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INSTALLATION QUALITY OF A TEMPERATURE TRANSMITTER AND INSTALLATION QUALITY DETERMINATION METHOD

Abstract

The invention relates to an air flow compensated room temperature transmitter configured to determine an installation quality score, IQS, of the temperature transmitter and comprising a computing device and an air flow measurement unit comprising a known mass, a resistive heating element, a thermistor, at least one heat sink, and data transmission means. The heating element is configured to heat the known mass to an elevated temperature and the thermistor is configured to measure its temperature during cooling for calculation of a cooldown time of the known mass defined based on the measured resistances of the heated known mass. The installation quality score, IQS, is determined based on the cooldown time. The invention further relates to an installation quality score determination method and a computer program product.

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Background/Summary

TECHNICAL FIELD

[0001] The present invention relates to a room temperature transmitter comprising an air flow measurement unit, which room temperature transmitter is configured to determine its installation quality.

[0002] The invention also relates to an installation quality determination method of a room temperature transmitter comprising an air flow measurement unit and a computer program product.

BACKGROUND

[0003] It is always useful to know the temperature of a room, house, or other indoor spaces. This allows to better manage the energy consumption, regulate the temperature and air conditioning and improve living or working comfort. Measuring thermal conditions in indoor spaces may be performed by several different measuring devices, thermometers. In heating, ventilating and air conditioning systems, there is especially a need for a thermometer measuring temperature correctly so that heating, ventilating and air conditioning can be correctly adjusted and controlled in indoor spaces. An example of a measuring device suitable to be used for this purpose is a room temperature transmitter (RTS) that has been designed for wall mounting and is used to sense temperature in indoor spaces.

[0004] Existing room temperature transmitters usually have a housing having ventilated openings, a connection terminal printed circuit board (PCB) and a temperature sensing element inside the housing. It measures indoor space temperature using approximation made by two sensors inside the housing, a main and secondary sensors. Internal heating of the RTS i.e. heating of electronics affects the readings of sensors. Heat is generated on the printed circuit board due power losses in electronics. The heat transfers by convection and conduction to both sensors inside the housing, which causes sensor readings usually raise. Therefore, the ambient air temperature reading provided by the RTS does not, at least in all conditions, represent the real ambient air temperature in an indoor space, even if a temperature reading of the main sensor is corrected by using a reading of the secondary sensor as a compensating factor. Air flow condition is one of those conditions in which the temperature measuring becomes more challenging. Air flow inside the RTS may be restricted or decreased with isolation walls or corresponding structures, which effect to convection heat transfer, but they do not prevent conduction heat transfer. In addition to that installation position of an RTS has its own effect on measured temperature readings.

SUMMARY

[0005] It is the aim of the invention to provide and present a room temperature transmitter comprising an air flow measurement unit, which room temperature transmitter is capable to determine its installation quality, so an installer can install the room temperature transmitter so that it would measure ambient air temperature more reliably. A further aim is to provide a method for determining installation quality of a room temperature transmitter comprising an air flow measurement unit. The scope of protection sought for various embodiments of the invention is set out by the independent claims. The embodiments, examples and features, if any, described in this specification that do not fall under the scope of the independent claims are to be interpreted as examples useful for understanding various embodiments of the invention.

[0006] According to a first aspect, there is provided an air flow compensated room temperature transmitter configured to determine an installation quality score, IQS, of the temperature transmitter. The air flow compensated room temperature transmitter comprises a computing device and an air flow measurement unit. The air flow measurement unit comprises a known mass, at least one resistive heating element, a thermistor, at least one heat sink, and data transmission means configured to transmit a resistance signal of the thermistor. The at least one resistive heating element is configured to heat the known mass to an elevated temperature and the thermistor is configured to measure temperature of the heated known mass during cooling for calculation of a cooldown time of the known mass defined based on the measured resistances of the heated known mass by the computing device. The installation quality score, IQS, is determined based on the cooldown time by the computing device (**404**) using the following calculation formula: [00001]$IQS = \text{MAX} - (1 - \frac{x}{f_{\text{target}}}) * f_{\text{scaling}}$, [0007] wherein the x is the cooldown time of the known mass, [0008] f.sub.target is a cooldown time of the known mass in seconds defined in ideal air flow conditions, [0009] f.sub.scaling is a scaling factor defining how much the measured airflow can differ from f.sub.target value, and [0010] MAX is the maximum possible installation quality score value.

[0011] According to an example, if the determined IQS value is greater than the MAX, the following calculation is performed for the IQS value:

[00002]$IQS = \text{MAX} - (IQS - \text{MAX})$.

