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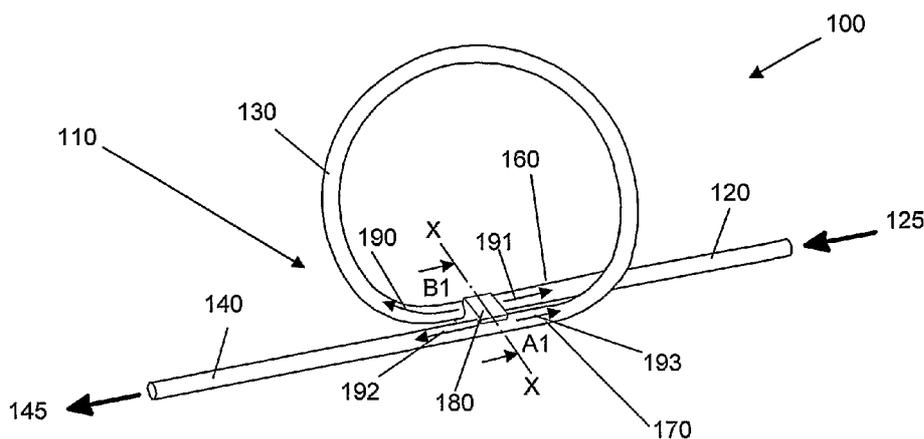
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(54) Title: GAS FLOW DETECTOR



(57) Abstract: Method and apparatuses for determination of gas flow, for instance in the form of a gas flow detector (100) comprising: a gas flow conductor (110) comprising a substantially loop-shaped part (130) cooperating with a gas inlet (120) part and a gas outlet (140) part, for the flow of gas from the gas inlet (120) part through the substantially loop-shaped part (130) of the gas flow conductor (110) to the gas outlet (140) part, at least one wave generating device (180) for generating mechanical waves in the gas flowing in the gas flow conductor (110), at least one wave detection device (153, 154) for detecting the mechanical waves generated in the gas flow conductor (110) by the wave generating device (180), and wherein said gas flow conductor (110) is arranged to form a continuous path for the mechanical waves and where the at least one wave generation device (180) is located between two or more adjacent pipe sections forming the substantially loop-shaped part (130) of the gas flow conductor (110) so as to generate the mechanical wave substantially simultaneously in the at least two adjacent pipe sections and where the at least one wave detection device (153, 154) is positioned inside at least one of the pipe sections of the at least two adjacent pipe sections of the loop-shaped part (130) of the gas flow conductor (110).

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GAS FLOW DETECTOR

TECHNICAL FIELD

The present invention relates to a gas flow detector and meter, method, computer
5 program, and system for measuring gas flow and in particular to gas flow detection
utilizing a transducer and detector system that is operating in an acoustic range.

BACKGROUND OF THE INVENTION

There are many known methods of measuring the volumetric flow rate of a gas:
10 technologies in widespread use include positive displacement meters, ultrasonic flow
meters, turbine meters, vortex shedding meters, and meters using pressure difference
methods such as venturis and orifice plates.

For mass market, low flow rate applications such as domestic gas metering, diaphragm
15 meters, a form of positive displacement meter, are in widespread use. These are
inherently mechanical devices which typically give an output of accumulated gas flow via
a dial gauge. A disadvantage of such meters is that they can be affected by mechanical
friction and wear and tear, thereby affecting their accuracy. Another disadvantage of
mechanical meters is that they must be manually "read", requiring the employment of
20 personnel to visit all locations at which they are installed at suitable intervals to verify the
readings.

It is desirable to have an "electronic" means of reading a meter, since this enables the use
of technologies for remote meter reading, thus resulting in a considerable cost saving.

25

It is possible, but not efficient, to "piggy-back" an electrical sensor onto a mechanical
meter to obtain an electronic reading. However, it would be more desirable to use an
inherently electronic metering principle. Ultrasonic meters, which measure flow rate by
measuring the "time of flight" of an acoustic pulse in the moving flow, inherently give an
30 electronic reading, and much effort has been dedicated to attempts to make a viable and
affordable ultrasonic meter. However the accuracy requirements are such that a plurality
of individually matched and calibrated transducers must be used in such meters,
something which increases costs significantly.

Ultrasound flow measurement techniques have been known for years, and are very accurate for large applications (pipe diameter greater than 5 cm, say). For smaller gas pipes and flows they are, however, not yet generally available.

5

US patent 5,168,762, (by Gill) describes a gas meter using ultrasonic acoustics and two transducers in a straight pipe configuration.

US patent 5,461,931 (by Gill) describes a similar system with an extra transducer and
10 acoustic path for direct flow speed measurement to improve accuracy – i.e. to overcome errors due to the variable characteristics of the transducers.

US Patent 5,777,238 (by Fletcher-Haynes) describes a further complex technique intended to compensate for the variable characteristics of the transducers.

15

European patent application EP 0566859 discloses an ultrasonic flowmeter for fluid media, having an ultrasonic measurement section in a measuring channel through which the fluid medium flows and preferably two ultrasonic transducers functioning as transmitter and/or receiver, as well as an electronic evaluating system for determining the
20 flow rate of the fluid medium on the basis of the transit time or phase difference of an ultrasonic signal, the measuring channel being wound in a worm-like or helical fashion. In one embodiment the transducer act as a wall between two adjacent parts of the flow channel; the same transducer is used for exciting and for measuring ultrasonic signals in the fluid media. In order to provide an accurate signal the sensor configuration need to be
25 carefully optimized and calibrated.

All of these disclosures and others require the use of expensive ultrasonic transducers and high-speed electronics and different configurations for calibration or compensation of errors due to media compositions, transducer characteristics and detector characteristics.

30

It is therefore an object of the present invention to provide a gas flow detector and a gas flow meter which provide an accurate measurement of gas flow at a reduced cost.

Further objects of the present invention provide a method of measuring gas flow, a
35 system for supplying gas and software for determining gas flow.

SUMMARY OF THE INVENTION

These and other objects are achieved by a gas flow detector according to the present invention, where the gas flow detector comprises a gas flow conductor which comprises a substantially loop-shaped part cooperating with a gas inlet part and a gas outlet part for the flow of gas from the gas inlet part through the substantially loop-shaped part of the gas flow conductor to the gas outlet part; where the gas flow detector additionally comprises at least one wave generating device for generating mechanical waves in the gas which flows in the gas flow conductor and at least one wave detection device for detection of the mechanical waves which are generated in the gas flow conductor by the wave generating device and wherein the gas flow conductor is arranged to form a continuous path for the mechanical waves and where the at least one wave generation device is located between two or more adjacent pipe sections which form the substantially loop-shaped part of the gas flow conductor in order to generate the mechanical wave substantially simultaneously in the at least two adjacent pipe sections and where the at least one wave detection device is positioned within at least one of the pipe sections of the at least two adjacent pipe sections in the loop-shaped part of the gas flow conductor.

The location of the wave generating device in the pipe sections which form the loop-shaped part of the gas flow conductor makes it possible to generate an acoustic response in both sections of the loop-shaped part of the gas flow conductor.

In one embodiment of the present invention the wave generating device may form part of a wall common to two adjacent pipe sections of the loop-shaped part of the gas flow conductor. One advantage of this arrangement of the wave generating device is that it is intrinsically a seal against gas flow between the adjacent pipe sections.

Alternatively, the wave generating device may be attached to a wall common to two adjacent sections of the loop-shaped part of the gas flow conductor. This would give the advantage of a less complicated mounting procedure for the wave generating device onto the gas flow conductor.

However, since it is desirable that the mechanical waves generated by the wave generating device meet as few obstructions as possible on its way through the loop-

shaped part of the gas flow conductor, the embodiment where the wave generating device forms part of a wall common two adjacent pipe sections is to be preferred.

The wave generating device is able to produce mechanical wave in the form of acoustic waves, i.e. sound waves, which may or may not be audible to the human ear.

In one embodiment of the present invention the wave generating device generates sound waves in the frequency range between 20 Hz - 20 kHz and in another embodiment the sound waves are produced in a frequency range from 20 kHz and higher, i.e. in the ultrasound frequency range.

Preferably, the sound waves generated by the wave generating device, which may, for example, be a sounder, are pulsed acoustic signals. The advantage of this type of signal is that it would enable non-ambiguous determination of flight times for the pulsed acoustic signals. Furthermore, the wave generation device may in this case operate with pulse centre frequencies in the range 20 Hz - 20 kHz.

Since acoustic pulse propagation is mainly single-mode, the use of acoustic pulses would minimise the dispersion of the pulse during propagation through the gas flow conductor.

Since parasitic resonances may occur at frequencies adjacent to the pulse centre frequency, one may choose to send the pulsed acoustic signals with an envelope which may be chosen to be a Raised Cosine, a Hamming or a Hanning or some similar envelope which has a low bandwidth for a given duration.

