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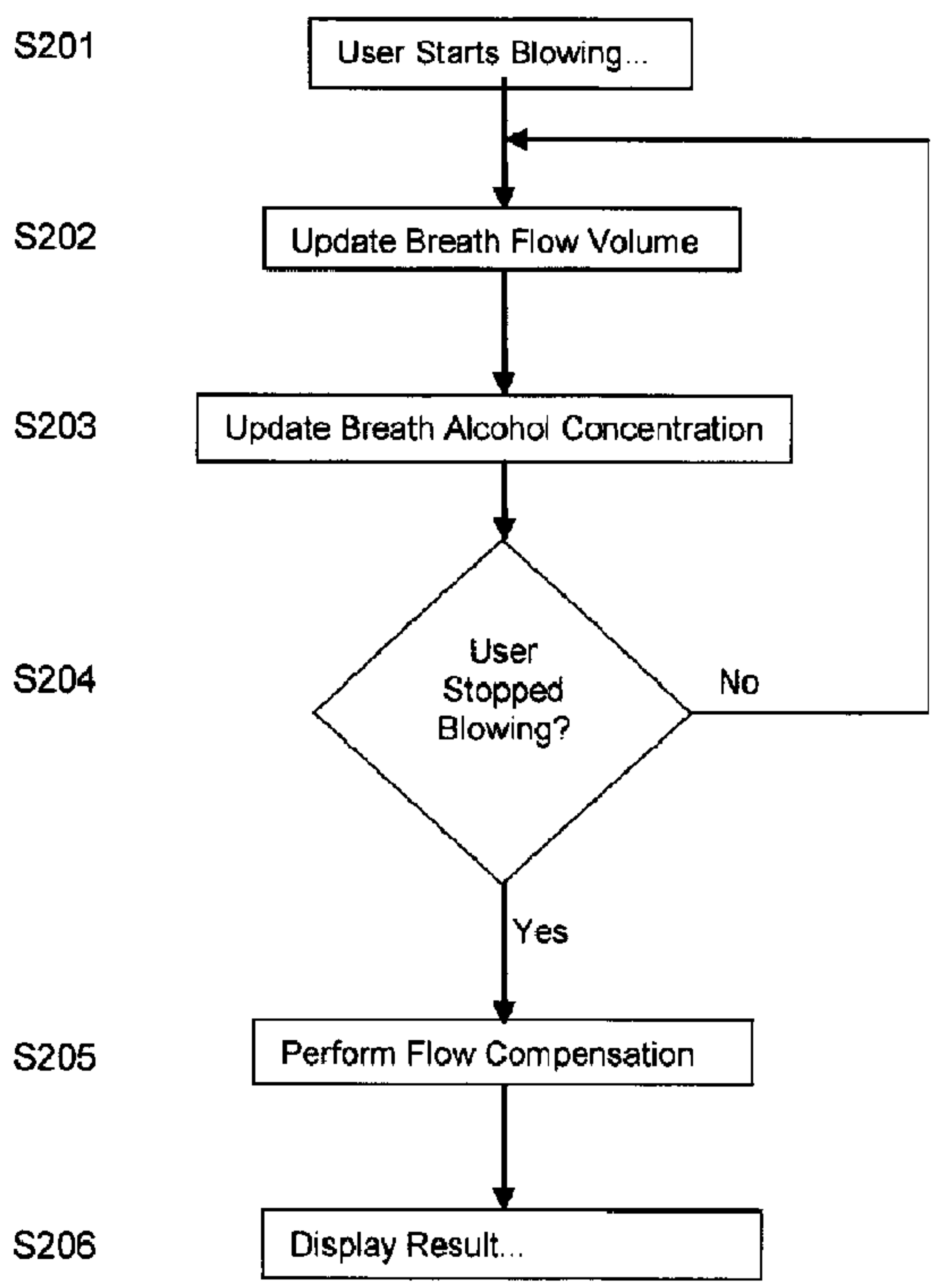
(54) Titre : PROCEDE ET APPAREIL DE MESURE DE CONCENTRATION D'ALCOOL DANS HALEINE
(54) Title: METHOD FOR MEASURING BREATH ALCOHOL CONCENTRATION AND APPARATUS THEREFOR



(57) Abrégé/Abstract:
The present invention relates to a method and apparatus for measuring breath alcohol concentration of a user. A flow of an expired breath sample is passed through a fuel cell sensor giving an output signal proportional to the amount of alcohol present in the

(57) **Abrégé(suite)/Abstract(continued):**
breath sample. By measuring the flow rate, the volume of the breath sample may be calculated, whereas the breath alcohol concentration is calculated based on the fuel cell output signal. Both the sample volume and the breath alcohol concentration values are continually updated by integrating the measured instantaneous flow rate and the fuel cell output signal over time. If the user stops blowing,flow compensation is performed to obtain a compensated fuel cell output signal using a stored calibration volume. Hence, an improved method for accurately measuring the breath alcohol concentration of a test person is achieved, capable of handling varied expired volumes of breath,which obviates the need for a sampling mechanism.

