ICING DETECTOR

TECHNOLOGICAL FIELD

The presently disclosed subject matter relates to icing detectors, particularly for aircraft.

BACKGROUND ART

References considered to be relevant as background to the presently disclosed subject matter are listed below:

- US 5823474
- US 9013332
- US 6010095
- US 5296853
- US 5551288
- WO 2015/114624
- US 4553137
- US 6206325
- US 2011/067726
- DE 102011102804
- WO 2010/006946
- US 2007/176049
- US 2008/110254
- US 5400144
- US 2014/263260
- US 2012/274938
- US 5760711
- US 4461178
- GB 1364845
- US 5191791
- US 2013/175396

- US 8060334
- US 2004/036630
- US 2002/158768
- US 2012/193477
- GB 563148
- US 2004/231410
- US 6091335
- US 5484121
- US 4797660
- US 2010/110431
- US 4681450
- US 8060334
- US 6206325
- US 2011/067726
- US 2012/036826
- DE 102011102804
- WO 2010/006946
- DE 2624801
- US 2009/055036
- GB 1561979
- GB 765802
- WO 2011/003963
- US 2681409
- US 2229740
- US 2015/115053
- CN 105369334
- FR 1270264
- JP 2010029573
- JP 2011110210
- US 2002/178493
- JP 2001329600

- AN OVERVIEW OF THE DEICING AND ANTIICING TECHNOLOGIES WITH PROSPECTS FOR THE FUTURE, 2004 (http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.476.6317&rep=rep1&type=pdf).
- A new technology De-Ice Anti Ice Proposal (http://www.iasa-intl.com/folders/belfast/laissez-faire.html)
- ICE CAT Aircraft Deicing System, 2004 (http://www.trimacsystems.com/icecat.php)

Acknowledgement of the above references herein is not to be inferred as meaning that these are in any way relevant to the patentability of the presently disclosed subject matter.

BACKGROUND

Ice buildup on aircraft, in particular on their aerodynamic lift and control surfaces, can seriously affect the performance and control of the aircraft, sometimes leading to the loss of lift and/or control, and thus of the aircraft.

Ice detectors are often used for the detection of ice buildup, and such detectors have been in use for many years. Such ice detectors can be based on a range of operating principles.

By way of non-limiting example, GB 563,148 discloses an ice-formation detector, enclosed behind the leading edge 6 of an aircraft wing, and comprises a metal chamber 5 having at its forward end a disc 7 of perforated metal to admit pressure air into the chamber during flight, a connection pipe 19 leading to a low-pressure area such as the underside of the wing trailing edge being provided of suitable bore to allow escape of pressure air from the chamber 5 at such a rate that during flight under non-icing conditions there will be maintained a pressure within the chamber which is high enough to act upon a resilient diaphragm 9, covering a hole in the chamber wall, so as to keep separated spring controlled electrical contacts 14, 15. According to this publication, when icing takes place so as to occlude perforations of disc 7 reduction of pressure occurs in the

chamber so that contacts 14, 15 are brought together to complete the circuit of an indicator and/or of de-icing means for the disc 7 and other de-icing means such as 6b within the wing structure.

Also by way of non-limiting example, US 6,010,095 provides an icing detector for detecting presence of both rime ice and clear ice in air comprising an ice collecting surface facing an oncoming air stream; light emitting apparatus for emitting a light beam crossing the ice collecting surface, having a prismatic light refracting window for refracting the light beam in a first direction, when no ice is present on the ice collecting surface; light sensing apparatus in a path of the second direction, and annunciating apparatus coupled to the light sensing apparatus for annunciating presence of ice when light is sensed by the light sensing apparatus.

GENERAL DESCRIPTION

According to a first aspect of the presently disclosed subject matter, there is provided a device for detecting presence of ice in an airstream, comprising:

- housing defining a first chamber and a second chamber, and a partition wall separating the first chamber and the second chamber;
- the first chamber having at least one inlet opening on a front housing wall facing the airstream, and at least one outlet opening, smaller than the at least one inlet opening;
- the second chamber configured for being operatively coupled to at least one electromagnetic (EM) system that is configured for transmitting EM energy to said first chamber at least via said partition wall, said partition wall being at least one of transparent and translucent with respect to said EM energy, said EM energy being configured for melting ice that can accrete with respect to the at least one inlet opening;
- the device being configured for being operatively coupled to at least one air pressure sensor in fluid communication with said first chamber for detecting at least pressure changes in said first chamber responsive to ice accretion on said at least one inlet opening.

According to the first aspect of the presently disclosed subject matter, the device can include one or more of the following features.

For example, said at least air one pressure sensor is coupled to said first chamber via a conduit between said first chamber and said at least air one pressure sensor. Alternatively, for example, said device comprises at least one opening between said first chamber and said second chamber providing free fluid communication therebetween, and wherein said at least air one pressure sensor is coupled to said second chamber via a conduit between said second chamber and said at least air one pressure sensor.

Additionally or alternatively, for example, said air pressure sensor is a pressure transducer.

Additionally or alternatively, for example, the device is made from non-metallic materials. For example, the housing and the partition wall are made from non-metallic materials.

Additionally or alternatively, for example, said at least one inlet opening is in the form of at least one slit. For example, each slit is in the form of a rectangular slit having a length dimension and a width dimension, the length dimension being greater than the width dimension. For example, the length dimension is at least partially vertical with respect to facing airstream. For example, the length dimension is vertical with respect to facing airstream. For example, said length dimension is between 5mm and 15mm. For example, said length dimension is about 10mm. For example, said width dimension is between 0.15mm and 0.65mm. For example, said width dimension is about 0.6mm. For example, a ratio of said length dimension to said width dimension is between 7.7 and 100. For example, a ratio of said length dimension to said width dimension is about 16.67. For example, said at least one slit has longitudinal edges that diverge in an aft direction through a thickness of said front housing wall. For example, said at least one slit has longitudinal edges that are parallel to one another through a thickness of said front housing wall; additionally or alternatively, for example, said longitudinal edges of at least one said slit are angled with respect to a front face of said front housing wall. For example, the device comprises two said slits transversely spaced from one another.

Additionally or alternatively, for example, said EM system is configured for providing laser energy of wavelength of about 1470nm or about 1550nm.

