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Nov. 9, 1965 B. W. DEVINE 3,216,477

FLAME SAFEGUARD SYSTEMS AND DEVICES

Original Filed Nov. 23, 1960 3 Sheets-Sheet 1

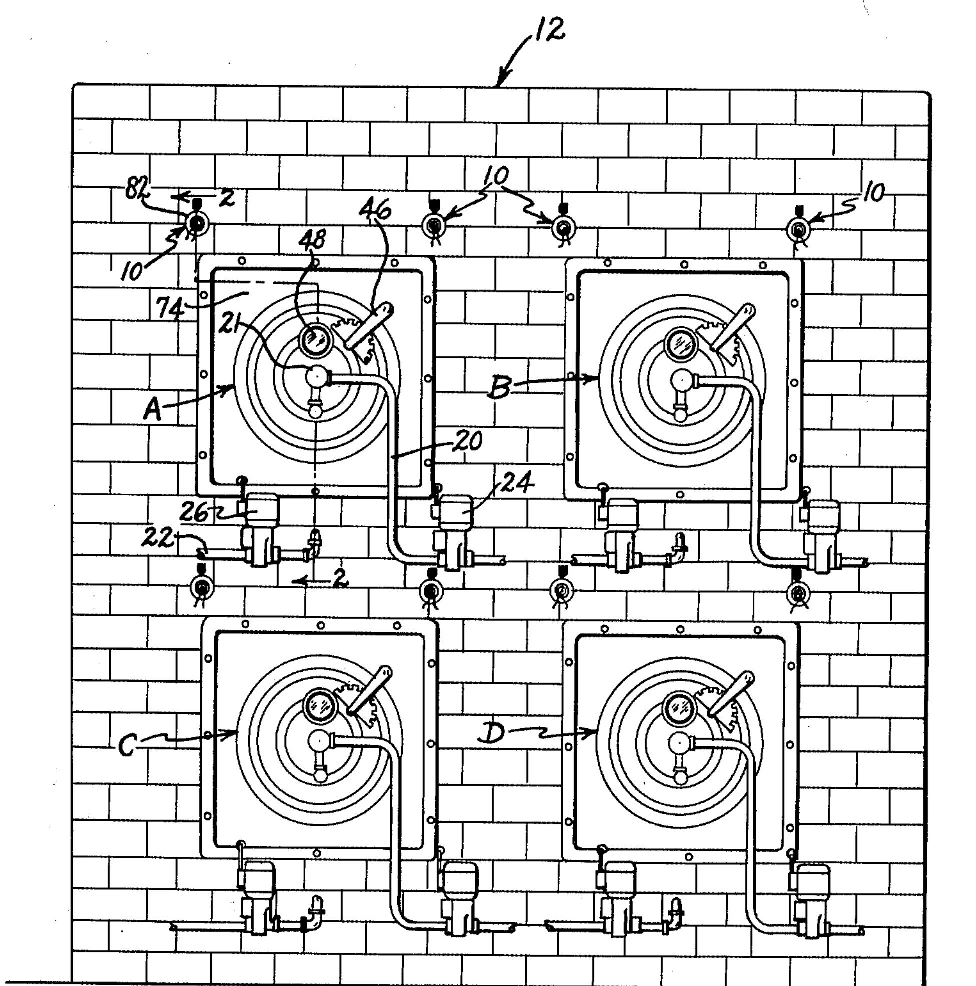

Fig. 1

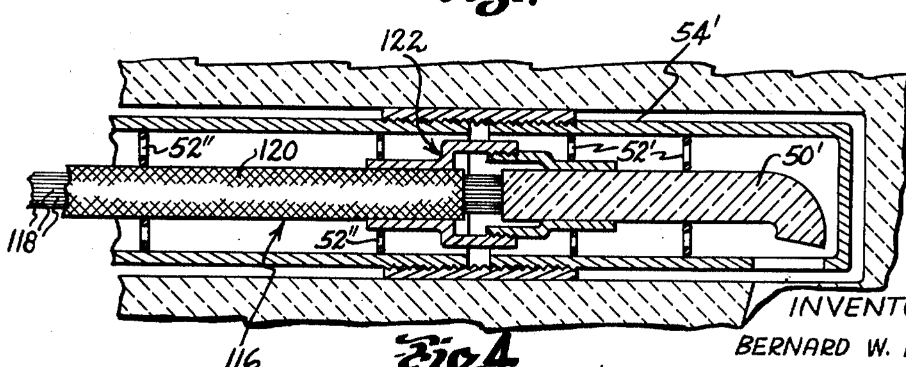

Fig. 4

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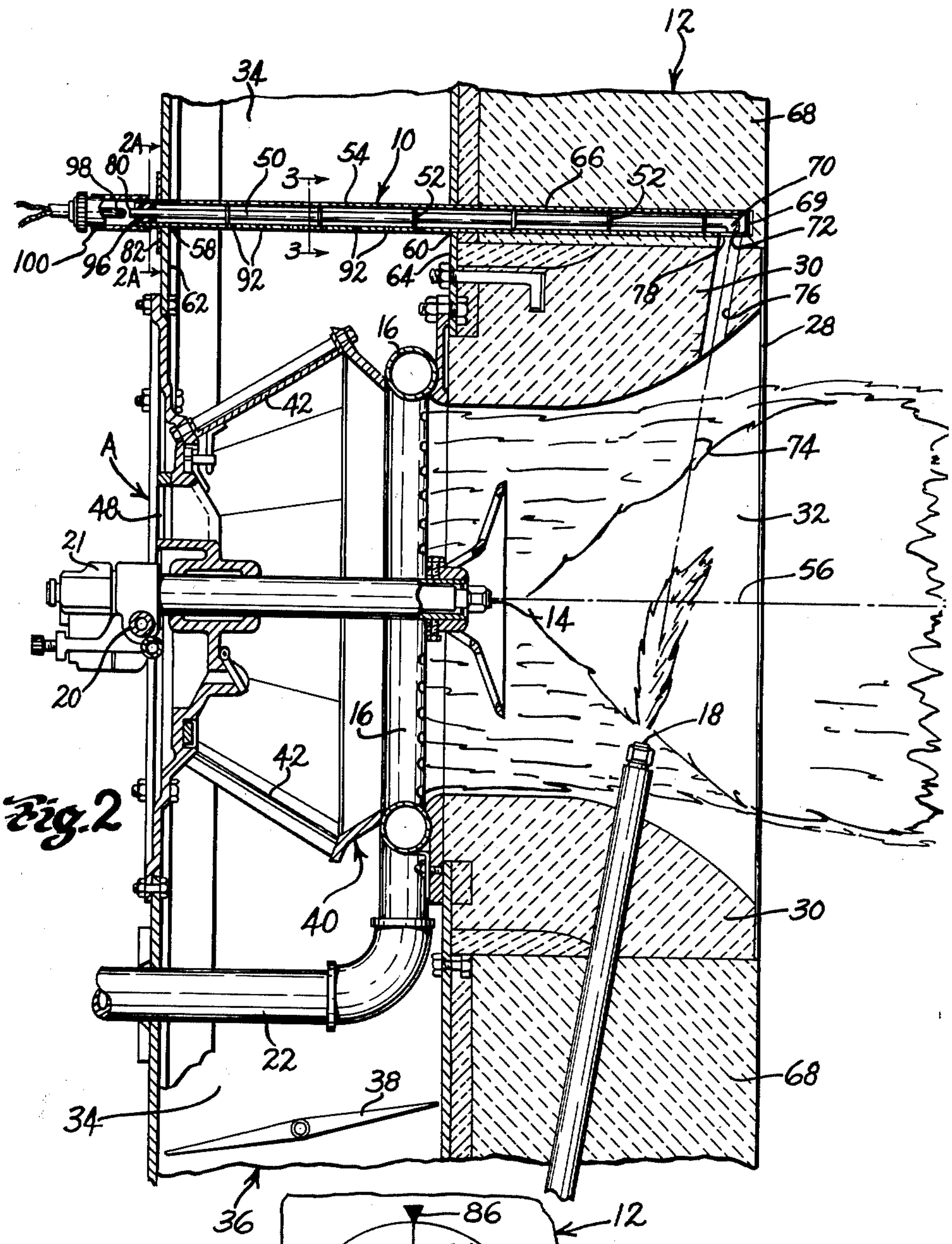

