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# [54] SMOKE, GAS, OR RAPID TEMPERATURE INCREASE DETECTOR UTILIZING A PERIODIC ELECTRIC FIELD TO CREATE A SELF-SUSTAINED AVALANCHE CURRENT

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[51] Int. Cl. .....G01n 27/62, G08b 21/00
[58] Field of Search .....324/33, 140; 340/227, 237; 73/359, 362

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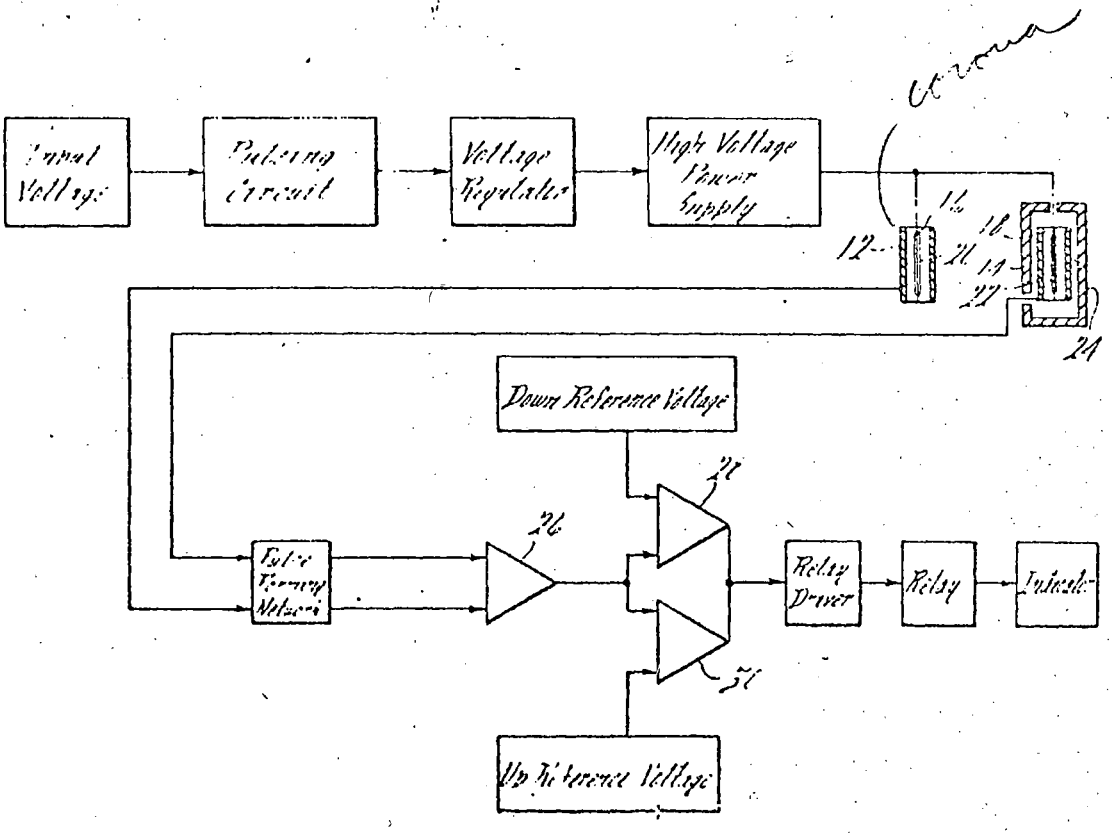
[57] ABSTRACT

A method and apparatus for detecting smoke, gaseous products of combustion such as CO, $CO_2$, and a rapid temperature rise, the method including the steps of periodically forming, in a location exposed to the ambient atmosphere to bet tested, an electric field of sufficient intensity and of the proper configuration to produce a self-sustained Townsend avalanche, and comparing the resultant current flow with that produced in a similar such electric field created at the same time in an area shielded from the ambient atmosphere to be tested. When the current flow difference is of a sufficient magnitude due to the presence of smoke, gaseous products of combustion, or the occurrence of a sudden temperature rise, an alarm or fire control device is operated. In a second version, the current flow in an electric field formed earlier in time in the same location serves as the reference. The apparatus includes a pulsing circuit to periodically apply a high voltage to a pair of detector tubes having center electrodes, one tube being exposed to the ambient atmosphere, the other shielded. In the second version, a pulsing circuit periodically applies a voltage to a single detector tube and a holding and comparison circuit is provided to compare successive pairs of voltage pulses created by current flows caused by the periodic application of high voltages to the tube.

