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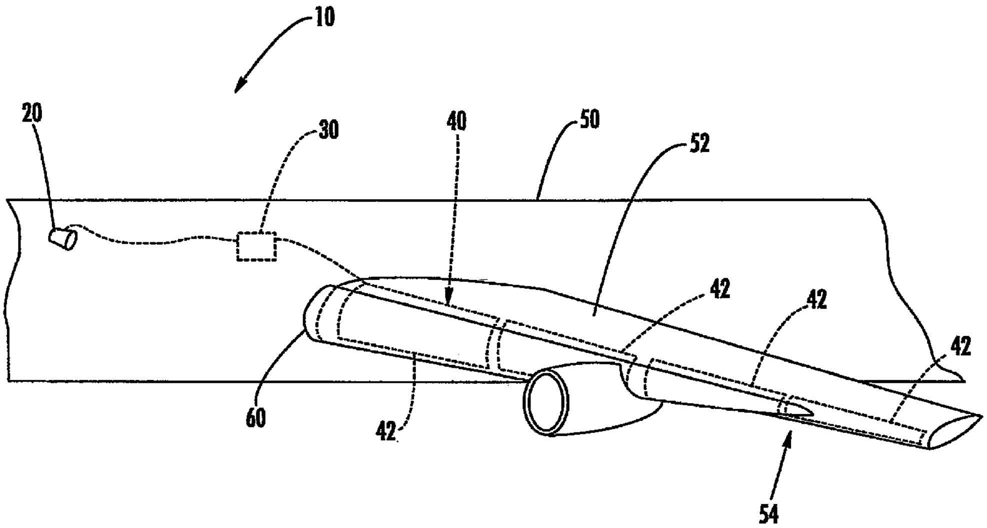
(54) **Title:** SYSTEM AND METHOD FOR THE DETECTION OF ICE AND OTHER DEBRIS ON A SURFACE MEMBER



(57) **Abstract:** A system and method for detecting debris on the surface of a member are provided, for example, for detecting ice or other debris on an other surface of an aircraft. The detection system includes a heating device in thermal communication with the member, an infrared sensing device configured to sense infrared radiation emitted from the member, and a monitoring device in communication with the sensing device. The monitoring device is configured to monitor a change in emission from the member and thereby detect the presence of debris on the surface of the member.

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SYSTEM AND METHOD FOR THE DETECTION OF ICE AND OTHER DEBRIS ON A SURFACE MEMBER

BACKGROUND OF THE INVENTION

1) Field of the Invention

The present invention relates to the detection of debris on a surface such as ice on an outer portion of an aircraft and, more particularly, relates to the detection of such debris according to the radiant characteristics of the surface and/or the debris.

2) Description of Related Art

The formation of ice and other debris on roadways, bridges, building structures, vehicles, and the like can negatively affect the characteristics of those devices. For example, the formation of ice on the outer surfaces of an aircraft can compromise the performance of the aircraft. For this reason, many aircraft have an ice detector that is used to determine whether ice may have formed on critical portions of the aircraft. One typical ice detector includes a probe that extends from the exterior of the aircraft. The probe is actuated to vibrate at a predetermined frequency. As ice or other debris forms or otherwise collects on the probe, the additional mass of the debris changes the frequency of vibration. The probe senses this change in frequency and, hence, recognizes that an icing condition exists at the probe. The icing condition on critical portions of the aircraft, such as the wings and control surfaces, can be inferred to exist when an icing condition exists at the probe, and a de-icing system can be activated. For example, the de-icing system can direct a flow of hot air from the aircraft engines through passages that extend through the wings, engine enclosures, or other portions of the aircraft to melt the ice. Alternatively, the de-icing system can include resistive heating elements disposed in the wings, engine enclosures, or other critical portions and configured to heat the critical portions to melt the ice.

Unfortunately, some uncertainty exists in the relationship between the icing condition as measured by the probe and the actual formation of ice on the critical portions of the aircraft. In order to provide a margin of safety to cover this uncertainty, the critical portions of the aircraft are at times heated when ice has not formed on those portions and to an extent beyond that which is necessary to de-ice them. This excessive heating requires bleed air from the aircraft engines or power from the aircraft electrical system and, therefore, unnecessary fuel consumption and/or decreased aircraft performance, thereby increasing the flight costs of the aircraft.

Thus, there exists a need for an improved system and method for detecting ice and/or other debris that can build up on critical portions of an aircraft or other devices. Preferably, the system should accurately detect the presence of debris on the critical portions of the device so that unnecessary heating or otherwise clearing of those portions can be minimized.

BRIEF SUMMARY OF THE INVENTION

The present invention provides a system and method for detecting debris on the surface of a member, e.g., ice on an outer surface of an aircraft, according to the change in the infrared radiation emitted from the member, which results from a diagnostic deposition of heat into the member. The presence of debris can be detected accurately and without relying on a correlation with an icing condition that exists at a remote probe.

According to one embodiment of the present invention, the detection system includes a heating device in thermal communication with the member, an infrared sensing device, and a monitoring device in communication with the sensing device. The heating device can be a conventional de-icing system, such as an electrical heating device or a system for directing hot gases through a passage in thermal communication with a wing or another member of an aircraft. The sensing device is configured to sense infrared radiation emitted from the member, and the monitoring device is configured to monitor a change in emission from the member and thereby detect the presence of debris on the surface of the member.

