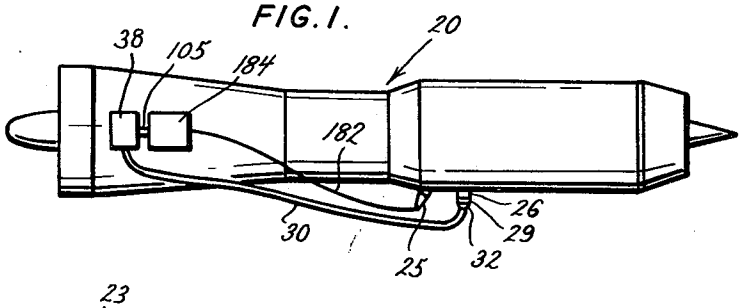
April 7, 1970 R. L. KLAMM 3,504,490

LIGHT SENSITIVE APPARATUS FOR PREVENTING FLAMEOUT IN COMBUSTION ENGINES

Filed Feb. 20, 1968

FIG. 1.



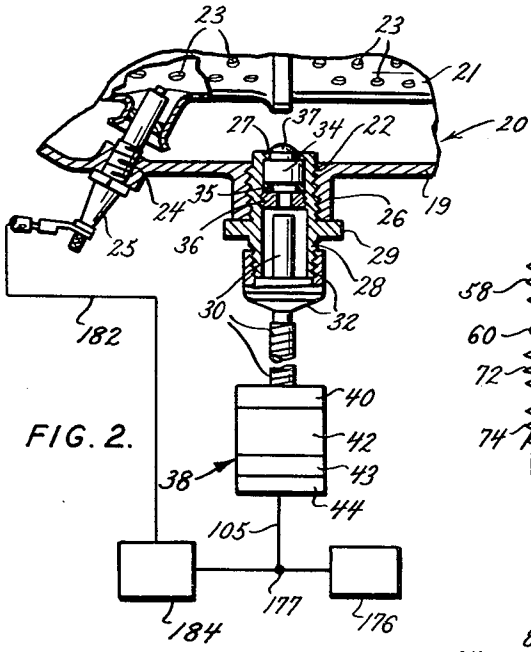
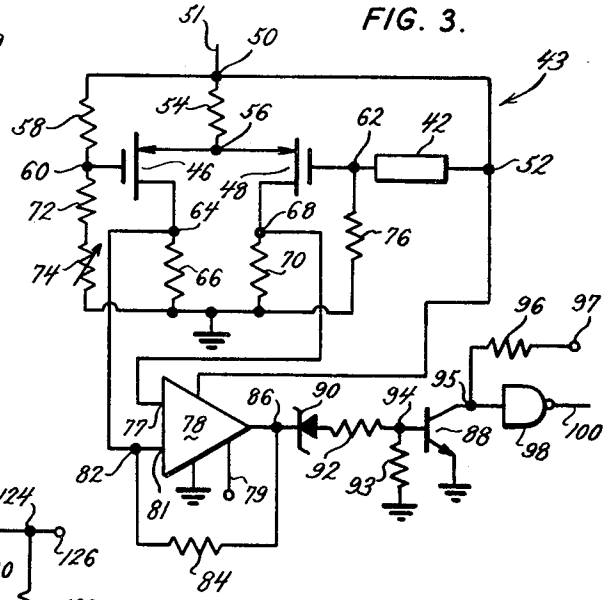


FIG. 2.

FIG. 3.



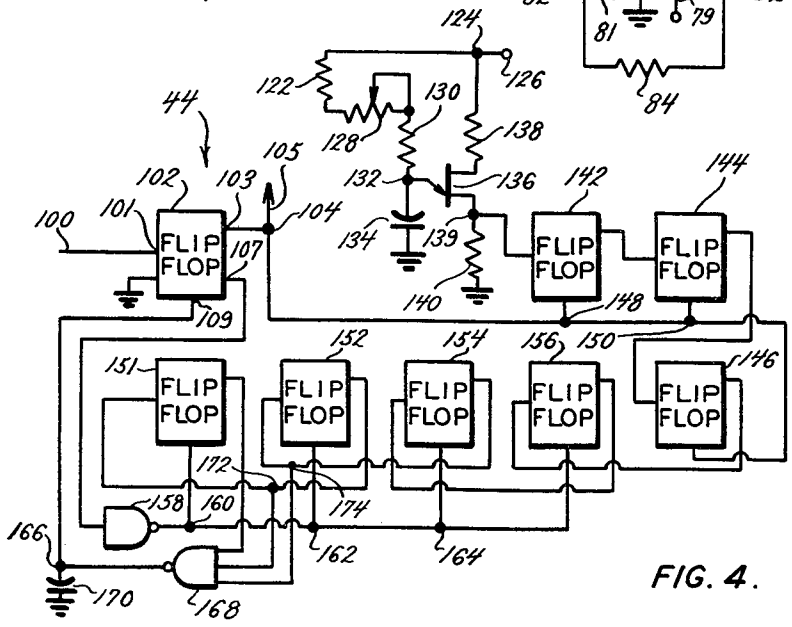


FIG. 4.

United States Patent Office 3,504,490 Patented Apr. 7, 1970

3,504,490

LIGHT SENSITIVE APPARATUS FOR PREVENTING FLAMEOUT IN COMBUSTION ENGINES

Robert L. Klamm, St. Charles, Mo., assignor to Conductron Corporation, St. Charles, Mo., a corporation of Delaware

Filed Feb. 20, 1968, Ser. No. 706,819
Int. Cl. F02c 7/26; F23n 5/08
U.S. Cl. 60—39.09 16 Claims

ABSTRACT OF THE DISCLOSURE

An elongated bundle of fiber optics has one end thereof disposed in visual communication with the interior of the housing of a reaction-type combustion engine, and has the other end thereof disposed in visual communication with a light-sensitive element which can respond to light having wavelengths within a narrow range; and that light-sensitive element will act, whenever the light from the flames within that housing falls below the range of wavelengths to which that light-sensitive element responds, to actuate the ignition-initiating system of that engine. Thereafter, that ignition-initiating system will then be kept actuated for a predetermined length of time by a timer to avoid a "flameout" of that engine.

This invention relates to improvements in control systems. More particularly, this invention relates to improvements in control systems, for reaction-type combustion engines, which are intended to prevent "flameouts" of those engines.

It is, therefore, an object of the present invention to provide an improved control system, for a reaction-type combustion engine, which can prevent "flameouts" of that engine.

A "flameout" of a reaction-type combustion engine can be extremely serious; and hence it would be desirable to provide a control system which could prevent such "flameouts." "Flameouts" can occur in a reaction-type combustion engine when the fuel-air ratio of that engine is changed rapidly or to an undue extent, can occur in response to transient reductions in the amount of air flowing into that engine, can occur in response to momentary interruptions in the flow of fuel, can occur when the exhaust products of rockets or other ordnance devices, which are "fired" adjacent the intake of that engine, enter that intake, and can occur when hail or sleet or heavy rain is drawn into the intake of that engine; but "flameouts" can be prevented if the ignition-initiating system of that engine is actuated, and then is kept actuated for a predetermined length of time, before a "flameout" actually occurs. Consequently, it would be desirable to provide a control system which could sense the development of incipient "flameouts" in a reaction-type combustion engine, and which could automatically actuate the ignition-initiating system of that engine before "flameouts" could actually occur. The present invention provides such a control system; and that control system has a light-sensitive element which is disposed in visual communication with the interior of the housing of a reaction-type combustion engine by means of an elongated bundle of fiber optics and which is responsive to light having wavelengths within a narrow range. As soon as the light from the flames within that engine falls below the range of wavelengths to which the light-sensitive element responds, that light-sensitive element will cause the ignition-initiating system of that engine to become actuated, and also will cause a timing circuit to keep that ignition-initiating system active for a predetermined length of time. That predetermined length of time will be long enough to encompass any period

of time during which a transient condition could cause a "flameout," and thus should be long enough to enable the reaction-type combustion engine to continue to operate without experiencing an actual "flameout." It is, therefore, an object of the present invention to provide a control system which has a light-sensitive element disposed in visual communication with the interior of the housing of a reaction-type combustion engine by means of an elongated bundle of fiber optics, which senses a relatively narrow range of light wavelengths, and which acts whenever the light from the flame within that housing falls below that range to actuate the ignition-initiating system of that engine, and also to cause a timer to keep that ignition-initiating system actuated for a predetermined length of time.

