(12) UK Patent Application (19) GB (11) 2 155 635 A

(43) Application published 25 Sep 1985

(21) Application No 8503131

(22) Date of filing 7 Feb 1985

(30) Priority data
(31) 8403145 (32) 7 Feb 1984 (33) GB

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(51) INT CL[4]
G01F 1/32 G01P 5/01

(52) Domestic classification
G1G EE PH

(56) Documents cited
GB A 2125549 GB 1478279 EP A1 0042433
GB 1569125 GB 1384105

(58) Field of search
G1G

(54) **Monitoring fluid flow**

(57) In a vortex flowmeter sonic signal transmitter 4 transmits an ultrasonic signal towards the stream of vortices 3, generated in the fluid which is preferably a liquid. A sonic signal receiver 5 detects the sonic signal after transmission through the vortex stream. Processing means (see Fig. 4) senses any changes in phase between the transmitted and detected signals and provides an output relating to fluid flow through the meter.

The transmitter and receiver transducers comprise piezoelectric crystals mounted in blind holes 6 in the pipe wall 1 and encased in a potting material 9.
The inner wall 7′ of the pipe may be modified to provide a constant thickness between the transducer and the fluid.

Fig.1.

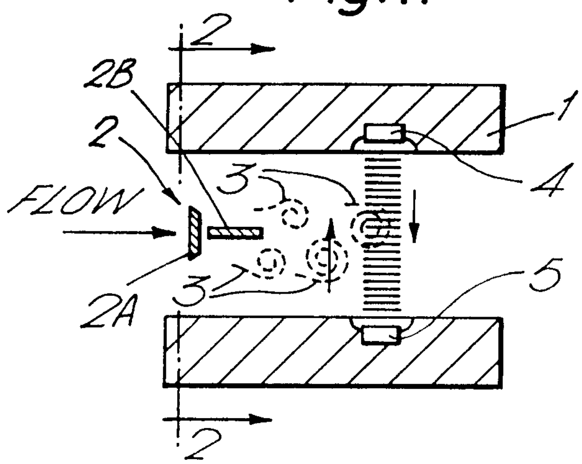

Fig.3B.

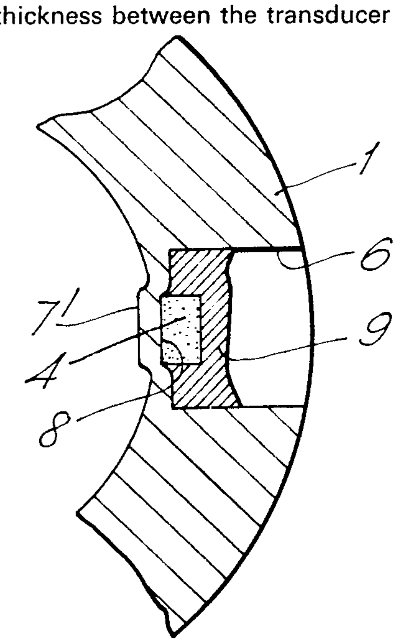

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Fig.1.

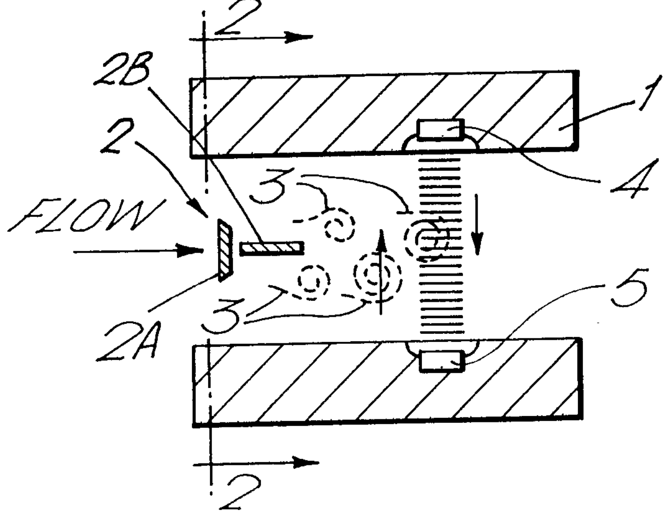


Fig.2.

