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Description

The invention relates to a calibration device for mass flowmeters having at least one test piece measuring section, into which the mass flowmeter test piece to be calibrated can be inserted, having at least one device for creating a flow of a medium through the test piece measuring section and having at least one temperature-measuring device in the test piece measuring section for detecting the temperature of the medium. Furthermore, the invention relates to a method for calibrating a mass flowmeter using such a calibration device.

Calibration devices of the above-mentioned type have been know for a long time from the prior art (see, for example, US 5,455,781). Here calibration serves the purpose of detecting the deviation of the measurement of the mass flowmeter test piece from a standard value provided by the calibration device in order to calibrate the mass flowmeter test piece using the deviation. Such calibration devices are also used in the calibration of mass flowmeters, wherein, here, the conformity with certain accuracy requirements is approved by certified institutes, such as, for example, the German Physikalisch-Technische Bundesanstalt. The requirement of – even repeated – calibration of a mass flowmeter results in part from the field of application of mass flowmeters, for example, the transportation of oil for custody transfer, in which only calibrated mass flowmeters may be used.

Apart from that a high accuracy is always desired from a technical perspective, there is, regarding in high-grade fluid or gaseous goods, such as crude oil and natural gas, quite a large interest – from the distributors point of view – that the amount to be delivered and only this amount is actually delivered and, from the purchasers point of view, that the requested amount – and especially at least the requested amount – is received. Measurement tolerances always impact one of the parties in trade; they usually impact the distributor.

The standard value, with which the measurement of the mass flowmeter test piece is compared, can exist in the form of a standard measuring device, which is also placed in the test piece measuring section and, in this manner, is subjected to the same flow as the mass flowmeter test piece to be calibrated arranged at a distance away in the test piece measuring section. This is valid, in particular in gaseous media, insofar as other variables influencing the mass or volume flow within the medium are stationary, or at least are stationary for as long as the standard measuring device and the mass flowmeter test piece have carried out their measurement under the same conditions. Normally, calibration devices also include pressure measuring devices, since – in particular in gaseous media – the pressure has a large influence on the density of the medium and, thus, represents an important variable for such mass flowmeters that are based on the measurement of the flow speed of the medium, as is the case in, for example, ultrasonic mass flowmeters as opposed to such measuring devices that allow a direct conclusion about the mass flow due to their measuring principle, such as is the case, for example, in Coriolis mass flowmeters.

Often, a standard value is also implemented as a volumetric standard value, in which a geometrically measured reference volume, for example in the form of a plunger system, is pushed in the volume of the test piece measuring section in a certain time, so that the flow can be adjusted very accurately using the test piece measuring section.

The temperature-measuring device in the calibration device, mentioned in the introduction, is necessary or advantageous for an accurate calibration for different reasons. On the one hand, the exact detection of the temperature of the medium is of interest for calibrating mass flow meter test pieces at different operating temperatures. On the other hand, the temperature of the medium also substantially influences the calibration device, itself. For example, geometric measurements of the tube system of the calibration device are dependent on the temperature of the medium, in particular thermal expansion or contraction.

It is known from the prior art to detect the temperature of the medium with high accuracy using invasive temperature probes, i.e. such temperature sensors that extend into the volume flowing through the test piece measuring section. Normally, temperature probes are used that are based on changes in electrical impedance, for example, platinum temperature sensors that are arranged in the tip of a measuring tube extending into the flow of the medium. Temperature measurement occurs, here, with high accuracy, however has the disadvantage that the flow at the measurement point and downstream from the measurement point have substantial disturbances so that the flow in the calibration device cannot be produced as steadily, in total, as is necessary for a highly accurate measurement. A further disadvantage consists in that an invasive temperature-measuring device only provides selective temperature information, which does not allow measurement of temperatures changing along the flow profile, i.e. a temperature profile, to be identified. This can be avoided by measuring the temperature with temperature probes at different points in the flow profile or in a flow cross-section, however, disturbances induced in the flow to be measured are then increased, which is very disadvantageous. Non-invasive temperature measurements by means of ultrasonic measuring technology are described, for example, in US 5,705,753 or EP 2 072 972 A1. A measuring configuration, which both a reflector for ultrasonic signals as well as a reference temperature measuring sensor, which is designed as NTC element, for example, is described in DE 10 2005 038 599 A1.

It is thus the object of the present invention to provide a calibration device for mass flowmeters, with which the disadvantages in the calibration devices known from the prior art can be avoided - at least partially, with which, in particular, an disturbance-free as possible and, just the same, highly-accurate detection of the temperature of the flowing medium is possible.

The depicted object is met initially according to the invention and essentially with the calibration device of the type being discussed in that the temperature-measuring device is designed as an ultrasonic temperature-measuring device, as aresult, in which the temperature of the medium is determined using the speed of an emitted ultrasonic signal in the medium, wherein the ultrasonic temperature-measuring device does not extend into the flow cross-section of the test piece measuring section, so that the flow in the test piece measuring section is essentially unaffected by the ultrasonic temperature-measuring device.

In ultrasonic temperature measurement, the fact known from physics is used that the sonic velocity within a medium depends on the temperature of the medium, so that in a known path length of the ultrasonic signal from the sender to the receiver, the warmth of the medium can be deduced from the measurement of the running time.

With the use of an ultrasonic temperature-measuring device for determining the temperature of the medium in the test piece measuring section, the advantage is initially achieved that the flow remains uninfluenced for the most part, since - as opposed to temperature measurement with invasive temperature-measuring device - the flow in the test piece measuring section is not disturbed. A further advantage of the use of an ultrasonic temperature-measuring device is that it determines a changing temperature of the medium practically immediately, wherein the measuring time is solely the time in which the ultrasonic signal needs to proceed through the signal path in the test piece measuring section, wherein such a signal path typically runs perpendicular to the direction of flow. Thus, the ultrasonic temperature-measuring device also allows for the detection of quick temperature changes of the medium. A further advantage of the use of ultrasonic temperature-measuring devices is that, in using them, not only a temperature at one point within the flowing medium is detected, but an average temperature value over the path of the ultrasonic signal in the test piece measuring section, since the ultrasonic signal is always propagated with a speed corresponding to a temperature of the medium in areas of different temperature and the running time of the ultrasonic signal acting as the actual measured value automatically describes the average temperature along the signal path of the ultrasonic signal.

The ultrasonic temperature-measuring device is preferably provided in the test piece measuring section where the mass flowmeter test piece to be calibrated is inserted, preferably on the incoming end of the mass flowmeter test piece, wherein it can also be advantageous to provide a further ultrasonic temperature-measuring device at the outgoing end of the mass flowmeter test piece in the test piece measuring section, since, in this manner, changes in temperature in close proximity to the mass flowmeter test piece can be identified and taken into account.