Other and further objects and advantages of the present invention should become apparent from an examination of the drawing and accompanying description.

In the drawing and accompanying description a preferred embodiment of the present invention is shown and described but it is to be understood that the drawing and accompanying description are for the purpose of illustration only and do not limit the invention and that the invention will be defied by the appended claims.

In the drawing,

FIG. 1 is an elevational view showing a reaction-type combustion engine with which the control system provided by the present invention is used,

FIG. 2 is a sectional view, on a larger scale, of part of the reaction-type combustion engine of FIG. 1, plus a block-type showing of the filter, light-sensitive element, sensing circuit, timing network, display-type counter, and elongated bundle of fiber optics used with that engine,

FIG. 3 is a diagram of the sensing circuit of the control system provided by the present invention, and

FIG. 4 is a circuit diagram of the timing network of that control system.

COMPONENTS OF CONTROL SYSTEM

Referring to the drawing in detail, the numeral **20** generally denotes a reaction-type combustion engine as, for example, a jet engine for an aircraft. The housing of that engine is denoted in FIG. 2 by the numeral **19**; and that housing has an opening **22** therein which has an internally-threaded boss **26** extending outwardly therefrom. The opening **22** is in register with a section of the burner casing **21** of the engine, as shown particularly by FIG. 2. A second opening **24** is provided in the housing **19**, and the spark plug **25** of the ignition-initiating system of the engine **20** is mounted within that second opening.

The numeral **28** denotes an externally-threaded, hollow plug which has an outwardly-directed annular flange **29** thereon intermediate the ends thereof, and which has an inwardly-directed annular flange **27** at the inner end thereof. The external threads on the plug **28** will mate with the internal thread of the boss **26**, so that plug can be solidly held within that boss. The outwardly-directed annular flange **29** on that plug can abut the outer end of the boss **26** to limit the extent to which that plug can telescope within that boss.

The numeral **34** denotes a window which is disposed within the inner end of the externally-threaded plug **28**; and the diameter of the major portion of that window is larger than the inner diameter of the inwardly-directed annular flange **27**. As a result, that inwardly-directed annular flange will keep the window **34** from falling, or being drawn, out of the externally-threaded plug **28**. That window has a smaller diameter end portion **37** which extends through the opening defined by the inwardly-directed annular flange **27** and which extends inwardly beyond the inner end of the externally-threaded plug **28**. That smaller

diameter end portion is generally spherical in configuration; and it will be located in the fast-moving body of relatively-cool compressed air that continually flows between the exterior of the burner casing **21** and the interior of the housing **19**. That fast-moving body of relatively-cool compressed air will keep the smaller diameter end portion **37** of the window **34** cool; and, importantly, it will keep dirt, dust and other foreign matter from coming to rest on that smaller diameter end portion. As a result, the window **34** will always be able to receive and transmit the light which will pass outwardly through the openings **23** in the burner casing **21** from the flames within that burner casing. The window **34** must be made from a material which is transparent to the wave lengths of light which are to be monitored, and it must be made of a material which will not soften or melt at the temperatures to which the housing **19** will be elevated; and one material that has been found to be very useful is quartz. A washer **35** is disposed immediately adjacent the outer face of the window **34**; and a threaded washer **36** is held in intimate engagement with the outer face of the washer **35** by an internal thread within the externally-threaded plug **28**. The threaded washer **36** will coact with the washer **35** to force the large diameter portion of the window **34** solidly against the inwardly-directed annular flange **27** at the inner end of the externally-threaded plug **28**.

The numeral **30** denotes an elongated bundle of fiber optics which has one end thereof telescoped into the externally-threaded plug **28**, and which has the other end thereof secured to a filter **40** that is intended to pass only the light within a given range of wavelengths. In one preferred embodiment of the present invention, that bundle of fiber optics is flexible, is seventy-two inches long, is one-eighth of an inch in diameter, and is encased within a helically-wound, flexible, metal, protective sheath. A coupling **32** is secured to the upper end of the helically-wound, flexible, metal, protective sheath for the elongated bundle **30** of fiber optics, as that elongated bundle is viewed in FIG. 2; and that coupling telescopes over the outer end of the externally-threaded plug **28** to hold the upper end of that bundle in register with the opening in the threaded washer **36**. The coupling **32** will provide a sufficiently intimate engagement between itself and the externally-threaded plug **28** to prevent accidental separation of the bundle **30** of fiber optics from that plug. The elongated bundle **30** of fiber optics is long enough to permit the housing **38**, which encases the light-sensitive element **42**, the filter **40**, the sensing circuit **43**, and the timing network **44** of the control system, to be located adjacent the air inlet of the engine **20**, and thus wholly away from the heat of the burner section of that engine. That elongated bundle is flexible enough to withstand the vibrations which will be imparted to it during the operation of the reaction-type combustion engine **20**. Further, that elongated bundle will have sufficient resistance to heat to enable that bundle to withstand the relatively high temperatures to which the boss **26** and the externally-threaded plug **28** will be elevated by the combustion occurring within the burner casing of the engine **20**.

The filter **40** will pass light having wavelengths in the range to which the light-sensitive element **42** can respond; and, in one preferred embodiment of control system provided by the present invention, that light-sensitive element is an LS400 silicon planar photo diode of the Texas Instrument Company. Such a light-sensitive element is desirable because it has a high degree of sensitivity to light having wave lengths in the range of four-tenths to one and one-tenth microns. That light-sensitive element can detect energy levels as low as one hundredth of a milliwatt per square centimeter of surface area.

The components and connections of the sensing system **43** of FIG. 2 are shown in FIG. 3; and the numerals **46** and **48** denote P-channel metal oxide silicon field effect transistors. Those field effect transistors are designed for enhancement mode operation; and they are diffused into one monolithic chip so they can be closely matched and so they will provide the same response to changes in temperature. The sources of those field effect transistors are connected together by a junction **56**; and that junction is connected to a source of positive fifteen volts by a resistor **54**, a junction **50**, and a conductor **51**. The drain of he field effect transistor **46** is connected to ground by a junction **64** and a resistor **66**; and the drain of the field effect transistor **48** is connected to ground by a junction **68** and a resistor **70**. A resistor **58**, a resistor **72**, and an adjustable resistor **74** are connected between the junction **50** and ground; and a junction **60** between the resistors **58** and **72** is connected to the gate of the field effect transistor **46** to apply a positive bias to that gate. The light-sensing element **42** and a resistor **76** are connected between the junction **50** and ground by junctions **52** and **62**; and that light-sensitive element and that resistor will constitute a voltage divider which will apply a positive bias to the gate of the field effect transistor **48**.