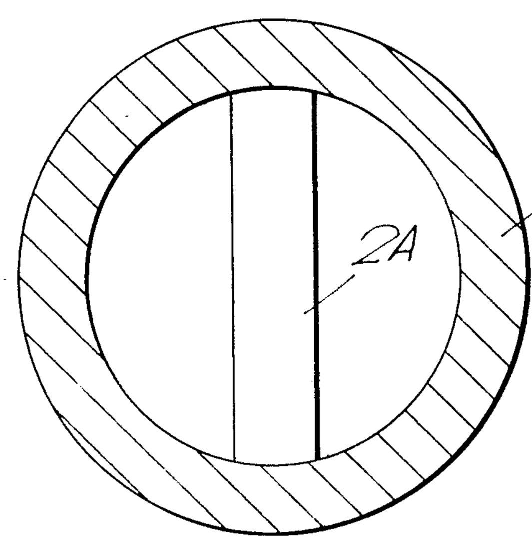


Fig.3A.

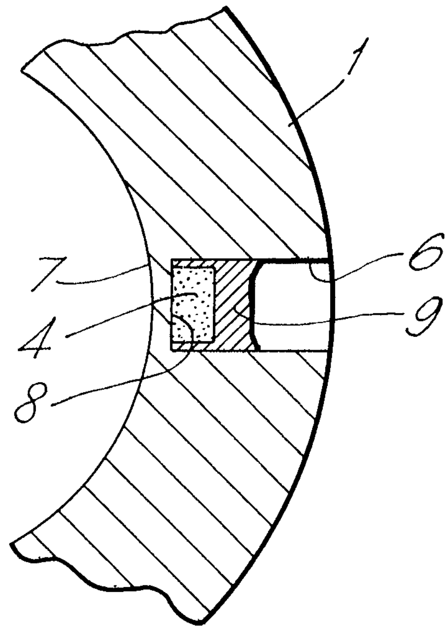
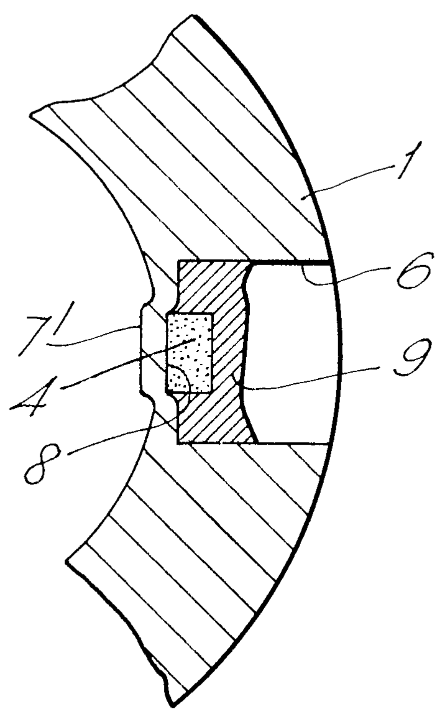


Fig.3B.



