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(54) Fire sensor and method of detecting fire

(57) A fire sensor is provided for detecting fire in a monitored region. The fire sensor comprises: a detection chamber in fluid communication with the monitored region via an inlet path; a sensor assembly adapted to detect fire products within the detection chamber, and to output a corresponding detection signal; and a cyclone chamber disposed upstream of the detection chamber in the inlet path between the detection chamber and the monitored region, the cyclone chamber comprising a fan impeller arranged to be rotationally driven by a motor so as to draw air from the monitored region into the detection chamber, and a peripheral wall enclosing the periphery of the fan impeller such that a vortex is established within the cyclone chamber when the fan impeller is driven. Due to centrifugal force, large droplets of liquid in the airflow through the cyclone chamber are removed by the vortex relative to small droplets of liquid, such that the average size of liquid droplets in the air drawn into the detection chamber is less than that of the air entering the fire sensor. A corresponding method of detecting fire is also provided. The performance of the fire sensor is improved as water droplets are removed from the sampled air, thereby reducing the false alarms triggered by steam rather than smoke.

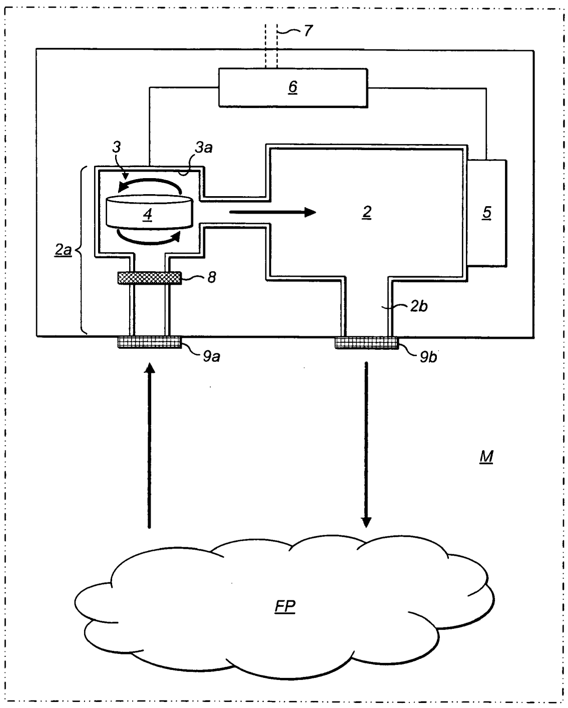

FIG. 1

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Description

[0001] This invention relates to fire sensors, particularly fire sensors with reduced steam sensitivity, and methods for detecting fires.

[0002] Traditionally, point-type fire sensors have generally fallen into two main categories, optical or ionisation. Ionisation-type sensors make use of radioactive sources for the detection of smoke. In most examples, an ionisation chamber is formed by providing two electrodes spaced across an air-filled region. The air is ionised by alpha particles emitted by the radiation source, and an electric current is thereby established between the electrodes, which can be measured. The introduction of smoke to the region between the electrodes disrupts this current since the heavy smoke particles bind to the ionised air molecules and slow down the charge transfer. The reduction in current is sensed and used to trigger an alarm.

[0003] Due to directives for the storage and transport of radioactive sources, ionisation sensors are now less favourable and the optical sensor (or optical-based multisensor) has become the most popular general-purpose smoke sensor used in industrial or commercial applications today. In general, optical smoke sensing technology involves emitting radiation into a detection chamber and providing a corresponding optical detector arranged to receive at least some of the radiation in certain circumstances and to output a corresponding signal. For instance, optical scatter sensors make use of a beam of radiation emitted into the chamber and at least one detector arranged off-beam such that, under normal conditions, little or no radiation is detected. When smoke or other particulates enter the chamber, the radiation is scattered and at least a portion will illuminate the detector, increasing the output signal which can be used to trigger an alarm.

[0004] Another type of optical sensor used for smoke detection is the optical obscuration sensor. An obscuration sensor typically comprises a radiation emitter aligned with a radiation detector such that, in the absence of fire products, the detector receives radiation. As smoke or other aerosols build up between the emitter and detector, the amount of received light drops. The obscuration sensor is quite sensitive to black smoke (since it absorbs light). However, when the path between the emitter and detector is short (as may be the case in a point-type sensor) then the drop in received light will also be small - possibly less than a 0.1 % drop in the signal level.

[0005] As a result of the principles upon which they operate, optical sensors of these sorts are often susceptible to false alarms caused by substances other than those produced by fires entering the detection chamber and tripping the optical sensor. Due to the risk of false alarms, heat-only sensors such as thermistors are often used in areas where an optical sensor would be unsuitable. However, there are many applications such as hotel bedrooms where the false alarm threat is very high due to kettles and showers being used, yet an early warning of fire is critical and as such an optical sensor would still normally be used, despite the possibility of false alarms.

[0006] One of the biggest false alarm problems for an optical sensor is its inherent high sensitivity to steam. What we generally call steam is in fact water vapour with visible condensed water droplets entrained above a body of hot or boiling water, formed as the hot vapour mixes with cooler air. The visible condensed water droplets are polydisperse (i.e. have a broad range of size, shape and/or mass characteristics) and normally end up fully evaporated after many phase changes, the lifetime of each droplet depending on the ambient environmental conditions of temperature, pressure and relative humidity (RH), as well as the droplet size itself. Fully evaporated water becomes invisible as the water particle size shrinks down towards the size of individual water molecules, of the order of 1/5000 μm. Larger droplets, however, remain visible and will interfere with the performance of an optical sensor.

[0007] Ionisation sensors are also susceptible to this problem since large water droplets will tend to disrupt the current flow in the ionisation chamber in a similar manner to smoke. Other sensor types may also be sensitive to steam as a result of its intrinsic high relative humidity (RH). For example, the performance of electrochemical and optical absorption gas sensors, which might be used for the detection of combustion gases such as carbon dioxide, carbon monoxide, hydrogen or NO_x, can be affected by RH. In the case of electrochemical sensors, high RH over a long period of time tends to result in a loss of sensitivity.

[0008] High levels of water vapour are not normally generated next to and directly under a point fire sensor. However, as the buoyant water vapour rises towards the ceiling, whilst it is usually cool enough not to trigger a heat element in a sensor, it can often trigger an optical sensor into an alarm condition.

[0009] Optical fire sensors almost entirely use the optical scatter principle and are more sensitive to larger aerosols above a particle size of about 1 μm, whilst most fire types generate submicron smoke particles. A typical optical sensor therefore has a high sensitivity to visible clouds of condensed water droplets, with some droplet sizes exceeding 10 μm, while its smoke sensitivity ranges from good for grey smoke to relatively poor for black smoke. Grey smoke consists of larger particles than those of black smoke. The optical sensor will be totally insensitive to very small invisible particles, including fully evaporated water. Whilst most optical sensors use infrared wavelengths in the scatter chamber, the above relative sensitivities still hold true if other wavelengths and/or different scatter angles are used, and at best it is only possible to minimise this effect.

[0010] The use of dual optical sensors, either using two different scatter angles or two different wavelengths, is now becoming more common in an attempt to reduce false alarms and, principally, to reduce the effect of water vapour on optical sensors. An example of a dual-angle optical scatter sensor is disclosed in US-A-6,218,950. The basic principle of operation is similar in both types of sensor, as a change in sensitivity occurs to different smoke types. By taking measurements on two significantly different wavelengths (for example infrared and blue), or two significantly different angles, and producing a ratio of the measurements taken, the ratio will then indicate the smoke type and hence the sensor or fire alarm system can apply different alarm sensitivities to the different smoke types.

