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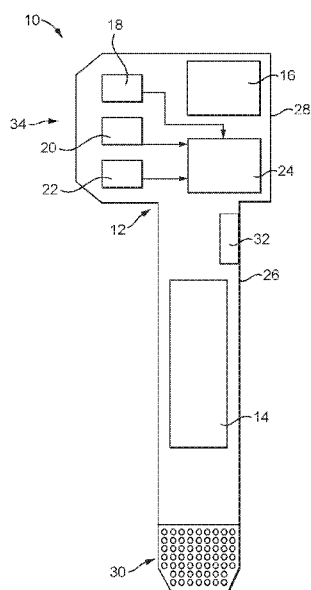


FIG. 1

(57) Abstract: A haircare appliance has a housing having an air inlet and an air outlet, an airflow generator for generating an airflow from the air inlet to the air outlet, and a heater for heating the airflow. The haircare appliance has an airflow temperature module for obtaining a value indicative of a temperature of the airflow at the air outlet, a distance sensor for sensing a distance to hair within a flow path from the air outlet and a temperature sensor for sensing a temperature of the hair. The haircare appliance has a moisture estimation module configured to estimate, based on received output values from the airflow temperature module, the distance sensor and the temperature sensor, a moisture content of the hair.

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A HAIRCARE APPLIANCE

Field of the Invention

5 The present invention relates to a haircare appliance.

Background of the Invention

During blow drying hair can reach an ‘over dry’ state. This may increase the
10 susceptibility of hair to mechanical or heat related damage, as well as negatively effecting
its look, feel, and the retention of any set style. To mitigate for this, it may be desirable
to determine a moisture content of hair being dried such that drying can be stopped before
the ‘over dry’ state is reached.

15 Summary of the Invention

According to a first aspect of the present invention there is provided a haircare appliance
comprising a housing having an air inlet and an air outlet, an airflow generator for
generating an airflow from the air inlet to the air outlet, a heater for heating the airflow,
20 an airflow temperature module for obtaining a value indicative of a temperature of the
airflow at the air outlet, a distance sensor for sensing a distance to hair within a flow path
from the air outlet, a temperature sensor for sensing a temperature of the hair, and a
moisture estimation module configured to estimate, based on received output values from
the airflow temperature module, the distance sensor and the temperature sensor, a
25 moisture content of the hair.

The haircare appliance according to the first aspect of the present invention may be
beneficial as the moisture estimation module utilises a value indicative of a temperature
of airflow at the air outlet, a distance between the air outlet and hair within a flow path

from the air outlet, and a temperature of the hair, to estimate a moisture content of the hair.

In particular, when hair is exposed to forced heated convection, such as that produced by a hairdryer, the hair's surface temperature may change proportionally with its moisture content. As moisture is removed from the hair its surface temperature increases, and this may occur at a reducing rate, with the hair tending towards a minimum moisture content level/equilibrium. The lower temperature of wet hair may be caused by an evaporative cooling effect and the inherently larger thermal mass.

The inventors of the present application have established that moisture content of hair may be reliably and accurately inferred by looking at a temperature differential between hair and the airflow proximal to the hair, and have recognised that such a temperature differential may be impacted by distance of the air outlet, and hence the haircare appliance, from the hair.

The moisture estimation module may be configured to estimate a temperature of airflow proximal to the hair based on the received outputs from the airflow temperature module and the distance sensor, and configured to estimate the moisture content of the hair based on the received output from the temperature sensor and the estimated temperature of airflow proximal to the hair.

The distance sensor may be located adjacent to the air outlet. The distance sensor may be configured to sense a distance between the air outlet and the hair.

The received output values may comprise instantaneous values. This may enable quicker estimation of moisture content than, for example, an estimation method that uses time-averaged values.

The temperature sensor may comprise a non-contact temperature sensor, for example a sensor configured to measure a surface temperature of the hair without contacting the hair. The temperature sensor may comprise a thermopile. The distance sensor may comprise a time-of-flight sensor.

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The airflow temperature module may be configured to directly determine the value indicative of a temperature of the airflow at the air outlet. For example, the airflow temperature module may comprise a further temperature sensor to directly obtain the value indicative of a temperature of the airflow at the air outlet. The further temperature sensor may comprise any of a thermistor, a thermocouple, or a resistance temperature detector (RTD). Directly obtaining the value indicative of a temperature of the airflow at the air outlet may provide a more accurate determination of temperature than, for example, indirectly obtaining the value indicative of a temperature of the airflow at the air outlet.

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The airflow temperature module may be configured to indirectly obtain the value indicative of a temperature of the airflow at the air outlet. For example, the airflow temperature module may be configured to infer the value indicative of a temperature of the airflow at the air outlet based on operating criteria of other components of the haircare appliance. Indirectly obtaining the value indicative of a temperature of the airflow at the air outlet may require less components than directly obtaining the value indicative of a temperature of the airflow at the air outlet, and hence may reduce costs. The airflow temperature module may be configured to indirectly obtain the value indicative of a temperature of the airflow at the air outlet based on any of a heater temperature of the heater, an airflow rate of the airflow generator, or a power draw of the haircare appliance. For example, the heater temperature may be utilised to infer the value indicative of a temperature of the airflow at the air outlet, and in some examples the heater temperature may be taken to be the value indicative of a temperature of the airflow at the air outlet.

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The moisture estimation module may comprise a filter, and the filter may be configured to process an output of the distance sensor and an output of the temperature sensor to provide a normalised temperature reading. The distance between the air outlet and the hair may comprise a major noise source for the value measured by the temperature sensor, and variation in distance may significantly change the absolute value observed for temperature of the hair, with offset distance being negatively associated with the observed temperature of the hair. By measuring and modelling this noise source its influence may be filtered using the filter, and the resulting moisture estimation may be normalised quickly without the need for long time-based averaging. The filter may comprise an adaptive filter.

The moisture estimation module may comprise a mathematical model indicative of a relationship between the temperature of the airflow at the air outlet, the distance to the hair and the temperature of the hair, and the moisture estimation module may be configured to estimate the moisture content of the hair based on the mathematical model. The mathematical model may enable quick estimation of moisture content without a direct reading from, for example, a moisture sensor or the like. The moisture estimation module may comprise a look-up table, for example a 2D look-up table based on airflow temperature proximal to the hair and temperature of the hair, or a 3D look-up table based on the value indicative of temperature of the airflow at the air outlet, the distance to hair within the flow path from the air outlet, and the sensed temperature of the hair.

The haircare appliance may comprise a motion sensor for determining a speed of motion of the haircare appliance relative to the hair, and the moisture estimation module may be configured to be inoperable when the speed of motion of the haircare appliance relative to the hair is above a threshold speed value. This may inhibit operation of the moisture estimation module during a condition where any estimation results risk being inaccurate, for example a condition where the haircare appliance is moved relatively quickly in relation to the hair. This may reduce power consumption and may, for example, be beneficial where the haircare appliance is battery operated.

The motion sensor may comprise an inertial measurement unit. The threshold speed value may, for example, be around 50mm/s.

- 5 The haircare appliance may comprise an image sensor for capturing images, and the moisture estimation module may be configured to be inoperable when an image captured by the image sensor does not indicate the presence of hair. This may inhibit false estimation of moisture content where the haircare appliance is positioned relative to objects other than hair. This may reduce power consumption and may, for example, be
- 10 beneficial where the haircare appliance is battery operated. The haircare appliance may comprise a processor to process images captured by the image sensor, for example to classify objects contained within images captured by the image sensor. The processor may be configured to determine the presence or absence of hair within images captured by the image sensor, and may be configured to communicate a signal indicative of the
- 15 presence or absence of hair to a controller of the haircare appliance, for example a controller of the moisture estimation module. The image sensor may comprise a thermal imaging sensor. Wet hair may be cooler than dry hair, and so a thermal imaging sensor may be used to indicate the presence of hair to be dried.
- 20 The haircare appliance may comprise an ambient sensor for sensing ambient temperature and/or humidity conditions, and the moisture estimation module may estimate a moisture content of the hair based on a received output from the ambient sensor. Ambient temperature and/or humidity conditions may influence a moisture level of the hair, and incorporating sensed ambient temperature and/or humidity conditions into the estimation
- 25 of moisture content of the hair may provide a more accurate estimation.

The haircare appliance may comprise an alert module to alert a user to the estimated moisture content of the hair. This may enable a user to, for example, stop drying of the hair and/or move on to drying a next section of the hair, in response to the estimated

30 moisture content of the hair. This may inhibit over-drying of hair, for example by

providing an alert where the estimated moisture content is at or below a pre-determined moisture content threshold. The alert module may be configured to alert a user when the estimated moisture content is at or below a pre-determined moisture threshold. The pre-determined moisture threshold may comprise a moisture value of 0%, for example to alert
5 a user that the hair is at a moisture equilibrium with the surrounding environment, or may comprise a value of 20%, for example to indicated that the moisture level of the hair is suitable for a styling operation, for example curling, to take place..

The alert module may comprise a haptic feedback module, for example configured to
10 provide haptic feedback to a user indicative of the estimated moisture content. This may ensure that an alert is provided to a user irrespective of whether or not the haircare appliance is visible to the user.

The alert module may comprise a visual indicia of the estimated moisture content of the
15 hair. For example, the alert module may comprise an LED or a visual display screen to communicate the estimated moisture content of the hair to a user of the haircare appliance. A visual indicia may provide a simple means of communicating the alert to the user.

The alert module may comprise an aural indicia of the estimated moisture content of the
20 hair. For example, the alert module may comprise a noise source to communicate the estimated moisture content of the hair to a user of the haircare appliance. An aural indicia may provide a simple means of communicating the alert to the user.

The haircare appliance may comprise a controller configured to control an output
25 parameter of the haircare appliance based on the estimated moisture content. This may be beneficial as it may reduce user input needed to control the haircare appliance, and may allow for automatic control of the haircare appliance in response to estimated moisture content of hair. The output parameter may comprise any of airflow, airflow temperature, or ion content.

The controller may be configured to modify an airflow rate of the airflow generator, for example increase or decrease the airflow rate of the airflow generator, in response to the estimated moisture content.

- 5 The controller may be configured to modify a temperature of the heater, for example increase or decrease the temperature of the heater, in response to the estimated moisture content. The controller may be configured to modify electrical power supplied to the heater, for example to increase or decrease a level of electrical power supplied to the heater, in response to the estimated moisture content.

