Feb. 15, 1966 T. N. VASSIL 3,235,860

FIRE DETECTOR

Filed June 29, 1960 9 Sheets-Sheet 1

FIG. 1

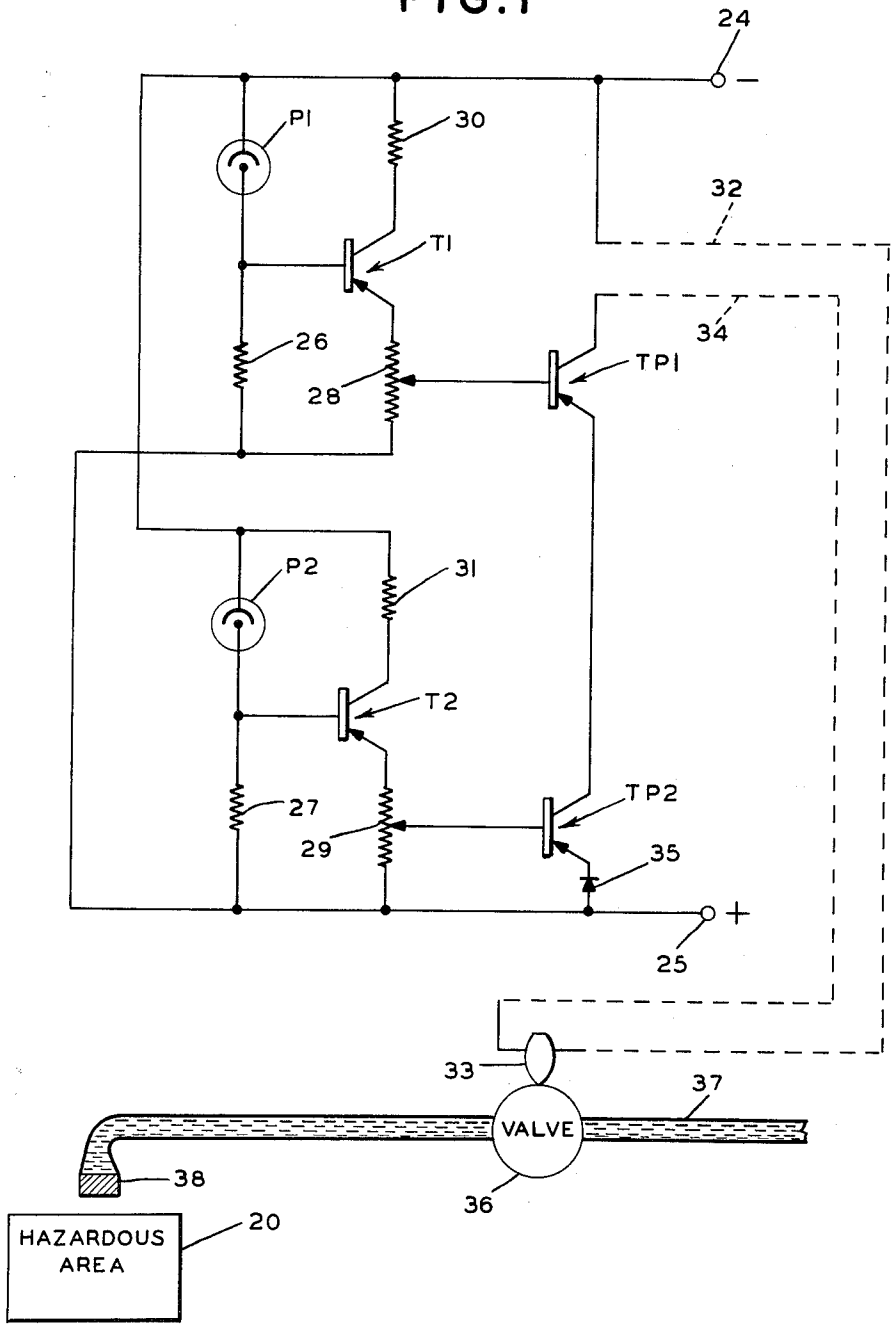
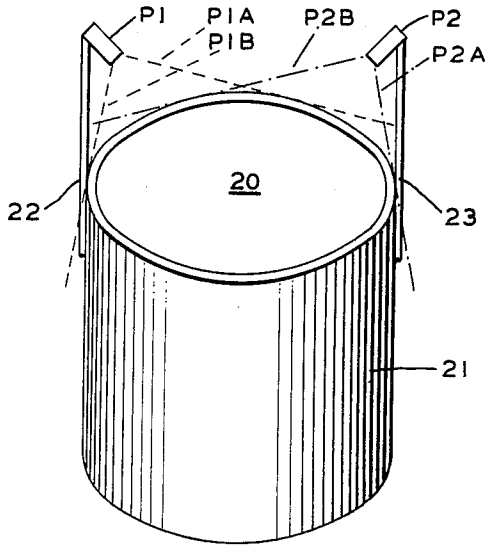


FIG. 2


P1
P1A
P1B
P2B
P2
P2A
20
22
23
21

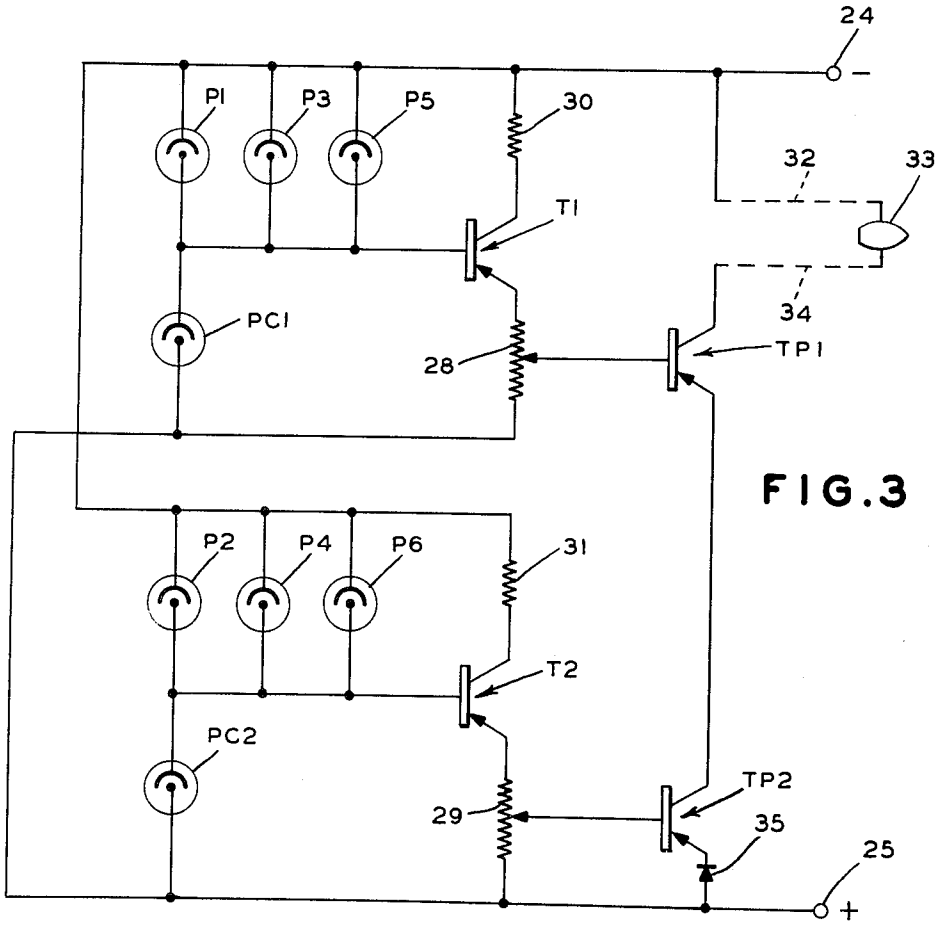

24
P1
P3
P5
30
32
33
T1
34
PC1
28
TP1
P2
P4
P6
31
T2
PC2
29
TP2
35
25
+

FIG. 3

Feb. 15, 1966 T. N. VASSIL 3,235,860

FIRE DETECTOR

Filed June 29, 1960 9 Sheets-Sheet 3

FIG. 4

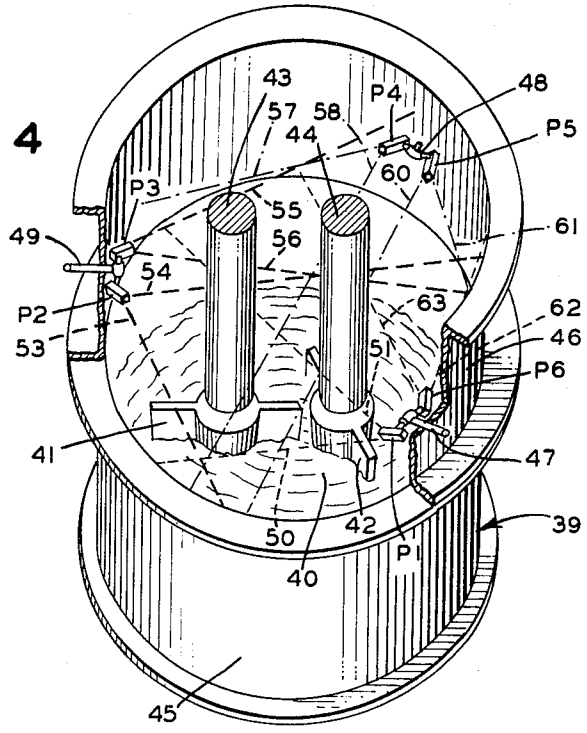
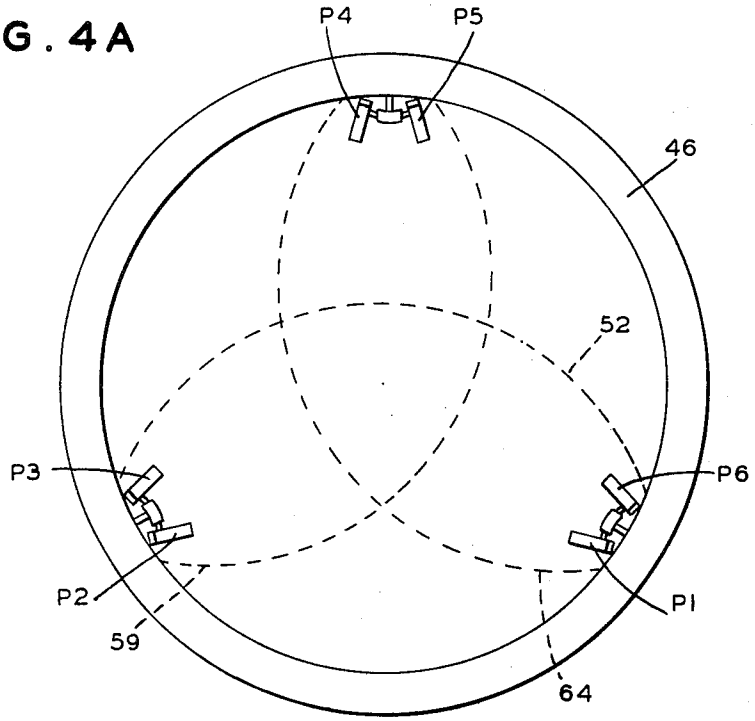