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(54) Title: METHOD FOR MEASURING BREATH ALCOHOL CONCENTRATION AND APPARATUS THEREFOR

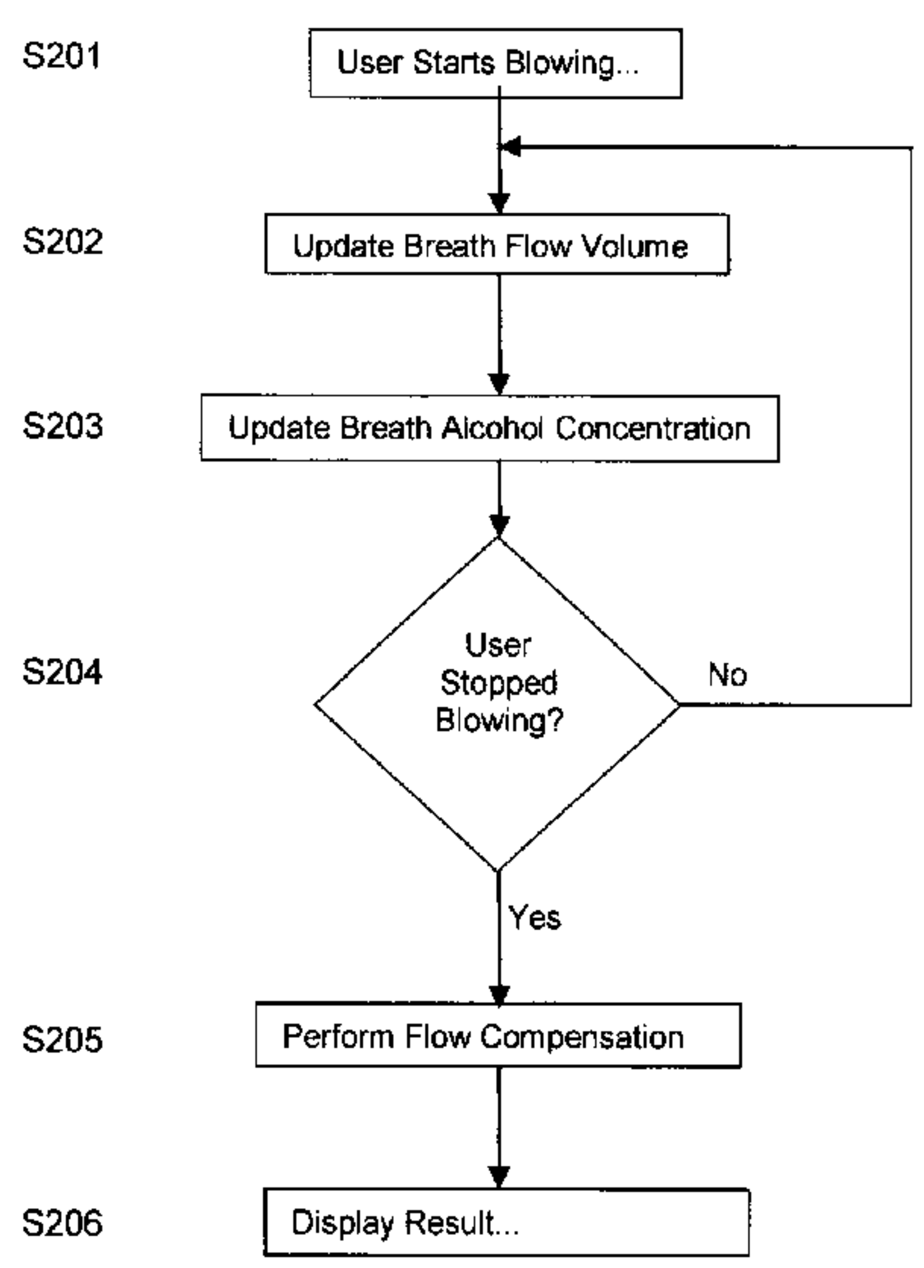

Fig. 2

(57) Abstract: The present invention relates to a method and apparatus for measuring breath alcohol concentration of a user. A flow of an expired breath sample is passed through a fuel cell sensor giving an output signal proportional to the amount of alcohol present in the breath sample. By measuring the flow rate, the volume of the breath sample may be calculated, whereas the breath alcohol concentration is calculated based on the fuel cell output signal. Both the sample volume and the breath alcohol concentration values are continually updated by integrating the measured instantaneous flow rate and the fuel cell output signal over time. If the user stops blowing,flow compensation is performed to obtain a compensated fuel cell output signal using a stored calibration volume. Hence, an improved method for accurately measuring the breath alcohol concentration of a test person is achieved, capable of handling varied expired volumes of breath,which obviates the need for a sampling mechanism.

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METHOD FOR MEASURING BREATH ALCOHOL CONCENTRATION AND APPARATUS THEREFOR

Field of the invention

The present invention relates to a method for measuring breath alcohol concentration of a user. The method comprises receiving a flow of an expired breath sample from a user and measuring the flow rate using a pressure sensor. At the same time, the breath sample is led into a fuel cell sensor. The output signal of the fuel cell sensor is used to determine the volume of alcohol present in the breath sample, and thus the breath alcohol concentration.

In a further aspect, the invention also relates to an apparatus for measuring breath alcohol concentration of a user. The apparatus comprises sampling means for receiving an expired breath sample of a user, means for measuring the flow rate of the sample, a fuel cell sensor and a microcontroller. The microcontroller is adapted to calculate the volume of alcohol present in the breath sample, and thus the breath alcohol concentration, based on an output signal of the fuel cell sensor

Background of the invention

Generally, there are two techniques employed for measuring the breath alcohol concentration and thereby determine a person's blood alcohol concentration. In a first method, infrared spectroscopy is used, whereby a breath sample from a person is subjected to infrared radiation. The molecules in the breath sample absorb specific frequencies, called resonant frequencies, which are characteristic to the molecules. For example the absorption by ethanol molecules gives rise to a specific infrared spectrum which may be used to determine the amount of ethanol present in the breath sample, and thus the breath alcohol concentration. Although this method gives high measuring accuracy, sensors incorporating infrared spectroscopy are expensive, which limits application in mass-produced devices.