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The haircare appliance may comprise an ion generator for introducing ions into the airflow, and the controller may be configured to modify a rate of ion generation of the ion generator, for example to increase or decrease the rate of ion generation of the ion generator, in response to the estimated moisture content.

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The moisture estimation module may be configured to monitor a received output value from the temperature sensor over a time period, calculate a heating rate of the hair and estimate the moisture content of the hair based on the calculated heating rate. Dry hair may have a rapid heating rate before trending toward a stable peak temperature, whilst
20 wet hair may take longer to reach the same stable peak temperature. Heating rate may thereby be used to infer an estimated moisture content, and may increase the accuracy of the moisture estimation.

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The moisture estimation module may be configured to receive an output value indicative of airflow rate, for example airflow rate of airflow generated by the airflow generator, and to estimate the moisture content of the hair based on the output value indicative of airflow rate. Airflow rate may have an impact on drying rate of the hair, and hence taking into account airflow rate may enable more accurate estimation of the moisture content. The moisture estimation module may be configured to filter the output value indicative

of airflow rate and/or apply a correction factor determined based on the output value indicative of airflow rate.

The haircare appliance may comprise a timer for timing a drying operation, and the moisture estimation module may be configured to estimate the moisture content of the hair based on a received output from the timer. A longer drying time may lead to a decrease in moisture level, for example, and including a time-based element in the estimation of moisture content may enable a more accurate estimation of the moisture content of the hair.

The moisture estimation module may be configured to receive an input value indicative of a hair property of the hair, and to estimate the moisture content of the hair based on the input value indicative of the hair property. Different hair properties may impact on moisture retention levels of the hair, and estimating the moisture content of the hair based on the input value indicative of the hair property may enable a more accurate estimation of the moisture content.

The hair property may comprise any of hair type, hair length, hair colour, or haircare product used on the hair.

The haircare appliance may comprise a user interface, and the input value indicative of the hair property may be received via the user interface. This may provide a simple arrangement that enables the hair property to be input by the user pre- or during styling.

In other examples the input value indicative of the hair property may be received from a remote device, for example a device remote from the haircare appliance. The remote device may comprise a computing device such as a phone or a tablet, and the input value indicative of the hair property may be entered to the remote device via an app. This may enable the input value indicative of the hair property to be entered during styling, without

the need for a user to remove the haircare appliance from its current location with respect to the hair.

The distance sensor may configured to sense a distance to hair outside of the flow path from the air outlet, the temperature sensor may be configured to sense a temperature of the hair outside of the flow path from the air outlet, and the moisture estimation module may be configured to estimate, based on received output values from the distance sensor and the temperature sensor, a moisture content of the hair outside of the flow path from the air outlet. This may enable analysis of hair not corresponding to hair currently being heated, which may enable the use of pre-and/or post- heating information, for example to determine whether hair adjacent to hair currently being dried has already been dried before.

The haircare appliance may comprise a main body within which the airflow generator and the heater are housed, and an attachment releasably attached to the main body, the attachment comprising the airflow temperature module, the distance sensor, the temperature sensor and the moisture estimation module. By providing the airflow temperature module, the distance sensor, the temperature sensor and the moisture estimation module as part of a releasable attachment, the moisture estimation functionality be selectively utilised by a user, and may also be retrofitted to an existing haircare appliance.

The attachment may be configured to communicate the estimated moisture content of the hair to the main body, for example via a wired or wireless connection. The attachment may comprise a transmitter configured to transmit estimated moisture content information, and the main body may comprise a receiver configured to receive the estimated moisture content information from the transmitter. This may, for example, allow control of components located within the main body, such as the heater and the airflow generator, to be controlled based on the estimated moisture content of the hair.

The attachment may comprise the alert module, and a power source to power the alert module, the airflow temperature module, the distance sensor, the temperature sensor and the moisture estimation module. In such a manner the attachment may comprise a self-contained unit for retro-fitting to an existing haircare appliance.

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According to a second aspect of the present invention there is provided a method of estimating a moisture content of hair, the method comprising directing an airflow at the hair, receiving a value indicative of a temperature of the airflow, receiving a value indicative of a distance to the hair, receiving a value indicative of a temperature of the hair, and estimating the moisture content based on the received values indicative of the temperature of the airflow, the distance to the hair and the temperature of the hair.

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According to a third aspect of the present invention there is provided an attachment for a haircare appliance having an airflow generator configured to generate an airflow and a heater for heating the airflow, the airflow generator and the heater disposed in a housing, the attachment comprising an air inlet for receiving heated airflow from the housing, an air outlet, an airflow temperature module for determining a temperature of the airflow at the air outlet, a distance sensor for sensing a distance to hair within a flow path from the air outlet, a temperature sensor for sensing a temperature of the hair, and a moisture estimation module configured to estimate, based on received output values from the airflow temperature module, the distance sensor and the temperature sensor, a moisture content of the hair.

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Optional features of aspects of the present invention may be equally applied to other aspects of the present invention, where appropriate.

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Brief Description of the Drawings

Figure 1 is a schematic illustration of a haircare appliance according to the present invention;

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Figure 2 is a graph illustrating hair temperature profile from wet to dry;

Figure 3 is a graph illustrating a comparison between heating rate of wet and dry hair;

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Figure 4 is a graph illustrating the effect of distance on surface temperature of dry hair for different heater temperatures;

Figure 5 is a graph illustrating hair temperature vs wetness value for a given distance offset;

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Figure 6 is a graph illustrating hair temperature vs wetness value for a several distance offsets;

Figure 7 is a first illustration of a 3D look-up table for use with the haircare appliance of Figure 1;

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Figure 8 is a second illustration of a 3D look-up table for use with the haircare appliance of Figure 1;

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Figure 9 is schematic illustration of a relationship between mass increase and wetness value;

Figure 10 is a schematic illustration of an adaptive filter system for use with the haircare appliance of Figure 1;

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Figure 11 is a schematic illustration of a first alternative embodiment of a haircare appliance according to the present invention;

Figure 12 is a schematic illustration of a second alternative embodiment of a haircare appliance according to the present invention;

Figure 13 is a schematic illustration of a third alternative embodiment of a haircare
5 appliance according to the present invention;

Figure 14 is a schematic illustration of a fourth alternative embodiment of a haircare appliance according to the present invention;

10 Figure 15 is a schematic illustration of a fifth alternative embodiment of a haircare appliance according to the present invention; and

Figure 16 is a flow diagram illustrating a method according to the present invention.

15 Detailed Description of the Invention

A haircare appliance, generally designated 10, according to the present invention is shown schematically in Figure 1. The haircare appliance 10 of Figure 1 is intended to connect to an AC mains power supply via an appropriate electrical cable (not shown), but it will
20 be appreciated that embodiments where the haircare appliance 10 comprises its own power source, for example its own battery, are also envisaged.

The haircare appliance 10 comprises a housing 12, an airflow generator 14, a heater 16, an airflow temperature module 18, a distance sensor 20, a temperature sensor 22, and a
25 moisture estimation module 24.

The housing 12 comprises a handle portion 26 and a body portion 28. The handle portion 26 is generally tubular in form, and is hollow. The handle portion 26 comprises an air inlet 30, which takes the form of a plurality of apertures, and the handle portion 26 also

house the airflow generator 14. A user interface 32 is disposed on the handle portion 26, and comprises a plurality of user-actuable buttons and/or a touch screen interface.

The body portion 28 is generally cylindrical in form, but is tapered toward an air outlet 34 of the haircare appliance 10, such that one end of the body portion 28 is generally frustoconical. The body portion 28 is hollow, and houses the heater 16, the airflow temperature module 18, the distance sensor 20, the temperature sensor 22, and the moisture estimation module 24. The air outlet 34 may comprise a generally circular aperture, or in embodiments where the body portion 28 has a central bore then the air outlet 34 may be generally annular and disposed radially outwardly of the central bore.

The airflow generator 14 comprises a motor driven impeller to draw airflow into the housing 12 via the air inlet 30. An example of an appropriate airflow generator 14 is the Dyson® digital motor V9, produced by Dyson Technology Ltd. The airflow generator 14 generates an airflow from the air inlet 30 through the handle portion 26 and the body portion 28 to the air outlet 34 in use.

The heater 16 is disposed in the body portion 28 of the housing 12, and is configured to convectively heat airflow flowing through the body portion 28 in use, such that a heated airflow exits the housing 12 of the haircare appliance 10 via the air outlet 34. An appropriate heater may be a ceramic heater, for example.

The airflow temperature module 18 is disposed in the body portion 28 of the housing 12 proximal to the air outlet 34. The airflow temperature module 18 in the embodiment of Figure 1 comprises a direct temperature sensor, for example a of a thermistor, a thermocouple, or a resistance temperature detector (RTD), that is configured to directly determine a temperature of airflow at the air outlet 34. It will be appreciated that alternative embodiments where the airflow temperature module 18 is configured to indirectly determine the temperature of airflow at the air outlet 34 are also envisaged. For example, the airflow temperature module 18 may be configured to infer the temperature

of airflow at the air outlet 34 based on any of a heater temperature of the heater 16, an airflow rate of the airflow generator 14, or a power draw of the haircare appliance 10.

The distance sensor 20 is disposed in the body portion 28 of the housing 12 proximal to the air outlet 34. The distance sensor 20 in the embodiment of Figure 1 comprises a laser time-of-flight sensor, although it will be appreciated that other types of distance sensor may also be utilised. The distance sensor is configured to sense a distance from the air outlet 34 to hair within a flow path from the air outlet 34 in use.

Whilst the distance sensor 20 in the embodiment of Figure 1 is located proximal to the air outlet 34, in other embodiments the distance sensor may be positioned further away from the air outlet 34, with an appropriate offset applied to any distance measurement to determine a distance from the air outlet 34 to the hair within the flow path from the air outlet 34.

The temperature sensor 22 is disposed in the body portion 28 of the housing 12 proximal to the air outlet 34. The temperature sensor 22 in the embodiment of Figure 1 comprises a thermopile configured to sense a surface temperature of hair with the flow path from the air outlet 34, although it will be appreciated that other types of non-contact temperature sensor are also envisaged. It will further be appreciated that the temperature sensor 22 may be located further from the air outlet 34 to mitigate for interference with the heated airflow, if required.