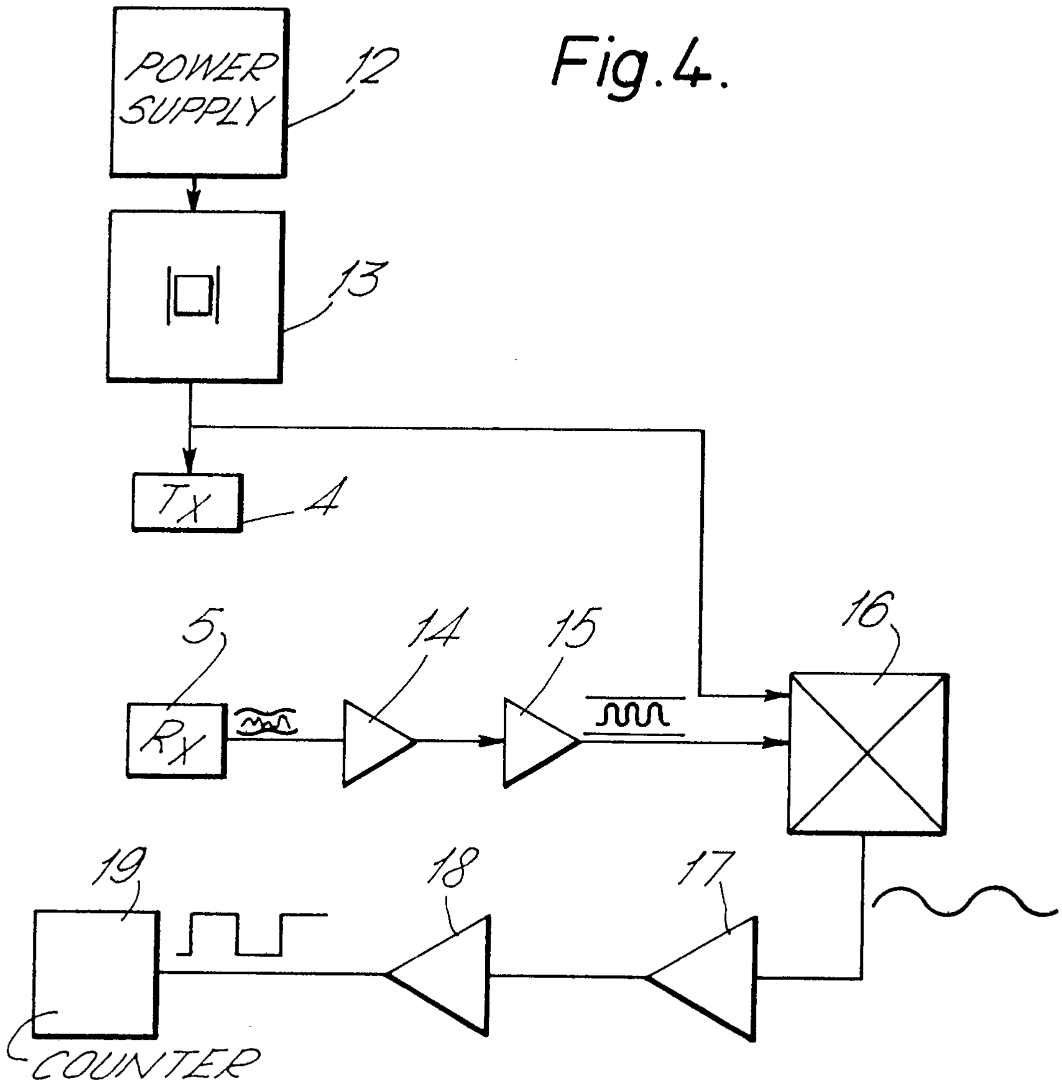

POWER SUPPLY
12
13
TX
4
5
RX
14
15
16
19
18
17
COUNTER

Fig.4.

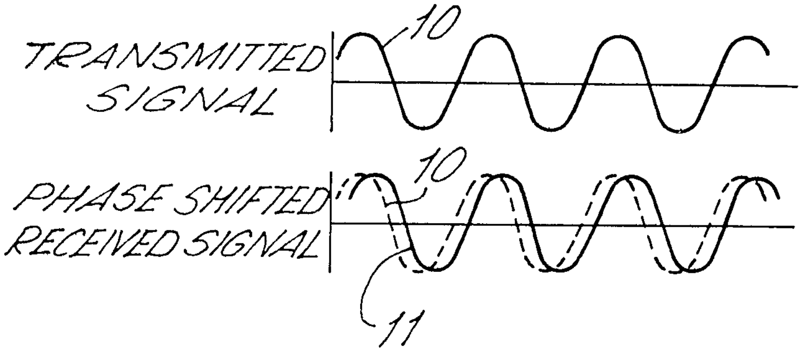

TRANSMITTED SIGNAL
10
PHASE SHIFTED RECEIVED SIGNAL
10
11

Fig.5.

Fig.6.