[0011] While this technique may be able to identify grey smoke from black smoke reliably, it is very difficult to distinguish water vapour from grey smoke reliably. This is partly due to the fact that both substances comprise relatively large particles, and also the output ratio from the dual sensor is almost the same. Since, for safety, a signal at or around this ratio must be treated as a fire condition rather than rejected as a false alarm, this potentially leads to a high false alarm rate. Existing fire sensors deal with this problem to an extent by making the alarm point for grey smoke quite high (i.e. the grey smoke sensor signal threshold taken to be indicative of fire is high), whilst setting a lower threshold for black smoke so that the fire sensor is sufficiently sensitive. While this technique will reduce the effect of water vapour to a limited extent, this is at the expense of smoke detection times for grey smoke produced by common fire types. Further, whilst black smoke tests are critical to set the sensitivity of the optical scatter sensor, to be approved it must also pass a range of fire type tests from smouldering grey smoke to flaming black smoke.

[0012] Another type of sensor that is often used in difficult environments is an aspirating smoke detector (ASD). ASD systems are well-known and involve drawing air through a system of tubes, normally with a number of sampling apertures, to a central unit containing a vacuum fan or suction pump. In a typical system, the sampled air is passed through a fine paper or foam filter to remove large dust particles, then through a smoke sensor. After passing through the smoke sensor, the air enters the suction fan and the outlet is then fed back into an exhaust tube to be either returned back to the protected area or expelled outside. If this system is to be used in very dusty or damp areas, additional finer pre-filtering elements are usually added to the sampling tubes, together with a condensation trap so that water vapour does not condense in the filters and block them up, or pass through the filters and into the smoke sensor. The condensation traps are normally made by an angled run of sampling pipe entering a pipe drop with a coiled micro-bore pipe connected to an end cap and filled with water. While condensation traps and high filtration filters are practical for an ASD system, more compact methods would be desirable, especially for use in a point sensor.

[0013] In accordance with the present invention, a fire sensor is provided for detecting fire in a monitored region, the fire sensor comprising: a detection chamber in fluid communication with the monitored region via an inlet path; a sensor assembly adapted to detect fire products within the detection chamber, and to output a corresponding detection signal; a cyclone chamber disposed upstream of the detection chamber in the inlet path between the detection chamber and the monitored region, the cyclone chamber comprising a fan impeller arranged to be rotationally driven by a motor so as to draw air from the monitored region into the detection chamber, and a peripheral wall enclosing the periphery of the fan impeller such that a vortex is established within the cyclone chamber when the fan impeller is driven; whereby large droplets of liquid in the airflow through the cyclone chamber are preferentially removed by the vortex relative to small droplets of liquid, such that the average size of liquid droplets in the air drawn into the detection chamber is less than that of the air entering the fire sensor.

[0014] The invention further provides a method of detecting a fire in a monitored region, comprising: drawing air from the monitored region into a cyclone chamber; driving a fan impeller disposed within the cyclone chamber to establish a vortex therein, whereby large droplets of liquid in the airflow through the cyclone chamber are preferentially removed by the vortex relative to small droplets of liquid; expelling air from the cyclone chamber into a detection chamber; using a sensor assembly to sense the presence of fire products within the detection chamber and outputting a corresponding detection signal; wherein the average size of liquid droplets in the air drawn into the detection chamber is less than that of the air entering the cyclone chamber.

[0015] By providing a cyclone chamber upstream of the detection chamber in this way, large, slowly evaporating, visible liquid water drops entrained in the steam entering the fire sensor are separated out by the centrifugal effect of the vortex and deposited onto the inside of the peripheral wall. Large water droplets are thus removed from the air stream before it enters the detection chamber so that mainly evaporated water will enter the detection chamber. In addition, even the smaller water droplets will tend to be intercepted by the blades of the fan impeller, forming an impacted water film on each blade in which multiple smaller droplets join by hydrophilic attraction. The collected water film moves radially outwards along each blade under the action of centrifugal force and is deposited on the peripheral walls along with the droplets removed by the vortex itself. Overall, any water vapour which does access the detection chamber has a droplet size distribution smaller (i.e. the average size is smaller) than that of the water vapour entering the sensor as a whole. Since aerosol sensors (such as optical sensors and ionisation sensors) are less sensitive to small droplet sizes, the possibility of steam triggering the sensor is thus greatly reduced. As such, the fire sensor provides low sensitivity even to very high levels of water vapour in the monitored region, while maintaining a high sensitivity to smoke or other aerosols. In addition, removal of the large water droplets reduces the overall amount of water in the air stream entering the detection chamber and so lowers the relative humidity, thus improving the performance of RH-sensitive detectors.

[0016] Since the cyclone chamber will preferentially remove particles above a certain cut size, which depends on the dimensions of the fan impeller and its angular velocity, the greater the average size of the liquid droplets entering the cyclone chamber, the greater the proportion of water vapour that will be removed by the effect of the vortex. Preferably, therefore, the fire sensor further comprises a coalescer disposed upstream of the cyclone chamber for increasing the average size of liquid droplets in the air drawn into the cyclone chamber, wherein the coalescer preferably comprises a mesh.

[0017] The overall cut size of the cyclone chamber and coalescer in combination is preferably between about 1 μm and 10 μm, still preferably between about 1 μm and 5 μm. The cut size is generally defined as the size of droplet that will be removed from the airstream with a 50% efficiency. Particles larger than the cut size will be removed with a greater efficiency, and smaller particles with a lower efficiency.

[0018] The coalescer could comprise, for instance, a metal or plastic grid, or a knit of metal or plastic wire. More than one layer of such material, spaced from each other, could be used if desired. The holes through the material are preferably of the order of 0.25 to 0.75 mm, still preferably around 0.5 mm, spaced by around 0.1 to 0.2 mm, preferably around 0.125 mm (e.g. the wire forming the mesh or knit may have a diameter of around 0.125 mm). The coalescent effect is achieved by incoming liquid droplets striking the coalescent material and joining to one another to form droplets of greater volume, before being drawn off the coalescent material into the cyclone chamber. By providing a coalescer in the form of a mesh, this can double as a guard for preventing foreign objects such as insects entering the fire sensor. A mesh may also be provided over any outlet from the detection chamber for the same reason.

[0019] The coalescer could be located anywhere upstream of the cyclone chamber. However, for maximum effect, it is preferred that the coalescer is in the vicinity of the entrance to the cyclone chamber, since the greater the distance the airflow travels between the coalescer and the cyclone chamber, the more change will occur to the particle sizes, potentially resulting in a reversal of the coalescent effect. Most advantageously, the coalescer is disposed immediately upstream of the cyclone chamber.

[0020] To further enhance the coalescence, the inlet path is preferably configured such that, at the location of the coalescer, the direction of the airflow is not perpendicular to the plane of the coalescer. That is, the airflow passes through the coalescent material at a non-zero angle to its normal. In this way, the coalescent effect is enhanced since the droplets move at an angle to the coalescent material, making impact more likely. In particularly preferred implementations, the airflow incident on the coalescer is substantially parallel to the plane of the coalescer, in order to maximise this effect.

[0021] This could be achieved by configuring the coalescer to sit at a non-orthogonal angle to the inlet path. However, in preferred implementations, this is achieved by configuring the inlet path such that the airflow undergoes a change in direction upon entry to the cyclone chamber and the coalescer is disposed in the course of the change in direction, the change in direction preferably being around 90 degrees. By changing the direction of the airflow as the liquid droplets move through the coalescer, such that the airflow is no longer parallel to the inlet path in this region, the coalescer can conveniently be disposed orthogonally to the inlet path whilst still enhancing the coalescent effect. Any change in direction will promote coalescence to some extent, but preferably the change in the airflow direction is by at least 10 degrees.

[0022] Depending on the geometry of the inlet path and the cyclone chamber, the direction in which the centrifugal force established by the vortex acts may be such that the removed droplets are not expelled towards the detection chamber. However, in other cases, it may be the case that the exit point is located on the peripheral wall and so, preferably, a baffle is disposed adjacent to the exit from the cyclone chamber, such that liquid droplets removed from the airflow by the vortex towards the exit are collected by the baffle. The baffle forms an inertia separator, causing the airflow to change direction and the heavy water droplets to exit the airstream and impact onto the baffle. The baffle could take any desirable form, such as a grid or a labyrinth (i.e. at least one contorted pathway), but preferably the baffle comprises at least one angled blade arranged to cause a change in direction of the airflow upon exiting the cyclone chamber.