The moisture estimation module 24 is configured to receive output values from each of the airflow temperature module 18, the distance sensor 20, and the temperature sensor 22, and to estimate a moisture content of the hair within the flow path from the air outlet 34 based on the received output values.

In particular, when hair is exposed to forced heated convection the hair's surface temperature may change proportionally with its moisture content. As moisture is

removed from the hair its surface temperature increases, and this may occur at a reducing rate, with the hair tending towards a minimum moisture content level/equilibrium. The lower temperature of wet hair may be caused by an evaporative cooling effect and the inherently larger thermal mass. This is illustrated in the graphs of Figures 2 and 3.

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The inventors of the present application have established that moisture content of hair may be reliably and accurately inferred by looking at a temperature differential between hair and the airflow proximal to the hair, and have recognised that such a temperature differential may be impacted by distance of the air outlet, and hence the haircare appliance, from the hair.

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The moisture estimation module 24 is therefore configured to estimate a temperature of airflow proximal to the hair based on the received outputs from the airflow temperature module 18 and the distance sensor 20, and configured to estimate the moisture content of the hair based on the received output from the temperature sensor 22 and the estimated temperature of airflow proximal to the hair.

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The relationship between the received outputs and the moisture content may be obtained via simulation and/or mathematical modelling and/or physical testing, and pre-programmed into the moisture estimation module 24.

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In particular, as seen in Figure 4, for a given heating mode of the haircare appliance 10, ie a given heating mode where the heater 16 is set at a certain temperature, and hence the temperature of air at the air outlet 34 can be inferred, the surface temperature of dry hair, ie hair determined to have a moisture content, ie a wetness value, of 0%, varies with the distance of the haircare appliance 10 from the hair, as measured by the distance sensor 20. The surface temperature of wet hair, ie hair determined to have a moisture content, ie a wetness value, of 100%, will also vary in a similar way.

25

For a particular measured offset in use in a given heating mode, ie for a given temperature at the air outlet 34, a surface temperature of hair can be measured and a value indicative of moisture content, ie a wetness value, can then be obtained, with such a wetness value labelled wetness in the plot of Figure 5. Examples of impact of distance on wetness can be seen in Figure 6.

In practice, a 3D look-up table may be utilised to obtain the wetness value from the received outputs from the airflow temperature module 18, the distance sensor 20, and the temperature sensor 22. Illustrative 3D look-up tables are shown in Figures 7 and 8.

In the plots of Figures 5 and 6, and the 3D look-up tables of Figures 7 and 8, a “wetness” value is taken to be the estimated moisture content of hair. Such a wetness value is obtained by looking at an increase in mass of hair due to moisture content, and is illustrated in Figure 9.

In Figure 9, hair is considered to have a pre-determined mass at 0% relative humidity. The percentage increase of mass is then used to infer a wetness value. For example, a 14% increase in mass corresponds to a relative humidity of 60%, and is deemed to be a wetness value of 0%. Increases in mass below 14% are considered to have a wetness value of 0%, ie to be dry, for the purposes discussed herein. A 25% increase in mass is deemed to be a wetness value of 10%, and a 125% increase in mass is deemed to be a wetness value of 100%. Thus an estimated moisture content of hair in use via the wetness value can be linked to a percentage of increase in mass due to moisture.

Whilst a particular wetness value scale has been defined above, it will be appreciated that different wetness value scales may be utilised in practice to estimate the moisture content of the hair.

In some embodiments, the moisture estimation module 24 comprises a filter configured to process the output of the distance sensor 20 and the output of the temperature sensor

22 to provide a normalised temperature reading for hair within the flow path from the air outlet 34.

5 The distance between the air outlet 34 and the hair may comprise a major noise source for the value measured by the temperature sensor 22, and variation in distance may significantly change the absolute value observed for temperature of the hair, as seen in Figure 4, with offset distance being negatively associated with the observed temperature of the hair. By measuring and modelling this noise source its influence can be filtered using the filter, and the resulting moisture estimation may be normalised quickly without
10 the need for long time-based averaging.

An appropriate adaptive filter system 100 is illustrated schematically in Figure 10.

15 The adaptive filter system 100 receives a sensed temperature of hair from the temperature sensor 22, which is illustrated as the signal source in Figure 10, and a sensed distance from the distance sensor 20, which is illustrated as $x(n)$ in Figure 10. The signal source and $x(n)$ are summed to obtain $d(n)$, which is representative of the sensed temperature of hair plus the noise introduced due to distance from the hair. The sensed distance from the distance sensor 20 is fed to an adaptive filter 102, which acts using an algorithm, in
20 this case a least mean squares algorithm to produce a filter output illustrated as $y(n)$ in Figure 10. The filter output $y(n)$ is removed from the value $d(n)$, to produce an output value $e(n)$ which is an approximation of the signal source only.

25 Use of an adaptive filter system 100 as shown in Figure 10 may enable the haircare appliance 10 to dynamically converge toward a relationship indicative of moisture content from received outputs, and may remove the need for extensive simulation and/or experimental work to determine a full relationship, for example by producing a relationship that can be fitted to only one or two known points.

With knowledge of the estimated moisture content of the hair within the flow path from the air outlet 34, the haircare appliance 10 may be utilised to prevent over-drying of hair in use.

- 5 An alternative embodiment of a haircare appliance 200, as illustrated in Figure 11, comprises an alert module 202 disposed in the handle portion 26 of the housing 12. The alert module 202 may be comprise any combination of a haptic feedback module, a visual indicia, or an aural indicia which can communicate to a user the estimated moisture content of the hair, for example communicating when the estimated moisture content of
- 10 the hair has dropped below a threshold value. This may enable the haircare appliance 200 to communicate the estimated moisture content to a user, which may inhibit over-drying of the hair in use.

- A further alternative embodiment of a haircare appliance 300 is illustrated in Figure 12.
- 15 Relative to the embodiment of the haircare appliance 10 of Figure 1, the haircare appliance 300 of Figure 12 further comprises a controller 302 configured to control an output parameter of the haircare appliance based on the estimated moisture content estimated by the moisture estimation module 24. Examples of output parameters that may be controlled by the controller 302 are a flow rate of airflow generated by the airflow
- 20 generator 14, a temperature of the heater 16, and ion content introduced into the airflow by an ioniser (not shown) of the haircare appliance 300. In such a manner the haircare appliance 300 may reduce user input needed to control the haircare appliance 300, and may allow for automatic control of the haircare appliance 300 in response to estimated moisture content of hair.

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Although shown here as a discrete controller 302, it will be appreciated that in practice the haircare appliance 300 may comprise separate controllers for each, or for combinations of, the components contained therein.

Whilst illustrated as separate embodiments in Figures 11 and 12, it will be appreciated that the alert module 202 and the controller 302 may be combined into a single haircare appliance if so desired.

5 Another alternative embodiment of a haircare appliance 400 is illustrated in Figure 13. The haircare appliance 400 of Figure 13 differs from the haircare appliance 10 of Figure 1 in that the haircare appliance 400 of Figure 13 further comprises a motion sensor 402 for determining a speed of motion of the haircare appliance 400 relative to the hair within the flow path from the air outlet 34, and an image sensor 404 for capturing images.

10 The motion sensor 402 comprises an inertial measurement unit that is configured to determine a speed of motion of the haircare appliance 400 relative to the hair within the flow path from the air outlet 34, and the moisture estimation module 24 is configured to be inoperable where the motion sensor 402 detects a speed of motion above a pre-
15 determined threshold, for example of around 50mm/s. This may inhibit operation of the moisture estimation module 24 during a condition where any estimation results risk being inaccurate, for example a condition where the haircare appliance 400 is moved relatively quickly in relation to the hair. This may reduce power consumption and may, for example, be beneficial where the haircare appliance 400 is battery operated.

20 Similarly, the moisture estimation module 24 is configured to be inoperable in response to an output of the image sensor 404, for example where an image captured by the image sensor 404 does not indicate the presence of hair. The image sensor 404 in the embodiment of Figure 13 is a visible light image sensor in the form of a video camera,
25 and also includes an image classifier to determine the presence or absence of hair in images, for example frames of a video, captures by the image sensor 404. Alternative image sensors, for example thermal imaging sensors or indeed any sensor capable of indicating the presence or absence of hair, are also envisaged

Although shown in Figure 13 as having both a motion sensor 402 and an image sensor 404, embodiments of haircare appliance that utilise only one of these sensors are also envisaged.

- 5 Another embodiment of a haircare appliance 500 according to the present invention is illustrated schematically in Figure 14. The haircare appliance 500 of Figure 14 differs from the haircare appliance 10 of Figure 1 in that the haircare appliance 500 of Figure 14 also comprises an ambient sensor 502 configured to sense ambient conditions of the haircare appliance 500, for example any of ambient temperature and ambient humidity.
- 10 The ambient sensor 502 provides an output value to the moisture estimation module 24, with the moisture estimation module 24 configured to estimate the moisture content of hair within the flow path from the air outlet 34 based on the received output from the ambient sensor 502, for example by applying an offset to the estimated moisture content, or the temperature of hair sensed by the temperature sensor 20, dependent on the
- 15 magnitude of a reading from the ambient sensor 502.

It will be appreciated that the moisture estimation module 24 may also take account of other parameters during the estimation of the moisture content of the hair within the flow path from the air outlet 34.

20

- For example, in one embodiment the moisture estimation module 24 may be configured to monitor a received output value from the temperature sensor 22 over a time period to calculate a heating rate of the hair within the flow path from the air outlet 34, and estimate the moisture content of the hair based on the calculated heating rate. In such an
- 25 embodiment the haircare appliance 10 may comprise a timer to calculate the heating rate.

- In another embodiment, the moisture estimation module 24 may be configured to receive an output value indicative of airflow rate, for example from the airflow generator 14 or a controller of the airflow generator 14, and to estimate the moisture content of the hair
- 30 within the flow path from the air outlet 34 based on the value indicative of airflow rate.

Airflow rate may, for example, impact on a drying rate of the hair hence taking into account airflow rate may enable more accurate estimation of the moisture content.

In some embodiments the moisture estimation module 24 may be configured to monitor a time of a drying operation, and to estimate the moisture content based on a time of the drying operation, for example by inferring a decrease in moisture level over time. In such embodiments the haircare appliance 10 comprises a timer for timing the drying operation.

