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(54) IMPROVEMENTS IN PYROMETERS

(71) We, NEGRETTI & ZAMBRA (AVIATION) LIMITED, a British company of The Airport, Southampton, Hamphire, S09 3FR, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:–

This invention relates to pyrometers.

It has been found that in some applications, temperature measurement of a primary source of heat can be subject to error due to the presence of spurious sources of heat at a much higher temperature. The turbine blade pyrometer permits the surface temperature of a turbine blade to be estimated by measurement of the emitted black body radiation flux. Unfortunately, the measurement can be degraded by the transitory presence of hot carbon particles, from the combustion chamber which gives rise to large 'pulses' of radiation which, without identification, could lead to unduly high estimations of the turbine temperature. The hot carbon particles have a temperature considerably in excess of that of the turbine-blade surface. Consequently, the spectral distribution of the emitted radiation will be different, in particular, a greater proportion of the energy will be in the shorter wavelengths such as are associated with the visible region of the spectrum.

We have found that errors in the measurement of the temperature of a primary source in an environment which is subject to the presence of radiation from spurious objects can be detected or identified by spectral discrimination, that is by separating the radiation into at least two radiation components which respectively comprise radiation in different wavelength ranges such that a substantial proportion of the radiation in at least a first one of said components comprises radiation emitted by the primary source and a significant proportion of the radiation of at least a second one of said components comprises radiation emitted by the spurious source whereby the relationship between said components can be used to detect or identify the presence of radiation from the spurious source of heat. In a preferred embodiment of the invention the ratio of the magnitudes of the said first and second radiation components is used to detect or identify the presence of radiation from a spurious object.

Preferably, means, such as a dichroic filter, prism or grating is provided for separating the radiation into at least two radiation components.

According to the invention, there is provided a pyrometer system for determining the temperature of a primary source of heat in an environment which is subject to the presence of a transient spurious source of heat at a substantially different temperature from that of the primary source, comprising means for receiving radiation from the primary and spurious sources of heat, means for separating the received radiation into at least two radiation components which respectively comprise radiation extending over different ranges of wavelength, said different wavelength ranges being so selected that a substantial proportion of the radiation of at least a first one of said components comprises radiation emitted by the primary source and a significant proportion of the radiation of at least a second one of said components comprises radiation emitted by the spurious source, at least two means respectively responsive to the radiation of each of said radition components for producing corresponding output signals, the arrangement being such that the relationship between said signals in the presence of radiation received from said spurious source differs from the relationship between said signals in the presence of radiation received only from the primary source, and means responsive to the said relationship between said signals for providing an error signal indicative of the presence of said spurious source of heat.

The error signal may be used to modify operation of the pyrometer in dependence upon the relationship between the magnitudes of the respective output signals for example said error signal may be used to inhibit operation of the pyrometer.

Preferably the said error signal producing means comprises ratio determining means for obtaining the ratio of the magnitudes of the said output signals, and detector means responsive to the output of said ratio determining means for providing said error signal.

Means responsive to the said magnitude of the said second radiation component may be arranged to provide a compensating signal to reduce errors in the determined temperature value of the primary source due to the heat of the spurious source.

The compensating signal may be arranged continuously to reduce the said errors in the determined temperature value.

The means for separating the radiation into two spectral components may be a dichroic beam-splitting device, a prism or a grating.

The invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of part of a pyrometer system according to the invention,

Figure *2a* is a block circuit diagram of part of one embodiment of a pyrometer system for use with Figure 1,

Figure *2b* is a block circuit diagram of part of a second embodiment of a pyrometer system for use with Figure 1.

Figure *2c* is a block circuit diagram of part of a third embodiment of a pyrometer system for use with Figure 1,

Figure 3 is a block circuit diagram of part of a fourth embodiment of a pyrometer system for use with Figure 1,

In the drawings, like parts are given like references.