[0023] The cyclone chamber can be disposed at any location upstream of the detection chamber but it is preferably located as close to the detection chamber as possible in order to reduce the overall size of the sensor. Hence, preferably the cyclone chamber is disposed immediately upstream of the detection chamber.

[0024] As noted above, the disclosed configuration provides benefits when used in conjunction with many different sensor types - indeed any sensor which is sensitive to or affected by steam or RH. However, the advantages are particularly significant where the sensor operates by detecting the physical presence of aerosols (i.e. a suspension of solid particles or liquid droplets in the air stream) rather than their chemical constituents, for example, since it is the largest and therefore most disruptive of these which are removed by the presently disclosed arrangement. Therefore, preferably, the sensor assembly is adapted to detect aerosols within the detection chamber, preferably smoke.

[0025] The disclosed technique is particularly advantageous when used in conjunction with optical-based sensing technologies. Hence, in preferred embodiments, the sensor assembly comprises an optical sensor, preferably an optical scatter sensor, a dual optical scatter sensor, or an optical obscuration sensor. The use of a dual optical scatter sensor such as a dual angle or dual wavelength sensor further reduces the likelihood of false alarms as previously described.

[0026] In this configuration, the baffle is preferably disposed within the detection chamber and provides a light trap for the optical sensor assembly. The light trap is preferably arranged to provide a degree of collimation of the light source by blocking direct light transmission between the LED and photodiode(s), and to reduce background scatter within the chamber.

[0027] Any desirable fan type may be used in the construction of the cyclone chamber, such as an axial fan. However, preferably, the fan impeller and peripheral wall are provided in the form of a centrifugal fan, the inlet path preferably being arranged such that the airflow enters the centrifugal fan substantially parallel to the rotation axis of the fan, and exits the fan tangentially, substantially perpendicular to the rotation axis. A centrifugal fan is particularly preferred since a high static pressure can be achieved in the airflow into the detection chamber, assisting in propelling the air through the chamber and out through the chamber outlet (if provided). In contrast, a much larger axial fan operating at greater rotational speeds would need to be provided to achieve the same effect. In addition, a centrifugal fan will collect water droplets by way of impaction on its blades more efficiently than other fan types.

[0028] Preferably, the fan impeller comprises forward-curved blades since these have been found to provide the most efficient effect, although straight or backwards-curved blades could be used if preferred. The blades are preferably formed from a solid and relatively rigid material to withstand the centrifugal force experienced during operation.

[0029] Advantageously, the peripheral wall surrounding the fan impeller and defining the cyclone chamber is substantially circular. It is desirable that the peripheral wall closely approaches the extremity of the fan impeller in order that substantially all of the volume within the cyclone chamber is filled by the vortex when in operation. However, small deviations from a circle can be accommodated without having a substantial effect on the vortex.

[0030] In a particularly preferred embodiment, the cyclone chamber has an approximate diameter of around 50mm, and the fan impeller is driven at around 4,000 rpm.

[0031] The fire sensor could be controlled remotely, for instance by processing components provided on a control panel in communication with the fire sensor across a suitable data connection. However, in preferred embodiments, such processing is carried out onboard the fire sensor and hence the fire sensor further comprises a processor arranged to activate the motor to drive the fan impeller, monitor the detection signal output from the sensor assembly whilst the motor is active, and compare the detection signal with a predetermined alarm criterion to determine whether alarm conditions are met.

[0032] The fan could be driven continuously but, preferably, the processor is adapted to intermittently activate the motor at predetermined intervals, or to activate the motor upon receipt of a trigger signal. By driving the fan at predetermined intervals, preferably at a low duty cycle of less than 50%, the power consumption of the fire sensor is greatly reduced. In the alternative, trigger signals (which may be provided by a remote control panel or via other systems provided on the fire sensor) could be used to activate the fan in certain circumstance, thereby further reducing the power consumption. In particular, the fan is preferably operated as described in our co-pending European Patent Application entitled "Fire Sensor and Method for Detecting Fire" (Attorney Reference No. RSJ10366EP) the entire contents of which are hereby incorporated by reference.

[0033] Examples of fire sensors in accordance with the present invention will now be described, with reference to the accompanying drawings, in which;

Figure 1 schematically depicts a first embodiment of a fire sensor;

Figure 2 shows a second embodiment of a fire sensor in exploded view for clarity;

Figure 3 shows the assembled fire sensor of Figure 2, in an inverted position;

Figure 4 shows the fire sensor of Figure 3 with the outer ceiling plate removed;

Figure 5 shows internal components of the fire sensor of Figure 3; and

Figure 6 shows a plan view of the internal components of Figure 5.

[0034] The description below will focus on the example of a ceiling-mounted optical point-type smoke sensor used preferably as part of an analogue addressable fire alarm system. However, it will be appreciated that the invention can be applied to any type of fire sensor wherever the need exists to reduce its sensitivity to water vapour. In particular, in place of an optical sensor assembly, an ionisation sensor or any other type of detector capable of detecting fire products such as smoke, other aerosols (e.g. chemicals, oils), heat, infrared radiation or gases such as carbon dioxide, carbon monoxide, hydrogen, or oxides of nitrogen (NO_x) could be used. In general, the disclosed configurations are most benefical where the sensor is an aerosol sensor, i.e. arranged to detect the presence of aerosols in the detection chamber. Optical sensors and ionisation sensors are examples of aerosol sensors. In addition, whilst the examples given below are low-profile point-type fire sensors, it should be noted that the present invention is equally applicable to high-profile fire sensors (which protrude from the ceiling or other surface on which they are mounted).

[0035] Figure 1 shows a fire sensor 1 disposed in a monitored region M which typically corresponds to a room, or a portion of a room, within a protected building.

The sensor comprises a detection chamber 2 defined internally which is in communication with the monitored region M via an inlet path 2a and, preferably, an outlet 2b. Disposed in the inlet path 2a upstream of the chamber 2 is a cyclone chamber 3 enclosing a fan 4. The fan 4 comprises a fan impeller, axial, centrifugal or otherwise, rotatably disposed within the peripheral walls 3a of the chamber 3. In use, the fan 4 is powered so as to draw a sample of air in from the region M to the detection chamber 2 where an optical detector assembly 5 is arranged to sense any fire products present in the sample. The optical sensor assembly 5 preferably comprises at least an optical scatter sensor or an optical obscuration sensor, most preferably a dual-angle optical scatter sensor or a dual-wavelength optical scatter sensor. Other types of sensors for detecting fire phenomena such as combustion gases (e.g. carbon monoxide, carbon dioxide, hydrogen or oxides of nitrogen, NO_x) or heat within the chamber 2 may additionally or alternatively be provided. The optical sensor assembly 5 and any additional sensors output a detection signal to a processor 6, which may be onboard the fire sensor 1 or provided remotely. The detection signal is compared with predetermined criteria to determine whether a fire condition exists. If so, an alarm signal is generated which can be used to trigger alarm devices such as sounders and/or strobe lights via a communications link 7, and communicate with external systems, such as a control centre, the premises owner and/or the Fire Brigade. The processor 6 may also control operation of the fan 4 if it is preferred not to operate the fan continuously. This will be described further below.

[0036] If visible water vapour (i.e. steam) is present in the sampled air, it will be drawn into the sensor unit through the inlet path 2a by the fan 4. The rotation of the fan impeller 4 within the cyclone chamber 3 leads to the creation of a fast rotating air vortex between the fan impeller 4 and the walls 3a of the cyclone chamber 3 which enclose the impeller, at least around the majority of its circumference. The air sample entering the sensor unit is thus caused to rotate at high speed within the cyclone chamber 3, thereby developing a significant centrifugal force on any water droplets entrained in the air sample. Since the magnitude of centrifugal force is proportional to the mass of the particle, the larger, heavier water droplets are caused to separate out and deposit onto the inside of the peripheral walls 3a.