According to the invention, it is provided that an invasive reference temperature-measuring device and an associated reference ultrasonic temperature-measuring device are arranged adjacent to one another in the calibration device and are arranged in the calibration device so that the flow in the test piece measuring section in the area of the ultrasonic temperature-measuring device and in the area of the mass flowmeter test piece is essentially unaffected by the invasive reference temperature-measuring device, so that the ultrasonic speed in the medium can be determined with the reference ultrasonic temperature-measuring device at the medium temperature determined using the invasive reference temperature-measuring device.

The calibration device according to the invention has substantial advantages. Due to the adjacent arrangement of the invasive reference temperature-measuring device and the associated reference ultrasonic temperature-measuring device, it is possible to detect a reliable correlation between the ultrasonic speed and the temperature of the same medium, which is used in the calibration device. For this reason, it is not necessary to use mathematical/physical relations that describe the temperature dependence of the ultrasonic speed in the medium, since such relations are not even known in some circumstances for a specific medium or, at any rate, are not known well enough. There is also no longer the necessity to have exact knowledge of the medium with which the measurement is carried out, since the relation between sonic velocity and medium temperature is determined metrologically in the calibration device itself.

When it is said that the invasive reference temperature-measuring device and the associated reference ultrasonic temperature-measuring device are arranged adjacent to one another, then it is meant that they are arranged as close to one another as possible, so that the measurement given by them is practically always related to one and the same section of the flowing medium. For this reason, the probability is decreased that, in the case of a temporal change of the temperature of the medium, this change has already been detected by one of the reference measuring devices, while the other of the two reference measuring devices could not have yet noticed this change within the medium. Preferably, the invasive reference temperature-measuring device is arranged downstream from the associated reference ultrasonic temperature-measuring device so that disturbances induced in the flow from the invasive reference temperature-measuring device do not affect the reference ultrasonic temperature-measuring device.

When it is further discussed that the flow in the test piece measuring section in the area of the ultrasonic temperature-measuring device and in the area of the mass flowmeter test piece is essentially not influenced by the invasive reference temperature-measuring device, then it is meant that disturbances in the flow induced by the invasive reference temperature-measuring device at the location of the ultrasonic temperature-measuring device and at the location of the mass flowmeter test piece to be calibrated are practically dissipated, i.e. for example, the turbulent kinetic energy of the flow is dissipated to at least 90% after the invasive reference temperature-measuring device at the location of the ultrasonic temperature-measuring device and at the location of the mass flowmeter test piece.

The great advantage of equipping the calibration device according to the invention with an invasive reference temperature-measuring device and an associated reference ultrasonic temperature-measuring device is then achieved when the relation obtained from the reference measurement between the ultrasonic speed vref in the medium and the medium temperature Tref is the basis for the temperature measurement with the ultrasonic temperature-measuring device in the test piece measuring section, because, in this case, the ultrasonic temperature-measuring device, which is preferably located close to the mass flowmeter test piece, is best calibrated to the special temperature dependency of the sonic velocity in the medium currently being used within the calibration device.

There are different possibilities for arranging the reference measuring devices in the calibration device so that the ultrasonic measuring device and the mass flowmeter test piece remain as much undisturbed as possible. According to a preferred design of the invention, it is provided that the invasive reference temperature-measuring device and the associated reference ultrasonic temperature-measuring device are arranged in the test piece measuring section. One influence can thus be avoided in that the invasive reference temperature-measuring device and the associated reference ultrasonic temperature-measuring device are arranged downstream from the ultrasonic temperature-measuring device and the mass flowmeter test piece. One influence, however, can be achieved with an arrangement of the reference measuring devices upstream from the ultrasonic temperature-measuring device and the mass flowmeter test piece in having the distance be chosen so that it is large enough.

According to an alternatively advantageous design of the invention, it is provided that a by-pass to the test piece measuring section is implemented in the calibration device and the invasive reference temperature-measuring device and the associated reference ultrasonic temperature-measuring device are arranged in the by-pass. Due to the by-pass to the test piece measuring section, it is essentially possible to channel off medium flowing from the test piece measuring section and to examine it with the invasive reference temperature-measuring device and the associated reference ultrasonic temperature-measuring device so that the reference measurement and the measurement in the flow of the test piece measuring section, in which the mass flowmeter test piece to be calibrated is located, are locally de-coupled, which prevents, in terms of construction, a mutual influencing of reference measurement and measurement in the test piece measuring section.

It has been seen to be of particular advantage when the by-pass can be de-coupled in terms of flow from the test piece measuring section by means of a stop valves, i.e. the by-pass can be opened and closed to the test piece measuring section, so that, for example, when the by-pass is closed a reference measurement can also occur with a large as possible flow-related de-coupling from the test piece measuring section.

According to a particularly preferred design of the invention, it is provided that the by-pass forms a by-pass loop, in particular wherein a conveying device and/or a heating device and/or a cooling device for the medium are provided in the by-pass loop. This opens up a plurality of possibilities for carrying out reference measurements independently of the occurrences in the test piece measuring section, since the flow in the by-pass loop and in the test piece measuring section are influenced independent of one another. The medium in the by-pass loop can be circulated with the conveying device, which is usually designed as a pump, so that, in particular, it is ensured that a homogeneous state of the medium is regulated within the by-pass loop, in particular a constant temperature. The temperature of the medium can be influenced by the conveying device, itself, but also specifically with the use of the above-mentioned heating or cooling devices. In this manner, a plurality of reference measurements can be easily carried out parallel to the test piece measuring section, so that the correlation $v_{ref} = f(T_{ref})$ between the ultrasonic speed v_{ref} in the medium and the medium temperature T_{ref} can be very accurately and easily determined, also , in terms of time, parallel or before the measurements on the mass flowmeter test piece.

The task derived in the introduction is further met by a method for calibrating a mass flowmeter with the above-described calibration device, wherein the calibration device has at least one test piece measuring section, into which the mass flowmeter test piece to be calibrated can be inserted, having at least one device for creating a flow of a medium through the test piece measuring section and having at least one temperature-measuring device in the test piece measuring section for detecting the temperature of the medium. Here, the temperature-measuring device is further designed as an ultrasonic temperature-measuring device and an invasive reference temperature-measuring device and an associated reference ultrasonic temperature-measuring device are provided that are arranged adjacent to one another in the calibration device in such a manner that the flow in the test piece measuring section in the area of the ultrasonic temperature-measuring device and in the area of the mass flowmeter test piece are essentially not influenced by the invasive reference temperature-measuring device, so that, with the reference ultrasonic temperature-measuring device, the ultrasonic speed v_{ref} in the medium can be determined using the medium temperature T_{ref} determined by the invasive reference temperature-measuring device. According to the method according to the invention, it is provided that a measurement of the ultrasonic speed by means of the reference ultrasonic temperature-measuring device and a measurement of the medium temperature by means of the invasive reference temperature-measuring device are carried out in the calibration device and the relation $v_{ref} = f(T_{ref})$ between the ultrasonic speed v_{ref} in the medium and the medium temperature T_{ref} obtained from these measurements forms the basis for the temperature measurement with the ultrasonic temperature-measuring device in the test piece measuring section. As has already been described referring to the calibration device according to the invention, the advantage of this approach is that a highly accurate reference measurement can be carried out in the calibration device with the medium, which is also used for calibrating the mass flowmeter test piece, while a quick measurement of the temperature can be carried out in the test piece measuring section averaged over the signal path of the ultrasonic signal – also in the immediate proximity of the mass flowmeter test piece – wherein a maximum accuracy of the ultrasonic temperature-measuring device is given by using the relation $v_{ref} = f(T_{ref})$ found via the reference measurement.