In a further embodiment, the moisture estimation module 24 is configured to receive an input value indicative of a hair property of the hair within the flow path from the air outlet 34, and to estimate the moisture content of the hair based on the input value indicative of the hair property. The hair property may be any of hair type, hair length, hair colour, or haircare product used on the hair, for example. The hair property may be input via the user interface 32 in some embodiments.

A further embodiment of a haircare appliance 600 is illustrated schematically in Figure 15. The haircare appliance 600 comprises an attachment 602 releasably attached to the housing 12. The attachment 602 may be releasably attached in any appropriate manner, including, for example magnetic attachment. The airflow temperature module 18, the distance sensor 20, the temperature sensor 22, and the moisture estimation module 24 are illustrated as being disposed in the attachment 602 in the haircare appliance 600 of Figure 15, but it will be recognised that any appropriate combination of the aforementioned components may be housed in the attachment 602 in practice. The attachment 602 receives airflow from the air outlet 34, and provides the airflow to the target hair via its own air outlet 604.

By locating any combination of the airflow temperature module 18, the distance sensor 20, the temperature sensor 22, and the moisture estimation module 24 in the attachment 602, the functionality discussed above, where a moisture content of hair within the flow

path from the air outlet 604 is estimated, may be selectively provided, and indeed may be retrofitted onto an existing haircare appliance.

In the embodiment of Figure 15, the attachment 600 further comprises an alert module 606, and a battery 608 to power the alert module 606, the airflow temperature module 18, the distance sensor 20, the temperature sensor 22, and the moisture estimation module 24. In such a manner the attachment 600 may itself provide the estimated moisture content of hair to a user of the haircare appliance.

The attachment 602 in other embodiments is configured to communicate the estimated moisture content to the main body 12, for example to one or more controllers disposed within the main body 12, such that action can be taken in response to the estimated moisture content as previously discussed. The communication may be via a wired or wireless communication method, as appropriate. In such an embodiment the attachment 602 or components housed therein may be powered via the main body 12.

In the embodiments described above, each haircare appliance has a distance sensor 20 to sense a distance to hair within the flow path from the air outlet 34. In some embodiments, the distance sensor 20 is configured to sense a distance to hair outside of the flow path from the air outlet 34, the temperature sensor 22 is configured to sense a temperature of the hair outside of the flow path from the air outlet 34, and the moisture estimation module 24 is configured to estimate, based on received output values from the distance sensor 20 and the temperature sensor 22, a moisture content of the hair outside of the flow path from the air outlet 34. This may enable analysis of hair not corresponding to hair currently being heated, which may enable the use of pre-and/or post- heating information, for example to determine whether hair adjacent to hair currently being dried has already been dried before.

A method 700 according to the present invention is illustrated schematically in the flow diagram of Figure 16. The method 700 comprises directing 702 airflow at hair, receiving

704 a value indicative of a temperature of the airflow, receiving 706 a value indicative of a distance to the hair, and receiving 708 a value indicative of the temperature of the hair. The method 700 comprises estimating 710 a moisture content of the hair based on the received values indicative of the temperature of the airflow, the distance to the hair and
5 the temperature of the hair.

Claims

1. A haircare appliance comprising a housing having an air inlet and an air outlet, an airflow generator for generating an airflow from the air inlet to the air outlet, a heater for
5 heating the airflow, an airflow temperature module for obtaining a value indicative of a temperature of the airflow at the air outlet, a distance sensor for sensing a distance to hair within a flow path from the air outlet, a temperature sensor for sensing a temperature of the hair, and a moisture estimation module configured to estimate, based on received output values from the airflow temperature module, the distance sensor and the
10 temperature sensor, a moisture content of the hair.
2. A haircare appliance as claimed in Claim 1, wherein the moisture estimation module is configured to estimate a temperature of airflow proximal to the hair based on the received outputs from the airflow temperature module and the distance sensor, and
15 configured to estimate the moisture content of the hair based on the received output from the temperature sensor and the estimated temperature of airflow proximal to the hair.
3. A haircare appliance as claimed in Claim 1 or Claim 2, wherein the moisture estimation module comprises a filter, and the filter is configured to process an output of
20 the distance sensor and an output of the temperature sensor to provide a normalised temperature reading.
4. A haircare appliance as claimed in any of Claims 1 to 3, wherein the moisture estimation module comprises a mathematical model indicative of a relationship between
25 the value indicative of a temperature of the airflow at the air outlet, the distance of the hair and the temperature of the hair, and the moisture estimation module is configured to estimate the moisture content of the hair based on the mathematical model.
5. A haircare appliance as claimed in any preceding claim, wherein the haircare
30 appliance comprises a motion sensor for determining a speed of motion of the haircare

appliance relative to the hair, and the moisture estimation module is configured to be inoperable when the speed of motion of the haircare appliance relative to the hair is above a threshold speed value.

- 5 6. A haircare appliance as claimed in any preceding claim, wherein the haircare appliance comprises an image sensor for capturing images, and the moisture estimation module is configured to be inoperable when an image captured by the image sensor does not indicate the presence of hair.
- 10 7. A haircare appliance as claimed in any preceding claim, wherein the haircare appliance comprises an ambient sensor for sensing ambient temperature and/or humidity conditions, and the moisture estimation module estimates a moisture content of the hair based on a received output from the ambient sensor.
- 15 8. A haircare appliance as claimed in any preceding claim, wherein the haircare appliance comprises an alert module to alert a user to the estimated moisture content of the hair.
- 20 9. A haircare appliance as claimed in Claim 8, wherein the alert module comprises at least one of a haptic feedback module, a visual indicia, and an aural indicia of the estimated moisture content of the hair.
- 25 10. A haircare appliance as claimed in any preceding claim, wherein the haircare appliance comprises a controller configured to control an output parameter of the haircare appliance based on the estimated moisture content.
11. A haircare appliance as claimed in Claim 10, wherein the output parameter comprises any of airflow, airflow temperature, or ion content.

12. A haircare appliance as claimed in any preceding claim, wherein the moisture estimation module is configured to monitor a received output value from the temperature sensor over a time period, calculate a heating rate of the hair and estimate the moisture content of the hair based on the calculated heating rate.

5

13. A haircare appliance as claimed in any preceding claim, wherein the moisture estimation module is configured to receive an output value indicative of airflow rate, and to estimate the moisture content of the hair based on the output value indicative of airflow rate.

10

14. A haircare appliance as claimed in any preceding claim, wherein the haircare appliance comprises a timer for timing a drying operation, and the moisture estimation module is configured to estimate the moisture content of the hair based on a received output from the timer.

15

15. A haircare appliance as claimed in any preceding claim, wherein the moisture estimation module is configured to receive an input value indicative of a hair property of the hair, and to estimate the moisture content of the hair based on the input value indicative of the hair property.

20

16. A haircare appliance as claimed in Claim 15, wherein the hair property is any of hair type, hair length, hair colour, or haircare product used on the hair.

17. A haircare appliance as claimed in Claim 15 or Claim 16, wherein the haircare appliance comprises a user interface, and the input value indicative of the hair property is received via the user interface.

25

18. A haircare appliance as claimed in any preceding claim, wherein the distance sensor is configured to sense a distance to hair outside of the flow path from the air outlet, the temperature sensor is configured to sense a temperature of the hair outside of the flow

30

path from the air outlet, and the moisture estimation module is configured to estimate, based on received output values from the distance sensor and the temperature sensor, a moisture content of the hair outside of the flow path from the air outlet.

5 19. A haircare appliance as claimed in any preceding claim, wherein the haircare appliance comprises a main body within which the airflow generator and the heater are housed, and an attachment releasably attached to the main body, the attachment comprising the airflow temperature module, the distance sensor, the temperature sensor and the moisture estimation module.

10

20. A haircare appliance as claimed in Claim 19, wherein the attachment is configured to communicate the estimated moisture content of the hair to the main body.

15 21. A haircare appliance as claimed in Claim 19, wherein the attachment comprises an alert module to alert a user to the estimated moisture content of the hair, and a power source to power the alert module, the airflow temperature module, the distance sensor, the temperature sensor and the moisture estimation module.

20 22. A method of estimating a moisture content of hair, the method comprising directing an airflow at the hair, receiving a value indicative of a temperature of the airflow, receiving a value indicative of a distance to the hair, receiving a value indicative of a temperature of the hair, and estimating the moisture content based on the received values indicative of the temperature of the airflow, the distance to the hair and the temperature of the hair.

25

23. An attachment for a haircare appliance having an airflow generator configured to generate an airflow and a heater for heating the airflow, the airflow generator and the heater disposed in a housing, the attachment comprising an air inlet for receiving heated airflow from the housing, an air outlet, an airflow temperature module for obtaining a
30 value indicative of a temperature of the airflow at the air outlet, a distance sensor for

sensing a distance to hair within a flow path from the air outlet, a temperature sensor for sensing a temperature of the hair, and a moisture estimation module configured to estimate, based on received output values from the airflow temperature module, the distance sensor and the temperature sensor, a moisture content of the hair.