Additionally or alternatively, for example, said EM system is configured for providing laser energy of intensity between 0.01 W/mm^2 and 0.1 W/mm^2.

Additionally or alternatively, for example, said EM system is configured for providing laser energy of intensity 0.03 W/mm^2.

Additionally or alternatively, for example, said EM system is further configured for directing said laser energy toward said front housing wall.

Additionally or alternatively, for example, said EM system is configured for directing said laser energy toward said at least one outlet opening.

Additionally or alternatively, for example, said EM system comprises at least one optical fiber accommodated in said second chamber for transmitting EM energy along a respective optical axis.

Additionally or alternatively, for example, the at least one outlet aperture includes a surface tension breaker. For example, said surface tension breaker includes a mechanical stop located just aft of the outlet opening. For example, said mechanical stop is located just aft of the outlet opening. Additionally or alternatively, for example, said mechanical stop has a generally cylindrical or spherical shape. Additionally or alternatively, for example, said mechanical stop projects generally towards and into said outlet opening, and further projects outwards in a general direction away from said outlet opening. Additionally or alternatively, for example, said mechanical stop comprises a continuous surface between an inside of the outlet opening and an outside of the device.

According to a second aspect of the presently disclosed subject matter, there is provided a device for detecting presence of ice in an airstream, comprising:

- housing defining a first chamber;
- the first chamber having at least one inlet opening on a front housing wall facing the airstream, and at least one outlet opening, smaller than the at least one inlet opening;

- the device configured for being operatively coupled to at least one electromagnetic (EM) system that is configured for transmitting EM energy to said first chamber via, said EM energy being configured for melting ice that may accrete on said front wall, especially the at least one inlet opening;
- the device being configured for being operatively coupled to at least one air pressure sensor in fluid communication with said first chamber for detecting at least pressure changes in said first chamber responsive to ice accretion on said at least one inlet opening.

According to the second aspect of the presently disclosed subject matter, the device can include one or more of the features disclosed above regarding the device according to the first aspect of the presently disclosed subject matter, *mutatis mutandis*.

According to a third aspect of the presently disclosed subject matter, there is provided a device for detecting presence of ice in an airstream, comprising:

- housing defining a first chamber having at least one inlet opening on a front housing wall facing the airstream, and at least one outlet opening, smaller than the at least one inlet opening;
- said first chamber being configured for coupling to at least air one pressure sensor to provide fluid communication with said first chamber for detecting at least pressure changes in said first chamber responsive to ice accretion on said at least one outlet opening;
- the at least one inlet aperture being in the form of at least one slit, the at least one slit being at least partially vertical with respect to facing airstream.

According to the third aspect of the presently disclosed subject matter, the device can include one or more of the features disclosed above regarding the device according to the first aspect or the second aspect of the presently disclosed subject matter, *mutatis mutandis*.

For example, each said slit is in the form of a rectangular slit having a length dimension and a width dimension, the length dimension being greater than the width dimension.

For example, the length dimension is at least partially vertical with respect to facing airstream.

For example, the length dimension is vertical with respect to facing airstream.

For example, said length dimension is between 5mm and 15mm.

For example, said length dimension is about 10mm.

For example, said width dimension is between 0.15mm and 0.65mm.

For example, said width dimension is about 0.6mm.

For example, a ratio of said length dimension to said width dimension is between 7.7 and 100.

For example, a ratio of said length dimension to said width dimension is about 16.67

For example, said at least one slit has longitudinal edges that diverge in an aft direction through a thickness of said front housing wall.

For example, said at least one slit has longitudinal edges that are parallel to one another through a thickness of said front housing wall.

For example, said longitudinal edges are angled with respect to a front face of said front housing wall.

For example, the device comprises two said slits transversely spaced from one another.

According to a fourth aspect of the presently disclosed subject matter, there is provided a device for detecting presence of ice in an airstream, comprising:

- housing defining a first chamber having at least one inlet opening on a front housing wall facing the airstream, and at least one outlet opening, smaller than the at least one inlet opening;
- said first chamber being configured for coupling to at least air one pressure sensor to provide fluid communication with said first chamber, for

detecting at least pressure changes in said first chamber responsive to ice accretion on said at least one outlet opening;

- wherein the at least one outlet aperture includes a surface tension breaker.

According to the fourth aspect of the presently disclosed subject matter, the device can include one or more of the features disclosed above regarding the device according to the first aspect or the second aspect or the third aspect of the presently disclosed subject matter, *mutatis mutandis*.

For example, said surface tension breaker includes a mechanical stop located just aft of the outlet opening.

For example, said mechanical stop is located just aft of the outlet opening.

For example, said mechanical stop has a generally cylindrical or spherical shape.

For example, said mechanical stop projects generally towards and into said outlet opening, and further projects outwards in a general direction away from said outlet opening.

For example, said mechanical stop comprises a continuous surface between an inside of the outlet opening and an outside of the device.

For example, the device being further configured for coupling to at least one electromagnetic (EM) system that is configured for transmitting EM energy to said first chamber, said EM energy being configured for melting ice that can accrete with respect to the at least one inlet opening.

According to the above aspects of the presently disclosed subject matter a number of devices are provided for detecting presence of ice in an airstream. In some examples such device includes a housing defining a first chamber and a second chamber, and a partition wall separating the first chamber and the second chamber. The first chamber has at least one inlet opening on a front housing wall facing the airstream, and at least one outlet opening, smaller than the at least one inlet opening. The second chamber is configured for being operatively coupled to at least one electromagnetic (EM) system that is configured for transmitting EM energy to the first chamber at least via the partition wall, which is transparent and/or translucent with respect to the EM energy, the EM

energy being configured for melting ice that can accrete with respect to the inlet opening. The device is configured for being operatively coupled to at least one air pressure sensor in fluid communication with the first chamber for detecting at least pressure changes in the first chamber responsive to ice accretion on the inlet opening.

A feature of at least one example of the presently disclosed subject matter is that effectively a large chamber is provided in the device, via two interconnected chambers, acting as a low pass filter which averages out small changes in the ambient air pressure that in some circumstances could otherwise lead to erroneous determination that there is ice accretion corresponding to a drop in the chamber pressure, when in reality such a drop is due to a sudden drop in the ambient air pressure.

