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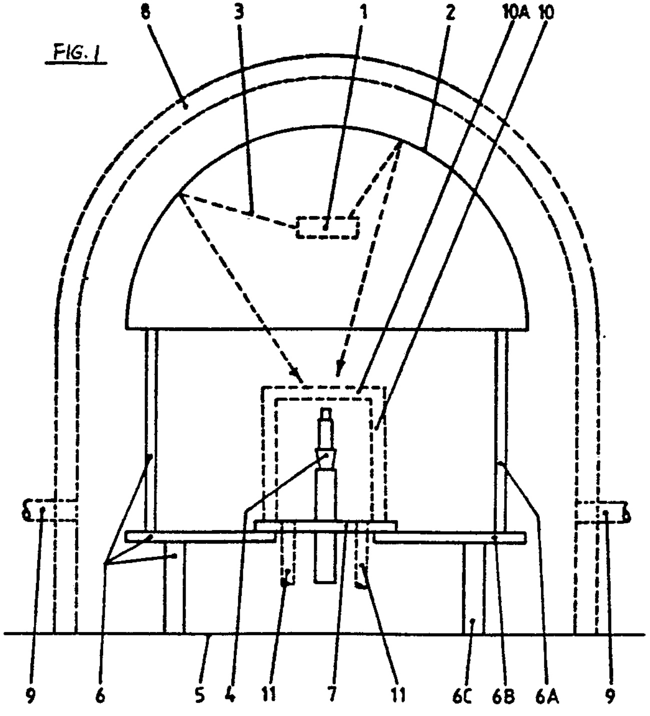
(54) Improvements in or relating to testing materials subject to thermal radiation

(57) The burning behaviour of material (4) subjected to incident thermal radiation is investigated by locating the material at one of the focal points of an elliptical reflector (2) and subjecting it to radiation (3) reflected from a source (1) located at the other focal point. The environment surrounding the material is controlled and the changes occurring when the material is irradiated are observed and/or measured. The entire apparatus may be provided with a glass cover 8, or the test material 4 alone may be provided with a glass cover 10. Pipes 9 or 11 allow the atmosphere surrounding material 4 to be controlled. The material 4 may be subjected to pulses of radiation and the loss in weight of the material may be measured. Wind effects the effect of particles impinging on the material 4 and the effect of other substances located adjacent the material may be investigated. Breakdown gases may be analysed and the reaction kinetics measured.