**10 Claims, 2 Drawing Figures**



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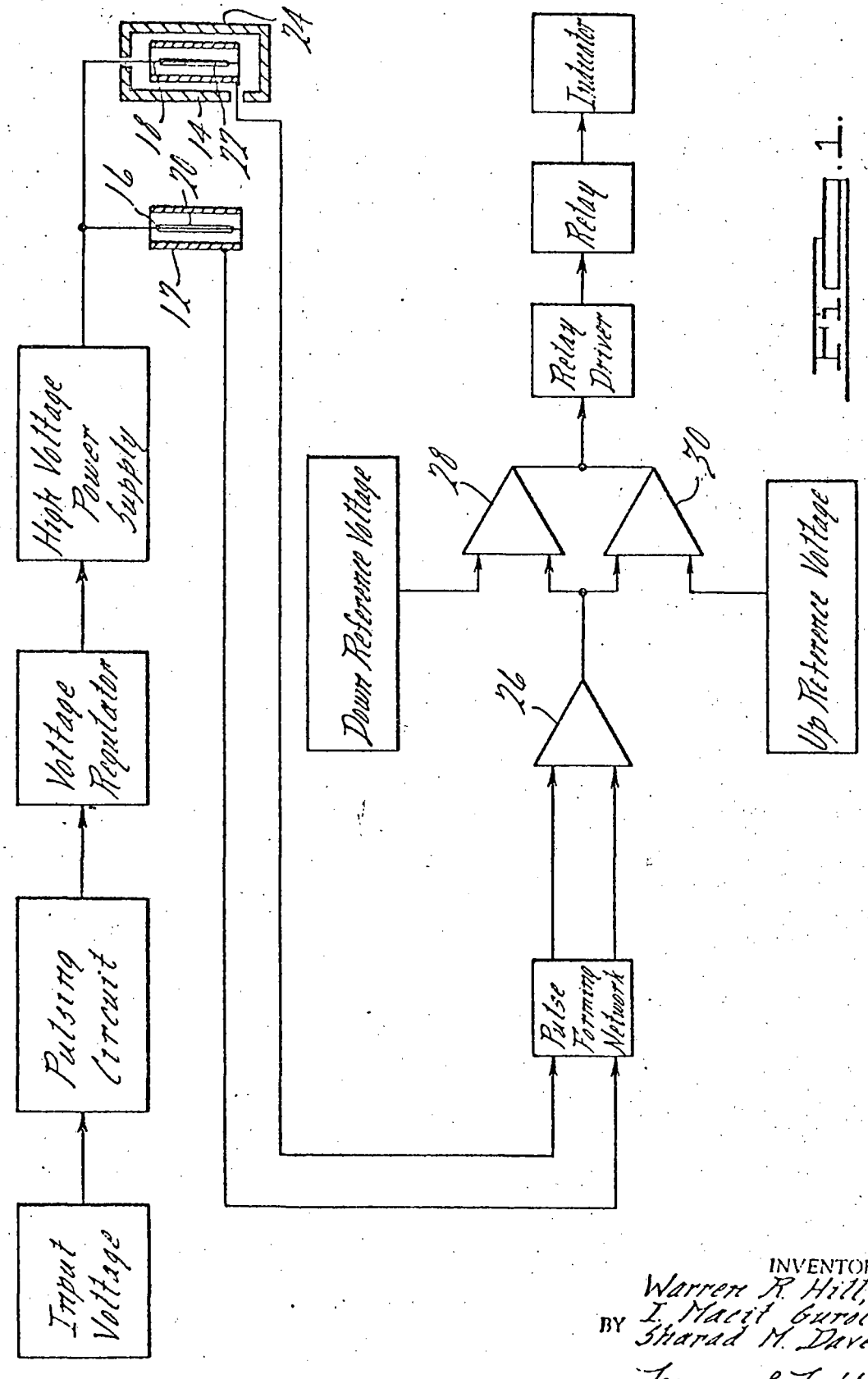


FIG. 1.