Another feature of at least one example of the presently disclosed subject matter is that the relative sizes of the two chambers allows the primary chamber to have a relatively small volume relative to the secondary chamber. By the primary chamber having a small volume allows the device as a whole to be compact. Furthermore, by having a relative small primary chamber volume, the amount of ice that is accumulated therein is relatively small, requiring less energy to melt the same and evacuate the primary chamber, which can lead to a requirement for a smaller ice melting system, with lower power requirements, than would otherwise be the case.

Another feature of at least one example of the presently disclosed subject matter is that the respective surface tension breaker allows the primary chamber to be evacuated from liquid water with the respective outlet opening having a small flow cross-section. This in turn allows the primary chamber to have a relatively small volume, which in turn allows the device as a whole to be compact. Furthermore, by having a relative small primary chamber volume, the amount of ice that is accumulated therein is relatively small, requiring less energy to melt the same and evacuate the primary chamber, which can lead to a requirement for a smaller ice melting system, with lower power requirements, than would otherwise be the case.

Another feature of at least one example of the presently disclosed subject matter is that by providing the device as a compact device, the device can be mounted eternally with respect to an air vehicle, for example a wing or fuselage, without incurring unacceptable drag or lift penalties.

Another feature of at least one example of the presently disclosed subject matter is that by providing the device with an electromagnetic energy system, in particular a laser-based ice melting system, for melting ice in the primary chamber and inlet openings, it is possible to do so by directly heating the ice and without the necessity to heat the primary chamber itself, which can lead to a requirement for a smaller ice melting system, with lower power requirements, than would otherwise be the case.

Another feature of at least one example of the presently disclosed subject matter is that by providing the device a partition wall between the primary chamber and the secondary chamber, in which the partition wall is transparent of translucent to laser radiation, it is possible to provide the device with an electromagnetic energy system, in particular a laser-based ice melting system, for directly melting ice in the primary chamber and inlet openings via the partition wall, without the necessity to heat the primary chamber itself, which can lead to a requirement for a smaller ice melting system, with lower power requirements, than would otherwise be the case.

Another feature of at least one example of the presently disclosed subject matter is that by providing the device a partition wall between the primary chamber and the secondary chamber, in which the partition wall is transparent of translucent to laser radiation, it is possible to provide the device with an electromagnetic energy system, in particular a laser-based ice melting system, for directly melting ice in the primary chamber and inlet openings via the partition wall, without the necessity to heat the primary chamber itself. This can lead to a requirement for a smaller ice melting system, with lower power requirements, than would otherwise be the case. This can also lead to the whole device or to the rest of the device, in particular the housing, to be made from non-metallic materials.

Another feature of at least one example of the presently disclosed subject matter is that the whole device or much of the device, in particular the housing, can be made from non-metallic materials.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to better understand the subject matter that is disclosed herein and to exemplify how it may be carried out in practice, examples will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1 is an isometric view of a device for detecting presence of ice in an airstream according to a first example of the presently disclosed subject matter.

Figs. 2(a), 2(b), 2(c), 2(d) show the device of Fig. 1 in side view, top view, front view and back view, respectively.

Fig. 3 shows, in cross-sectional side view, the example of Fig. 1 taken along Section A-A in Fig. 2(b).

Fig. 4 shows in front view the front housing wall of the example of Fig. 1; **Fig. 4(a)** is a cross-sectional partial view of the example of Fig. 4 taken along section E-E; - **Figs, 4(b), 4(c), 4(d)** are cross-sectional partial views of alternative variations of the example of Fig. 4(a).

Fig. 5 shows, in cross-sectional side view, an alternative variation of the example of Fig. 3.

Fig. 6 shows, in cross-sectional side view, another alternative variation of the example of Fig. 3.

Figs. 7(a) shows in front view an alternative variation of the front housing wall of the examples of Figs. 1, 5, 6; **Figs. 7(b)** shows in front view another alternative variation of the front housing wall of the examples of Figs. 1, 5, 6; **Figs. 7(c)** shows in front view another alternative variation of the front housing wall of the examples of Figs. 1, 5, 6; **Figs. 7(d)** shows in front view another alternative variation of the front housing wall of the examples of Figs. 1, 5, 6; **Figs. 7(e)** shows in front view another alternative variation of the front housing wall of the examples of Figs. 1, 5, 6; **Figs. 7(f)** shows in front view another alternative variation of the front housing wall of the examples of Figs. 1, 5, 6.

Fig. 8 shows, in cross-sectional side view, detail "C" of the example of Fig. 3.

Fig. 9 shows in cross-sectional view of an alternative variation of the example of Fig. 4(a).

DETAILED DESCRIPTION

Referring to Figs. 1, 2(a), 2(b), 2(c), 2(d), 3, a device for detecting presence of ice in an airstream **AS** according to a first example of the presently disclosed subject matter, generally designated **100,** comprises a housing **200** defining a first chamber **230** and a second chamber **270.**

In at least this example, the device **100** comprises, or at least is configured for being operatively connected to, at least to one air pressure sensor **300.**

Furthermore, in at least this example, the device **100** comprises, or at least is configured for being operatively connected to, at least to an electromagnetic (EM) system **600.**

A partition wall **250** separates the first chamber **230** from the second chamber **270.**

The housing **200** in this example is made from two parts, a forward housing part **210** and an aft housing portion **220.** In alternative variations of this example the housing **200** can be formed as an integral component, or alternatively can be formed as an assembly of more than two parts.

The aft housing portion **220** defines the second chamber **270,** and includes the partition wall **250** at a front end **222** thereof, and an interface aft wall **280** including flange **282,** and side walls **260.** The device **100** can be mounted to a structure via the interface aft wall **280** and flange **282.** Such a structure can include, for example, an aircraft wing, fuselage or any other part of the aircraft on which ice accretion is to be monitored.

In this example, and as best seen in Figs. 1, 2(a), 2(b), 2(c), 2(d), the aft housing portion **220,** in particular an aft portion thereof, has an aerodynamic profile, for example an aerofoil cross-section, for minimizing drag in the airstream AS, and thus the entire device **100** can be exposed to the airstream.

In alternative variations of this example, the aft housing portion **220** can be generally tubular and can have any suitable cross-section – for example circular, elliptical, square, rectangular, polygonal etc.

