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[54] **ICING CONDITION DETECTING APPARATUS**
8 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **340/234**
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[50] **Field of Search** 340/234; 324/61; 73/17, 53

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ABSTRACT: An icing condition detecting apparatus, by means of transducers, compares the temperature of a monitored surface against the temperature of an established reference temperature and further compares dew point against the temperature of said monitored surface in order to determine if such psychrometric parameters indicate the existence of conditions conducive to frost or ice formation on said monitored surface.

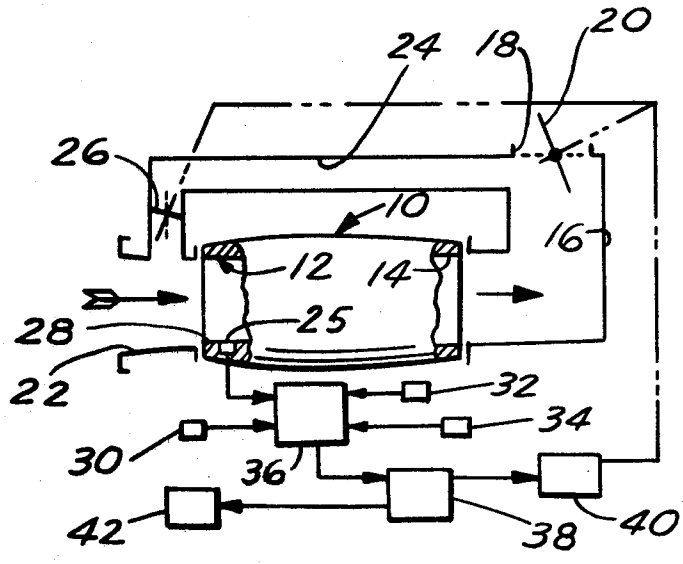


FIG. 2

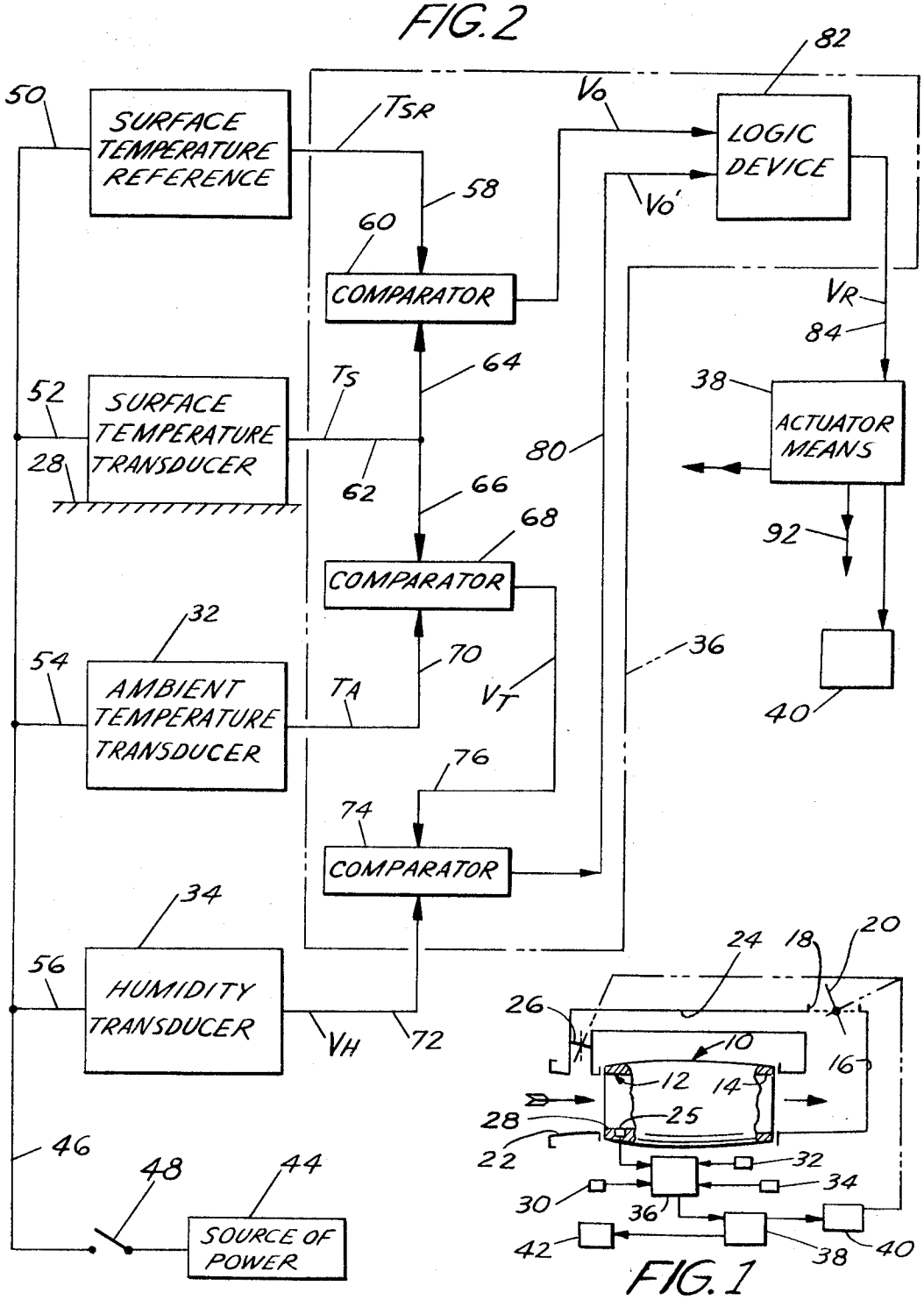


FIG. 1

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ICING CONDITION DETECTING APPARATUS

BACKGROUND OF THE INVENTION

Problems of frost formation and icing conditions with respect to stationary turbine engine power plants have not been successfully overcome by devices or apparatus proposed or suggested by the prior art.

It has been found that the air intake of such engines often experiences the formation of frost or ice thereon. Such a formation becomes dangerous, even if the physical size thereof is relatively small, because when such formations break off they have been known to puncture and fracture not only turbine blades but also combustor sections of the engine.

The prior art has attempted to solve this frost and icing problem by the application of heat thereto as by the recirculation of exhaust gases to the engine intake. Such an approach is generally acceptable; however, the manner and means by which the prior art devices attempted to achieve such a solution have not been acceptable.

For example, one prior art device employs a two-conductor grid with an associated heater. However, such a grid will detect the presence of only free water and it is not necessary to have free water to obtain frost formation. That is, any time the monitored surface temperature is 32° F. or below and is equal to dew point, frost will start to form on the surface even in the absence of free water. Accordingly, such prior art devices often failed to either detect the frost formation or protect the engine because the engine intake surface would often be cooled to temperatures of freezing, or below, by the venturi effect of the air flowing therethrough, and the intake surface reaching dew point would start to have frost buildup even though there was no presence of free water.