In such a calibration device, in which a by-pass to the test piece measuring section is implemented and the invasive reference temperature-measuring device and the associated reference ultrasonic temperature-measuring device are arranged in the by-pass, further in which the by-pass can be de-coupled from the test piece measuring section in terms of flow, a preferred further development of the above-mentioned method exists in that the relation between the ultrasonic speed v_{ref} in the medium and the medium temperature T_{ref} is obtained in the by-pass after the by-pass is flooded with the medium present in the test piece measuring section and then the by-pass is de-coupled in terms of flow from the test piece measuring section by means of the stop valves. Using this approach, the temperature dependency of the ultrasonic speed can be detected very accurately in the by-pass and particularly without running the risk that the reference measurement influences the actual calibration process. Since the temperature measurement by means of the invasive reference temperature-measuring device is particularly highly accurate, but comparably slow, a preferred design of the method described here provides that first, a stationary temperature state of the resting or also flowing medium is watched for in the by-pass, in particular a stationary state in view of the medium temperature determined with the reference temperature-measuring device before the relation $v_{ref} = f(T_{ref})$ between the ultrasonic speed v_{ref} in the medium and the medium temperature T_{ref} is determined and approved for use in the ultrasonic temperature-measuring device in the test piece measuring section. Such a stationary state of the medium can be detected in that successive reference measurements have to fall below a pre-determined maximum change threshold so that the reference measurement is accepted as such and goes into the revealed relation between the ultrasonic speed in the medium and the medium temperature.

It is of particular advantage when – as mentioned above – the relation between the medium temperature and the sonic velocity within the medium exists in the form of a characteristic curve, wherein further influencing factors, such as pressure, for example, can be taken into account here. Insofar, it is provided in a preferred embodiment of the invention that multiple temperatures are adjusted subsequently in the by-pass, in particular while using a conveying device and/or a heating device and/or a cooling device for the medium provided in the by-pass or by-pass loop and multiple relations $v_{ref} = f(T_{ref})$ between the ultrasonic speed v_{ref} in the medium and the medium temperature T_{ref} are obtained, in particular the medium pressure is also measured and noted for every detected correlation.

In detail, there are a number of possibilities for designing and further developing the calibration device according to the invention and the method for calibrating a mass flowmeter according to the invention. Here, please refer to the patent claims subordinate to patent claim 1 on the one hand and, on the other hand, to the following description in connection with the drawing. The drawing shows:

Fig. 1 schematic representation of a calibration device known from the prior art,

Fig. 2 schematic calibration device according to the invention with an ultrasonic temperature-measuring device,

Fig. 3a, 3b schematic calibration device according to the invention with a reference measuring device in the test piece measuring section,

Fig. 4 schematic calibration device according to the invention with a reference measuring device in a by-pass to the test piece measuring section,

Fig. 5 a further schematic representation of a calibration device according to the invention and

Fig. 6 schematic section of a further calibration device according to the invention with attention to the particular design of the ultrasonic temperature-measuring device.

In Fig. 1, a known calibration device 1 from the prior art is represented section by section and schematically, which has a test piece measuring section 2 in which a mass flowmeter test piece 3 to be calibrated can be inserted and presently is inserted. The calibration device 1 additionally has a device 4 for creating a flow of a medium through the test piece measuring section 2, wherein this is a pump in this device. Furthermore, the calibration device 1 has a temperature-measuring device 5 in the test piece measuring section 2 in immediate proximity to the mass flowmeter test piece 3, which serves to detect the temperature of the medium. The temperature-measuring device 5 in Fig. 1 is an invasive temperature-measuring sensor that extends in the volume of the test piece measuring section 2 and is designed as a enclosed PT100 resistance element. The temperature measurement is particularly highly accurate with such an invasive temperature receiver, however has the disadvantage that the measurement only occurs at points in a small section of the flow cross-section and furthermore, the flow is influenced by the sensor extending into the volume of the test piece measuring section 2, so that disturbances 6 are induced in the practically interference-free flow downstream from the temperature-measuring device 5.

The calibration device 1 here, also has a pressure sensor 7, which is provided on the circumference in the tube wall of the test piece measuring section 2, but does not extend into the volume of the test piece measuring section 2. The pressure is, in particular for gaseous media, an essential variable for determining the mass flow and for determining the pressure-dependent parameters of the medium.

The temperature-measuring device 5 is provided very close to the mass flowmeter test piece 3, so that an exact impression of the temperature conditions of the medium can be obtained in immediate proximity of the mass flowmeter test piece 3.

Calibration devices 1 normally also have a standard measuring device, wherein the results of the mass flowmeter test piece 3 are compared with the measurements of the standard measuring device. In other known calibration devices, a volumetric standard is used, for example in the form of a plunger system, in which a defined flow can be adjusted, in which the plungers of the volumetric standard displace a certain medium volume in a certain time and press through the test piece measuring section. This is not shown in detail here, since these details are not important for essential points of the calibration device 1 according to the invention.

A calibration device 1 according to the invention is shown in Fig. 2, that differs from the calibration device 1 known from the prior art according to Fig. 1 in that the temperature-measuring device 5 is designed as an ultrasonic temperature-measuring device 8, so that the medium temperature, consequently, is determined using the speed of an emitted ultrasonic signal in the medium. The ultrasonic signals emitted from the ultrasonic temperature-measuring device 8 move in the medium practically without disturbance. It is important that the ultrasonic temperature-measuring device 8 does not extend into the flow cross-section of the test piece measuring section 2, so that the flow in the test piece measuring section 2 is essentially not influenced by the ultrasonic temperature-measuring device 8. The advantage of a ultrasonic temperature-measuring device 8 – here also being used in immediate proximity to the mass flowmeter test piece 3 – is that the information about the ultrasonic speed and thus about the temperature is present practically without delay, since, as opposed to invasive temperature-measuring devices, a sensor and its casing do not have to be heated first by the medium, rather the medium is measured practically by itself using the propagation speed of the acoustic noise. Further, the running time of the ultrasonic signal is always measured via the signal path and thus, automatically, also the averaged temperature along this signal path, so that the ultrasonic temperature-measuring device 8 does not only give a selective impression of the temperature, but rather provides an average overall temperature via the signal path. The signal paths of the ultrasonic temperature-measuring device 8 implemented and shown here run practically perpendicular to the flow of the medium within the calibration device 1.