[0037] In addition to this mechanism, water droplets in the airstream within the chamber 3 will frequently collide with the blades of fan impeller 4, forming a continuous hydrophilic water film impacted onto each blade. This also has a coalescent effect since small droplets will be collected and join to form larger droplets. The collected water moves radially outwards under the influence of centrifugal force and is deposited onto the walls of the chamber.

[0038] In practice, there is a droplet cut size (or equivalent mass) above which the droplets will tend to be removed by action of the vortex and coalescers, and below which the centrifugal force in the chamber 3 will be insufficient to remove a significant portion of the droplets from the airstream. The droplet cut size of the vortex depends on factors including the radius of the fan impeller and its angular velocity. Increasing either of these parameters will reduce the droplet cut size and so increase the proportion of droplets that will be removed from the airstream. Improving the efficiency of the coalescer 8 and coalescent effect of the fan impeller (blade impaction) will also effectively reduce the cut size, since smaller particles will be joined into droplets large enough to be removed by the vortex. The overall droplet cut size is preferably arranged to be in the region of 1μm to 10μm in order that large droplets are removed whilst submicron particles (such as smoke) are unaffected.

[0039] In this way, the air sample entering the detection chamber 2 will include water droplets whose size is, on average, less than that of the steam entrained in the sample originally drawn into the fire sensor, thereby reducing the likelihood of the optical sensor being triggered by the water droplets. If the fan speed and radius is sufficiently high, only evaporated (or near evaporated) water will remain in the airstream entering the detection chamber 2, which is invisible to the optical sensor.

[0040] Optionally, the effect of the cyclone chamber 3 can be enhanced by providing a coalescer 8 upstream of the cyclone chamber 3. The coalescer 8 typically comprises one or more layers of coalescent material, such as a metal or plastic grid or mesh. The coalescer 8 acts to increase the average size of the water droplets entering the cyclone chamber 3. Water droplets entrained in the airstream entering the sensor unit through inlet path 2a will strike the coalescent material 8 and join one another by virtue of hydrophilic attraction between the droplets to form fewer, larger water droplets which are then drawn off the coalescent material 8 into the vortex of the cyclone chamber 3. Thus, for any given cut size, the cyclone chamber 3 will be able to remove a larger proportion of the incoming water droplets, since a larger number will have sizes at or greater than the cut size threshold. The coalescer 8 covers the inlet to the detection chamber 2 and so will inherently provide a degree of ingress protection, preventing foreign objects, including insects and spiders entering the detection chamber. However, additional ingress protection in the form of a mesh or filter 9a may be provided over the inlet 2a. Likewise, a mesh or filter 9b should be provided over any outlet point.

[0041] The mesh size or porosity of the coalescer 8 (and ingress protection 9 if provided separately) should be large enough to avoid possible blockages, even in excessive levels of water vapour, but fine enough to promote water droplet growth. In addition, where the coalescer 8 doubles as ingress protection, it must be fine enough to prevent access by all but the smallest of insects or spiders. In a preferred implementation, a metal or plastic grid formed of 0.125 mm diameter wire defining 0.5 mm (square) holes is used. Any additional ingress protection guards provided (such as 9a / 9b) are subject to the same conditions.

[0042] Figure 2 shows components of a second embodiment of a fire sensor 20, disassembled for clarity. The sensor unit 20 is made up of three main assemblies. Ceiling plate 21 provides the outer surface of the sensor unit and, in use, will be arranged flush with the ceiling panel or other surface into which the sensor unit 20 is fitted. As shown in more detail in Figure 3, the ceiling plate 21 comprises a central disc-shaped region 21 a and an outer annular region 21 b, connected by four bridges 22. Four apertures 23 are defined between the centre disk 21 a and outer annulus 21 b and provide together a substantially annular inlet through which air is drawn into the sensor unit by the fan. The ceiling plate 21 also exhibits a central aperture 12b which provides an outlet from the detection chamber. The solid arrows represent the airflow into and out of the sensor unit, with arrows in dashed lines representing internal airflow. This configuration has been found to promote mixing of the air within the monitored region M, thus improving sampling as described further in our co-pending European patent application entitled "Fire Sensor and Method of Detecting Fire" (Attorney ref: RSJ10366EP).

[0043] The ceiling plate 21 mounts to a housing 25 which accommodates the internal sensing components and provides apertures for establishing the necessary airflow path. Air drawn in through the ceiling plate 21 passes through aperture 26a provided in the housing 25. Air expelled from the detection chamber exits the sensor unit through aperture 26b which is located within a recess 26c providing an air pathway to exit aperture 12b in the ceiling plate 21. This is shown in Figure 4 in more detail, from which it will also be apparent that inlet aperture 26a and output aperture 26b are covered by meshes 28 and 29 respectively. Mesh 28 covering the inlet aperture 26a performs two functions, acting both as a coalescer, upstream of the cyclone chamber, and ingress protection. Mesh 29 covering the outlet aperture 26b is provided for ingress protection. In this example, the meshes 28 and 29 are formed of the same material, although this need not be the case. For optimum coalescent action, the mesh 28 is preferably a metal mesh.

[0044] On passing through the mesh 28, the airflow enters cyclone chamber 13, shown more clearly in Figures 5 and 6. In this example, the cyclone chamber 13 is provided in the form of a centrifugal fan having a substantially cylindrical casing 13a enclosing a fan impeller 14 comprising a central hub 14b upon which a plurality of radial fan blades 14a are mounted. A centrifugal fan is preferred since, compared to other fan types (such as axial fans) of similar size and power, a higher static pressure is generated. This helps to drive the airflow through the detection chamber and also expel any dust or foreign bodies that have managed to gain access. In this example, the fan blades 14a are curved forward (i.e. in the direction of rotation) since this has been found to be most efficient, generating the highest static pressure downstream of the fan. However, straight or backward-curved fan blades could be used instead. Hub 14b conceals a fan motor provided underneath the fan impeller, arranged to drive the fan impeller 14 in use. The centrifugal fan 13 is mounted alongside detection chamber 12 on a PCB acting as a support plate 27. When the fan is activated, air is drawn into the chamber defined by housing 13 along a direction approximately parallel to the axis of rotation of fan impeller 14. Upon entry to chamber 13, the air is caused to change direction as it begins to rotate within the vortex established by the rotating fan blades 14a. This change in direction enhances the effectiveness of the coalescer mesh 28, which sits immediately adjacent the entry to cyclone chamber 13 when the sensor is fully assembled. The change in air direction causes the air entering the cyclone chamber to pass through the coalescer 28 at an angle to its normal, thereby increasing the likelihood of water droplets carried by the airstream being intercepted by the coalescent material 28. The drawn external air flow arrives substantially parallel to the mesh, maximising the amount of water droplets that strike the mesh. The air is then drawn into the fan normal to the mesh.

[0045] As shown best in the plan view of Figure 6, the walls 13a of chamber 13 are substantially circular and not spaced far from the extremities of the fan blades 14a, such that substantially the whole chamber 13 is filled by the rotating air vortex when the fan impeller is active. Since the fan blades 14a will describe a substantially circular path, the walls 13a are preferably also substantially circular. However, as demonstrated in Figure 6, the walls 13a need not be completely circular (or coaxial with the fan impeller) since deviations can be accommodated without substantial disruption of the vortex. As already described, the fast rotating air vortex causes the larger particles to separate out from the airstream under the action of centrifugal force. In addition, water droplets will impact onto the fan blades forming a film of water which, as illustrated by arrows 'W' in Figure 6, will move radially outwards due to the centrifugal force and deposit on the inside of the fan case (peripheral wall 13a) together with the large droplets already separated from the rotating airflow. Typically, the impeller water film is so thin that if no more water vapour is sampled, then the film will flashevaporate.

[0046] The airflow (illustrated by arrows 'A' in figure 6) exits the cyclone chamber 13 tangentially and enters detection chamber 12. In the present example, the exit point from the cyclone chamber 13 is provided in the circumferential wall 13a and, as such, water droplets may be accelerated towards the exit point by the action of the centrifugal force. To prevent separated droplets from entering the detection chamber 2, a baffle 30 is preferably situated at the exit from the cyclone chamber. It will be appreciated that the need for such a baffle will depend on the sensor geometry and hence it will not always be required. However, as will now be described, the provision of the baffle permits a particularly compact arrangement of the cyclone chamber and detection chamber without detriment to the reduction in water vapour sensitivity.