Fig. 2

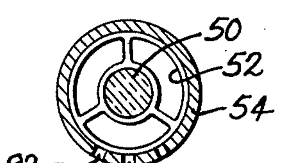

Fig. 3

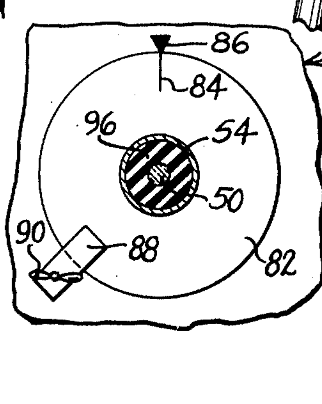

Fig. 2A

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FLAME SAFEGUARD SYSTEMS AND DEVICES

Original Filed Nov. 23, 1960 3 Sheets-Sheet 3

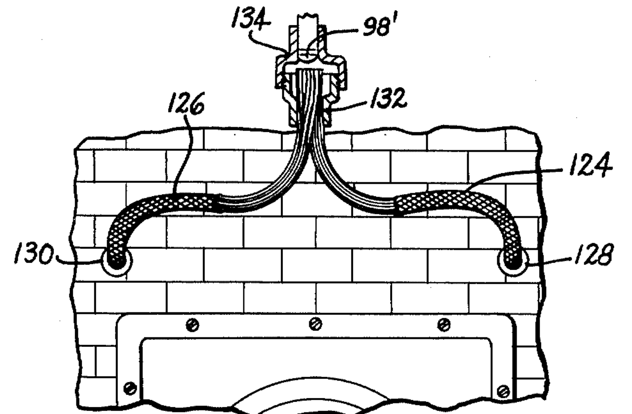

Fig. 5

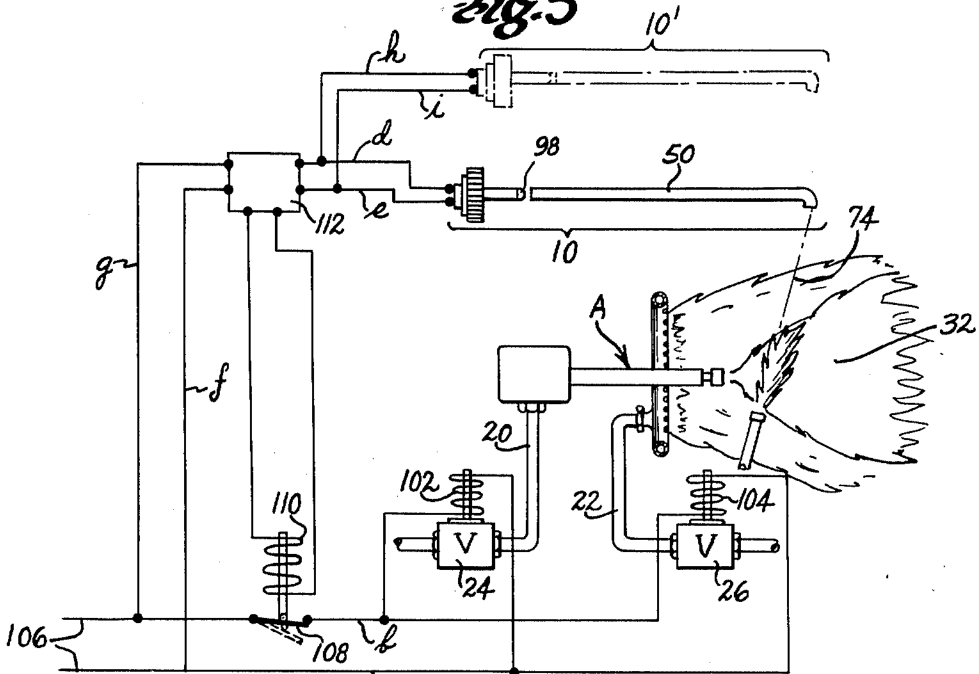

Fig. 6

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FLAME SAFEGUARD SYSTEMS AND DEVICES

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Continuation of abandoned application Ser. No. 71,185, Nov. 23, 1960. This application Aug. 8, 1963, Ser. No. 301,940
7 Claims. (Cl. 158—28)

This application is a continuation of application Serial No. 71,185, filed November 23, 1960, now abandoned.

This invention relates to a novel flame safeguard system and devices incorporated therein for protecting boiler furnaces or the like against explosion hazard.

Many lives are lost each year as a result of boiler explosions and too may millions of dollars are wasted because of the inadequacy of present-day flame safeguards.

While excellent photosensitive elements in themselves are available to verify the existence or absence of flame, their failure to fully protect against furnace explosions has resulted mainly from inferior installations wherein the detection elements cannot function properly or to their best advantage.

Conventional safeguard systems have numerous design shortcomings which, for example, have resulted in their inability to unfailingly sense and respond to such hazards as the loss of flame particularly in one of more burners of a multi-burner furnace or the moving of a burner flame front radically away from its intended origin. Surveillance of one flame source to the complete exclusion of other flame sources in multi-burner installations has, heretofore, been a problem of great concern to manufacturers of flame safeguard systems and to insurance companies alike since the issuance of false indications of safe operation when actually a burner flame has extinguished can be extremely hazardous.

Other drawbacks of present-day safeguard systems relate to the so-called "fail safe" systems which act to immediately stop the fuel supply to a burner at the slightest indication of sub-normal operation either of the furnace burner or of the system itself. These systems often cause unnecessary and costly shut-downs of boiler furnaces for disturbances which are not of a dangerous nature.