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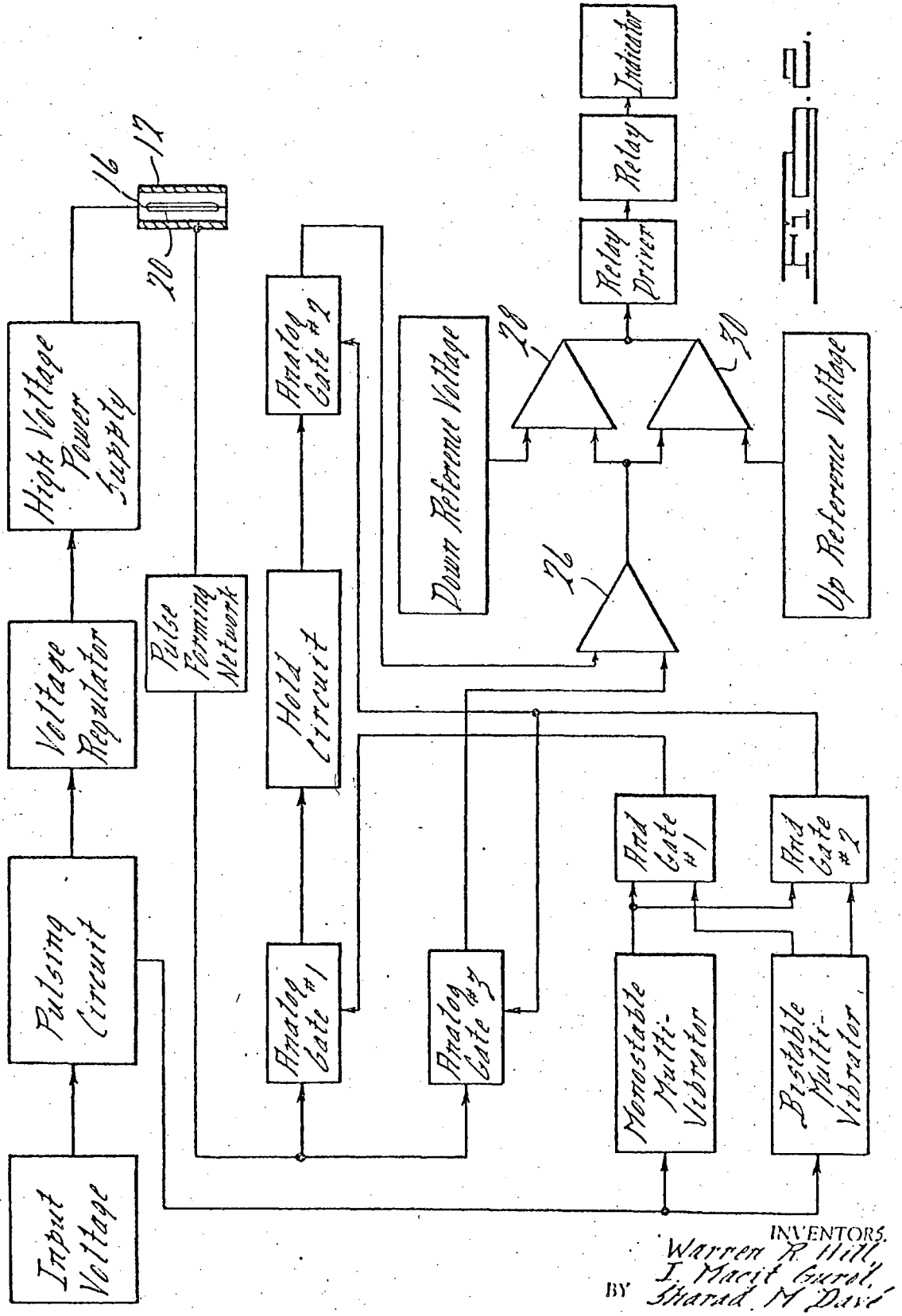


Fig. 2.

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# SMOKE, GAS, OR RAPID TEMPERATURE INCREASE DETECTOR UTILIZING A PERIODIC ELECTRIC FIELD TO CREATE A SELF-SUSTAINED AVALANCHE CURRENT

## BACKGROUND OF THE INVENTION

This invention is concerned with smoke, gas, and rapid temperature increase detectors and is an improvement over the method and apparatus disclosed in U.S. Patent application Ser. No. 806,190 assigned to the assignee of the present application.

As discussed in this referenced application, prior art smoke and fire detectors have for the most part relied on light beam smoke detectors, flame detectors, or high temperature responsive devices.