FIG. 4A



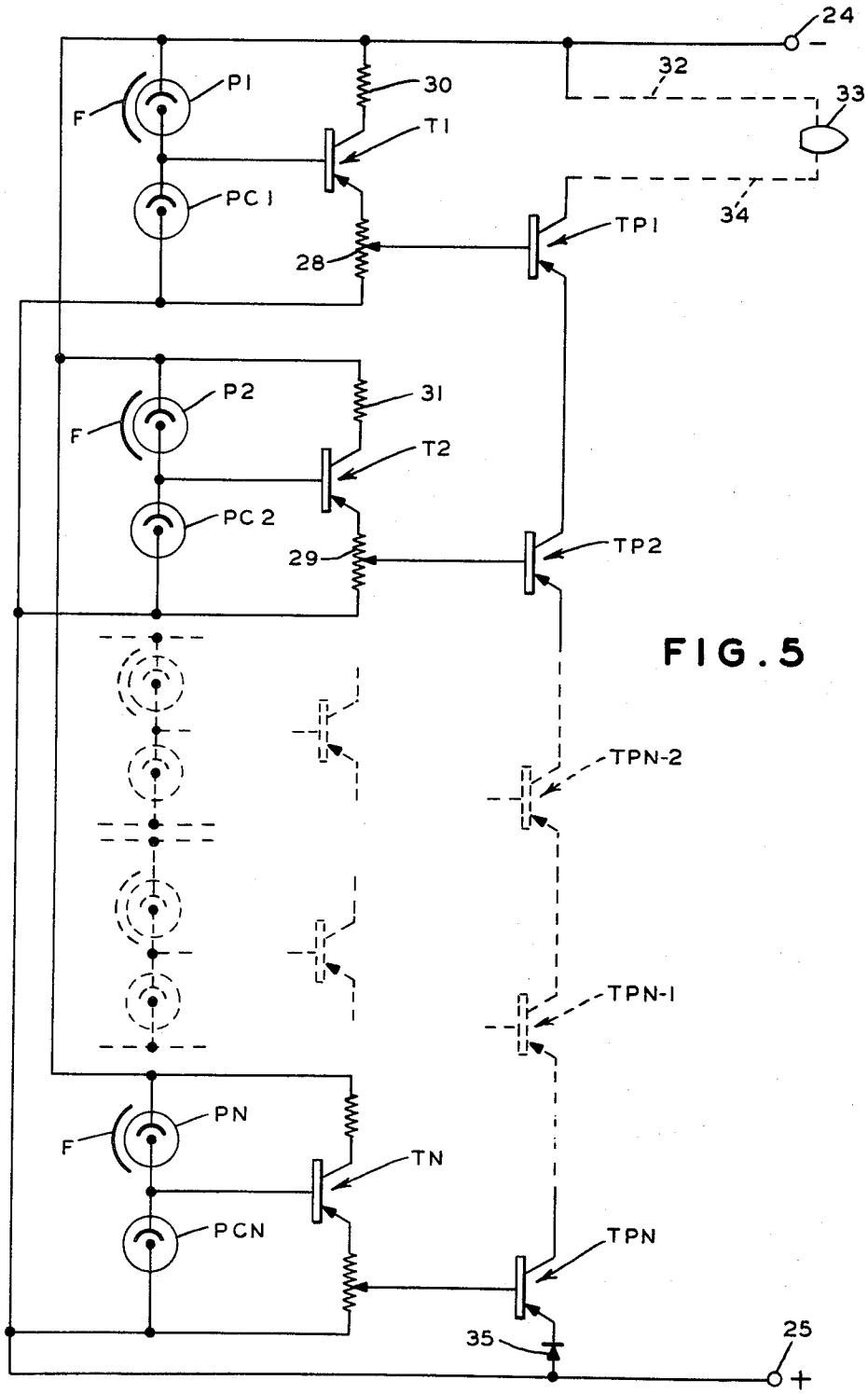

24
32
33
34
P1
F
30
T1
PC 1
28
TP1
P2
31
T2
PC 2
29
TP2
TPN-2
TPN-1
PN
TN
PCN
TPN
35
25
+

FIG. 5

FIG. 5A

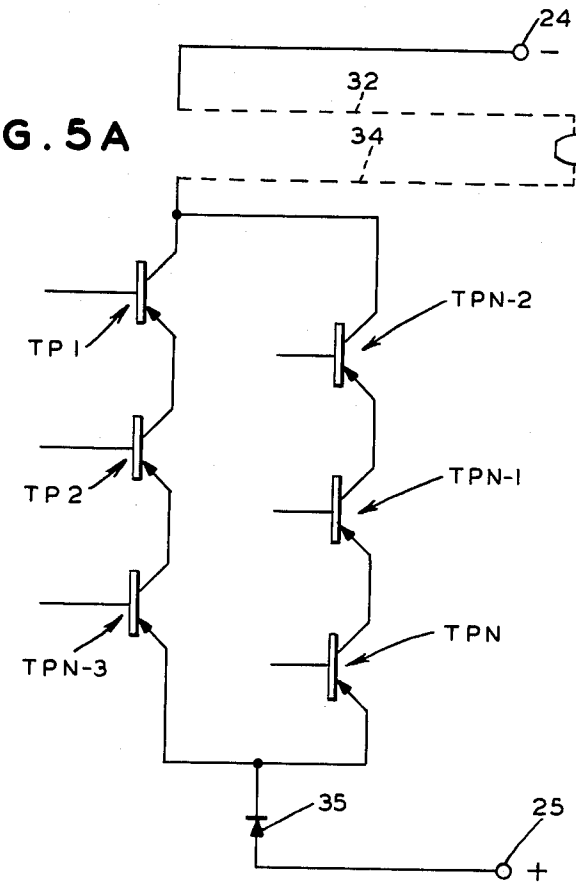
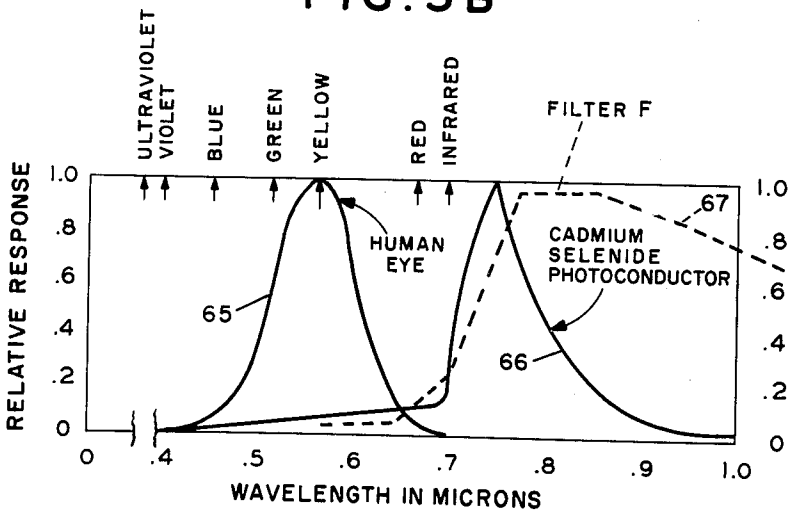

24
32
33
34
TP 1
TP 2
TPN-3
TPN-2
TPN-1
TPN
35
25
+

FIG. 5B


ULTRAVIOLET
VIOLET
BLUE
GREEN
YELLOW
RED
INFRARED
FILTER F
RELATIVE RESPONSE
1.0
.8
.6
.4
.2
0
HUMAN EYE
65
66
67
CADMIUM SELENIDE PHOTOCONDUCTOR
.4
.5
.6
.7
.8
.9
1.0
WAVELENGTH IN MICRONS

Feb. 15, 1966 T. N. VASSIL 3,235,860

FIRE DETECTOR

Filed June 29, 1960 9 Sheets-Sheet 6

FIG. 6

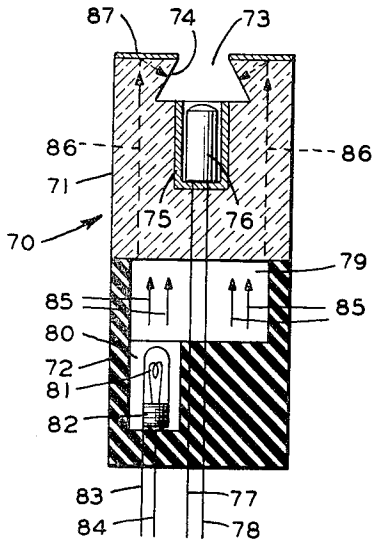


FIG. 7

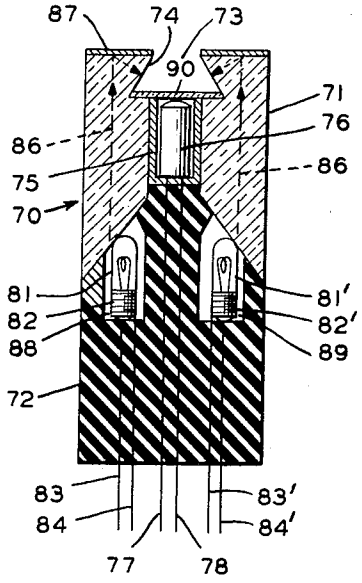


FIG. 8

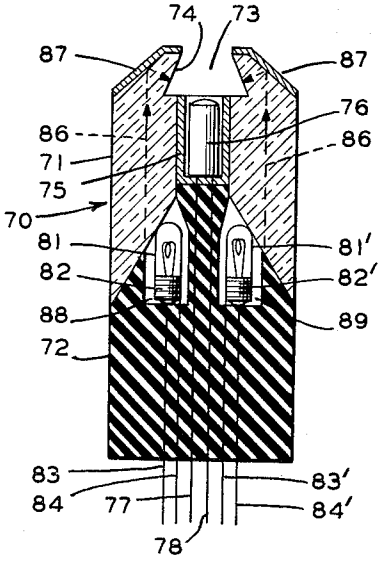
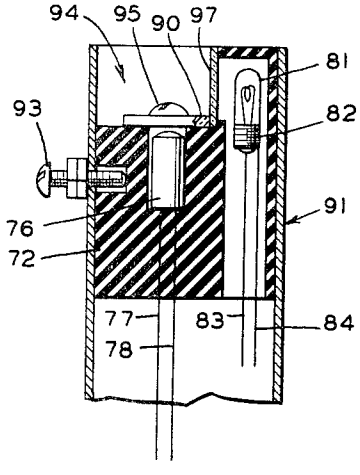