FIG. I



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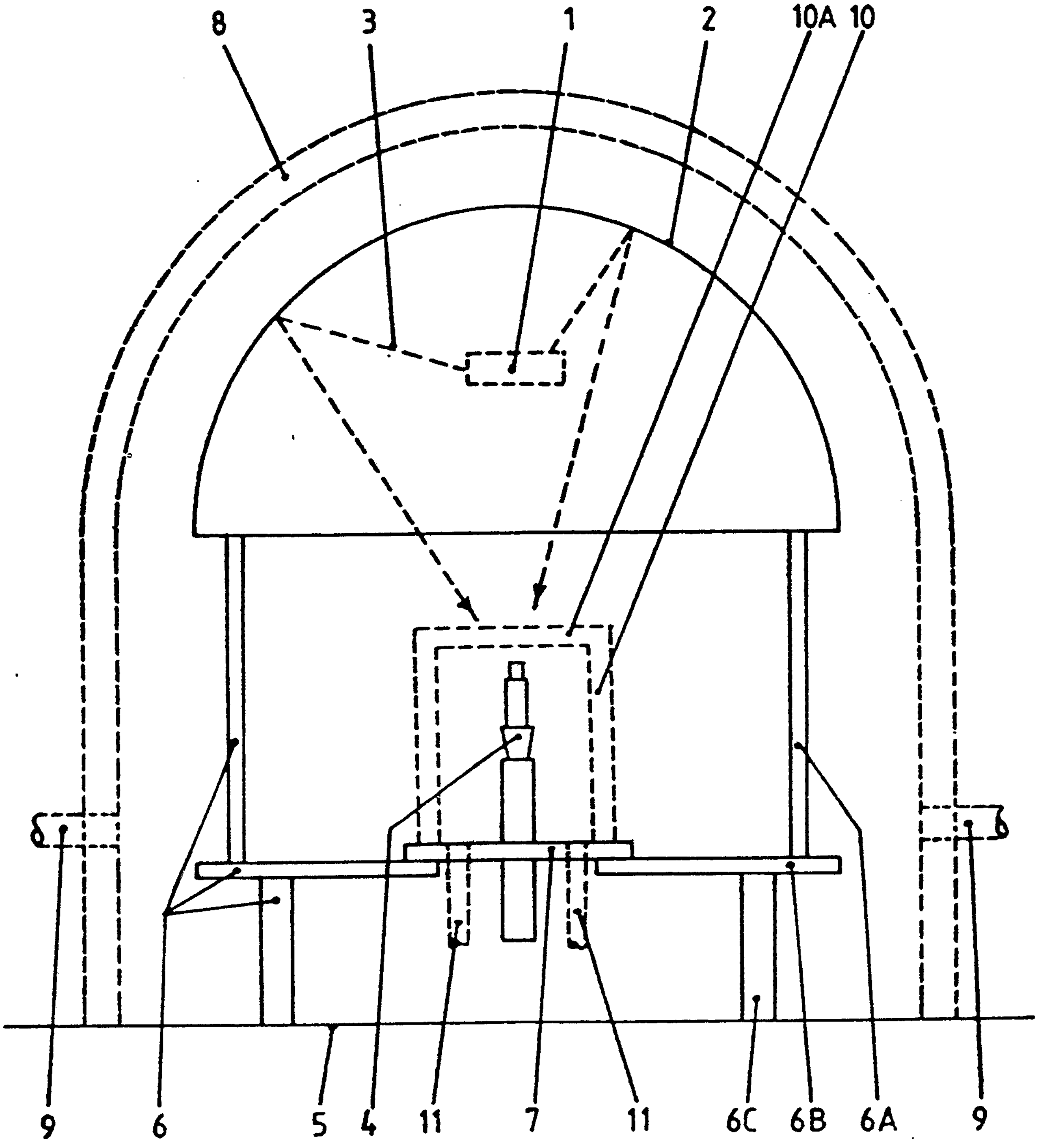

FIG. 1

IMPROVEMENTS IN OR RELATING TO THERMAL IMAGING TECHNIQUES

This invention relates to thermal imaging and is concerned with its use as a modelling technique wherein a small section of a component or a model of a larger object may be selectively or entirely subjected to a controlled thermal flux.

The effects of fires are horrifying on those directly caught in the inferno and their would-be rescuers. Major fires, e.g. in airliners, tower blocks or industrial establishments, are usually highly publicised and have led to major studies in the development of fire resistant and fire retardant materials.

It is normal practice to test fire resistant and fire retardant materials under certain arbitrary conditions. The test scale may be of a magnitude whereby an assembly in a compartment, etc., is undertaken. Full scale testing usually proves only whether or not a particular material or component passes or fails. It is often impossible to study the kinetic and thermal processes occurring because smoke obscures direct observation and the intense heat may damage the probes, instruments, etc., designed to study the propagation of the fire in its early stages. Even small scale tests do not fully overcome these problems and additionally suffer from other ones.

There is thus a need for a means of testing components and parts thereof under reproducible laboratory scale conditions so that detailed studies can be performed on the thermal, kinetic and chemical processes involved. A further advantage of small scale tests is that they are much more cost-effective and can be designed to determine reaction kinetics and rate determining processes.