The numeral **78** denotes a differential voltage comparator; and that differential voltage comparator preferably is an integrated circuit formed on a silicon chip. The input **77** of that differential voltage comparator amplifier is the inverting input; and it is connected directly to the junction **68**. The input **81** of that differential voltage comparator is the noninverting input; and it is connected to the junction **64** by a junction **82**. The positive voltage input of the differential voltage comparator **78** is connected to the junction **50** by the junction **52**, the "ground" input is connected directly to ground, and the remaining input is connected to a source of positive five volts by a conductor **79**. The output of the differential voltage comparator **78** is connected to the noninverting input **81** by a junction **86**, a resistor **84**, and the junction **82**.

An NPN transistor **88** has the base thereof connected to the output of the differential voltage comparator **78** by the junction **86**, a Zener diode **90**, a resistor **92**, and a junction **94**; and that base is spaced from ground by a resistor **93** which is connected between the junction **94** and ground. The emitter of transistor **88** is connected directly to ground; and the collector of that transistor is connected to a source of positive five volts by a junction **95**, a resistor **96**, and a terminal **97**. That collector also is connected to the input of a Nand gate **98**; and the output of that Nand gate is connected to the timing network **44** by a conductor **100**.

The components and connections of the timing network **44** of FIG. 2 are shown in FIG. 4; and the numeral **102** denotes a clocked J–K flip-flop diode transistor integrated circuit. The numerals **142**, **144**, **146**, **151**, **152**, **154** and **156** denote further clocked J-K flip-flop diode transistor integrated circuits. The conductor **100** connects the output of the Nand gate **98** of FIG. 3 to the "clock" input **101** of the flip-flop **102**, and the "set" input of that flip-flop is connected directly to ground. The $\overline{Q}$ output of flip-flop **102** is denoted by the numeral **103**, and it is connected to the "direct set" inputs of the flip-flops **142**, **144** and **146** by two or more of the junctions **104**, **148** and **150**. That output also is connected to a display-type counter **176** and to the ignition-initiating system **184** of the engine **20** by the junction **104**, a conductor **105**, and a junction **177**, as shown by FIG. 2. The Q output **107** of the flpi-flop **102** is directly connected to the input of a Nand gate **158**; and the "direct set" input **109** of that flip-flop is connected to the output of a Nand gate **168** by a junction **166**. That junction, and hence the input of that Nand gate and the "direct set" input **109**, are spaced from ground by a capacitor **170**.

The Nand gates **98**, **158** and **168** preferably are parts of a triple three-input Nand gate formed on a monolithic chip. However, only one of the three inputs of Nand gate **98** is used; and, similarly, only one of the three inputs of Nand gate **158** is used. The output of the Nand gate **158** is connected to the"direct set" inputs of the flip-flops

151, 152, 154 and 156 by one or more of junctions 160, 162 and 164.

The numeral 136 denotes a unijunction transistor; and the base-two of that unijunction transistor is connected to a source of positive fifteen volts by a resistor 138, a junction 124 and a terminal 126. The base-one of that unijunction transistor is connected to ground by a junction 139 and a resistor 140. A resistor 122, an adjustable resistor 128, a resistor 130, and a capacitor 134 are connected between the junction 124 and ground; and a junction 132 between resistor 130 and capacitor 134 is connected directly to the emitter of the unijunction transistor 136. That unijunction transistor, that capacitor, resistors 122, 130, 138 and 140, and adjustable resistor 128 constitute a relaxation oscillator.

The junction 139 is directly connected to the "clock" input of the flip-flop 142; and the $\overline{Q}$ output of that flip-flop is directly connected to the "clock" input of the flip-flop 144. The $\overline{Q}$ output of the latter flip-flop is directly connected to the "clock" input of the flip-flop 146. The $\overline{Q}$ output of the flip-flop 146 is directly connected to the "clock" input of flip-flop 156, and the $\overline{Q}$ output of flip-flop 156 is directly connected to the "clock" input of flip-flop 154. The $\overline{Q}$ output of flip-flop 154 is connected to the "clock" input of flip-flop 152 and to the lower input of Nand gate 168 by a junction 174. The $\overline{Q}$ output of flip-flop 152 is connected to the "clock" input of flip-flop 151 and to the middle input of Nand gate 168 by a junction 172; and the $\overline{Q}$ output of flip-flop 151 is directly connected to the upper input of that Nand gate. The ignition-initiating control system 184 is connected to the spark plug 25 by conductors 182, as shown particularly by FIG. 1.

The flip-flop 102 is a master-slave, type K, integrated circuit flip-flop; and hence that flip-flop will store information in the "master" stage thereof whenever the voltage at the "clock" input 101 thereof is "high," and will then transfer that information to the "slave" stage thereof when that voltage is "low." Whenever a low votage is applied to the "direct set" input 109 of that flip-flop, that "direct set" input will dominate the other inputs of that flip-flop and will make the Q output 107 of that flip-flop "high." The "set" input of that flip-flop is grounded, and hence the voltage at that input always is low; and that low "set" input voltage will make the Q output go "low" when the voltage at the "clock" input 101 goes "low."

The flip-flops 142, 144, 146, 151, 152, 154 and 156 are internally connected in the JK mode; and hence those flip-flops will change state on the negative-going edges of the pulses applied to the "clock" inputs thereof—if no input is being applied to the "direct set" bottom inputs of these flip-flops. The "set" inputs and the Q outputs of the flip-flops 142, 144, 146, 151, 152, 154 and 156 are not used.

OPERATION OF CONTROL SYSTEM WHEN REACTION-TYPE COMBUSTION ENGINE IS OPERATING NORMALLY

When the operator of the reaction-type combustion engine 20 closes the switch that supplies electric power to that engine, that switch or another switch or a relay will supply power to the sensing circuit 43 and to the timing network 44. Power will continue to be supplied to that sensing circuit and to that timing network as long as power is supplied to the engine 20; and hence that sensing circuit and that timing network will always be ready to actuate the ignition-initiating system 184 whenever an incipient "flameout" develops.

After the operator of the reaction-type combustion engine 20 has applied power to that engine, he will close a switch, not shown, which will actuate the ignition-initiating system 184; and that ignition-initiating system will cause flames to develop in the burner casing 21 within the housing 19. After the reaction-type combustion engine 20 has started to operate in its intended fashion, the operator of that engine will permit that switch to reopen so the ignition-initiating system 184 can become inactive. Flames will continue to develop in the burner casing 21 within the housing 19; and the window 34 will permit light from those flames to pass through the openings in the washers 35 and 36 to the bundle 30 of fiber optics. That bundle of fiber optics will conduct that light to the filter 40 which will pass the portions of that light, which have wave lengths between fourteenths and one and one-tenth microns, to the light-sensitive element 42; and that light-sensitive element will respond to those portions of that light to experience a sharp decrease in the resistance thereof.

