Claims

1. A flow sensor (1) configured to measure the flow (Q) of a fluid (26) flowing through a tubular structure (2), wherein the flow sensor (1) comprises a first detection unit (34) that is configured to detect flows (Q) above a predefined lower flow level (Q_A) representing the lowest flow (Q_A) that can be measured by using the first detection unit (34), wherein the flow sensor (1) comprises a second detection unit (36) that comprises:

- a first temperature sensor (12) arranged and configured to detect the temperature (T_s) of the surroundings (the ambient temperature);

- a second temperature sensor (14) arranged and configured to detect the temperature (T_f) of the fluid (26);

- a data processor (10) connected to the temperature sensors (12, 14),

wherein the second detection unit (36) is configured to estimate the flow (Q) below the lower flow level (Q_A) on the basis of the temperature difference (ΔT_{Sf}) between the surroundings and a fluid (26), wherein the temperature difference (ΔT_{Sf}) is measured by the first temperature sensor (12) and the second temperature sensor (14), **characterised in** that the second detection unit (36) is configured to estimate the flow (Q) below the lower flow level (Q_A) on the basis of two or more measurements (M_1, M_2) made in a flow-calibration-area (B_2), in which the flow sensor (1) can detect the flow (Q) that depends on the temperature difference (ΔT_{Sf}), wherein the two or more measurements (M_1, M_2) made in the flow-calibration-area (B_2) are used to determine one or more parameters required to determine how the flow (Q) depends on the temperature difference (ΔT_{Sf}) in the flow-calibration-area (B_2) and in the flow area (Bi) below the flow-calibration-area (B_2).

2. A flow sensor (1) according to claim 1, wherein the second detection unit (36) is configured to estimate the flow (Q) below the lower flow level (Q_A) on the basis of the two or more measurements (M_1, M_2) made in a flow-calibration-area (B_2).

3. A flow sensor (1) according to claim 1 or 2, wherein the flow sensor (1) is configured to regularly or continuously:

- carry out the one or more measurements (M_1, M_2) in a flow- calibration-area (B_2) and

- update the parameters required to determine how the flow (Q) depends on the temperature difference (ΔT_{Sf}) in the flow-calibration- area (B_2) and in the flow area (Bi) below the flow-calibration-area (B_2).

4. A flow sensor (1) according to one of the preceding claims, wherein the dependency between the flow (Q) and the temperature difference (ΔT_{Sf}) is defined by of the following equations:

$$\Delta T_{sf}(Q) = \Delta T_B\left(1 - e^{-C_1 Q}\right) \text{ or } Q(\Delta T_{sf}) = \frac{-1}{C_1}\ln\left(1 - \frac{\Delta T_{sf}}{\Delta T_B}\right)$$

where C_1 is a constant and ΔT_B is a temperature difference corresponding to a base flow level.

5. A flow sensor (1) according to one of the preceding claims, wherein the second temperature sensor (14) is arranged and configured to detect the temperature (T_f) of the fluid (26) by measuring a temperature at the outside of the tubular structure (2).

6. A flow sensor (1) according to one of the preceding claims, wherein the data processor (10) and the second temperature (14) sensor are arranged inside a housing (20).

7. A flow sensor (1) according to claim 6, wherein the first temperature sensor (12) is arranged in the housing (20).

8. A flow sensor (1) according to claim 6, wherein the first temperature sensor (12) is arranged outside the housing (20).

9. A flow sensor (1) according to one of the preceding claims, wherein the second detection unit (36) comprises:

- an intermediate temperature sensor (16) arranged and configured to detect an intermediate temperature (T_i) of a position inside the housing (20), wherein said position is expected to have a temperature between the ambient temperature (T_s) and the temperature (T_f) of the fluid (26).

10. A flow sensor (1) according to one of the preceding claims, wherein the flow sensor (1) is a clamp-on flow sensor (1) configured to measure the flow (Q) of the fluid (26) from outside the tubular structure (2).