Since large volumes of dense smoke, flame, or high temperatures are present only after a fire is well established, it can be seen that these devices do not provide detection at the earliest, most easily controlled stages of the fire, and hence are unsatisfactory for this reason.

Another class of prior art device has provided an electric field exposed to the ambient atmosphere and an external ionization energy source in said field, usually by means of a radioactive element. Flow of the ions in this field produces a current, which varies with the presence of smoke and gas. This class of device however suffers from the drawback of the necessity to include the radioactive element or other energy source with its attendant disadvantages and also since the resultant current flow is very small, sophisticated amplifier elements and circuitry are necessary for measuring and comparing the current flow.

The invention disclosed in Ser. No. 806,190 on the other hand, establishes an electric field of sufficient intensity and of proper configuration so that a Townsend avalanche will occur and in addition the field is of sufficient strength so that substantial numbers of ions are produced by photoionization (corona) and photo-emission and supply enough ions so that the basic Townsend avalanche will be self-sustaining and a steady current flow result. This current flow for the configuration disclosed therein is on the order of microamperes, greater by a factor of $10^3$ to $10^6$ than that of the prior art device discussed above. The presence of smoke particles or typical gaseous of combustion such as CO and $CO_2$ affects the current flow and variations in current flow provide an indication of their presence.

In addition, it has been discovered by the present inventors that a substantial temperature rise aids in the avalanche process since a localized drop in the atmospheric density occurs, allowing greater mobility of the ions and hence increasing the current flow, in turn providing an additional indication of the existence of a fire.

However, the basic invention disclosed in Ser. No. 806,190, now abandoned, while satisfactory in most regards, has suffered to some extent from dust buildup on the wire electrode and the resulting reduction in current and also is subject to false tripping due to sensitivity to ambient temperature swings.

Therefore, it is an object of the present invention to eliminate electrostatic dust precipitation in the smoke and gas detector of the type described.



It is another object of the present invention to eliminate false tripping in this device due to ambient temperature changes.

## SUMMARY OF THE INVENTION

These and other objects which will become apparent upon a reading of the following specification and claims are accomplished by periodically establishing the electric field, rather than creating a continuously sustained electric field. The current flow in this field is referenced either against that occurring in a second field shielded from ambient effects or against an earlier current flow in the same field, to thus minimize false tripping due to normal ambient temperature swings. In addition, increases in current flow over that occurring in the reference field due to a rapid temperature rise are utilized to signal a fire condition.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows in a block diagram one form of the invention.

FIG. 2 is a block diagram representation of a second form of the invention.

## DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings and particularly to FIG. 1, a dual tube arrangement 10 is shown. As indicated, the arrangement includes an input voltage source, the output of which is controlled by a pulsing circuit that switches the voltage source in and out of the rest of the circuit periodically. This circuit, of which many types are well known in the art, provides a pulsing output which for this particular design is of the order of 30 milliseconds duration every 10 seconds. This pulse is regulated by means of a voltage regulator as indicated so as to minimize the effects of line variations in voltage, and provide a constant voltage through the duration of the periodic pulse, since variations in voltage during the pulse would lead to current flow variations, and possible false trippings.

This regulated output is then applied to a high voltage power supply, which may be of any suitable design, to provide an output voltage of positive polarity and of the order of 3,500 volts. This voltage is selected so as to cause the sustained Townsend avalanche for the particular geometry of the detector tubes.

This voltage is then applied to the detector tubes 12, 14 via center electrodes 16 and 18. These electrodes are constructed, in this embodiment, of 0.003 inch tungsten wire, while the tubes are approximately 5½ inch long and have an ID of 0.302 inch, and each is equipped with slots 20, 22 to allow ambient atmosphere to pass into the tube.

The positive polarity of the center electrodes 16, 18 creates a positive corona, since these are the high intensity electrodes. It has been found that this type of arrangement is much superior to that producing a negative corona, since the ionization process is sustained by the movement of the relatively low mass electrons, rather than the high mass positive ions. Thus much lower voltages are possible while producing the self-sustained Townsend avalanche, and the system is much less sensitive to changes in humidity, etc.

Detector tube 14 is partially sealed from the ambient atmosphere by means of a shield enclosure 24. This enclosure is designed so that slow changes in temperature of the surrounding atmosphere are felt within the enclosure, while rapid rises in temperature, as well as the presence of smoke, and gaseous products of combustion are at least temporarily prevented from affecting the air contained within tube 14 in order to provide a reference as will hereinafter be more fully discussed.