Referring to Figures 1 there is shown part of a pyrometer system 10 for determining the temperature of a turbine blade shown schematically at 12 in the presence of hot carbon particles 13. Radiation from the blade 12 is coupled by way of a glass fibre optical wave guide 14 and lens 16 to a dichroic beam-splitting device 18. The radiation from the turbine blade 12 can be contaminated by radiation emitted by carbon particles at a much higher temperature than the blade in the space between the blade and the light guide. The radiation emitted by the carbon particles will therefore have a significant proportion of its energy at a shorter wavelength than that emitted by the turbine blade. Typically the pyrometer is arranged to respond to radiation emitted by the blade 12 having a wave length in a range of approximately 0.8 to 1 μm. The radiation emitted by the blade 12 will probably have a wider range of wavelength, up to say 5 μm or more. The radiation emitted by the carbon particles will include components having a wave length in the range 0.8 to 1 μm but it will also include a significant proportion at a shorter wave length. The beam-splitting device 18 is arranged to split the radiation received from the direction of the source 12 into two radiation components, that is a first component having a range of wavelengths equal to or greater than 0.8 μm and a second component having a range of wavelengths less than 0.8 μm. The radiation of the first component is coupled by way of a signal channel comprising a filter 20 and lens 22 to a photodetector 24 of the pyrometer (not shown), the output of the photodetector 24 being amplified and processed in the pyrometer to produce an indication of the temperature of the turbine blade 12.

The radiation of the second component is coupled by way of an error channel comprising a filter 26 and lens 28 to a second photodetector 30. The filter 20 is arranged to substantially reduce or eliminate radiation at a wave length less than 0.8 μm and similarly, the filter 26 is arranged to substantially reduce or eliminate radiation at a wave length equal to or greater than 0.8 μm.

In an ideal situation, that is in the absence of any hot carbon particles, and for a given temperature of the blade 12, the magnitude of the radiation detected by detector 30, to generate an 'error channel' photo current, would be much less than that detected by detector 24, to generate a 'signal channel' photo current. Typically, in the absence of a hot carbon particle, the 'error channel' current would be about 1% to 16% of the 'signal channel' current depending upon the temperature of the turbine blade 12. In the presence of a hot particle, typically at 2,000°C, the 'error channel' current could rise significantly to a maximum of about 44% of the signal current.

The pyrometer system in its simple form could be arranged to determine the ratio of the error signal channel currents and if the proportion of the error channel current is greater than a predetermined value, say 16%, means could be provided for inhibiting the temperature measurement or otherwise indicating that the measurement may be in error.

Thus the output from the short wavelength error channel could be used to validate or conversely to suppress the output from the long wavelength signal channel from which the blade temperature is deduced. Figures 2A to C show three embodiments of apparatus of such a system.

Referring to Figures 1 and 2A, the output signals from the photodetectors 24 and 30 are coupled to the inputs of two pre-amplifiers 32 and 34 respectively. The output of the amplifier 32 is processed by the pyrometer to provide an indication of temperature and is coupled to one input of a divider circuit 36. The output of the amplifier 34 is coupled to the other input of the divider circuit 36. The output of the divider circuit 36, which is equal to the ratio of the magnitudes of the error and signal currents, is coupled to a threshold detector circuit 38 which is arranged to provide a 'flag' output signal to a processor 27 if the ratio exceeds a predetermined value to indicate an erroneous temperature reading due to the presence of hot carbon particles.

Referring to Figure 2B, there is shown a circuit similar to that of Figure 2A but in this circuit the output of the signal current amplifier 32 is coupled through a gate 40 to be processed and the output from detector 38 is coupled to a control input of the detector 40 so that a measurement is suppressed by the flag signal when the said ratio exceeds a predetermined value to close the gate 40.

Figure 2C is again similar to Figure 2A, with the exception that the output of amplifier 32 is coupled to the main processor by way of a high-speed sample and hold circuit 42 which is strobed by a clock signal coupled by way of a gate circuit 44 from a clock pulse generator 46. The gate 44 is controlled by the output from the threshold detector 38. When the threshold detector 38 indicates an erroneous measurement, the clock is gated and the processor is supplied with the last obtained 'good' signal. In this case the 'flag' signal indicates that the indicated temperature reading is a stored rather than a current reading.