Other prior art devices attempted to correct these problems by having the device activated whenever, for example, the ambient temperature was 46° F. or below and relative humidity was 90 percent or above. This arrangement is based on the assumption that a constant temperature gradient would always exist between the engine intake surface temperature and ambient temperature; such an assumption is not true.

Such prior art systems often unnecessarily caused the recirculation of exhaust gases to the engine intake. The supply of such recirculating air or gas causes additional vibrations and stresses to occur in the engine guide vanes and therefore the too frequent and unnecessary supply of such gases leads to a shortened engine life because of such attendant unnecessary stresses. Further, the supply of such recirculated heated exhaust gases reduces engine efficiency thereby requiring more fuel for the same output horsepower. Accordingly, it can be seen that such prior art devices were not totally acceptable because of the often unnecessary resulting reduced engine efficiency and attendant deleterious effects on engine components.

SUMMARY OF THE INVENTION

An icing condition detecting apparatus according to the invention comprises first means for creating a first output signal indicating that the temperature of a monitored surface has attained a value equivalent to a predetermined temperature value, second means for creating a second output signal indicating that the said temperature of said surface is equivalent to dew point, and third means responsive to said first and second output signals for causing actuation of related output means.

Accordingly, a general object of this invention is to provide an icing condition detecting device which is effective for determining the precise moment at which conditions are proper for the formation of frost or ice.

Another more specific object of this invention is to provide an extremely accurate apparatus for detecting icing conditions by analog comparison of psychrometric parameters and exact digital switching when certain of such parameters exist.