A second commonly used technology is based on a fuel cell sensor which converts fuel in the shape of alcohol (ethanol) to electric current in an electrochemical reaction. Fuel cell sensors have a somewhat lower accuracy than infrared spectroscopy sensors, but are much cheaper. However, fuel cell sensors require that the breath sample is of a determinable volume in order to correctly determine the breath alcohol concentration.

Traditional fuel cell based analyser systems operate by means of a mechanical sampling system which draws a pre-specified volume of breath into the fuel cell for analysis. The mechanical means may comprise motors, solenoid valves, piston-cylinder devices, diaphragm mechanisms or push buttons connected to a pump or bellows system. In US 6,167,746 there is disclosed an apparatus comprising an electronically controlled valve to ascertain that a requisite volume of breath is passed through a fuel cell. US 2005/0241871 discloses a sobriety interlock device comprising a pressure transducer and a solenoid valve operating independently of each other providing a variable flow of breath to a fuel cell. A microprocessor instructs the solenoid valve to remain open for a finite period of time to give a predetermined breath sample volume, and calculates an algorithmic correction factor based on pressure readings to provide a pressure compensated alcohol result.

The methods described in the prior art involve advanced control circuitry and complex or bulky mechanical components which introduce extra cost to the system and limit the ability to reduce the size of the system without compromising accuracy.

Hence, there is a need for improved methods for measuring breath alcohol concentration with high accuracy, which allow for compact devices that may be produced at low cost.

Summary of the invention

It is an object of the present invention to provide an improved method for measuring breath alcohol concentration with high accuracy, which allows for compact measuring devices that may be produced at low cost.

According to the present invention, there is provided a method for determining breath alcohol concentration. The method includes performing specific measures, as disclosed herein. From the measured flow rate, the volume of the breath sample is calculated. Throughout the expiration of the breath sample, the breath sample volume and the volume of alcohol present in the breath sample are continually updated by integrating the measured instantaneous flow rate and the fuel cell output signal over time. If the user stops blowing, flow compensation is performed wherein the fuel cell output signal is compensated using a stored calibration volume to obtain a final compensated fuel cell output signal.

By compensating the fuel cell output signal, the measuring accuracy of the method and apparatus is ensured, irrespective of the volume of the breath sample. Since the method does not require a predetermined breath sample volume, the mechanical sampling systems as used in the prior art become unnecessary, and the measuring apparatus may be made more compact with fewer or no moving parts. Thereby the size and cost of apparatus may be greatly reduced.

In preferred embodiments, the method according to the present invention further comprises determining the blood alcohol concentration based on the breath alcohol concentration, and displaying the resulting blood alcohol concentration.

In a preferred embodiment, the method according to the present invention comprises performing the compensation using the formula:

$$FC_{comp} = FC_{out} \cdot \frac{V_{cal}}{V_b}$$

In a further preferred embodiment, the method according to the present invention comprises preventing start-up of a vehicle if the calculated breath alcohol concentration exceeds a predetermined threshold value.

In a further preferred embodiment, the method according to the present invention comprises, measuring the flow rate by means of a pressure-based flow meter, preferably a Venturi meter or orifice plate in combination with a pressure sensor. The pressure-based flow meter has the advantage of providing a compact component with few or no moving parts, ensuring efficient use of space in a device carrying out the method of the invention.

According to the present invention, there is also provided an apparatus for determining breath alcohol concentration. The apparatus includes specific features, as disclosed herein. Based on the flow rate measurements, the microcontroller is adapted to calculate the volume of the breath sample. The microcontroller is further adapted to continually update the breath sample volume and the breath alcohol concentration by integrating the measured instantaneous flow rate and the fuel cell output signal over time. The microcontroller is configured to perform flow compensation on the fuel cell output signal to obtain a final compensated fuel cell output signal, if the user stops blowing.

Preferred embodiments of the apparatus according to the present invention comprise features corresponding to the method described above.

In a preferred embodiment, a breath alcohol interlock device comprising an apparatus for determining breath alcohol concentration according to the present invention and a vehicle comprising such an interlock device are provided.

Brief description of the drawings

Fig. 1 is a graphical representation of a fuel cell output signal over time;

Fig. 2 is a flowchart illustrating the method according to the present invention; and

Fig. 3 is a schematic diagram of an apparatus according to the present invention.

Detailed description of the invention

The invention will be further explained below through the detailed description of examples thereof and with reference to the accompanying drawings. It is to be understood that the invention should not be limited to the embodiments shown in the figures and described below, but may be varied to encompass any combination of equivalent features within the scope defined by the attached claims.

When an expired breath sample is passed through the fuel cell of a breath alcohol measuring device, also known under the name Breathalyser® (trade mark owned by Dräger), any alcohol (ethanol) present in the breath sample is oxidised in an electrochemical reaction, which generates a measurable electrical current. Fig. 1 shows a typical output response from a fuel cell in a graph of the output voltage versus time. The area under the curve is calculated by integrating the voltage over time, which gives a value *FC* that is directly proportional to the alcohol concentration in the breath.