It is also important to carefully choose the centre frequency for the acoustic pulses in order to have control over resonances in the wave generation device, such as in a sounder, in the wave detection device, the gas flow conductor, launch volume resonances and other types of resonances.

In this fashion, the envelope of the launched acoustic pulse, which can have the envelope shapes described above, is preserved.

Many types of wave generating devices may be used and they may be chosen from the group of piezoelectric, piezo resistive, magneto elastic, capacitive, moving coil or diaphragm motion devices. The wave generating device may for example comprise a

diaphragm of elastic material, such as a metal disc with an actuator, such as a piezo-electric actuator or some other electro-mechanical actuator.

On the other hand, the wave detecting device mentioned above is adapted for detection of
5 mechanical waves, and in particular pulsed acoustic mechanical waves in the same frequency range as the acoustic pulses sent out by the wave generation device. There are many types of wave detection devices which may be used in the gas flow detector according to the present invention. Some of the possible choices for such wave detection devices may comprise one of the following types of detecting devices: piezoelectric, piezo
10 resistive, magneto elastic, capacitive, moving coil or diaphragm motion detection devices.

According to the present invention, the wave detecting device is adapted to detect the time of flight for the acoustic mechanical waves and of acoustic pulses in particular.

Additionally, the wave detection device may comprise a matched correlation filter in order
15 to perform signal processing on the received sound pulse and to determine the timing of the sound pulse. This would have the advantage of only letting the energy in the pulsed sound signal received pass that corresponds to the sound pulse launched by the wave generating device.

20 According to one other embodiment of the present invention the gas flow detector may comprise two wave detection devices which are located inside two adjacent pipe sections of the loop-shaped part of the gas flow conductor. These wave detection devices are adapted to measure both the sound pulses generated by the wave generating device and the sound pulses that are received after propagation through the loop-shaped part of the
25 gas-flow conductor.

Preferably, these two wave detection devices are located flush with the walls of the gas flow conductor in the vicinity of the wave generating device. In particular, they may be placed directly opposite the wave generation device. By placing the two detectors in such a fashion, one could minimise the effects of different pulse times when the first pulses are
30 sent out by the wave generating device.

In another embodiment of the present invention, these two wave detecting devices may be preferably be located flush with the wall of the each of at least two adjacent pipe sections belonging to the loop-shaped part of the gas flow conductor, but offset from the

wave generating device and towards each other by a distance less than the diameter of the gas flow pipe.

Variations in the time for the sound pulse when it enters the gas flow conductor would thereby be partially corrected.

5

Alternatively, the two wave detecting devices could be located flush with the wall of each of the at least two adjacent pipe sections belonging to the loop-shaped part of the gas flow conductor, but offset from said wave generating device and towards each other by a distance larger than the diameter of the gas flow conductor.

10

Even though this location of the wave detection devices would increase the variation for the sound pulse generated by the sound generating device, it would have the advantage of simpler construction of the gas flow detector.

- 15 In yet another embodiment of the present invention, the at least one wave detection device may be located in the loop-shaped part of the gas flow conductor substantially at 90 degrees clockwise or counter clockwise from the wave generating device and perpendicular to the direction of flow of gas in the gas flow conductor. An advantage of this placement of the wave detecting device is the reduction of the effect of the first
20 interfering (non-planar) mode of response from the gas flow conductor, when the sound pulse is sent into the same.

The gas flow conductor may also be constructed so that its gas inlet and gas outlet parts are of greater length than the loop-shaped part of the gas flow conductor. Constructing
25 the gas flow conductor in this fashion would minimise the impact of reflections of the sound pulse on the measurement of the sound pulses propagating in the loop-shaped part of the gas flow conductor, since reflections occurring at the ends of the gas inlet and gas outlet parts would arrive later at the wave detecting devices than the sound pulses propagating in the loop-shaped part of the gas flow conductor.

30

In one embodiment the gas inlet and outlet parts each has a length equal or larger than:

$$L_{GMIN} = \frac{n \cdot L}{2} + \frac{t_P \cdot v_S}{2},$$

where L_{GMIN} is the minimum length of the gas inlet or the gas outlet pipe sections, n the number of loops of the loop-shaped pipe section, L the length of the loop-shaped pipe

section, t_p the duration of the sound pulse generated by the sounder and v_s the speed of sound in the gas flow pipe.

Of course, the loop-shaped portion of the gas flow conductor may have a number of
5 different shapes, among which it could take the shape of a toroid, a spiral, an ellipsoid, an oval shape, a rectangle with or without smoothed corners, rhomboid or other quadrilateral, or other topologically multilateral shapes.

It would be preferred however, to choose a shape for the loop-shaped portion of the gas flow conductor having substantially smoothed corners to avoid undesired reflections from
10 these walls.

Also, the gas flow conductor may be manufactured from a number of different materials, among which there may be at least one of the following materials: metal, plastic, and ceramic based pipes.

15

According to a second aspect of the present invention, the object of the invention is achieved by a method of measuring gas flow comprising the steps of:

- generating at least one mechanical wave transmitted in gas flowing in a gas flow conductor which comprise a substantially loop-shaped part cooperating with a gas inlet
20 part, a gas outlet part and arranging the mechanical wave so as to flow with a flow of gas between the gas inlet part, the substantially loop-shaped part and the gas outlet part;
- transmitting the mechanical wave in substantially opposite directions and substantially simultaneously in two or more adjacent pipe sections which form the substantially loop-shaped part of the gas flow conductor
- 25 -detecting said mechanical wave with at least one detector positioned inside at least one of the pipe sections of the at least two adjacent pipe sections in the loop-shaped part of the gas flow conductor;
- analysing the waves for timing characteristics and
- determining gas flow using said timing characteristics.

30

In yet another embodiment of the method according to the present invention may further comprise the step of measuring the mechanical wave both when it is generated in the gas flow conductor and when it is received after having travelled along the gas flow conductor. Measuring the time of flight for the pulsed sound wave in this fashion would have the
35 advantage of accurate matching of the wave detecting devices and the signal processing

performed in these devices when there is more than one wave detecting device present in the pipe section forming the loop-shaped part of the gas flow conductor.

The timing analysis for the received pulse shaped signal may for example comprise phase
5 determination for the sound pulses in the direction of the gas flow and in the opposite flow direction using a complex correlation function for each detected pulse

An advantage of this embodiment is that one may obtain a direct measure of the time of flight for the pulsed acoustic signal in the phase of the result of the correlation operation when the magnitude of the result is at its maximum.

10

In yet another aspect of the present invention, the object of the present invention is achieved by a gas flow meter comprising a gas flow detector in turn comprising a gas flow conductor which comprise a substantially loop-shaped part cooperating with a gas inlet part and a gas outlet part for the flow of gas from the gas inlet part, through the
15 substantially loop-shaped part of the gas flow conductor to said the gas outlet (3) part, where the gas flow meter additionally comprises at least one wave generating device which generates mechanical waves in gas flowing in the gas flow conductor, at least one wave detection device for detecting the mechanical waves generated in said gas flow conductor by said wave generating device, wherein the gas flow conductor is arranged to
20 form a continuous path for the mechanical waves and where the at least one wave generation device is located between two or more adjacent pipe sections which form the substantially loop-shaped part of the gas flow conductor to generate the mechanical wave substantially simultaneously in the at least two adjacent pipe sections and where the at least one wave detection device is positioned inside at least one of the pipe sections of
25 the at least two adjacent pipe sections in the loop-shaped part of the gas flow conductor, where the gas flow meter further comprises a computational device which calculates and stores gas flow data and a communication device which communicates stored gas flow data.

30 In another aspect of the present invention, the object of the present invention is achieved by a system for supplying gas in a building which comprises the above described gas flow meter; a main gas inlet connected the gas flow meter at an upstream position relative to the flow meter, at least one gas conduit which is arranged to distribute gas within the building, wherein the at least one gas conduit is connected to the gas flow meter at a

downstream position relative to the flow meter and at least one gas appliance receiving gas via the gas conduit.

Finally, in another aspect of the present invention, the object of the invention is achieved
5 by a computer program which determines gas flow and further comprises instruction sets which generate at least one mechanical wave which is transmitted in gas flowing in a gas flow conductor which comprise a substantially loop-shaped part cooperating with a gas inlet part, a gas outlet part and where the mechanical wave is arranged so as to flow with a flow of gas between the gas inlet part, the substantially loop-shaped part and the gas
10 outlet part, transmits the mechanical wave in substantially opposite directions and substantially simultaneously in two or more adjacent pipe sections which form the substantially loop-shaped part of the gas flow conductor, detect said mechanical wave with at least one detector which is positioned inside the at least one of the pipe sections of the at least two adjacent pipe sections in the loop-shaped part of the gas flow conductor,
15 analyse the waves for timing characteristics; and determine gas flow using these timing characteristics, wherein the analysis comprises measuring the times between detected signals.