According to the present invention, there is provided a method of obtaining data concerning the manner in which a material behaves when subject to incident thermal radiation, said method comprising:-

(i) providing a part elliptical reflector having first and second focal points;

(ii) placing a source of radiation essentially at the first focal point of the reflector;

(iii) placing the material essentially at the second focal point of the reflector;

(iv) energising said source of radiation for a predetermined time so that said radiation is focussed on said material;

(v) controlling the environmental conditions surrounding said material; and

(vi) observing and/or measuring changes which occur to said material as a consequence of being subjected to the radiation.

The method of the present invention can be carried out using a thermal imaging apparatus comprising:

(i) a source of radiation;

(ii) a reflector having the shape of a surface of revolution of part of an ellipse rotated about its major axis such that the reflector has first and second focal points;

(iii) mounting means for supporting said source of radiation at the first focal point of said reflector; and

(iv) a supporting means for supporting said source and reflector such that the second focal point of said reflector is at a predetermined position in relation to the surrounding environment.

The material under test is located at said position and the radiation emitted by said source is concentrated by said reflector onto the material. The material to be tested may be one or more substances or one or more assemblies of substances. For example, it may be a model or a piece of equipment.

Preferably the first focal point is nearer to the reflector than the second focal point and a means of accurate adjustment is provided in the mounting means to position the source of radiation as near the first focal point as possible. The adjustment may be achieved by moving the position of the source or the reflector, or both. The mounting means preferably provides a minimum of optical obstruction so that the maximum amount of radiation emitted from the source at the first focal point is focussed at the second focal point. The supporting means is used to locate the reflector assembly at a suitable position above a bench, or workpiece and may also include means by which the material under test e.g. a test piece, may be located at the second focal point. Preferably the reflector is at least semi-elliptical.

In use the test material is mounted at the second focal point and, when the source is activated, either on a continuous or intermittent basis, the radiation emitted is focussed on to the material. The resulting reaction to the energy input may then be monitored by suitable sensors in a detailed scientific way.

One of the advantages of using such an apparatus for combustion testing, is that the material being tested can be surrounded in a suitable glass envelope through which the combustion processes can be observed. In such an environment, other conditions may be simulated, e.g. differing gas mixtures, wind effects, the effect of solids impinging on the material, the presence of other substances nearby, etc. Other operations, e.g. rotation of the material during the test, etc., can also be performed, if required. The apparatus does not require a fume cupboard with all its appendages for ventilation and consequent fixed siting in the laboratory. Further, it does not require a heat shield below it since the energy is focussed at a focal point on a base plate above a work bench. The apparatus can be sited anywhere in the laboratory.

The method of the invention may be used for qualitatively assessing the resistance of the material to a given level of thermal radiation. Alternatively, the method may be used quantitatively, e.g. by using a series of short bursts of radiation and examining the material between each burst to determine reaction kinetics.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example only, to the accompanying drawing which is an elevation of a thermal imaging apparatus for use as a means of testing the thermal properties of materials.

Referring to the Figure there is shown, a source of radiation 1 mounted at one of the two focal points of a semi-elliptical reflector 2 formed as a surface of revolution of a part ellipse about its major axis. Reflector 2 is a three-dimensional polished member and acts as a "mirror" to reflect radiation 3, emitted by source 1. It is a property of an ellipse that radiation from the first focal point is "reflected" by the ellipse so as to pass through the second focal point; the term "reflected" is used here to imply that the normal laws of optical reflection are obeyed, i.e.

angle of incidence = angle of reflection.

Thus radiation 3 emitted by source 1 located at one focal point of an elliptical mirror will be reflected and concentrated at the second focal point. In the apparatus shown in Figure 1, a test piece 4, or a critical part of it, is mounted at the second focal point of reflector 2.

Although a semi-elliptical reflector 2 is shown in Figure 1, the actual surface area of the reflector 2 may be greater or less, than that shown. For use where high efficiencies are required, the area of the reflector would be increased by extending the ellipsoidal surface downwards towards the test piece 4 at the second focal point, i.e. to give an inverted "pear shaped" reflector.