[0012] According to an example, the maximum possible installation quality score value is 100 and the minimum possible installation quality score value is 0. According to an example, the cooldown time is the time of cooling of the mass (**101**) from a first temperature of the elevated temperature to a second temperature of the elevated temperature. According to an example, the cooldown time is the time of cooling of the mass from 90% to 10% of the elevated temperature. According to an example, the at least one resistive heating element is at least one heating resistor. According to an example, the resistance of the thermistor is measured using a resistance measurement circuit, a voltage divider, a current measurement circuit, or combination of these. According to an example, the air flow compensated room temperature transmitter further comprises a housing, and a main temperature sensor, a secondary temperature sensor inside the housing The computing device is further configured to receive and process temperature data of the main temperature sensor and the secondary temperature sensor and resistance data of the air flow measurement unit for determining an air flow compensated ambient temperature of the air flow compensated room temperature transmitter. According to an example, the ambient temperature is determined using an air flow compensated ambient temperature compensation formula that is: Ambient temperature=main sensor reading+(secondary sensor reading−main sensor reading)*factor a+offset+cooldown time*factor b, wherein main sensor reading is a temperature reading of the main sensor, the secondary sensor reading is a temperature reading of the secondary sensor, the factors a and b are correction coefficients of the air flow compensated room temperature transmitter predetermined in a testing conditions, the offset is a difference between the actual temperature of the space and temperature measured by the air flow compensated room temperature transmitter, and the cooldown time is a cooling time of the known mass of the air flow measurement unit. According to an example, the air flow compensated room temperature transmitter further comprises a data transmitting means for receiving data from the main temperature sensor and the secondary temperature sensor and resistance data of the air flow measurement unit or for transmitting the ambient temperature data to a HVAC device. According to an example, the air flow measurement unit also acts as a secondary temperature sensor. According to an example, the air flow compensated room temperature transmitter also comprises a display for displaying the installation quality score.

[0013] According to a second aspect, there is provided an installation quality score determination

method of an air flow compensated room temperature transmitter comprising a computing device and an air flow measurement unit.
[0014] The method comprises heating a known mass of the air flow measurement unit to an elevated temperature by at least one resistive heating element of the air flow measurement unit, measuring resistances of a thermistor on the known mass during cooling of the known mass, transmitting the measured resistances to a computing device for calculating a cooldown time of the known mass, and determining an installation quality score, IQS, based on the calculated cooldown time.
[0015] According to an example, determining the installation quality score, IQS, based on the cooldown time is calculated based on:
[00003] $IQS = \text{MAX} - (1 - \frac{x}{f_{\text{target}}}) * f_{\text{scaling}}$, [0016] wherein the x is the cooldown time of the known mass, [0017] f.sub.target is a cooldown time of the known mass in seconds defined in ideal air flow conditions, f.sub.scaling is a scaling factor defining how much the measured airflow can differ from f.sub.target value, and MAX is the maximum possible installation quality score value. According to an example, if the determined IQS value is greater than the MAX, the method further comprises performing the following calculation the calculated IQS value:
[00004] $IQS = \text{MAX} - (IQS - \text{MAX})$.
[0018] According to a third aspect, there is provided a computer program product embodied on a non-transitory computer readable medium, the computer program product comprising computer instructions that, when executed on at least one processor of an air flow compensated room temperature transmitter is configured to perform the method according to the second aspect and its examples.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0019] In the following, various embodiments of the invention will be described in more detail with reference to the appended figures, in which
[0020] FIG. **1** shows an air flow measurement unit of an air flow compensated RTS,
[0021] FIG. **2** shows, as an example, a graphic of an air flow measurement cycle of the air flow measurement unit shown in FIG. **1**,
[0022] FIG. **3** shows, as an example, a more detailed graphic of an air flow measurement cycle of the air flow measurement unit shown in FIG. **1**,
[0023] FIG. **4** shows, as an example, an air flow compensated RTS,
[0024] FIG. **5** shows an installation quality determination method of an air flow compensated room temperature transmitter comprising a computing device and an air flow measurement unit, and
[0025] FIG. **6** shows an installation quality graph comprising two different IQS value graphics of an air flow compensated room temperature transmitter, when arranged in different installation locations, and a graph of an air flow according to an example embodiment.
DETAILED DESCRIPTION
[0026] Heating, ventilation, and air conditioning (HVAC) system controls temperature, humidity, and purity of the air in an enclosed indoor space. Its goal is to provide thermal comfort and acceptable indoor air quality. A HVAC system includes heating equipment, ventilation equipment, and cooling or air-conditioning equipment. The HVAC system is an important part, for example of residential structures such as single family homes, apartment buildings, hotels, and senior living facilities; medium to large industrial and office buildings and hospitals, where safe and healthy building conditions are regulated with respect to temperature, humidity and ventilation. The HVAC system controls heating, cooling and air-ventilation based on temperature readings of a room or other indoor space measured by a room temperature transmitter, RTS, designed for automatic

HVAC systems. A room temperature transmitter can also be used as such just for measuring and indicating ambient temperatures of an indoor space.