In one embodiment of the computer program according to the present invention the timing
20 analysis comprises phase determination by using a complex correlation function for each detected pulse.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following the invention will be described in a non-limiting way and in more detail
25 with reference to exemplary embodiments illustrated in the enclosed drawings, in which:

Fig. 1 illustrates schematically a perspective side view of an embodiment of the present invention;

30 Fig. 2 illustrates schematically a cross sectional view of the embodiment in Fig. 1

Fig. 3 illustrates schematically a number of pulses detected during measurement using the embodiment according to Fig. 1 and Fig. 2;

Fig. 4 illustrates schematically a perspective side view of a second embodiment of the present invention,

Fig. 5 illustrates schematically a cross sectional view of a fourth embodiment of the
5 present invention,

Fig. 6 illustrates schematically a cross sectional view of a fifth embodiment of the present invention

10 Fig. 7 illustrates schematically a computational device according to the present invention;

Fig. 8 illustrates schematically a flow diagram representing a method according to the present invention; and

15 Fig. 9 illustrates schematically a building having a flow meter according to the present invention;

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

20 Fig. 1 illustrates a perspective side view of a first embodiment of a gas flow detector 100, showing a gas flow pipe 110 comprising a gas inlet part 120, a loop-shaped section of the gas flow pipe 130 and a gas outlet part 140. The direction of gas flow is indicated by the arrows in Fig. 1, where the first arrow 125 indicates the inflow of gas into the gas inlet part 120 and the second arrow 145 the direction of outflow of gas from the gas outlet part 140
25 of the gas flow pipe. The pipe sections 160 and 170 are shown in Fig. 1 as substantially straight portions of the loop-shaped section 130 of the gas flow pipe sharing a common wall; however these sections 160, 170 may also be formed as curved portions, for instance as part of a continued loop together with the looped shaped section 130 forming a multi looped gas detector 100. Also, a sounder 180 for producing mechanical waves, for
30 instance sound pulses, is located between the first substantially straight pipe section 160 and the second substantially straight pipe section 170.

Fig. 2 illustrates a cross section of the first embodiment of the present invention along the line X-X. In the common wall 151 shared by the two substantially straight pipe portions
35 160 and 170 forming part of the loop-shaped portion of the gas flow pipe 110, a sounder

180 is installed, which in this embodiment forms part of the common wall for the two pipe sections. Having the sounder 180 built into the common wall 151 in the manner described above has the advantage that two sound pulses can be launched at two distinct flow locations along the gas flow pipe. It also minimises cavity resonances in a coupling
5 system between the sounder and the gas flow tube.

The sounder may 180 for example be constructed as a diaphragm of elastic material, such as in the form of a metal disc, with an actuator, such as a piezo-electric element bonded to it. Using for example a resilient ring, such as an O-ring, the sounder may be
10 bonded to the common wall and at the same time present a seal against gas leakage from one pipe section to the other. In this fashion, it is possible to control sounder motion and therefore manage resonance effects stemming from the natural frequencies of vibration for the sounder. Also, the material for the sounder 180 may be chosen so as to be able to resist the pressure difference between the two pipe sections 160 and 170.

15

Directly opposite the sounder 180 a first microphone 153 and a second microphone 154 are arranged flush with the walls belonging to the first and the second pipe sections 160 and 170. The function of the microphones is to receive the sound pulses launched by the
20 sounder 180 in both the first pipe section 160 and the second pipe section 170.

During high flow rates there may be perturbations introduced in the sound pulse measured by the microphones stemming from the interaction between the gas flow and the microphone or interaction between the pulses travelling in the gas and the microphone
25 (or the microphone mounting) when the microphones are located at the inner walls of the pipe which may negatively affect the measurements; for instance in a position of the microphone on the inner side of the wall thus protruding into the flow path of gas in the gas flow pipe 110. These perturbations may be, for example, due to the acoustic mismatch between the pipe section leading to the location of the microphone and the
30 microphone position or due to the occurrence of flow turbulence around or nearby the microphones,

As an additional advantage, the incorporation of the microphones flush with the gas pipe walls may serve to avoid cavity resonances in a possible coupling pipe between the gas flow pipe 110 and the microphone.

35

Now, the principle of functioning for the embodiment in Fig. 1 and Fig. 2 will be described. It should be mentioned that reference numbers depicting the same component or part will be retained throughout the text and in all the figures.

- 5 A continuous gas flow entering the gas inlet part 120 in the direction of the arrow 125 passes through the loop-shaped pipe section 130 of the gas flow pipe 110 and exits the gas flow pipe 110 through the gas outlet pipe section 140 in the direction of the of the second arrow 145.
- 10 At a time instant t the sounder 180 launches a sound pulse in the direction of the gas flow 125 and in the counter-flow direction (not shown) through the substantially straight pipe sections 170 and 180 forming part of the loop-shaped section 130 in the gas flow pipe 110 and sharing a common wall 151.
- 15 With reference also to Fig. 3, the first microphone 153 and second microphone 154 register the sound pulse almost immediately after it is launched at time instants t_1 and t_3 . At the time instant t_2 the pulse launched by the sounder 180 in the direction of gas flow 125 arrives at the second microphone 154 and at a time instant t_4 the sound pulse launched against the direction of gas flow 125 in the second pipe section 170 arrives at
20 the first microphone 160 after having travelled one or more turns in the loop-shaped pipe section 130 of the gas flow pipe 110. Although the loop-shaped pipe section of the gas flow pipe may comprise more than one loop, it is here chosen for the sake of clarity to illustrate the one-loop version of the gas flow pipe 110.
- 25 Thus four signal pulses will be registered by the first and the second microphone 153 and 154. An advantage of gas flow detector 100 with two microphones is that the pulses are compared roughly at the time they are produced and after they have travelled a certain distance through the loop-shaped pipe section 130, which would avoid the additional difficulty in matching the response of the two microphones and their channel signal
30 processing.

Also, using two microphones has the additional advantage that the pulses travelling with the flow of gas and against the flow of gas may be measured simultaneously.

- Naturally, it is possible to only have one microphone positioned inside one of the
35 substantially straight pipe portions of the loop-shaped pipe portion of the gas flow pipe,

but the arrangement of two microphones makes it possible to compensate for the changes in the microphone characteristics which might deteriorate or change over time. Such changes may be long or short-termed, such as for example due to the natural ageing process of the microphone membrane or by temperature changes.

5

In this context, it would be possible to use two sounders and one microphone, but the use of only one sounder sending sound pulses in both with the gas flow and against the gas flow directions eliminates the need of accurate sounder matching as well as the need to deal with variations of the transfer function for the actuator due to temperature variations
10 and the aging process of the sounder component.

The mechanical wave pulses sent out by the sounder 180 may be generated in the acoustic range, i.e. within the 20 Hz - 20 kHz audible range, where there exists a number of wave generating and detecting devices on the market that may readily be utilized and
15 at an advantageous price. However, it is equally feasible to use a sounder 180 which produces sound pulses in the ultrasound range, i.e. from 20 kHz and above. This would, of course, necessitate the use of transducers receptive to sound pulses in this frequency area.

20 Apart from that, it is advantageous to use an acoustic wavelength at which only planar waves propagate in the waveguide. The frequency will depend on the size of the pipe. A suitable combination for low speed gas, for example, is to use a 0.4 m long loop-shaped pipe section 180 of diameter 16mm with a pulse consisting of a Hanning windowed sine wave of length 6 cycles and frequency 8 kHz. However, it should be understood by the
25 person skilled in the art that other combinations of lengths, cycles, pulse shapes and frequencies will be applicable depending on gas composition, flow speed ranges and required (or desired) resolution of gas flow measurements. To name a few, the sounder 180 may produce sound pulses from the group of Raised Cosine, Hamming or similar pulses which have a low bandwidth for a given pulse duration. The important aspect here
30 is to use a pulse shape that will minimise pulse duration and bandwidth. Using such a bandwidth-limited pulse in the gas flow detector 100 minimises the risk of giving rise to undesired parasitic resonances in the gas flow pipe 110 which occur at frequencies adjacent to the pulse.

One may also choose the centre frequency of the sound pulse itself in such a way as to control resonance frequencies for the sounder and/or the gas flow pipe and the launch volume resonances. Avoiding the resonant frequencies for at least the gas flow pipe and launch volume resonances will ensure that the sound pulse launched by the sounder 180 is substantially preserved. Another aspect of avoiding resonant frequencies for the sound pulse will also make sure that the envelope of the sound pulse during travel through the gas flow pipe will not change significantly due to temperature variations of the gas inside the pipe or the gas flow pipe itself and the variations in the sounder mounting.