In a development of the invention, it may be possible to compensate the signal channel continuously for errors which can be determined from the error channel and arising from spurious heat sources such as hot carbon particles. The ratio of the powers in each channel generated by a hot surface in isolation is constant for a particular temperature and this is, of course, the basis of the well known technique of two colour pyrometery from which this invention is distinguished by the fact that the former is simply a technique for temperature estimation whereas the present invention is concerned with a technique for reducing or eliminating the effects on temperature estimation of a primary source such as a turbine blade from corruption by radiation from a spurious source, such as hot carbon particles. The compensation process can comprise subtracting a fixed proportion or multiple of the magnitude of the radiation in the short wave error channel from that of the signal channel in an electronic circuit. The value of this technique would depend upon the consistency of the hot particle temperatures and would have the benefit that the turbine blade temperature could be sensed even in the presence of hot particles, whereas the basic invention would be used merely to identify and invalidate erroneous measurements taken in the presence of hot particles.

By the use of the invention it should also be possible to compensate the temperature estimation of a primary source of heat from the corrupting influence of radiation from another spurious source of radiation such as reflections from a turbine blade of flames in the combustion chamber and sunlight from the engine outlet. The error detecting channel could also be used to monitor faulty operation of the engine.

Figure 3 shows a simplified block circuit diagram of a circuit in which the error current from amplifier 34 is subtracted continuously from the signal current from amplifier 32 in a subtraction circuit 48. The output from amplifier 34 is coupled to circuit 48 by way of a scale factor circuit 50 by means of which the error current can be scaled as required. The efficiency of this mode of operation is dependent upon the constancy of the anomalous signal characteristics.

Linear preamplifiers are shown in the Figure 2. However, these are not essential and logarithmic preamplifiers may be used. In this case, the ratio can be obtained by simple subtraction as

$$\log A - \log B = \log (A/B)$$

There are many other ways of obtaining the ratio. These include analogue means such as logarithmic modules and integrated dividers, and digital means involving analogue to digital conversion and subsequent computing using hard wired logic or microprocessors.

WHAT WE CLAIM IS:–

1. A pyrometer system for determing the temperature of a primary source of heat in an environment which is subject to the presence of a transient spurious source of heat at a substantially different temperature from that of the primary source, comprising means for receiving radiation from the primary and spurious sources of heat, means for separating the received radiation into at least two radiation components which respectively comprise radiation extending over different ranges of wavelength, said different wavelength ranges being so selected that a substantial proportion of the radiation of at least a first one of said components comprises radiation emitted by the primary source and a significant proportion of the radiation of at least a second one of said components comprises radiation emitted by the spurious source and at least two means respectively responsive to the radiation of each of said radiation components for producing corresponding output signals, the arrangement being such that the relationship between said signals in the presence of radiation received from said spurious source differs from the relationship between said signals in the presence of radiation received only from the primary source, and means responsive to the said relationship between said signals for providing an error signal indicative of the presence of said spurious source of heat.

2. A pyrometer system according to Claim 1, in which the error signal is used to modify operation of the pyrometer in dependence upon the relationship between the magnitudes of the said output signals.

3. A pyrometer system according to Claim 1 or 2, in which the said error signal producing means comprises ratio determining

means for obtaining the ratio of the magnitudes of the said output signals, and detector means responsive to the output of said ratio determining means for providing said error signal.

4. A pyrometer system according to Claim 1, 2 or 3, in which the said error signal is arranged to inhibit operation of the pyrometer.

5. A pyrometer system according to Claim 1 or 2, in which an output signal representative of the magnitude of the first radiation component is coupled to an input of a sample and hold circuit having a clock input whereby operation of the sample and hold circuit can be synchronised to clock pulses from a clock pulse generator coupled through a gate, the output of the error signal producing means being coupled to the control input of the gate means to inhibit operation of the sample and hold circuit in the presence of an error signal.