For maximum efficiency, the test piece and the source are aligned on the optical axis. Provided this optical alignment is maintained, the apparatus can be used in any plane, i.e. the test piece 4 could be above reflector 2. However the arrangement shown in the drawing where the reflector 2 is mounted vertically above the test piece is the most convenient for normal laboratory work.

One problem with thermal testing is that gases are produced, usually as a partially opaque 'smoke'. It is also possible for solid or liquid matter to be ejected. To contain these emissions, it is desirable to isolate the test piece from the rest of the laboratory. The specimen under test 4 is therefore isolated from the rest of the laboratory by enclosing it and the reflector and source in an envelope in the form of in a glass cover 8. Alternatively, only the test piece 4 may be isolated by means of a glass cover 10 transparent to the wavelength of radiation 3 being used. To avoid reflection, the glass cover 10 is provided with an optically prepared flat surface 10A. However it could have a hemispherical surface (not shown) instead. The smaller isolating cover 10 is preferred over the larger glass cover 8 as the reflector 2 is thereby protected from smoke and spatter. In either case, the atmosphere inside the cover 8 or 10 can be varied via tubes 9 or 11 respectively. A whole range of variations is possible, e.g. reduced pressure, enriched oxygen level, gaseous contamination or merely simple replacement of stale air with fresh, etc. The volumes enclosed by the covers need to be of known size for subsequent calculations.

Reflector 2 is supported on a structure comprising upper vertical supports 6A, horizontal bars 6B and lower vertical supports 6C resting on a bench 5. The bench 5 may have a special surface to catch any burning debris ejected from the test piece 4 when glass cover 8 is used in preference to cover 10. The reflector 2 is preferably made from metal, e.g. aluminium, stainless steel, etc., of a thickness sufficient to avoid distortion under its own weight and consequent loss in optical efficiency. The inside of the reflector is highly polished. To avoid obscuring reflection of the rays 3, the reflector 2 rests on its edge on the top of pads (not shown) which are screwed into the supports 6A so that the height of reflector 2 is adjustable. The supporting pads are so constructed that by means of a screw mechanism (not shown), the reflector 2 can be moved horizontally and vertically to aid focussing. Source 1 is mounted between thin angled rods (not shown) to avoid obscuring reflection. Each rod is screwed into insulators (not shown) which are screwed into horizontal bus bars (not shown). The height of the source 1 is therefore adjustable by screwing the rods in or out. The source 1 needs to be moved in conjunction with the reflector 2 to achieve focussing. The source 1, mounted in this way, causes a minimum of optical disturbance. The whole is designed so that source 1 can be positioned exactly at the first focal point. The rods form the connections for the electric supply to source 1.

A second method of construction (not shown in the figure) is to space supports 6A further apart and to suspend reflector 2 from its rim or from fixing points on its outer surface. In this case, source 1 may be mounted from a suitable platform supported by an extension of supports 6A and passed through a hole in apex of reflector 2.

Depending on the size of the test piece 4, the whole, or a critical part of it, is mounted on table 7 supported on bars 6B so that it is on the optical axis at the second focal point of reflector 2. In this way the test piece 4 may be changed at will and complete models of a combination of components may be tested, e.g. a bushing in a flange (in this case the flange may replace table 7).

By shining a light through glass cover 10 the optical density of any smoke produced can be measured by means of a suitable sensor. The breakdown gases can be exhausted through one of the two tubes 9 (or 11) with the other of the tubes being closed and then be subjected to analysis by a suitable sensor to determine the chemical products of combustion. Alternatively one of tubes 9 (or 11) may be used to supply a stream of air or other gas so that studies can be carried out under constant volume of control gas if required.

A variety of sources of radiation 1 can be used, e.g. discharge lamps, conventional coiled filaments, etc., but a coiled filament tungsten - iodide lamp is preferred. Such a lamp provides a concentrated line source of radiation which can be focussed into a small spot on the test piece 4. Thermal radiation lies mainly in the wavelength range from 0.3-5.0μm. The tungsten-iodide lamp produces its maximum intensity of radiation in the wavelength range 0.7-0.9μm and is thus ideally suited for the purpose. Glass, e.g. cover 10, is transparent to radiation of this wavelength.