While a furnace burner can be re-started almost immediately, start-ups always are potentially dangerous and explosion records prove overwhelmingly that when a burner start-up is on a crash basis to save a factory process or plant load or the like, the probability of explosion skyrockets. Unnecessary shutdowns can be dangerous in view of the potential explosion hazard which accompanies furnace start-ups. Therefore, it is obvious that the conventional so-called "fail safe" systems leave much to be desired in the search for reliability of operation with optimum safety.

For maximum protection against furnace explosions and the avoidance of unnecessary shutdowns, a flame detector must "see" the flame that it is to protect at all times and not be affected by other flames or by refractory glow or other forms of incandescence. It must instantly detect a hazardous movement of the flame away from its proper origin and be so located relative to the flame and to the various parts of the furnace configuration as to be unaffected by dust, carbon particles or other foreign matter which might cause failure or spurious responses of the system and/or unnecessary shutdown of the furnace.

While in single burner furnaces, the problems of applying adequate safety measures would seem to be a simple matter since discrimination between multiple flame sources is unnecessary, it is a fact that conventional single burner flame-detection devices are considerably lacking in many respects. For example, the most common

practice of "sighting" generally along the burner axis either from the front or the back of the furnace permits the "seeing" of the burner's pilot and main flame with a single detector but neglects the possibility that the main flame might move dangerously out into the furnace along said axis and away from its proper origin as a result of system malfunction. Axially "sighted" detection devices cannot sense this hazard. By altering the "line of sight" of a detector so as to protect against the danger of a flame pulling away from the burner, simultaneous surveillance of the burner's pilot and main flames cannot be successfully accomplished with the single detection devices presently used. Thus, along with the main flame detector, a second detector "sighted" on the burner's pilot is needed. Such added equipment increases installation problems and costs and complicates the flame safeguard system thereby enhancing the possibilities of failure or malfunction in the system itself.

The above-mentioned "sighting" problems grow to be much more complex in furnaces having more than one burner since the pilot and main flames of each burner must be kept under surveillance to the complete exclusion of the pilot and the main flame sources of the other burners in the same furnace. That is, the flame detector "seeing" the pilot and main flame of one burner must not at any time "see" any of the flames from other adjacent burners. Furthermore, if two burners, for example, are initially in operation and one loses ignition, raw fuel would be poured into the furnace from the extinguished burner if its flame scanner were to continue its hold-in function or falsely indicate a condition of safety by picking up light from the other burner. The hazards of pouring unignited fuel into a furnace are well known and feared.

As more burners per furnace enter the picture, the safety problem becomes increasingly difficult and, in line with this, flame safeguard systems previous to this invention have become extremely complicated and costly with the ultimate in protection seldom, if ever, realized.

The prime requisite for optimum protection in multi-burner furnaces is maximum discrimination between burners. Discrimination is defined herein as meaning a flame detector's ability to "see" its own burner flame to the exclusion of other burner flames. One hundred percent discrimination, as termed by insurance companies, is the condition where a flame detector will "see" or detect the presence of a flame from a particular burner completely to the exclusion of flames issuing from other burners when the furnace is operating up to one hundred percent of its boiler rating.

One hundred percent discrimination has not been possible to achieve in any practical manner heretofore and, for that matter, most installations previous to this invention do not even approach this figure. This is quite evident from the standards set by insurance companies who, while being eager to enforce one hundred or nearly one hundred percent discrimination, have had to accept discrimination of only fifty percent of boiler rating. Enforcing one hundred percent discrimination, while highly desirable, has proven impractical. The lower figure is accepted by the insurance companies with the hope that a burner losing ignition will re-ignite from other adjacent burners. This, of course, does not always happen.

While safety is of prime importance in the operation of furnaces in general, there is the need for reliability of service particularly in power plants where boilers are used to generate steam for electrical power generation, factory processing and heat and where shutdowns even of minimum duration are extremely costly and disconcerting as well as hazardous.

The present invention overcomes the shortcomings of conventional equipment which does not offer a satisfactory solution to the achievement of optimum safety with reliability of service.

Accordingly, it is a principal object of the invention to provide improved means for safeguarding boiler furnaces or similar forms of equipment in such a manner as to assure maximum safety of operation without sacrifice of reliability of service.

Another object is to provide installations which will accomplish the above results and which are readily adaptable to existing forms of boiler equipment.

Another object is to provide flame safeguard equipment of the above character which is unique in its simplicity and economy of construction, ease of installation and reliability of operation.

Another object is to provide flame safeguard equipment which offers the advantages of being readily standardized for installation in present-day furnaces of all known dimensions regardless of the particular flame shape or location of the burner in the furnace and which equipment may be readily integrated in new burner constructions so as to permit burner manufacturers to provide insurance approved package units each including the burner, igniter and flame safeguard system of the invention.

Another object is to provide flame-detection devices of the above character which may be readily and economically installed in dual form in each burner of a furnace with each of the devices either electrically or optically coupled in such a relationship with one another as to permit removal of one of said devices for cleaning or maintenance needs while the burner is in operation and without affecting the normal operation of the burner or in any way violating safety regulations.

Another object is to provide a flame detector capable of simultaneously monitoring both the pilot and main flames of a burner completely to the exclusion of other flame sources in multi-burner installations and further to the exclusion of incandescent bodies such as glowing furnace refractories or the like.

Another object is to provide, in installations of the above character, novel means for protecting the flame-detecting or sensing elements thereof from temperatures which would tend, in any way, to adversely affect their proper function and further to protect the flame "viewing" areas of said elements from becoming obscured or in any way optically degraded by foreign matter within the furnace burner to which they are applied.

Another object is to accomplish the above, at least in part, by applying a positive air pressure at and around the area of the "viewing" end section of said flame-sensing elements which pressure is such as to direct foreign matter away from the said "viewing" end of said elements during operation of the burner with which said elements are associated.

Another object is to provide a flame-detecting device of the above character, fiber optical light-conducting means forming at least a part of said "viewing" section, of said device for receiving and transferring radiation from a location within a furnace adjacent an existing flame source remotely to a desired convenient position externally of said furnace at which a photosensitive member is placed for sensing said radiation with full protection against the adverse effects of high temperatures and/or foreign matter.

A further object is to provide, through the use of the above-mentioned fiber optical light-conducting means, a novel coupling arrangement for operatively connecting two or more flame "viewing" sections of a flame-detection device together in such manner as to permit continual efficient surveillance of a flame source through the use of a single photosensitive detection unit regardless of whether one or the other or both of said "viewing" sections are positioned to receive spectral radiation from said flame source.

A still further object is to provide flame-detecting means of the above character which is particularly useful in multiple burner furnace installations and wherein, in accordance with the invention, said detecting means as applied separately to each burner of said furnace will operate to detect and indicate the existence of absence of flame issued from its particular respective burner substantially completely to the exclusion of other adjacent burners in said furnace thereby offering the long sought feature of substantially 100 percent discrimination in multiple burner furnaces.

