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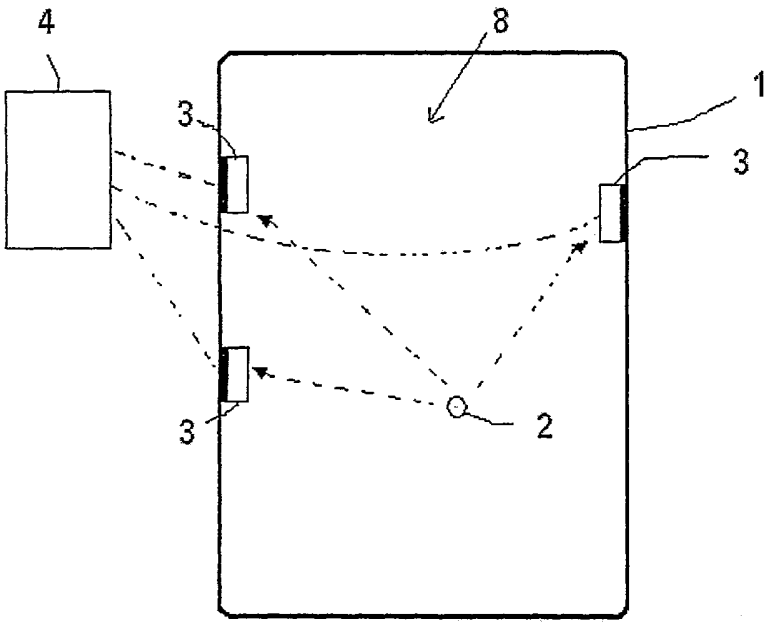
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(54) **Title:** METHOD AND APPARATUS FOR WIRELESS MEASURING IN A CLOSED SPACE



(57) **Abstract:** A method of wireless measuring of various measurable variables in a closed space (8), wherein at least one measuring device, such as a measuring ball (2), is made to fall in and travel freely in the gaseous atmosphere of the closed space, which measuring ball (2) contains a wireless transmitter/receiver unit (5) for determining the location of the measuring ball in the closed space.

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Method and apparatus for wireless measuring in a closed space

Background of the invention

The present invention relates to a measuring method according to the preamble of claim 1 and an apparatus according to the preamble of independent claim 5 for implementing said method.

The conditions prevailing in various furnaces and reactors and reactor-like mainly closed spaces, such as furnaces of recovery boilers used in cellulose pulping industry are often highly demanding. The conditions may be corrosive, and in addition to that the temperatures inside these closed spaces, such as recovery boilers, may rise very high during various chemical processes and burning processes. For example the temperature of the gaseous atmosphere inside a furnace of a recovery boiler may be in the range of 900 – 1400 degrees Celsius, depending on the location inside the mainly closed space, such as a furnace of a recovery boiler. Difficult conditions, which result from the large dimentions of the closed spaces, such as a recovery boiler, and chemical substances, which often are in molten form in the bottom part of the recovery boiler, and specific conditions of the gaseous atmosphere, such as reducing conditions, make measuring in the closed space, such as a recovery boiler and other reactors, highly laborious and demanding, as well as expensive. It is especially laborious and expensive to determine the flow and velocity fields of gases and to measure the temperatures and compositions of gases. Numerical simulations and also various calculation models are thus commonly used nowadays for clarifying the operation of a recovery boiler.

However, numerous simplifications and assumptions have to be made to a significant extent when using numerical methods and various calculation models, due to inadequate or nonexistent measuring data, and therefore the results obtained by means of calculation models and numerical methods are inaccurate and deficient.

SE-patent publication 445389 (US 4590466) discloses a method, in which sensors are mixed at a blast furnace inlet into a mass traveling through the blast furnace, which sensors are equipped with means for measuring a desired property of the mass. Additionally the sensors are equipped with a wireless transmitter connected to the measuring means and transmit signals with information on the obtained measuring results to a receiver. The position of the sensor in the mass traveling in the blast furnace is determined based on a property of the obtained signal, such as strength or time position. In addition to that, also the measured mass property is determined based on the signal.

An object of the present invention is to provide a new kind of method for obtaining measurement data on gas flows in mainly closed spaces, such as recovery boilers used in cellulose pulping industry, and a further object of the invention is an apparatus for effecting the measurements. The invention allows to avoid prior art problems and to obtain reliable measurement results from closed spaces, where it is difficult or impossible to effect measurements by means of conventional, known apparatuses and methods.