[0047] As shown best in Figure 6, in the present example, the baffle 30 takes the form of three angled blades 30a, 30b and 30c which are arranged to change the direction of the airflow at the exit point of the cyclone chamber and intercept water droplets. In other examples, a labyrinth could be provided adjacent the exit position, or a lattice of material could be provided. However, the use of one or more angled blades is preferred for compactness. Changing the direction of the air stream in this way acts as an inertial separator, causing the heavy water droplets to exit the air stream and collect on the baffle as it changes direction.

[0048] Condensed water droplets deposited on the inside of the peripheral wall 13a and baffle 30 are safely channelled away from the electronic components within the sensor, due to the combination of gravity and aerodynamic drag by the airflow. The condensed water drains down the sides of the peripheral wall 13a and baffle 30 into a sump defined in the interior of housing 25, and is then allowed to drip away from the sensor from the central outlet point 12b. However, many other drainage configurations are possible.

[0049] Figure 6 also shows the arrangement of the detection chamber 12 and the optical sensing components. It will be seen that the detection chamber 12 is situated immediately adjacent the output from cyclone chamber 13, which is preferred for compactness. This proximity of the detection chamber and cyclone chamber is enabled by the provision of the baffle 30 which can also be arranged to form part of the detection chamber and, in the present case, defines a light trap within the chamber. As shown in Figures 5 and 6, the surfaces of the angled blades 30b and 30c facing towards the interior of the detection chamber 12 are serrated, comprising a series of ridges, which has the effect of reducing or near eliminating light reflections from the surface of the blades, to help prevent the optical sensor 15 being triggered by internal reflections. In this example, the optical sensor assembly 15 comprises a dual-angle optical scatter sensor (such as that disclosed in US-A-6,218,950) including emitters 15a and 15c such as LEDs and a detector 15b such as a photodiode. The two LEDs are arranged to emit radiation beams making two different angles with the detector. The optical sensing components 15 are preferably configured to operate at infrared wavelengths. In addition, the detection chamber is provided with a gas sensor 16 arranged to detect a gas indicative of fire such as carbon monoxide, carbon dioxide, hydrogen or NO_x. Suitable gas detectors are available from City Technology Limited, Portsmouth, UK. A heat sensor (not shown) such as a thermistor may additionally be provided. The signals generated by the optical sensor 15, gas sensor 16 and/or the heat sensor can be used by a processor either onboard the sensor unit or provided remotely to determine whether fire conditions exist in the monitored environment.

[0050] The operation of the sensor unit in-situ will now be described. If steam is present in the sampled air, it is initially diluted into a flow of less moist air (lower RH) drawn from other points around the annular inlet 23, which increases evaporation. However, if excess water vapour has been generated, then it will eventually surround the sensor and an undiluted sample of steam will be drawn into the optical sensor by the fan 14. The action of the vortex created by the fan 14 within the chamber 13 reduces the size of water droplets which will be present in the airflow which enters chamber 12. As such, the likelihood of a false alarm caused by triggering of the optical sensor is reduced. Alternatively, if smoke or other fire products are present in the monitored region and are sampled by the sensor, whilst the sample may contain some water vapour (as in the case of some smouldering fires) the actual smoke particles will not be separated out by the action of the vortex since the cut size is high compared to the sub-micron smoke particle size. Additionally, in true fire scenarios, the coalescent action of both the coalescer 28 and the fan blades 14a becomes very inefficient due to the relatively low ratio of water vapour present and hence smoke will pass relatively unchanged into the detection chamber 12 for rapid detection. The smoke sensitivity of the optical sensor 15 can now be set very high (i.e. the signal threshold taken to be indicative of fire is set very low) since it is largely independent of water vapour, thus allowing more freedom in the sensor design. This, in combination with the use of a fan to draw air into the detection chamber 12 results in both very fast and very reliable smoke detection.

[0051] As already indicated, the fan's size and its operating speed are important in determining how well the cyclone chamber will remove water droplets. Since the motion of the water droplets in the vortex is circular, their acceleration can be calculated as the product of the impeller radius and the square of the angular velocity. The efficiency with which the fan impeller coalesces water will also depend on the fan speed and its size, more specifically the total impaction area of all of the blades 14a on the fan impeller. While the efficiency of the fan will improve with its size and angular velocity, a good compromise needs to be made as these parameters will ultimately limit how small the sensor unit can be made and also determine its maximum current consumption. It has been found that a fan size of approximately 50mm in diameter and 15mm impeller blade height removes almost all of the water droplets that the optical sensor is sensitive to when operated at 4,000 rpm. For instance, the GB1205PHV2-8AY centrifugal fan available from the Sunon Group has been found to be suitable. However many other arrangements would also provide the same effect.

[0052] The use of a fan to actively sample air from the monitored region before testing in the internal detection chamber also provides the inherent advantage that any foreign bodies such as transient dust particles and small insects or spiders which have managed to enter the sensor unit, despite the ingress protection provided, tend to be rapidly blown out of the exit point 12b and safely away from the sensor's air inlet 23 without triggering an alarm. This further reduces the effect of other known false alarm sources on the sensor.

[0053] If desired, the fan 14 could be powered continuously. However, to save power, it is preferred that the fan be operated on a pulsed regime at a low duty cycle of less than 50%. For example, the fan may be switched off for a period not exceeding 1 minute, then switched back on for a period to sample the ambient air. If no fire products are detected by the sensor assembly 15 after a period of between about 5 to 10 seconds, then the fan is again switched off and the cycle repeated. Alternatively, a more preferred method to further reduce power consumption, reduce maintenance requirements and speed up detection times is to only switch on the fan if fire products are detected within the monitored area by an external detector assembly provided to monitor conditions outside the sensor. This is described in detail in our co-pending European Patent Application entitled "Fire Sensor and Method for Detecting Fire" (Attorney Reference No RSJ10366EP), filed on even date herewith and incorporated herein by reference. In either case, control of the fan may be effected onboard the sensor or remotely at a control panel.

[0054] With either type of intermittent fan operation, there will be a very short delay before the fan reaches its operational speed, whilst sampled air will still flow through the internal chamber. As a result, any water vapour present may not be immediately removed from the airflow, causing the optical sensor 15 to be initially sensitive to its presence. To compensate for this, a small delay may be inserted into the signal generated by the optical sensor or the alarm routine may be programmed to effectively ignore triggering of the optical sensor within a short period immediately after start up. In this way, the sensor can readily recognise the presence of a large amount of water vapour and then be made insensitive to its presence once the fan reaches its operational speed, whilst maintaining high sensitivity to smoke. Additionally if a high water vapour condition exists for an extended period, a warning can also be generated. For instance, this could be achieved by registering the presence of water vapour (i.e. an apparent high signal from the internal sensor) before the fan reaches speed over multiple testing events. Alternatively, where the sensor also comprises an external detection assembly (such as that disclosed in our co-pending European patent application filed on even date, Attorney Ref: RSJ10366EP), the tripping of the external sensors followed by no tripping of the internal detection assembly could be taken to be indicative of steam. In practice, a combination of the two approaches may be used.

Claims

1. A fire sensor for detecting fire in a monitored region, the fire sensor comprising:

a detection chamber in fluid communication with the monitored region via an inlet path;
a sensor assembly adapted to detect fire products within the detection chamber, and to output a corresponding detection signal;
a cyclone chamber disposed upstream of the detection chamber in the inlet path between the detection chamber and the monitored region, the cyclone chamber comprising a fan impeller arranged to be rotationally driven by a motor so as to draw air from the monitored region into the detection chamber, and a peripheral wall enclosing the periphery of the fan impeller such that a vortex is established within the cyclone chamber when the fan impeller is driven;
whereby large droplets of liquid in the airflow through the cyclone chamber are preferentially removed by the vortex relative to small droplets of liquid, such that the average size of liquid droplets in the air drawn into the detection chamber is less than that of the air entering the fire sensor.