10 Fig. 3 illustrates a signal registered by the wave detection devices 160, 170 at various times after a pulse has been transmitted from the sounder 180. A first pulse A1 to be registered is a pulse which is sent downstream, i.e. in the direction of the arrow 190, from the sounder 180 in the first straight pipe section 160 into the loop-shaped pipe section 130 of the gas flow pipe 100. The second pulse B1 is generated by the sounder 180 in the
15 second straight pipe section 170 and sent into the direction of the arrow 191 opposite to the direction 190 of the pulse A1 into the loop-shaped pipe section 130, which is the pulse that has travelled in the other direction through one or more loops of the loop-shaped pipe section 130 and upstream, 145. The third pulse A2 to be registered is from the downstream travelling pulse after it has travelled through one or more loops of the loop-
20 shaped pipe section 130 and the fourth pulse B2 to be registered is from the upstream travelling pulse after it has travelled upstream through one or more loops of the loop-shaped pipe section 130. Pulse times between consecutive pulses of the same character (i.e. pulses travelling in the same direction) will be fairly constant as long as the flow has not changed significantly between detections. These times are shown in Fig. 3 as the time
25 between pulse A1 and A2, i.e. time t_1 , and B1 and B2, i.e. time t_2 . A number of pulses from reflections at the ends of the gas inlet and gas outlet pipe sections 120 and 140 or other sections of the pipe will also be detected and thus need to be dealt with by an electronic controller. Such an electronic controller is used for synchronizing measurements, controlling excitation pulses, acquiring signals from the detector, and
30 analysing measurements. The difference $\Delta t_2 - \Delta t_1$ between pulse arrival times for the pulse going in the flow direction and the pulse travelling against the flow will be used for determining the flow of the gas since the speed of the acoustic pulses are generally known and it is possible to approximate the arrival times of pulses as a function of flow rate and length of the travelled distance between detector locations.

With this type of transducer/detector configuration, problems due to the sounder 180 and/or the microphones' 153, 154 characteristics are reduced significantly since no matching between multiple wave sounders or matching between multiple microphones are needed. Also, by using a loop-shaped pipe section of the gas flow tube for the signals the speed of sound in the gas composition may be measured using the same signals and therefore compensated for automatically without the use of extra speed of sound detection devices.

The accuracy of the flow measurement will depend on the accuracy to which the pulse timings can be determined. To obtain the accuracy generally required for fiscal metering it is necessary to use a phase measurement technique, such as described herein below.

In one embodiment of the present invention, signal processing involving a correlation operation on the received signal is performed by a matched correlation filter which is loaded with filter coefficients that match the launched sound pulse shape sent to the sounder. Using the pre-loaded coefficients for the filter will have the advantage of only passing energy in the sound pulse received in the microphone which corresponds to the pulse shape sent out to by the sounder,

Using the maximum value of the filter output after the correlation operation performed by such a matched correlation filter would then give a direct measure of the time of flight for the received sound pulse in the phase of the filter output.

Having in mind that the pulse sent to the sounder 180 may not match the pulse actually propagating in the gas flow pipe, due to imperfections of the gas flow pipe itself and the gas flow in the pipe, the matched correlation filter may be loaded with coefficients for the pulse sent to the sounder convolved with the frequency response of the sounder. This way the received sound pulses will be processed to match a signal that better approximates the actual pulse propagating in the gas flow pipe.

Alternatively, the correlation filter may be loaded with filter coefficients that are adapted to match the first pulse received by the microphones 153, 154. Then the subtraction of the first and second pulse timings is processed to match a pulse that actually propagates in the gas flow tube convolved with the frequency response of the microphone. Also, the second pulse (the pulse that has travelled through the loop-shaped pipe section and

arrived at the other microphone) is processed to match a pulse that actually propagates in the gas flow tube convolved with the frequency response of the microphone.

Generally one may say that if the microphone is positioned away from the sounder it will
5 measure the first signal (A1 and B1) as a more fully developed signal, i.e. any near field variations will be reduced; however, if the microphone is located too far away other effects will start to distort the signal, such as temperature variations, flow disturbances and so on. This means that there will be an optimal distance between the microphone and the sounder for optimal signal detection.

10

Fig. 4 illustrates a different embodiment of the present invention, where the two microphones 153 and 154 have been moved a distance D from the sounder 180 towards each other in the direction of the loop-shaped pipe section 130 of the gas flow pipe 110. In the enlarged view below, the width of the gas flow pipe is set to d and the distance D
15 between the microphones 153 and 154.

Having the microphones moved from opposite the sounder 180, but still close to it, an advantage is achieved when measuring sound pulses sent into the pipe by the sounder 180, namely that the sound pulses are less susceptible by variation, which may occur
20 after some time when the pulse has travelled through the gas flow pipe 110.

Although introducing variation into the sound pulses received, which among others depend on how much greater the distance D between the microphones and the sounder and the width of the pipe is, this may have benefits in the form of easier construction of
25 the microphones into the loop-shaped portion of the gas flow pipe.

The embodiment of the present invention shown in Fig. 5 is similar to the first embodiment of the gas flow detector 100 from figure 1, in that the two microphones 153, 154 are located at the same streamwise location as the sounder 180. However, the microphones
30 are positioned at 90 degrees from the sounder 180 and perpendicular to the direction of gas flow into the gas flow pipe 110 indicated by the arrow 125. The microphones may also be positioned either at 90 degrees counter clockwise in relation to the sounder 180 or clockwise. Also, they need not be positioned at the same streamwise location as the sounder 180, but instead at a distance D from the sounder 180 and towards each other
35 either such that either $D < d$ or $D > d$, where d is the width of the pipe 110. Even though the

microphones are depicted as being mounted on the inside of the pipe walls they may alternatively be mounted flush with the wall as is the case illustrated in Fig. 2.

When launching a sound pulse into the pipe 110 non-planar modes for the pulse
 5 propagation may occur due to the response of the pipe and they may be minimised by the placement of the microphones 153, 154 in the way illustrated in Fig. 5.

According to yet another embodiment of the present invention illustrated in Fig. 6, the
 10 sounder may be instead of forming part of the common wall 151 for the two flat pipe sections 160 and 170 of the gas flow tube 110, be located outside the common wall 151 and attached to it. This arrangement has the added advantage of the overall easier construction of the gas flow meter, since mechanical modification of the straight pipe sections 160 and 170 can be avoided. It may however not give equally good measurement values for the launched and received sound pulses generated by such a
 15 sounder 180.

The use of an external rather than an internal sounder 180 in the gas flow pipe 110 may however be performed in all of the earlier described embodiments of the present invention.

20

One other means for improving the quality of received signals is choosing the length of the gas inlet and gas outlet pipe sections 120 and 140 to be at least as long as the length of the loop-shaped pipe section 130 or even longer. This would eliminate degradation in the received pulses due to reflections of sound pulses sent in the directions 192 and 191
 25 from the pipe ends. Choosing their length in this fashion would ensure that the sound pulses travelling in the loop-shaped pipe section 130 of the gas flow pipe 110 would arrive at the two microphones 153 and 154 before the sound pulses reflected from the two pipe-ends arrive at the microphones. More specifically, the minimum length for the gas inlet and gas outlet pipe sections 120 and 140 can be calculated from the expression below:

30

$$L_{GMIN} = \frac{n \cdot L}{2} + \frac{t_p \cdot v_s}{2},$$

where L_{GMIN} is the minimum length of the gas inlet or the gas outlet pipe sections 120 and 140, n the number of loops of the loop-shaped pipe section 130, L the length of the loop-

shaped pipe section 130, t_p the duration of the sound pulse generated by the sounder 180 and v_s the speed of sound in the gas flow pipe 110.

Also, the amplitude of the sound pulses generated by the sounder 180 may be increased
5 in order to account for increasing flow rates which may introduce acoustic flow noise into the gas flow pipe 110, thus maintaining a desired Signal-to-Noise ratio when measuring the received sound pulses. As a bi-product of the increased amplitude and maintained S/N-ratio the overall power consumption of the gas flow meter 100 is reduced. A similar argument may be used for optimizing the repetition rate of the sound pulses, with a higher
10 repetition rate of the sound pulses a higher accuracy may be obtained on the expense of power consumption, i.e. it is possible to dynamically alter either or both of the amplitude and repetition rate to find a suitable signal to noise ration for the specific application or installation. This may also be adjusted over time for a specific installation due to changes of the system or the environment, for instance temperature changes, wear, ageing,
15 changed components and so on.

Another measure which may improve the overall quality of the measured sound pulse is the modification of the shape of the inlet and outlet pipe sections 120 and 140.

20 By, for example, fitting the inlet and outlet pipe section 120 and 140 with bell shaped elements (not shown), an acoustic miss-match for the sound pulses travelling in these two directions is introduced at a minimal pressure loss. Due to the acoustic mismatch the most part of the arriving sound pulses will be reflected at the area where the mismatch occurs back into the flat pipe sections 160 and 170. In this way acoustic propagation is
25 mostly contained in the gas flow detector 100 without propagating further into other parts of the pipe system where the gas flow detector 100 according to the present invention is installed.