Another object of this invention is to provide an apparatus as set forth in the preceding objects which will not only detect icing conditions but also cause actuation of associated control and/or warning means for either or both giving warning of the occurrence of such icing conditions and taking appropriate corrective measures as by actuation of heating means associated with a monitored surface.

Other more specific objects and advantages of the invention will become apparent when reference is made to the following detailed description considered in conjunction with the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a schematic illustration of apparatus embodying the invention being employed in combination with a stationary turbine engine power plant provided with an exhaust gas recirculating system; and

FIG. 2 is a schematic illustration of apparatus embodying the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now in greater detail to the drawings, FIG. 1 illustrates, by way of example, a gas turbine engine **10** having an air intake **12** and exhaust outlet **14**. Outlet **14** may be in communication with suitable conduitry **16** having an outlet **18** formed therein communicating with the atmosphere. A valve structure or member **20**, situated within outlet orifice **18**, is normally in an opened position as shown.

An air intake plenum **22**, communicating between the atmosphere and air intake **12**, is in communication with conduit means **24** communicating generally between plenum conduit **22** and exhaust conduitry **16**. A second normally closed valve **26** situated within interconnecting conduit **24** normally prevents the flow of relatively hot exhaust gases to plenum conduit **22**.

Various parameter and reference signal producing means are provided which, as will become apparent, cooperate to exercise certain ultimate control functions. For example, a surface temperature sensing transducer **25** is situated in the throat **28** of intake **12** so as to sense the temperature of the throat surface; further, a surface temperature reference device **30**, an ambient temperature sensing transducer **32**, and a humidity transducer **34** are each provided so as to direct their respective signals to associated circuitry, schematically represented at **36**, from which suitable correlated signals are produced and applied to associated actuator means **38** which may in turn energize a related control **40** as well as other means such as sensory or other signal producing means **42**. When conditions dictate, control **40** would cause valve **20** to be rotated to a more nearly closed position while valve **26** would be rotated to a more nearly opened position thereby permitting hot exhaust gases to be admitted to the intake **12** in order to heat the throat surface **28** and any frost or icing situated thereon.

Referring now to FIG. 2, it can be seen that a source of electrical power **44**, preferably regulated, provides electrical energy to surface temperature reference device **30**, surface temperature transducer **25**, ambient temperature transducer **32** and humidity transducer **34** via conductor **46** (and series situated switch **48**) and respective branch conductors **50**, **52**, **54** and **56**.

Before progressing with the description it should be noted that it is not essential to have the presence of free water in order to have frost or icing formation. That is, any time the surface temperature equals dew point (dew point being defined as that temperature at which a sample of air will have a relative humidity of 100 percent) and is at a temperature of 32° F. or below, frost or icing can form on that surface without the presence of free water in the atmosphere or on the surface.

Accordingly, the surface temperature reference device **30**, which may be an adjustable potentiometer, is adjusted and set

so as to create an output voltage signal, T_{SR}, on conductor means **58**, so as to apply such signal to an electrical comparator **60**. The potentiometer **30** may be adjusted so as to have voltage signal T_{SR} of a magnitude indicative of a temperature of 32° F.

Surface temperature transducer **25**, which may be a thermistor, is situated as to be continually reflective of the temperature of surface **28**. Accordingly, thermistor **25** continually creates a variable output voltage signal, T_S, on conductor means **62** and parallel branch conductors **64** and **66**, so as to apply such signal to electrical comparator or differential amplifier **60** as well as a second electrical comparator **68**.

Ambient temperature transducer **32**, which may be a thermistor, continually senses the atmospheric temperature and creates, in accordance therewith, a variable output voltage signal, T_A, on conductor means **70** so as to apply such signal to comparator **68**.

Humidity transducer **34**, which is of the differential type, that is, a differential humidity transducer, responds to the difference between dew point and ambient temperature and creates in accordance therewith a variable voltage signal, V_H, on conductor means **72** thereby applying such signal to a third comparator **74**. The other side of comparator **74** has applied thereto, as by conductor means **76**, a variable voltage signal, V_T, created as an output by comparator **68**.

Conductor means **78** and **80** respectively operatively connected to comparators **60** and **74** are each connected to suitable logic circuitry or logic device **82** which, in this instance, may be a NOR logic. As will become apparent, comparators **60** and **74** will at times respectively produce output signals, V_O, and V'_O, on conductors **78** and **80** so as to apply such signals to logic device **82**. When such signals are simultaneously received by logic device **82**, the device **82** creates an output signal, V_R, directed via conductor means **84** to associated actuator means **38** in order to achieve energization thereof.