In order to give an accurate measurement of the breath alcohol concentration (BrAC), the breathalyser must be calibrated using a sample of known alcohol concentration and volume. When subsequently performing an alcohol breath test on a test person, the breathalyser requires a pre-determined sample volume, corresponding to the one used for calibration. When the required volume is supplied, the breathalyser will compare the area under the curve of the fuel cell output signal (voltage) of the test sample with the value stored from the calibration routine and give a reading for the tested breath alcohol concentration.

The requirement of a specific sample volume represents a major inconvenience in breathalysers known in the art. Firstly, if for example the test person has reduced lung capacity, or for some other reason is not able to provide the pre-determined volume of breath sample, a valid breath test may not be performed. Secondly, the sampling mechanism needed in a breathalyser to measure and obtain a certain chosen sample volume and to furnish it to the fuel cell (e.g. pressure sensors, valves, pumps, etc.) can be rather expensive and/or bulky, which puts a constraint on the possibilities to minimise the size of the apparatus and to reduce production costs.

In a similar method as when measuring the fuel cell area, the volume of the breath sample can be determined by calculating the area under a curve of the volumetric flow rate of the sample versus time. The flow rate is measured using a suitable flow meter, e.g. mechanical, pressure-based, optical, thermal or electromagnetic. In a preferred embodiment of the present invention, a pressure-based flow meter is used such as a Venturi meter, orifice plate or equivalent in combination with a pressure sensor.

Laboratory test have proven that the variation of breath volume V_b correlates linearly with the fuel cell output signal FC_{out} for any specified alcohol concentration:

$$FC_{out} = k \cdot V_b$$

By using a measured and stored calibration volume V_{cal} to perform a “flow” compensation of the fuel cell output signal FC_{out}, and substituting the expression for the constant $k = FC_{out}/V_b$ into the corresponding equation, a compensated value for the fuel cell output signal FC_{comp} is obtained:

$$FC_{comp} = FC_{out} \cdot \frac{V_{cal}}{V_b}$$

Hence, a new and inventive method of accurately measuring the breath alcohol concentration of a test person is achieved, capable of handling varied expired volumes of breath, which obviates the need for a sampling mechanism.

Fig. 2 shows a flowchart illustrating the method according to the present invention. In a first step S201, the user starts blowing into a measuring apparatus, typically by means of a sampling tube or pipe made of plastic or other suitable material which is cheap to produce and replaceable, to ensure hygienic conditions to the users.

As the user continues to blow into the apparatus, the flow rate Q of the expired breath sample is measured and used to calculate the volume V_b of the breath sample. In step S202 the calculated breath volume V_b is continually updated throughout the measuring procedure by integrating the flow rate Q over time.

At the same time, the breath alcohol concentration BrAC is calculated from the fuel cell output signal FC_{out} and is also continually updated in step S202 by integrating the fuel cell output signal FC_{out} over time.

In step S204, it is checked whether the user has stopped blowing. If that is the case, flow compensation is performed in step S205 as explained above, whereby a final compensated value for the fuel cell output signal FC_{comp} is obtained and used to calculate a compensated breath alcohol concentration $BrAC_{comp}$. This value may then be displayed to the user in step S206 and/or used to determine the blood alcohol concentration of the user.

Fig. 3 schematically shows an apparatus for measuring breath alcohol concentration BrAC, according to the present invention. The measuring apparatus is contained within a housing 1 and comprises a replaceable breath sample inlet tube 2 for receiving an expired breath sample from a user or test person. Arrows indicate the direction of breath flow through the measuring apparatus. The breath flow is led through a first channel 3 which is closed at a distal end. A flow meter 5 is located near the distal end of the first channel 3 and measures the instantaneous flow rate Q of the breath sample through the measuring apparatus 1.

In a preferred embodiment, flow meter 5 comprises a pressure-based flow meter such as a Venturi meter, an orifice plate or equivalent in combination with a pressure sensor. However the flow rate Q may be measured using any suitable flow meter, e.g. mechanical, pressure-based, optical, thermal or electromagnetic.

Part of the breath flow is led through a sampling channel 4 and enters a fuel cell sensor 6 near a proximal end of the first channel 3. Any alcohol (ethanol) present in the breath sample fuels an electrochemical reaction in the fuel cell 6 which gives rise to an electric current. This current then is a measure of the amount of alcohol in the breath sample and represented by a fuel cell output signal FC_{out}, normally the voltage measured across the fuel cell 6.

The flow meter 5 and the fuel cell 6 are connected with a microcontroller 7 which comprises means for processing the measurements of the flow rate and the fuel cell voltage. In this context, processing incorporates finding the area under the curves of the flow rate Q and the fuel cell output signal FC_{out} versus time. The area corresponds to the volume V_b of the breath sample and the breath alcohol concentration BrAC, respectively. This may also be achieved by integrating the flow rate Q, and the fuel cell output signal FC_{out}, respectively, with respect to time. The microcontroller 7 is adapted to continually update the breath sample volume V_b and the fuel cell output signal FC_{out} throughout the duration of the breath test.

When the breath sample has passed the fuel cell 6, it exits the housing 1 of the measuring apparatus through an exhaust tube 8.