At the instant the timing network 44 is connected to the source of power therefor, the voltages at one or more of the $\overline{Q}$ outputs of flip-flops 151, 152 and 154 will be "low"; and hence the Nand gate 168 will tend to apply a "high" voltage to the "direct set" input 109 of flip-flop 102. However, the capacitor 170 will require a finite time to charge up, and thus will initially hold that voltage down—thereby enabling the "direct set" input 109 to cause the voltage at the Q output 107 to be "high" long enough to enable the Nand gate 158 to apply a "low" signal to the "direct set" inputs of flip-flops 151, 152, 154 and 156, and also enabling the "direct set" input 109 to cause the voltage at the $\overline{Q}$ output 103 to apply a "low" signal to the "direct set" inputs of the flip-flops 142, 144 and 146. As a result, each of the flip-flops 142, 144, 146, 151, 152, 154 and 156 will have a "low" signal applied to the "direct set" input thereof; and that signal will make the voltage at the $\overline{Q}$ output thereof "low." Thereafter, the voltage at the Q output 107 will continue to be "high" and the voltage at the $\overline{Q}$ output 103 will continue to be "low"—and hence each of the flip-flops 142, 144, 146, 151, 152, 154 and 156 will continue to have a "low" signal applied to the "direct set" input thereof—until a signal is applied to the "clock input 101 of the flip-flop 102.

The unijunction transistor 136, the capacitor 134, the resistors 122, 130, 138 and 140, and the adjustable resistor 128 will, as soon as the timing network 44 is connected to the source of power therefor, cause that capacitor to charge up to the emitter peak point voltage of that unijunction transistor; and, thereupon, that unijunction transistor will become conductive and will permit that capacitor to discharge through the emitter base—one circuit of that unijunction transistor and the resistor 140 to ground. The resulting voltage pulse across that resistor will not cause the flip-flop 142 to change state; because that flip-flop, as well as the rest of the flip-flops 144, 146, 151, 152, 154 and 156 will continue to have a "low" voltage applied to the "direct set" terminal thereof, and thus will be unable to respond to any signals applied to the "clock" input thereof.

As soon as the capacitor 134 has become discharged, it will start charging again; and, when the voltage across that capacitor again reaches the emitter peak point voltage of the unijunction transistor 136, that unijunction transistor will become conductive and again permit the capacitor 134 to discharge through the resistor 140. Once again, however, the resulting voltage pulse across that resistor will be unable to cause the flip-flop 142 to change its state; because that flip-flop will continue to have a "low" voltage applied to the "direct set" input thereof.

The relaxation oscillator, which includes the unijunction transistor 136, the capacitor 134, the resistors 122, 130, 138 and 140, and the adjustable resistor 128, will develop voltage pulses across the resistor 140, and those voltage pulses will be applied to the "clock" input of the flip-flop 142, as long as the timing network is connected to the source of power therefore. In one preferred embodiment of the present invention, adjustment of the

position of the movable contact of the adjustable resistor **128** will enable that relaxation oscillator to develop those voltage pulses at a rate between about one per second and about eleven per second.

The field effect transistors **46** and **48** of FIG. 3 are "matched" so they have substantially identical characteristics; and the resistors **66** and **70** are "matched" so they have substantially identical values of resistance. Because the sources of both of those field effect transistors are connected to the terminal **50** by the resistor **54**, and because those field effect transistors and the resistors **66** and **70** are "matched," those field effect transistors can provide a close comparison of the voltages applied to the gates thereof. The series-connected resistors **58** and **72** and adjustable resistor **74** will develop a substantially fixed voltage at the gate of the field effect transistor **46**, whereas the series-connected light-sensitive element **42** and resistor **76** will develop a voltage at the gate of field effect transistor **48** that will be a function of the light, in the range of four-tenths through one and one-tenth microns, which impinges upon that light-sensitive element. In one preferred embodiment of the present invention, the resistance of resistor **58** is about twice the sum of the resistance of resistor **72** and the maximum resistance of adjustable resistor **74**; and, when the reaction-type combustion engine **20** is operating properly, the resistance of the light-sensitive element **42** will be considerably less than twice the resistance of resistor **76**. Consequently, as long as the engine **20** is operating properly, the voltage at the gate of the field effect transistor **48** will be higher than the voltage at the gate of the field effect transistor **46**; and, because those field effect transistors are P-channel metal oxide silicon transistors designed for enhancement mode operation, the amount of current flowing through the resistor **70** will be less than the amount of current flowing through the resistor **66**. The resulting voltage at the inverting input **77** of the differential voltage comparator **78** will be less than the resulting voltage at the noninverting input **81** of that differential voltage comparator; and hence the voltage at the output of that differential voltage comparator will be "high." The Zener diode **90** will become conductive and will apply a positive signal to the base of transistor **88**, thereby causing that transistor to become conductive at the saturation level; and the resulting "low" voltage at the input of Nand gate **98** will enable that Nand gate to apply a "high" voltage to the "clock" input **101** of the flip-flop **102**. Because that flip-flop does not respond to positive signals at the "clock" input thereof, the voltage at the $\overline{Q}$ ouput of that flip-flop will continue to remain "low."

As long as the reaction-type combustion engine operates properly, the flames in the burner casing **21** within the housing **19** will supply sufficient light, within the range of four-tenths to one and one-tenth microns, to the light-sensitive element **42** via the bundle **30** of fiber optics to enable the voltage at the gate of field effect transistor **48** to be higher than the voltage at the gate of field effect transistor **46**; and hence the sensing circuit **43** will continue to apply a "high" voltage to the "clock" input of the flip-flop **102**. That flip-flop will not respond to such a signal; and hence that flip-flop will not apply a "high" signal to the ignition-initiating system **184**—and, for lack of such a signal, that ignition-initiating system will remain inactive. Also, the flip-flop **102** and the Nand gate **158** will continue to apply "low" voltages to the "direct set" inputs of the flip-flops **142**, **144**, **146**, **151**, **152**, **154** and **156**; and hence those flip-flops will not be able to respond to the voltage pulses which the relaxation oscillator develops across the resistor **140**.

The position of the movable contact of the adjustable resistor **74** will determine the minimum level of flame intensity which is needed to keep the voltage at the gate of field effect transistor **48** higher than the voltage at the gate of field effect transistor **46**. Ordinarily, that movable contact will be set so the voltage at the gate of field effect transistor **48** will be higher than the voltage at the gate of field effect transistor **46** as long as the level of flame intensity equals or exceeds the level of flame intensity that is developed while the reaction-type combustion engine **20** is "idling," but will drop below the voltage at the gate of field effect transistor **46** whenever the level of flame intensity drops below the level of flame intensity developed while that engine is "idling." Such a setting will avoid needless and premature actuations of the ignition-initiating system **184**, but will provide prompt actuation of that ignition-initiating system whenever such actuation is needed.