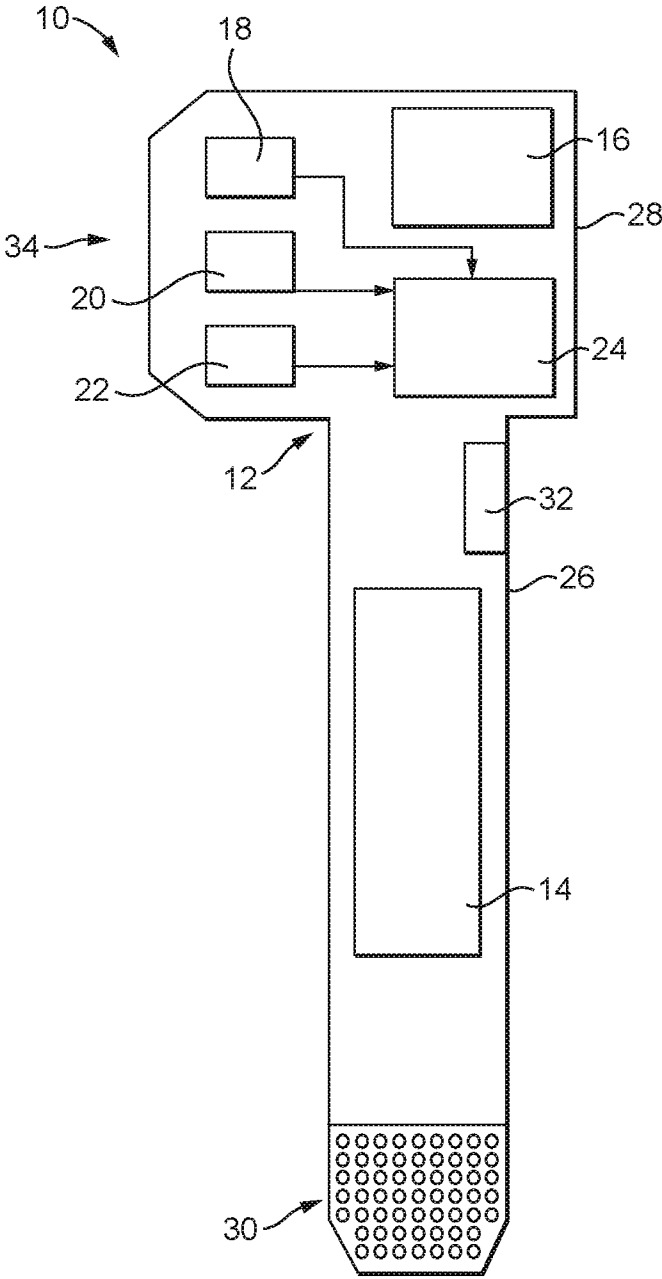


FIG. 1

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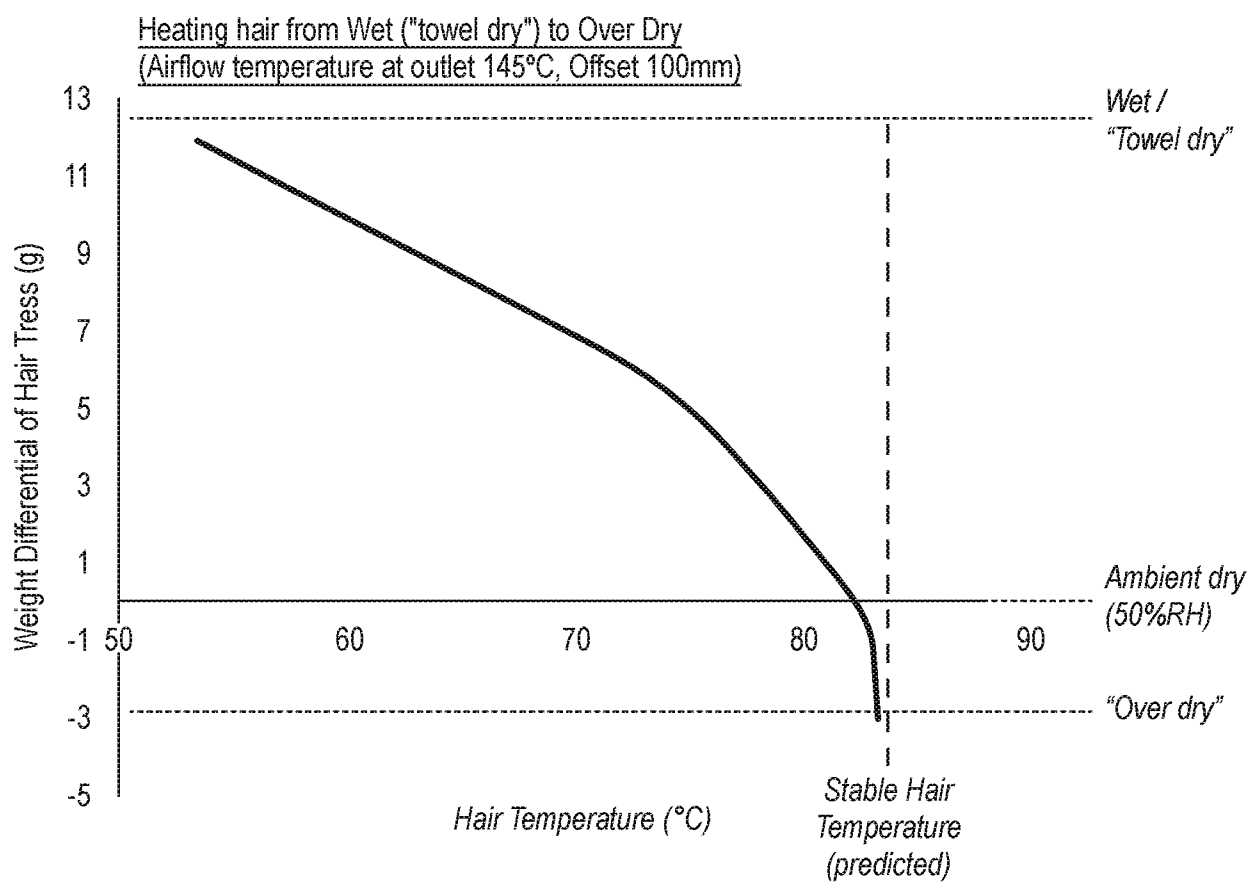


FIG. 2

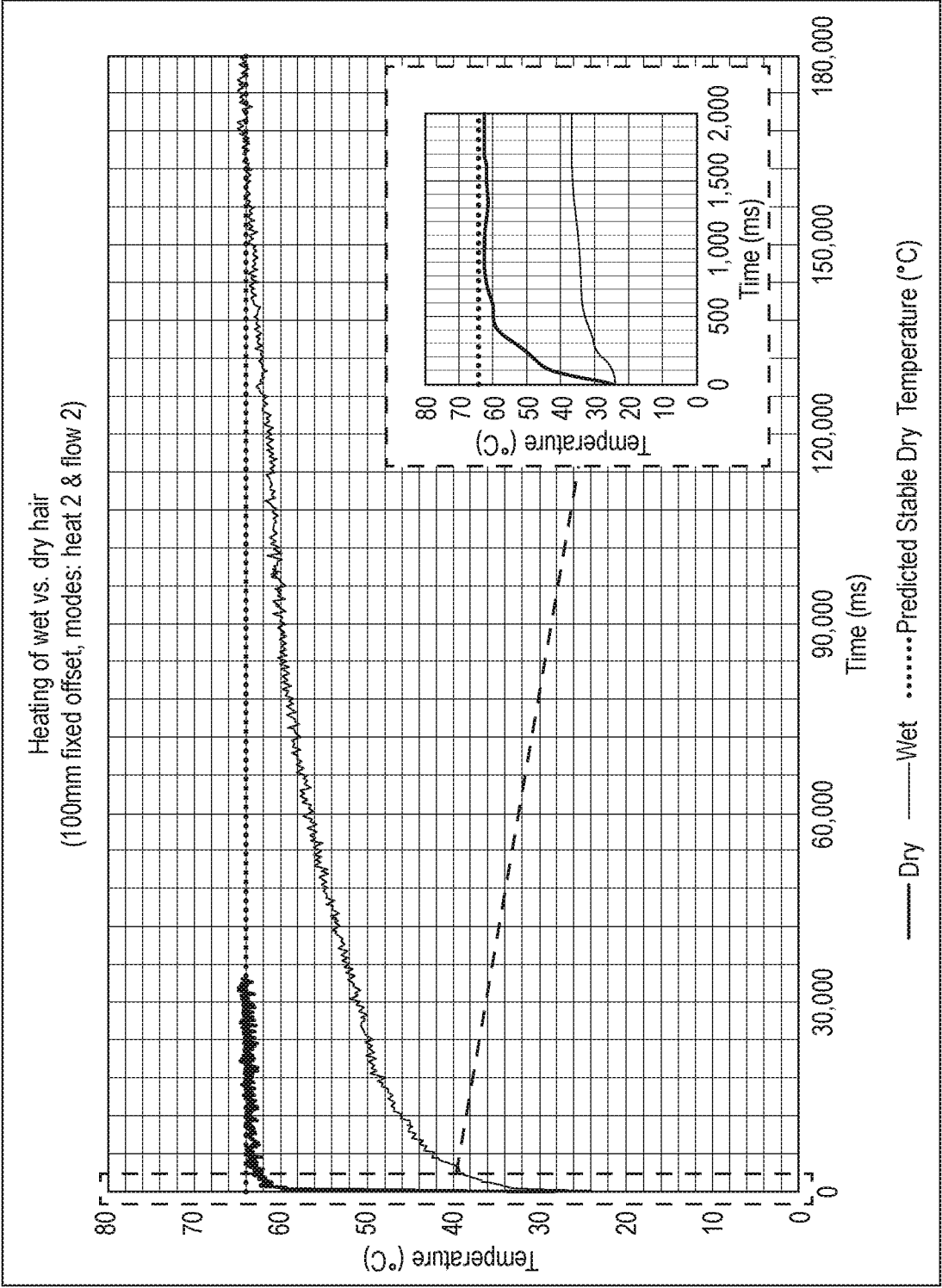


FIG. 3

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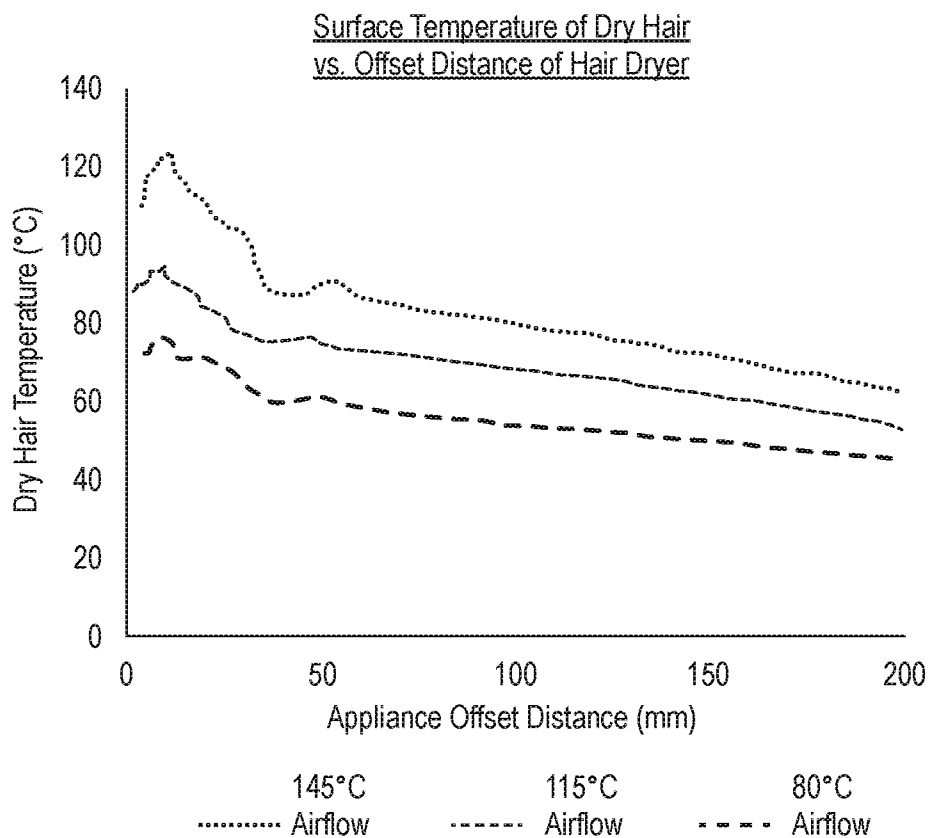