2. A fire sensor according to claim 1, further comprising a coalescer disposed upstream of the cyclone chamber for increasing the average size of liquid droplets in the air drawn into the cyclone chamber, wherein the coalescer preferably comprises a mesh.

3. A fire sensor according to claim 2, wherein the inlet path is preferably configured such that, at the location of the coalescer, the direction of the airflow is not perpendicular to the plane of the coalescer.

4. A fire sensor according to claim 2 or 3, wherein the coalescer is disposed immediately upstream of the cyclone chamber.

5. A fire sensor according to any of the preceding claims, wherein a baffle is disposed adjacent to the exit from the cyclone chamber, such that liquid droplets removed from the airflow by the vortex towards the exit are collected by the baffle.

6. A fire sensor according to claim 5, wherein the baffle comprises at least one angled blade arranged to cause a change in direction of the airflow upon exiting the cyclone chamber.

7. A fire sensor according to any of the preceding claims, wherein the cyclone chamber is disposed immediately upstream of the detection chamber.

8. A fire sensor according to any of the preceding claims, wherein the sensor assembly is adapted to detect aerosols within the detection chamber, preferably smoke.

9. A fire sensor according to any of the preceding claims, wherein the sensor assembly comprises an optical sensor, preferably an optical scatter sensor, a dual optical scatter sensor, or an optical obscuration sensor.

10. A fire sensor according to at least claims 5 and 9, wherein the baffle is disposed within the detection chamber and provides a light trap for the optical sensor.

11. A fire sensor according to any of the preceding claims, wherein the fan impeller and peripheral wall are provided in the form of a centrifugal fan, the inlet path preferably being arranged such that the airflow enters the centrifugal fan substantially parallel to the rotation axis of the fan, and exits the fan tangentially, substantially perpendicular to the rotation axis.

12. A fire sensor according to any of the preceding claims, wherein the peripheral wall is substantially circular.

13. A fire sensor according to any of the preceding claims, wherein the cyclone chamber has an approximate diameter of around 50 mm and the fan impeller is driven at around 4000 rpm.

14. A fire sensor according to any of the preceding claims, further comprising a processor arranged to activate the motor to drive the fan impeller, monitor the detection signal output from the sensor assembly whilst the motor is active, and compare the detection signal with a predetermined alarm criterion to determine whether alarm conditions are met.

15. A fire sensor according to claim 14 wherein the processor is adapted to intermittently activate the motor at predetermined intervals, or to activate the motor upon receipt of a trigger signal.

16. A method of detecting a fire in a monitored region, comprising:

drawing air from the monitored region into a cyclone chamber;
driving a fan impeller disposed within the cyclone chamber to establish a vortex therein, whereby large droplets of liquid in the airflow through the cyclone chamber are preferentially removed by the vortex relative to small droplets of liquid;
expelling air from the cyclone chamber into a detection chamber;
using a sensor assembly to sense the presence of fire products within the detection chamber and outputting a corresponding detection signal;
wherein the average size of liquid droplets in the air drawn into the detection chamber is less than that of the air entering the cyclone chamber.

17. A method of detecting a fire according to claim 16, further comprising:

coalescing liquid droplets upstream of the cyclone chamber to thereby increase the average size of the liquid droplets in the airflow entering the cyclone chamber.

18. A method of detecting a fire according to claim 15 or claim 16, further comprising:

collecting liquid droplets removed from the airflow by the vortex using a baffle disposed adjacent the exit of the cyclone chamber.