The monitoring device can be configured to compare the change in emission of the member to a predetermined characteristic. Further, the sensing device can be configured to sense infrared radiation emitted from a plurality of portions on the surface of the member, and the monitoring device can be configured to detect changes in radiation emitted from the plurality of portions and thereby detect the presence of debris on the surface of the member at each portion.

The monitoring device can also be configured to control the heating device. For example, the monitoring device can actuate the heating device upon detection of ice on the member. Further, the monitoring device can be configured to transmit an electronic signal to a status indicator device indicating the detection of debris on the member.

According to one method of the present invention, a heating device is actuated and thereby heats the member, a resulting change in the infrared radiation emitted from the member is sensed, and that change is analyzed to determine the presence or absence of debris on the surface of the member. For example, a profile of the radiation emitted from the member as a function of time can be determined, and that profile can be compared to predetermined characteristic temporal profiles. The predetermined profile characteristic can be determined by actuating the heating device when debris is known to exist on the member, sensing the infrared radiation emitted from the member, and determining the resulting change in the infrared radiation. Further, profiles of the radiation emitted from the member can be sensed and monitored for a plurality of portions of the surface to detect the presence of ice on the surface at each portion.

The debris can be detected according to the rate of increase in the radiation emitted from the member during and following the heating step or the rate of decrease in the radiation emitted from the member subsequent to the heating step. Further, upon detection of debris on the member, an electronic signal can be transmitted to a status indicator device, and/or the heating device can be automatically actuated to a debris-clearing mode.

According to one aspect of the invention, the detection method and system are used to detect ice on an outer portion of an aircraft. The heating device and the sensing device can be onboard the aircraft and configured to operate during flight or on the ground. Alternatively, the sensing device can be remote from the aircraft and configured to sense the radiation emitted while the aircraft is on the ground or in flight. In either case, the actuating, sensing, and determining can be repeated according to a predetermined schedule.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

Figure 1 is a plan view illustrating an aircraft with a system for detecting ice or other debris on the aircraft according to one embodiment of the present invention;

Figure 2 is a perspective view illustrating one wing of the aircraft of Figure 1;

Figure 3 is a schematic diagram illustrating the detection system according to one embodiment of the present invention;

Figure 4 is a graph illustrating the magnitudes and temporal behavior of diagnostic thermal energy impulses delivered to the surface to be tested, and the magnitudes and temporal behavior of the resulting infrared radiation signature impulses emitted by the combination of the surface and any debris accreted thereon, as observed by a detection system such as the detection system illustrated in Figure 3; and

Figure 5 is a flow chart illustrating the operations for detecting ice or other debris on a surface according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, this invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

Referring now to the figures and, in particular, Figures 1-3, there is shown a detection system **10** for detecting ice or other debris on an aircraft **50**. The application of the detection system **10** of the present invention is not limited to aircraft, and it is understood that the detection system **10** can be used to detect ice or other debris on a variety of members and surfaces. For example, the detection system **10** can be used to detect ice on any part of the aircraft **50**. Alternatively, in other embodiments of the invention, the detection system **10** can be used to detect debris on a roadway, bridge, aircraft runway, building, space structure, marine or other vehicles, and the like. Further, the system **10** can be used for detecting various types of debris including ice, dirt or dust, water, and other materials. Such members emit infrared radiation in varying magnitudes, and the magnitude of infrared radiation from each member generally varies as a function of temperature.

As shown in Figures 1 and 2, the detection system **10** includes at least one infrared sensing device **20** that is configured to sense infrared radiation emitted by a member of the aircraft **50**. For example, each sensing device **20** illustrated in Figure 1 is configured to sense radiation emitted from a respective wing **52** of the aircraft **50**, but in other embodiments, the sensing device **20** can additionally or alternatively sense emissions from other members of the aircraft **50** such as the rudders, elevators, engine shrouds, propellers, and the like. In addition, while the sensing device **20** is shown to be an onboard device, i.e., mounted on the aircraft **50**, the device **20** can alternatively be remotely mounted. For example, the sensing device **20** can be mounted on the ground proximate to a runway or hangar for sensing radiation emission from the aircraft **50** while the aircraft **50** is stationary or in motion. Alternatively, the sensing device **20** can be portable, e.g., a handheld device that can be held by an operator. In any case, the sensing device **20** can be an infrared camera that senses the infrared radiation emitted from a plurality of portions or points of the wing **52** and any debris accreted thereon. In particular, the device **20** can be a multi-pixel device, each pixel configured to sense the radiation emitted from a corresponding portion of the wing **52**.

As illustrated in Figures 2 and 3, the sensing device **20** communicates with a monitoring device **30** that is configured to monitor the infrared emissions from the wing **52**. For example, the monitoring device **30** can be located within the cabin of the aircraft **50** and can be electrically connected to the sensing device **20** by wire. Alternatively, the monitoring device **30** can be located integrally with the sensing device **20**, or the monitoring device **30** can be a remote device configured to communicate with the sensing device **20** via radio transmission or otherwise. Where multiple sensing devices **20** are used, such as for the wings **52** of the aircraft **50** of Figure 1, each sensing device **20** can be connected to a separate monitoring device **30** or more than one sensing device **20** can be connected a single monitoring device **30**.