OPERATION OF CONTROL SYSTEM WHEN REACTION-TYPE COMBUSTION ENGINE FAILS TO OPERATE PROPERLY

If the fuel-air ratio of the reaction-type combustion engine **20** is changed rapidly or to an undue extent, if a transient reduction in the amount of air flowing into that engine occurs, if a momentary interruption in the flow of fuel to that engine occurs, if excessive amounts of the exhaust products of rockets or other ordnance devices enter the intake of that engine, or if excessive amounts of hail, sleet or rain enter the intake of that engine, an incipient "flameout" develops, the intensity of the light, having wave lengths in the range of four-tenths to one and one-tenth microns, will decrease; and, if that intensity falls below the level of flame intensity that is developed while the reaction-type combustion engine **20** is "idling," the resistance of the light-sensitive element **42** will increase to the point where the voltage at the gate of field effect transistor **48** will no longer exceed the voltage at the gate of field effect transistor **46**. Thereupon, the reduced voltage at the inverting input **77** of the differential voltage comparator **78** will cause the voltage at the output of that differential voltage comparator to drop below the Zener voltage of the Zener diode **90**; and, at such time, that Zener diode will be unable to cause current to continue to flow through the base-emitter circuit of the transistor **88**. That transistor will then become nonconductive; and the resulting "high" voltage at the input of Nand gate **98** will cause that Nand gate to apply a negative-going signal to the "clock" input **101** of the flip-flop **102**. That flip-flop will respond to that negative-going signal to eliminate the "high" voltage at the Q output **107** thereof—thereby causing the Nand gate **158** to eliminate the "low" voltage which it had been maintaining at the "direct set" inputs of the flip-flops **151**, **152**, **154** and **156**; and it will also respond to that negative-going signal to develop a "high" voltage at the $\overline{Q}$ output **103** thereof—thereby actuating the ignition-initating system **184** and the display-type counter **176**, and also eliminating the "low" voltage which had been maintained at the "direct set" inputs of the flip-flops **142**, **144** and **146**. The total time required for the sensing system **43** and the flip-flop **102** to apply a "high" voltage to the ignition-initiating system **184** is quite short—being less than one-thousandth of a second; and hence that ignition-initiating system can supply power to the spark plug **25** via conductors **182** before a "flameout" actually occurs. That spark plug will enable further fuel and air introduced into the reaction-type combustion engine **20** to burn and to provide the energy which that engine requires.

Once the "low" voltages at the "direct set" inputs of the flip-flops **142**, **144**, **146**, **151**, **152**, **154** and **156** are eliminated, those flip-flops can respond to negative-going signals at the "clock" inputs thereof; and, almost immediately, the relaxation oscillator, which includes the unijunction transistor **136**, the capacitor **134**, the resistors **122**, **130**, **138** and **140**, and the adjustable resistor **128**, will apply such a negative-going signal to the "clock" input of the flip-flop **142**. That flip-flop will respond to that negative-going signal to develop a positive-going signal at the $\overline{Q}$ output thereof, but the "clock" input of the flip-flop **144** will not respond to such a signal. However,

when that relaxation oscillator supplies a further negative-going signal, flip-flop **142** will respond to that negative-going signal to develop a negative-going signal at the $\overline{Q}$ output thereof; and the flip-flop **144** will respond to that negative-going signal. The flip-flops **142, 144, 146, 156, 154, 152,** and **151** are connected as a seven digit, rippple carry, binary counter, with the Q output of each flip-flop thereof serving as the "clock" for the next-succeeding flip-flop. The relaxation oscillator will continuously supply signals to the "clock" input of the flip-flop **102**; and, as long as the voltage at the "direct set" input of that flip-flop is "high," that flip-flop will respond to every second signal to cause the $\overline{Q}$ output voltage thereof to go "low." The flip-flop **144** will respond to every fourth signal, the flip-flop **146** will respond to every eighth signal, the flip-flop **156** will respond to every sixteenth signal, the flip-flop **154** will respond to every thirty-second signal, and the flip-flop **152** will respond to every sixty-fourth signal from the relaxation oscillator to cause the $\overline{Q}$ output voltage thereof to go "low." At the same time the negative-going trailing edge of the one hundred and twelfth signal from the relaxation oscillator is applied to the "clock" input of the flip-flop **142**, the signals at the $\overline{Q}$ outputs of the flip-flops **154, 152** and **151** will all be "high"; and the Nand gate **168** will respond to the resulting "high voltages at the three inputs thereof to apply a "low" voltage to the "direct set" input **109** of the flip-flop **102.** Thereupon, the voltage at the $\overline{Q}$ output **103** will become "low"—permitting the ignition-initiating system **184** to become inactive and causing the flip-flops **142, 144** and **146** to reset—and the voltage at the Q output **107** will become "high"—causing the Nand gate **158** to reset the flip-flops **151, 152, 154** and **156.** All of this means that the seven digit, ripple carry, binary counter, which includes the flip-flops **142, 144, 146, 156, 154, 152** and **151,** will count to one hundred and twelve and then coact with flip-flop **102** and Nand gate **158** to automatically reset itself; and, as that seven digit, ripple carry, binary counter resets itself, it will cause a low voltage to appear at the $\overline{Q}$ output **103** of the flip-flop **102** and thereby permit the ignition-initiating system **184** to become inactive.

The action of the control system, in actuating the ignition-initating system **184,** is so rapid that it will usually occur before the operator of the reaction-type combustion engine **20** realizes that an actuation of that ignition-initiating system was necessary. However, because it is advisable for that operator to know whenever an actuation of the ignition-initiating system **184** was necessary, the display-type counter **176** will be actuated each time the ignition-initiating system **184** is actuated; and that display-type counter will display the total number of actuations of the ignition-initiating system **184** which have occurred during any given period of operation of the reaction-type combustion engine **20.** If an appreciable number of actuations of the ignition-initiating system **184** are caused, within a short period of time, by the control system of the present invention, the operator of the engine **20** should take whatever action he can to avoid any further need of actuations of that ignition-initiating system.

The action of the timing network **44** in resetting the flip-flop **102**—and thus permitting the ignition-initiating system **184** to become inactive—after a predetermined period of time is desirable; because it will keep the spark plug **25** from "burning out"—as it would do if the ignition-initiating system was operated continuously. However, that timing network will keep that ignition-initiating system actuated for a period of time which is long enough for any transient conditions, which caused the incipient "flameout," to disappear. Even after the timing network **44** has permitted the ignition-initiating system **184** to become inactive, the operator of the reaction-type combustion engine **20** can actuate that ignition-initiating system. The control system of the present invention thus minimizes the need of manual actuation of the ignition-initiating system **184** but does not prevent such manual actuation.

When the spark plug **25** helps re-establish the flames in the burner casing **21** within the housing **19,** the window **34,** the openings in the washers **35** and **36,** the bundle **30** of fiber optics, and the filter **40** will enable the light-sensitive element **42** to "see" the light from those flames. That light will decrease the resistance of that light-sensitive element until the voltage at the gate of the field effect transistor **48** is again above the voltage at the gate of the field effect transistor **46;** and, at such time, the voltage at the "clock" input **101** of flip-flop **102** will be "high." That "high" voltage will not cause that flip-flop to change state; and hence that flip-flop will continue to have a "high" voltage at the $\overline{Q}$ output **103** thereof until the Nand gate **168** applies a "low" voltage to the "direct set" input **109** thereof. Thereafter, that flip-flop will develop a "low" voltage at the $\overline{Q}$ output **103** thereof and a "high" voltage at the Q output **107** thereof as long as the flame intensity equals or exceeds the flame intensity that is developed while the reaction-type combustion engine **20** is "idling."

CONCLUSION

The flip-flop **102** will apply a signal to the "direct set" inputs of the flip-flops **142, 144** and **146** which will make the voltages at the $\overline{Q}$ outputs of those flip-flops "low" whenever the voltage at the $\overline{Q}$ output **103** goes from "high" to "low." The power-supplying capability of the flip-flop **102** will not be great enough to enable that flip-flop to also apply signals to the "direct set" inputs of the flip-flops **151, 152, 154** and **156** which will make the voltages at the $\overline{Q}$ outputs of those flip-flops go from "high to "low whenever the voltage at the $\overline{Q}$ output **103** goes from "high" to "low." However, the voltage at the Q output **107** will rise as the voltage at the $\overline{Q}$ output **103** falls; and the Nand gate **158** will respond to the "high" voltage at the input thereof to apply a "low" voltage to the "direct set" inputs of the flip-flops **151, 152, 154** and **156**—thereby causing the $\overline{Q}$ outputs of those flip-flops to be "low." If a flip-flop **102** were to be used which had sufficient power to enable the voltage at the $\overline{Q}$ output **103** thereof to directly reset all of the flip-flops **142, 144, 146, 151, 152, 154** and **156,** the Nand gate **158** could be eliminated.