11. A flow sensor (1) according to one of the preceding claims, wherein flow sensor (1) is an ultrasonic flow sensor (1) and that the first detection unit (34) comprises at least one ultrasonic transducer (4, 4') arranged to transmit ultrasonic waves (6) and least one ultrasonic transducer (4, 4') arranged to receive ultrasonic waves (8).

12. A flow sensor (1) according to claim 11, wherein the flow sensor (1) is configured to:

- determine the time-of-flight (t, t_1, t_2) of the ultrasonic waves (6, 8) and calculate a change in the speed of sound on the basis of the time-of-flight (t, t_1, t_2);

- calculate the expected change in speed of sound (c) as function of the detected temperature (T_f) of the fluid (26) and

- determine if the expected change in speed of sound (c) corresponds to the change in speed of sound calculated on the basis of the time- of-flight (t, t_1, t_2).

13. A flow sensor (1) according to one of the preceding claims, wherein the ultrasonic flow sensor (1) is configured to calculate a corrected value of the change in the density (ρ) of the fluid (26) on the basis of the change in speed of sound calculated on the basis of the time-of-flight (t, t_1, t_2), if the expected speed of sound (c) does not correspond to the change in speed of sound calculated on the basis of the time-of-flight (t, t_1, t_2).

14. A flow sensor (1) according to claim 13, wherein the ultrasonic flow sensor (1) is configured to calculate a corrected value of the specific heat capacity (c_p) of the fluid (26) on the basis of the corrected value of the density (p), if the expected change in speed of sound (c) does not correspond to the change in speed of sound calculated on the basis of the time-of-flight (t, t_1, t_2).

15. A flow sensor (1) according to one of the preceding claims 13-14, wherein the ultrasonic flow sensor (1) is configured to calculate a corrected value of the flow (Q) of the fluid (26) on the basis of the change in speed of sound calculated on the basis of the time-of-flight (t, t_1, t_2), if the expected change in speed of sound (c) does not correspond to the change in speed of sound calculated on the basis of the time-of-flight (t, t_1, t_2).

16. A flow sensor (1) according to one of the preceding claims 12-15, wherein the data processor (10) is configured to automatically calculate the distance (L) that the transmitted ultrasonic waves (6) and receive ultrasonic waves (8) travel in the fluid (26) on the basis of a detected value of the speed of sound (c).

17. Method for measuring the flow (Q) of a fluid (26) flowing through a tubular structure (2) by using a first detection unit (34) that is configured to detect flows (Q) above a predefined lower flow level (Q_A) representing the lowest flow (Q_A) that can be measured by using the first detection unit (34), wherein the method comprises the steps of applying a second detection unit (36) to:

- detect the temperature (T_s) of the surroundings (the ambient temperature) by means of a first temperature sensor (12);

- detect the temperature (T_f) of the fluid (26) by means of a second temperature sensor (14);

- estimating the flow (Q) below the lower flow level (Q_A) on the basis of the temperature difference (ΔT_{Sf}) between the surroundings and a fluid (26)

measured by the first temperature sensor (12) and the second temperature sensor (14),

characterised in that the method comprises the following steps:

a) performing two or more flow measurements (M_1, M_2) by means of the first detection unit (34) in a flow-calibration-area (B_2), in which flow-calibration-area (B_2) the flow sensor (1) can detect the flow (Q) that depends on the temperature difference (ΔT_{Sf});

b) applying the two or more measurements (M_1, M_2) made in the flow-calibration-area (B_2) to determine one or more parameters required to determine how the flow (Q) depends on the temperature difference (ΔT_{sf}) in the flow-calibration-area (B_2) and in the flow area (B_i) below the flow-calibration-area (B_2) and

c) estimating the flow (Q) below the lower flow level (Q_A) on the basis of the two or more measurements (M_1, M_2) made in the flow-calibration-area (B_2).

18. Method according to claim 17, wherein the method comprises the step of performing two or more flow measurements in the flow-calibration-area.

19. Method according to claim 17or 18, wherein the method comprises the step of regularly or continuously:

- carrying out the one or more measurements (M_1, M_2) in a flow- calibration-area (B_2) and

- updating the parameters required to determine how the flow (Q) depends on the temperature difference (ΔT_{Sf}) in the flow- calibration-area (B_2) and in the flow area (Bi) below the flow- calibration-area (B_2).