In using ultrasonic temperature-measuring devices 8 for determining the temperature of a medium, it can be a problem that the relation between the medium temperature, on the one hand, and the ultrasonic speed in the medium, on the other hand, is very dependent on the medium used. This relation has to be known , consequently, in order to obtain the speed and, thus, the temperature in the medium as a result of the measuring running time of an ultrasonic signal. In the calibration devices 1 according to Fig. 3 to 5, it is thus provided that an invasive reference temperature-measuring device 9 and an associated reference ultrasonic temperature-measuring device 10 are arranged adjacent to one another in the calibration device 1, so that the state variables medium temperature T_{ref} and ultrasonic speed v_{ref} can be detected metrologically by the reference measuring devices 9, 10 practically at one location; "adjacent to one another" is to be understood in this sense. The reference temperature-measuring device 9 and the associated reference ultrasonic temperature-measuring device 10 are additionally arranged in the calibration device 1 in such a manner that the flow in the test piece measuring section 2 in the area of the ultrasonic temperature-measuring device 8 – which is implemented in addition to the reference ultrasonic temperature-measuring device 10 – and in the area of the mass flowmeter test piece 3 is essentially not influenced by the invasive reference temperature-measuring device 9, so that the ultrasonic speed v_{ref} in the medium at the medium temperature T_{ref} determined by the invasive reference temperature-measuring device 9 is determined with the reference ultrasonic temperature-measuring device 10. This measure allows for the advantages of the highly exact invasive reference temperature-measuring device 9, which is arranged away from the mass flowmeter test piece 3 and the ultrasonic temperature-measuring device 8, to be combined with the quick ultrasonic temperature-measuring device 8 that makes an average via the cross-section in the proximity of the mass flowmeter test piece 3 to be calibrated, since the creation of the relation between the medium temperature and the ultrasonic speed can be produced in the medium via the reference ultrasonic temperature-measuring device 10 provided adjacent to the invasive reference temperature-measuring device 9.

The invasive reference temperature-measuring device 9 and the associated reference ultrasonic temperature-measuring device 10 are arranged downstream from the ultrasonic temperature-measuring device 8 and the mass flowmeter test piece 3 to be calibrated in Fig. 3a, however, are so far away that the disturbances 6 in the flow image induced by the invasive reference temperature-measuring device 9 are practically dissipated in the area of the mass flowmeter test piece 3 to be calibrated and the ultrasonic temperature-measuring device 8. In contrast, the invasive reference temperature-measuring device 9 and the associated reference ultrasonic temperature-measuring device 10 are arranged downstream from the mass flowmeter test piece 3 in the calibration device 1 according to Fig. 3b, so that the induced disturbance6 can initially not easily make its way to the area of the mass flowmeter test piece 3 and the ultrasonic temperature-measuring device 8. The calibration devices 1 according to Fig. 3a, 3b are designed so that the relation $v_{ref} = f(T_{ref})$ between the ultrasonic speed v_{ref} in the medium and the medium temperature T_{ref} obtained from the reference measurement forms the basis for the temperature measurement with the ultrasonic temperature-measuring device 8 in the test piece measuring section 2, i.e.

this relation is taken into account in the evaluation of the signal running times obtained by the ultrasonic temperature-measuring device 8, which is indicated in Fig. 3a, 3b by the curvy arrow. In practice, the calibration device 1 has an evaluation unit not shown here, in which the measurement data for the ultrasonic temperature-measuring device 8, the invasive reference temperature-measuring device 9 and the associated reference ultrasonic temperature-measuring device 10 are centrally detected and further processed as described above. In the embodiments according to Fig. 3a, 3b, the influence-free arrangement of the invasive reference temperature-measuring device 9 and the associated reference ultrasonic temperature-measuring device 10 is implemented in that both reference measuring device 9, 10 are arranged in the test piece measuring section 2 and arranged practically with enough distance to the mass flowmeter test piece 3 and the ultrasonic temperature-measuring device 8 in the test piece measuring section 2 so that reference measurements and calibration measurements can be carried out simultaneously. If the reference measurement should be carried out with the invasive reference temperature-measuring device 9 and the associated reference ultrasonic temperature-measuring device 10 for determining the relation $v_{ref} = f(T_{ref})$, then this is to be carried out using the entire calibration device 1.

Most of the flow tubes of the calibration device 1 are shown only as lines in Fig. 4 and 5. It is provided in the calibration device 1 according to Fig. 4 and 5 that a by-pass 11 to the test piece measuring section 2 is implemented, wherein the invasive reference temperature-measuring device 9 and the associated reference ultrasonic temperature-measuring device 10 are arranged in the by-pass 11; only this part of the tube system is shown two-dimensionally. Further, it is provided in the calibration device 1 that the by-pass 11 can be de-coupled from the test piece measuring section 2 in terms of flow by means of stop valves 12, 13, 14. The operation of the invasive reference temperature-measuring device 9 in the by-pass allows a very simple, effective and far-reaching isolation of the reference measurement from the measurement in the test piece measuring section

2, wherein this is particularly the case when the stop valves 12, 13 prevent any flow-related interaction between the by-pass 11 and the test piece measuring section 2.

The design of the by-pass 11 shown in Fig. 4b is of particular advantage, in which the by-pass 11 forms a by-pass loop, in which a conveying device 15 in the form of a pump and a combined heating and cooling device 16, 17 for the medium are provided. Using a by-pass loop that is designed in such a manner, it is possible to always mix and homogenize the medium so that a stationary state of the medium can be set in the by-pass 11, so that the invasive reference temperature-measuring device 9 – which is highly accurate, but slow – shows a stationary temperature measurement, so that correlations between the medium temperature T_{ref} and the ultrasonic propagation speed v_{ref} in the medium can be determined with high accuracy. These correlations can be determined for different temperatures and dependent on other parameters, such as the pressure P of the medium, for example, so that characteristic curves can be gathered for the quick ultrasonic temperature-measuring device 8 practically decoupled from the test piece measuring section 2 with the by-pass loop, indicated in the value table with $v_{ref,i}$ $T_{ref,i}$. The shown by-pass 11 is loaded with the medium at regular intervals in the test piece measuring section 2, so that it is always guaranteed that the medium used in the test piece measuring section 2 for calibration is also the medium forming the basis for the reference measurements in the by-pass 11.