6. A pyrometer system according to Claim 1, comprising means responsive to the magnitude of the said second radiation component and arranged to provide a compensating signal to reduce errors in the determined temperature value of the primary source due to the heat of the spurious source.

7. A pyrometer system according to claim 6, in which the compensating signal is arranged continuously to reduce the said errors in the determined temperature value.

8. A pyrometer system according to any one of the preceding Claims, in which the means responsive to the said radiation components comprise photoelectric devices.

9. A pyrometer system according to Claim 8, as dependent upon Claim 6 or 7, in which the compensating signal is derived from the photo-electric device responsive to said second radiation component and the pyrometer further comprises means for subtracting said compensating signal from the output signal from the photo-electric device responsive to the first radiation component to effect the reduction in error in the determined value of temperature.

10. A pyrometer system according to any one of the preceding Claims, including a dichroic beam-splitting device for separating the received radiation into two components.

11. A pyrometer system according to Claim 8 or Claim 9 or Claim 10 as dependent upon Claim 8, in which a first filter is arranged between said means for separating the radiation and one of said photo-electric devices, the filter being arranged to define one of said wavelength ranges.

12. A pyrometer system according to Claim 11, in which a second filter is arranged between said means for separating the radiation and the other or another photo-electric device, the second filter being arranged to define the other or another of said wavelength ranges.

13. A pyrometer system according to Claim 11 or 12, in which means is arranged between each said filter and its associated photo-electric device to focus radiation passing through the filter on the photo-electric device.

14. A pyrometer system according to any one of the preceding Claims, comprising means for focusing radiation from said primary and spurious sources of heat on the means for separating the radiation.

15. A pyrometer system according to Claim 14, in which the radiation from said sources is transmitted to said pyrometer system by way of a light guide.

16. A pyrometer system according to any one of the preceding Claims, in which the said primary source is a turbine blade.

17. A pyrometer system according to claim 16, in which the spurious source comprises hot carbon particles from the combustion chamber of the turbine.

18. A pyrometer system according to claim 16 or 17, in which the spurious source comprises reflections from the turbine blades such as reflections of flames in the combustion chamber or light, for example sunlight, from the engine outlet.

19. A pyrometer system substantially as hereinbefore described with reference to and as illustrated in Figure 1 or Figure 1 with Figure 2A, B or C or Figure 1 with Figure 3 of the accompanying drawings.

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1602160 COMPLETE SPECIFICATION