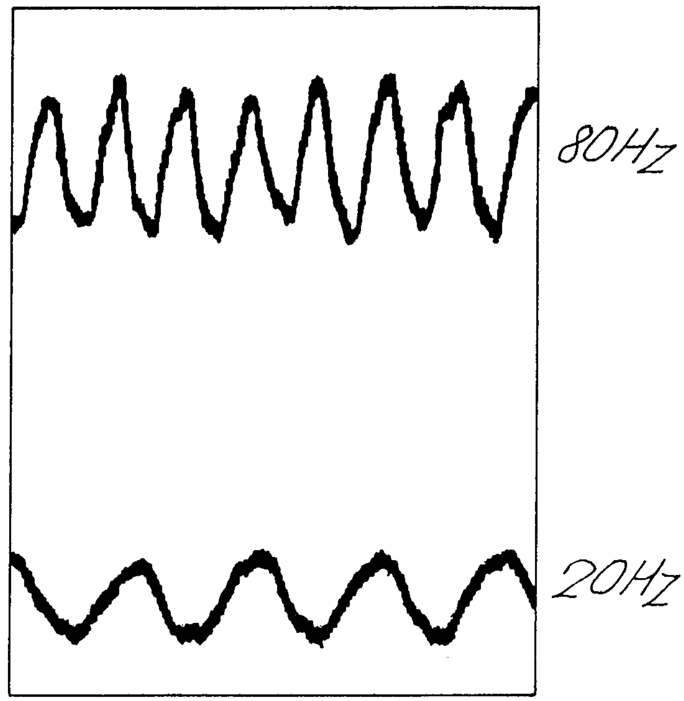
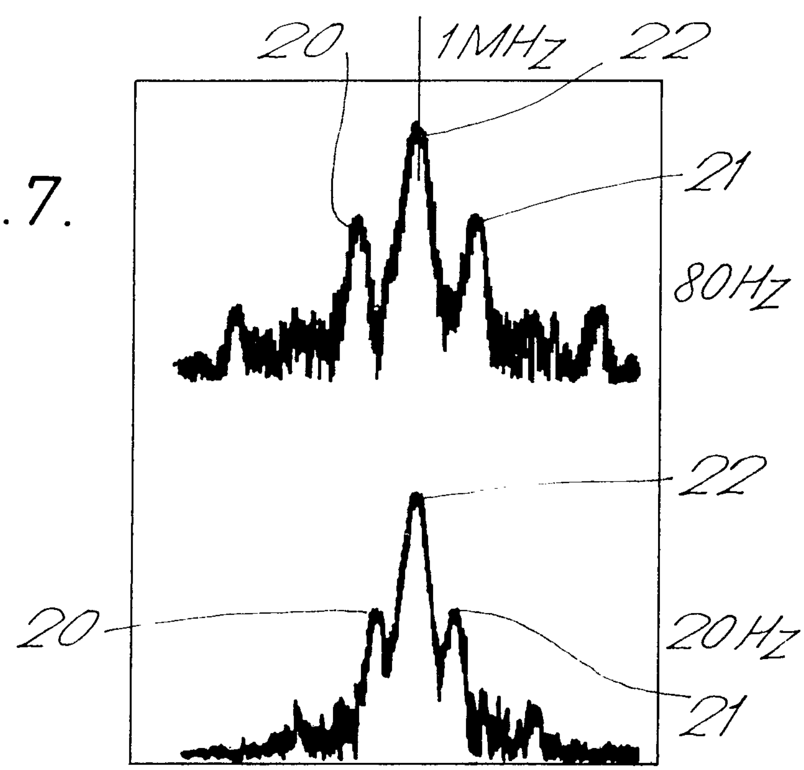


Fig.7.



SPECIFICATION

Monitoring fluid flow

The invention relates to a method and apparatus for monitoring fluid flow.

There are a great many ways in which fluid flow can be monitored and one method which is frequently used is based on vortex shedding. In this method, vortices are induced in a flowing fluid and then the frequency of the vortices is determined which is indicative of the fluid flow rate as will be described below. Various proposals have been made in the past for detecting the vortices including the use of thermistors and the measurement of pressure flutuations. These known systems all suffer from various problems which are undesirable.

British Specification No. 1,318,404 describes a method and apparatus for monitoring fluid flow in which a vortex street is generated in a fluid and ultrasonic signals are transmitted through the vortex street between a transmitter and a receiver. The receiver monitors changes in amplitude of the received signal which is said to be indicative of the vortices generated which in turn is dependant on the relative velocity between the fluid and a strut generating the vortices.

Fluid flow meters based on the invention described in this British specification have been used successfully to monitor gas flows. However, it has not been possible to devise flow meters based on the same principles for measuring liquid flow rates even through amplitude modulation could be detected.

In accordance with one aspect of the present invention, a method of monitoring fluid flow comprises causing a stream of vortices to be generated in the fluid; transmitting a sonic signal through the fluid along a path intercepting the vortex stream; detecting the sonic signal after transmission through the vortex stream; sensing any changes in phase between the transmitted and detected signals; and determining from the sensed changes information relating to the fluid flow.