FIG. 9



Feb. 15, 1966 T. N. VASSIL 3,235,860

FIRE DETECTOR

Filed June 29, 1960 9 Sheets-Sheet 7

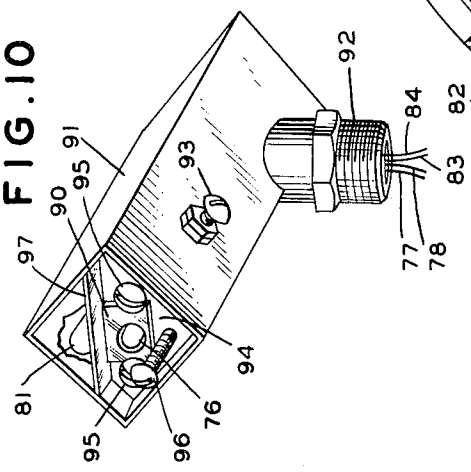


FIG. 10

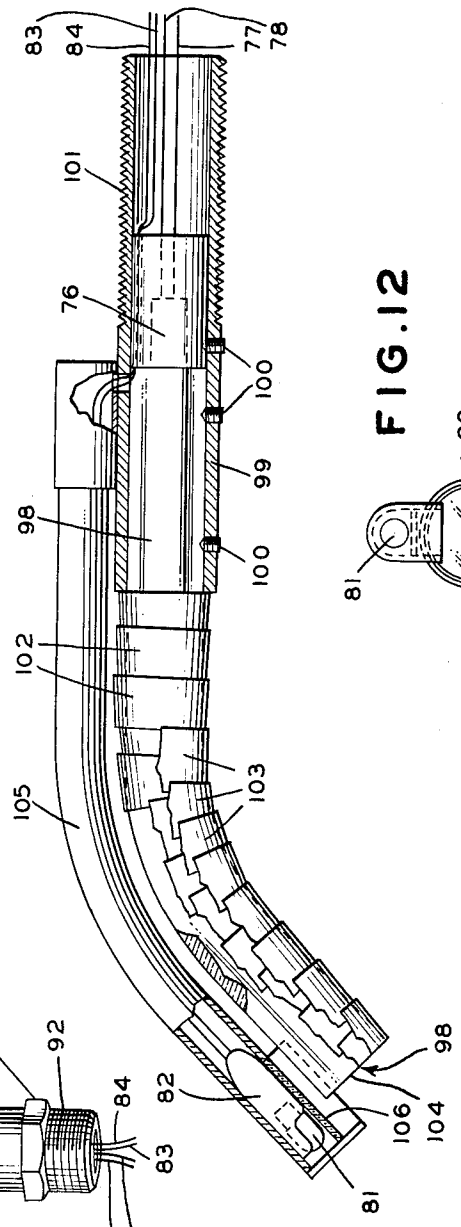


FIG. 11

FIG. 12

Feb. 15, 1966 T. N. VASSIL 3,235,860

FIRE DETECTOR

Filed June 29, 1960 9 Sheets-Sheet 8

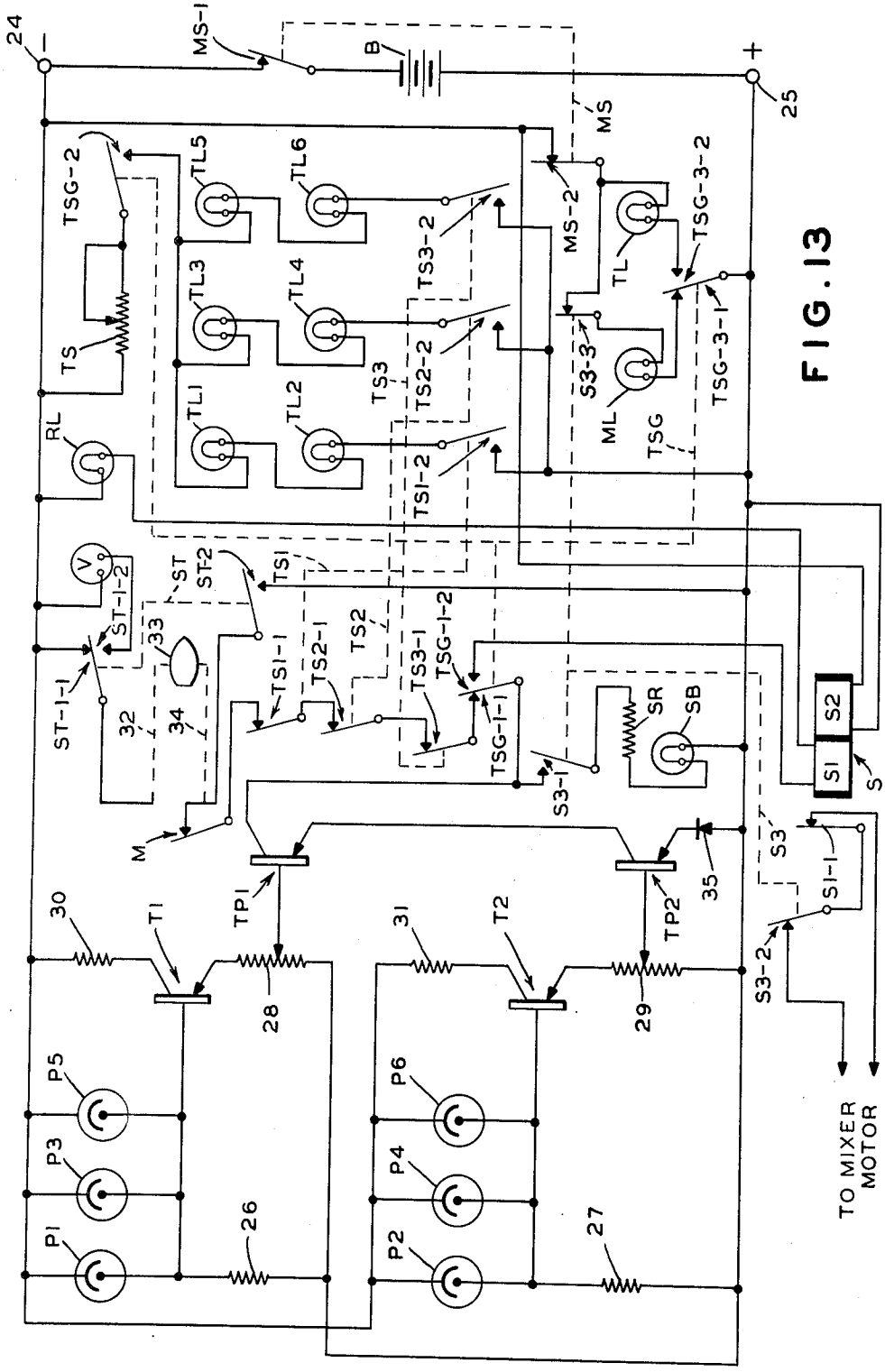


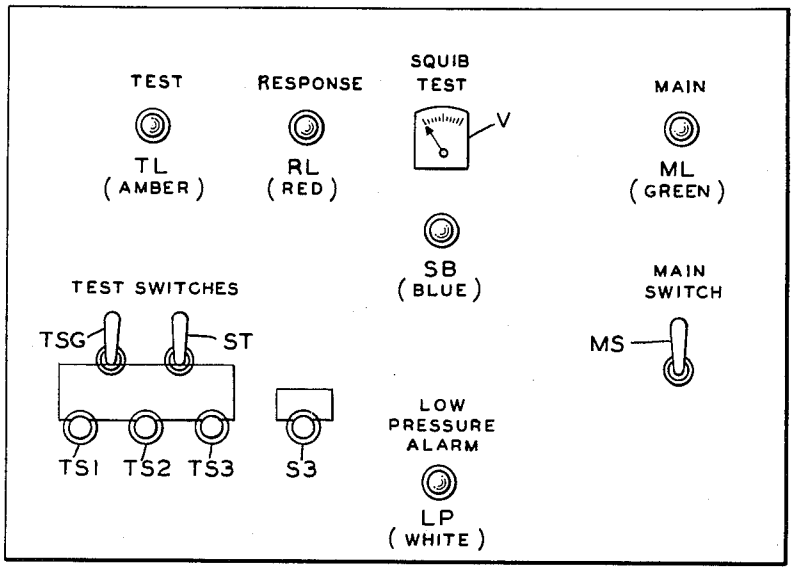
FIG. 13

Feb. 15, 1966 T. N. VASSIL 3,235,860

FIRE DETECTOR

Filed June 29, 1960 9 Sheets-Sheet 9

FIG. 14



United States Patent Office 3,235,860 Patented Feb. 15, 1966

3,235,860

FIRE DETECTOR

Theo N. Vassil, Flushing, N.Y., assignor to American District Telegraph Company, Jersey City, N.J., a corporation of New Jersey

Filed June 29,1960, Ser. No. 39,528
14 Claims. (Cl. 340—228)

The present invention relates to fire detectors and more particularly to fire detectors adapted especially for use with extremely hazardous and rapid burning materials.

In the handling and processing of explosives and other hazardous materials, peculiar fire protection requirements are encountered in view of the necessity for prompt remedial action upon the advent of a fire condition. In most fire protection situations, speed of detection is important, but usually a delay of many seconds or even minutes is tolerable. However, when handling or processing flame-sensitive explosives and certain other hazardous materials, it is desirable that detection and remedial action be extremely prompt and preferably in a time interval of the order of a few milliseconds.