20. Method according to one of the preceding claims 17-19, wherein the dependency between the flow (Q) and the temperature difference (ΔT_{Sf}) is defined by of the following equations:

$$\Delta T_{sf}(Q) = \Delta T_B\left(1 - e^{-C_1 Q}\right) \text{ or } Q(\Delta T_{sf}) = \frac{-1}{C_1}\ln\left(1 - \frac{\Delta T_{sf}}{\Delta T_B}\right)$$

where C_i is a constant and ΔT_B is a temperature difference corresponding to a base flow level.

21. Method according to one of the preceding claims 17-20, wherein the second temperature sensor (14) is arranged and configured to detect the temperature (T_f) of the fluid (26) by measuring a temperature at the outside of the tubular structure (2).

22. Method according to one of the claims 17-21, wherein the method comprises the step of detecting an intermediate temperature (T,) by means of an intermediate temperature sensor (16) arranged in a position inside a housing (20) that houses the second temperature sensor (14) and the intermediate temperature sensor (16), wherein the inter mediate temperature (T,) is expected to have a value between the ambient temperature (T_s) and the temperature (T_f) of the fluid (26).

23. Method according to one of the preceding claims 17-22, wherein the method comprises the steps of measuring the density and/or the estimated inhomogeneity of the fluid (26) prior to measuring the flow (Q).

24. Method according to one of the preceding claims 17-23, wherein the method comprises the following steps:

- determining the time-of-flight (t, t_1, t_2) of the ultrasonic waves (6,

8);

- calculating the change in the speed of sound on the basis of the time-of-flight (t, t_1, t_2);

- calculating the expected change in the speed of sound as function of the detected temperature (T_f) of the fluid (26);

- determining if the expected change in speed of sound (c) corresponds to the change in speed of sound (c) calculated on the basis of the time-of-flight (t, t_1, t_2).

25. Method according to claim 24, wherein the method comprises the step of calculating a corrected value of change in the density (ρ) of the fluid (26) on the basis of the change in speed of sound calculated on the basis of the time-of-flight (t, t_1, t_2), if the expected speed of sound (c) does not correspond to the change in speed of sound calculated on the basis of the time-of-flight (t, t_1, t_2).

26. Method according to claim 24 or 25, wherein the method comprises the step of calculating a corrected value of the specific heat capacity (c_p) of the fluid (26) on the basis of the corrected value of the density (ρ), if the expected change in speed of sound (c) does not correspond to the change in speed of sound calculated on the basis of the time-of-flight (t, t_1, t_2).

27. Method according to one of the claims 24-26, wherein the method comprises the step of calculating a corrected value of the flow (Q) of the fluid (26) on the basis of the change in speed of sound calculated on the basis of the time-of-flight (t, t_1, t_2), if the expected change in speed of sound (c) does not correspond to the change in speed of sound calculated on the basis of the time-of-flight (t, t_1, t_2).

28. Method according to one of the preceding claims 17-27, wherein the method is carried out by using a clamp-on flow sensor (1) configured to measure the flow (Q) of the fluid (26) from outside the tubular structure (2).

29. Method according to one of the preceding claims 17-28, wherein the method is carried out by means of an ultrasonic flow sensor (1) and that the first detection unit (34) comprises at least one ultrasonic transducer (4, 4') arranged to transmit ultrasonic waves (6) and least one ultrasonic transducer (4, 4') arranged to receive ultrasonic waves (8).

30. Method according to one of the preceding claims 17-29, wherein the method comprises the step of:

- calculating the expected speed of sound (c) as function of the detected temperature (T_f) of the fluid (26) and

- automatically calculating the distance (L) that the transmitted ultra sonic waves (6) and receive ultrasonic waves (8) travel in the fluid (26) on the basis of a detected value of the speed of sound (c).

31. Method according to one of the preceding claims 17-30, wherein the method comprises the step of estimating the heat energy in a heating system or a cooling system.

32. Heat energy meter (5) comprising a sensor (1) according to one of the preceding claims 1-16.