Brief description of the invention

A characteristic feature of the method according to the invention is that at least one measuring device, preferably having the form of a ball, is made to fall freely and move freely in a gaseous atmosphere inside a closed space and that the measuring device comprises a wireless transmitter/receiver unit, which transmits and/or receives electromagnetic/acoustic signal, which is further submitted to a transmitter/receiver station communicating with a calculation unit, and the location of the measuring device is calculated based on time differences or phase differences of signals entering various measuring points.

The apparatus according to the invention is characterized in that it comprises

- at least one measuring device, such as measuring ball, which travels freely in the gaseous atmosphere inside the closed space and contains a wireless transmitter/receiver unit for transmitting/receiving an electromagnetic/acoustic signal,
- at least three transmitter/receiver stations, and
- a calculation unit, which communicates with the transmitter/receiver stations and calculates the location of the measuring ball based on time differences or phase differences of signals entering various measuring points.

More exactly, the method and apparatus according to the invention are characterized in what is stated in the appended claims.

The solution according to the invention provides significant advantages, as the method and apparatus in accordance with the solution allow measurements in a closed space, wherefrom it earlier has been even impossible to obtain reliable measurement results due to the demanding and very complicated measuring conditions.

Brief description of the drawings

In the following, the invention is described in more detail by means of exemplary embodiments with reference to Figures 1 and 2, of which

Fig. 1 outlines the measuring method according to the invention in general terms.

Fig. 2 illustrates an enlarged view of a measuring ball according to the invention.

Detailed description of the invention

Figure 1 is a general illustration of the wireless measuring method according to a solution of the invention.

In the method for measuring various measurable variables wirelessly in a closed space 8, at least one measuring device, preferably a measuring ball 2, is made to fall freely or move freely in the closed space. In the closed space the measuring device, such as the ball, is deflected under the effect of gas from an ideal falling path. If the ball is lightweighted in relation to the streams prevailing in the space, the ball may rise upwards and travel together with the flowing medium in the space being measured. In practice, however, the ball cannot be so light that it would follow the gas streams exactly, but the travel of the measuring ball is determined by the intensity of active forces. Active forces include e.g. aerodynamic forces generated by gas flows, pressure differences, lift generated by density differences, and earth gravity.

The measuring ball 2 contains a wireless transmitter/receiver unit 5 for determining the location of the measuring ball in the closed space 8. The transmitter/receiver unit of the measuring ball transmits and/or receives electromagnetic/acoustic signal, which is supplied to a transmitter/receiver station 3 and further to a calculation unit 4. The calculation unit 4 is a numerical simulation program or the calculation unit uses a neural network or neural networks, statistic methods or combinations thereof for calculating the flow field around the measuring ball in the closed space. The location of the measuring ball is calculated from the time differences or phase differences of signals received by various receiving points (measuring points) or from time differences or phase differences of signals received by the measuring ball, and the above-mentioned calculation methods in their turn are used for calculating, what are the forces or velocities that have effected the ball and made the ball travel in the measured way. The signal

transmitted by the measuring ball 2 allows to calculate the exact location of the measuring ball 2 inside the closed space and to monitor the travel of the measuring ball inside the closed space as a function of time. This way, gas streams (flow field of the gases, velocity field of the gases) in the closed space may be determined.

As the measuring ball travels in the closed space, various measurement variables may be measured simultaneously, such as temperature, pressure, gas composition and other properties prevailing in the gaseous atmosphere inside the closed space, and this data is submitted further to a transmitter/receiver station 3, the number of which in the method is at least three. The obtained signal representing the measuring results is received and processed in the calculation unit into data on the measured property's values as a function of time and location. This way, the temperature history of the gaseous atmosphere in the closed space and the history of the physical or chemical composition of gases are obtained as a function of time and coordinates, which data together with velocity data can be used for determining e.g. various turbulent variables prevailing in a furnace of a recovery boiler.

From the measured variables transmitted by the measuring ball 2 and further submitted by the transmitter/receiver station 3, the calculation unit calculates (and stores) data on conditions prevailing in the closed space, whereby by combining the data on the measured variables and the location data of the measuring ball, continuous monitoring of the chemical and physical conditions in the closed space may be accomplished. In accordance with the invention, the measuring ball 2 may also function so that it receives signals transmitted by the transmitters 3, which signals are submitted to the calculation unit 4.