OPERATION

Let it now be assumed that engine **10** is in operation, switch **48** closed, and surface temperature reference potentiometer **30** adjusted and set so as to create voltage signal T_{SR} of a magnitude indicative of 32° F.

It is further assumed that because of such phenomena as the venturi effect of the air flowing through the intake throat of the engine **10**, that the temperature of throat surface **28** will progressively decrease. As the thermistor or surface temperature transducer **25** senses such changes in temperature of throat surface **28**, thermistor **25** creates output voltage signal, T_S, of a magnitude reflective of the then existing temperature of surface **28**.

When signal T_S finally indicates that surface **28** has attained a temperature equivalent to that established by the reference potentiometer **30**, which in this case is assumed to be 32° F., comparator **60** senses the equality between signals T_S and T_{SR} and in response thereto creates output voltage signal V_O on conductor **78** and applies it to logic device **82**. However, this single signal V_O will not command the logic device **82** to produce the final output signal or actuating voltage V_R because the logic device **82** requires the simultaneous presence of both signals V_O and V'_O before it will produce output V_R.

The same signal, T_S, is applied to comparator **68** by means of conductor **66**. The other side of comparator **68** has applied thereto the variable signal, T_A, created by the ambient temperature transducer **32**, reflective of the actual ambient temperature. Preferably, comparator **68** is a differential amplifier which will amplify the difference between the signals T_A and T_S and create an output signal, V_T, proportional to such difference; however, comparator or amplifier **68** will only amplify the difference if the signal T_S from surface temperature thermistor **25** is less than the signal T_A created by ambient temperature transducer **32**.

For purposes of illustration, let it be assumed that the ambient temperature is 36° F. and that, as described, signal T_A is reflective thereof. Accordingly, it can be seen that signal T_S (equivalent at this point to 32° F.) is less than signal T_A and therefore comparator or amplifier **68** will create a signal V_T, on conductor **76**, equivalent to a difference of 4.0° F. and apply it as an input signal to a third comparator **74** which, preferably is also a differential amplifier.

As previously stated, humidity transducer **34** continually creates an output signal, V_H, indicative of the difference between dew point and ambient temperatures. This signal, V_H, is applied to comparator **74** via conductor means **72**. When signal V_H is reflective of a difference of 4.0° F. then both signals V_T and V_H are equal to each other and comparator **74** will then produce or create the second output signal V'_O on conductor **80** and apply it to the logic device **82**. As previously discussed, the simultaneous presence of signals V_O and V'_O on logic means **82** results in the creation of final output signal V_R for energizing appropriate actuator means **38**.

From the preceding, it should be apparent that comparator **74** determines when the surface **28** is actually at dew point. That is, first, comparator **68** creates a signal, V_T, which may be described in the following manner:

V_T = (ambient temperature) − (surface **28** temperature)

while differential humidity transducer **34** creates a signal, V_H, which may be described in the following manner:

V_H = (ambient temperature) − (dew point)

Accordingly, it can be seen that in each of the above equations, the "ambient temperature" values are equal to each other; therefore, when signal V_T is equal to signal V_H it means that surface **28** temperature must be equal to dew point (as defined herein).

Therefore, when both signals V_O and V'_O are present both "icing" conditions are existent; that is, the monitored surface **28** is at a temperature of at least 32° F. and the surface **28** is at dew point.

Actuator means **38**, upon being energized, may in turn cause actuation of related control means such as at **40** (FIG. **1**) for causing valve **20** to move to a more fully closed position and valve **26** to move to a more fully opened position. In such case, the heated exhaust gases will be communicated via conduitry **16** and **24** to the intake plenum **22** and intake **12** thereby heating the surface **28** of the intake throat in order to prevent any frost formation or icing buildup on such surface.

Other suitable related devices such as **42** may be actuated as by means of mechanical or electrical transmission means **90** and **92**.

The invention has been described with reference to its use in combination with a stationary power plant turbine engine **10**. However, it should be apparent that the invention is not limited to use in combination with such an engine and that the invention may be employed with reference to any surface to be monitored and protected from frost and ice formation.

One of the major advantages of this invention is its extreme accuracy in detecting icing conditions. This, of course, is accomplished through analog comparison of psychrometric parameters and exact digital switching when certain of such parameters exist.