The connecting of the $\overline{Q}$ outputs of the flip-flops **151, 152** and **154** to the three inputs of the Nand gate **168** is desirable, because it enables the seven digit, ripple carry, binary counter to count to one hundred and twelve before that binary counter resets itself. In enabling that seven digit, ripple carry, binary counter to count to one hundred and twelve before it resets itself, the control system of the present invention utilizes a very high percentage of the capacity of that binary counter while minimizing the number of flip-flops which are needed to decode the counter-resetting number.

As the various flip-flops of the seven digit, ripple carry, binary counter change state, false signals may tend to develop at the output of the Nand gate **168.** It would be undesirable for any such false signals to be applied to the "direct set" input **109** of the flip-flop **102,** because one or more of those false signals might reset that flip-flop prematurely. The capacitor **170** will absorb any such false signals, and will thereby keep false signals which may tend to develop at the ouput of the Nand gate **168** from resetting the flip-flop **102.**

In one preferred embodiment of the present invention, the movable contact of the adjustable resistor **74** was set so the sensing circuit **43** and the flip-flop **102** actuated the ignition-initiating system **184** whenever the intensity of the light from the flames in the burner casing **21** fell slightly below the level of intensity experienced whenever

the reaction-type combustion engine **20** is "idling." However, that movable contact can be set to cause that sensing circuit and that flip-flop to actuate that ignition-initiating system at any desired level of intensity of the flames in the burner casing **21**.

If an accident to the vehicle, in which the reaction-type combustion engine **20** is mounted, severed the bundle **30** of fiber optics, the sensing circuit **43** would actuate the ignition-initiating system **184**. Similarly, if an "open" were to develop in the light-sensing element **42**, or if any breakdown were to occur in any of the other components of the sensing circuit **43** which would cause the voltage at the "clock" input of flip-flop **102** to go "low," the ignition-initiating circuit **184** would become actuated. The resulting "fail safe" operation of the control system is desirable, because it will enable that control system to provide protection for the operator of the reaction-type combustion engine even after that control system is unable to operate in normal fashion.

The filter **40** can be used to limit the wave lengths of light, which reach the light-sensitive element **42**, to a specific range; and thus can enable the control system to respond to the intensities of light having just those wavelengths. Those wavelengths can be in the invisible as well as the visible range of light. For example, if it was desirable to have the light-sensitive element **42** respond to light having wavelengths in the infrared region, a light-sensitive element **42** would be selected which could respond to light having wavelengths in the infrared region and a filter **40** would be selected which would pass light having wevelengths in the infrared region but which would attenuate light having other wavelengths. On the other hand, if it was desirable to keep the light-sensitive element **42** from responding to light having wavelengths in the infrared region, a filter **40** could be selected which would attenuate light having wavelengths in the infrared region. As a result, it should be apparent that the light-sensitive element **42** can be made to respond to light having any of the wavelengths in the flames within the burner casing **21**.

In at least one embodiment of the present invention, a filter **40** was not needed and was not used. The light-sensitive element **42** of that embodiment of control system was selected so it was sensitive to a range of light wavelength which included the range of wavelengths of the light developed by the flames within the burner casing **21**; and that embodiment of control system operated quickly and effectively to actuate the ignition-initiating system **184** whenever the intensity of light having the said wave lengths fell below a given level.

The field effect transistors **46** and **48**, the resistors **54**, **58**, **66**, **70**, **72** and **76**, and the adjustable resistor **74** perform a treble function. Not only do they sense changes in the intensity of the light "seen" by the light-sensitive element **42**, but they act as an impedance buffer between the high impedance of that light-sensitive element and the relatively low input impedance of the differential voltage comparator **78**, and they shift the voltage levels to make the output voltage of that light-sensitive element compatible with the voltage at the input of that differential voltage comparator.

Whereas the drawing and accompanying description have shown and described a preferred embodiment of the present invention, it should be apparent to those skilled in the art that various changes may be made in the form of the invention without affecting the scope thereof.

What I claim is:

1. A control system for a combustion engine which develops a predetermined level of flame intensity whenever it is "idling" and which comprises:

a light-sensitive element in visual communication with the interior of said combustion engine, and

a sensing circuit that is connected to the ignition-initiating system of said combustion engine and that is adapted to cause said ignition-initiating circuit to try to initiate ignition of fuel and air in said combustion engine,

said light-sensitive element and said sensing circuit responding to levels of flame intensity, within said combustion engine, at least as great as said predetermined level of flame intensity to permit said ignition-initiating system to be inactive, whereby said light-sensitive element and said sensing circuit permit said ignition-initiating circuit to be inactive as long as said light-sensitive element "sees" levels of flame intensity, within said combustion engine, at least as great as said predetermined level of flame intensity,

said light-sensitive element and said sensing circuit responding to flames within said combustion engine which produce flame intensity levels below said predetermined level of flame intensity to cause said ignition-initiating circuit to try to initiate ignition of fuel and air in said combustion engine, whereby said light-sensitive element and said sensing circuit automatically cause said ignition-initiating system to try to initiate ignition of fuel and air in said combustion engine whenever said light-sensitive element "sees" a flame within said combustion engine but fails to "see" said predetermined level of flame intensity,

said light-sensitive element and said sensing circuit being adapted to anticipate and halt incipient "flameouts" by causing said ignition-initiating circuit to try to initiate ignition of fuel and air in said combustion engine while a flame still exists within said combustion engine.

2. A control system for a combustion engine which has a housing and a burner casing spaced inwardly of said housing and which comprises:

a light-sensitive element,

a sensing circuit that is connected to the ignition-initiating system of said combustion engine and that is adapted to cause said ignition-initiating circuit to try to initiate ignition of fuel and air in said combustion engine,

said light-sensitive element and said sensing circuit permitting said ignition-initiating system to be inactive as long as said light-sensitive element "sees" a predetermined intensity of light within said combustion engine,

said light-sensitive element and said sensing circuit automatically causing said ignition-initiating system to try to initiate ignition of fuel and air in said combustion engine whenever said sensing circuit fails to "see" said predetermined intensity of light within said combustion engine,

a window mounted in said housing for said combustion engine,

said window being close enough to said burner casing of said combustion engine to "see" light within said burner casing of said combustion engine but said window being spaced away from said burner casing of said combustion engine by an area through which air moves rapidly,

said window having a surface thereof directly contacted by said rapidly-moving air,

said light-sensitive element being in visual communication with said window and said rapidly-moving air keeping said window clean to enable said window to maintain said light-sensitive element in visual communication with said burner casing of said combustion engine,

said rapidly-moving air also cooling said window, whereby the temperature of said window will be essentially the same as the temperature of said housing.

3. A control system for a combustion engine which has a housing and a burner casing spaced inwardly of said housing and which comprises:

a light-sensitive element,

a sensing circuit that is connected to the ignition-initiating system of said combustion engine and that is

adapted to cause said ignition-initiating circuit to try to initiate ignition of fuel and air in said combustion engine,

said light-sensitive element and said sensing circuit permitting said ignition-initiating system to be inactive as long as said light-sensitive element "sees" a predetermined intensity of light within said combustion engine,

said light-sensitive element and said sensing circuit automatically causing said ignition-initiating system to try to initiate ignition of fuel and air in said combustion engine whenever said sensing circuit fails to "see" said predetermined intensity of light within said combustion engine,

a mounting in said housing for said combustion engine which holds a window close enough to said burner casing of said combustion engine to "see" light within said combustion engine,

said light-sensitive element being in visual communication with said window and thus being in visual communication with light within said combustion engine,

said window having a portion thereof which extends inwardly of said mounting and extends into an area through which air passes,

said air keeping said window clean to enable said window to maintain said light-sensitive element in visual communication with the interior of said combustion engine.