The calibration device 1 according to Fig. 5 shows a test piece measuring section 2 designed as a test piece measuring section loop, which additionally has a combined heating and cooling device 18, 19 for the medium and furthermore a mass flowmeter 20 as a working standard. In this manner, the calibration device 1 can be operated practically at any flows and states of the medium, which allows for a comprehensive calibration of the mass flowmeter test piece 3. As can be seen in Fig. 5, multiple ultrasonic temperature-measuring devices 8a, 8b, 8c and 8d are arranged in the direction of flow spaced from one another in the test piece measuring section 2, so that also a temperature curve within the test piece measuring section 2 can be detected, which is of particular interest when, for example, the changing geometry of the calibration device 1 – in particular caused by temperature influences – has to be compensated.

In Fig. 6, it is shown schematically that the ultrasonic temperature-measuring device 8 has multiple ultrasonic measuring paths 20a, 20b, 20c through a cross-section of the test piece measuring section 2 in the test piece measuring section, wherein the ultrasonic measuring paths 20a, 20b, 20c run radially or parallel through the cross-section of the test piece measuring section. For this reason, it is possible in the case of radial ultrasonic measuring paths 20a, 20b, 20c to measure the average of the entire flow cross-section, wherein simultaneously layering effects within the flow, in particular layering effects due to gravitation, can be taken into account practically. The alignment of parallel measuring paths 20a, 20b, 20c allows, in turn, specific boundary current effects to be acknowledged and taken into account in further measurements.

Patentkrav

1. Kalibreringsindretning (1) til flowmålere, hvilken indretning har mindst en målesektion (2) til et prøvestykke, i hvilken sektion flowmålerens prøvestykke (3), som skal kalibreres, kan indsættes, hvilken målesektion har mindst en indretning (4) til at danne et flow af et medium gennem prøvestykmålesektionen (2) og har mindst en indretning (5) til at måle temperatur i prøvestykmålesektionen (2) for at måle temperaturen af mediet, kendetegnet ved, at temperaturmåleindretningen (5) er udformet som en indretning (8) til at måle temperatur ved hjælp af ultralyd, hvoraf det følger, at temperaturen af mediet bestemmes ved at anvende hastigheden af et udsendt ultralydssignal i mediet, hvilken ultralydstemperaturmåleindretning (8) ikke udstrækker sig ind i flowtværsnittet af prøvestykmålesektionen (2), således at flowet i prøvestykmålesektionen (2) i det væsentlige er upåvirket af ultralydstemperatur-måleindretningen (8), især i området af flowmålerens prøvestykke (3), at en invasiv referencetemperaturmåleindretning (9) og en tilhørende reference-ultralydstemperaturmåleindretning (10) er anbragt ved siden af hinanden i kalibreringsindretningen (1) og er anbragt i kalibreringsindretningen (1), således at flowet i prøvestykmålesektionen (2), i området for ultralydstemperatur-måleindretningen (8) og i området for flowmålerens prøvestykke (3), er i det væsentlige upåvirket af den invasive referencetemperaturmåleindretning (9), således at ultralydshastigheden (v_{ref}) i mediet kan bestemmes med referenceultralydstemperaturmåleindretningen (10) ved medietemperaturen (T_{ref}), der er bestemt ved at anvende den invasive referencetemperaturmåleindretning (9), og at relationen ($v_{ref} = f(T_{ref})$), der er opnået fra referencemålingen, mellem ultralydshastigheden (v_{ref}) i mediet og medietemperaturen er grundlaget for temperaturmålingen med ultralydstemperaturmåleindretningen (8) i prøvestykmålesektionen (2).

2. Kalibreringsindretningen ifølge krav 1, kendetegnet ved,

at den invasive referencetemperaturmåleindretning (9) og den tilhørende referenceultralyds-temperaturmåleindretning (10) er anbragt i prøvestykmålesektionen (2).

3. Kalibreringsindretningen ifølge krav 1, kendetegnet ved, at der er realiseret et bypass (11) til prøvestykmålesektionen (2), og at den invasive reference-temperaturmåleindretning (9) og den tilhørende referenceultralydstemperatur-måleindretning (10) er anbragt i bypasset (11).

4. Kalibreringsindretningen ifølge krav 3, kendetegnet ved, at bypasset (11) kan afkobles flowteknisk fra prøvestykmålesektionen (2) ved hjælp af stopventiler (12, 13, 14).

5. Kalibreringsindretning ifølge krav 3 eller 4, kendetegnet ved, at bypasset (11) danner et bypass-loop, især hvor en transportindretning (15) og/eller en varmeindretning (16) og/eller en køleindretning (17) til mediet er tilvejebragt i bypass-loopet.

6. Kalibreringsindretning ifølge et hvilket som helst af kravene 1 til 5, kendetegnet ved, at prøvestykmålesektionen (2) er udformet som et måleloop til prøvestykket, især hvor en transportindretning (4) og/eller en varmeindretning (18) og/eller en køleindretning (19) for mediet er tilvejebragt i måleloopet til prøvestykket.

7. Kalibreringsindretning ifølge et hvilket som helst af kravene 1 til 6, kendetegnet ved, at ultralydstemperaturmåleindretningen (8) i prøvestykmålesektionen (2) og/eller referenceultralydstemperaturmåleindretningen har flere ultralydsmåleveje (20a, 20b, 20c) gennem et tværsnit af prøvestykmålesektionen (2) eller gennem et tværsnit af bypasset (11), hvilke ultralydsmåleveje (20a, 20b, 20c) især løber radialt eller parallelt gennem et tværsnit af prøvestykmålesektionen (2) eller bypasset (11).

8. Kalibreringsindretning ifølge et hvilket som helst af kravene 1 til 7, kendetegnet ved, at flere ultralydstemperaturmåleindretninger (8a, 8b, 8c og 8d) er anbragt i flowretningen i afstand fra hinanden i prøvestykmålesektionen (2), især er anbragt opstrøms fra stedet, hvor flowmålerprøvestykket (3) skal kalibreres.