The method of using the apparatus is as follows. The apparatus and test piece are assembled, as shown, together with any instrumentation, e.g. thermocouples (not shown). The atmosphere within the cover 10 (or 8) is adjusted, if necessary. Since two tubes 11 (or 9) are present, a flow of gas through the apparatus can be provided, e.g. to facilitate smoke removal. The source 1 may be operated continuously or intermittently as required. The radiation 3 from source 1 is concentrated at the second focal point on test piece 4 causing intense local heating. The progress of the resulting combustion may be observed visually or photographically. Analysis of the breakdown gases may be used to determine the reactions occurring at different stages and hence the rate-determining steps can be identified and individual reaction kinetics can be measured or calculated. It is also possible to operate source 1 in a series of short bursts and examine test piece 4 after each burst so that the precise progress of each step of the degradation can be established. This is a powerful diagnostic tool in determining the relative importance of all parameters affecting the degradation process and hence is particularly useful when devising substances to resist or retard degradation.

The apparatus described hereinbefore, and the methods for which it may be used, thus add greatly to the scientific and engineering tools available to establish the precise process of degradation and hence allow a more fire-resistant environment to be designed. It will be apparent to those skilled in the art that other scientific and engineering tools could be combined synergetically with the apparatus disclosed. For example, if the apparatus is operated using a series of short separate bursts of radiation, the stages of deterioration of the test piece 4 can be assessed by dielectric measurements and infra red analysis of the gases given off, without removing the sample and interrupting the process. In this way the reaction rate can be calculated. Alternatively, test piece 4 may be removed after each burst of radiation and the reaction rate calculated by weight change measurements. The effectiveness of protective layers can be judged by specialist techniques, such as electronmicroscopy or surface emission spectroscopy as well as dielectric measurements. The use of detailed tests such as these are an essential part of the development of non-toxic, thermally resistant materials.

CLAIMS:

1. A method of obtaining data concerning the manner in which a material behaves when subjected to incident thermal radiation, said method comprising:-

   (i) providing a part elliptical reflector having first and second focal points;

   (ii) placing a source of radiation essentially at the first focal point of the reflector;

   (iii) placing the material essentially at the second focal point of the reflector;

   (iv) energising said source of radiation for a predetermined time so that said radiation is focussed on said material;

   (v) controlling the environmental conditions surrounding said material; and

   (vi) observing and/or measuring changes which occur to said material as a consequence of being subjected to the radiation.

2. A thermal imaging apparatus for investigating the manner in which a material behaves when subjected to incident thermal radiation, which apparatus comprises

   (i) a source of radiation;

   (ii) a reflector having the shape of a surface of revolution of part of an ellipse rotated about its major axis such that the reflector has first and second focal points;

   (iii) mounting means for supporting said source of radiation at the first focal point of said reflector; and

   (iv) a supporting means for supporting said source and reflector such that the second focal point of said reflector is at a predetermined position in relation to the surrounding environment at which position the material is to be located.

3. An apparatus as claimed in claim 2 wherein the

mounting means for supporting said source is adjustable with respect to the reflector.

4. An apparatus as claimed in claim 2 or 3 wherein the supporting means for supporting said source and reflector also includes a means for supporting the material at said predetermined position.

5. An apparatus as claimed in any one of claims 2 to 4 wherein the reflector is at least semi-elliptical.

6. An apparatus as claimed in any one of claims 2 to 5 and including an envelope around the reflector, the source and said position.

7. An apparatus as claimed in any one of claims 2 to 5 and including an envelope around said position.

8. An apparatus as claimed in claim 6 or 7 and including means for changing the atmosphere within said envelope.

9. An apparatus as claimed in any one of claims 2 to 8 and additionally including a sensor to analyse the composition of combustion products obtained as a consequence of the material being subjected to radiation.