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Sheet 1

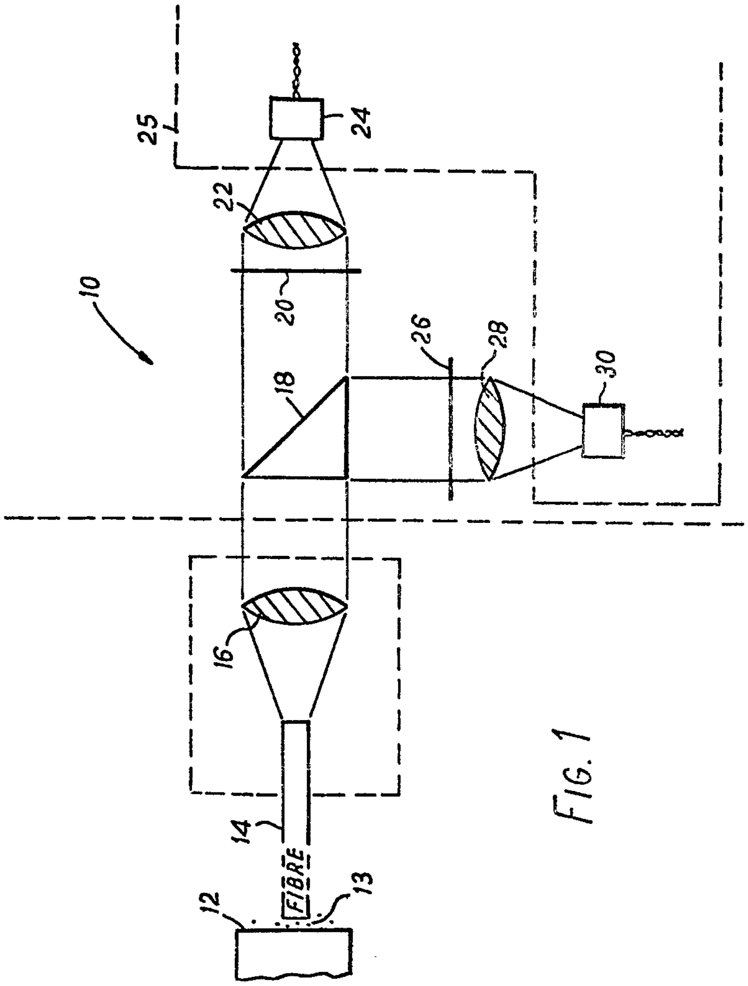

FIG. 1

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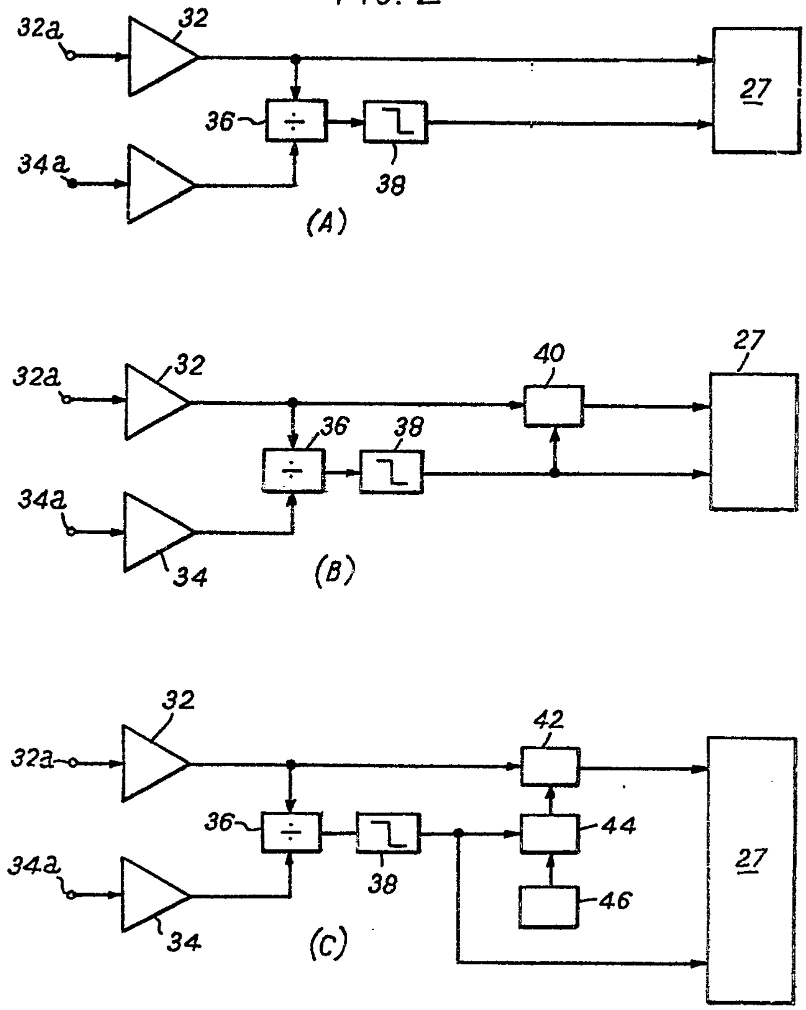
Sheet 2

FIG. 2



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Sheet 3

FIG. 3