Many other objects and advantages of the invention will become apparent from the following description when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a front elevational view of a multi-burner type of boiler furnace embodying a flame safeguard arrangement of the type relating to this invention;

FIG. 2 is a cross-sectional view of one of the burners of said furnace and flame safeguard means therefor taken substantially along line 2—2 of FIG. 1 looking in the direction indicated by the arrows;

FIG. 2A is a cross-sectional view taken on line 2A—2A of FIG. 2 looking in the direction indicated by the arrows;

FIG. 3 is an enlarged cross-sectional view taken approximately along line 3—3 of FIG. 2 looking in the direction indicated by the arrows;

FIG. 4 is a fragmentary cross-sectional view of a modification of the invention;

FIG. 5 is a partially cross-sectioned diagrammatic illustration of a further modification of the invention; and

FIG. 6 is a schematic illustration of a simplified electrical system shown in operably connected relation with the major elements of the invention for the purpose of illustrating an example of a completely functional arrangement of the type embodying the invention for safeguarding boiler furnaces or the like.

In referring more particularly to the drawings wherein like characters of reference designate like parts throughout the several views, it will be seen that the invention relates to novel means and method for safeguarding boiler furnaces or the like against explosion hazard and features a unique flame-detection device **10** (see FIGS. 1 and 2) and novel means for installing the same to its fullest advantage in a boiler furnace or other similar forms of equipment with which it is to be used.

In FIG. 1 there is shown diagrammatically a multi-burner furnace **12** having a plurality of flame-detection devices **10** of the type embodying the invention each installed therein.

The furnace **12** having burners A, B, C and D has been shown diagrammatically as being of the so-called "two over two" multi-burner type only for the purpose of illustrating one of many well-known furnace burner arrangements which are, at present, urgently in need of more efficient and reliable flame-safeguarding systems such as this invention provides for protection against explosion hazard.

As pointed out, hereinabove, the inadequacy of present-day flame safeguard systems extends to single burner furnace installations as well as the multi-burner arrangement of the type shown in FIG. 1 of the drawings and, in view of this, the devices **10** of the invention are in no way limited in application to multi-burner furnaces for it will become apparent as this description progresses that each of the flame-detection devices **10** which are shown throughout the drawings are basically similar in structure and function independently for use with and in all types of furnace installations irrespective of the burner flame shapes or sizes or the fuels used to support the burner flames.

Referring more particularly to FIG. 2 wherein a substantially vertical cross-sectional view of a typical furnace burner A has been shown for purposes of illustrating the invention, it will be noted that the burner A is of the commonly known gun-type embodying an oil nozzle

14 and a concentrically related perforated gas ring 16 for supplying fuel to the furnace. As in the usual case of such burners, a pilot 18 (usually gas fed) is provided to initially ignite fuel issuing from the main burner outlets 14 or 16 when the fuels are force-fed therethrough.

In the burner A (FIGS. 1 and 2) oil is pumped under pressure through a line 20 into an atomizer 21 from which it is fed to the nozzle 14 and in a similar manner but without the atomizer, gas is fed to the ring 16 through a pressurized line 22. In the lines 20 and 22, there is provided shut-off valves 24 and 26 respectively of the well-known solenoid operated type usually considered as being standard equipment in burner installations having flame-safeguard systems. The valves 24 and 26 are adapted to be manually opened to allow the passing of fuel into their respective burner for start-up purposes but are thereafter controlled by the burner flame-safeguard system which holds them open when flame is present in the burner acts to close the same when flame failure or other hazardous conditions occur. The valve 24 in the oil line 20 operates to open when its solenoid is energized and thereby allow fuel to pass into the burner and when de-energized, it automatically closes to shut off the oil supply to the burner. The valve 26 in the gas line 22 operates in a manner identical to that of the oil shut-off valve 24.

It is pointed out, at this time, that, in accordance with this invention, the valves 24 and 26 being electrically operated are connected in circuit with a burner safeguard-system which is controlled through the use of the flame-detector 10 which is featured herein and it will become apparent that the flame-detector 10 functions in such manner as to cause the valves 24 and 26 to close and shut off the fuel supply to the burner A when a hazardous condition exists in the burner A. The detector 10 and its associated electrical circuit including the solenoids in the valves 24 and 26 will be described in detail shortly. However, in order to more fully understand the operation of the burner A itself with a view toward a better understanding of the description of the detector 10 and its operation which will follow, it will be seen in FIG. 2 that the oil nozzle 14 and gas ring 16 are set back from the inner furnace wall 28 and supported by burner tiles 30 which are shaped to form a throat aperture defining combustion area 32 within which the burner flames are initiated from either or both the nozzle 14 and/or the ring 16. In the usual manner of burner operation, a forced draft is provided through the combustion area 32 in a direction passing into the furnace firebox to propagate the burner flames. That is, immediately upon issuing from either the nozzle 14 or the ring 16, the fuel is mixed with air which is forced past the nozzle 14 and ring 16 into the combustion area 32. Combustion then takes place somewhat forwardly of the nozzle 14 and ring 16 as illustrated in FIG. 2. As mentioned above, the burner may be operated solely with either the oil-burning nozzle 14 or with the gas ring 16 or both simultaneously. The forced draft system embodies a so-called "wind box" 34 which is merely an air chamber behind the fuel-emitting elements of the burner (see FIG. 2). The chamber or "wind box" 34 is pressurized by forcing air thereinto through the use of fans or the like (not shown) in the usual manner well known and common to most burner installations. In the case illustrated (FIG. 2), the air is forced into the "wind box" 34 at an entrance 36 and by means of a damper 38, the extent of pressure within the "wind box" is controlled. Furthermore, in order to provide a positive control of the forced draft through the burner, a second damper arrangement 40 is provided in the "wind box" 34. The damper arrangement 40 embodies what are usually referred to as "air doors" 42 opening into the "wind box" 34 which may be operated to open or close to the extent needed to adjust the velocity of air directed through the burner. A hand lever 46 (see FIG. 1) is provided outwardly of the furnace 12 which, through conventional mechanical linkages (not shown) may be operated to open or close the "air doors" 42.

It will also be noted as a matter of interest that, as shown in FIGS. 1 and 2, there is provided a window 48 through which an operator may view the burner flames and to some extent visually determine the firing conditions within the burner. However, since a fireman tending many burners cannot keep a constant vigilance on any one burner nor can he visually readily detect hazardous conditions such as the pulling away of a flame from its proper location relative to the burner nozzles or other potentially hazardous conditions within the burner, automatically operated flame-safeguard systems are a "must" in present-day boiler furnace installations. In fact, they are required by insurance companies for the reasons discussed hereinabove.

The flame-safeguard system of the invention embodies, as mentioned above, novel flame-detectors 10 so constructed and arranged in the furnace 12 as to each "see" the flames of their respective burners only and to the complete exclusion of other adjacent burner flames.

The flame-detectors 10, as shown in FIG. 1, are preferably installed in pairs, that is, two for each burner for the convenience of maintenance or periodic checking of their performance or for replacement purposes wherein one of the two units may be completely removed from the furnace without shutdown of the burner or in any way affecting its normal operation. To this end, it will become apparent that each detector in the system of the invention functions independently of the others thereof to safeguard its respective burner. Therefore, a single one of the flame-detectors 10 will be described in detail, it being understood that all others are substantially physically and functionally identical.