As illustrated in Figures 1 and 2, the detection system **10** also includes a heating device **40** in thermal communication with the wing **52**. The illustrated heating device **40** is a conventional de-icing system for melting and thereby removing ice **60** from the wings **52** of the aircraft **50** before or during flight. Electrically resistive material **42** is disposed in, on, or near the wing **52**, for example, on the inner surface of the leading edge **54** of the wing **52**. When used for conventional de-icing, the resistive material **42** is electrically energized, and the resulting thermal energy heats the wing **52** and melts ice thereon. Alternatively, the de-icing system can be a system for directing hot gas, i.e., "bleed air," from the aircraft engines through one or more passages in thermal communication with the wings **52**. The use of hot gas and electrical resistive heating for de-icing is described in, for example, U.S. Patent Nos. 3,981,466 to Shah; 5,011,098 to McLaren, et al.; 5,865,397 to Herrmann; and 4,741,499 to Rudolph, et al., each of which is assigned to the assignee of the present application, and the entirety of each is incorporated herein by reference.

The monitoring device **30** is configured to monitor changes in emission radiated by the wing **52**, for example, an increase in infrared emission due to operation of the heating device **40** or a decrease in infrared emission upon terminating operation of the heating device **40**. It is understood that infrared energy can also be emitted by ice **60** or other debris accreted or deposited on the wing **52**, and the total emission from the combination of the wing **52** and any ice **60** or other debris thereon is generally referred to herein as radiation from the wing **52**, even though some of the radiation may originate in the ice **60** or debris. Figure 4 graphically illustrates a time sequence of three thermal input impulses **70** delivered to the wing **52**, as generated by the heating device **40**, e.g., three intervals during which the electrical heating device **40** is energized. Figure 4 also graphically illustrates two exemplary resulting emission profiles **80**, **90** of radiation coming from the wing **52** of the aircraft **50** during and following the three thermal impulses **70** delivered by the heating device **40**. The first profile **80** is representative of the emission from a wing **52** on which no ice **60** is deposited, i.e., a bare or clean wing. In the illustrated embodiment, the infrared emission of the bare wing rises rapidly upon operation of the heating device **40**, peaks shortly after each thermal impulse **70** ends, and subsequently decreases. The second profile **90** is representative of the emission from a wing **52** on which ice **60** or other debris is deposited. As shown, the emission of the ice-bearing wing is expected to rise less rapidly than that of the bare wing and to rise to a maximum value that is smaller than the maximum value observed in the case of the bare wing. In addition, the emission from the ice-bearing wing can decrease at a slower rate than the rate of decreases for the bare wing. For simplicity of illustration, Figure 4 exhibits a case in which the bare-wing response **80** and the ice-bearing response **90** both start from the same baseline, that is the same equilibrium level of emission as it exists before the diagnostic thermal impulse **70** is applied. However, in other embodiments of the present invention, the detection system **10** can compare the profiles **80**, **90** even if the profiles **80**, **90** have different baseline levels.

While the present invention is not limited to any particular theory of operation, it is believed that if a thermal impulse **70** is delivered to the wing **52**, the resulting radiation energy observed by the sensing device **20** will be different depending on whether the wing **52** does or does not carry accreted debris such as ice. Using ice as an example, this difference in observed radiation can result for the following reasons among others: (a) any ice **60** that has formed a layer between the wing **52** and the sensing device **20** has a significant coefficient of infrared absorption and therefore tends to block radiation transmitted from the wing **52** to the sensing device **20**, so that less radiation from the underlying wing surface will be observed by the sensing device **20**, and at the same time, that ice layer itself emits characteristic radiation from its surface, which will be observed by the sensing device **20**; (b) the accreted ice **60** will have added mass and thereby will have added heat capacity to the wing **52**, and so will reduce the temperature rise of the wing **52** relative to the temperature rise of the bare wing **52** for a given quantity of thermal energy delivered by the heat input impulse **70**; (c) the finite thermal diffusivity of the ice **60** results in a delay between the time of the thermal impulse **70** and the rise in temperature of the outer surface of the ice **60**; (d) the ice **60** possesses a significant heat of fusion and therefore, for the case in which the inner surface of the ice reaches melting temperature, the temperature rise of the ice layer, including the outer surface of the ice layer observed by the sensing device **20**, is delayed during the time that the inner surface of the ice layer is being converted to water. For these reasons and/or other or different reasons, a thermal impulse to an ice-bearing surface of the wing typically results in a time-dependent profile of radiation, i.e., a temporal emission profile, from the wing in which the maximum value is smaller in magnitude and occurs later in time, relative to the time-dependent profile of radiation from the bare-wing surface.

The monitoring device **30** detects the presence of ice **60** or other debris on the surface of the wing **52** according to the change in radiation observed from the wing **52**. For example, the monitoring device **30** can compare the change in emission of the wing **52** to a predetermined characteristic, such as a predetermined value, rate, or temporal profile of radiation emission. According to one embodiment of the present invention, the profile characteristic is determined by a calibration operation in which a thermal impulse is initiated by actuating the heating device **40** at a time when ice is known to exist on the wing **52** and, separately, at a time when the wing **52** is known to be bare. The monitoring device **30** monitors the changes in the infrared radiation emitted and determines a profile characteristic that is representative of the ice-bearing wing and a profile characteristic that is representative of the bare wing. For a particular thermal impulse, the profile characteristic can be a particular rate of increase or decrease in emission or a range of such rates, a multi-order or other complex profile representative of the increase or decrease in emission, a time or range of times for which the emission is above or below a particular value, and the like. It is understood that a variety of other profile characteristics can be determined including, for example, a maximum value, i.e., the peak height of the radiation emission curve of Figure 4; the time interval between the thermal impulse and the maximum value or the overall phase of the emission profile relative to a periodic thermal impulse; the total radiation emitted from the wing **52**, e.g., represented by the area defined by the emission profile and determined as an integral of the emission profile; and/or other aspects of the shape of the emission profile. Further, the profile characteristic can be determined by theoretical or other methods. In particular, the profile characteristic can be determined as a function of the magnitude and duration of the heating impulse, the thermal characteristics of the wing material, the presence and thermal characteristics of any debris on the wing **52**, and the emissivity of the surface of the wing **52** and/or debris material.