Furthermore, and referring particularly to Fig. 2(a), in this example the aft housing portion **220** is elbow-shaped, i.e., the aft housing portion **220** has a central axis **AA** therethrough in which a front portion **AAF** of the central axis **AA** is angularly displaced from an aft portion **AAA** of the axis **AA** by an elbow angle α. In this example the elbow angle α is about 90°.

However, in other alternative variations of this example the aft portion can have any other suitable elbow angle, and/or any other suitable shape; for example in other alternative variations of this example the aft portion **220** can have a rectilinear central axis, and elbow angle α is thus about 180°.

The forward housing portion **210** is affixed with respect to the aft housing portion **220** at the front end **222.** Referring in particular to Fig. 3, the forward housing portion **210** has an open aft end **223** that cooperates with front end **222.** The forward housing portion **210** includes front housing wall **205,** that in operation of the device **100** is facing the airstream **AS**, and side walls **285.** When affixed to the aft housing portion **220,** the forward housing portion **210** defines the first chamber **230,** and thus the first chamber **230** is defined by the partition wall **250** side walls **285,** and front housing wall **205.**

Referring in particular to Figs. 1, 2(c), 2(d), 3 and 4, the housing **200,** in particular the first chamber **230,** in this example has a plurality of inlet openings **500** on the front housing wall **205** facing the airstream, and one outlet opening **550** facing a direction generally away from the airstream.

Referring in particular to Figs. 1 and 3, the total cross-sectional flow area **A1** provided by all inlet openings **500** together is larger than the total cross-sectional flow area A**2** provided by the outlet opening **550.** For example the ratio **A1/A2** is about 15 or greater than 15, for example 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30. Alternatively, for example the ratio **A1/A2** is less than about 15, for example 14, 13, 12, 11, 10, 9, 8, 7, 6, or 5.

In at least this example, the total cross-sectional flow area **A1** provided by each the two inlet openings **500** is also larger than the total cross-sectional flow area **A2** provided by the outlet opening **550.**

Referring in particular to Fig. 3, the housing **200,** in this example the aft housing portion **220,** includes a chamber opening **225** that provides open fluid communication between the first chamber **230** and the second chamber **270.** In this example, other than for the chamber opening **225,** the second chamber **270** has no other openings that allow fluid communication between an outside of the housing **200** and the second chamber **270.** Thus, in operation of the device **100** the air pressure in the first chamber **230** and in the second chamber **270** are equalized via the chamber opening **225.** The first chamber **230** and the second chamber **270** each act as plenum chambers.

Referring to Fig. 3, the first chamber **230** has a first internal volume **V1**, and the second chamber **270** has a second internal volume **V2**, the combined volume being designated herein as **V** (= **V1** + **V2**).

The combined internal volume **V** of the first chamber **230** and the second chamber **270** can be chosen to be large enough to together operate as a low pass filter, i.e., such that small fluctuations in external total pressure do not affect the chamber pressure **P**. Furthermore, in at least this example, the second internal volume **V2** is much larger than the first internal volume **V1**. This allows for the feature of low pass filter, and also for a relatively small size for the first chamber **230.** Having a relatively small first internal volume **V1** for the first chamber **230** results in a relatively small volume of ice being accreted therein, and thus requiring in turn less EM energy to melt this ice.

For example the ratio of the second internal volume **V2** to the first internal volume **V1** is 1 or greater than 1, and can be for example in a range from 1 to any one of the following values: 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,l 26, 27, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 60, 70, 80, 90, 100.

For example the ratio of the second internal volume **V2** to the first internal volume **V1** can be for example any one of the following values: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,l 26, 27, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 60, 70, 80, 90, 100.

The chamber opening **225** is located at a bottom portion of side walls **260,** and aft of the partition wall **250.** The outlet opening **550** is below chamber opening **225.**

In this example, the device **100** comprises one air pressure sensor **300** in fluid communication with the second chamber **270** via conduit **320,** and thus the air pressure sensor **300** is operatively coupled to the housing **200** via conduit **320.** Alternatively, the device **100** is configured to be connected to the air pressure sensor **300,** and thus the device **100** includes a suitable connector for connecting the conduit **320** to the air pressure sensor **300.**

Thus, ultimately, in operation the air pressure sensor **300** is in fluid communication with the first chamber **230** (via the opening **225,** second chamber **270,** and conduit **320**), and is configured for detecting at least pressure changes in the first chamber **230** responsive to ice accretion on the inlet openings **500,** as will become clearer herein. In at least this example the air pressure sensor **300** is also configured for providing actual pressure readings of the air pressure **P** in the first chamber **230,** and is operatively connected to a controller **900** that also controls operation of at least the electromagnetic (EM) system **600.**

In any case, the air pressure sensor **300** can be, for example, any one of the following a General Purpose Pressure Transducer and Transmitter model 55p, provided by Validyne Engineering (USA) .

In this example, the device **100** comprises one electromagnetic (EM) system **600** configured for selectively transmitting EM energy to the front housing wall **500** via, i.e., through, said partition wall **250.** The EM system **600** is operatively coupled to the housing **200** via a plurality of optical fiber elements **620** accommodated in the second chamber **670.** Alternatively, the device **100** is configured to be connected to the EM system **600,** and thus the device **100** includes a suitable optical connector for connecting the optical fiber elements **620** to the EM system **600.**

The first optical fiber elements **620** can include a single optical fiber or a bundle of optical fibers.

It is to be noted that the partition wall **250** is transparent and/or translucent with respect to the aforesaid EM energy provided by the EM system **600.**

It is also to be noted that the aforesaid EM energy is configured for melting ice that in operation of the device **100** can accrete on said front housing wall **205,** especially over the inlet openings **500.** Accordingly, the intensity **I** and/or wavelength λ of the EM energy

generated by the EM system **600** and transmitted towards the front housing wall **205** are such as to enable any ice that may have accreted on the inlet openings **500** and/or on the front housing wall **205** to become heated directly in response to receiving the EM energy, and to raise the temperature thereof such as to melt this ice**,** sufficient for such ice to be removed away from the inlet openings **500.**

For example such intensity **I** of the EM energy can be 0.03 W/mm^2, or at least between 0.01 W/mm^2 and 0.1 W/mm^2.

For example such wavelength λ of the EM energy can be about 1470nm or 1550nm.