These requirements are perhaps most stringent when the materials involved are of the type in which combustion propagates at a high velocity and which include oxygen-supplying compounds, since with such materials, if an incipient fire is not detected and extinguished within an extremely short time interval, extinguishment will rapidly become impossible, or at least extremely difficult. An example of such a material is a mixture of a flammable polymer, e.g., polyurethane or polybutadiene, and an oxygen-furnishing material, e.g., ammonium perchlorate. With such a material a fire cannot be smothered but must be extinguished by cooling to below the combustion temperature. For most practical purposes, such cooling will be impossible unless the cooling medium is brought into contact with the flame in a very short time. 500 milliseconds is sometimes considered an outside time limit for detection and application of the cooling medium, but in some cases even such a time interval may be too long. It is, of course, desirable to achieve these results in a much shorter time, and preferably a time of the order of a few milliseconds.

In the handling and processing of materials which are or may become explosive in the presence of flame, prompt detection and application of the extinguishing medium is desirable to minimize the explosion hazard, and again a time interval of the order of a few milliseconds is highly desirable.

In fire detection under the hazardous conditions contemplated, every effort must be made to ensure operating reliability of the detection and extinguishing equipment. On the other hand, in many instances it is also of great importance that ambient conditions of a permanent or transient nature not be allowed to initiate a spurious detection of fire.

In accordance with the foregoing, a principal object of the invention has been the provision of a novel and improved fire detector.

More particularly, it has been a principal object of the invention to provide such a detector which is especially adapted for use in protecting hazardous materials, in that the detection time is extremely short.

Still another object of the invention has been the provision of a fire detector which will produce a usable output signal in a time interval of the order of a few microseconds.

Another object of the invention has been the provision of a fire detector which will detect a fire condition and actuate an extinguishing system in a time interval of the order of a few milliseconds or less and which will result

in application of an extinguishing medium to the fire in a very short time after detection.

A further object of the invention has been the provision of such a detector which will be highly resistant to spurious detection resulting from permanent or transient ambient conditions.

Still another object of the invention has been the provision of such a detector which will exhibit extreme reliability.

Yet another object of the invention has been the provision of a fire detector of the above type which is adapted for intermittent use and which may be tested fully prior to each use.

A further object of the invention has been the provision of a fire detector having multiple detecting units with partially overlapping detecting fields which will eliminate blind spots formed by masked areas on a surface to be protected.

Still a further object of the invention has been the provision of a fire detecting element having in association therewith a testing element which affords a realistic and reliable test of the integrity of the detecting element.

Another object of the invention has been the provision of a fire detecting and extinguishing system adapted to respond to a fire condition in a very short time interval, and which will bring a fire extinguishing medium into operative contact with an incipient fire within a total elapsed time interval of the order of a few milliseconds.

A feature of the invention has been the provision of a fire detector which produces virtually instantaneously a usable signal voltage upon the occurrence of a fire condition in a protected area.

Another feature of the invention has been the provision of a fire detector of the above type which contains no moving parts.

Other and further objects, features and advantages of the invention will appear more fully from the following description.

The invention will now be described in detail with reference to the appended drawings, in which:

FIG. 1 is a schematic drawing illustrating one form of fire detecting and extinguishing system in accordance with the invention;

FIG. 2 is a perspective view showing a typical installation of the fire detecting unit of FIG. 1;

FIG. 3 is a schematic drawing illustrating another form of fire detector in accordance with the invention employing multiple fire detecting units and having ambient compensating elements;

FIG. 4 is a perspective view showing a typical installation of the fire detecting units of FIG. 3;

FIG. 4A is a plan view illustrating the fields of view of the detecting units of FIG. 4;

FIG. 5 is a schematic drawing illustrating another form of fire detector in accordance with the invention;

FIG. 5A shows a modification of the circuit of FIG. 5;

FIG. 5B is a curve of typical response characteristics;

FIG. 6 is a longitudinal cross-sectional view illustrating one form of combined fire detecting element and test element in accordance with the invention;

FIG. 7 is a view similar to FIG. 6 illustrating a modified form of construction of a detecting and test element in accordance with the invention;

FIG. 8 is a view similar to FIG. 6 illustrating another modified form of construction of a detecting and test element in accordance with the invention;

FIG. 9 is a view similar to FIG. 6 illustrating still another modified form of construction of a detecting and test element in accordance with the invention;

FIG. 10 is a perspective view of the element of FIG. 9;

FIG. 11 is a longitudinal sectional view of yet another modified form of detecting and test elements in accordance with the invention;

FIG. 12 is an end view of the element of FIG. 11;

FIG. 13 is a schematic diagram illustrating a test circuit in accordance with the invention; and

FIG. 14 is an elevational view showing a typical test panel for the circuit of FIG. 13.

In the various figures of the drawings like reference characters denote like elements.

Referring now to the drawings, and more particularly to FIGS. 1 and 2, there is illusrated a simple form of system embodying the invention. The hazardous area to be protected is designated **20** and is shown in FIG. 2 as a material surface at or near the top of a cylindrical container **21**. The container **21** is provided with upstanding brackets **22** and **23** which have mounted thereon detecting elements formed by photocells **P1** and **P2**, respectively. The photocells **P1** and **P2** are mounted and adjusted so that the field of view of each is the entire surface area **20** with as little additional outside area as possible. The field of view of photocell **P1** is outlined by lines **P1A** and **P1B** while that of photocell **P2** is outlined by lines **P2A** and **P2B**.

Each of the photcells views this hazardous area from a different horizontal position. As shown, these positions are 180° apart, but different angular dispositions may be used so long as ambient illumination coming from a source in the surrounding area and impinging on one of the photocells is not likely to impinge on the other. It is contemplated that this ambient illumination may be permanent or transient, and may be reflected from the surface **20**. An unpredictable glint of light reflected from the hazardous surface is perhaps the most likely source of a spurious alarm.

The term "photocell" as used herein is intended to designate the various forms of light-sensitive devices whose conductivity is altered when light contacts a photosensitive surface thereof. It is highly desirable but not necessary that the photocells used in the invention be of the solid state type, and preferably photoconductive cells or phototransistors.

Where a fire in the protected hazard has a predominant spectral energy frequency or band of frequencies, as will usually be the case, the photocells may be selected to produce a peak response at this frequency or band of frequencies. Moreover, an optical filter may be installed in front of each photocell to allow the predominant spectral energy frequency or band of frequencies of the protected hazard to pass and to inhibit the passage of other frequencies. When protecting a material such as the mixture of polyurethane and ammonium perchlorate mentioned above, spectral energy in the infrared range will tend to predominate, and photocells especially sensitive to this range (with or without optical filters) may be used to advantage. Photocells **P1** and **P2** might, for example, be cadmium selenide cells whose response peaks in the infrared range at about 0.75 micron. Light energy incident thereon may with advantage be passed through an optical filter which cuts off spectral energy below about 0.7 micron.

The light-sensitive surfaces or cathodes of the photocells **P1** and **P2** are connected to a negative terminal **24** of a source of potential. For convenience the terms cathode and anode will be used in referring to the photocell electrodes as in the case of conventional photoelectric cells, although these terms are not necessarily properly used in connection with certain solid state devices. The anodes of photocells **P1** and **P2** are each coupled to positive terminal **25** through a respective one of resistors **26** and **27**. The anode of photocell **P1** is also connected to the base of a transistor **T1**, while the anode of photocell **P2** is connected to the base of a transistor **T2**. The emitters of transistors **T1** and **T2** are coupled to positive terminal **25** through a respective one of potentiometers **28** and **29**. The collectors of transistors **T1** and **T2** are coupled to negative terminal **24** through a respective one of resistors **30** and **31**.

The slider of poteniometer **28** is connected to the base of a power transistor **TP1**, while the slider of potentiometer **29** is connected to the base of a power transisttor **TP2**. The emitter-collector circuits of transistors **TP1** and **TP2** are included in a series circuit extending from negative terminal **24** through a conductor **32**, an explosive squib or primer **33**, a conductor **34**, the emitter-collector circuit of transistor **TP1**, the emitter-collector circuit of transistor **TP2**, and a rectifier **35** to positive terminal **25**. This series circuit may conveniently be termed the "squib" circuit.

The sliders of potentiometers **28** and **29** are normally adjusted so that under steady state conditions the emitter-base voltage of power transistors **TP1** and **TP2** will be insufficient for these transistors to conduct and hence current cannot flow through the series circuit including the squib **33**. The diode **35** insures that current cannot flow through this series circuit in any event unless the voltage in the emitter-base circuits of the power transistors equals or exceeds the breakdown voltage of diode **35**. Thus even though steady state ambient light conditions may be such that transistors **TP1** and **TP2** would be conditioned so as to be conductive, as will be explained below, the emitter-base voltages of those power transistors must reach a minimum or threshold value before conduction occurs, and this value is determined by the rating of diode **35**.

Under steady state conditions, photocell **P1** and resistor **26** act as a voltage divider setting the emitter-base voltage of transistor **T1** to a value at which the current flow through potentiometer **28** produces the desired emitter-base voltage for transistor **TP1**. Photocell **P2** and resistor **27** act similarly for transistors **T2** and **TP2**.

Should light energy (photons) from a fire contact the light-sensitive surfaces of photocells **P1** and **P2**, the electrical resistances of these photocells will drop. In general, the drop in resistance of the photocells will be proportional to the light energy incident thereon, and, if this light energy is from a fire in the direct field of view of the photocells, the drop in resistance will be appreciable.

The drop in resistance of photocell **P1** will cause an increase in the voltage drop across resistor **26** (because photocell **P1** and resistor **26** act as a voltage divider), while the drop in resistance of photocell **P2** will cause a similar increase in the voltage drop across resistor **27**. As a result, the emitter-base voltages of both transistors **T1** and **T2** will increase, increasing the corresponding current flows in potentiometers **28** and **29**. A part of the corresponding increased voltage drops across potentiometers **28** and **29** will be applied to the bases of transistors **TP1** and **TP2**, respectively, making these power transistors conduct. The emitter-base voltages of the power transistors in response to detection of a fire will be more than sufficient to produce a voltage in the squib circuit in excess of the breakdown voltage of diode **35**.

Conduction of power transistors **TP1** and **TP2** will produce an operating current in the series circuit including squib **33** and will cause squib **33** to explode. Squib **33** is operatively associated with a valve **36** interposed in a water (or other extinguishing medium) supply line **37**. The squib **33** is arranged when exploded immediately to open valve **36** and thereby allow the high fluid pressure upstream of the valve **36** to become effective downstream of the valve. The downstream portion of pipe **37** is primed with water (or other medium) at a low pressure, the water being retained by a plug or cap **38**. As soon as valve **36** opens, the high pressure becomes effective to force open the discharge end or nozzle of the pipe **37** by blowing out or pivoting the cap or plug **38**, allowing the water to be discharged onto the hazardous area thereby to extinguish the fire. The valve **36**, the primed

pipe and the provision of the plug or cap 38 form no part of the present invention.