We have investigated in some detail the affects of gases and liquids on sonic signals. This has shown that gases have two affects on transmitted sonic signals. Firstly, because they are compressible, density changes occur in the vicinity of the vortices which cause changes in the acoustic impedance of the gas and therefore modulate the amplitude of transmitted sonic signals. In addition, the transverse velocity components of the vortices impart phase changes in the transmitted signals. In liquids, however, there are no density changes and thus amplitude modulation should not occur. It should be expected that changes of phase continue to occur. Thus, in the case of liquids, to which the invention is particularly applicable, fluid flow can be monitored by monitoring phase changes in the transmitted signal.

We believe that the apparatus described in British Specification No. 1,318,404 produced amplitude modulation even when monitoring liquid flow rate because a significant proportion of the sonic signal was transmitted around the pipe through which the liquid was flowing and this interfered with the directly transmitted signal.

It is well known that the relative velocity (V) between a body generating vortices and a fluid in which the body is positioned is related to the vortex shed frequency (f) and the diameter (d) of the body by the following equation:

$$S = Fd/V$$

where S is the Strouhal number.

Since each change in phase corresponds to the passage of a vortex various information concerning the fluid flow can be determined. For example, monitoring the frequency of the sensed changes in phase provides an indication of the fluid flow rate. Alternatively, the number of phase changes can be counted to provide an indication of volume flow rate.

Typically, the stream of vortices will be generated by positioning an object such as a strut in a flowing fluid which is moving, for example, through a pipe. It should be understood that this relative movement could be caused by movement of a pipe relatively to the fluid in for example a boat.

Conveniently, the sonic signal is an ultrasonic signal, preferably having a frequency of substantially one MHz. This is particularly suitable for monitoring liquid flow whereas for gases the sonic signal should have a lower frequency, for example 160 kHz.

In accordance with a second aspect of the present invention, a vortex flow meter for generating a stream of vortices in a flowing fluid includes a sonic signal transmitter for transmitting a sonic signal towards the stream of vortices generated in the fluid; a sonic signal receiver for detecting the sonic signal after transmission through the vortex stream; and processing means for sensing any changes in phase between the transmitted and detected signals, and for providing an output relating to fluid flow through the meter.

The processing means may include a demodulator to which is fed the detected signal and the transmitted signal and which provides an output signal whose frequency is related to the vortex frequency.

An example of a vortex flow meter and a method of monitoring fluid flow in accordance with the present invention will now be described with reference to the accompanying drawings, in which:–

Figure 1 is a diagrammatic longitudinal section through the meter;

Figure 2 is a section taken on the line 2–2 in Fig. 1;

Figures 3A and *3B* illustrate two alternative ways for mounting the transmitting and receiving crystals in the meter housing;

Figure 4 is a block circuit diagram of the processing electronics;

Figure 5 illustrates the affect on phase of the transmitted signal by a single vortex;

Figure 6 iluustrates the output signal from the demodulator for two different flow rates; and,

Figure 7 is a spectrum analysis of the received signal mixed with the transmitted signal for two different flow rates.

The vortex flow meter shown in Figs. 1 and 2 comprises a metal pipe 1 of circular cross-section and a strut 2 having a trapezoidal cross-section portion 2A fixed across a diameter of the pipe 1 and a rectangular cross-section portion 2B spaced from the portion 2A and extending in the direction of fluid flow. Liquid flowing through the pipe 1 will flow around the strut 2 whidh will cause the generation of vortices 3 downstream of the strut 2. The form of the vortices 3 is shown diagrammatically in Fig. 1.

Piezoelectric crystals 4, 5 are mounted in the pipe 1 for transmitting a sonic signal into the fluid and detecting the sonic signal respectively. Fig. 3A illustrates one way for mounting the piezoelectric crystals, particularly the crystal 4 in the pipe 1. A blind bore 6 is drilled in the pipe 1 to a position adjacent but spaced from an inner surface 7 of the pipe. The crystal 4 is secured to a base 8 of the blind bore 6 by means of conventional potting material 9. The advantage of this form of mounting is that it substantially prevents sonic signals being transmitted around the pipe 1 rather than across the surface 7 into the fluid.

In the arrangement shown in Fig. 3A, there is a varying distance between the surface 7 and the base 8 of the blind bore 6. An alternative arrangement is shown in Fig. 3B in which the surface 7 has been flattened at 7′ so that the spacing between the crystal 4 and the surface 7′ is substantially constant.