In this example the EM system **600** includes two optical fiber elements **620,** for ease of reference being further identified with reference numerals **621, 622.** It is to be noted that in alternative variations of this example the EM system **600** can include only one optical fiber **620** or more than two optical fiber elements.

Each of the optical fiber elements **621, 622** has a respective forward facing transmission end **623, 624,** and in operation of the EM system **600** transmits EM energy along respective optical axes **626, 627** in a generally forward direction.

The second chamber **270** comprises channels **631, 632** for guiding the optical fiber elements **621, 622** from at least the interface aft wall **280** to a location just aft of the partition wall, and aligned along optical axes **626, 627** with respect to the front housing wall **205.**

In particular, the optical axis **626** of one optical fiber **621** is directed towards, the lower portion of the first chamber **230;** thus, in operation of the EM system **600,** EM energy transmitted via the optical fiber **621** irradiates the front housing wall **205** and an upper portion of the first chamber **230** via the partition wall **250** enabling ice therein to be melted.

Furthermore, the optical axis **627** of the other optical fiber **622** is directed towards, and intersects, the partition wall **250** and also the front housing wall **205;** thus, in operation of the EM system **600,** EM energy transmitted via the optical fiber **622** irradiates the lower portion of the first chamber **230** enabling ice therein to be melted.

In any case, the EM system **600** can be, for example, the M1470 product by Photontec (Germany).

In at least this example housing **200,** and in particular the forward housing part **210,** the aft housing part **220,** and the partition wall **250** are made from non-metallic materials. For example, the housing **200** can be made entirely from any suitable plastics materials, or any other suitable materials that are transparent or translucent to the wavelength **λ** of the EM energy generated by the EM system **600,** for example any one of: polycarbonate, glass.

Alternatively, in some alternative variations of the above examples, the housing **200,** and in particular one or more of the forward housing part **210,** the aft housing part **220,** are made from metallic materials, for example aluminum, titanium, steel, brass, or other suitable metals or alloys, while the partition wall **250** can be made from any suitable plastics materials, or any other suitable materials that are transparent or translucent to the wavelength **λ** of the EM energy generated by the EM system **600.**

Alternatively, in some alternative variations of the above examples, in which the EM system **600** is omitted or replaced with a non-laser heating system for melting the accreted ice, the housing **200,** and in particular one or more of the forward housing part **210,** the aft housing part **220,** and the partition wall **250** are made from metallic materials, for example aluminum, titanium, steel, brass, or other suitable metals or alloys.

In alternative variations of this example, and referring to Fig. 5, the air pressure sensor **300** can be directly coupled to the first chamber **230** rather than to the second chamber **270,** for example via modified conduit **320'** and first chamber opening **325'**, without the need for opening **255** between the first chamber **230** and the second chamber **270.** For example, in this example there is a lack of fluid communication within the housing **200,** between the first chamber **230** and the second chamber **270.** The air pressure sensor **300** can be directly coupled to the first chamber **230** via conduit **320'**.

Furthermore, in yet other alternative variations of these examples, and referring to Fig. 6 for example, the air pressure sensor **300** can also be directly coupled to the first chamber **230,** for example in a similar manner to the example of Fig. 5, *mutatis mutandis*, i.e., via conduit **320'** and first chamber opening **325'**, and there is no need for the second chamber **270** per se. Thus, in this example, there is no open chamber aft of the first chamber **230,** or, alternatively, the second chamber **270** can in fact be filled with material, for example a non-gaseous material, for example a solid material.

In at least this example, and referring to Fig. 8 in particular, the outlet opening **550** comprises a surface tension breaker **590** for breaking surface tension of any liquid water that can accumulate in the first chamber **230** above the outlet opening **550** and thus facilitate flow of such liquid water out of the outlet opening **550.** The surface tension breaker **590** is of particular use in examples of the device **100** where the device **100** is compact and of relative small dimensions, for example in terms or overall volume of the device and/or in terms of the linear dimensions thereof. Providing such a device having compact and of relative small dimensions can allow the device to be provided as a stand-alone device that can be mounted onto a structure, for example the fuselage or wing of an air vehicle, at minimal drag penalty, and does not need to be embedded within the structure.

For example the outlet opening is in the form of a channel that can have a transverse cross-sectional diameter of about 1mm, providing an outlet area **A2** of about 0.8mm^2**.** The outlet **591** of the channel is scarfed, and thus the edges **593** of the outlet **591** lies on an outlet plane **OP** that is slanted with respect to the axis of the channel. Accordingly, the exit area circumscribed by the edges **593** at outlet plane **OP** is larger than the cross-sectional area of the channel that defines the outlet opening **550.**

In at least this example, the surface tension breaker **590** is in the form of an artifact that provides a surface that projects from forward of the outlet (i.e., within the outlet opening **550)** to an outside of the outlet **591,** sufficiently to essentially allow flow of water from the outlet opening **550** to an outside thereof via this surface, countering the effects of the surface tension of the water.

In at least this example, the surface tension breaker **590,** i.e., the artifact, is in the form of a mechanical stop **592**, having a generally cylindrical or spherical shape, and located just aft of the outlet opening **550,** so that part of the stop **592** projects generally forwards towards, and penetrates the outlet plane **OP**, as to provide the outlet opening **550** with a generally annular flow area, and the stop also projects aft of the outlet plane **OP**, providing a continuous surface **594** between the inside of the outlet opening **550** and an outside of the device.

Without being bound to theory, the inventors consider that when liquid water accumulates in the outlet opening **550** (for example as a result of ice in the primary chamber **230** being melted), and this outlet opening is of small diameter, this water runs towards and

into the outlet opening **550,** and in the absence of the stop **592** would project in a direction away from the outlet plane **OP** as a result of surface tension (typically in the form of a "bubble" of water. This surface tension essentially overcomes the gravitational forces of the water, and essentially prevents the water from actually exiting the outlet opening **550.** However, the presence of the stop **592** provides another surface **594** for the projecting water to attach itself to, and thus spreads over the stop **592,** in particular an aft portion thereof, aft of the outlet plane **OP**, and drips thereforrm via gravity, thereby providing a flow of water from the primary chamber **230** to an outside of the device, and minimizing adverse effects of surface tension.