Referring more particularly to FIG. 2, it will be seen that in one aspect of the invention, the detector 10 embodies an elongated light-conducting rod 50 formed of fused quartz which is supported by spider-like spacer members 52 (see FIG. 3) substantially centrally within a surrounding tubular outer casing 54. The casing 54 containing the light-conducting rod 50 is passed to one side of but in approximately axially parallel relation with the burner axis 56 through openings 58 and 60 in the respective opposite wall parts 62 and 64 of the "wind box" 34 and thence into a relatively close fitting bore 66 in the furnace wall refractory 68 above and to one side of the burner A (see FIGS. 1 and 2). When in position as shown in FIG. 2, the end 69 of the casing 54 is located adjacent the inner furnace wall 28 and above the burner tile 30. The adjacent end of the light-conducting rod 50 is provided with a fixed bend 70 substantially as shown in FIG. 2 and terminates with a flat optically finished light-receiving face 72 disposed substantially normal to an axis 74 which axis is directed obliquely in a rearward direction into the combustion area 32 of the burner A. This axis 74 will hereinafter be referred to as the "sight line" 74 of the detector 10 and is disposed at an acute angle relative to the axis 56 of the burner A.

To permit light from the burner flames to illuminate or be received by the rod 50, an opening 76 substantially axially concentric with the sight line 74 is provided through the burner tile 30 and the adjacent furnace wall refractory 68 so as to communicate with the bore 66. Also adjacent the end 69 of the casing 54, there is provided a lateral or side opening 78 of such size, shape and location as to expose the light-receiving face 72 of the rod 50 to light passing from the burner flames through the opening 76.

The light-receiving face 72 which was said to be optically finished may be formed by grinding and polishing or alternatively formed by scoring the side of the rod 50 at the point where the face 72 is to be formed and breaking the rod 50 at the score mark. It has been found that a clean break in a fused quartz rod will produce a face finish fully equivalent to that obtainable by optical grinding and polishing. The opposite light-emitting end **80** of the rod **50** is finished in a similar manner to that of its face **72**.

The bend **70** is controlled in accordance with the furnace construction so as to incline the sight line **74** rearwardly toward the burner A an amount such as to prevent the face **72** of the rod **50** from accepting any light emanating from sources outside the combustion area **32**. For applications such as illustrated herein, a sight line **74** angled approximately 10° from a normal to the axis **56** of the burner is appropriate when using a rod **50** of approximately ⅜ to ½ inch in diameter. However, the angle of the sight line **74** must be appropriate for the particular burner installation to which the flame-detector **10** is applied. That is, the cross-sectional size of the rod **50**, the proximity of its end face **72** relative to the inner wall **28** of the furnace, the size of the opening **76** and diameter as well as thickness of the combustion area are all factors to consider in the determination of the optimum degree of tilt of the sight line **74** relative to a normal from the burner axis.

Since the flame-detectors **10** are each set to one side of the burner axis **56**, as shown in FIG. 1, the light-receiving face **72** of the rod **50** must be so oriented as to cause the sight line **74** to intersect the burner axis **56**, as shown in FIGS. 1 and 2. This orientation of the face **72** is accomplished by rotating the tubular casing **54** about its axis to align the opening **78** therein and the face **72** of the rod **50** with the opening **76** in the burner tile **30**. In order to permit the assembly of the rod **50** and its associated casing **54** to be removed and accurately replaced from outside the furnace **12**, an annular disc **82** (see FIG. 2A) is welded or otherwise secured to the casing **54** and provided with an index mark **84** which, when aligned with a suitable fixed reference point **86** on the outer wall of the furnace **12**, will establish the proper orientation of the light-receiving face **72** of the rod **50**. Also, the disc **82** functions as stop means to properly locate the face **72** of the rod **50** in a fore and aft direction substantially axially concentric with the opening **76** when the disc **82** is seated firmly against the outer furnace wall. One or more clamps **88** securable with thumb screws or the like **90** may be used to fix the disc **82** and casing **54** assembly in the above-mentioned desired aligned relationship with the burner axis **56**. It is pointed out that in initially assembling the rod **50**, disc **82** and the casing **54**, the rod **50** is rotationally correctly pre-aligned relative to the index mark **84** or vice-versa and by means of the tight-fitting spider-like spacer members **52**, it is thereafter permanently held in place.

By reason of the fact that fused quartz rods will inherently transfer light by the well-known principle of internal reflection with a minimum of intensity loss, the installation of the assembly just described will pick up light or spectral radiation from the flame sources in the burner combustion area **32** and emit said light with a minimum of loss in intensity at the end **80** thereof which is located outside the furnace **12** as shown in the drawings.

When referring to light herein, it is intended to include either visible or invisible radiation of the type inherently emitted by flame sources. However, because of the features slightly rearwardly directed sight line **74** of the quartz rod and the shielding of its end face **72** by the side walls the opening **76**, practically all light within the furnace fire box emanating from flames of adjacent burners B, C or D or other sources within the furnace **12** will not illuminate the face **72** of the quartz rod **50**. Moreover, any light from outside the combustion area **32** which might somehow illuminate portions of said area **32** when the burner A flames are extinguished will not illuminate the quartz rod because of the shielding of its face **72** by the side walls of the opening **76**. That is, a quartz rod will only receive and transfer light passing substantially axially through the opening **76**.

From the foregoing, it can be seen that the quartz rod **50** when installed in a furnace as described above will, by receiving and transmitting only light emanating from within the burner combustion area **32**, provide a multiple burner furnace such as **12** with a 100% discrimination factor. This means that the flame-detector **10** (FIG. 2) will pick up and transmit light to its end **80** only from burner A and to the complete exclusion of all light from other burners such as B, C and D in FIG. 1.

The sight line **74** of the quartz rod **50** being substantially co-axial with the pilot **18**, while intersecting the burner axis **56**, will cause the quartz rod **50** to "see" the pilot flame as well as the flames from the oil nozzle and the gas ring **16**.

Since during the operation of a furnace burner, there is a tendency for carbon particles or other foreign matter to collect to some degree on the burner tiles **32** and adjacent areas of the furnace, means is provided in accordance with this invention to prevent an accumulation of this matter on the face **72** of the quartz rod **50** or the adjacent areas of the detector **10**. In this respect, the portion of the casing **54** which extends through the "wind box" **34** is perforated at **92** and a stopper **96** is provided to seal off the end of said casing **54** adjacent the end face **80** of the quartz rod **50**. Thus, because of the air pressure in the "wind box" **34**, air will be continuously forced into and through the perforations **92** and be directed forwardly in casing **54** toward its end **68** where it will exit through the opening **78** into the opening **76** in the burner tile and thence into the combustion area **32** of the burner. This flow of air, in passing the light-receiving face **72** of the quartz rod **50**, will prevent foreign matter from accumulating upon the said face **72** and at the same time produce a cooling effect upon the quartz rod **50** itself to avoid possible overheating thereof by the burner flames and adjacent heated burner tiles **30**. It is pointed out, however, that by proper control of the number and size of the perforations **92**, the air flow through the casing **54** is controlled to be of a force only sufficient to accomplish the results of keeping the quartz rod clean and relatively cool without causing an appreciable disturbance of the burner flames upon issuing from the opening **76** into the combustion area **32**.