In use, as will be explained in more detail below, an ultrasonic signal of for example 1MHz is transmitted from the crystal 4 into the fluid flowing through the pipe 1. The crystal 4 is positioned so that the ultrasonic signal will intersect the stram of vortices 3. It will be apparent from Fig. 1 that the vortices 3 have a component of velocity transverse to their flow direction along the pipe 1. This component will cause a change in phase of the transmitted ultrasonic signal. This is illustrated graphically in Fig. 5 which illustrates the effect of the passage of vortices through the signal path between the crystals 4, 5. The transmitted ultrasonic signal is indicated at 10 while the received ultrasonic signal is indicated at 11. The passage of a vortex 3 is thus detected by sensing this phase change. It should be noted that the liquid will have little if any affect on the amplitude of the transmitted signal.

The processing circuitry of the meter is illustrated in block diagram form in Fig. 4. Each of the components of the circuitry are conventional and will not be explained in detail. The circuitry comprises a power supply 12 which powers a one MHz crystal oscillator 13. The oscillator 13 is connected to the piezoelectric crystal 4 which transmits an ultrasonic signal of one MHz into the fluid (not shown) in Fig. 4). The receiving piezoelectric crystal 5 generates an electrical signal output which is fed to an operational amplifier 14. The amplified signal will be slightly amplitude modulated due to a small portion of the ultrasonic signal being transmitted around the pipe 1 and due to internal reflections. To deal with this, the output signal from the amplifier 14 is fed to an RF limiter 15 which generates an output signal having the same frequency as the input signal but with a constant amplitude. This signal is fed to a quadrature phase demodulator 16. A signal corresponding to the transmitted signal is tapped off from the output of the crystal oscillator 13 and is also fed to the demodulator 16. The amplifier 14 is adjusted so that the amplitudes of the two signals input to the demodulator 16 are the same.

The two input signals are mixed in the demodulator 16 and an output signal is produced which has a relatively low frequency corresponding to the phase differences between the two input signals. This signal is fed to a low frequency amplifier 17 whose output is fed to a Schmitt Trigger 18 which provides a square wave output.

The output of the Schmitt Trigger 18 is shown as being fed to a counter 19 which counts incoming pulses. This provides an indication of the total volume flow.

Alternatively, the frequency of the output signal from the Schmitt Trigger 18 could be determined to indicate the liquid flow rate. In another example, the output signal from the Schmitt Trigger 18 may be fed to an analogue display.

As mentioned above, each change in phase corresponds to the passage of a vortex so that detecting the number of phase changes is equivalent to detecting the number of vortices 3 generated.

Fig. 6 illustrates the output signal from the demodulator 16 at two different frequencies 20 Hz and 80 Hz corresponding to different liquid flow rates. Fig. 7 is a spectrum analysis of the received ultrasonic signal mixed with the transmitted signal to demonstrate the results of this mixing with different fluid flow rates equivalent to those of Fig. 6. It will be seen in Fig. 7 that the two side bands 20, 21 are differently positioned relatively to the central band 22 in each case.

CLAIMS

1. A method of monitoring fluid flow comprising causing a stream of vortices to be generated in the fluid; transmitting a sonic signal through the fluid along a path intercepting the vortex stream; detecting the sonic signal after transmission through the vortex stream; sensing any changes in phase between the transmitted and detected signals; and determining from the sensed changes information relating to the fluid flow.

2. A method according to claim 1, wherein the sonic signal is an ultrasonic signal.

3. A method according to claim 2, wherein the sonic signal has a frequency of substantially 1 MHz.

4. A method of monitoring fluid flow substantially as hereinbefore described with reference to the accompanying drawings.

5. A vortex flow meter for generating a stream of vortices in a flowing fluid, the meter including a sonic signal transmitter for transmitting a sonic signal towards the stream of vortices generated in the fluid; a sonic signal receiver for detecting the sonic signal after transmission through the vortex stream; and processing means for sensing any changes in phase between the transmitted and detected signals, and for providing an output relating to fluid flow through the meter.

6. A vortex flow meter according to claim 5, wherein the processing means includes a demodulator to which is fed the detected signal and the transmitted signal and which provides an output signal whose frequency is related to the vortex frequency.

7. A vortex flow meter substantially as hereinbefore described with reference to the accompanying drawings.

Printed in the United Kingdom for
Her Majesty's Stationery Office, Dd 8818935, 1985, 4235.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.