Also comprised in the measuring apparatus is a battery 9 or other suitable source of energy to power the flow meter 5, the fuel cell 6 and/or the microcontroller 7.

In a preferred embodiment of the present invention, the measuring apparatus may further comprise display means to display the measured breath alcohol concentration BrAC and/or the blood alcohol concentration BAC. The blood alcohol concentration BAC may be determined from the blood-to-air partition ratio, i.e. the relation between the amount of alcohol in a given volume of breath and blood. Most breathalysers use an international standard partition ratio of 2100:1, that is, for every part alcohol in the breath there are 2100 parts alcohol in the blood.

The alcohol measuring apparatus according to the present invention may be made very compact and included in a sobriety interlock device. Such interlock devices are known in the art and will not be described in detail here. The interlock device may comprise means for measuring the temperature, humidity and/or alcohol concentration of the breath of a user, and based on these measurements falling within permitted ranges (corresponding to the user being non-intoxicated by alcohol), the interlock device allows starting up of a vehicle or other machinery connected to the interlock device. Further, the interlock device may be equipped with a microprocessor for analysing the results of the alcohol measuring apparatus and a relay electrically connected to the starter of the vehicle or machine.

When provided with an alcohol measuring apparatus according to the present invention, a compact and low-cost sobriety interlock device may be achieved and used to control start-up of any vehicle or machine.

CLAIMS

1. Method for measuring breath alcohol concentration of a user, comprising the steps of:

- receiving a flow of an expired breath sample from the user at a measuring apparatus comprising a flow meter, a fuel cell sensor, and a microcontroller coupled to the flow meter and fuel cell sensor, operable to measure the breath alcohol concentration without requiring fixed breath sample volumes;
- measuring, by the flow meter, the flow rate of the breath sample while the flow of expired breath is received by the measuring apparatus;
- receiving at least a portion of the breath sample via a flow channel into the fuel cell sensor to generate an output signal comprising an electric current based on an electrochemical reaction in the fuel cell sensor;
- having the microcontroller measure the breath alcohol concentration without requiring a fixed breath sample volume by:
    - calculating the breath alcohol concentration based on the output signal of the fuel cell sensor;
    - calculating the volume of the breath sample based on the measured flow rate from the flow meter;
    - updating continually the calculated breath sample volume and the calculated breath alcohol concentration by integrating the measured flow rate and the fuel cell output signal over time, irrespective of the breath sample volume; and
    - if the user stops blowing, and before determining a final breath alcohol concentration:
        - compensating the fuel cell output signal using a stored calibration volume, stored in the measuring apparatus, to obtain a final compensated fuel cell output signal; and
- outputting, by the measuring apparatus, the final breath alcohol concentration.

2. Method according to claim 1, further comprising the step of:

- determining, by the microcontroller, the blood alcohol concentration based on the final breath alcohol concentration.

3. Method according to claim 2, further comprising the step of:

- displaying, on a display of the measuring apparatus, the resulting blood alcohol concentration.

4. Method according to any one of claims 1 to 3, wherein said compensating is performed, by the microcontroller, using the formula:

$$FC_{comp} = FC_{out} \cdot \frac{V_{cal}}{V_b}$$

5. Method according to any one of claims 1 to 4, further comprising the step of:
   - preventing start-up of a vehicle if the calculated breath alcohol concentration exceeds a predetermined threshold value.

6. Method according to any one of claims 1 to 5, wherein the flow rate is measured by a pressure-based flow meter.

7. Method according to claim 6, wherein the pressure-based flow meter is a Venturi meter or orifice plate in combination with a pressure sensor.

8. Apparatus for measuring breath alcohol concentration, comprising:
   - an inlet for receiving an expired breath sample of a user;
   - a flow meter for measuring the flow rate of the breath sample;
   - a fuel cell sensor connected to a flow channel to receive at least a portion of the breath sample;
   - a microcontroller coupled to the flow meter and the fuel cell sensor to measure the breath alcohol concentration without requiring a fixed breath sample volume, the microcontroller comprising computer executable instructions to:
     - calculate the breath alcohol concentration based on an output signal of the fuel cell sensor;
     - calculate the volume of the breath sample based on the measured flow rate from the flow meter;
     - continually update the calculated breath sample volume and the calculated breath alcohol concentration by integrating the measured flow rate and the fuel cell output signal over time, irrespective of the breath sample volume; and
     - if the user stops blowing, and before determining a final breath alcohol concentration, perform a flow compensation to obtain a final

compensated fuel cell output signal using a stored calibration volume; and

- an output for providing an indication of the final breath alcohol concentration.

9. Apparatus according to claim 8, wherein the microcontroller is further adapted to determine the blood alcohol concentration based on the final breath alcohol concentration.

10. Apparatus according to claim 9, wherein the apparatus further comprises a display to display the resulting blood alcohol concentration.

11. Apparatus according to any one of claims 8 to 10, wherein said flow compensation is performed using the formula:

$$FC_{comp} = FC_{out} \cdot \frac{V_{cal}}{V_b}$$

12. Apparatus according to any one of claims 8 to 11, wherein the flow meter for measuring the flow rate comprises a pressure-based flow meter.

13. Apparatus according to claim 12, wherein the pressure-based flow meter is a Venturi meter or orifice plate in combination with a pressure sensor.

14. A breath alcohol interlock device equipped with an apparatus according to any of claims 8 to 13 to process the indication of the final breath alcohol concentration.