The monitoring device **30** can also be configured to communicate with the heating device **40** to initiate the operation of the heating device **40** in a pulsed diagnostic mode to test for debris on command. The monitoring device **30** can also actuate the heating device **40** according to a predetermined schedule to periodically test for debris. In particular, the monitoring device **30** can control the heating device **40** to initiate operation of the heating device **40** for a predetermined interval and thereby initiate thermal impulses for heating the wing **52**. For example, the monitoring device **30** can energize the heating device **40** during an interval of between a fraction of a second and one or more minutes. The monitoring device **30** can be configured to initiate such impulses in order to determine the profile characteristics by the calibration operation described above.

Further, the monitoring device **30** can be configured to perform various functions upon detection of ice **60** on the wing **52**. For example, the monitoring device **30** can transmit an electronic signal to a status indicator device **32** such as a visual or audible enunciator in the cockpit of the aircraft to alert the pilot or other crew members. In addition, the status indicator can be recorded as a data entry in a flight log or other record. The monitoring device **30** can also be configured to actuate the heating device **40** to automatically begin a de-icing process upon detection of the ice **60**. While the heating device **40** can be pulsed or otherwise selectively operated in the diagnostic mode, the heating device **40** in the de-icing mode can be operated to provide sufficient thermal output for de-icing the wing **52**, e.g., by continuously heating the wing **52** until any ice thereon is melted.

In one advantageous embodiment of the present invention, the sensor device **20** is a multi-pixel device, and the monitoring device **30** is configured to independently detect the ice **60** on a plurality of portions of the wing **52**. The term "pixel" is not meant to be restrictive, and it is understood that each pixel can include one or more of the most elementary sensing members of the device **20**. Each pixel of the sensor device **20** can be configured to sense the radiation emitted from a corresponding portion of the wing **52**, and the monitoring device **30** can be configured to monitor each pixel independently and detect ice on each portion of the wing **52** according to profile characteristics of each portion. Thus, the detection system **10** can be used to "map" the location of the ice **60** on the wing **52**. Further, once ice has been detected, the monitoring device **30** can control individual units of the heating device **40**, e.g., the individual resistive materials **42**, so that the heating device **40** heats those portions of the wing **52** that bear the ice **60**. In some embodiments of the present invention, multiple monitoring devices **30** can be used to analyze spatially separate portions of a member.

Figure 5 illustrates the operations of detecting debris on a surface of a member according to one method of the present invention. It is understood that some of the operations can be omitted and/or additional operations can be performed without departing from the present invention. For example, in Block **100**, a heating device in thermal communication with the member is actuated to heat the member. The heating device can be a de-icing system that is integral to an aircraft wing or other member, such as an electrical heating device or a system for directing hot gas through a passage in thermal communication with the member. The resulting infrared radiation that is emitted from the member is sensed. See Block **110**. If the member is part of an aircraft, the radiation can be sensed during flight or while the aircraft is on the ground. Subsequently, the characteristics of the observed temporal profile of the infrared radiation are analyzed to determine if debris is present on the member. See Block **120**. For example, a profile of the radiation that is emitted from the member can be determined, and the profile can be compared to a predetermined profile characteristic, which can be determined by actuating the heating device and sensing the infrared radiation at a time when debris is known to exist on the member. Upon detection of ice or other debris on the member, the heating device can be automatically actuated, and/or an electronic signal can be communicated to a status indicator device. See Block **130**.

Many modifications and other embodiments of the invention set forth herein will come to mind to one skilled in the art to which this invention pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

THAT WHICH IS CLAIMED:

1. A detection system for detecting debris on a surface of a member, the system comprising:

a heating device in thermal communication with the member;

an infrared sensing device configured to sense infrared radiation emitted from the member; and

a monitoring device in communication with the sensing device and configured to monitor a change in emission from the member and thereby detect the presence of debris on the surface of the member.

2. A detection system according to Claim 1 wherein the heating device is an electrical heating device.

3. A detection system according to Claim 1 wherein the heating device includes a system for directing hot gases through a passage in thermal communication with the member.

4. A detection system according to Claim 1 wherein the heating device is a de-icing system for removing ice from the member.

5. A detection system according to Claim 1 wherein the member is an outer portion of an aircraft and the heating device is onboard the aircraft and configured to heat the outer portion of the aircraft.

6. A detection system according to Claim 5 wherein the sensing device is mounted on the aircraft and configured to sense the radiation emitted from the outer portion.

7. A detection system according to Claim 5 wherein the sensing device is remote from the aircraft and configured to sense the radiation emitted from the member.

8. A detection system according to Claim 1 wherein the monitoring device is configured to control the heating device to selectively activate the heating device to a diagnostic mode for the detection of debris and to a debris-removal mode.