By means of the invention it is thus typically possible to determine the flow field surrounding the measuring ball, the temperature history and the history of physical or chemical composition as a function of time and coordinates. By means of data thus obtained, numerical simulation models and various calculation models may be more exactly defined, which previously inevitably had been drawn up making different assumptions and simplifications.

The wavelength of the signal transmitted by the measuring ball 2 (digitalized signal) has been selected thus that reflections caused by the walls of the closed space (due to the geometry of the closed space) and the conditions prevailing in the closed space or other possible disturbance sources do not hamper or prevent the travel of the signal into the transmitter/receiver station 3.

According to the method, in order to obtain reliable measurement results, the measuring balls 2 are introduced into the closed space 8 at various locations of the closed space or correspondingly the measuring balls are introduced at the same location but with different velocities and at different angles into the closed space, so that measurement results are obtained from several locations inside the closed space.

Fig. 2 is an enlarged view of the measuring ball of the apparatus according to the invention.

The measuring ball has an outer casing 7 made of dense and highly heat-resistant material, such as ceramic or corresponding highly heat-resistant materials. Inside the outer casing the measuring ball is provided with an insulating shell 6, which is made of heat-insulating material and protects the transmitter/receiver unit 5 located inside the measuring ball. The transmitter/receiver unit 5 comprises devices required for transmitting and receiving electromagnetic/acoustic signals and sensor systems as well as other measuring means for obtaining the measurable data from the closed space.

The method and apparatus according to the invention for wireless measuring in a closed space may be used, in addition to measurements effected in a recovery boiler, especially in the furnace thereof, in the cellulose pulping industry, also in measurements performed in various chemical reactors, thermal reactors and other corresponding closed spaces.

Further, the method and apparatus according to the invention may be applied for use in various containers and pipe systems or channels.

It is also evident for a person skilled in the art that various embodiments of the invention are not limited to the above-presented examples only, and thus they may vary in the scope of the appended claims.

CLAIMS:

1. A method of wireless measuring of various measurement variables in a mainly closed space (8) in such a way that a measuring device is introduced into the closed space and its location is determined by means of electromagnetic/acoustic signals, **characterized** in that at least one measuring device, preferably ball-shaped (2), is made to fall and travel freely in the gaseous atmosphere of the closed space and that the measuring device (2) contains a wireless transmitter/receiver unit (5), which transmits and/or receives electromagnetic/acoustic signal, which is further submitted to a transmitter/receiver station (3) communicating with a calculation unit (4), and the location of the measuring device is calculated from time differences or phase differences of signals entering various measuring points.

2. A method according to claim 1, **characterized** in that the transmitter/receiver station (3) is in continuous contact with the calculation unit (4).

3. A method according to claim 1, **characterized** in that the transmitter/receiver station (3) is in cyclic contact with the calculation unit (4) and at the end of the measuring cycle the data on the location of the measuring device (2) is transferred into the calculation unit (4).

~~4.~~ A method according to claim 1, **characterized** in that the calculation unit (4) is a numerical simulation program, or that the calculation unit uses a neural network or neural networks, statistic methods or combinations thereof for calculating the force and flow fields effecting the measuring ball (2) and its travel in the closed space (8).

5. A method according to any of the preceding claims, **characterized** in that properties surrounding the measuring ball, such as temperature, gas composition are measured and the obtained signal representing the measurement result is received and processed in the calculation unit into data on the values of the measured property as a function of time and location.

6. An apparatus for wireless measuring of measurable variables in a closed space, **characterized** in that the apparatus comprises

- at least one measuring device, such as a measuring ball (2), which travels freely in the gaseous atmosphere of the closed space and which contains a wireless transmitter/receiver unit (5) for transmitting/receiving electromagnetic/acoustic signal,

at least three transmitter/receiver stations (3), and

a calculation unit (4), which communicates with the transmitter/receiver stations and calculates the location of the measuring ball based on time differences or phase differences of signals entering various measuring points.

7. An apparatus according to claim 6, **characterized** in that the transmitter/receiver station (3) communicates with the calculation unit (4), which calculation unit is a numerical simulation program, or that the calculation unit (4) uses a neural network or neural networks, statistic methods or combinations thereof for calculating force and flow fields effecting the measuring ball (2) and its travel in the closed space.

8. An apparatus according to claim 6 or 7, **characterized** in that the measuring ball (2) comprises means for measuring the properties surrounding the measuring ball, which means are connected to the transmitter unit (5) for transmitting the measurement results in form of signals to the receiver station (3) and the calculation unit (4).