15. Use of a breath alcohol interlock device according to claim 14 in a vehicle or machine.

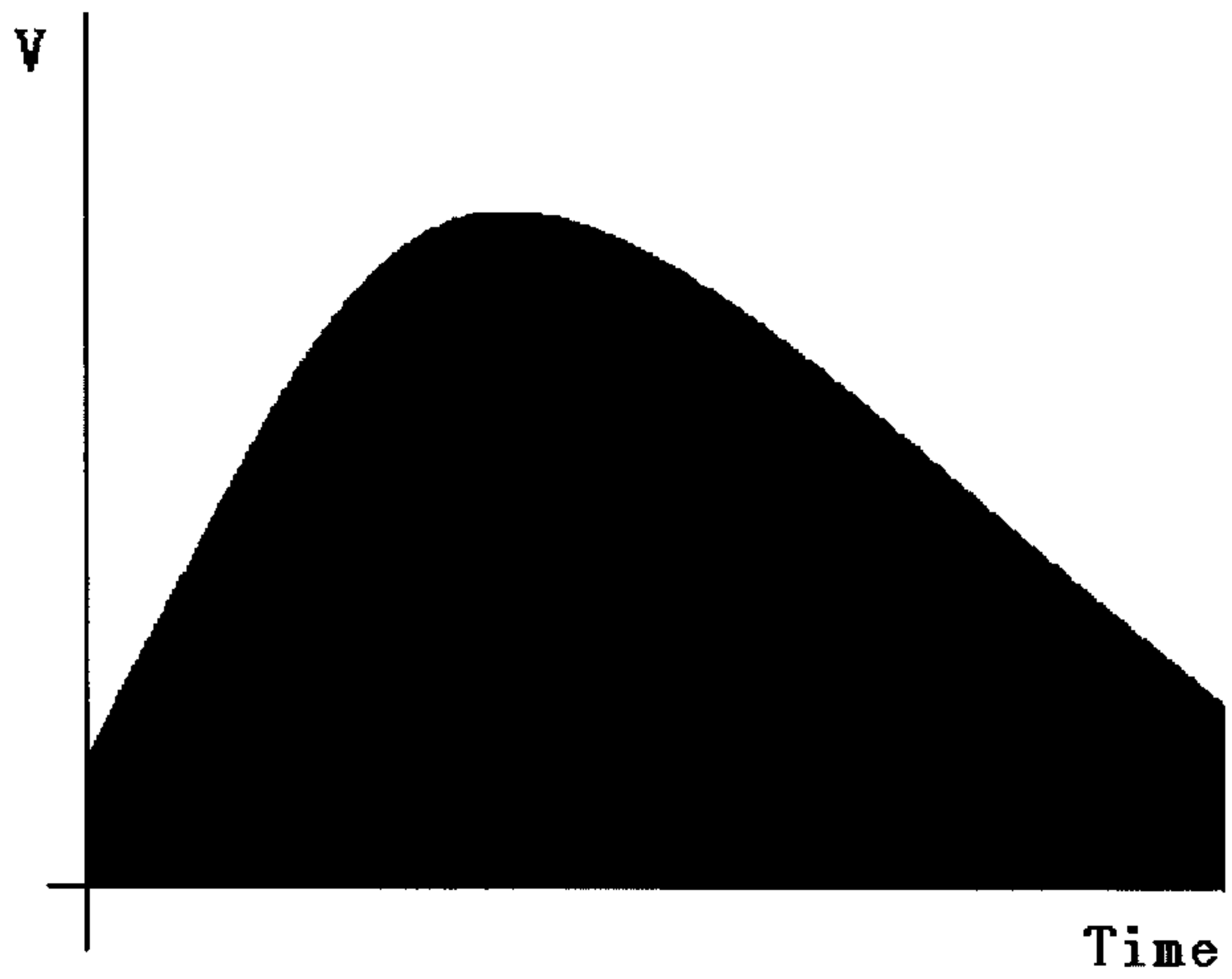

V
Time

Fig. 1

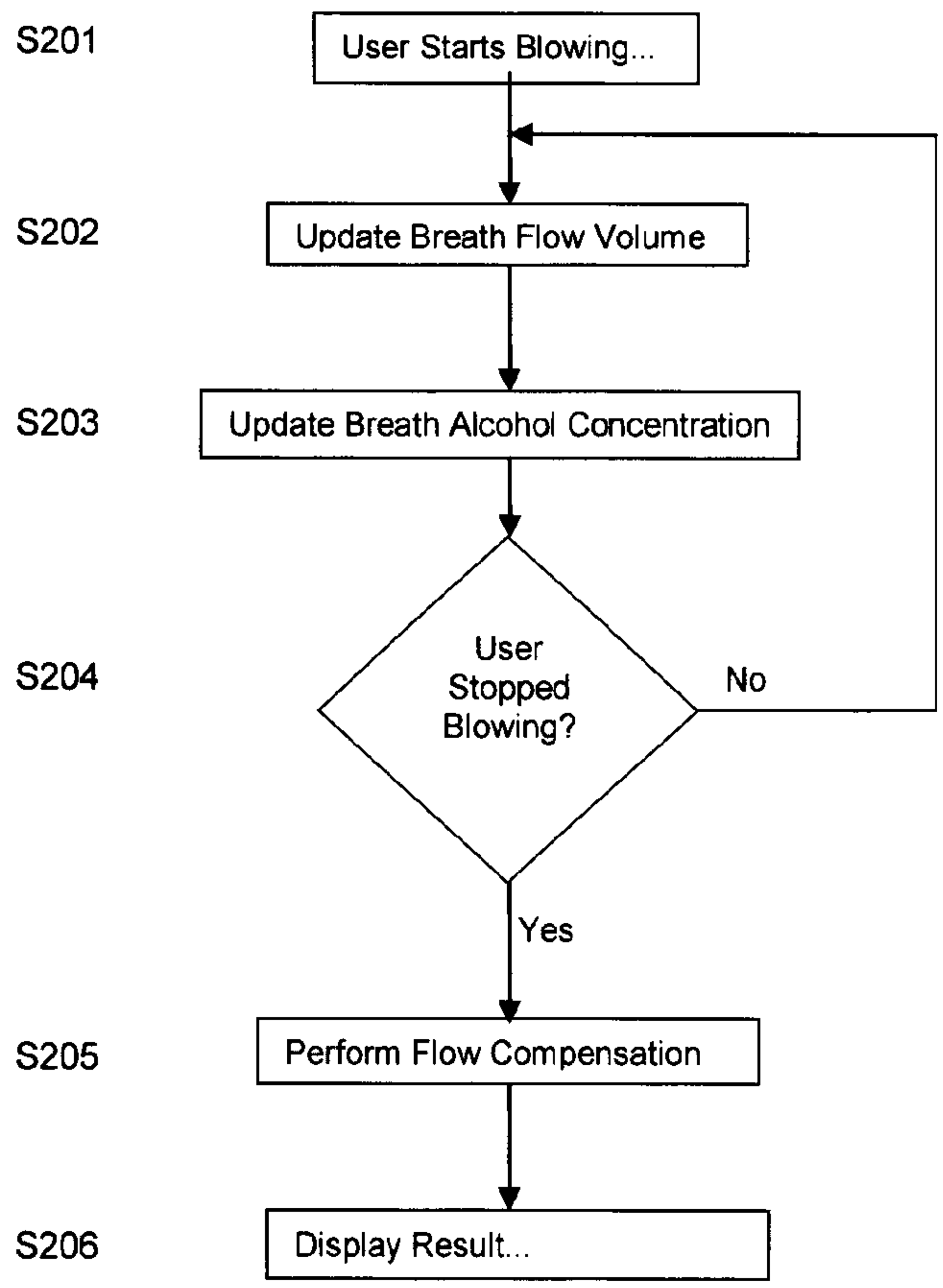

S201
User Starts Blowing...
S202
Update Breath Flow Volume
S203
Update Breath Alcohol Concentration
S204
User Stopped Blowing?
No
Yes
S205
Perform Flow Compensation
S206
Display Result...