In order to utilize the light-conducting feature of the quartz rod **50** which indicates the presence or absence of flame in the burner combustion area by emitting light from its face **80** when flame is present in the burner A and being substantially dark when flame is non-existent in the burner A, a photosensitive element **98** mounted within a suitable housing **100** such as shown in FIG. 2 is coupled to the casing **54** in such manner as to place the element **98** adjacent the face **80** of the quartz rod **50**. The photosensitive element **98** and end **80** of the rod **50**, in this manner of construction, are completely confined within a dust and light-proof enclosure so as to be uneffected by foreign matter or external light.

The photosensitive element **98** may be either of a type which will produce an electrical current when exposed to light or of the well-known photoconductive type.

For purposes of illustration, the element **98** will be considered to be photoconductive and, in FIG. 6, a simplified circuit for such an element is shown to illustrate its function in a flame-safeguard system of the type relating to this invention. It is to be understood, however, that other types of photosensitive elements such as mentioned above may be used to accomplish the end result obtainable with the photoconductive element **98** to be described herein. Elements of the type which produce electrical energy when exposed to light rather than becoming more or less conductive require a somewhat different but conventional operating circuit than that to be described hereinafter.

The electrical circuit in FIG. 6 is strictly elementary and unrefined to illustrate the principle of operation of the flame-detector **10** of the invention, it being understood that in actual practice, a more conventional and elaborate circuit would normally be used. In FIG. 6, the burner A of FIGS. 1 and 2 is illustrated schematically and its associated fuel lines **20** and **22** with valves **24** and **26** are likewise schematically illustrated. Solenoids **102** and **104** which operate to hold the respective valves **24** and **26** open when energized are electrically connected to a current source **106** by leads *b* and *c* and a switch **108** is provided in the lead *b* which, when opened, will de-energize the solenoids **102** and **104** thereby causing them to drop out and close the valves **24** and **26** to shut off the fuel supply to the burner A. The switch **108** is opened and closed by means of a solenoid **110** which is energized by a circuit through a conventional electrical gating device **112** connected in circuit with the photosensitive element **98** by leads *d* and *e*. The gating device **112** is, in turn, connected to the source of current **106** by leads *f* and *g*. The photosensitive element **98** being of the photoconductive type as mentioned above will, when exposed to light, become more conductive and permit the passage of more current through the leads *d* and *e* and when dark (not receiving light from the quartz rod **50**), it will become more resistive and tend to block the flow of current through leads *d* and *e*. The photosensitive element **98** may be formed of any one or combinations of various well-known materials such as cadium selenide, cadmium sulfide or lead sulfide.

With the gating device **112** set to operate at a particular threshold voltage which is pre-established to energize the solenoid **110** when the photosensitive element is rendered conductive by light from the quartz rod **50** and to de-energize the solenoid **110** when the photosensitive element **98** is dark (not receiving light from the quartz rod **50**) it will be seen that the switch **108** will remain closed and hold the solenoids **102** and **104** in such a position as to open the full valves thereby continuing to supply fuel to the burner while flame is present in the combustion area **32** thereof. However, in the absence of flame in the burner A, the solenoid **110** will be de-energized to open the switch **108** and thereby de-energize the solenoids **102** and **104** to shut off the fuel supply to the burner A. Thus, it can be seen that the safeguard system of the invention embodying the novel flame-detector **10** functions immediately in response to the absence of flame in the burner A so as to shut off the fuel supply in the event of flame failure.

In addition to the above, it will be noted by again referring to FIG. 2 that because of the fact that the flame-detector **10** can only "see" a flame in the immediate vicinity of its sight line **74**, it will also provide means for protection against the hazardous condition where, because of system malfunction, the burner flames might pull away from their proper origin. In the event of such a happening, once the origin of the flames has moved into the furnace fire box past the sight line **74** of the detector **10** wherein it will no longer "see" or receive light from the burner flames, the photosensitive element will become less conductive and thereby, through the circuit in FIG. 6, cause the solenoid valves **24** and **26** to close and shut off fuel to the burner. In this way, a potentially explosive condition will be avoided. Also, in view of the fact that the flame-detector **10** is sighted upon the pilot **18**, the potential danger of pilot flame failure in burner start-ups is avoided since failure of the pilot flame will render the photosensitive element dark and de-energize the solenoids **102** and **104** (FIG. 6) so that the valves **24** and **26** which are manually opened to start the burner A will not hold open. Therefore, in the event of pilot failure, raw fuel will be prevented from issuing into the burner combustion area **32**.

It is pointed out that after the burner A has been started, the flame-detector will act to hold-in the solenoids **102** and **104** of the valves **24** and **26** by receiving light from the main burner flames. The pilot **18** can then be and usually is shut off mainly for reasons of economy since gas for pilot burners is normally separately metered at a relatively high cost per cubic foot while the main burner gas is metered at a relatively low cost per cubic foot.

From the above, it can be seen that the ultimate in safety with reliability of operation can be achieved with the flame-safeguard system and apparatus of the invention which provides substantially 100% discrimination between flame sources in multi-burner applications. Furthermore, in single or multi-burner application, the invention, among other things, provides maximum protection against pilot failure and pulling away of flame sources from their proper origin.

As mentioned above, the flame-detectors **10** are preferably provided in pairs for each burner and are electrically or otherwise paralleled so as to be able to operate independently of each other to hold-in the solenoids **102** and **104** of the valves **24** and **26** under normal burner operating conditions and to drop out or close off the burner fuel supply when hazardous or potentially hazardous burner conditions occur.

The detector **10** can be electrically paralleled simply by connecting a second detector **10'** shown by dot-dash outline in FIG. 6 through leads *h* and *i* to the gating device **112**. However, if it is desired to operate the pair of detectors **10** with a single photosensitive element, an arrangement such as shown in FIGS. 4 and 5 may be used.

In FIG. 4, there is shown a modification of the flame-detector **10** wherein a shorter but otherwise identical quartz rod **50'** is used to sight the burner flames. The quartz rod **50'** is supported substantially centrally within a casing **54'** with annular spider-like members **52'** similar to the above-described members **52**.

In differing from the detector **10** construction shown in FIGS. 1 and 2, the arrangement of FIG. 4 embodies a bundle **116** of optical light-conducting fibers **118** which is coupled to the quartz rod **50'** so as to receive light from the rod **50'** and conduct the same through the tubular supporting member **54'** to a point outside the furnace.