Should ambient light, as from a glint reflected from the surface 20, contact either photocell P1 or photocell P2, but not both, the current through potentiometer 28 or potentiometer 29, as the case may be, may be raised to a level at which the corresponding power transistor will be conditioned to conduct. However, since transistors TP1 and TP2 are connected in an AND gate, both must be conditioned to conduct before the squib circuit will be complete. Hence, such a stray light beam contacting one but not both of the photocells cannot act to discharge the extinguishing medium onto the hazardous area. The disposition of the photocells P1 and P2 angularly downward onto the same field of view makes the possibility of a glint of light or other stray beam contacting both photocells remote. Thus, each of the photocells is arranged to see essentially only the protected area and external illumination impinging thereon can come, as a practical matter, only from the protected area. But a light beam from a remote source reflected from the protected area is not likely to contact both photocells. On the other hand, since both photocells have the same field of view, i.e., the surface 20, a fire occurring on this surface will cast energy onto both photocells and hence will reliably operate the system.

Since any change in illumination acting on the photocells will tend to alter the current through the corresponding potentiometers 28 and 29, these potentiometers should be set so as to produce the desired emitter-base voltages on the corresponding power transistors. It will be evident that the potentiometers 28 and 29 are effectively gain or sensitivity controls, since the higher the setting of a potentiometer the lower will be the incident light energy necessary to operate the corresponding power transistors. The selection of diode 35 (or a number of such diodes connected in series) creates a threshold voltage in the power transistor emitter-base circuits below which conduction of the power transistors in the squib circuit cannot occur.

The valve 36 may be of any convenient type. For example, it may of the type in which the valve is opened upon motion of a short-travel plunger actuated by motion of a spring-urged arm and in which the arm is normally restrained by a frangible link arranged to be broken by the squib 33 when the latter is exploded.

Depending upon the valve construction and size, the squib 33 may be what is technically called a primer. And more than one squib or primer may be used if needed, the same being connected in parallel.

Since the switching time of solid state elements is very small and the speed of light very great, the operating voltage will appear across the squib terminals virtually instantaneously upon the occurrence of a fire condition in the protected area which will actuate the photocells, the actual time required being of the order of 5 to 10 microseconds. The operation of a typical squib or primer is also very rapid. For example, a typical primer may have a firing time ranging from 1.2 milliseconds at a current of 200 milliamperes to 0.1 millisecond at 500 milliamperes. The power transistors TP1 and TP2 are preferably arranged to produce an operating current in the squib circuit near the high end of the squib or primer rating. The opening time of a properly designed valve is likewise small so that if the downstream water delivery pipe is primed and the upstream pipe is maintained at a suitable high pressure, water can be delivered to the protected area in an extremely short time after the occurrence of a visible fire condition. By operating the squib or primer at or near its high current rating, the time interval is reduced for practical purposes to the valve opening time. Hence, water can be delivered to the fire area in a time of the order of a few milliseconds. Such rapid response will not be needed for some hazards, but for others a response in such a short time interval will be of extreme importance.

It will be observed that the squib operating voltage is applied to the squib in FIG. 1 without the interposition of a relay. Since even a sensitive relay has an appreciable operating time, e.g., 5 to 10 milliseconds, it is desirable that relays or similar devices not be used so that the time delay will be reduced substantially to the inescapable minimum of the valve opening time. By making the squib a part of the valve mechanism, this time is reduced to a very small value.

Since spurious ignition of the squib, though unlikely, is possible (especially if the squib should be defective), the squib is preferably located some distance away from the protected area, e.g., 20 feet. In this way spurious ignition of the squib will not tend to ignite the hazardous material. By using a primed pipe downstream of the squib controlled valve, little time delay results from this separation.

Referring now to FIGS. 3, 4 and 4A, there is shown a modified form of fire detector in accordance with the invention. The construction of FIGS. 3 and 4 is similar to that of FIGS. 1 and 2, but whereas FIGS. 1 and 2 show a single fire detector unit comprising two fire detecting elements P1 and P2, in FIGS. 3 and 4 there are three fire detecting units each comprising a pair of fire detecting elements. Photocells P1 and P2 form one pair of fire detecting elements, photocells P3 and P4 form another pair of fire detecting elements, and photocells P5 and P6 form the third pair of detecting elements.

As shown in FIG. 3, photocells P1, P3 and P5 are connected in parallel with each other in a circuit position corresponding to that of photocell P1 in FIG. 1. Similarly, photocells P2, P4 and P6 are connected in parallel with each other in a circuit position corresponding to that of photocell P2 in FIG. 1.

In FIG. 4 the hazardous area or zone is the interior of a mixer 39 having a material surface 40. The material in the mixer is agitated and mixed by a pair of paddles 41 and 42 rotated by shafts 43 and 44, respectively. The mixer 39 may comprise a removable mixing bowl 45 adapted to fit beneath a mixer body 46.

Brackets 47, 48 and 49 extend through holes in mixer body 46 located above the surface 40 and are spaced at 120° intervals. Bracket 47 carries photocells P1 and P6, bracket 48 carries photocells P5 and P4, and bracket 49 carries photocells P2 and P3. The photocells are inclined downwardly to yield fields of vision generally elliptical in shape (in a horizontal plane), as shown in FIG. 4A. However, portions of the ellipses are cut off by the mixer walls.

The field of vision of photocell P1 is indicated by lines 50 and 51 yielding elliptical area 52 at surface 40 (FIG. 4A). Photocell P2, which views the same elliptical area 52 as photocell P1, has a field of vision indicated by lines 53 and 54. Photocells P3 and P4 have fields of vision indicated by lines 55–56 and 57–58, respectively, and jointly view elliptical area 59 (FIG. 4A). Photocells P5 and P6 have fields of vision indicated by lines 60–61 and 62–63, respectively, and jointly view elliptical area 64 (FIG. 4A).

Basically, each pair of photocells P1–2, P3–4, and P5–6 is intended to view a respective 120° segment of the surface 40. However, since the shafts and paddles obscure portions of the surface 40 as viewed by any individual photocell, the fields of view are somewhat enlarged to provide overlapping, as shown in FIG. 4A. By means of this overlapping, it can be assured that each individual portion of surface 40 will be viewed at all times by at least one of the even numbered photocells and also by at least one of the odd numbered photocells. For example, if a portion of the surface 40 normally in the field of view of photocell P1 is temporarily or permanently masked from this photocell by the paddle 41 or the shaft

43, such masked portion will be viewed by one or both of photocells P3 and P5.

In general, it is desirable that the field of view of each photocell be relatively limited and that no more overlapping of these fields than necessary to avoid blind spots be provided. Such limitation will minimize the likelihood of a spurious alarm. Thus, where appropriate, masks or other field limiting means may be provided in association with the photocells so that each will see its intended protection area but little or nothing outside of this area.

In the arrangement shown in FIG. 2, there is nothing to create blind spots, so two photocells are adequate to provide proper coverage of the hazardous area. Of course, if the hazardous area were large additional pairs of photocells could be used, as in FIG. 4, to limit the working area assigned to each pair of photocells.

With the relatively simple paddle and shaft mechanism of FIG. 4, three pairs of photocells can be arranged to prevent blind spots and so that there is no portion of the hazardous area that is not viewed at all times by at least one odd numbered photocell and at least one even numbered photocell. Should the elements tending to produce blind spots present a more complicated masking situation or should the hazardous area be large, a larger number of pairs of photocells may be used. It will be observed that the individual photocells of each pair, e.g., P1 and P2, view their common areas from opposite directions, as in FIG. 2.

As shown in FIG. 3, the even numbered photocells are connected in parallel with each other and the odd numbered photocells are connected in parallel with each other. The photocells PC1 and PC2 (not shown in FIG. 4) replace the resistors 26 and 27, respectively, of FIG. 1 and are disposed so as to receive ambient light only and are shielded from the hazardous zone so that they will not receive light energy from a fire in that zone.

The photocells PC1 and PC2 should be arranged so that they are substantially equally affected by any changes in ambient light and so that this effect is substantially the same as that affecting the fire detecting photocells as groups, i.e., P1, 3, 5 and P2, 4, 6. Should it prove difficult in any case to have a change in ambient light result in about equal resistance changes for a group of detecting photocells and the corresponding compensating photocell, two or more compensating photocells may be connected in parallel. Since changes in ambient light affect both the detecting and compensating photocells about equally, such changes in ambient light will produce little or no net change in the emitter-base voltages of the transistors T1 and T2, and hence will not tend to render the power transistor TP1 and TP2 conductive. A similar compensating effect is provided with respect to changes in ambient temperature. Resistance elements could be used in place of the compensating photocells, as in FIG. 1, if desired, for example, where changes in ambient light level are not a serious problem.

Light from a fire contacting any one or more of photocells P1, P3 and P5 (which light will not contact photocell PC1) will increase the emitter-base voltage of transistor T1 and in turn increase the voltage drop across potentiometer 28, conditioning power transistor TP1 to become conductive, as described in connection with FIG. 1. Similarly, light from a fire contacting any one or more of photocells P2, P4 and P6 will condition power transistor TP2 to become conductive. When both power transistors are thus conditioned (and when the emitter-base voltages are sufficient to overcome the threshold value imposed by diode 35), current will flow in the squib circuit and squib 33 will be fired, as in FIG. 1. Thus, for the squib to be fired requires at least one photocell from each of the odd and even numbered groups of detecting photocells to view the fire. In most cases this would be corresponding photocells of a detector unit, e.g., P1 and P2 or P3 and P4. But should the fire occur in the P1 segment of the surface 40 but be masked from P1, then the fire would be viewed by P3 and/or by P5, satisfying the AND gate requirement that at least one photocell of each detecting group view the fire.

FIG. 5 illustrates another single fire detecting unit arrangement. However, the arrangement of FIG. 5 differs from that of FIGS. 1 and 3 in that the fire detecting unit is formed from a multiple number of detecting elements. As shown, there are *n* detecting photocells P, *n* compensating photocells PC, *n* transistor amplifiers T, and *n* power transistors TP. The circuit operation is the same as that previously described except that the AND gate formed by the power transistors TP requires all *n* detecting photocells to detect a fire condition before the squib circuit will be energized.