In view of the preceding, it can be seen that, contrary to the prior art, heated exhaust gases are not delivered to the engine air intake **12** until such time as such gases are actually needed in order to prevent frost or ice formation. This, of course, results in not only increased engine efficiency, in comparison to prior art devices, but also extended engine life.

Although only one preferred embodiment of the invention has been disclosed and described, it is apparent that other embodiments and modifications of the invention are possible within the scope of the appended claims.

What I claim as my invention is:

1. Apparatus for detecting icing conditions on a surface, said apparatus comprising first means for creating a first output signal indicating that said surface has attained a temperature equivalent to a predetermined temperature, second

means for creating a second output signal indicating that said temperature of said surface is equivalent to dew point, and third means responsive to said first and second output signals for causing actuation of related output means, said first means comprising temperature responsive transducer means responsive to said temperature of said surface and effective for producing a variable signal in accordance therewith, reference signal producing means effective for creating a reference signal indicative of said predetermined temperature, and comparator means for receiving said variable signal and said reference signal, said comparator means being effective to create said first output signal when said variable signal and said reference signal collectively indicate that said temperature of said surface and said predetermined temperature are equal to each other, said second means comprising fourth means effective for both sensing ambient temperature and creating a first variable signal in accordance with the difference between said temperature of said surface and said ambient temperature, humidity responsive transducer means effective for sensing relative ambient humidity and creating a second variable signal in accordance with the difference between said ambient temperature and dew point, and first comparator means for receiving said first and second variable signals, said first comparator means being effective to create said second output signal when said first and second variable signals are equal to each other.

2. Apparatus according to claim 1 wherein said related output means comprises means for applying heat to said surface in order to raise said temperature of said surface above said predetermined temperature value.

3. Apparatus according to claim 1 wherein said temperature responsive transducer means comprises a thermistor, and wherein said reference signal producing means comprises a potentiometer.

4. Apparatus according to claim 1 wherein said temperature responsive transducer means comprises a thermistor, wherein said reference signal producing means comprises a potentiometer, and wherein said comparator comprises a differential amplifier.

5. Apparatus according to claim 1 wherein said humidity responsive transducer means comprises a differential humidity transducer continually responsive to the difference between dew point and said ambient temperature, and wherein said first comparator means comprises a differential amplifier.

6. Apparatus according to claim 1 wherein said fourth means comprises temperature responsive transducer means responsive to ambient temperature and effective for creating a first variable parameter signal in accordance therewith, second comparator means adapted to receive said first variable parameter signal and a second signal indicative of the temperature of said surface, said second comparator being effective to create said first variable signal in accordance with the difference between said first variable parameter signal and said second signal.

7. Apparatus according to claim 1 wherein said fourth means comprises temperature responsive transducer means responsive to ambient temperature and effective for creating a first variable parameter signal in accordance therewith, second comparator means adapted to receive said first variable parameter signal and a second signal indicative of the temperature of said surface, said second comparator being effective to create said first variable signal in accordance with the difference between said first variable parameter signal and said second signal, wherein said humidity responsive transducer means comprises a differential humidity transducer continually responsive to the difference between dew point and said ambient temperature, and wherein said first comparator means comprises a differential amplifier.

8. Apparatus according to claim 1 wherein said first means comprises temperature responsive thermistor means responsive to said temperature of said surface and effective for producing a first variable signal in accordance therewith, an adjustable potentiometer effective for creating a reference signal indicative of said predetermined temperature, and first comparator means comprising differential amplifier means for receiving said first variable signal and said reference signal, said differential amplifier means being effective to create said first output signal when said first variable signal and said reference signal collectively indicate that said temperature of said surface and said predetermined temperature are equal to each other, wherein said second means comprises second temperature responsive thermistor means responsive to ambient temperature and effective for creating a second variable parameter signal in accordance therewith, second comparator means adapted to receive said second variable signal and said first variable signal, said second comparator being effective to create a third variable signal in accordance with the difference between said first and second variable signals, a differential humidity transducer continually responsive to the difference between ambient temperature and dew point and effective to create a fourth variable signal in accordance therewith, third comparator means responsive to said third and fourth variable signals and effective to create said second output signal when said third and fourth variable signals are equal to each other, and wherein said third means comprises NOR logic circuitry.