9. Fremgangsmåde til kalibrering af et flowmåler med en kalibreringsindretning ifølge et hvilket som helst af kravene 1 til 6, hvilken kalibreringsindretningen (1) har mindst en målesektion (2) til et prøvestykke, i hvilken en flowmålers prøvestykke (3), der skal kalibreres, kan indsættes, og har mindst en indretning (4) til at danne et flow af et medium gennem prøvestykmålesektionen (2) og har mindst en temperaturmåleindretning (5) i prøvestykmålesektionen (2) til at måle temperaturen i mediet, hvilken temperaturmåleindretning (5) er udformet som en ultralydstemperaturmåleindretning (8), og hvor en invasiv referencetemperatur-måleindretning (9) og en tilknyttet referenceultralydstemperaturmåleindretning (10) er anbragt ved siden af hinanden i kalibreringsindretningen (1) og er anbragt i kalibreringsindretningen (1), således at flowet i prøvestykmålesektionen (2) i området for ultralydstemperaturmåleindretningen (8) og i område for flowmålerprøvestykket (3) i det væsentlige er upåvirket af den invasive referencetemperaturmåleindretning (9), således at ultralydshastigheden (v_{ref}) i mediet kan bestemmes med referenceultralydstemperaturmåleindretningen (10) ved medietemperaturen (T_{ref}), der er bestemt ved anvendelse af den invasive referencetemperaturmåleindretning (9), kendetegnet ved, at en måling af ultralydshastigheden (v_{ref}) udføres i kalibreringsindretningen (1) ved hjælp af referenceultralydstemperaturmåleindretningen (10) og en måling af medietemperaturen (T_{ref}) udføres ved hjælp af den invasive referencetemperatur-måleindretning (9), og relationen ($v_{ref} = f(T_{ref})$), der er opnået fra referencemåling mellem ultralydshastigheden (v_{ref}) i mediet og medietemperaturen er grundlaget for temperaturmåling med

ultralydstemperaturmåleindretningen (8) i prøvestykmålesektionen (2).

10. Fremgangsmåden ifølge krav 9 i forbindelse med en kalibreringsindretning (1) ifølge krav 4, i hvilken et bypass (11) til prøvestykmålesektionen (2) er realiseret, og den invasive referencetemperaturmåleindretning (9) og den tilhørende referenceultralydstemperaturmåleindretning (10) er anbragt i bypasset (11), og bypasset (11) kan yderligere afkobles flowteknisk fra prøvestykmålesektionen (2) ved hjælp af stopventiler (12, 13, 14), kendetegnet ved, at relationen ($v_{ref} = f(T_{ref})$) mellem ultralydshastigheden (v_{ref}) i mediet og medietemperaturen (T_{ref}) opnås, efter at bypasset (11) er blevet oversvømmet med medium, der er til stede i prøvestykmålesektionen (2), og bypasset (11) derefter er afkoblet flowteknisk fra prøvestykmålesektionen (2) ved hjælp af stopventiler (12, 13, 14).

11. Fremgangsmåden ifølge krav 10, kendetegnet ved, at en stationær tilstand af mediet først afventes i bypasset (11), især en stationær tilstand med hensyn til medietemperaturen, der er bestemt med referencetemperaturmåleindretningen (9), før relationen ($v_{ref} = f(T_{ref})$) mellem ultralydshastigheden (v_{ref}) i mediet og medietemperaturen (T_{ref}) fastlægges og frigives til brug for ultralydstemperaturmåleindretningen (8) i prøvestykmålesektionen (2).

12. Fremgangsmåde ifølge krav 10 eller 11, kendetegnet ved, at flere temperaturer indstilles i bypasset (11), især ved at anvende en transportanordning og/eller en opvarmningsindretning og/eller en køleindretning til mediet, der er tilvejebragt i bypasset (11) eller bypass-loopet, og flere relationer ($v_{ref} = f(T_{ref})$) mellem ultralydshastigheden (v_{ref}) i mediet og medietemperaturen (T_{ref}) opnås, især hvor medietrykket også måles og noteres for hver opnået relation.