The lower portion of the first chamber **230** is also sloped in at least this example to facilitate the outward flow of any accumulated water in the first chamber **230.**

For example, and referring in particular to Figs. 2(a) and 2(c), the device **100,** in particular the housing **200,** has a height dimension **B1,** length dimension **B2** and width dimension **B3** according to the following examples:

Example 1: **B1** = 60 cm; **B2** = 80 cm; **B3** = 17 cm.

Example 2: **B1** = 60 cm; **B2** = 100 cm; **B3** = 17 cm.

Example 3: **B1** = 40 cm; **B2** = 54 cm; **B3** = 17 cm.

Example 4: **B1** = 35 cm; **B2** = 50 cm; **B3** = 15 cm.

In alternative variations of the above examples, the device **100,** in particular the housing **200,** can have a height dimension **B1,** length dimension **B2** and width dimension **B3,** different from the above.

Referring in particular to Fig. 3 and Fig. 4, the housing **200,** in particular the first chamber **230,** in this example has two inlet openings **500** on the front housing wall **205** facing the airstream. In at least this example, each of the inlet openings **500** is in the form of a slit **510,** having a longitudinal edges **510L**, having a longitudinal dimension **L**, and transverse edges **510T**, having a transverse dimension **T**, the longitudinal edges **510L** and the transverse edges **510T** being in general rectangular arrangement.

Referring to Fig. 4(a), in at least this example the longitudinal edges **510L** of each slit **510** diverge in an aft direction to provide an increasing flow are along the thickness **d** of the front housing wall **205.**

In alternative variations of this example, and referring to Figs. 4(b), 4(c) and 4(d), the longitudinal edges **510L** of each slit **510** are parallel to one another, and can be parallel to front portion **AAF** of the central axis **AA** (Fig. 4(b). Alternatively, the longitudinal edges **510L** of each slit **510** are parallel to one another, and can be angled with respect to the front face **505** for diverting the flow towards a side wall **285** (Fig. 4(c)), or away from the side wall **285** (Fig. 4(d)).

Furthermore, in at least this example the two inlet opening **500** are identical in size and shape to one another, and are transversely spaced from one another in the front housing wall **205** by a transverse spacing **S**.

Furthermore, in at least this example the longitudinal dimension **L** is 10 mm, or at least between 5mm and 15mm, and the transverse dimension **T** is 0.6 mm, or at least between 0.15mm and 0.65mm. In other words the ratio **L/T** of the longitudinal dimension **L** to the transverse dimension **T** is 16.67, or at least between 7.7 and 100.

These values for the longitudinal dimension **L** and the transverse dimension **T** can be particularly effective for enabling ice particles of small size (for example diameter 0.15mm or larger) to accumulate on the slits **510**.

Furthermore, in at least this example the longitudinal dimension L is arranged to be in the vertical direction, or at least partially vertical. By partially vertical is meant that the longitudinal dimension **L** is arranged to be inclined to the vertical direction by an inclination angle β, where angle β is in the range 0° to 45° .

In at least this example, the front face **505** of the front housing wall **205** is on a vertical plane, when in operation of the device **100.** However, in alternative variations of this example the front face **505** can be inclined to the vertical when in operation of the device **100:** in such cases, angle β can be defined as the inclination of longitudinal dimension **L** to the vertical direction, where the longitudinal dimension **L** is projected to a vertical plane. In other words, angle β can be defined as the inclination of longitudinal dimension **L** to the vertical direction, taken on a vertical plane.

In operation of the device **100,** mounted to a structure and facing the airstream **AS**, air enters first chamber **230** via the two inlet openings **500,** and leaves the first chamber **230** via the outlet opening **550,** but at a lower rate because of the area ratio **A1/A2,** thereby

elevating the air pressure **P** within the first chamber **230.** This air pressure P is generally higher than the static pressure **Ps** of the airstream **AS**. However, in absolute terms the dynamic pressure or the total (pitot) pressure $\mathbf{P_T}$ of the airstream **AS** can vary, and thus can depend on the airspeed of the device (i.e., on the airspeed of the structure (e.g. the aircraft) on which the device **100** is mounted) as well as on the altitude. This total pressure $\mathbf{P_T}$ of the airstream **AS**, can be determined by other sensors, for example via a pitot probe, and optionally the air pressure **P** within the first chamber **230** can be non-dimensionalised to incorporate the real time values of total pressure $\mathbf{P_T}$ and/or altitude pressure effects.

So long as the two inlet openings **500** remain unblocked with respect to the airstream **AS**, and the full cross-sectional flow area **A1** is available to the airstream **AS**, the air pressure **P** will remain elevated, and is generally a function of the total (pitot) pressure $\mathbf{P_T}$ of the airstream **AS**.

Furthermore, when there is a presence of ice, which can include for example one or more of supercooled water droplets, snow particles or ice particles, in the airstream **AS**, some of this ice can begin to accrete on the front housing wall **205,** in particular on the front face **505** thereof, more particularly on and/or around the openings **500,** for example in a manner analogous to or corresponding to ice accretion that can be taking place on important areas of the aircraft, for example leading edges of the wings or other control surfaces.

As more and more ice accretes over the openings **500,** the available open area **A1'** available for airflow into the first chamber **230** from the airstream **AS** diminishes, and correspondingly the air pressure **P'** in the first chamber diminishes from the former nominal air pressure **P**. When the openings **500** are totally blocked with ice, the available open area **A1'** available for airflow into the first chamber **230** from the airstream **AS** is zero, and the pressure **P'** reaches a minimum. In this manner, changes in the air pressure **P** within the first chamber **230** can indicate the level of blockage of the openings **500.**

As the air pressure sensor **300** is operatively coupled to controller **900,** the controller **900** thus receives data or signals from the air pressure sensor **300** indicative of the air pressure **P** within the first chamber **230,** and the controller **900** can then determine the status of ice accretion. The controller **900** can also be configured to determine whether or not the level of ice accretion has reached or passed critical thresholds, according to the drop in pressure of the air pressure in the first chamber **230.** Such critical thresholds can correspond

to, for example, analogous ice accretions in ice-sensitive parts of the aircraft, for example leading edges of the wings or other control surfaces, which could lead to significant or catastrophic loss in performance of the aircraft.

Responsive to determining the status of ice accretion, in particular whether such thresholds have been reached, the controller **900** can selectively take one or more of the following courses of action:

(a) Transmit a suitable ice accretion warning signal to the user.