One other possible way of solving the above-mentioned problem may also be to have the
30 sectional area for the gas inlet and gas outlet pipe sections 120 and 140 increase exponentially with distance from the straight pipe sections 160 and 170 with an appropriate expansion coefficient for the frequencies which are used for the sound pulses launched by the sounder 180. In this fashion, the change from the straight to the expanding pipe section would minimise acoustic reflections for the launched sound
35 pulses.

In order to further improve the reliability of the measurements it would be advantageous to use some form of protection for the sounder 180 in order to guard it against interference from other external acoustical sources. This may be achieved by constructing the sounder
5 180 out of metal or some other suitably rigid material and with walls having a thickness which would prevent interference from external acoustic sources. Another variant of insulation for the sounder 180 may be to build the sounder or the flow meter into a box with air isolating the sounder or flow meter from the walls. Enclosing the flow meter in such a manner will also provide security from tampering means in the form of inducing
10 sound pulses in the piping of the flow meter.

One should also mention that the present invention is not limited to gas flow pipes of any particular length or width. It is possible to use it in pipes with a relatively small width which are relatively short in length for instance residential gas delivery pipes, but also pipes with
15 a diameter of one meter or more and lengths of 100 meters or more if necessary for instance gas pipes from gas wells.

Turning now to Fig. 7 illustrating schematically the electronic controller in the form of a computational device 800, the computational device 800 is used for analyzing and storing
20 data from above analysis examples and controlling measurements. The computational device 300 comprises a computational unit 801, such as e.g. a microprocessor, a DSP (Digital Signal Processor), an ASIC (Application Specific Integrated Circuit) or an FPGA (Field Programmable Gate Array) or a combination of these. The computational device may further comprise a storage unit (e.g. volatile or non-volatile memory) 802 and/or a
25 communication unit 803. The communication unit 803 may use any suitable communication method and protocol, including different forms of wired or wireless communication methods; the communication unit 803 may actually comprise a combination of communication methods and/or protocols, each used for different types of communication links (e.g. a short ranged wireless protocol for service communication and
30 a long range wireless protocol for sending metering data to a billing system). Further, the computational device 800 has a control interface 804 and a detector interface 805. The control interface 804 is used for sending control signals to the wave generating device 180 or to an intermediate pulse generator (not shown) in turn driving the wave generating device 180. The detector interface receives signals directly or indirectly from the wave
35 detecting devices 153, 154, for instance in some cases a signal conditioning device (not

shown) may be needed in order to provide the computational device 800 with appropriate signal types and levels, or for reducing noise levels.

The invention is not limited to any special communication types or protocols for
5 communicating measured flow data, but may include for instance short range wireless standards as WLAN (Wireless Local Area Network) protocols (e.g. from the IEEE 802.11 family, IEEE 802.16 family, or IEEE 802.15.4 family) or WPAN (Wireless Personal Area Networks) such as for instance the Bluetooth protocol or any proprietary wireless solution (e.g. low power solutions that may be run on battery for long periods of time). Other types
10 of wireless communication may be using long range wireless communication methods, including but not limited to NMT (Nordic Mobile Telephone), GSM (Global System for Mobile Communication), GPRS (General Packet Radio Service), EDGE (Enhanced Data rate for Global Evolution), UMTS (Universal Mobile Telecommunications Service), variations of CDMA (Code-Division Multiple Access), and future similar communication
15 types. Communication may also utilize wired solution, including but not limited to Ethernet link, serial connection, parallel connection, and power line communication.

Fig. 8 illustrates a flow chart representing a method according to the present invention of measuring gas flow, comprising the steps of:

- 20 - generating at least one mechanical wave transmitted in gas flowing in a gas flow conductor consisting of an substantially loop-shaped part cooperating with a gas inlet part, a gas outlet part and arranging said mechanical wave so as to flow with a flow of gas between said gas inlet part, said substantially loop-shaped part and said gas outlet part (901);
- 25 - transmitting said mechanical wave in substantially opposite directions and substantially simultaneously in two or more adjacent pipe sections forming said substantially loop-shaped part of the gas flow conductor of the substantially loop-shaped part of said gas flow conductor (902);
- detecting said mechanical wave with at least one detector positioned inside
30 said at least one of the pipe sections of the at least two adjacent pipe sections of the loop-shaped part of the gas flow conductor (903);
- analysing said waves for timing characteristics (904); and
- determining gas flow using said timing characteristics

Such a system is illustrated in Fig. 9, wherein a gas flow meter 1001 meters the amount of gas entering the building 1000 via an incoming gas conduit 1004. Within the building, gas conduits 1005 conduct gas to different appliances, such as a boiler 1002 for generating warm water and a central heating unit 1003 for generating heat to the building 1000.

5

The gas flow detector may of course also be used in gas flow applications such as within industrial processes where it is desirable to determine the amount of gas delivered to a certain process but not used for billing purposes in a metering application.

10 The loop-shaped pipe section 130 of the gas flow pipe 110, for example, need not be round, as shown in Figure 1. It can be any closed shape, although the corners should not be too sudden or abrupt. Other shapes include, but the invention is not limited to these shapes, ellipsoid, oval, rectangle with or without smoothed corners, and rhomboid, or other quadrilateral, or other topologically multilateral shapes.

15

There are many possible actuator and detector technologies, depending on the wavelength, including for example piezoelectric, piezo resistive, magneto elastic, capacitive, moving coil, or diaphragm motion (detection) devices. However, it is a desirable feature of this invention that the working frequency can be in the acoustic range,
20 making use of the transducers (earpieces) manufactured for personal entertainment systems and low cost miniature microphones as used, for example, in mobile telephones.

All the above described embodiments of gas flow detector and method may be utilized in a gas flow meter for use in measuring gas flow volumes in both residential and industrial
25 applications. The gas flow meter sends measured and/or stored flow measurements to a central aggregating device (such as a billing server) for later billing to customers acquiring gas volumes. Data may be sent as flow data together with time data and later converted to volumes or as volume data converted by the flow meter itself. The gas flow meter may be used in a system, for instance in a residential home, for measuring the amount of gas
30 domestic appliances (e.g. water heating, stove, and heating of living area) consume.

All the above described embodiments of the present invention may be built into a gas leak proof containment unit in order to provide a convenient box for mounting purposes and protection purposes; it may also provide extra safety against gas leaks.

35

An additional advantage of the present invention is that it permits the use of relatively low-cost transducer components, such as low cost microphones since measurements are based on arrival times of pulses from a single source.

- 5 It should be noted that the word "comprising" does not exclude the presence of other elements or steps than those listed and the words "a" or "an" preceding an element do not exclude the presence of a plurality of such elements. It should further be noted that any reference signs do not limit the scope of the claims, that at least parts of the invention may be implemented by means of both hardware and software, and that several "means",
- 10 "units" and "devices" may be represented by the same item of hardware.

The above mentioned and described embodiments are only given as examples and should not be seen to be limiting to the present invention. Other solutions, uses, objectives, and functions within the scope of the invention as claimed in the below

15 described patent claims should be apparent for the person skilled in the art.

CLAIMS

1. A gas flow detector (100) comprising:

- a gas flow conductor (110) comprising a substantially loop-shaped part (130) cooperating with a gas inlet (120) part and a gas outlet (140) part, for the flow of gas from said gas inlet (120) part through said substantially loop-shaped part (130) of the gas flow conductor (110) to said gas outlet (140) part;
- at least one wave generating device (180) for generating mechanical waves in said gas flowing in said gas flow conductor (110);
- at least one wave detection device (153, 154) for detecting said mechanical waves generated in said gas flow conductor (110) by said wave generating device (180); and

wherein said gas flow conductor (110) is arranged to form a continuous path for said mechanical waves and where said at least one wave generating device (180) is located between two or more adjacent pipe sections forming said substantially loop-shaped part (130) of the gas flow conductor (110) so as to generate the mechanical wave substantially simultaneously in the at least two adjacent pipe sections and where said at least one wave detection device (153, 154) is positioned inside at least one of said pipe sections of the at least two adjacent pipe sections of the loop-shaped part (130) of the gas flow conductor (110).

2. The gas flow detector (100) according to claim 1, wherein said wave generating device (180) is adapted for generation of mechanical waves in an acoustic range.

3. The gas flow detector (100) according to claim 1 or 2, wherein said mechanical waves comprise pulsed acoustic mechanical waves.

4. The gas flow detector (100) according to any one of the claims 1 to 3, wherein an envelope of said pulsed acoustic mechanical waves is chosen to be one of Raised Cosine, Hamming or Hanning or a similar pulse with low bandwidth for a given duration of said pulse.

5. The gas flow detector (100) according to any one of the claims 1 to 4, wherein the pulse centre frequency is chosen so as to control resonances in the wave generation device (180), wave detection device (153, 154), the gas flow conductor (110), launch volume resonances and other types of resonances.