It will be appreciated that where *n* is greater than two, the likelihood of a spurious alarm is decreased below the level afforded by the arrangement of FIG. 1. On the other hand, where *n* is greater than two, the danger that a fire may not be detected immediately is somewhat increased. To overcome this it may be desirable to connect certain of the detecting photocells in parallel, as in FIG. 3, and yet provide each detecting unit with more than two photocells, as in FIG. 5.

Another arrangement which may be used in place of parallel connected detecting photocells is to connect certain of the power transistors in an OR gate while maintaining the squib circuit as a whole in the configuration of an AND gate. Such an arrangement is illustrated in FIG. 5A, in which power transistors TP1, TP2 and TP*n*–3 are connected in series and power transistors TP*n*–2, TP*n*–1 and TP*n* are connected in series, the series combinations being connected in parallel. With this arrangement, the squib circuit as a whole is an AND gate, but the AND condition may be satisfied by either TP1, TP2, and TP*n*–3 or TP*n*–2, TP*n*–1, and TP*n*.

As shown in FIG. 5, optical filters F may be provided in associatiion with each of the detecting photocells. The filters F are disposed between the respective photocells and their corresponding segments of the hazardous area to allow the predominant spectral energy frequencies of the protected hazard to pass, but to minimize passage of other frequencies.

The filtering action is illustrated in FIG. 5B, which is a plot of wave length in microns versus relative response. In FIG. 5B, curve 65 represents typical response of a human eye, curve 66 represents typical response of a cadmium selenide photoconductor, while curve 67 represents the energy passing response of the filters F. From FIG. 5B it will be seen that the cadmium selenide photoconductor response peaks at about 0.75 micron, while the filter F cuts off energy below about 0.7 micron. Since visible light energy lies generally below about 0.7 micron, it will be evident that visible light beams will not be likely to cause spurious operation of the system.

While protection of the type contemplated by the invention can be provided on a continuous basis, in many cases protection will be required only while a hazardous operation is being conducted. For example, while hazardous materials are being mixed or while a shaping operation is being performed, e.g., a cutback operation, the danger of fire is acute and protection is required. Whether protection is required on a continuous basis or only during spaced intervals, testing of the system integrity and operability is important.

Considerable advantage can be secured in combining the testing and detecting elements. For example, in this way it can be ensured that the testing operations are uniform and that a desired test sensitivity is achieved. Moreover, testing in this manner can be performed just before a hazardous operation is commenced but without creating an additional hazard such as would occur in operating electrical equipment in close proximity to the hazardous material.

Referring now to FIG. 6, there is shown a combined detecting and test element having a housing **70** which may (but need not) be cylindrical in shape and which has an upper portion **71** made of transparent material and a lower portion **72** made of opaque material. For example, the upper portion **71** might be made of Lucite (methyl methacrylate), while the lower portion **72** might be made of Bakelite. The outer end of the transparent upper portion **71** has a circular opening **73** with tapered walls **74** (forming a frusto-conical section). The conical walls **74** are polished windows. The base of the opening **73** itself has an opening accommodating an opaque cylinder **75** open at its upper end and closed at its bottom end and holding a photocell **76**, e.g., a cadmium selenide cell. The photocell **76** is preferably movable axially within the cylinder **75** to adjust the field of vision of the photocell. This field of vision will be conical in shape (for a circular light sensitive surface) and will be greatest when not restricted by the walls of the cylinder **75** or of the cone **74**. By moving the photocell inwardly, the cylinder walls form a mask which limits the field of vision. As the photocell is moved outwardly the conical surface **74** acts as a field limiting mask, the masking effect being diminished as the photocell approaches the opening **73**. Electrical leads **77** and **78** extend outwardly through the upper and lower portions **71** and **72**, as shown, to afford electrical connection to the photocell. The cylinder **75** may be made of any suitable material, e.g., brass or Bakelite.

The lower portion **72** of the housing **70** has a cylindrical hollow space **79** in one end thereof, and the hollow space **79** communicates with a hollow well **80** housing a test lamp **81** and socket **82**. Power leads **83** and **84** extend outwardly from the socket **82**. The lamp **81** is designed to produce illumination having spectral characteristics resembling as closely as possible the spectral characteristics of the hazard which the photocell **76** is to protect. For example, for a cadmium selenide photoconductive element, the lamp **81** should produce primarily infrared energy.

Light from the lamp **81** travels through the space **79**, as shown by the arrows **85**, and through the transparent housing portion **71**, as shown by the arrows **86**. The outer end of the housing portion **71** is provided with an annular metallized reflecting surface **87** which reflects the light from lamp **81** incident thereon, a portion of this reflected ligh passing through the conical walls **74** and contacting the light-sensitive surface of the photocell **76**, energizing the latter in the manner of a detected fire. By adjusting the intensity of the lamp **81**, the photocell output resulting from operation of lamp **81** may be caused to match the desired sensitivity of the detecting system.

It will be observed that should dirt or other matter obscure the photocell **76**, light from lamp **81** will be blocked from the photocell to the same extent as would light from a fire, and hence if such obscuration were sufficient to reduce materially system sensitivity, the illumination of lamp **81** would not yield a test signal representing a successful test.

The detecting and test element of FIG. 7 is similar to that of FIG. 6 except that two test lamps **81** and **81'** are provided, the lamp **81'** having a socket **82'** and leads **83'** and **84'**. The hollow space **79** is omitted and the lamps **82** and **82'** are mounted in wells **88** and **89**, respectively, each having an open end communicating with the transparent portion **71**. A filter **90** is mounted above the photocell **76** so as to be in the path of spectral energy entering the opening **73** or passing through the conical walls **74** and impinging on the photocell **76**.

The detecting and test element of FIG. 8 is similar to that of FIG. 7 except that the upper end of the transparent housing portion **71** is frusto-conical in shape except for an inner annular ring surrounding the opening **73**. This conical upper end and annular ring are provided with the metallized reflecting surface **87** which, as in FIGS. 6 and 7, reflects test light through the polished window **74** but limits incident light from the hazardous area to the opening **73**. The filter **90** is omitted in FIG. 8.

FIGS. 9 and 10 illustrate still another form of combined detecting and test element in accordance with the invention. This element comprises a rectangular opaque housing **91** carried on a mounting bracket or nipple **92**. The housing **91** has mounted therein a photocell **76** which is axially movable and may be locked in a desired position by a locking screw **93** acting in a threaded hole provided in the housing **91**.

The housing **91** has a recess **94** in one end thereof extending over somewhat more than half the end surface of the housing. The photocell **76** is mounted beneath this recess and beneath filter **90** which covers a hole in the housing for passage of light to the photocell **76**. The filter **90** is affixed to the bottom of the recess **94** by screws **95** acting in threaded holes provided in the recess bottom. A screw **96**, also acting in a threaded hole provided in the bottom of the recess **94**, serves as a convenient handle for adjusting the axial position of the photocell **76**. For this purpose, the photocell is arranged to move with the recess bottom and the latter is axially slidable in the housing. When the desired photocell axial position is achieved, the screw **96** may be removed.

Light from test lamp **81** passes through a window **97** into the recess **94** above the filter **90**. The side edge of the filter **90** is preferably opaqued or shielded so that light from lamp **81** can reach photocell **76** only through the upper surface of filter **90** and hence through the same path as light from a fire.

It will be observed that the walls of recess **94** afford a pentagonal mask for the photocell **76** and hence the field of view of photocell **76** will be generally pentahedral in shape.

In certain explosive atmospheres it may be hazardous to introduce any electrical power carrying wires and components which are not completely shielded. For operation under these circumstances, light-conducting tubes may be used, e.g., of the rigid plastic variety or the flexible fiber variety. Again, metallic tubing with polished metallized or electroplated walls may be used for light conduction.

A combined detecting and testing element in accordance with the invention and having all electrical connections shielded or remote from the hazardous area is illustrated in FIGS. 11 and 12. In these figures a photocell **76** is mounted partially within a recess in one end of a light-conducting rod or tube **98**, this end of tube **98** being slidably mounted in a metal tube **99**. Locking screws **100** are provided to lock the tube **98** and photocell **76** in a desired axial position. The end of the tube **99** may be threaded as shown at **101** for easy attachment to a mounting bracket.

A light-reflective coating **102** is provided about that portion of the tube **98** which extends outside of the tube **99**, e.g., an aluminum foil wrapping. Such a coating affords the multiple reflections which provide superior light conductance axially of the tube **98**. A protective opaque tape **103** is provided around the foil **102**. The coating and tape would not be used where the tube itself is opaque. The rod or tube **98** may be curved in any desired manner for convenient exposure to the hazardous area, the end **104** of this tube or rod serving as the light-admitting surface. Where this element **98** is a hollow tube, it is desirable that the light-admitting end be closed by a transparent window to prevent contamination of the tube walls.

A metal tube **105** is mounted on the tube **98** and one end of the tube **105** overlies the light-admitting end **104** of the tube **98**. The tube **105** contains a test lamp **81** and socket **82** and is provided with a window **106** from which light from lamp **81** may enter the end **104** of the tube **98**. The end of tube **105** should be closed to prevent any exposure of the hazardous area to a possible spark from the

electrical connections. If desired, the tube 105 may be light conducting and the lamp 81 may then be located at a point remote from the hazardous area.

A detecting and test circuit in accordance with the invention is illustrated in FIG. 13. In this circuit the detecting photocells P1–P6 and the transistor amplifiers T1 and T2 are connected as shown in FIG. 3. However, the compensating photocells are replaced by the resistors 26 and 27 of FIG. 1. The squib circuit is more complicated than has been shown in previous figures and extends from negative terminal 24 through front contacts ST–1–1 of a squib test switch ST, conductor 32, squib 33, conductor 34, microswitch contacts M, contacts TS1–1, TS2–1 and TS3–1 of test switches TS1, TS2 and TS3, respectively, contacts TSG–1–1 of general test switch TSG, the collector-emitter circuits of power transistors TP1 and TP2 and rectifier 35 to positive terminal 25.

Each of the detecting photocells is provided with a test lamp which may correspond to the test lamps of FIGS. 6–12 or be otherwise suitably disposed for test purposes. These lamps are designated TL1, TL2, TL3, TL4, TL5 and TL6 and are operatively associated with photocells P1–P6, respectively. The test lamps are divided into three pairs, the lamps of each pair being connected in series and the pairs being connected in parallel. The lamps corresponding to the detecting photocells which view the same fields of the hazardous area (FIGS. 4 and 4A) form the pairs. Thus lamps TL1 and TL2, TL3 and TL4, and TL5 and TL6 form the respective pairs.

