a large gas turbine exhausts, a problem hitherto unsolved in the field. It is anticipated that if an electric signal is required from the device when used as part of an anti-surge control mechanism on centrifugal and axial compressors, the rotation of the drum can be conveniently converted into such a signal.

Obviously such a signal could also be used to give a reading of fluid velocity in the pipe, remote from the instrument in a central control room.

CLAIMS

1. A flow indicating and measuring device comprising a flexible elongate inelastic element or ligament, a portion of which, when immersed and appropriately supported in a flowing fluid, will deflect into a curve between the supports under the dynamic pressure of the fluid.

2. The combination according to claim 1, whereby the ligament is attached at one end to a fixed support and intermediate between the fixed end of the ligament and the free end is placed a nearly frictionless fixed support or roller, over which the ligament is free to move lengthways within the constraint imposed by a biassing and resisting means. The ligament is attached at its free end to the periphery of a cylinder or drum concentrically mounted on a spindle on which it is free to rotate. As the drum rotates, the ligament is wound on or off the drum.

3. The combination according to claims 1 and 2, whereby the biassing means comprises a cam rigidly attached to an end face of the drum and having the same centre of rotation, a strong thread being attached at one end to a point at or near the centre of the cam, the other end of the thread attaching to the resisting means. The cam is designed and mounted in such a way that as ligament winds off the drum, thread winds on to the cam and vice versa.

4. The combination according to claims 1, 2 and 3, whereby the thread, attached at one end to the cam, is attached at its other end to a resisting means in the form of a coil spring, the remote end of which in turn, attaches to an adjuster, providing the fixed restraint for the resisting means.

5. The combination according to claims 1, 2 and 3, whereby a housing means provides a rigid structure for mounting the ligament, the fixed and roller supports, the drum and cam on a common spindle, the biassing and resisting means and for maintaining the relative positions of the fixed parts. The housing means also encloses all the parts except the active portion of the ligament, i.e. that portion which is subjected to the flowing fluid. The positioning of the fixed roller within the housing means determines the length of active portion of the ligament. The material of the housing means adjacent to the ligament is transparent and a scale is marked thereon. A predetermined mark on the ligament can be observed to move along the scale as ligament winds on or off the drum, thus providing a quantitative measure of fluid velocity, mass flow or other appropriate fluid transport property. The invention is characterized by the flexible ligament and the method by which an increasing tension is applied to it as it deflects under the dynamic pressure of a flowing fluid, so that a particular fluid velocity an equilibrium position is reached between ligament deflection and the tension applied by the resisting means to limit that deflection.

6. The combination according to claim 5 with the role of the drum and the cam reversed, whereby the drum, instead of being cylindrical, now becomes a cam and the cam becomes a circular disc. In this configuration, the ligament winds on and off the cam and the thread winds on and off the periphery of the circular disc.

7. The combination according to claim 6, but with the resisting means being provided by a spiral spring instead of a disc, thread and coil spring. The spiral spring will have the outside end attached to the housing means and the inside end to an end face of the cam.

8. The combination according to claims 5, 6 or 7, except that the housing means no longer provides the restraint for the fixed end of the ligament. The

housing means may be attached to a duct or pipe with a slot to allow passage of the ligament and the remote wall of the duct or pipe provides the fixed support for the end of the ligament.

9. The combination according to claim 8, except that drum rotation is converted to an electrical signal for remote reading of the fluid property required, or for use as a signal to trigger some other device.

10. The combination according to claims 5, 6, 7, 8 or 9, except that the ligament may be supported on two or more fixed rollers appropriately spaced under the active portion of the ligament.

11. The combinations substantially as herein before described, with reference to the accompanying drawings.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1983.
Published at the Patent Office, 25 Southampton Buildings, London WC2A 1AY, from which copies may be obtained.