The fibers **118** may be of any conventional construction but are preferably of the so-called light-insulated or clad type each embodying a core part of material such as optical flint glass or the like having a relatively high index of refraction with a surrounding relatively thin cladding of material such as crown or soda-lime glass or the like having a relatively low index of refraction. Fiber bundles of this type are usually made up of many thousands of fibers each of a cross-sectional diameter of only a few thousandths of an inch. The low index claddings function to prevent at least the major portion of light entering the respective fibers from passing from one adjacent fiber to another and provide an interface adjacent the sides of the fiber core parts at which light is substantially totally internally reflected. In this way, light is transferred through each of the fibers from end to end with a minimum of overall intensity loss.

The fiber bundle **116** is preferably provided with a protective flexible sheath **120** and, in itself, is preferably of the type which is flexible between its opposite ends. Fiber bundles of this flexible type are formed with the fibers attached to each other only adjacent their opposite ends.

The fiber bundle **116** is provided with optically finished opposite end faces and the quartz rod **50'** is likewise optically finished at its opposite end. The quartz rod **50'** and the fiber bundle are placed and held in optical end-to-end fixed abutting relation with each other by a coupling **122**.

The fiber bundle **116** is supported substantially coaxially within the casing **54'** by means of spider-like members **52''** and the outermost terminal end of the bundle

116 is coupled in adjacent relation with a photosensitive element by means of a construction which is identical to the housing **100** shown in FIG. 2 and described above. Light received by the quartz rod **54′** will then pass therethrough and into the fiber bundle **116** to be transmitted by the bundle **116** to a photosensitive element such as shown by reference numeral **98** in FIGS. 1 and 6. The operation and function of the modified flame-detector of FIG. 4 is identical to that described with relation to the detector **10** in FIGS. 1, 2 and 6. The relative lengths of the quartz rod **54′** and the fiber bundle **116** can be altered from the proportions shown in accordance with any arrangement desired. The quartz rod is used primarily because of its resistance to heat but with adequate cooling through the use of circulating cool air in the manner set forth above with relation to the device **10**, the quartz rod **54′** may be eliminated entirely if desired and the fiber bundle extended and bent around at one end to view the burner flames itself and without the quartz rod. If it is desired to optically couple two or more of the flame-detectors together so as to permit them to operate with a single photosensitive element **98′**, an arrangement such as shown in FIG. 5 would be used. In this instance, fiber bundles **124** and **126** extending from their respective tubular supporting members **128** and **130** are brought together adjacent their outermost terminal ends and are together fitted by a coupling **132** to the photosensitive element housing **134**. Thus, light from either or both of the fiber bundles **124** and/or **126** will illuminate the photosensitive element **98′**. The photosensitive element **98′** would be connected in circuit with the valve solenoids **102** and **104** in a manner identical to that shown in FIG. 6 so as to control the operation of the fuel valves **24** and **26**.

With the arrangement shown in FIG. 5, one or the other of the tubular supporting members **128** or **130** may be removed from the furnace for replacement or maintenance purposes without disturbing the operation of the furnace burner. In all cases cited herein where the flame detectors of the invention are installed in pairs per burner, one or the other of each of said pairs thereof may be removed for checking, maintenance or replacement without interrupting the operation of the particular burner to which they are applied.

It should be clearly understood that the electrical operating circuit shown in FIG. 6 and described herein is purely for demonstrative purposes and would normally be modified considerably to resemble the circuitry in conventional safeguard and alarm systems which incorporate the more elaborate relay programming circuits and/or various other well-known arrangements for operatively interconnecting the photosensitive detectors and fuel valves of a burner. The present invention features primarily, the flame-detector construction **10** which can be readily and cheaply installed in any or all types of conventional furnaces whether of the oil, gas or coal-burning type and which will offer, among the other advantages pointed out above, 100% discrimination between burner flames in multi-burner furnaces. This has not been possible heretofore as evidenced by insurance company regulations which have heretofore insisted upon only 50% discrimination while their people are eager to enforce the maximum possible in flame-discrimination.

It should also be understood that glasses which are capable of withstanding furnace temperatures may be used as a substitute for the fused quartz and/or the fiber glasses mentioned hereinabove.

Furthermore, it will be noted that, to this point, no mention of the effects of after-glow resulting from heated furnace refractories or burner tiles has been made since this condition would be taken care of in the usual manner well-known to conventional flame-safeguard systems wherein the electronics of the system will differentiate between flame radiation and incandescence such as is produced by refractory glow. In this respect, it is well known that an incandescent refractory is a source of infrared radiation as is a flame source. However, refractory radiation is of a constant intensity (dependent upon the refractory temperature) while flame radiation is a flickering or fluctuating radiation having a flicker rate of approximately 10 cycles per second and, consequently, in an arrangement such as described above, the photosensitive element will respond to flame radiation by variations in its conductivity at substantially the 10 cycle per second rate while it will, when exposed to refractory radiation, be constantly conductive in accordance with the intensity of said refractory radiation. In conventional flame-safeguard electronic circuits, discrimination between flame and refractory radiation sources is accomplished by the use of well-known flicker discriminators so as to prevent the effects of furnace refractory after-glow from causing an unwanted burner shutdown. That is, the electronic system will respond only to flame radiation and not to incandesense. Such a flicker discriminator, while not shown as a part of this invention since it would not have any pertinence to the present case would, nevertheless, normally be incorporated in the circuit of FIG. 6. Alternatively, other well-known light-filtering devices used to discriminate between flame and incandescence might be placed between the photosensitive element and its source of illumination to accomplish substantially the same result.

From the foregoing, it can be seen that improved, simple and economical means and method have been provided for accomplishing all of the objects and advantages of the invention. However, it should be apparent that many changes in the details of construction, arrangement of parts and steps in the method may be made without departing from the spirit of the invention as expressed in the accompanying claims and the invention is not limited to the exact matters shown and described as only preferred matters have been given by way of illustration.

I claim:

1. A furnace having a fire box including a refractory burner supporting wall having a number of throat apertures therein extending from the exterior of said furnace to an inner end within the said fire box, a main burner disposed adjacent the opposite outer end of each of said throat apertures to project air and fuel toward said fire box through said throat aperture for combustion in an area within said throat aperture adjacent the inner end thereof and spaced a substantial distance from said main burner, a pilot burner adjacent one side of each of said throat apertures adapted to produce a pilot flame in said combustion area, a passage in said wall adjacent each of said throat apertures extending from the exterior of said wall and opening into said throat aperture at a side thereof opposite said pilot burner, said opening of said passage into said throat aperture being nearer the inner end of said throat aperture than said pilot burner, the axis of said passage adjacent its opening into said throat aperture being substantially aligned with said pilot burner, an elongated light-conducting member having one end within said passage and spaced inwardly from the opening a distance sufficient to restrict the angle of view of said light-conducting member to substantially only the combustion area within said throat aperture, the other end of said light-conducting member being coupled to a light responsive cell.