The free terminal of each of lamps TL1, TL3 and TL5 is coupled to negative terminal 24 through contacts TSG–2 of switch TSG and a potentiometer TS. The free terminals of lamps TL2, TL4 and TL6 are connected to positive terminal 25 through respective contacts TS1–2, TS2–2 and TS3–2 of switches TS1, TS2 and TS3 respectively.

The source of potential for the system, here shown as a battery B, is connected to terminals 24 and 25 through contacts MS–1 of a main switch MS. Contacts MS–2 of switch MS supply battery power to a lamp ML through a circuit including contacts TSG–3–1 of switch TSG. Lamp ML might conveniently be green since its illumination signifies a protection-on or "in-service" condition. Upon operation of general test switch TSG to its test position, lamp ML will be extinguished and lamp TL will be illuminated, the circuit for the latter including contacts MS–2 and contacts TSG–3–2 of switch TSG. Contacts TSG–3–1 and TSG–3–2 share a common armature. Lamp TL might conveniently be amber in color.

Contacts TSG–1–2 of switch TSG (which share a common armature with contacts TSG–1–1) are provided to complete the power transistor circuit to negative terminal 24 through an operating coil S1 of a relay or stepping switch S and a lamp RL instead of squib 33. Lamp RL might conveniently be red in color.

Contacts ST–1–2 of switch ST (which share a common armature with contacts ST–1–1) are provided to connect one terminal of squib 33 to negative terminal 24 through a voltmeter V. Contacts ST–2 of switch ST serve to connect the other terminal of squib 33 to positive terminal 25.

The switch contact positions shown in FIG. 13 are for the protection-on condition and hence the protection-on or "in-service" lamp ML will be illuminated. Should a fire be detected by any one or more of photocells P1, P3 and P5 and also by any one or more of photocells P2, P4 and P6, squib 33 will be fired as previously described.

Switch M provided in the squib operating circuit might be a microswitch or the like arranged to be closed automatically when the mixing bowl or other apparatus is in position, thus preventing accidental firing of the squib in the absence of a hazard to be protected.

When it is desired to test the system, switch TSG will be operated. When apparatus such as the mixer of FIG. 4 is being protected, such testing should be undertaken before the mixer or other equipment is started, i.e., before the hazardous operation is commenced.

Upon operation of switch TSG, contacts TSG–1–1 open and contacts TSG–1–2 close, breaking the squib operating circuit and connecting red response lamp RL to positive battery through the power transistors TP1 and TP2. Contacts TSG–2 close connecting negative battery to test lamp pairs TL1 and 2, TL3 and 4 and TL5 and 6. Contacts TSG–3–1 open extinguishing green lamp ML and contacts TSG–3–2 close illuminating amber test lamp TL.

Each pair of detecting photocells may now be tested sequentially by operating and then releasing, in sequence, test switches TS1, TS2 and TS3. Operation of switch TS1 completes the power circuit for test lamps TL1 and TL2 by closing contacts TS1–2. The illumination provided by test lamps TL1 and TL2 simulates an actual fire condition in the field of view of photocells P1 and P2, causing a response by these photocells and a corresponding response by transistors T1 and T2 and by power transistors TP1 and TP2. Proper operation of these elements will cause squib operating current to flow through lamp RL, illuminating the latter as a visual signal of a satisfactory test. Subsequent operation of switches TS2 and TS3 will cause test lamps TL3–4 and TL5–6 to test the operation of the corresponding photocells and to illuminate lamp RL twice more if a satisfactory test is achieved in each case.

It may be desired automatically to prevent operation of the mixer or other apparatus until the tests have been completed satisfactorily. For this purpose operating coil S1 of relay or stepping switch S is connected in series with lamp RL. The squib operating current flowing through coil S advances the relay or switch armature by one step. Three such steps are required however to close contacts S1–1 which are included in the operating circuit of the mixer motor. Holding coil S2 is provided so that when main switch MS is operated to disconnect battery power at contacts MS–1, relay or switch S will reset to zero count and open contacts S1–1. The three surges of squib operating current through coil S1 required to close contacts S1–1 are achieved by successive operation of switches TS1, TS2 and TS3 accompanied by successful tests of the corresponding photocells and apparatus. Coil S1 may be made sufficiently sensitive as not to operate on a marginal current in the squib operating circuit so that even though lamp RL may be illuminated three times as required, contacts S1–1 will not close unless a satisfactory level of squib current flow is achieved on each of the three tests and hence the hazardous operation cannot be commenced.

The switch contacts TS1–1, TS2–1 and TS3–1 provided in series with squib 33 provide redundant protection (in view of contacts TSG–2) against accidental firing of the squib on operation of any of switches TS1, TS2 and TS3. Integrity of the switch contacts in series with the squib operating circuit, including switch M, may be assured by momentarily operating a switch S3. Contacts S3–1 of switch S3, when closed, complete a circuit extending from negative battery through the various switch contacts in the squib circuit, contacts S3–1, a current limiting resistor SR and a lamp SB to positive battery. Lamp SB, which might conveniently be blue, when illuminated shows integrity of the contact portion of the squib operating circuit. To guard against interference with squib operation through switch S3 accidentally being left in operated condition, contacts S3–2 are arranged to open the circuit of the mixer motor when switch S3 is operated. The lamp SB should, of course, not draw sufficient current to fire the squib.

Potentiometer TS in the test lamp circuit provides a test sensitivity control. For this purpose the slider of potentiometer TS is connected so as to permit variation of the current flow to the test lamps. By varying this cur-

rent to the test lamps and observing the current level at which detection occurs as indicated by illumination of lamp RL, the sensitivity characteristics of the individual detecting photocell pairs may be ascertained. This determination affords a quantitative measure of system sensitivity in addition to the qualitative determination afforded by illumination of lamp RL and stepping of switch S.

Testing of squib integrity is afforded by operation of switch ST. This operation opens contacts ST–1–1, closes contacts ST–1–2 and closes contacts ST–2. Squib 33 and voltmeter V are thus connected in series between negative and positive battery. Displacement of the voltmeter needle affords a quantitative determination of squib condition. The high impedance afforded by voltmeter V, like that afforded by resistor SR, limits the test current through the squib to a value insufficient to fire the squib. This test is to some extent redundant to that afforded by operation of switch S3. However, the test effected by operation of switch ST requires switch TSG to be in its test position, while switch S3 may be operated to effect a test with switch TSG in normal detection position. Contacts S3–3 of switch S3 may be included in series with "in-service" lamp ML to prevent illumination of the latter with switch S3 operated.

Since the squib circuit integrity test afforded by operation of switch S3 may be effected with the circuit otherwise in detecting condition, operation of switch S3 is preferably the last test. In this way proper closing of contacts ST–1–1, M, TS1–1, TS2–1, TS3–1 and TSG–1–1 is assured.

In FIG. 14 there is shown the face of a typical test panel showing lamps TL, RL, ML and SB, switches TSG, ST, MS, TS1, TS2, TS3 and S3, voltmeter V and an additional lamp LP. Lamp LP, which may be associated with an audible alarm, is arranged to provide an alarm signal should pressure in the water line controlled by the squib operated valve fall below a predetermined safe level.

A removable shield may be mounted so as to prevent accidental operation of any of switches TSG, ST, TS1, TS2 and TS3. A similar shield is shown for switch S3.

Switches TS1, TS2, TS3 and S3 may be spring loaded, self resetting push buttons, while switches MS, TSG and ST may be toggle switches of the break-before-make type.

When testing during a protection-on period is to be provided, it may be desired to simplify somewhat the test procedure so that protection is interrupted only while actual tests are in progress. For example, switch TSG may be omitted and protection will be afforded except during actual operation of switches TS1, TS2 and TS3. Relay or switch S may be omitted since it will not generally be desirable to stop the hazardous operation while testing.

It may be sufficient in some cases to effect testing by means of one or more lamps located in the hazardous area. In such case photocell pairs (or groups) other than a pair being tested, may be disabled so that system testing by pairs (or other groups may be achieved.

While the invention has been described in connection with specific embodiments thereof and in specific uses, various modifications thereof will occur to those skilled in the art without departing from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. Apparatus for detecting the occurrence of a fire condition in a hazardous zone and for supplying an operating signal to a fire extinguishing mechanism, comprising a plurality of radiation detectors arranged so that radiation emanating from said zone will impinge thereon, said radiation detectors being oriented with respect to each other and with respect to said zone so that said detectors view said zone from respectively different angles, means coupled to said radiation detectors, said signalling means being arranged to produce said operating signal only when radiation having an intensity greater than a predetermined minimum value simultaneously impinges upon each of said radiation detectors, and means to supply said operating signal to said fire extinguishing mechanism.

2. Apparatus for detecting the occurrence of a fire condition in a hazardous zone and for supplying an operating signal to a fire extinguishing mechanism, comprising a plurality of radiation detectors arranged so that radiation emanating from said zone will impinge thereon, said radiation detectors being oriented with respect to each other and with respect to said zone so that said detectors view said zone from respectively different angles, a like plurality of individual signalling means each coupled to and controlled by a respective one of said radiation detectors, said signalling means being arranged electrically with respect to each other in AND gate relationship thereby to produce said operating signal only when radiation having an intensity greater than a predetermined minimum value impinges upon all of said radiation detectors, and means to supply said operating signal to said fire extinguishing mechanism.

3. Apparatus for detecting the occurrence of a fire condition in a hazardous place having a plurality of substantially symmetrical zones, comprising a plurality of groups of radiation detectors, each of said groups comprising a plurality of individual radiation detectors arranged with respect to said place so that radiation emanating from a particular zone will impinge thereon, the radiation detectors of each group being arranged with respect to each other so as to view the corresponding particular zone from respectively different angles, said different angles of view with respect to the corresponding zones being generally similar for all of said groups so that each individual detector has a correspondingly disposed detector in each group, said correspondingly disposed detectors in all of said groups forming sets of detectors, said zones overlapping sufficiently so that a fire condition producing radiant energy at any point in said place will cause radiation to impinge on at least one detector of each set, a plurality of individual signalling means each coupled to all of the detectors of a respective set and arranged to be controlled by any of the detectors of the corresponding set, and means intercoupling said individual signalling means in AND gate relationship, each of said individual signalling means being arranged partially to condition said AND gate to produce an output signal when at least one of the detectors of the corresponding set receives radiation having an intensity greater than a predetermined value, said AND gate producing said output signal only when all of said individual signalling means are so conditioned.