(b) Initiate operation of any anti-icing systems in the aircraft.

(c) Activate operation of the EM system **600** to remove the ice accretion over the openings **500.**

Regarding option (c), this feature allows the device **100** to continue operating to determine whether there is fresh ice accretion, and to thus monitor ongoing ice accretion. Otherwise, it is possible for the ice already accreted in the openings **500** to remain there, even when there is no further ice present in the airstream, and thus provide false indications to the controller **900.**

Nominal operation of the EM system **600** results in melting of ice accreted at the openings **500,** and at least part of the melted ice flows into the first chamber **230** and is removed therefrom via the outlet opening **550,** and the dynamic pressure of the airstream also assists in this.

Furthermore, the surface tension breaker **590** also assists in preventing the outlet opening **550** from otherwise effectively becoming blocked with water as a result of surface tension, particularly in examples where the device **100** is compact and of small dimensions, as discussed herein.

In alternative variations of this example, the housing **200,** in particular the first chamber **230,** can have a single inlet opening **500** or more than two inlet openings **500** on the front housing wall **205** facing the airstream, and/or more than one outlet opening **550.** Furthermore, the size and shape of such inlet openings **500** and/or of such outlet openings **550** can also vary.

For example, Fig. 7(a) shows such an alternative variation of the above examples in which there is a single inlet opening **500A**, having an open area of **A1.** In this example the

opening **550A** is in the form of two slits **551A** intersecting one another in crucifiorm arrangement, in which each one of the slits **551A** is at an angle θ to the vertical, where each angle θ (which can be the same or different from one another) is between 0° and 60°, for example. Fig. 7(b) shows a variation of the example of Fig. 7(a), in which there is a single inlet opening **500A**' in the form of a "Y".

In another example illustrated in Fig. 7(c), there is also a single inlet opening **500B**, having area **A1,** also in the form of slit, but in which the slit is not rectilinear, but rather curved. In an alternative variation of this example, and referring to Fig. 7(d) for example, the curved slit can be replaced by a number of shorter slits **500B**' together having an open area of **A1.**

It is also to be noted that in alternative variations of this example the opening **500** can be in the form of respective one or more slits, in which the slits are not of uniform width. For example, and referring to Fig. 7(e), such an alternative variation of the above examples in which there are two openings **500C**, together having an open area of **A1,** each opening has a trapezoidal shape or a wedge shape. In the illustrated example of Fig. 7(e), one opening **500B** is in the form of a slit being narrow at the top and wider at the bottom, while the other opening is in the form of a slit but wide at the top and narrow at the bottom.

In yet another example illustrated in Fig. 7(f), there are three rectangular slits **500D**.

It is also to be noted that in general the higher the ratio **A1/A2**, the less time it will take for the opening **500** to become completely clogged, given a particular set of icing conditions.

Thus, the value of ratio **A1/A2,** in particular transverse dimension T, can be chosen for a particular device **100** such as to become clogged at a particular set of icing conditions within a desired period of time and that are of particular importance or value to the user.

In this connection, for example, and according to another aspect of the presently disclosed subject matter, a battery of devices **100** can be provided, and installed in an aircraft for example, each such device differing from the other devices in the value of the transverse dimension **T** and all operatively coupled to controller **900.** As icing conditions worsen, one after another of the devices **100** becomes sequentially clogged with ice, providing the user

with an indication of how quickly the icing conditions could be changing, and allowing for more time to take counter measures.

In an alternative variation of the above examples the device **100** can be configured to further facilitate supercooled water droplets or ice particles of particular small size to accumulate and block the inlet openings **500,** where such a small size is significantly smaller than the width **T** of the openings **500.** For example, and referring to Fig. 9, the device **100** comprises an impact plate element **530** just aft of each of the inlet openings **500.** Each plate element **530** has a longitudinal length dimension similar to the length dimension **L** of the slits **510,** and includes an impact surface **532** aligned with the respective slit **510.** Furthermore, each impact surface **532** has a width dimension r such as to ensure that the flow area available to the incoming air from airstream **AS** , between the plate element **530** and the slit **510** is not less than **A1.** In operation of the device **100,** small supercooled water droplets or ice particles that would otherwise pass through the slits **510** instead impact on the respective impact surface **532** of the respective impact plate element **530,** enabling ice accretion thereat which eventually blocks the inlet opening **500.**

Finally, it should be noted that the word "comprising" as used throughout the appended claims is to be interpreted to mean "including but not limited to".

While there has been shown and disclosed examples in accordance with the presently disclosed subject matter, it will be appreciated that many changes may be made therein without departing from the spirit of the presently disclosed subject matter.

CLAIMS:

1. A device for detecting presence of ice in an airstream, the device comprising:

- a housing defining a first chamber and a second chamber, and a partition wall separating the first chamber and the second chamber;
- the first chamber having at least one inlet opening on a front housing wall facing the airstream, and at least one outlet opening, smaller than the at least one inlet opening;
- the second chamber configured for being operatively coupled to at least one electromagnetic (EM) system that is configured for transmitting EM energy to said first chamber at least via said partition wall, said partition wall being at least one of transparent and translucent with respect to said EM energy, said EM energy being configured for melting ice that can accrete with respect to the at least one inlet opening;
- the device being configured for being operatively coupled to at least one air pressure sensor in fluid communication with said first chamber for detecting at least pressure changes in said first chamber responsive to ice accretion on said at least one inlet opening.

2. The device according to claim 1, wherein said at least one air pressure sensor is coupled to said first chamber via a conduit between said first chamber and said at least air one pressure sensor.

3. The device according to claim 1, further comprising at least one opening between said first chamber and said second chamber providing free fluid communication therebetween, and wherein said at least air one pressure sensor is coupled to said second chamber via a conduit between said second chamber and said at least air one pressure sensor.