9. A detection system according to Claim 1 wherein the monitoring device is configured to compare the change in emission of the member, resulting from a diagnostic heating of the member by the heating device, to a predetermined characteristic.

10. A detection system according to Claim 1 wherein the sensing device is configured to sense infrared radiation emitted from a plurality of portions on the surface of the member, and the monitoring device is configured to detect changes in the radiation emitted from the plurality of portions and thereby detect the presence of debris on the surface of the member at each portion.

11. A detection system according to Claim 1 wherein the monitoring device is configured to actuate the heating device to a debris-removal mode upon detection of debris on the member.

12. A detection system according to Claim 1 wherein the monitoring device is configured to transmit an electronic signal to a status indicator device indicating the detection of debris on the member.

13. A detection system for detecting ice on a surface of an aircraft, the system comprising:

a heating device in thermal communication with the surface and configured to heat the surface;

an infrared sensing device configured to independently sense infrared radiation emitted from a plurality of portions of the surface; and

a monitoring device in communication with the heating device and the sensing device, the monitoring device being configured to control the heating device and monitor changes in radiation emitted from the plurality of portions to determine a temporal emission profile for each of the portions and thereby detect the presence of ice on the surface at each portion.

14. A detection system according to Claim 13 wherein the heating device is an electrical heating device.

15. A detection system according to Claim 13 wherein the heating device includes a system for directing hot gases through a passage in thermal communication with the surface.

16. A detection system according to Claim 13 wherein the surface defines at least a portion of a wing of the aircraft.

17. A detection system according to Claim 13 wherein the monitoring device is configured to compare each temporal emission profile to a predetermined temporal emission profile characteristic.

18. A detection system according to Claim 13 wherein the monitoring device is configured to perform at least one function of the group consisting of actuating the heating device to a diagnostic mode, actuating the heating device to an ice-removal mode, and transmitting an electronic signal to a status indicator device indicating the presence or absence upon detection of ice on the surface.

19. A method of detecting debris on a surface of a member, the method comprising:

heating the member;

sensing an infrared radiation emitted from the member; and

determining a resulting change in the infrared radiation and thereby detecting the presence of debris on the surface of the member.

20. A method according to Claim 19 wherein said heating step comprises electrically energizing an electrical heating device.

21. A method according to Claim 19 wherein said heating step comprises directing a flow of hot gases through a passage in thermal communication with the member.

22. A method according to Claim 19 wherein said heating step comprises actuating a de-icing system integral to the member.

23. A method according to Claim 19 wherein said heating step comprises actuating a heating device for a predetermined interval.

24. A method according to Claim 19 wherein said sensing step comprises sensing the radiation emitted from at least one surface of an aircraft.

25. A method according to Claim 24 wherein said heating step comprises heating an outer surface of the aircraft during flight of the aircraft and said sensing step comprises sensing during the flight.

26. A method according to Claim 24 wherein said sensing step comprises sensing the radiation emitted from the outer surface while the aircraft is on the ground.

27. A method according to Claim 19 wherein said determining step comprises determining a temporal emission profile of the radiation emitted from the member.

28. A method according to Claim 27 wherein said determining step comprises comparing the temporal emission profile of the member to a predetermined profile characteristic and thereby detecting the presence of debris.

29. A method according to Claim 28 further comprising, before said heating step:

heating the member at a time when debris is known to exist on the member;

sensing the infrared radiation emitted from the member; and

determining a change in the infrared radiation and thereby establishing the predetermined profile characteristic.

30. A method according to Claim 27 wherein said determining step comprises determining the profile of the radiation emitted from the member during said heating step.

31. A method according to Claim 27 wherein said determining step comprises determining the profile of the radiation emitted from the member following said heating step.

32. A method according to Claim 19 further comprising automatically actuating a heating device to a debris-clearing mode, upon detection of debris on the member.

33. A method according to Claim 19 further comprising transmitting an electronic signal to a status indicator device upon detection of debris on the member.

34. A method according to Claim 19 further comprising repeating said heating, sensing, and determining steps according to a predetermined schedule.

35. A method for detecting ice on a surface of an aircraft, the method comprising:

heating the surface as a diagnostic measure by activating a heating device in thermal communication with the surface;

independently sensing infrared radiation emitted from a plurality of portions of the surface; and

determining changes in the infrared radiation emitted from the plurality of portions to determine an emission profile for each of the portions and thereby detecting the presence of ice on the surface of each portion.

36. A method according to Claim 35 wherein said heating step comprises electrically energizing an electrical heating device.

37. A method according to Claim 35 wherein said heating step comprises directing a flow of hot gases through a passage in thermal communication with the member.

38. A method according to Claim 35 wherein said heating step extends for a predetermined interval of time.

39. A method according to Claim 35 wherein said sensing step comprises sensing the radiation emitted from a plurality of portions of at least one surface of the aircraft.

40. A method according to Claim 35 wherein said determining step comprises comparing the profiles to predetermined profile characteristics and thereby detecting the presence of ice on the portions.

41. A method according to Claim 40 further comprising, before said heating step:

actuating the heating device and thereby heating the surface at a time when ice is known to exist on the surface;

sensing the infrared radiation emitted from the plurality of portions of the surface with ice; and determining a change in the infrared radiation for each portion and thereby establishing the predetermined profile characteristic for each portion.