- 5
6. The gas flow detector (100) according to any one of claims 1 to 4, wherein said wave generating device (180) operates in a frequency range of 20 Hz to 20 kHz or in an ultrasound frequency range above 20 kHz.
7. The gas flow detector (100) according to any of the claims 1 to 6, wherein said wave detecting device (153, 154) is adapted for detection of mechanical waves in an acoustic range.
- 10 8. The gas flow detector (100) according to any of the claims 1 to 6, wherein said flow detector (100) is arranged to adjust at least one of amplitude of generated mechanical waves and repetition rate of generated mechanical waves for optimizing signal to noise ratio with respect to power consumption.
- 15 9. The gas flow detector (100) according to any of the claims 1 to 8, wherein said wave detecting device (153, 154) is adapted for detection of time of arrival for said acoustic mechanical waves.
- 20 10. The gas flow conductor (1) according to any of the claims 1 to 9, wherein said wave detecting device (153, 154) comprises a matched correlation filter for performing signal processing on the received pulsed mechanical wave and for determining the timing of said pulsed acoustical mechanical wave.
- 25 11. The gas flow detector (100) according to any of the claims 1 to 5, further comprising two wave detecting devices (153, 154) located inside two adjacent pipe sections of the loop-shaped part (130) of the gas flow conductor (110), where said wave detecting devices (153, 154) are adapted for measuring both the mechanical waves generated by the wave generating device (180) and the mechanical waves as they are received after propagation through the loop-shaped part (130) of said gas-flow conductor (110).
- 30 12. The gas flow detector (100) according to any of the claims 1 to 11, wherein said wave detecting devices (153, 154) are located substantially flush with the walls of the gas flow conductor (110) in the vicinity of said wave generating device (180).

13. The gas flow detector (100) according to claim 1, wherein said gas inlet part (120) and gas outlet part (140) has a length greater than said loop-shaped part (130) of the gas flow conductor (110).

5 14. The gas flow detector (100) according to claim 1, wherein said gas inlet part (120) and gas outlet part (140) each has a length equal or larger than:

$$L_{GMIN} = \frac{n \cdot L}{2} + \frac{t_P \cdot v_S}{2},$$

10 wherein L_{GMIN} is the minimum length of the gas inlet or the gas outlet pipe sections (120 140), n the number of loops of the loop-shaped pipe section (130), L the length of the loop-shaped pipe section (130), t_P the duration of the sound pulse generated by the sounder (180) and v_S the speed of sound in the gas flow pipe (110).

15 15. The gas flow detector (100) according to any one of claims 1 to 3, wherein said wave generating device (180) comprise one of the following types of actuators: piezoelectric, magneto elastic, capacitive, moving coil or diaphragm motion devices.

20 16. The gas flow detector (100) according to any one of claims 1 to 4, wherein said wave detecting device (153, 154) comprise one of the following types of detecting devices: piezoelectric, piezo resistive, magneto elastic, capacitive, moving coil or diaphragm motion detection devices.

25 17. The gas flow detector according to any one of claims 1 to 5, wherein said at least one wave generating device (180) comprises a diaphragm of elastic material, such as a metal disc, with an actuator, such as piezo-electrical actuator.

30 18. The gas flow detector according to any one of claims 1 to 6, wherein said at least one wave generating device (180) forms part of a wall common to two adjacent sections of said loop-shaped gas flow conductor (110).

19. The gas flow detector according to any one of the claims 1 to 6, wherein said at least one wave generating device (180) is attached to a wall common to two adjacent sections of said loop-shaped gas flow conductor (110).

20. The gas flow detector (100) according to any one of claims 1 to 8, wherein said at least one wave detection device (153, 154) is located inside said loop-shaped gas flow conductor (110) and opposite said wave generating device (180).

5

21. The gas flow detector (100) according to any one of claims 1 to 8, wherein said at least one wave detection device (153, 154) is located inside said loop-shaped part (130) of the gas flow conductor (110) and located substantially at 90 degrees clockwise or counter clockwise from said wave generating device (180) and perpendicular to the direction of flow of gas in said gas flow conductor (110).

10

22. The gas flow detector (100) according to any one of claims 1 to 8, wherein said loop-shaped part (130) of the gas conductor (4) has a shape of a toroid, spiral, ellipsoid, oval, rectangle with or without smoothed corners, rhomboid or other quadrilateral, or other topologically multilateral shape.

15

23. The gas flow detector (100) according to any one of claims 1 to 10, wherein said gas flow conductor (110) is made of one of at least one of the following materials: metal, plastic, and ceramic based pipes.

20

24. A method of measuring gas flow comprising the steps of:

- generating at least one mechanical wave transmitted in gas flowing in a gas flow conductor (110) comprising a substantially loop-shaped part (130) cooperating with a gas inlet part (120), a gas outlet part (140) and arranging said mechanical wave so as to flow with a flow of gas between said gas inlet (2) part, said substantially loop-shaped part (130) and said gas outlet part (140);
- transmitting said mechanical wave in substantially opposite directions (190, 191) and substantially simultaneously in two or more adjacent pipe sections forming said substantially loop-shaped part (130) of the gas flow conductor (110) of the substantially loop-shaped part (130) of said gas flow conductor (110);

25

30

- detecting said mechanical wave with at least one detector (7) positioned inside said at least one of the pipe sections of the at least two adjacent pipe sections of the loop-shaped part (130) of the gas flow conductor;
 - analysing said waves for timing characteristics; and
 - 5 - determining gas flow using said timing characteristics.
25. The method according to claim 24, wherein said mechanical wave is generated in an acoustic range.
- 10 26. The method according to claim 25, wherein said mechanical wave is generated as a pulsed acoustic mechanical wave.
- 15 27. The method according to any of the claims 24 to 26 wherein said step of analysing said waves for timing characteristics comprises measuring the time of flight for said mechanical wave both in the direction of the flow of gas toward said gas inlet part (120) and said gas outlet part (140) of the gas flow conductor (110) as well as in the opposite direction of the flow of gas through the gas flow conductor (110).
- 20 28. The method according to claim 26, further comprising the step of measuring said mechanical wave both when it is generated in said gas flow conductor (110) and when it is received after having travelled along the gas flow conductor (110).
- 25 29. The method according to any one of claims 24 or 26, wherein said timing analysis comprises phase determination using a complex correlation function for each detected pulse.
30. A gas flow meter comprising
- a gas flow detector (100) comprising:
 - 30 a. a gas flow conductor (110) comprising a substantially loop-shaped part (130) cooperating with a gas inlet part (120) and a gas outlet part (140) for the flow of gas from said gas inlet part (120), through said substantially loop-shaped part (130) of the gas flow conductor (110) to said gas outlet part (140)

- b. at least one wave generating device (180) for generating mechanical waves in gas flowing in said gas flow conductor (110);
- c. at least one wave detection device (153, 154) for detecting said mechanical waves generated in said gas flow conductor (110) by said wave generating device (180); and

wherein said gas flow conductor (110) is arranged to form a continuous path for said mechanical waves and where said at least one wave generation device (180) is located between two or more adjacent pipe sections forming said substantially loop-shaped part (130) of the gas flow conductor (110) so as to generate said mechanical wave substantially simultaneously in said at least two adjacent pipe sections and where said at least one wave detection device (153, 154) is positioned inside at least one of said pipe sections of the at least two adjacent pipe sections of the loop-shaped part (130) of the gas flow conductor of at least two adjacent loops of said loop-shaped part (130) of the gas flow conductor (110),

said meter further comprising:

- a computational device (301) for calculating and storing gas flow data; and
- a communication device (303) for communicating stored gas flow data.

31. A system for supplying gas in a building (500) comprising

- a gas flow meter (501) according to claim 31;
- a main gas inlet (504) connected to said gas flow meter (501) at an upstream position relative to said flow meter (501);
- at least one gas conduit (505) arranged to distribute gas within said building (500), wherein said at least one gas conduit is connected to said gas flow meter at a downstream position relative to said flow meter (501); and
- at least one gas appliance (502, 503) receiving gas via said gas conduit (505).

32. A computer program for determining gas flow, comprising instruction sets for:

- generating at least one mechanical wave transmitted in gas flowing in a gas flow conductor (110) comprising a substantially loop-shaped part (130) cooperating with a gas inlet part (120), a gas outlet part (140) and arranging said mechanical wave so as to flow with a flow of gas between said gas inlet (2) part, said substantially loop-shaped part (130) and said gas outlet part (140);

- transmitting said mechanical wave in substantially opposite directions (10, 11) and substantially simultaneously in two or more adjacent pipe sections forming said substantially loop-shaped part (130) of the gas flow conductor (110);
 - detecting said mechanical wave with at least one detector (7) positioned inside
5 said at least one of the pipe sections of the at least two adjacent pipe sections of the loop-shaped part (130) of the gas flow conductor,
 - analysing said waves for timing characteristics; and
 - determining gas flow using said timing characteristics,
- wherein said analysis comprise measuring times between detected signals.

10

33. The computer program according to claim 32, wherein said timing analysis comprises phase determination using a complex correlation function for each detected pulse.