FIG. 4

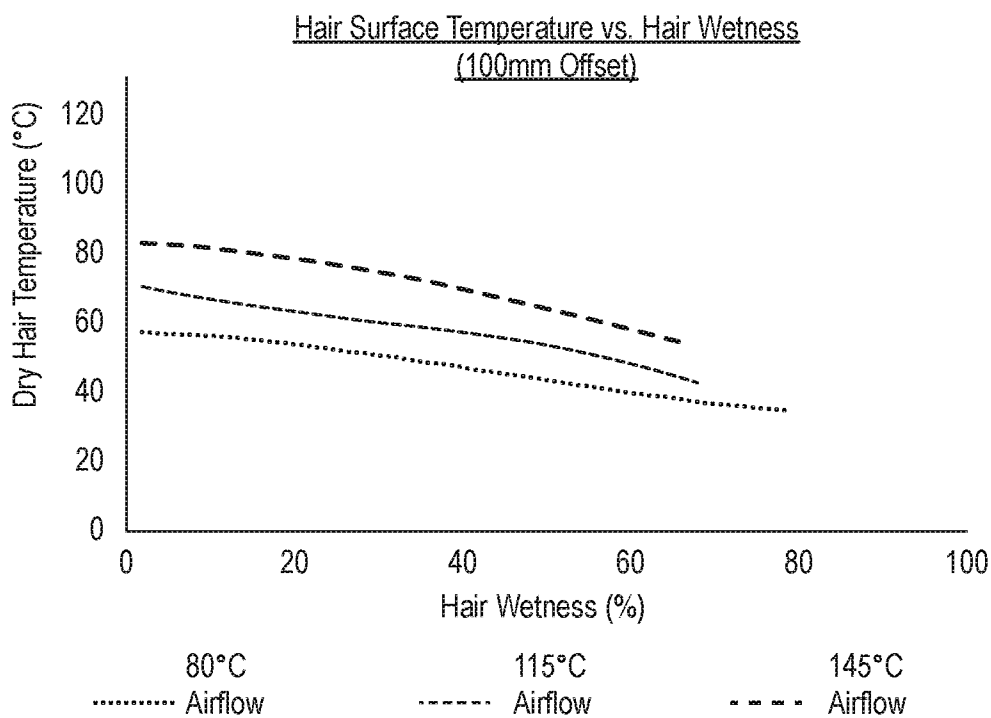


FIG. 5

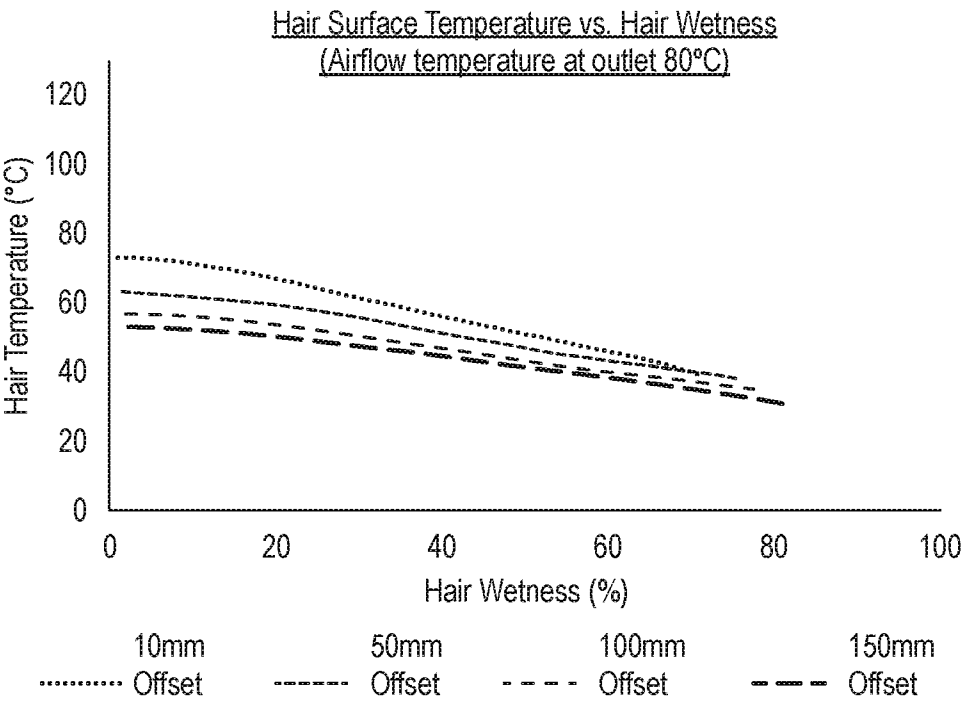


FIG. 6

Airflow temperature at outlet																	
80°C					115°C					145°C							
		Hair Temperature						Hair Temperature						Hair Temperature			
		50°C	60°C	80°C	100°C			50°C	60°C	80°C	100°C			50°C	60°C	80°C	100°C
Offset Distance	10mm	56%	36%	NA	NA	Offset Distance	10mm	>70%	58%	32%	0%	Offset Distance	10mm	>70%	>70%	51%	35%
	50mm	47%	20%	NA	NA		50mm	66%	52%	3%	NA		50mm	>70%	66%	43%	0%
	100mm	33%	1%	NA	NA		100mm	59%	29%	NA	NA		100mm	>70%	55%	15%	NA
	150mm	28%	NA	NA	NA		150mm	50%	17%	NA	NA		150mm	64%	50%	NA	NA
Hair Wetness																	