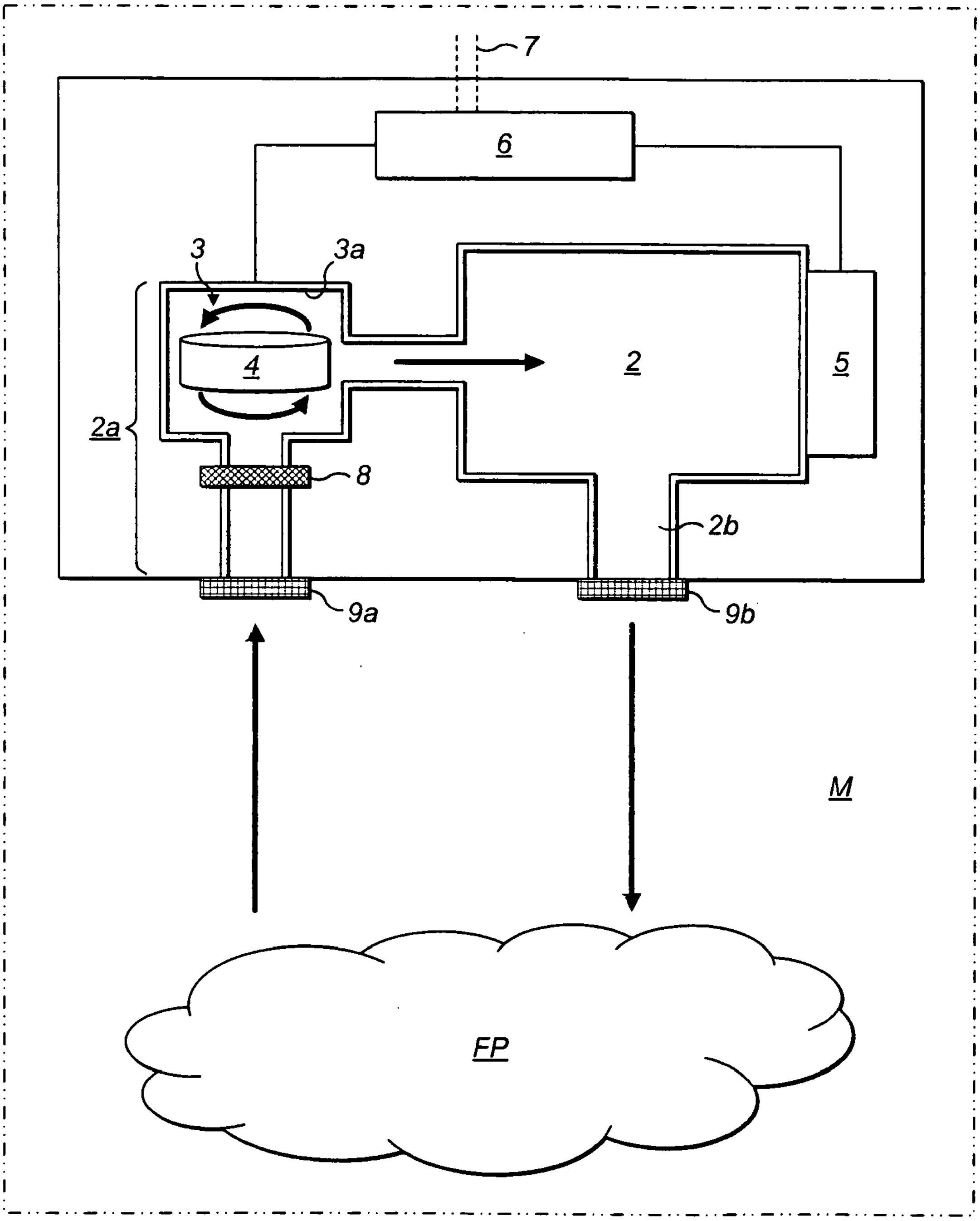

FIG. 1

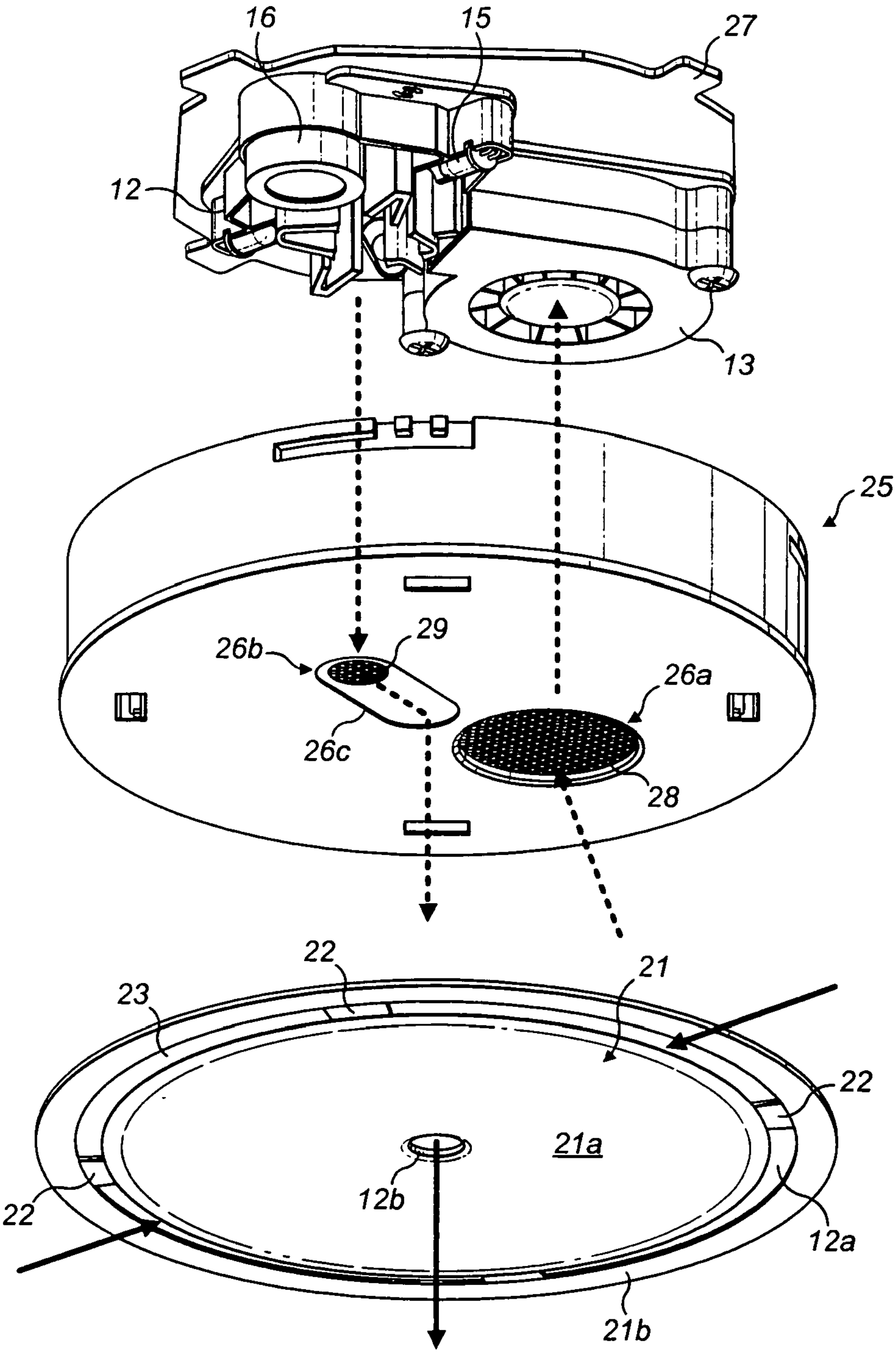

FIG. 2

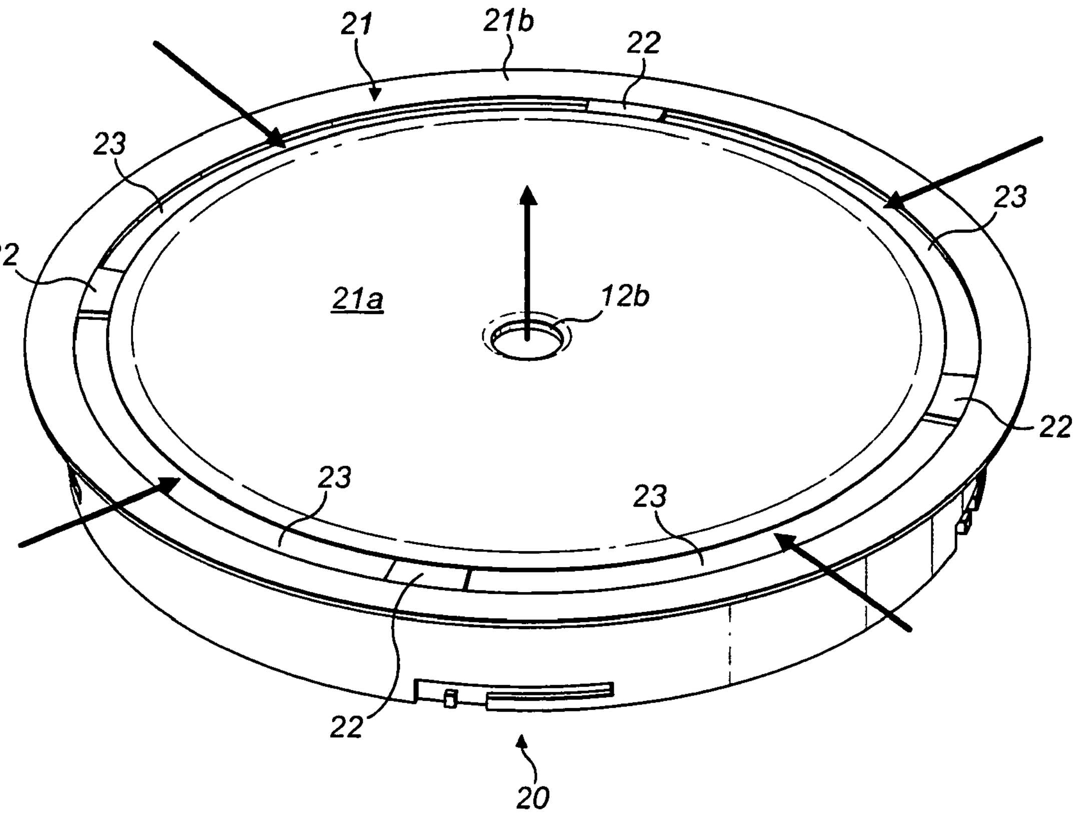

FIG. 3

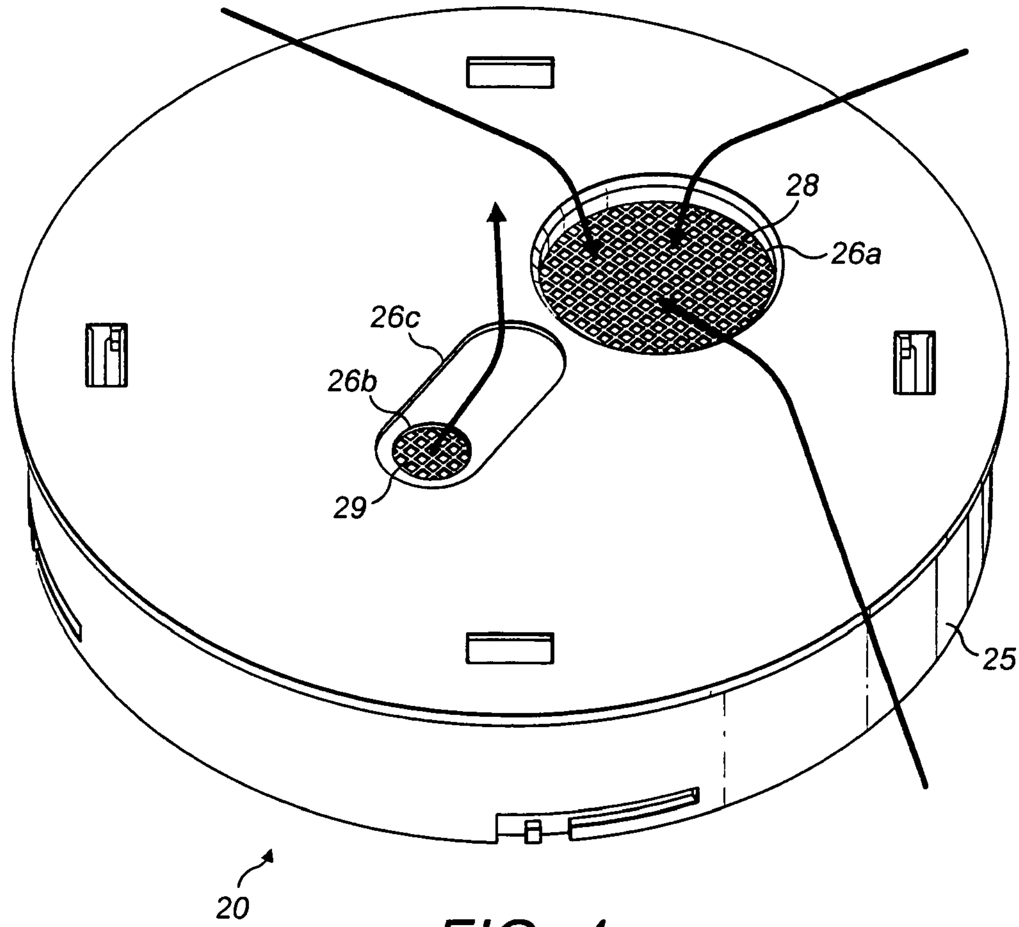

FIG. 4

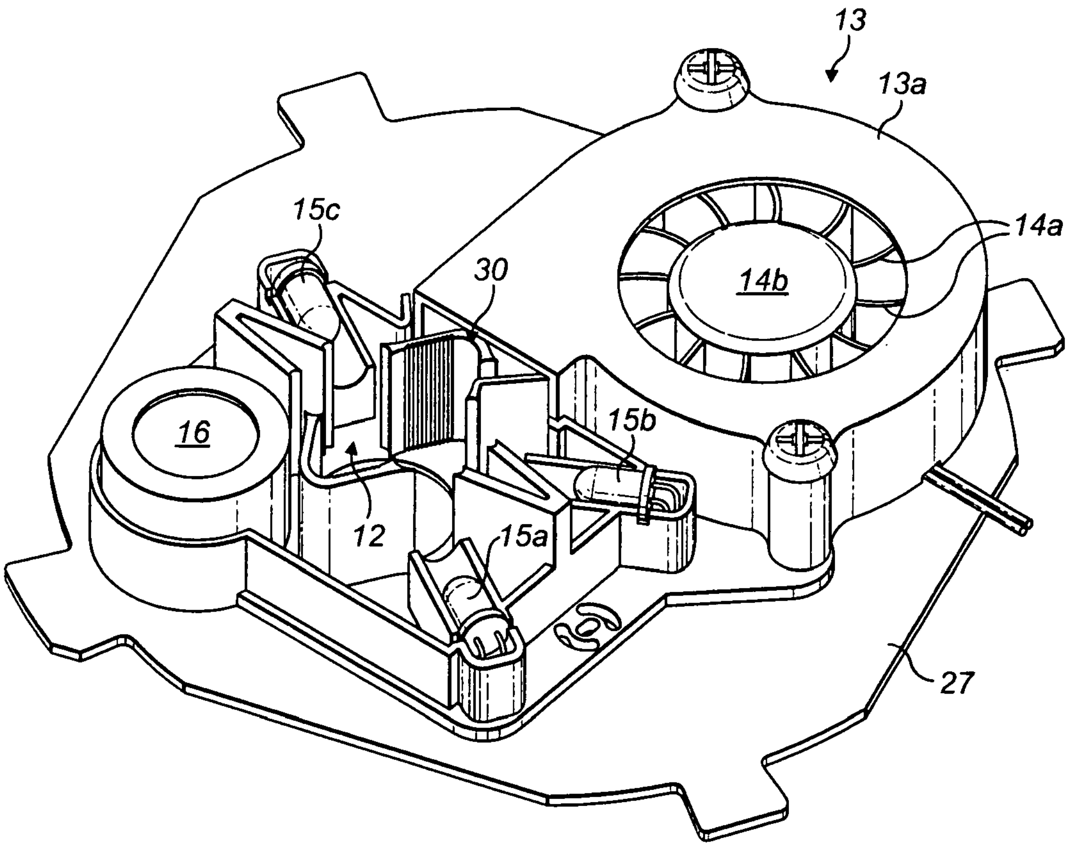

FIG. 5

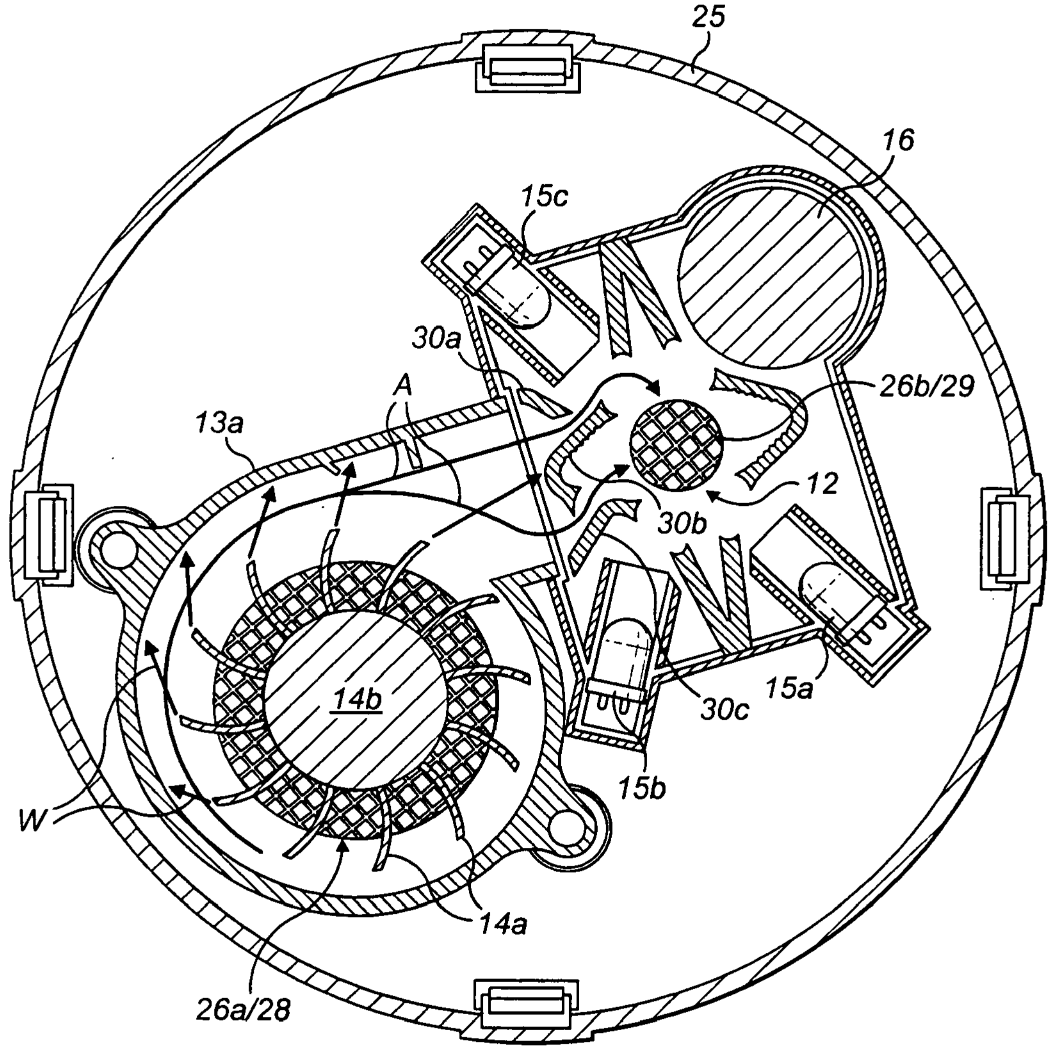

FIG. 6

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EUROPEAN SEARCH REPORT

Application Number
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Place of search	Date of completion of the search	Examiner
Munich	13 April 2010	Russo, Michela

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