4. A control system for a combustion engine which has a housing and a burner casing spaced inwardly of said housing and which comprises:

a light-sensitive element,

a sensing circuit that is connected to the ignition-initiating system of said combustion engine and that is adapted to cause said ignition-initiating circuit to try to initiate ignition of fuel and air in said combustion engine,

said light-sensitive element and said sensing circuit permitting said ignition-initiating system to be inactive as long as said light-sensitive element "sees" a predetermined intensity of light within said combustion engine,

said light-sensitive element and said sensing circuit automatically causing said ignition-initiating system to try to initiate ignition of fuel and air in said combustion engine whenever said sensing circuit fails to "see" said predetermined intensity of light within said combustion engine,

a mounting in said housing for said combustion engine which holds a window close enough to said burner casing of said combustion engine to "see" light within said combustion engine,

said light-sensitive element being in visual communication with said window and thus being in visual communication with light within said combustion engine,

said window having a large diameter portion and a small diameter portion,

said mounting having an inwardly-directed annular flange which defines an opening through which said small diameter portion of said window extends but through which said large diameter portion of said window can not pass,

whereby said window is held in assembled relation with said mounting with said small diameter portion thereof extending through said opening.

5. A control system for a combustion engine which has a housing and a burner casing spaced inwardly of said housing and which comprises:

a light-sensitive element,

a sensing circuit that is connected to the ignition-initiating system of said combustion engine and that is adapted to cause said ignition-initiating system to try to initiate ignition of fuel and air in said combustion engine,

said light-sensitive element and said sensing circuit permitting said ignition-initiating system to be inactive as long as said light-sensitive element "sees" a predetermined intensity of light within said combustion engine,

said light-sensitive element and said sensing circuit automatically causing said ignition-initiating system to try to initiate ignition of fuel and air in said combustion engine whenever said sensing circuit fails to "see" said predetermined intensity of light within said combustion engine,

a mounting in said housing for said combustion engine which holds a window close enough to said burner casing of said combustion engine to "see" light within said combustion engine,

said light-sensitive element being in visual communication with said window and thus being in visual communication with light within said combustion engine,

said window having a portion thereof which extends inwardly of said mounting and extends into an area through which air passes,

said air keeping said window clean to enable said window to maintain said light-sensitive element in visual communication with the interior of said combustion engine,

said window being transparent and being made of heat-resistant material,

said inwardly-extending portion of said window having a configuration which minimizes the likelihood of dust, dirt or other foreign matter settling thereon and adhering thereto.

6. A control system for a combustion engine which comprises:

a light-sensitive element in visual communication with the interior of said combustion engine, and

a sensing circuit connected to the ignition-initiating system of said combustion engine,

said light-sensitive element and said sensing circuit permitting said ignition-initiating system to be inactive as long as said light-sensiitve element "sees" a predetermined intensity of light within said combustion engine,

said light-sensitive element and said sensing circuit automatically causing said ignition-initating system to try to initiate ignition of fuel and air in said combustion engine whenever said sensing circuit fails to "see" said predetermined intensity of light within said combustion engine,

said light-sensitive element being sensitive to light having wave lengths within a narrow range,

said narrow range including light developed by a burning hydrocarbon fuel within said combustion engine whenever said combustion engine is operating normally but excluding light radiated by heated but essentially non-combustible parts of said combustion engine.

7. A control system for a combustion engine as claimed in claim 6 wherein said light-sensitive element is sensitive to light having wave lengths within a range of four-tenths to one and one-tenth microns.

8. A control system for a combustion engine which comprises:

a light-sensitive element in visual communication with the interior of said combustion engine, and

a sensing circuit connected to the ignition-initiating system of said combustion engine,

said light-sensitive element and said sensing circuit permitting said ignition-initiating system to be inactive as long as said light-sensitive element "sees" a predetermined intensity of light within said combustion engine,

said light-sensitive element and said sensing circuit automatically causing said ignition-initiating system to try to initiate ignition of fuel and air in said com-

bustion engine whenever said sensing circuit fails to "see" said predetermined intensity of light within said combustion engine,

said sensing circuit having series-connected impedances that establish a reference voltage,

an impedance connected in series with said light-sensitive element to establish a second voltage that varies in response to the intensity of the light impinging upon said light-sensitive element, and

said sensing circuit responding to a predetermined difference between said reference voltage and said second voltage to cause said ignition-initiating system to try to initiate the ignition of fuel and air in said combustion engine.

9. A control system for a combustion engine which comprises:

a light-sensitive element in visual communication with the interior of said combustion engine, and

a sensing circuit connected to the ignition-initiating system of said combustion engine,

said light-sensitive element and said sensing circuit permitting said ignition-initiating system to be inactive as long as said light-sensitive element "sees" a predetermined intensity of light within said combustion engine,

said light-sensitive element and said sensing circuit automatically causing said ignition-initiating system to try to initiate ignition of fuel and air in said combustion engine whenever said sensing circuit fails to "see" said predetermined intensity of light within said combustion engine,

said sensing circuit applying a "high" voltage to a voltage-sensitive element of said control system whenever said combustion engine is operating normally but applying a "low" voltage to said voltage-sensitive element of said control system if an incipient "flame out" develops,

said sensing circuit also applying a "low" voltage to said voltage-sensitive element of said control system if said light-sensitive element is not in visual communication with said interior of said combustion engine or if improper operation of any part of said sensing circuit keeps said sensing circuit from applying said "high" voltage to said voltage-sensitive element of said control system,

whereby said control system will "fail safe."

10. A control system for a combustion engine which comprises:

a light-sensitive element in visual communication with the interior of said combustion engine, and

a sensing circuit connected to the ignition-initiating system of said combustion engine,

said light-sensitive element and said sensing circuit permitting said ignition-initiating system to be inactive as long as said light-sensitive element "sees" a predetermined intensity of light within said combustion engine,

said light-sensitive element and said sensing circuit automatically causing said ignition-initiating system to try to initiate ignition of fuel and air in said combustion engine whenever said sensing circuit fails to "see" said predetermined intensity of light within said combustion engine,

said sensing circuit having means to establish a reference voltage,

an impedance connected in series with said light-sensitive element to establish a second voltage that varies in response to the intensity of the light impinging upon said light-sensitive element,

said sensing circuit responding to a predetermined difference between said reference voltage and said second voltage to cause said ignition-initiating system to try to initiate the ignition of fuel and air in said combustion engine, and

said sensing circuit having an impedance buffering and voltage-level-shifting means between said light-sensitive element and said voltage-sensitive element of said control system.