42. A method according to Claim 35 wherein said determining step comprises determining the profiles of the radiation emitted from the portions during said heating step.

43. A method according to Claim 35 wherein said determining step comprises determining the profiles of the radiation emitted from the portions following said heating step.

44. A method according to Claim 35 further comprising performing at least one function of the group consisting of actuating the heating device to a de-icing mode and transmitting an electronic signal to a status indicator device upon detection of ice on the surface.

45. A method according to Claim 35 further comprising repeating said heating, sensing, and determining steps according to a predetermined schedule.

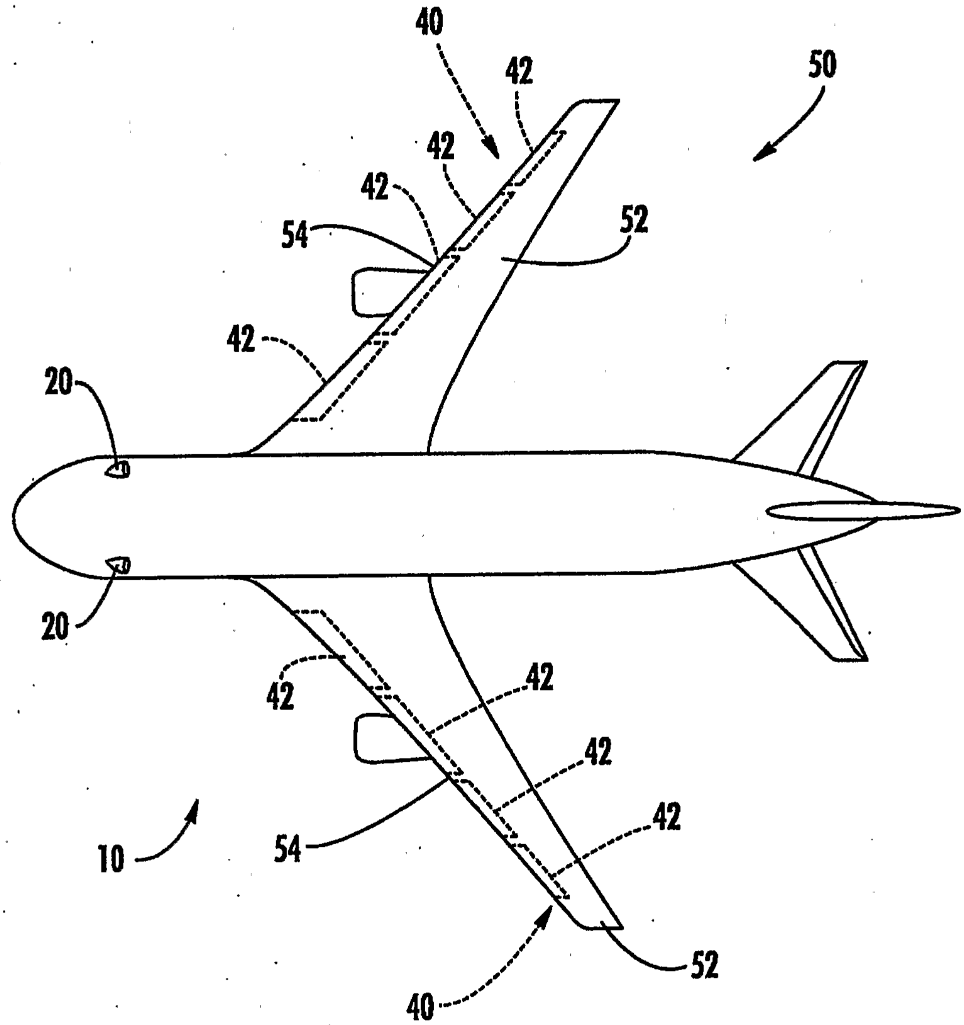

FIG. 1

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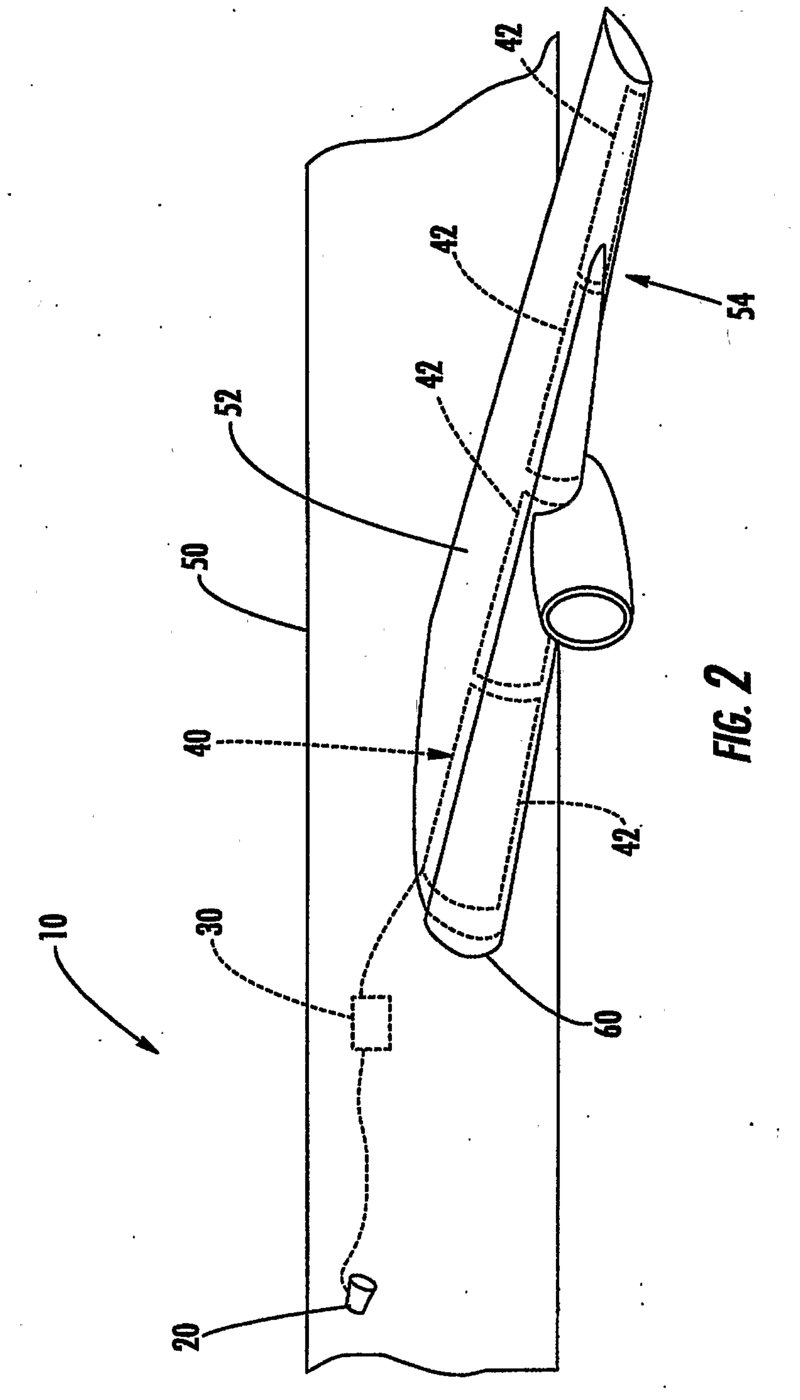

FIG. 2

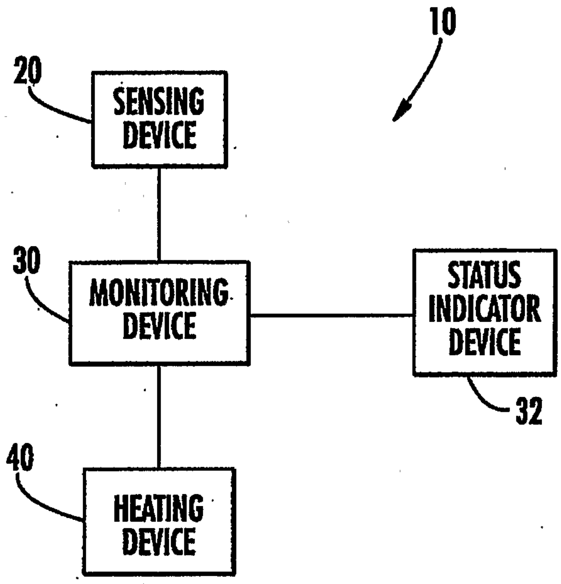
10
20
SENSING DEVICE
30
MONITORING DEVICE
STATUS INDICATOR DEVICE
32
40
HEATING DEVICE