[0027] In order to control heating, cooling and air-ventilation correctly, a HVAC system needs a room temperature transmitter that measures ambient temperature accurately. Accurate measuring is not always possible in indoor spaces especially not in air flow conditions. Air flow inside a housing of an RTS increases temperature around sensors and thus temperature measurement readings of sensors. This is because the air flow pushes heat to sensors when flowing through the RTS housing, for example, an air flow flowing downwards pushes heat from a top of the housing to sensors, and thus measured temperature readings will be too high. This is the case, for example, with existing RTSs, which do not take into account heating properties of an air flow inside the housing effecting temperature readings of the sensors of the RTS and causing erroneous readings. The size and/or change of an error of a measured ambient air temperature reading depends on, for example, an amount of an air flow, how the air flow affects sensors i.e. how the air flow reaches the sensors and an amount of internal heating of electronics (thermal load inside the housing). Thus some temperature transmitter designs may be less affected by an air flow. In general, large heat loads cause more problems and incorrect heat readings with air flow than small ones. In addition to that some installation locations of temperature transmitters may be less affected by an air flow than other locations. Therefore it is important to install a temperature transmitter to a location, where it has air flow conditions, which does not affect too much to ambient air temperature measurement readings or which affect as less as possible to them and that an installer knows that the installation location is proper and according to installation instructions for ambient air temperature measuring. Multiple factors i.e. so called location conditions of a temperature transmitter location affect to temperature measurement readings, such as airflow coming from a window(s), for example an open window or a draft from a window, an open door(s), a ventilation or a replacement air valve(s), etc. An external device or devices may also affect to temperature measurement readings, such as a heater(s), an electrical equipment, a TV, etc. Also, for example the sun heating a wall beneath a temperature transmitter may cause an excessive airflow and thus error to temperature measurement readings. Airflow can also be limited by external factors, such as other devices mounted on top or bottom of an RTS, or added insulation that blocks ventilation holes in the housing of an RTS.

[0028] The effect of an air flow to temperature measurement readings is especially big, when the air flow is large or varying. The air flow may affect the measuring readings of an RTS, even significantly, even if its temperature measuring results are corrected by a correction factor. This is because this correction factor is defined under stable conditions when there is no air flow or just small constant air flow. Therefore, measurement accuracy of existing RTS may be valid only in very narrow conditions and may get lower in changing air flow conditions. This increases probability and size of erroneous temperature measurement readings.

[0029] Therefore, there is a need for an air flow compensated room temperature transmitter i.e. an air flow compensated RTS that takes into account the heating effects of an air flow to temperature sensors of the RTS in its measurements by correcting temperature measurement readings with a formula, in which an air flow is compensated, and which further guides installation of the temperature transmitter so that it would be installed in an ideal air flow conditions i.e. air flow free or almost air flow free conditions, as possible. For this air flow compensation the amount of air flow inside a housing of the RTS has to be measured. Disruption to heat transfer inside an RTS housing can be estimated and correct ambient air temperature can be calculated using the measured air flow. This way an effect of an air flow to ambient temperature readings of an RTS can be minimized and the temperature measurement accuracy can be kept high and size of errors low even in changing air flow conditions. In this context the term “RTS” covers different kinds of room temperature transmitters, temperature transmitters, indoor temperature transmitters, and room temperature controllers.

[0030] The air flow compensated RTS has been designed for wall mounting on a wall surface or on a flush mounting box. Because the air flow compensated RTS takes into account an air flow in its measuring, it can be installed more freely, but it still measures temperature readings better if it is arranged, as above mentioned, in ideal conditions. Thus, a room temperature transmitter comprising an air flow measurement unit, which room temperature transmitter is configured to determine its installation quality by an installation quality score, IQS, of a room temperature transmitter comprising an air flow measurement unit is beneficial. This kind of RTS can inform an installer, for example that an excessive or too big air flow is detected in a current position of the installed RTS and temperature measurement errors are more likely. In other words, the installation quality score is a scoring system for installation. IQS value range may be, for example from 0 to 100, where 100 is the maximum and best IQS value and 0 is the minimum and worst IQS value i.e. 100 means the best possible installation, where temperature measurement errors are more unlikely, and 0 means the bad installation, where temperature measurement errors are more likely. But it should be noted that the maximum IQS value may be determined to be something else than 100 as well as the minimum IQS value may be determined to be something else than 0. The IQS value is proportional to an airflow measured within an RTS device and it is referenced to laboratory installation of device, if installation of the RTS is correct, which means that installation instructions are followed, there is very little air flow measured inside the RTS, hence the IQS value will be close to 100. However, an IQS value can fluctuate due to a measurement noise. Good installation range is between 100-80. When an air flow is increased inside the RTS the IQS value will decrease.