11. A control system for a combustion engine which comprises:

a light-sensitive element in visual communication with the interior of said combustion engine, and

a sensing circuit connected to the ignition-initiating system of said combustion engine,

said light-sensitive element and said sensing circuit permitting said ignition-initiating system to be inactive as long as said light-sensitive element "sees" a predetermined intensity of light within said combustion engine,

said light-sensitive element and said sensing circuit automatically causing said ignition-initiating system to try to initiate ignition of fuel and air in said combustion engine whenever said sensing circuit fails to "see" said predetermined intensity of light within said combustion engine,

said sensing circuit having means to establish a reference voltage,

an impedance connected in series with said light-sensitive element to establish a second voltage that varies in response to the intensity of the light impinging upon said light-sensitive element,

said sensing circuit responding to a predetermined difference said reference voltage and said second voltage to cause said ignition-initiating system to try to initiate the ignition of fuel and air in said combustion engine, and

said sensing circuit having a voltage-sensitive breakdown device that forces said sensing circuit to supply either a "high" voltage or a "low" voltage to said voltage-sensitive element of said control system.

12. A control system for a combustion engine which comprises:

a light-sensitive element in visual communication with the interior of said combustion engine, and

a sensing circuit connected to the ignition-initiating system of said combustion engine,

said light-sensitive element and said sensing circuit permitting said ignition-initiating system to be inactive as long as said light-sensitive element "sees" a predetermined intensity of light within said combustion engine,

said light-sensitive element and said sensing circuit automatically causing said ignition-initiating system to try to initiate ignition of fuel and air in said combustion engine whenever said sensing circuit fails to "see" said predetermined intensity of light within said combustion engine,

a display-type counter which is actuated each time said ignition-initiating system is actuated.

13. In a control system, for use with a combustion engine which has a burner casing:

a light-sensitive element which is incapable of withstanding the temperatures attained by said burner casing of said combustion engine during the operation of said combustion engine,

said light-sensitive element being located remotely from said burner casing of said combustion engine and being located where it is relatively cool,

an elongated bundle of fiber optics interposed between said light-sensitive element and said burner casing of said combustion engine,

said elongated bundle of fiber optics having one end thereof disposed to receive light from within said burner casing and having the other end thereof disposed to direct light onto said light-sensitive element,

said elongated bundle of fiber optics conducting light, but virtually no heat, from said burner casing of said combustion engine to said light-sensitive element,

whereby said light-sensitive element is maintained in visual communication with the interior of said combustion engine but is protected from the heat of said burner casing of said internal combustion engine, and

a window mounted in the housing of said combustion engine,

said window being close enough to said burner casing of said combustion engine to "see" light within said burner casing of said combustion engine,

said window being capable of withstanding the heat that is radiated toward it by said burner casing of said combustion engine,

said window being interposed between said burner casing of said combustion engine and that end of said elongated bundle of fiber optics which is adjacent to said burner casing of said combustion engine,

said window being spaced away from said burner casing of said combustion engine by an area through which air moves rapidly,

said window having a surface thereof directly contacted by said rapidly-moving air,

sai rapidly-moving air keeping said window clean and also cooling said window.

14. In a control system, for use with a combustion engine which has a burner casing:

a light-sensitive element which is incapable of withstanding the temperatures attained by said burner casing of said combustion engine during the operation of said combustion engine,

said light-sensitive element being located remotely from said burner casing of said combustion engine and being located where it is relatively cool,

an elongated bundle of fiber optics interposed between said light-sensitive element and said burner casing of said combustion engine,

said elongated bundle of fiber optics having one end thereof disposed to receive light from within said burner casing and having the other end thereof disposed to direct light onto said light-sensitive element,

said elongated bundle of fiber optics conducting light, but virtually no heat, from said burner casing of said combustion engine to said light-sensitive element,

whereby said light-sensitive element is maintained in visual communication with the interior of said combustion engine but is protected from the heat of said burner casing of said internal combustion engine, and

a window mounted in the housing of said combustion engine,

said window being close enough to said burner casing of said combustion engine to "see" light within said burner casing of said combustion engine,

said window being capable of withstanding the heat that is radiated toward it by said burner casing of said combustion engine,

said window being interposed between said burner casing of said combustion engine and that end of said elongated bundle of fiber optics which is adjacent to said burner casing of said combustion engine,

said window being spaced away from said burner casing of said combustion engine by an area through which air passes,

said air keeping said window clean to enable said window and said elongated bundle of fiber optics to maintain said light-sensitive element in visual communication with the interior of said combustion engine.

15. In a control system, for use with a combustion engine which has a burner casing:

a light-sensitive element which is incapable of withstanding the temperatures attained by said burner casing of said combustion engine during the operation of said combustion engine,

said light-sensitive element being located remotely from said burner casing of said combustion engine and beng located where it is relatively cool,

an elongated bundle of fiber optics interposed between said light-sensitive element and said burner casing of said combustion engine,

said elongated bundle of fiber optics having one end thereof disposed to receive light from within said burner casing and having the other end thereof disposed to direct light onto said light-sensitive element,

said elongated bundle of fiber optics conducting light, but virtually no heat, from said burner casing of said combustion engine to said light-sensitive element,

whereby said light-sensitive element is maintained in visual communication with the interior of said combustion engine but is protected from the heat of said burner casing of said internal combustion engine, and

a window mounted in the housing of said combustion engine,

said window being close enough to said burner casing of said combustion engine to "see" light within said burner casing of said combustion engine,

said window being capable of withstanding the heat that is radiated toward it by said burner casing of said combustion engine,

said window being interposed between said burner casing of said combustion engine and that end of said elongated bundle of fiber optics which is adjacent to said burner casing of said combustion engine, and

a mounting in said housing for said burner casing of said combustion engine which holds said window,

said window having a portion thereof which extends inwardly of said mounting and extends into an area through which air passes,

said air keeping said window clean to enable said window and said elongated bundle of fiber optics to maintain said light-sensitive element in visual communication with the interior of said combustion engine.

16. In a control system, for use with a combustion engine which has a burner casing:

a light-sensitive element which is incapable of withstanding the temperatures attained by said burner casing of said combustion engine during the operation of said combustion engine,

said light-sensitive element being located remotely from said burner casing of said combustion engine and being located where it is relatively cool,

an elongated bundle of fiber optics interposed between said light-sensitive element and said burner casing of said combustion engine,

said elongated bundle of fiber optics having one end thereof disposed to receive light from within said burner casing and having the other end thereof disposed to direct light onto said light-sensitive element,

said elongated bundle of fiber optics conducting light, but virtually no heat, from said burner casing of said combustion engine to said light-sensitive element,

whereby said light-sensitive element is maintained in visual communication with the interior of said combustion engine but is protected from the heat of said casing of said internal combustion engine, and

a window mounted in the housing of said combustion engine,

said window being close enough to said burner casing of said combustion engine to "see" light within said burner casing of said combustion engine,

said window being capable of withstanding the heat that is radiated toward it by said burner casing of said combustion engine,

said window being interposed between said burner casing of said combustion engine and that end of said elongated bundle of fiber optics which is adjacent to said burner casing of said combustion engine, and

a mounting in said housing for said burner casing of

said combustion engine which holds said window,

said window having a large diameter portion and a small diameter portion,

said mounting having an inwardly-directed annular flange which defines an opening through which said small diameter portion of said window extends but through which said large diameter portion of said window cannot pass,

whereby said window is held in assembled relation with said mounting with said small diameter portion thereof extending through said opening.

References Cited

UNITED STATES PATENTS

2,804,131	8/1957	Ator	431—79
3,080,708	3/1963	Carr	431—79
2,797,336	6/1957	Loft	60—39.09
3,216,477	11/1965	Devine	431—79
3,364,971	1/1968	Hayes	431—79

FOREIGN PATENTS

660,178	10/1948	Great Britain.

MARK M. NEWMAN, Primary Examiner

D. HART, Assistant Examiner

U.S. Cl. X.R.

60—39.82; 250—215; 431—79