2. A furnace having a fire box including a refractory burner supporting wall having a number of throat apertures therein extending from the exterior of said furnace to an inner end within the said fire box, a burner disposed adjacent the opposite outer end of each of said throat apertures to project air and fuel toward said fire box through said throat aperture for combustion in an area within said throat aperture adjacent the inner end thereof and spaced a substantial distance from said burner, a passage in said wall adjacent each of said throat apertures extending from the exterior of said wall and having an angular portion of considerable length opening into said throat aperture adjacent the inner end of said throat aperture, the longitudinal axis of said angular portion being directed across the axis of said throat aperture so as to cross said combustion area along a path extending from adjacent the inner end of said throat aperture toward the opposite outer end thereof, a relatively long and thin light-conducting member disposed within said passage and having an angularly disposed end face spaced inwardly of the opening of said angular portion into said throat aperture and disposed substantially normal to the longitudinal axis of said angular portion whereby the angle of view of said light-conducting member from within said angular portion embraces substantially only said combustion area within said throat aperture and the other end of said light-conducting member being coupled with light-responsive means in such manner as to cause said means to receive the major portion of light received and conducted by said light-conducting member.

3. A flame-detecting device for use with a furnace having a fire box including a refractory burner supporting wall through which a number of throat apertures each extend from the exterior of said furnace to an inner end within the said fire box, a burner disposed adjacent the opposite outer end of each of said throat apertures to project air and fuel toward said fire box through said throat aperture for combustion in an area within said throat aperture adjacent the inner end thereof and spaced substantial distance from said burner, a passage in said wall adjacent each of said throat apertures extending from the exterior of said wall and having an angular portion of considerable length opening into said throat aperture adjacent the inner end thereof, the longitudinal axis of said angular portion being directed across the axis of said throat aperture so as to cross said combustion area along a path extending from adjacent the inner end of said throat aperture toward the outer end thereof, said device comprising a relatively long and thin light-conducting member having an angularly disposed face portion at one end thereof and light-responsive means coupled to its opposite end, said member being adapted to be positioned within said passage along its axis with said angularly disposed face portion being aligned with and spaced inwardly of the opening of said angular portion into said throat aperture, and being further disposed substantially normal to the longitudinal axis of said angular portion whereby the angle of view of said light-conducting member from within said angular portion embraces substantially only said combustion area within said throat aperture.

4. A flame-detecting device for use with a furnace having a fire box including a refractory burner supporting wall through which a number of throat apertures each extend from the exterior of said furnace to an inner end within the said fire box, a burner disposed adjacent the opposite outer end of each of said throat apertures to project air and fuel toward said fire box through said throat aperture for combustion in an area within said throat aperture adjacent the inner end thereof and spaced a substantial distance from said burner, each of said throat apertures being additionally provided with means for projecting a pilot flame into said combustion area, a passage in said wall adjacent each of said throat apertures extending from the exterior of said wall and having an angular portion of considerable length opening into said throat aperture diametrically opposite said pilot flame means, said opening of said angular portion into said throat aperture being nearer the inner end of said throat aperture than said pilot flame means, said device comprising a relatively long and thin light-conducting member having an angularly disposed face portion at one end thereof and light-responsive means coupled to its opposite end, said member being adapted to be positioned within said passage along its axis with said angularly disposed face portion being spaced inwardly of the opening of said angular portion into said throat aperture and disposed substantially normal to the longitudinal axis of said angular portion whereby the angle of view of said light-conducting member from within said angular portion embraces substantially only said combustion area and pilot flame within said throat aperture.

5. A furnace having a fire box including a refractory burner supporting wall through which a number of throat apertures each extend from the exterior of said furnace to an inner end within the said fire box, a passage in said wall adjacent each of said throat apertures extending substantially parallel to the axis of said throat aperture from the exterior of said wall and having an angular portion of considerable length extending toward and opening into said throat aperture adjacent the inner end thereof, a burner disposed adjacent the opposite outer end of each of said throat apertures adapted to project air and fuel toward said fire box through said throat aperture for combustion in an area within said throat aperture adjacent the inner end thereof and spaced a substantial distance from said burner, a fuel line leading to said burner, valve means in said fuel line, a relatively long and thin light-conducting member disposed within said passage and having an angularly disposed end faces spaced inwardly of the opening of said angular portion into said throat aperture and disposed substantially normal to the longitudinal axis of said angular portion whereby the angle of view of said light-conducting member from within said angular portion embraces substantially only said combustion area within said throat aperture, photosensitive means coupled to the opposite end of said member and means responsive to said photosensitive means adapted to open said valve means when light is conducted through said member onto said photosensitive means and to close said valve means in the absence of such light.

6. A flame safeguard system for use in a furnace having a fire box including a refractory burner supporting wall having a number of throat apertures therein extending from the exterior of said furnace to an inner end within the said fire box, a passage in said wall adjacent each of said throat apertures extending from the exterior of said wall and having an angular portion of considerable length opening into said throat aperture adjacent the inner end thereof, a burner disposed adjacent the opposite outer end of each of said throat apertures adapted to project air and fuel toward said fire box through said throat aperture for combustion in an area within said throat aperture adjacent the inner end thereof and spaced a substantial distance from said burner and a fuel line leading to said burner to supply said fuel to said burner, said flame safeguarding embodying valve means in said fuel line, a relatively long and thin light-conducting member having an angularly disposed face portion at one end thereof, photosensitive means coupled to the opposite end of said member and means responsive to said photosensitive means adapted to open said valve means when light is conducted through said member and to close said valve means in the absence of such light, said member being adapted to be positioned within said passage along its axis with said angularly disposed face portion spaced inwardly of the opening of said angular portion into said throat aperture and being further disposed substantially normal to the longitudinal axis of said angular portion whereby the angle of view of said light-conducting member within said angular portion is such as to cause said member to receive substantially only light produced by combustion of fuel and air in said combustion area.

7. A flame-detecting device for use with a furnace having a fire box including a refractory burner supporting wall through which a number of throat apertures each extend from the exterior of said furnace to an inner end within the said fire box, a burner disposed adjacent the opposite outer end of each of said throat apertures to project air and fuel toward said fire box through said throat aperture for combustion in an area within said throat aperture adjacent the inner end thereof and spaced a substantial distrance from said burner, a passage in said wall adjacent each of said throat apertures extending from the exterior of said wall and having an angular portion of considerable length opening into said throat aperture adjacent the inner end of said throat aperture, the longitudinal axis of said angular portion being directed across said combustion area along a path extending from adjacent the inner end of said throat aperture toward the other end thereof, said device comprising an elongated light-conducting member embodying a plurality of long and thin individually clad light-conducting fibers disposed in side-by-side relation in a bundle with corresponding opposite ends thereof arranged to form light-receiving and light-emitting opposite end faces of said bundle and a rod of light-conducting material having light-receiving and light-emitting opposite end faces, means coupling one of said end faces of said rod to an end face of said bundle to place said rod and bundle in sequence, the other end face of said rod being angularly disposed relative to its one end face and photoelectric means coupled to said bundle adjacent its other end face, said light-conducting member being adapted to be positioned within said passage in said wall along its axis with said angularly disposed end face of said rod spaced inwardly of the opening of said angular portion into said throat aperture and being further disposed substantially normal to the longitudinal axis of said angular portion whereby the angle of view of said light-conducting member from within said angular portion embraces substantially only said combustion area within said throat aperture.

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