[0031] The air flow compensated RTS with installation quality determination solves problems caused to temperature measurement readings by an air flow, even when internal heating of the RTS is major i.e. the RTS comprises large thermal loads, major internal heating heats the sensors more, and its effect is even bigger when air flows through the RTS. Examples of RTSs with large thermal loads are room units with a display, a display backlight with a high power heat source and room temperature unit controllers, where display and outputs for thermal actuators are needed. By installation quality determination it can be ensured that RTS is installed in a qualified way, following installation instructions.

[0032] Using an air flow compensated temperature measurement method performed by an air flow compensated RTS in air flow conditions, can an air flow inside a housing of the RTS be measured and used as an input parameter for an air flow compensated temperature compensation formula. When air flow is included in compensation, temperature measurement errors of RTS devices can be kept within more accurate tolerances. Temperature measurement errors in air flow conditions using an air flow compensated RTS may usually vary only around +/−0.3 C, when temperature measurement errors in air flow conditions using an existing RTS without air flow compensation can vary around +/−1.0° C. While the general i.e. common requirement for the room temperature measurement accuracy is +/−0.5°.

[0033] A cooldown time of a known mass is measured. Measured cooldown time is proportional to the air flow velocity through a housing of RTS. Air flow velocity can be calculated from the cooldown time of that known mass. Cooldown time is averaged over multiple measurements. This prevents short airburst affecting the measurement, such as person passing by. Only a constant air flow, such as air conditioning fan turned on, is noted. After the fan is turned off, cooldown time returns to no flow value i.e. as 0. An air flow measurement unit with a known mass is arranged inside a housing of an air flow compensated RTS (not shown). An air flow measurement unit **100** of an air flow compensated RTS is shown in FIG. **1**. The air flow measurement unit **100** comprises a known mass **101**, at least one heater i.e. a resistive heating element **102**, for example, a heating resistor, a thermistor **103**, at least one heat sink **104**, and data transmission means **105** configured to transmit the resistance signal of thermistor **103** to a computing device of the air flow compensated RTS. Temperature of known mass **101** is determined based on the data transmission means **105** by the computing device of the air flow compensated RTS, by converting the received resistance to temperature using a voltage divider, current-to-voltage conversion, or resistance measurement

circuit. The mass **101** may be made, for example, of circuit board FR4 and copper that is plated with e.g. tin or gold. The heat sink may be made of copper that is plated with tin or gold or any other suitable material.
[0034] Cooling of the mass **101** happens by convection to the air inside a housing of the RTS. Temperature of the mass **101** is measured using the thermistor **103**. The cooldown time of the mass **101** i.e. heat transfer rate is proportional to convection heat-transfer coefficient of air.
[0035] Before cooling, the mass **101** is heated above ambient temperature, for example +2 C above the air inside the housing using resistive heating elements **102**. Then the mass **101** is let to cool down back to the starting temperature i.e. to the temperature inside the housing. This increase of temperature caused by heating may be marked by dt. The mass **101** is heated to temperature using, for example, a PI-controlled heating process. This ensures that elevated temperature can be reached accurately and fast, regardless of conditions.
[0036] Formula used for measuring heat transfer rate is as follows:

$Q=hA\Delta T$, where [0037] Q=a heat transfer rate of the known mass of the air flow measurement unit, [0038] H=a convection heat-transfer coefficient of air, [0039] A=an exposed surface area i.e. area of at least one heat sink **104** and at least one resistive heating element **102**, and [0040] ΔT=a temperature difference (dt)
[0041] The heat transfer rate of the known mass **101** of the air flow measurement unit **100** is proportional with the cooldown time, and vice versa, and the cooldown time may be, for example, the time of cooling of the mass **101** from 90% to 10% of the temperature increase i.e. the elevated temperature, meaning that the cooldown time is, for example, if the mass **101** is heated 2° C. above the temperature inside the casing, the measured cooldown time is a time that it takes for the temperature to decrease from 1.8° C. to 0.2° C. Measured cooldown time is then normalized to no-air flow-condition cooldown time to determine air flow. The cooldown time may be also other than the above mentioned time of cooling of the mass **101** from 90% to 10% of the temperature increase. It may be, for example, from 80% to 10%, from 95% to 15% or any other desired and suitable range. In other words, the cooldown time is measured during cooling of the mass **101** from some point of the elevated temperature to some point above the ambient temperature i.e. cooling of the mass **101** from a first temperature of the elevated temperature to a second temperature of the elevated temperature. The cooldown time is determined/calculated by the computing device of the RTS. The temperature increase i.e. the elected temperature can also be something else than 2° C., it may be, for example, between 1° C. to 4° C., or even more.
[0042] As the cooldown time is calculated, the air flow compensated ambient temperature reading may be calculated using an air flow compensated ambient temperature compensation formula that is as follows:

Ambient temperature=main sensor reading+(secondary sensor reading−main sensor reading)*factor *a*+offset+cooldown time*factor *b* [0043] wherein [0044] main sensor reading=a temperature reading of the main sensor, [0045] secondary sensor reading=a temperature reading of the secondary sensor, [0046] factors a and b=correction coefficients of an RTS predetermined in a testing conditions, where the RTS was used in different environments and use cases/scenarios. [0047] offset=a difference between the actual temperature of the space and temperature measured by the RTS, and [0048] cooldown time=cooling time of a mass of the air flow measurement unit.
[0049] Factors a and b are needed, because the heating of the RTS is not constant, but depends on a thermal load, for example whether the display backlight is on or off, in which cases the heating and power loss are different. As the power loss increases, the temperature difference between the main and secondary sensor increases, so with offset correction alone, the sensor reading would also increase compared to the actual ambient temperature. The offset is defined in the testing conditions, where the actual temperature is measured by an external temperature sensor arranged in the vicinity

of the RTS.
[0050] IQS values are also determined/calculated by the computing device of the RTS.
[0051] An IQS value is calculated with the following equation. In this example, the maximum IQS value is predetermined to be 100 and used in the equation, but it may be determined to be something else, and in that case the number **100** of the following equations are replaced by that number:
[00005] $IQS = 100 - (1 - \frac{x}{f_{\text{target}}}) * f_{\text{scaling}}$, [0052] wherein x is the above mentioned cooldown time of the mass **101** of the air flow measurement unit **100** of the RTS in seconds, [0053] f.sub.target is a cooldown time of the mass **101** in ideal air flow conditions in seconds, defined in the development phase of the RTS by test installations in the laboratory environment where the external airflow can be adjusted and ideal air flow can be found, and [0054] f.sub.scaling is a scaling factor, which defines how much the measured airflow can differ from f.sub.target value. f.sub.scaling is adjusted so that IQS reaches 0 or some other defined low value, ex<25, when errors in the measurement become greater than is allowed by the specification of RTS.
[0055] If the determined IQS value is calculated to be greater than that 100, the following calculation is performed for the IOS value
[00006] $IQS = 100 - (IQS - 100)$, [0056] which will lower the IQS value, if the cooldown time is increased from the target value. IQS minimum score value is limited to 0.
[0057] IQS values may also be measured at variable or fixed intervals, result values will be placed in the **5** measurement median calculation. Measurement is averaged over a measuring time period. For example, if a measuring time period is 1 hour, the measurement frequency may be averaged to be, every minute, so that there is 60 measurements per that hour i.e. n=60. Some other measuring time periods and measurement frequencies may also be used. But the averaged IQS.sub.avg would be calculated by the following equation:
[00007] $IQS_{\text{avg}} = \frac{1}{n} \text{.Math.}_{i=1}^{n} IQS_i$
[0058] Standard deviation of values can be calculated to determine turbulence of measured airflow by the following equation:
[00008] $IQS = \frac{\sqrt{\text{.Math.} (IQS_i \text{ .fwdarw. } IQS_{\text{avg}})^2}}{N}$
[0059] These IQS values and the result of 5 median can be used in location to determine problems in the installation. For example, a thermostat controlled heater or cooler will cause a rapid airflow that can be seen in the standard deviation of measured IQS values. Resulting averaged 0-100 IQS value can be split further for example in 4 zones (100-75, 74-50, 49-25, <25 IQS) corresponding values 1 to 4, where each value can be used as approximation of resulting errors in measurements, for example different distribution of errors in the measurement or the absolute inaccuracy of the measurement.
[0060] If the maximum possible IQS value (MAX) is not predetermined to be 100, the following equations would be used instead of above mentioned equations comprising the value 100:
[00009] $IQS = \text{MAX} - (1 - \frac{x}{f_{\text{target}}}) * f_{\text{scaling}}$ and $IQS = \text{MAX} - (IQS - \text{MAX})$
[0061] FIG. **2** shows, as an example, a graphic of an air flow measurement cycle of the air flow measurement unit **100** shown in FIG. **1**. The air flow measurement is performed by measuring cooldown time of the mass **101**. The reference number **200** indicates a heating time period, during which the heater **102** is on and is configured to heat the mass **101** 2° C. The curve **201** indicates a cooldown time of the mass **101**, when there is an air flow 0.2 m/s and the curve **202** indicates a cooldown time of the mass **101**, when there is no air flow and cooling of the mass **101** happens just by natural convection.
[0062] FIG. **3** shows, as an example, a more detailed graphic of an air flow measurement cycle of the air flow measurement unit **100** shown in FIG. **1**. The air flow measurement cycle starts at the time point t0 with the heating of mass **101** to the predetermined elevated temperature. In this

example it is +2° C. to an ambient air temperature. After the mass **101** temperature is reached this elevated temperature at the time point t1, the temperature of the mass **101** is kept at that constant temperature for time period t1-t2 to ensure that the whole mass **101** has heated and evenly heated in order to achieve a better measurement accuracy. This time period of keeping the mass **101** at the elevated temperature may be called, for example, as a steady state window. This cooldown time of the mass **101** is measured when temperature reaches/cools a start point t3 that is 10% below the elevated temperature i.e. the ambient air temperature +1.8 C. Cooldown time measuring ends at an end point t4, when temperature reaches 90% below the elevated temperature i.e. the ambient air temperature +0.2 C.