FIG. 7

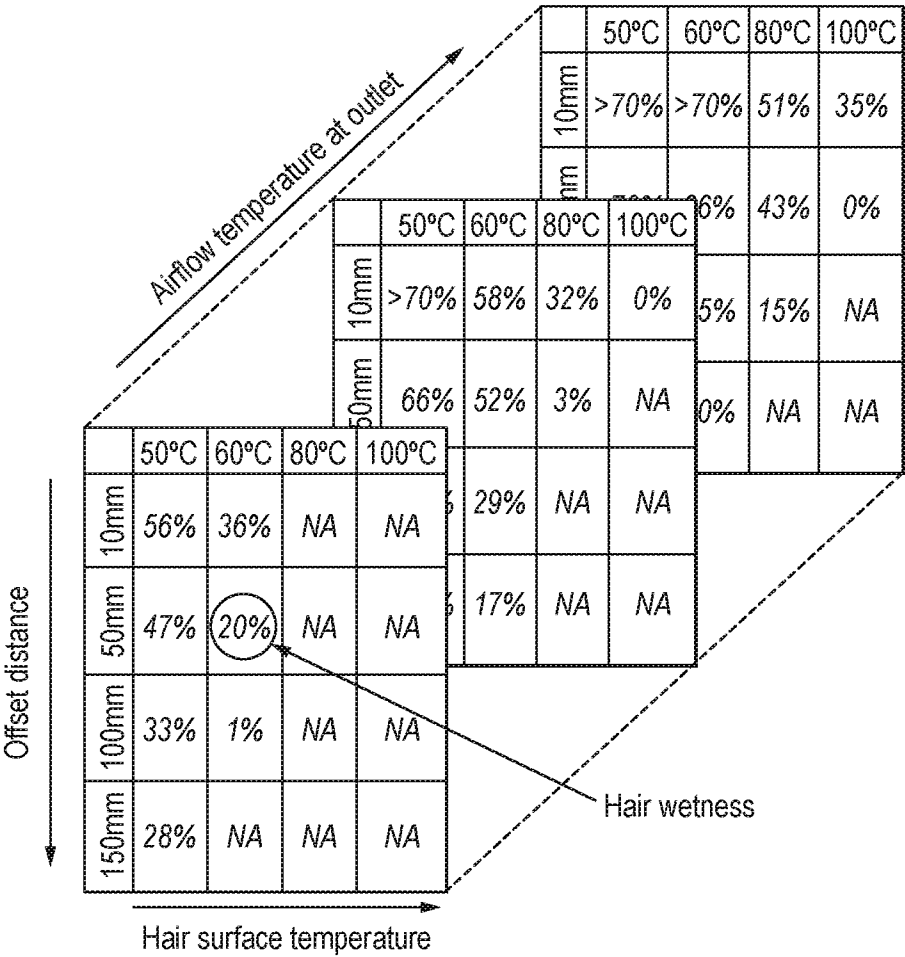


FIG. 8

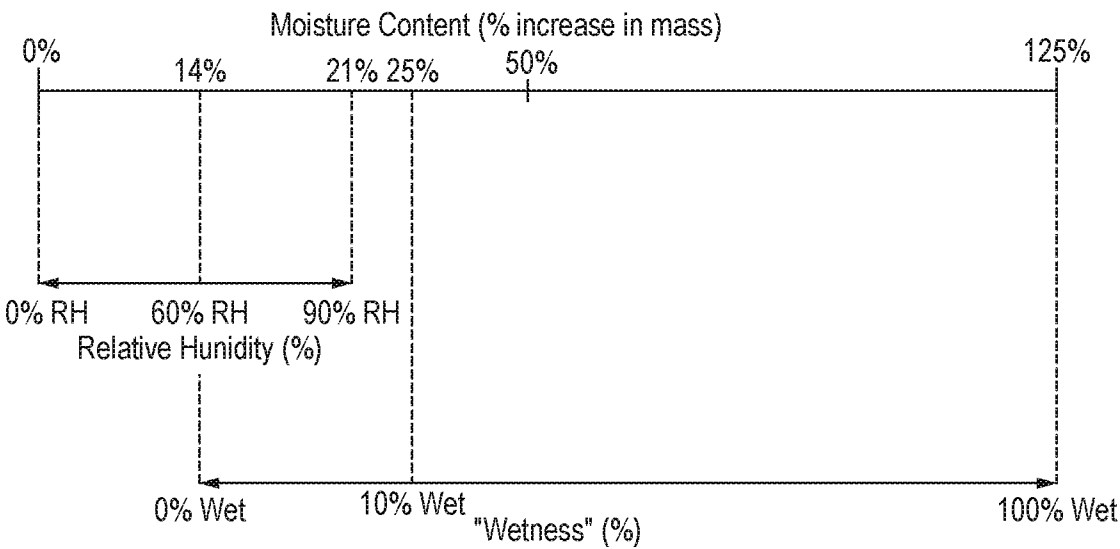


FIG. 9

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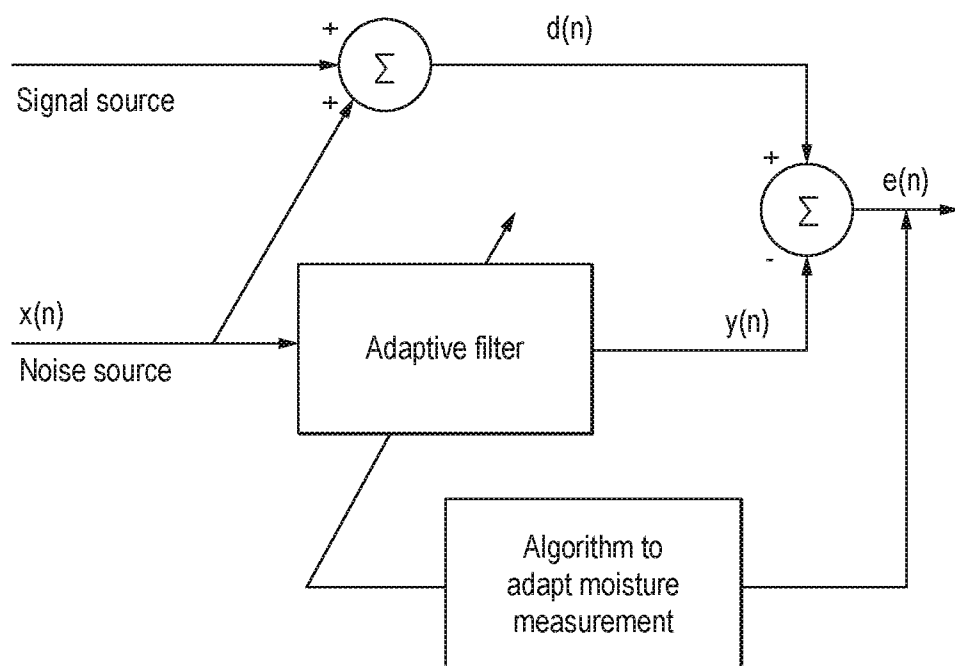


FIG. 10

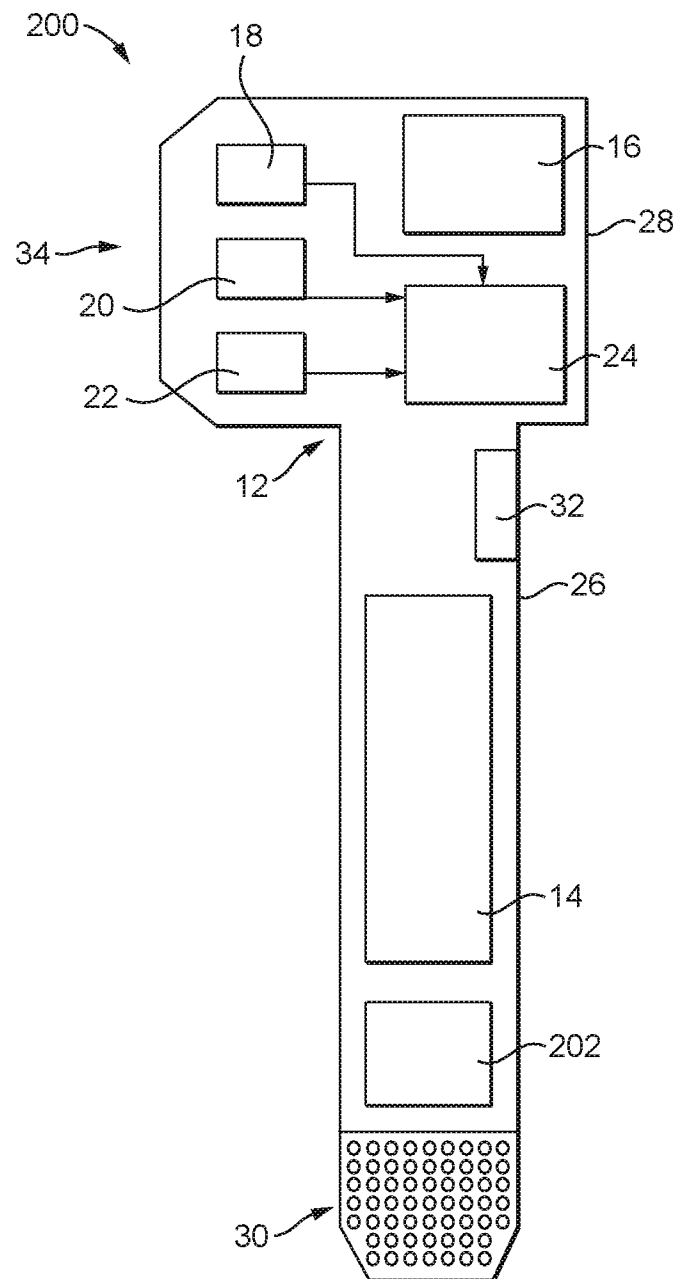


FIG. 11

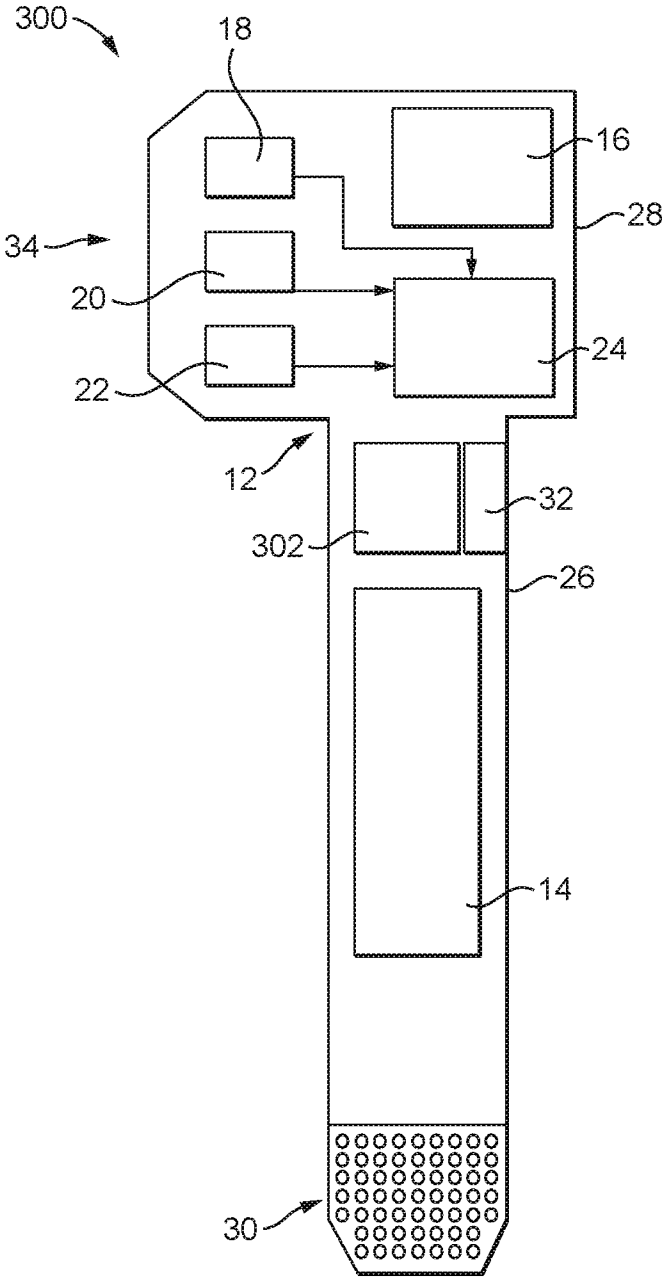


FIG. 12

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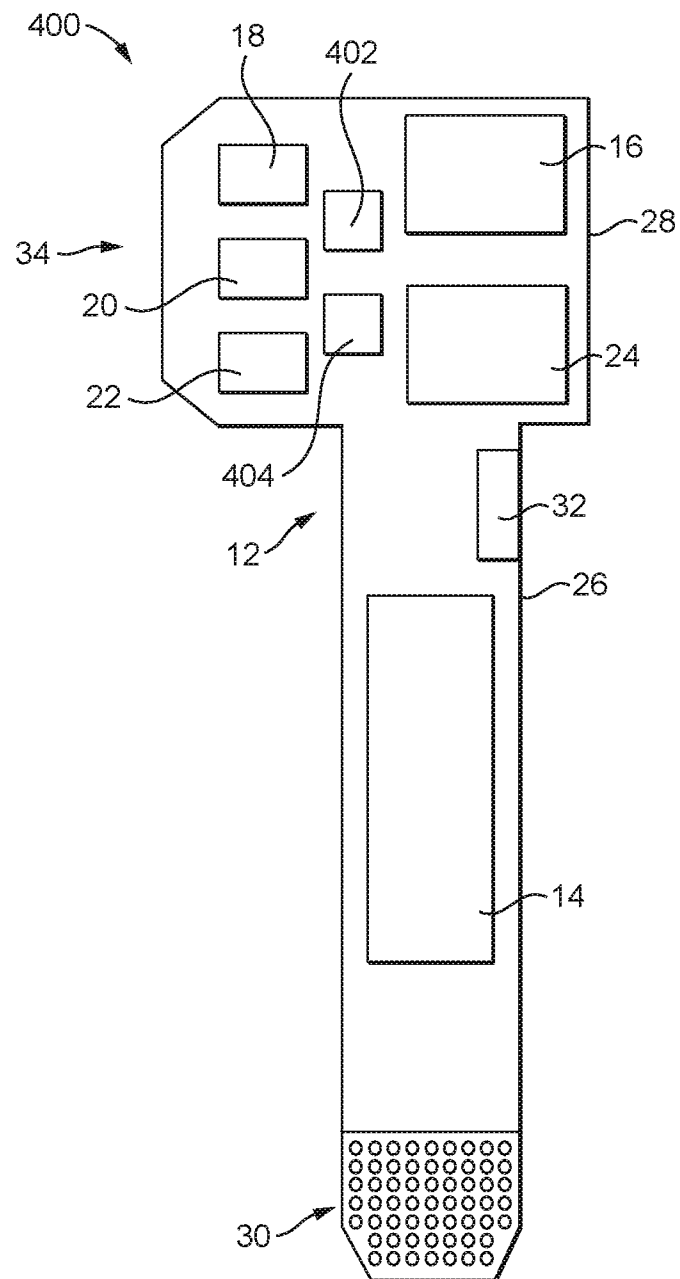