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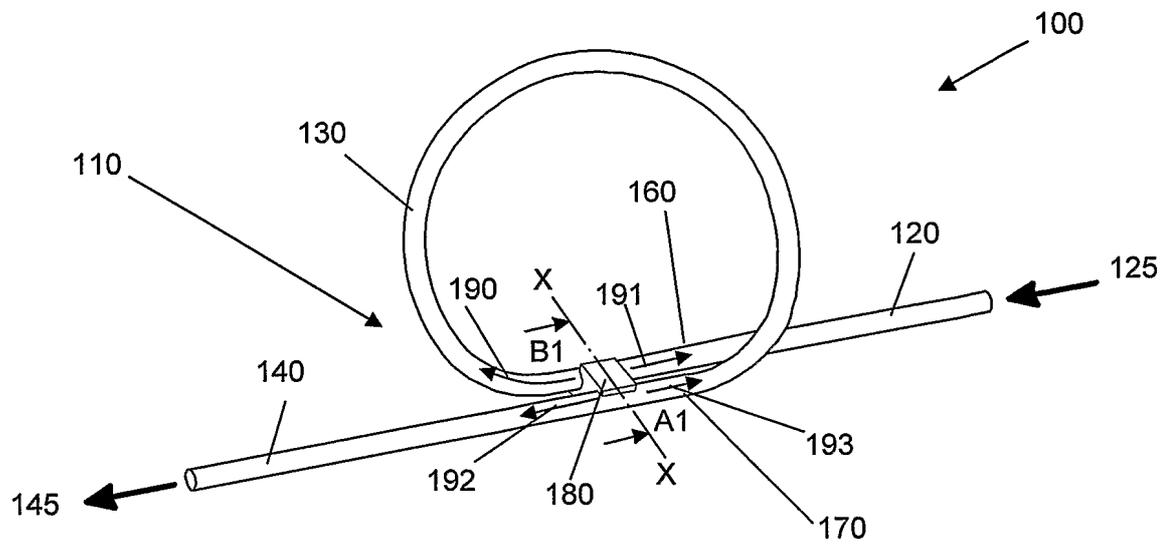


Fig. 1

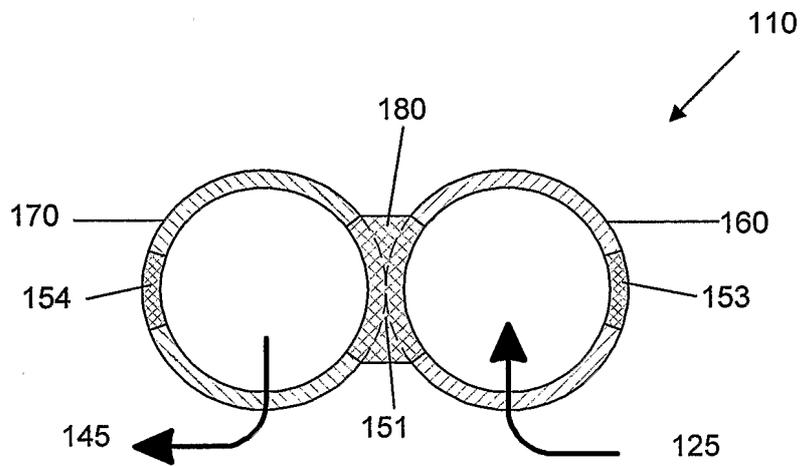


Fig. 2

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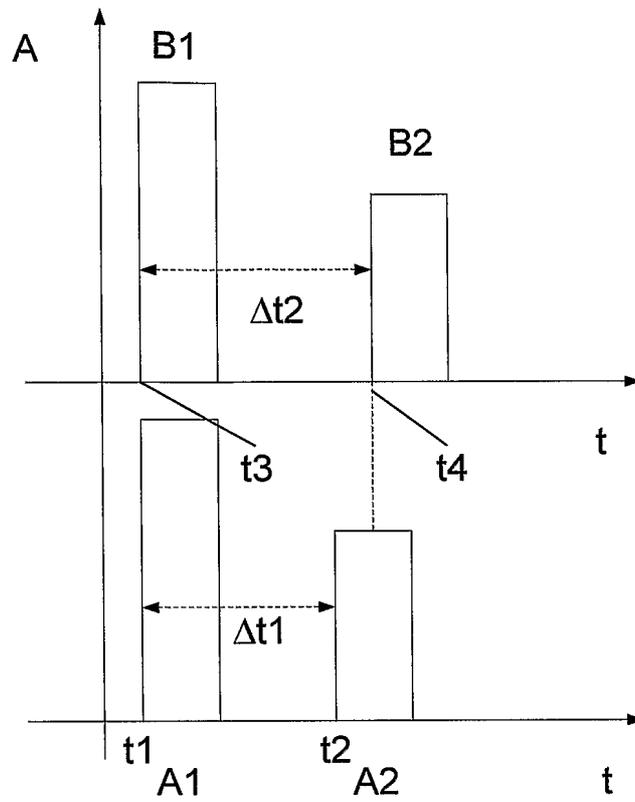


Fig. 3

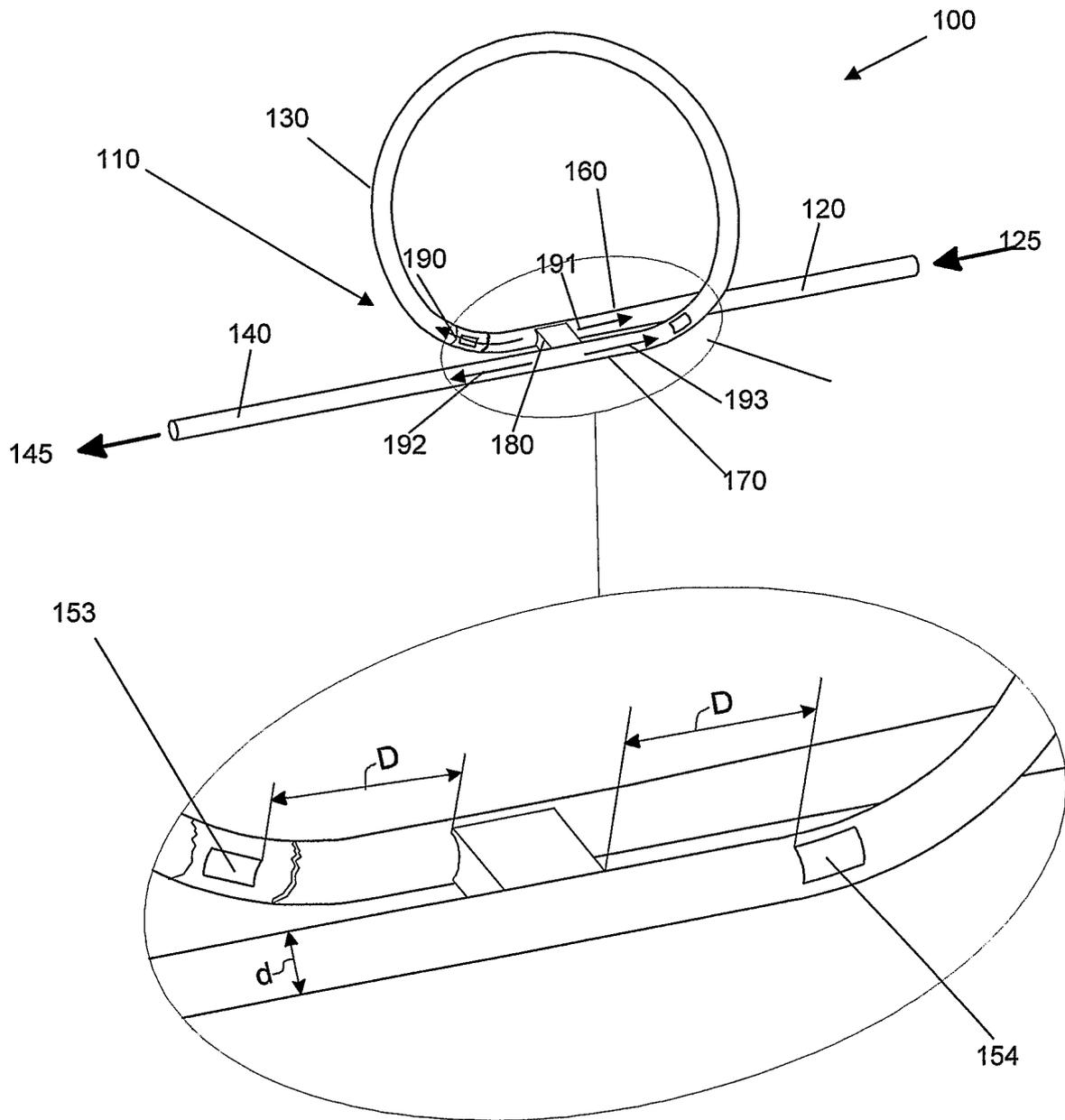


Fig. 4

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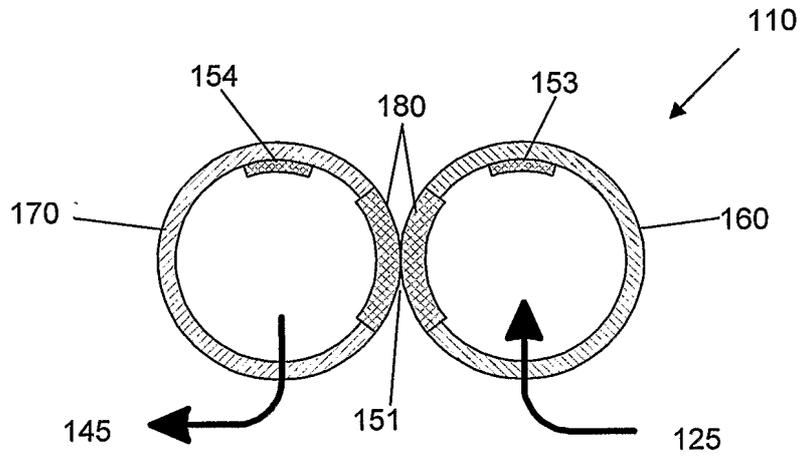