[0063] New cooldown time measurement cycle may begin again after the mass temperature has cooled back to the start temperature i.e. to the temperature inside the housing of the RTS; this starting time point is again t0. Time between air flow measurement cycles may be calculated as a multiple of a cooldown time, for example, if the cooldown time is 60 seconds, a new cycle air flow measurement cycle may be started after 5*60 s has passed. This ensures that the whole mass **101** has reached the constant temperature +0° C. to the ambient air. Air flow measurement may be done, for example, every couple of minutes and after a couple air flow measurements temperature readings of the RTS are correct ambient temperature readings.

[0064] In FIG. **4** it is shown an air flow compensated RTS **400** comprising a housing **405**, a first (main) sensor **401** and a second i.e. secondary sensor **402** and an air flow measurement unit **100**, a data transmitting means **406**, for example, a wired or wireless data transmitter, and a computing device **404** configured to process received data i.e. temperature data of the first sensor and the secondary sensor and resistance data of a thermistor of the air flow measurement unit **100**, which are connected to the computing device **404**. The first sensor **401** and the secondary sensor **402** and the air flow measurement unit **100** are connected to the computing device **404** in such a way, in a wired or wireless manner, that the sensor data can be transmitted from them **401**, **402**, **100** to the computing device **404**. The computing device **404** may be, for example, a microcontroller, MCU, and comprise at least one memory **407** for storing a computer program and sensor data, a processor for running the computer program, and one or more types of data transmission means for receiving sensor data and/or transmitting data such as configuration signals or messages for controlling temperature, ventilation or humidity. There is a thermal separation, for example, a slot in the PCB, between the main sensor **401** and the air flow measurement unit **100** i.e. they are not next to each other so that the heat does not transfer to the main sensor **401**, when the mass of the air flow measurement unit **100** is heated when measuring cooldown time. In this example embodiment the secondary sensor **402** and the air flow measurement unit **100** are two separate means, however it is possible that the air flow measurement unit **100** also acts as a secondary temperature sensor in addition to be used for cooldown time measuring of the mass so that separate secondary sensor **402** is not needed at all. Ventilation openings **414** of the housing **405** are such that the air flow inside the housing **405** is configured to flow over sensors **401**, **402** and to cool other components inside the housing **405**.

[0065] The computing device **404** is configured to process measured data provided by temperature sensors **401**, **402** and the air flow measurement unit **100** for calculating the air flow compensated ambient temperature reading. The RTS **400** may also comprise a display for displaying installation quality scores, air flow corrected temperature readings, and also possible air flow readings i.e. an amount of the air flow/second, as well as other means, such as means for receiving user inputs, for example, a keyboard, a touch screen, touch areas, soft keys, a microphone, a speaker, or other input/output mechanisms (not shown). The RTS **400** may further comprise user interface circuitry configured to control at least some functions of the user interface. The RTS **400** communicates with a HVAC system, it transmits by its data transmitting means **406** at least the calculated air flow compensated ambient temperature reading, but it may also transmit air flow readings, or temperature readings measured by the main and secondary sensors, over a data transmission network, for example, using WLAN (Wireless Local Area Network), Bluetooth, Modbus, some other digital data transfer bus, voltage or current signal, or GSM, CDMA or WCDMA technologies or future technologies, or other data network technologies.

[0066] The computing device **404** comprises at least one processor that may, for example be embodied as one or more of various hardware processing means such as a coprocessor, a microprocessor, a controller, a digital signal processor (DSP), a processing element with or without an accompanying DSP, etc. The processor may include one or more processing cores configured to perform independently. The processor may be configured to execute instructions stored in at least one memory of the computing device **404** or otherwise accessible to the processor. The processor may, for example be configured to analyse temperature and cooldown time data captured by the sensors **401**, **402** and air flow measurement unit **100**. The data transmitting means **406** may be any means such as a device or circuitry embodied in either hardware or a combination of hardware and software that is configured to receive and/or transmit data. The air flow compensated RTS **400** may further comprise a power supply **408** of the air flow compensated RTS **400**, an output connector **409**, a circuit board (PCB) **410**, a data to voltage/current signal converter **411**, mounting holes **412** and **413** for mounting the air flow compensated RTS **400** on the wall by fixing means, for example, screws, an input terminal **415**, where, for example an external temperature sensor can be connected.