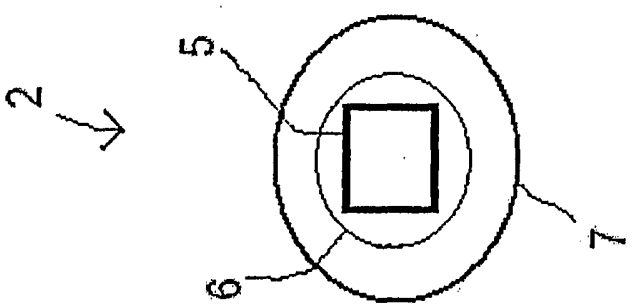


FIG.2

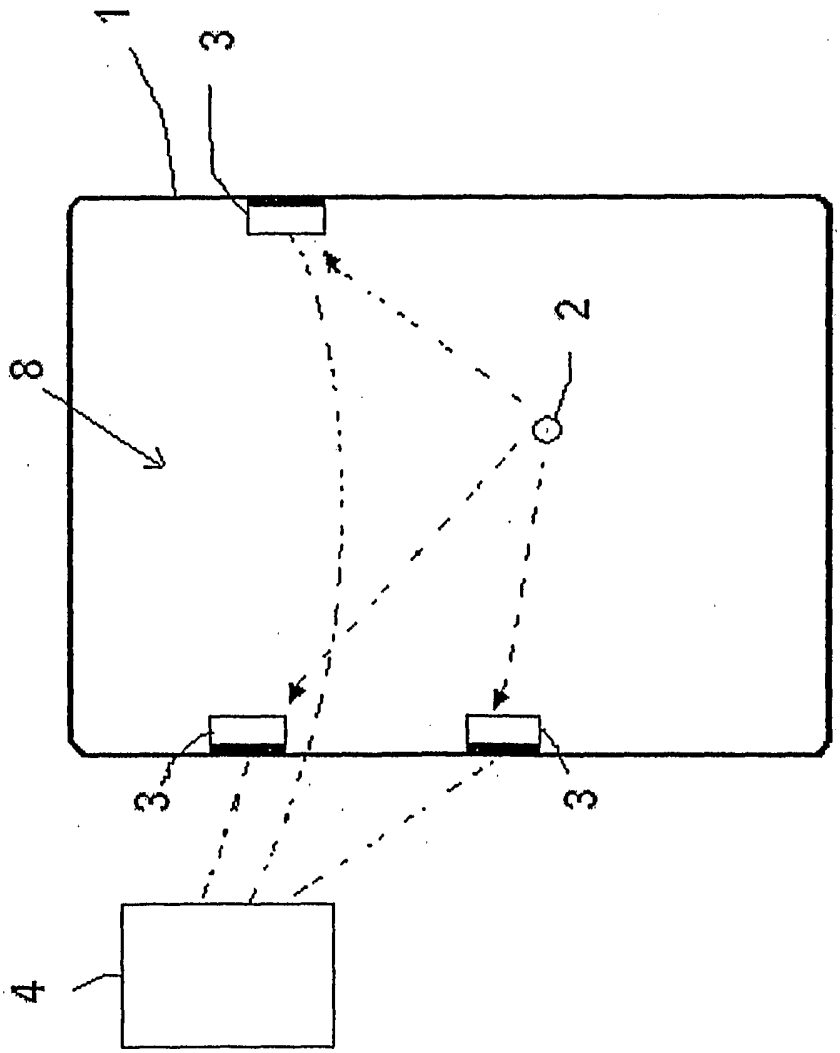


FIG.1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 2005/000472

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: G01K, G01S, G08C

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4590466 A (KLAS R. WIKLUND ET AL), 20 May 1986 (20.05.1986), column 1, line 63 - column 7, line 35, figure 1	1-8
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A	US 6726358 B2 (DEAN E. DRAXTON ET AL), 27 April 2004 (27.04.2004), abstract	1-8
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☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL PATENT CLASSIFICATION (IPC):

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G01K 1/02 (2006.01)
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US	4590466	A	20/05/1986	DE	3323111	A 29/12/1983
				FR	2529353	A,B 30/12/1983
				JP	3045437	B 11/07/1991
				JP	59022189	A 04/02/1984
				SE	445389	B,C 16/06/1986
				SE	8203983	A 29/12/1983
US	6726358	B2	27/04/2004	NONE		