FIG. 13

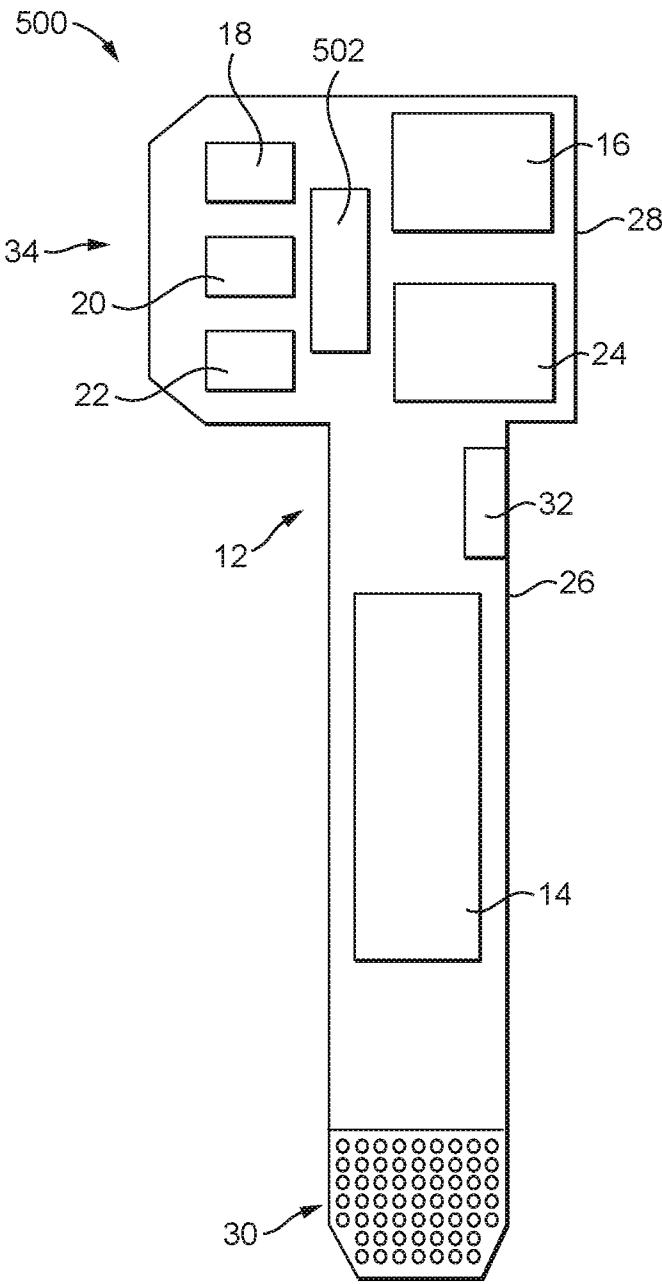


FIG. 14

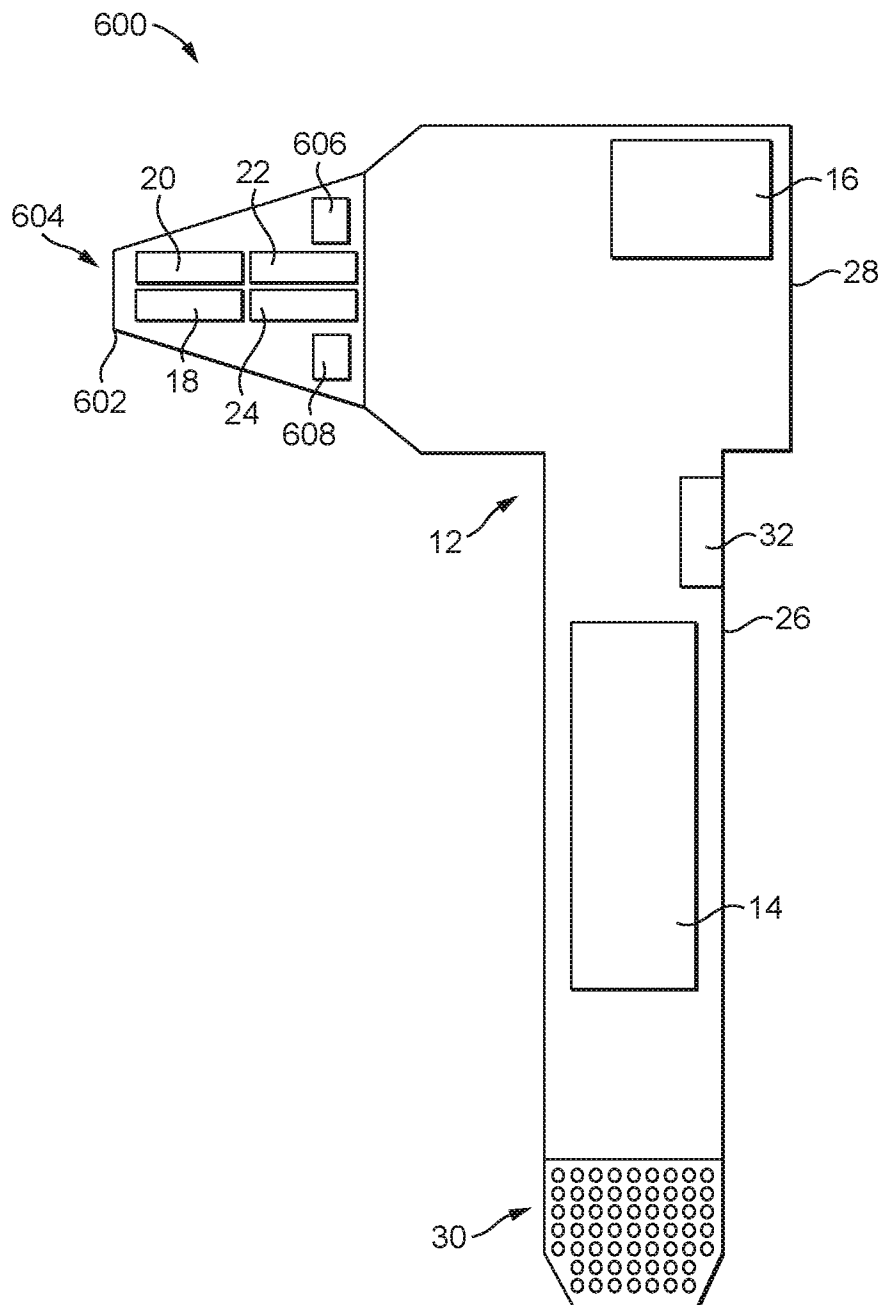


FIG. 15

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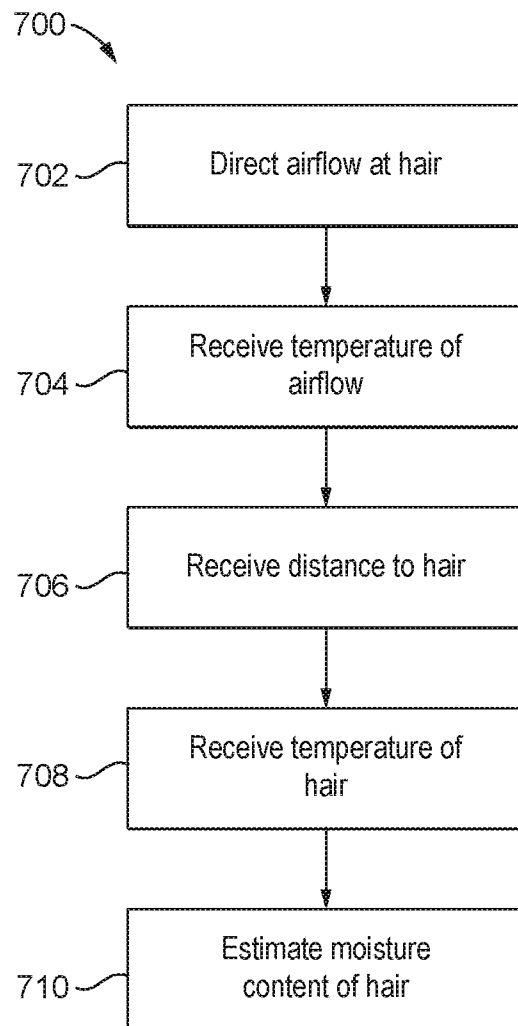


FIG. 16

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2021/052643

A. CLASSIFICATION OF SUBJECT MATTER

INV. A45D20/12 G08B21/20

ADD.

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)

A45D G08B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2020/125807 A1 (TINECO INTELLIGENT TECH CO LTD [CN]) 25 June 2020 (2020-06-25)	1, 3, 4, 8-12, 19-23
A	the whole document	2, 5-7, 13-18
Y	JP H05 184420 A (MATSUSHITA ELECTRIC WORKS LTD) 27 July 1993 (1993-07-27)	1, 3, 4, 8-12, 19-23
A	the whole document	
A	US 10 722 017 B1 (ABEHASERA BENYAMIN [US]) 28 July 2020 (2020-07-28)	1, 8
A	the whole document	
A	CN 204 796 994 U (ZHANG XU) 25 November 2015 (2015-11-25)	1
A	the whole document	

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

13 January 2022

Date of mailing of the international search report

21/01/2022

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Nicolás, Carlos

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2021/052643

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 10722017 B1	28-07-2020	NONE	
CN 204796994 U	25-11-2015	NONE	