[0067] The output connector **409** may be configured to connect the air flow compensated RTS **400**, for example to a HVAC system or auxiliary device, such as to a heating valve/actuator. The data to voltage/current signal converter **411** is configured to convert data to suite connected device that is connected to the output connector **409**. The parts **401**, **402**, **404** and **406-415** of the air flow compensated RTS **400** are arranged on the circuit board **410**, which is arranged inside the housing **405**. It should be noted that all the shown parts in the FIG. **4** may not be essential part of the air flow compensated (RTS) **400**.

[0068] FIG. **5** shows an installation quality score determination method **500** of an air flow compensated room temperature transmitter, which the air flow compensated room temperature transmitter comprises a computing device and an air flow measurement unit. In step **510**, a known mass of the air flow measurement unit is heated to an elevated temperature by at least one resistive heating element of the air flow measurement unit. In step **520**, resistances of a thermistor on the known mass are measured during cooling of the known mass, for example using a voltage divider. It is also possible to measure temperature of known mass instead of resistances of the thermistor. In step **530**, measured resistance are transmitted to a computing device for determining a cooldown time of the known mass for determination of an air flow corrected ambient temperature of the air flow compensated room temperature transmitter. In step **540**, an installation quality score, IQS, is determined based on the calculated cooldown time.

[0069] FIG. **6** shows an installation quality score graph **600** comprising two different IQS value graphics **601**, **602** of an air flow compensated room temperature transmitter, when the air flow compensated room temperature transmitter is arranged in two different installation locations or when two different installation methods are used, right and wrong, and with different air flow amounts, shown by a graph of an air flow **603** according to an example embodiment. In the first installation, the temperature transmitter is installed on a wall following installation instructions, its IQS value graph is shown by the reference number **601**. Increase in the air flow **603** starts to gradually decrease the IQS values of the first installation as shown by its graph **601**. In the second installation, the temperature transmitter is installed in improperly allowing air to flow through the housing of the RTS, for example the back side of the housing of the RTS has been left unblocked. As can be seen from the graph of the second installation **602**, when the airflow **603** starts, IQS values shown in the graph of the second installation **602** immediately rapidly falls below 50 and IQS values shown in the graph of the second installation **602** reach even zero values when the air flow **603** is further increased.

[0070] Thus, an air flow-compensated room temperature transmitter used for determining

installation quality is an installation quality determining air flow-compensated room temperature transmitter, which may also be simply called an installation quality determining room temperature transmitter. Its additional function, in addition to determine air flow-compensated room temperature, is to determine installation quality based on an Installation Quality Score (IQS), which indicates calculated likelihood of temperature measurement errors. It is explained above, how this IQS can be determined and how it allows reliably installation quality to be determined based on it.
[0071] The various example embodiments of the invention can be implemented with the help of computer program code that resides in a memory and causes the relevant device to carry out the invention. For example, an RTS may comprise circuitry and electronics for handling, receiving, and transmitting sensor, air flow measurement unit, and IQS value data, a computer program code in a memory, and a processor that, when running the computer program code, causes the RTS device to carry out the features of an example embodiment.
[0072] It will be obvious that the present invention is not limited solely to the above-presented embodiments, but it can be modified within the scope of the appended claims.

Claims

1. An installation quality determining air flow compensated room temperature transmitter, the air flow compensated room temperature transmitter comprises a computing device and an air flow measurement unit, which the air flow measurement unit comprises a known mass, at least one resistive heating element, a thermistor, at least one heat sink, and data transmission means configured to transmit a resistance signal of the thermistor, the at least one resistive heating element is configured to heat the known mass to an elevated temperature and the thermistor is configured to measure temperature of the heated known mass during cooling for calculation of a cooldown time of the known mass defined based on the measured resistances of the heated known mass by the computing device, wherein the installation quality is determined based on an installation quality score, IQS, indicating likelihood of temperature measurement errors, and which is determined based on the cooldown time by the computing device based on:
$IQS = \mathrm{MAX} - (1 - \frac{x}{f_{\mathrm{target}}}) * f_{\mathrm{scaling}}$, wherein the x is the cooldown time of the known mass, f.sub.target is a cooldown time of the known mass in seconds defined in ideal air flow conditions, f.sub.scaling is a scaling factor defining how much the measured airflow can differ from f.sub.target value, and MAX is the maximum possible installation quality score value.
2. An air flow compensated room temperature transmitter according to claim 1, wherein if the determined IQS value is greater than the MAX, the following calculation is performed for the IQS value: $IQS = \mathrm{MAX} - (IQS - \mathrm{MAX})$.
3. An air flow compensated room temperature transmitter according to claim 1, wherein the maximum possible installation quality score value is 100 and the minimum possible installation quality score value is 0.
4. An air flow compensated room temperature transmitter according to claim 1, wherein the cooldown time is the time of cooling of the mass from a first temperature of the elevated temperature to a second temperature of the elevated temperature.
5. An air flow compensated room temperature transmitter according to claim 1, wherein the cooldown time is the time of cooling of the mass from 90% to 10% of the elevated temperature.
6. An air flow compensated room temperature transmitter according to claim 1, wherein the at least one resistive heating element is at least one heating resistor.
7. An air flow compensated room temperature transmitter (**400**) according to claim 1, wherein the resistance of the thermistor is measured using a resistance measurement circuit, a voltage divider, a current measurement circuit, or combination of these.
8. An air flow compensated room temperature transmitter according to claim 1, wherein the air