Fig. 2

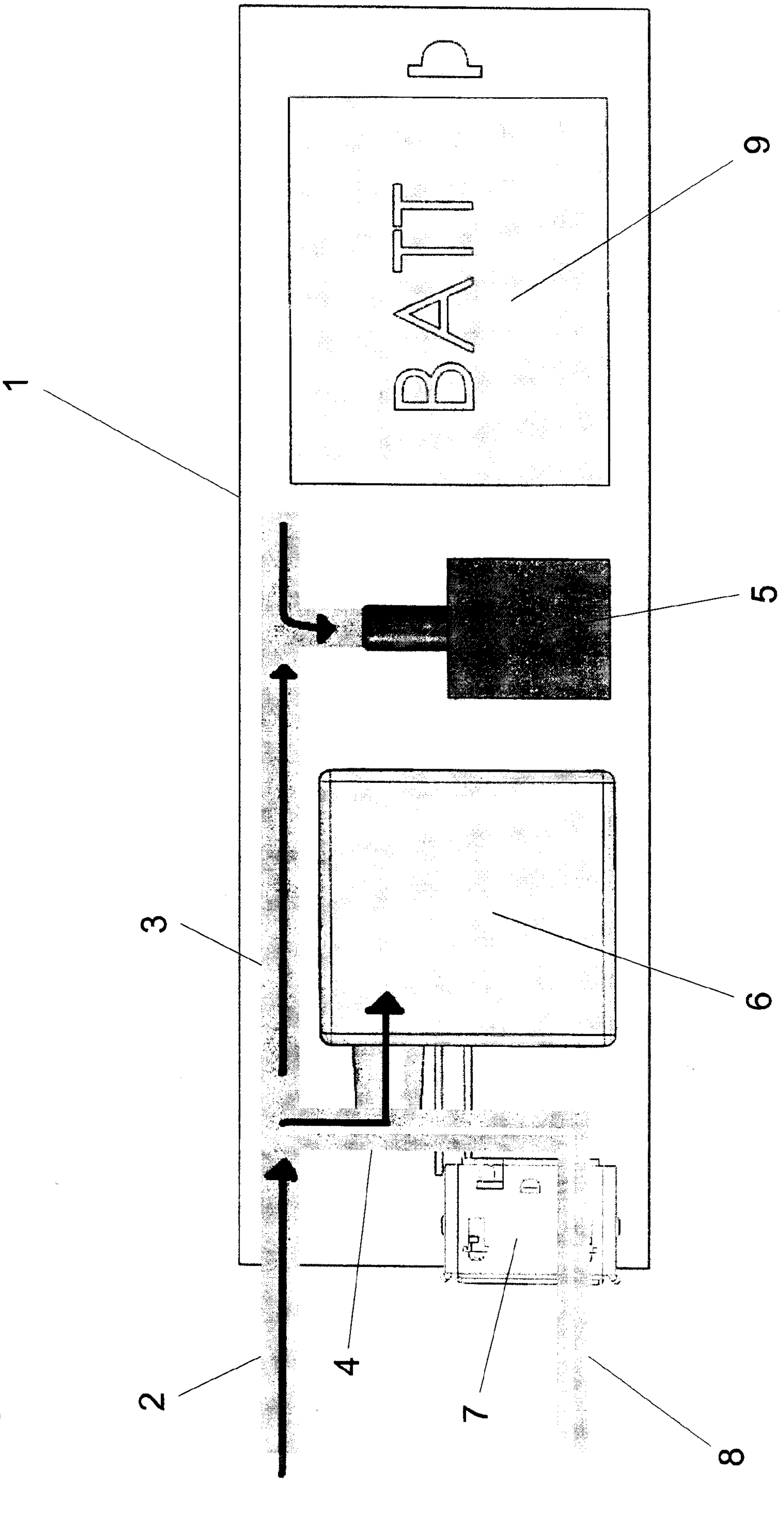
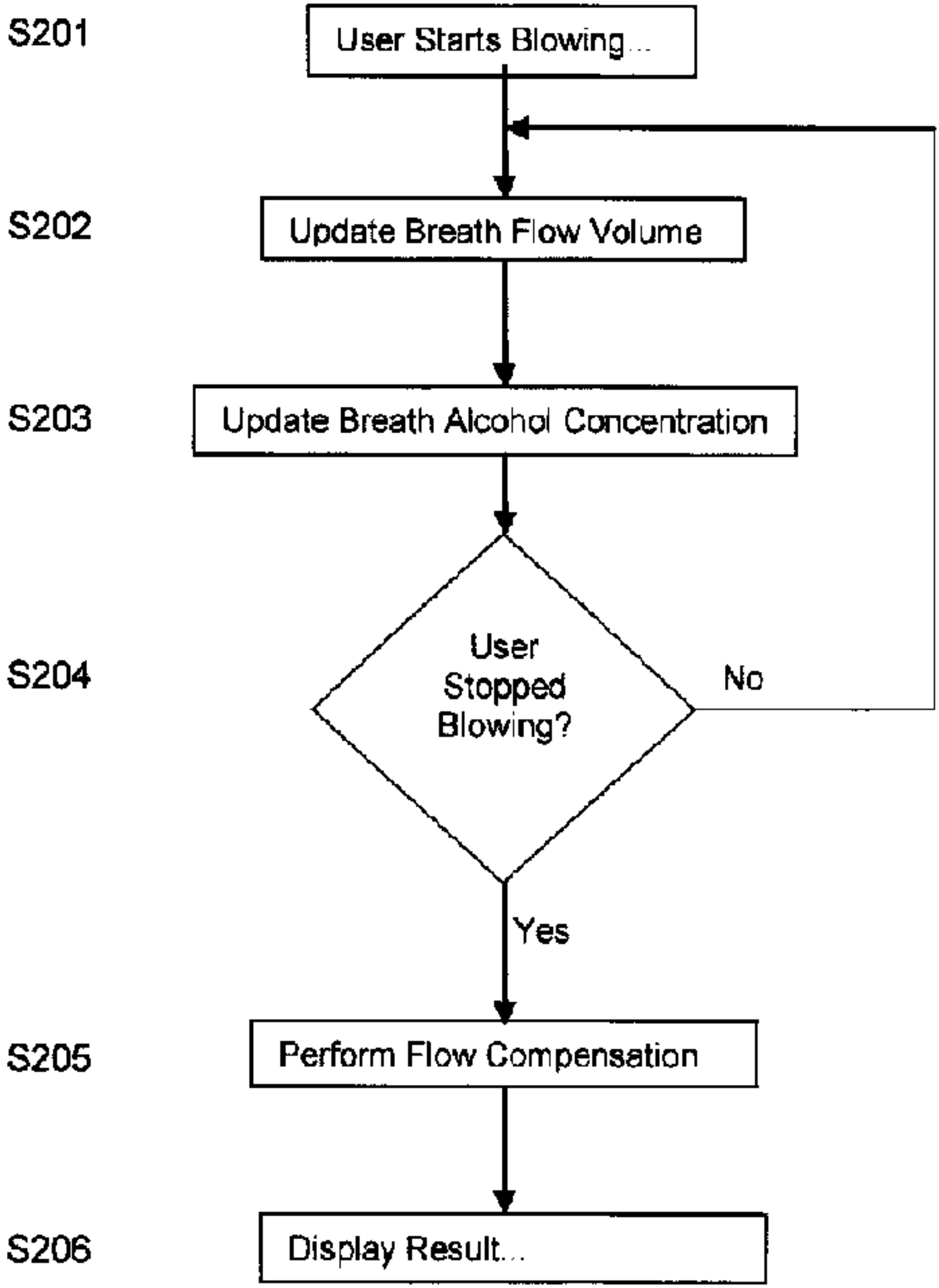


Fig. 3


S201
User Starts Blowing...
S202
Update Breath Flow Volume
S203
Update Breath Alcohol Concentration
S204
User Stopped Blowing?
No
Yes
S205
Perform Flow Compensation
S206
Display Result...