4. Apparatus for detecting the occurrence of a fire condition in a hazardous place having a plurality of zones and for supplying an operating current to an explosively actuated fire extinguishing mechanism operatively arranged with respect to said place and having a current operated explosive actuator, comprising a plurality of groups of radiation detectors, each of said groups comprising a plurality of individual radiation detectors arranged with respect to said place so that radiation emanating from a particular zone will impinge thereon, the radiation detectors of each group being arranged with respect to each other so as to view the corresponding particular zone from respectively different angles, said different angles of view with respect to the corresponding zones being generally similar for all of said groups so that each individual detector has a correspondingly disposed detector in each group, said correspondingly disposed detectors in all of said groups forming sets of detectors, said zones overlapping sufficiently so that a fire condition producing radiant energy at any point in said place will cause radiation to impinge on at least one detector of each set, a plurality of individual signalling means each operatively associated with all of the detectors of a respective set and arranged to be controlled by any one of the detectors of the corresponding set, each of said individual signalling means comprising a power tran-

sistor having an output circuit, and an actuating circuit including, in series connection, said output circuits of said power transistors, a source of actuating potential and said current operated explosive actuator, said individual signalling means each being arranged to condition the corresponding power transistor to become conductive when at least one of the detectors of the corresponding set receives radiation having an intensity greater than a predetermined minimum value, all of said power transistors becoming conductive only when at least one detector of each set receives at least said minimum intensity radiation, said actuating circuit being closed when all of said power transistors become conductive thereby to operate said explosive actuator.

5. Apparatus as set forth in claim 4 comprising selectively operable means to supply to the radiation detectors of each of said groups radiation simulating the occurrence of a fire condition in the corresponding zone, and current responsive signal registering means, said selectively operable means being arranged when operated to disconnect said explosive actuator from said actuating circuit and to connect said signal registering means in said actuating circuit whereby said signal registering means registers current flow in said actuating circuit in response to said simulated fire condition.

6. Apparatus for detecting the occurrence of a fire condition in at least a hazardous zone of a hazardous place and for operating a current responsive fire extinguishing mechanism, comprising a plurality of photocells each disposed so that substantially said entire zone lies in the effective field of view of each of said photocells, said photocells being arranged with respect to each other and with respect to said zone so that said photocells view said zone from respectively different angles, a like plurality of transistor amplifiers each coupled to a respective one of said photocells and each being arranged to have an output proportional to the intensity of radiation incident on the corresponding one of said photocells, a like plurality of power transistors each having an input circuit, said input circuits of said power transistors each being coupled to a respective one of the output circuits of said transistor amplifiers and being arranged to condition said power transistors to become conductive when the output of the corresponding one of said transistor amplifiers reaches a predetermined minimum value, and a signal output circuit including the output circuits of said power transistors, said output circuits of said power transistors being connected in predetermined AND gate arrangement in said signal output circuit whereby said signal output circuit is closed only when more than one of said power transistors are conductive in accordance with said gate arrangement whereby only radiation incident on a combination of said photocells which will satisfy said gate arrangement will result in closing of said signal output circuit.

7. Apparatus as set forth in claim 6, comprising a plurality of additional photocells each exposed to ambient illumination but shielded from said hazardous place, each of said additional photocells being coupled to the input circuit of a respective one of said transistor amplifiers and being arranged to oppose any change in input to the corresponding transistor amplifier caused by changes in ambient illumination impinging on the corresponding photocell disposed so as to view said zone.

8. Apparatus for detecting the occurrence of a fire condition in at least a hazardous zone of a hazardous place and for supplying an operating current to a current responsive explosively actuated fire extinguishing mechanism comprising first and second photoconductive elements arranged so that radiation emanating from said zone will impinge thereon, said first and second elements being oriented with respect to each other with respect to said zone so that said first and second elements view said zone from substantially opposite directions, signalling means coupled to said first and second elements, said signalling means being arranged to produce said operating current only when radiation having an intensity greater than a predetermined minimum value simultaneously impinges upon both of said first and second elements, and means including a signalling circuit to supply said operating current to said current responsive explosively actuated fire extinguishing mechanism.

9. Apparatus as set forth in claim 8 in which said signalling means comprises first and second solid state signal amplifiers having input circuits coupled to said first and second photoconductive elements, respectively, and first and second solid state power amplifiers having input circuits coupled to and being controlled by the output circuits of said first and second solid state signal amplifiers, respectively, the output circuits of said power amplifiers being connected in series as part of said signalling circuit.

10. Apparatus as set forth in claim 9, comprising third and fourth photoconductive element exposed to ambient illumination but shielded from said hazardous place, and a source of direct potential, said first and third photoconductive elements and said second and fourth photoconductive elements being connected, respectively, as voltage dividers across said source of potential, the input circuits for said first and second solid state signal amplifiers being coupled to said voltage dividers between said first and third photoconductive elements and between said second and fourth photoconductive elements, respectively.

11. Apparatus for detecting the occurrence of a fire condition in a hazardous place having a plurality of zones, comprising a plurality of groups of photocells, said photocells being arranged so that each of said zones lies substantially completely within the field of view of all of the photocells forming a respective one of said groups, the photocells of each group being arranged with respect to each other in angular disposition so as to view the corresponding zone from respectively different angles, said angular disposition of individual photocells within each group with respect to the corresponding zone being generally similar for all of said groups whereby each photocell of a group corresponds to a similarly disposed photocell of the other groups, said corresponding photocells forming a set, a plurality of transistor amplifiers each having an input circuit coupled to the photocells of a respective one of said sets and having an output proportional to the intensity of radiation incident upon the photocells of the respective set, a plurality of adjustable impedance elements, means to supply the output of each of said transistor amplifiers to a respective one of said impedance elements, a plurality of power transistors each having an input circuit coupled to a respective one of said impedance elements, and a signalling circuit including, in series connection, the output circuits of more than one of said power transistors and a source of signalling potential, said power transistors each being arranged to be conditioned to become conductive when the radiation incident on any of the photocells of the corresponding set reaches an intensity at which the output of the corresponding transistor amplifier reaches a predetermined minimum value, said power transistors having series connected output circuits becoming conductive to close said signalling circuit only when at least one photocell of each of the corresponding sets receives radiation having said intensity sufficient to condition the corresponding power transistors to become conductive whereby radiation not incident on at least one of the photocells of any one of said corresponding sets will not result in the flow of current in said signalling circuit.

12. Apparatus for detecting the occurrence of a fire condition in a hazardous place having a plurality of substantially symmetrical zones and for supplying an operating current to an explosively actuated fire extinguishing mechanism operatively arranged with respect to said place and having a current actuated explosive actuator, comprising a plurality of groups of photocells, said photo-

cells being arranged so that each of said zones lies substantially completely within the field of view of all of the photocells forming a respective one of said groups, the photocells of each group being arranged with respect to each other in angular disposition so as to view the corresponding zone from respectively different angles, said angular disposition of individual photocells within each group with respect to the corresponding zone being generally similar for all of said groups whereby each photocell of a group corresponds to a similarly disposed photocell of the other groups, said corresponding photocells forming a set, means intercoupling the photocells of each set in parallel with each other, a plurality of voltage divider circuits each including a respective one of said sets of photocells, a plurality of transistor amplifiers each having an input circuit coupled to a respective one of said voltage divider circuits and having an output proportional to the intensity of radiation incident upon the photocells of the set included in the corresponding voltage divider, a plurality of adjustable impedance elements, means to supply the output of each of said transistor amplifiers to a respective one of said impedance elements, a plurality of power transistors each having an input circuit coupled to a respective one of said impedance elements, and an actuating circuit including, in series connection, a rectifier element, the output circuits of said power transistors, a source of actuating potential and said current actuated explosive actuator, said power transistors each being arranged to be conditioned to become conductive when the radiation incident on any of the photocells of the corresponding set reaches an intensity at which the output of the corresponding transistor amplifier reaches a predetermined minimum value, said power transistors becoming conductive to close said actuating circuit only when at least one photocell of each of said sets receives radiation having said intensity sufficient to condition the corresponding power transistors to become conductive whereby radiation not incident on at least one of the photocells of any one of said sets will not result in the supplying of current to said explosive actuator.

13. Apparatus for detecting the occurrence of a fire condition in a hazardous place having a plurality of substantially symmetrical zones and for supplying an operating current to an explosively actuated fire extinguishing mechanism operatively arranged with respect to said place and having a current actuated explosive actuator, comprising a plurality of groups of photocells, said photocells being arranged so that each of said zones lies substantially completely within the field of view of all of the photocells forming a respective one of said groups, the photocells of each group being arranged with respect to each other in angular disposition so as to view the corresponding zone from respectively different angles, said angular disposition of individual photocells within each group with respect to the corresponding zone being generally similar for all of said groups whereby each photocell of a group corresponds to a similarly disposed photocell of the other groups, said photocells corresponding to similarly disposed photocells of said other groups forming a set, means intercoupling the photocells of each set in parallel with each other, a plurality of voltage divider circuits each including a respective one of said sets of photocells, a plurality of transistor amplifiers each having an input circuit coupled to a respective one of said voltage divider circuits and having an output proportional to the intensity of radiation incident upon the photocells of the set included in the corresponding voltage divider, a plurality of adjustable impedance elements, means to supply the output of each of said transistor amplifiers to a respective one of said impedance elements, a plurality of power transistors each having an input circuit coupled to a respective one of said impedance elements, an actuating circuit including, in series connection, a rectifier element, the output circuits of said power transistors, a source of actuating potential and said current actuated explosive actuator, said power transistors each being arranged to be conditioned to become conductive when the radiation incident on any of the photocells of the corresponding set reaches an intensity at which the output of the corresponding transistor amplifier reaches a predetermined minimum value, said power transistors becoming conductive to close said actuating circuit only when at least one photocell of each of said sets receives radiation having said intensity sufficient to condition the corresponding power transistors to become conductive whereby radiation not incident on at least one of the photocells of any one of said sets will not result in the supplying of current to said explosive actuator, an individual source of radiation for each of said photocells, each of said sources of radiation simulating a fire condition in the corresponding zone, selectively operable switching means for sequentially emergizing said sources of radiation corresponding to the photocells of each group, and current responsive signal registering means, said switching means, when operated, acting to substitute said signal registering means for said explosive actuator in said actuating circuit whereby said signal registering means registers current flow in said actuating circuit in response to said simulated fire condition.

14. Apparatus as set forth in claim 13 comprising means to adjust the intensity of radiation provided by said individual sources of radiation through a range of values whereby operation of said signal measuring means provides a comparative indication of the fire detection sensitivity of said individual groups of photocells.

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