Fig. 5

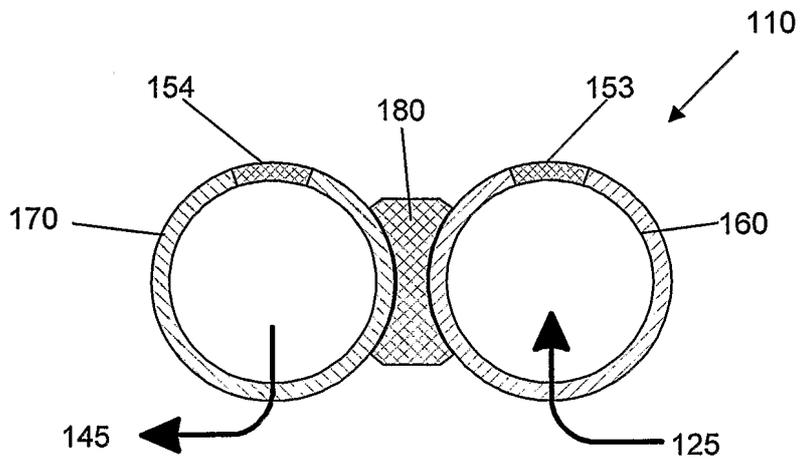


Fig. 6

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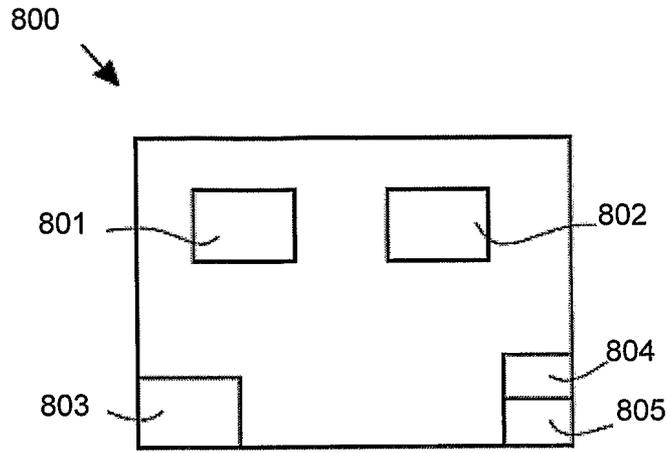


Fig. 7

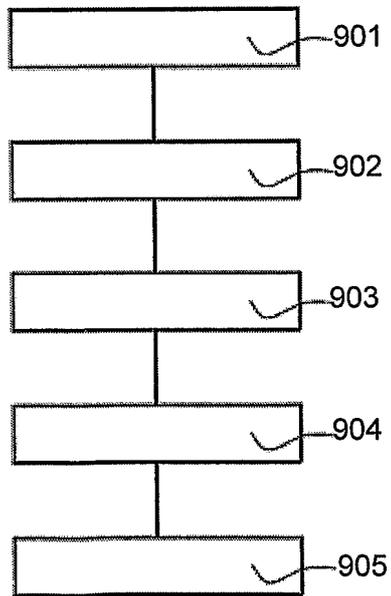


Fig. 8

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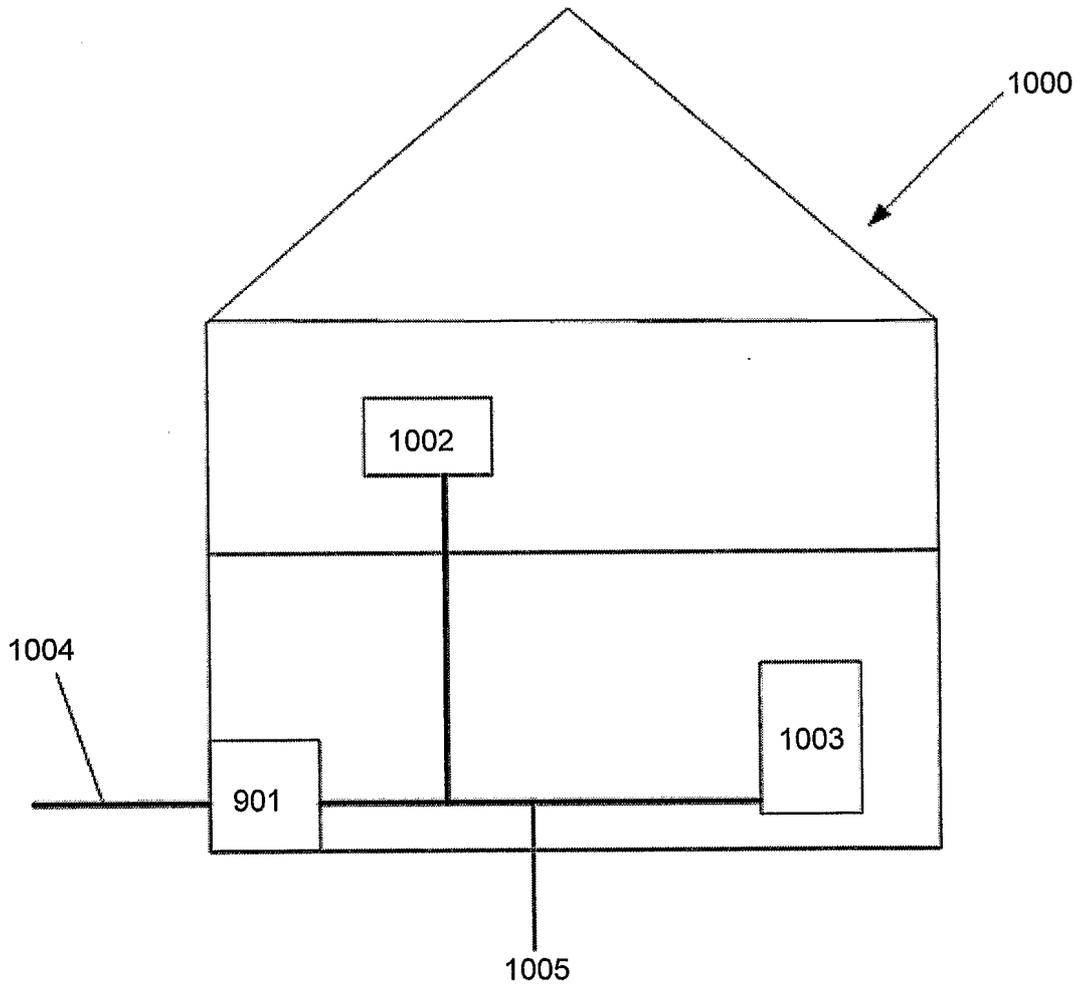


Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/002763

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01F1/66

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 28 33 793 A1 (DAIMLER BENZ AG) 14 February 1980 (1980-02-14)	1, 3, 4, 6, 9, 11, 12, 18, 19, 22-28, 30
A	page 6, line 14 - page 7, line 14 page 11, line 30 - page 19, line 27; claim 1; figures 1,2	2, 5, 7, 8, 10, 13-17, 20, 21, 29, 31-33
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Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

A document defining the general state of the art which is not considered to be of particular relevance

E earlier document but published on or after the international filing date

L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

O document referring to an oral disclosure, use, exhibition or other means

P document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

B document member of the same patent family

Date of the actual completion of the international search

23 April 2007

Date of mailing of the international search report

04/05/2007

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Authorized officer

Yildiz, Dilek

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/002763

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 566 859 A1 (HYDROMETER GMBH [DE]) 27 October 1993 (1993-10-27) cited in the application	1-3,5-7, 9,18,19, 22, 24-30, 32,33
A	the whole document	4,8, 10-17, 20,21, 23,31
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