FIG. 3

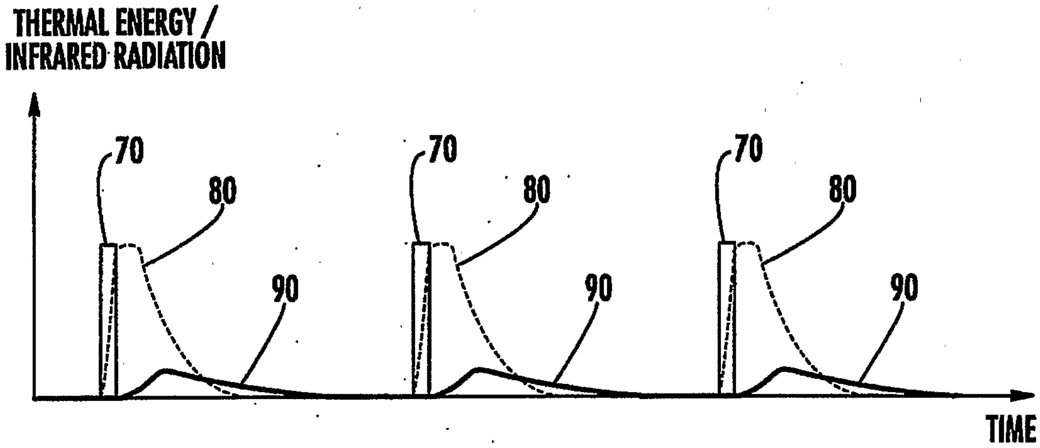
THERMAL ENERGY / INFRARED RADIATION
70
80
90
70
80
90
70
80
90
TIME

FIG. 4

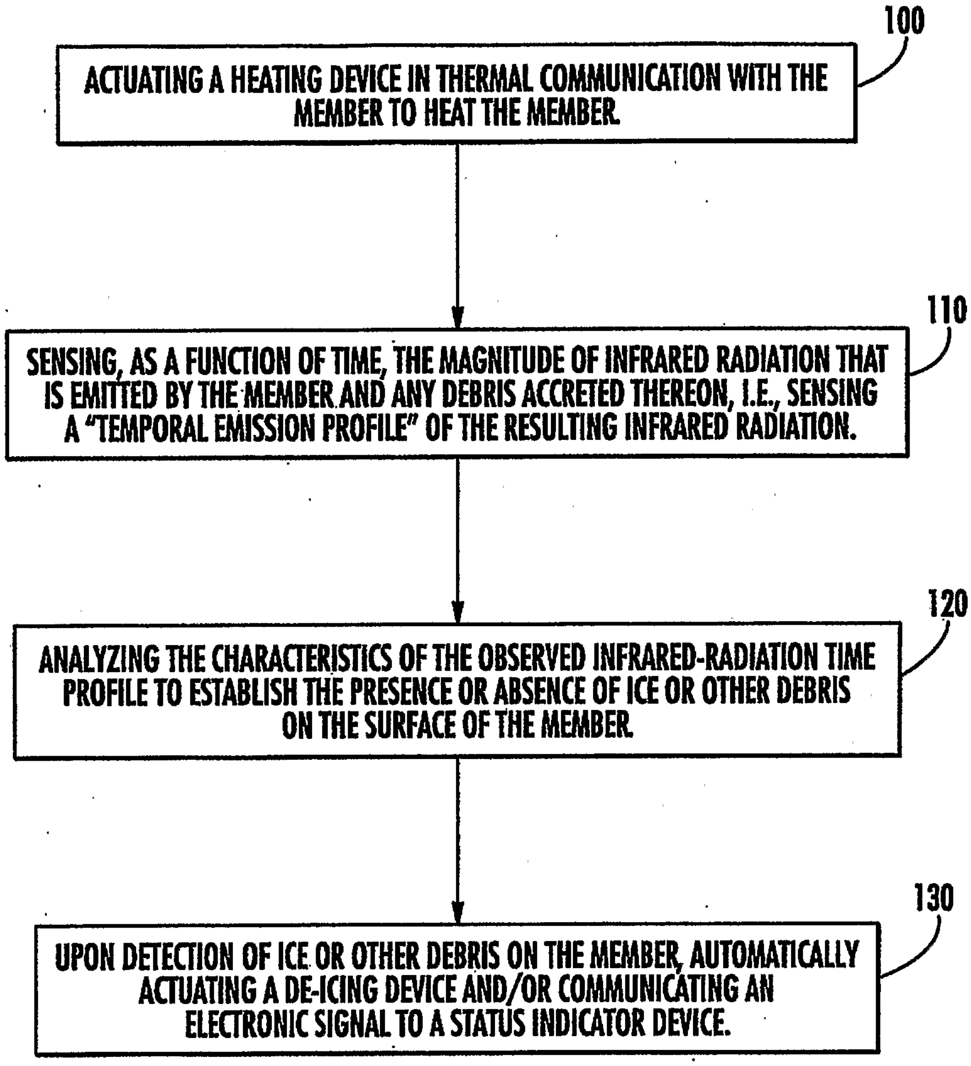
100
ACTUATING A HEATING DEVICE IN THERMAL COMMUNICATION WITH THE MEMBER TO HEAT THE MEMBER.
110
SENSING, AS A FUNCTION OF TIME, THE MAGNITUDE OF INFRARED RADIATION THAT IS EMITTED BY THE MEMBER AND ANY DEBRIS ACCRETED THEREON, I.E., SENSING A "TEMPORAL EMISSION PROFILE" OF THE RESULTING INFRARED RADIATION.
120
ANALYZING THE CHARACTERISTICS OF THE OBSERVED INFRARED-RADIATION TIME PROFILE TO ESTABLISH THE PRESENCE OR ABSENCE OF ICE OR OTHER DEBRIS ON THE SURFACE OF THE MEMBER.
130
UPON DETECTION OF ICE OR OTHER DEBRIS ON THE MEMBER, AUTOMATICALLY ACTUATING A DE-ICING DEVICE AND/OR COMMUNICATING AN ELECTRONIC SIGNAL TO A STATUS INDICATOR DEVICE.

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2005/015530

A. CLASSIFICATION OF SUBJECT MATTER
B64D15/20 G01N21/71 G01J5/00 G01J5/52 B64F5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B64D G01N G01J B64F

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 198 32 833 A1 (FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V) 10 February 2000 (2000-02-10) page 1, lines 3-8,64-66 page 2, lines 27-35; figures	1,2,9, 10,12, 19,20, 23, 27-29, 31,33
X	US 6 452 180 B1 (NISTLER JOHN L ET AL) 17 September 2002 (2002-09-17) column 1, lines 7-9 column 2, lines 8-17 column 2, line 66 - column 6, line 16; figures	1,2,9, 10,12, 19,20, 23, 27-31,33

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 April 2006	10/04/2006

Name and mailing address of the ISA/	Authorized officer
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 2002/162962 A1 (RUDOLPH RALPH G) 7 November 2002 (2002-11-07) the whole document	1-45
A	US 5 313 202 A (HANSMAN, JR. ET AL) 17 May 1994 (1994-05-17)	

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In tional application No
F . ./US2005/015530

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			WO	0173819 A2	04-10-2001
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			WO	9938774 A1	05-08-1999
US 2002162962	A1	07-11-2002	NONE		
US 5313202	A	17-05-1994	NONE		