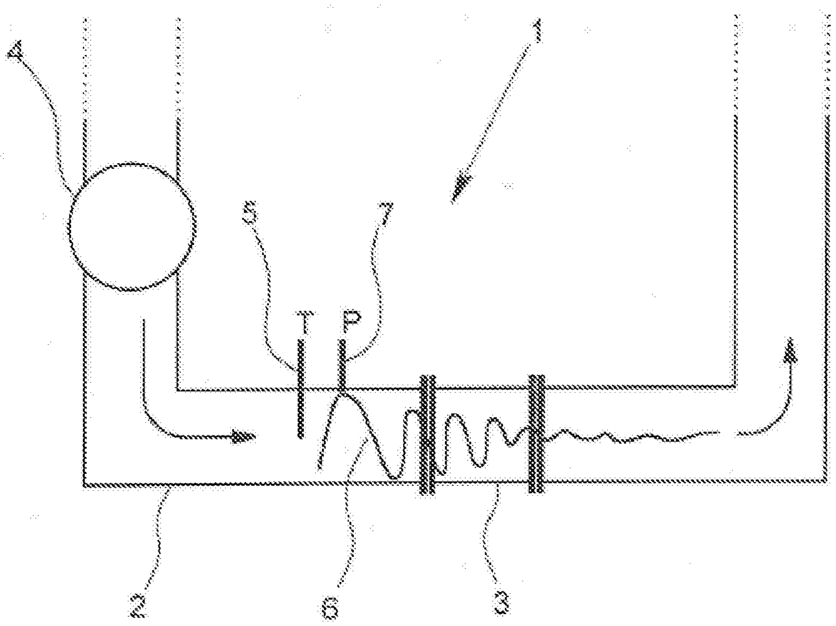

Fig. 1

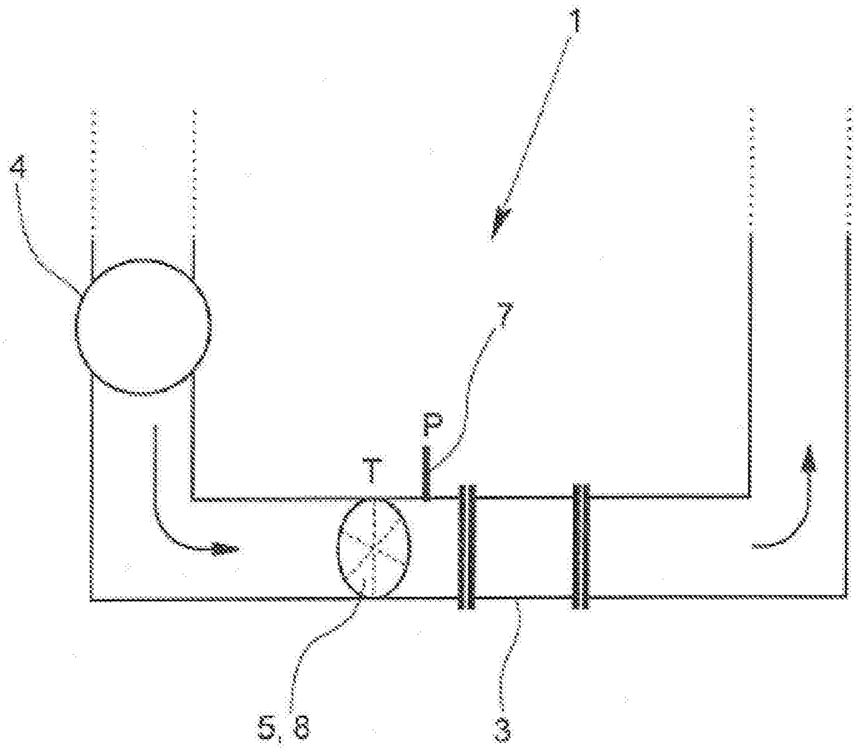

Fig. 2

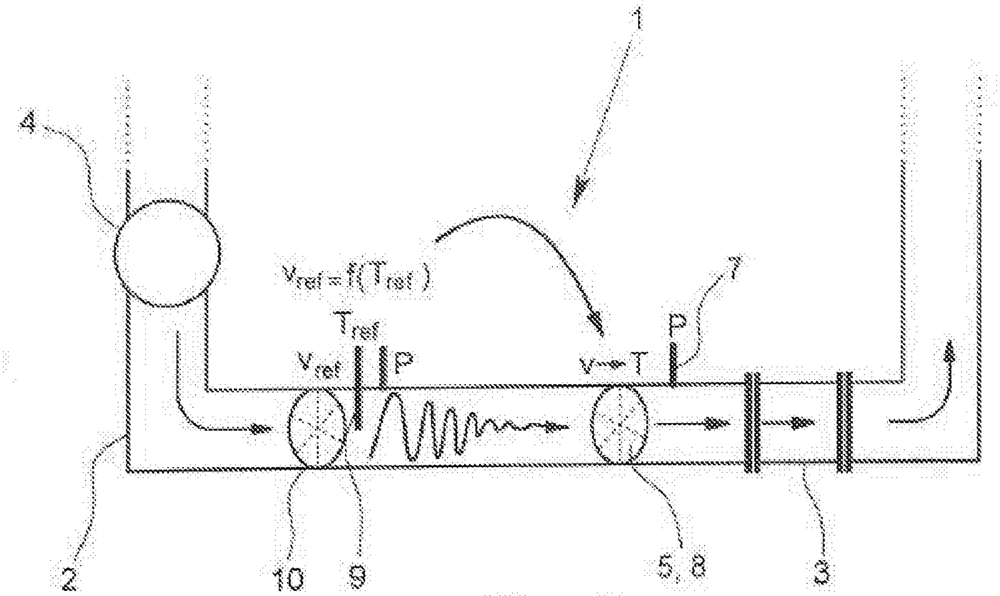
1
4
$v_{ref} = f(T_{ref})$
7
T_{ref}
P
v_{ref}
v → T
P
2
10
9
5, 8
3

Fig. 3a

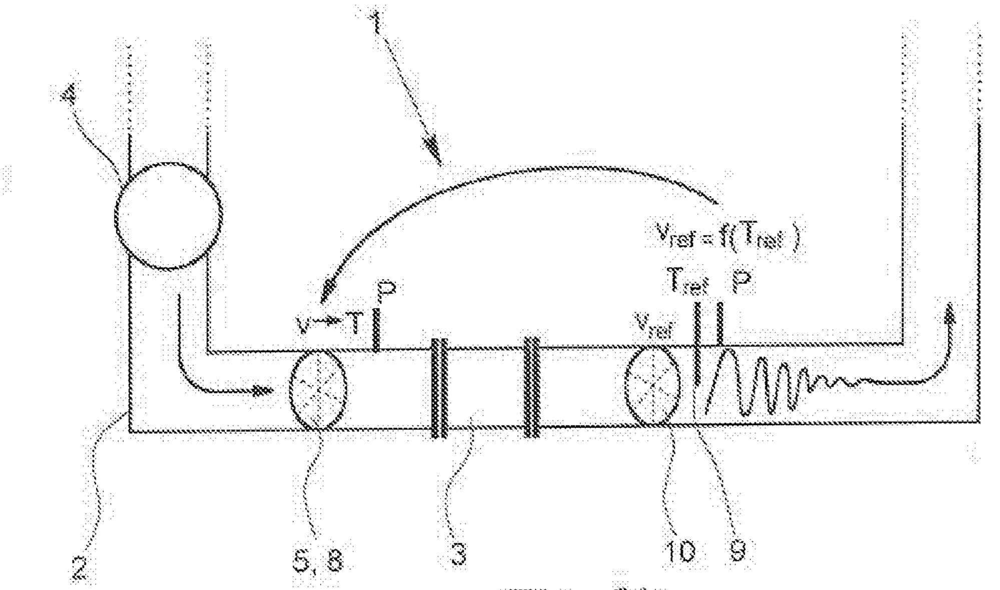
1
4
$v_{ref} = f(T_{ref})$
P
T_{ref}
P
v → T
v_{ref}
2
5, 8
3
10
9

Fig. 3b

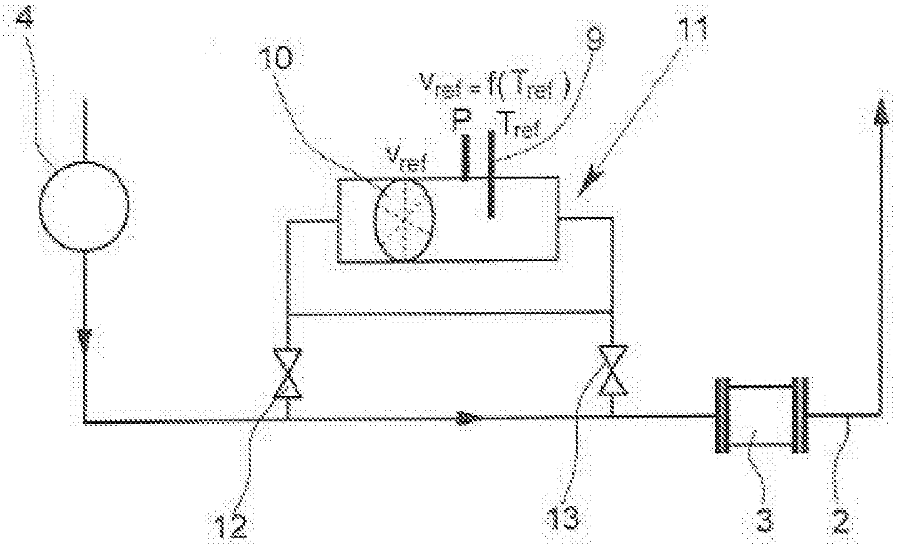
4
10
9
11
$v_{ref} = f(T_{ref})$
P
T_{ref}
v_{ref}
12
13
3
2