flow compensated room temperature transmitter further comprises a housing, and inside the housing a main temperature sensor, a secondary temperature sensor, and which the computing device is further configured to receive and process temperature data of the main temperature sensor and the secondary temperature sensor and resistance data of the air flow measurement unit for determining an air flow compensated ambient temperature of the air flow compensated room temperature transmitter.

9. An air flow compensated room temperature transmitter according to claim 8, wherein the ambient temperature is determined using an air flow compensated ambient temperature compensation formula that is:

Ambient temperature=main sensor reading+(secondary sensor reading−main sensor reading)*factor *a*+offset+cooldown time*factor *b*, wherein main sensor reading=a temperature reading of the main sensor, secondary sensor reading=a temperature reading of the secondary sensor, factors a and factor b=correction coefficients of the air flow compensated room temperature transmitter predetermined in a testing conditions, offset=a difference between the actual temperature of the space and temperature measured by the air flow compensated room temperature transmitter, and cooldown time=cooling time of the known mass of the air flow measurement unit.

10. An air flow compensated room temperature transmitter according to claim 8, wherein the air flow compensated room temperature transmitter further comprises a data transmitting means for receiving data from the main temperature sensor and the secondary temperature sensor and resistance data of the air flow measurement unit or for transmitting the ambient temperature data to a HVAC device.

11. An air flow compensated room temperature transmitter according to claim 8, wherein the air flow measurement unit also acts as a secondary temperature sensor.

12. An air flow compensated room temperature transmitter according to claim 8, wherein the air flow compensated room temperature transmitter also comprises a display for displaying the installation quality score.

13. An installation quality determination method of an air flow compensated room temperature transmitter comprising a computing device and an air flow measurement unit, the method comprises: heating a known mass of the air flow measurement unit to an elevated temperature by at least one resistive heating element of the air flow measurement unit, measuring resistances of a thermistor on the known mass during cooling of the known mass, transmitting the measured resistances to a computing device for calculating a cooldown time of the known mass, and determining the installation quality based on an installation quality score, IQS, indicating likelihood of temperature measurement errors and being determined based on the calculated cooldown time.

14. An installation quality score determination method according to claim 13, wherein determining the installation quality score, IQS, based on the cooldown time is calculated based on: $IQS = \mathrm{MAX} - (1 - \frac{x}{f_{\mathrm{target}}}) * f_{\mathrm{scaling}}$, wherein the x is the cooldown time of the known mass, f.sub.target is a cooldown time of the known mass in seconds defined in ideal air flow conditions, f.sub.scaling is a scaling factor defining how much the measured airflow can differ from f.sub.target value, and MAX is the maximum possible installation quality score value.

15. An installation quality score determination method according to claim 13, wherein if the determined IQS value is greater than the MAX, the method further comprises performing the following calculation for the calculated IQS value: $IQS = \mathrm{MAX} - (IQS - \mathrm{MAX})$.

16. A computer program product embodied on a non-transitory computer readable medium, the computer program product comprising computer instructions that, when executed on at least one processor of an installation quality determining air flow compensated room temperature transmitter according to claim 1, is configured to perform an installation quality determination method of an air flow compensated room temperature transmitter comprising a computing device and an air flow measurement unit, the method comprises: heating a known mass of the air flow measurement unit to an elevated temperature by at least one resistive heating element of the air flow measurement unit, measuring resistances of a thermistor on the known mass during cooling of the known mass, transmitting the measured resistances to a computing device for calculating a cooldown time of the known mass, and determining the installation quality based on an installation quality score, IQS, indicating likelihood of temperature measurement errors and being determined based on the calculated cooldown time.

17. An installation quality score determination method according to claim 13, wherein determining the installation quality score, IQS, based on the cooldown time is calculated based on:

$IQS = \mathrm{MAX} - (1 - \frac{x}{f_{\mathrm{target}}}) * f_{\mathrm{scaling}}$, wherein the x is the cooldown time of the known mass, f.sub.target is a cooldown time of the known mass in seconds defined in ideal air flow conditions, f.sub.scaling is a scaling factor defining how much the measured airflow can differ from f.sub.target value, and MAX is the maximum possible installation quality score value.