4. The device according to claim 1 , wherein said at least one air pressure sensor is a pressure transducer.

5. The device according to claim 1, wherein the device is made from non-metallic materials.

6. The device according to claim 1, wherein said at least one inlet opening is in the form of at least one slit.

7. The device according to claim 6 and including at least one of the following:

- wherein the slit is in the form of a rectangular slit having a length dimension and a width dimension, the length dimension being greater than the width dimension;

- wherein the slit is in the form of a rectangular slit having a length dimension and a width dimension, the length dimension being greater than the width dimension, and, wherein the length dimension is at least partially vertical with respect to facing airstream;

- wherein the slit is in the form of a rectangular slit having a length dimension and a width dimension, the length dimension being greater than the width dimension, and, wherein the length dimension is vertical with respect to facing airstream;

- wherein the slit is in the form of a rectangular slit having a length dimension and a width dimension, the length dimension being greater than the width dimension, and, wherein said length dimension is between 5mm and 15mm;

- wherein the slit is in the form of a rectangular slit having a length dimension and a width dimension, the length dimension being greater than the width dimension, and, wherein said length dimension is about 10mm;

- wherein the slit is in the form of a rectangular slit having a length dimension and a width dimension, the length dimension being greater than the width dimension, and, wherein said width dimension is between 0.15mm and 0.65mm;

- wherein the slit is in the form of a rectangular slit having a length dimension and a width dimension, the length dimension being greater

than the width dimension, and, wherein said width dimension is about 0.6mm;

- wherein the slit is in the form of a rectangular slit having a length dimension and a width dimension, the length dimension being greater than the width dimension, and, wherein a ratio of said length dimension to said width dimension is between 7.7 and 100;

- wherein the slit is in the form of a rectangular slit having a length dimension and a width dimension, the length dimension being greater than the width dimension, and, wherein a ratio of said length dimension to said width dimension is about 16.67;

- wherein said at least one slit has longitudinal edges that diverge in an aft direction through a thickness of said front housing wall;

- wherein said at least one slit has longitudinal edges that are parallel to one another through a thickness of said front housing wall; or

- wherein said at least one slit has longitudinal edges that are parallel to one another through a thickness of said front housing wall, and, wherein said longitudinal edges are angled with respect to a front face of said front housing wall;

- comprising two said slits transversely spaced from one another.

8. . The device according to claim 1, including at least one of the following:

- wherein said EM system is configured for providing laser energy of wavelength of about 1470nm or about 1550nm;

- wherein said EM system is configured for providing laser energy of intensity between 0.01 W/mm2 and 0.1 W/mm2;

- wherein said EM system is configured for providing laser energy of intensity 0.03 W/mm2;

- wherein said EM system is further configured for directing said laser energy toward said front housing wall;

- wherein said EM system is configured for directing said laser energy toward said at least one outlet opening; or

- wherein said EM system comprises at least one optical fiber accommodated in said second chamber for transmitting EM energy along a respective optical axis.

9. The device according to claim 1, wherein the at least one outlet aperture includes a surface tension breaker.

10. The device according to claim 9, wherein said surface tension breaker includes a mechanical stop located just aft of the outlet opening.

11. The device according to claim 10, including at least one of the following:

- wherein said mechanical stop is located just aft of the outlet opening;

- wherein said mechanical stop projects generally towards and into said outlet opening, and further projects outwards in a general direction away from said outlet opening; or

- wherein said mechanical stop comprises a continuous surface between an inside of the outlet opening and an outside of the device.

12. A device for detecting presence of ice in an airstream, the device comprising:

- a housing defining a first chamber;

- the first chamber having at least one inlet opening on a front housing wall facing the airstream, and at least one outlet opening, smaller than the at least one inlet opening;

- the device configured for being operatively coupled to at least one electromagnetic (EM) laser system that is configured for transmitting EM laser energy to said first chamber, said EM laser energy being configured

for melting ice that may accrete on said front wall, especially the at least one inlet opening;

- the device being configured for being operatively coupled to at least one air pressure sensor in fluid communication with said first chamber for detecting at least pressure changes in said first chamber responsive to ice accretion on said at least one inlet opening.

13. A device for detecting presence of ice in an airstream, the device comprising:

a housing defining a first chamber having at least one inlet opening on a front housing wall facing the airstream, and at least one outlet opening, smaller than the at least one inlet opening;

said first chamber being configured for coupling to at least one air pressure sensor to provide fluid communication with said first chamber for detecting at least pressure changes in said first chamber responsive to ice accretion on said at least one inlet opening;

the at least one inlet opening being in the form of at least two slits, the at least two slits being at least partially vertical with respect to facing airstream;

wherein each of the two slits is in the form of a rectangular slit having a length dimension and a width dimension, the length dimension being greater than the width dimension; and

wherein the at least two slits are transversely spaced from one another.

14. The device according to claim 13, including at least one of the following:

- wherein the length dimension is at least partially vertical with respect to facing airstream;
- wherein the length dimension is vertical with respect to facing airstream;
- wherein said length dimension is between 5mm and 15mm;
- wherein said length dimension is about 10mm;

- wherein said width dimension is between 0.15mm and 0.65mm;
- wherein said width dimension is about 0.6mm;
- wherein a ratio of said length dimension to said width dimension is between 7.7 and 100;
- wherein said at least one slit has longitudinal edges that diverge in an aft direction through a thickness of said front housing wall; or
- wherein said at least one slit has longitudinal edges that are parallel to one another through a thickness of said front housing wall, and wherein optionally said longitudinal edges are angled with respect to a front face of said front housing wall.

15. A device for detecting presence of ice in an airstream, the device comprising:

- a housing defining a first chamber having at least one inlet opening on a front housing wall facing the airstream, and at least one outlet opening, smaller than the at least one inlet opening;
- said first chamber being configured for coupling to at least one air pressure sensor to provide fluid communication with said first chamber, for detecting at least pressure changes in said first chamber responsive to ice accretion on said at least one inlet opening;
- wherein the at least one outlet aperture includes a surface tension breaker in the form of a mechanical stop;
- the at least one aperture comprising an outlet edge, and wherein said mechanical stop projects aft of the outlet edge.

16. The device according to claim 15, including at least one of the following:

- wherein said mechanical stop has a generally cylindrical or spherical shape;
- wherein said mechanical stop projects generally towards and into said outlet opening; or

- wherein said mechanical stop comprises a continuous surface between an inside of the outlet opening and an outside of the device.

17. The device according to claim 15, the device being further configured for coupling to at least one electromagnetic (EM) system that is configured for transmitting EM energy to said first chamber, said EM energy being configured for melting ice that can accrete with respect to the at least one inlet opening.