Fig. 4a

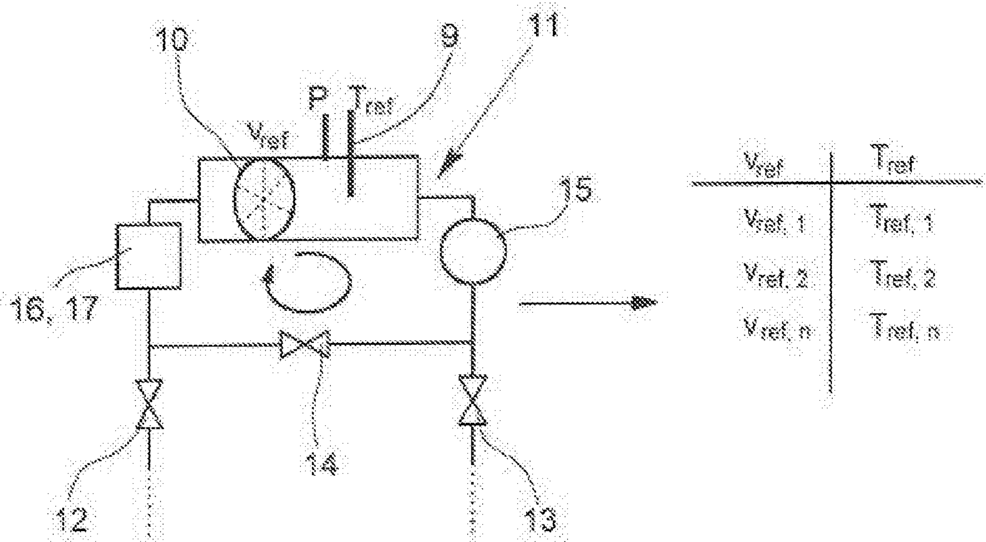
10
9
11
P
T_{ref}
v_{ref}
15
16, 17
14
12
13
v_{ref}
T_{ref}
$v_{ref,1}$
$T_{ref,1}$
$v_{ref,2}$
$T_{ref,2}$
$v_{ref,n}$
$T_{ref,n}$

Fig. 4b

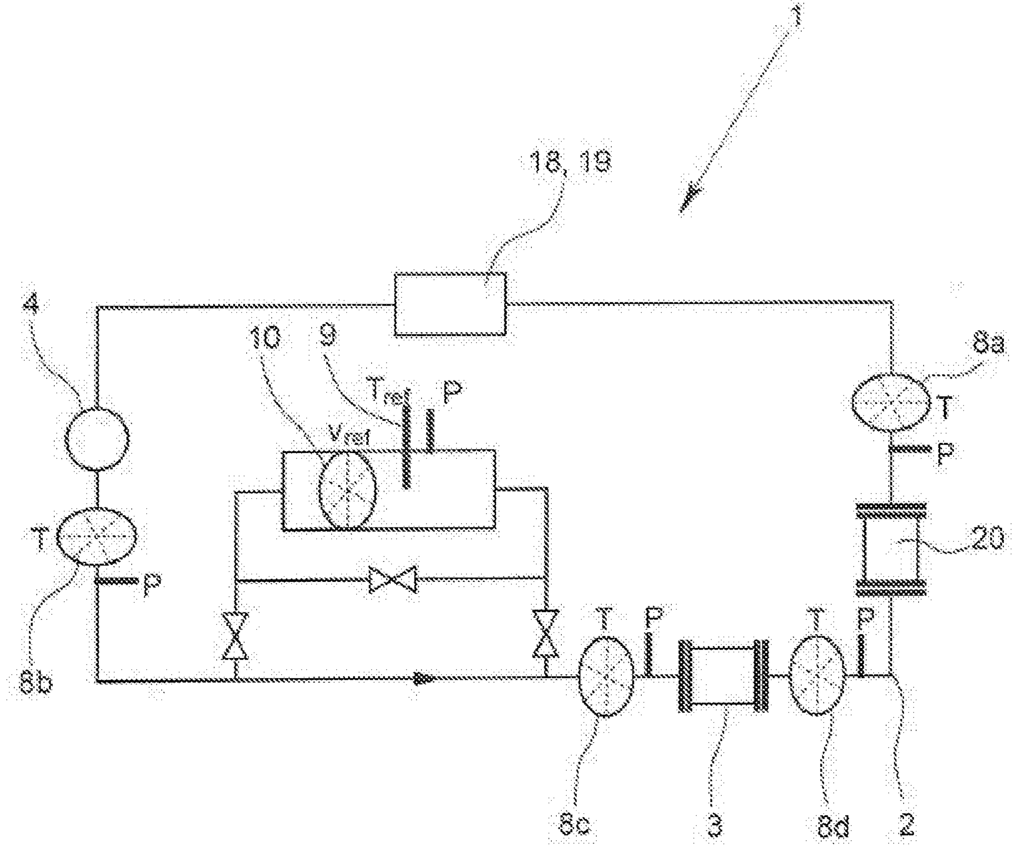

Fig. 5

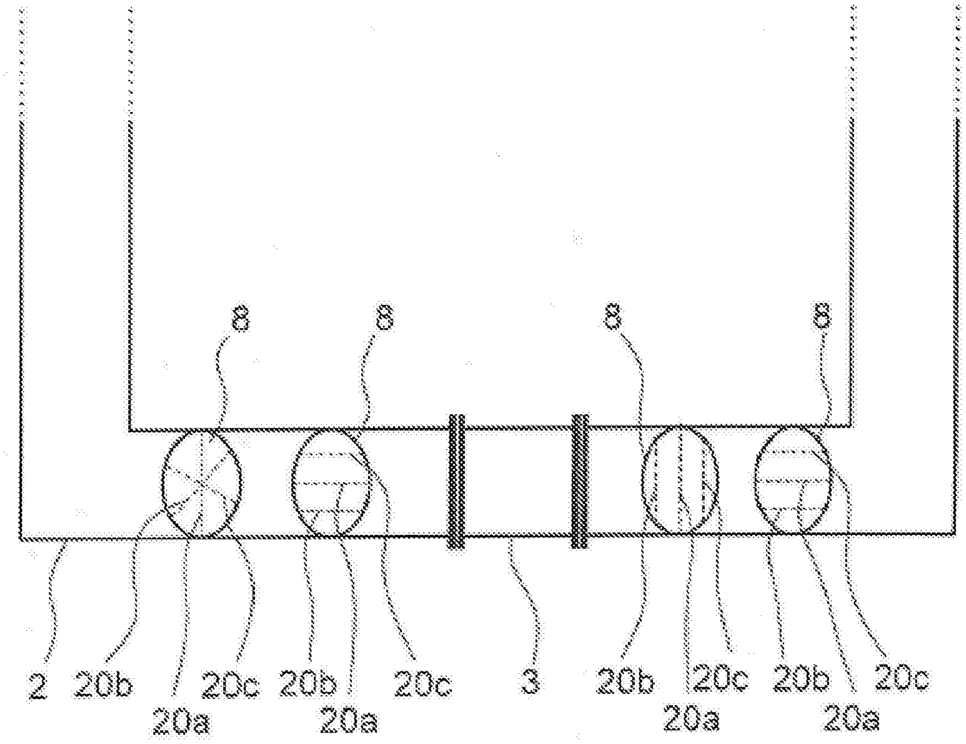

Fig. 6