Detector tubes 12 and 14 are connected with the control circuitry so that the current pulses resulting from the avalanche effect created between the center electrodes 16, 18 and their respective tubes 12, 14 is fed through a pulse forming network which may be any suitable RC circuit as indicated which serves to provide pulses free from "hash" and transient effects, so that reliable indications of variations in temperature and the presence of smoke and gas are obtained. In addition, a potentiometer may be included to equalize current flow through the tubes under no fire conditions, since variations may occur due to normal manufacturing dimensional variations, surface finish, etc.

Voltages corresponding to each of the current flows are then applied to a differential amplifier 26 which provides an amplified voltage signal corresponding to the difference in these voltages.

The output voltage of this element 26 is then applied to a pair of comparators 28, 30, which function to provide an output signal if the voltage output of the amplifier indicates a predetermined current flow difference between tubes 12, 14.

This predetermined difference is established by applying a reference voltage to each comparator, one for a voltage difference corresponding to a greater current flow in tube 12 than tube 14, indicating a higher ambient temperature of the atmosphere in tube 12 than 14, and another for a voltage difference corresponding to less current flow in tube 12 than 14, indicating the presence of smoke or the gaseous products of combustion in tube 12.

This predetermined difference should be set to allow for some variations due to localized effects but still trigger reliably when a condition indicating a fire exists. For the tube geometry and applied voltages given, it has been found that a current flow difference of plus or minus 10 microamps is a satisfactory level to create an output signal indicating a fire condition. Hence, voltage levels produced by the differential amplifier corresponding to this current flow difference would give the indicated signal condition.

The output signal may then be fed to a relay driver which amplifies the signal current before being applied to a relay. The relay is used to activate an indicator device such as an alarm or to operate fire control devices. In the alternative, the signal could of course be fed to a high sensitivity relay, eliminating the need for amplification of the signal.

In operation, the pulsing circuit periodically will apply a pulse of high positive voltage to the detector tubes 12, 14, which for the geometry given at atmospheric pressure and normal temperature will be sufficient to create a Townsend avalanche, and also will produce sufficient incidence of photoionization and photoemission via the positive corona established so that this avalanche will be self-sustaining.

If smoke and gaseous products of combustion are not present in tube 12 and the temperature of atmosphere within the two tubes 12, 14 are substantially the same, the current flow will in turn be substantially the same in both tubes and no output signal will be emitted from differential amplifier 26.

If, on the other hand, smoke or gas is present in tube 12 or a substantial temperature difference therebetween exists, a current difference will be created, as explained infra, and an output signal will emanate from the differential amplifier 26, which if greater than the reference voltages applied, will cause the relay to be operated and the fire control or alarm device to be brought into operation.

It has been found that the tube geometry and the applied voltage are critical for a successful operation of the pulsing mode of operation. While a complete understanding concerning the exact process of the self-sustained Townsend avalanche is not as of yet available, it is known that unless an electric field of sufficiently great volume and intensity is created, an occasional delay in the establishment of the avalanche will occur. This delay will be read as a current difference by the rest of the circuitry, hence leading to false tripping.

This occasional delay, it is felt, is the result of the necessity of the presence of a free electron in the field at point sufficiently far removed from the collector electrode to enable it to acquire sufficient kinetic energy to produce ionization of molecules it will encounter before reaching the collector electrode. The number of free electrons, created by cosmic rays and background radiation, which are present in the field at the start of a pulse is substantially a function of the volume of the field, and the probability that an electron will be present at a point where an avalanche will be created is a function of the field intensity. From this it can be seen that the length of the tube and the applied voltage can be adjusted until the probability of a delay in the start of the avalanche is reduced to an insignificant level, which is the case for the specific dimensions and voltages of the embodiment disclosed.

A second embodiment of the invention is shown in schematic form in FIG. 2. In this embodiment currents created by voltage pulses applied at different points in time to a single detector tube 12 are compared and differences therein are utilized to trigger the indicator device in a manner similar to the above described embodiment. Since the spacing of the pulses is of relatively short duration, (approximately 20 seconds) slow changes in ambient temperature conditions such as created by normal temperature swings will not produce significant current differences, hence eliminating one cause of false tripping, and also providing the advantage of the pulsed electric field in eliminating electrostatic coating of the electrodes of the detector.

This arrangement is comprised of an input voltage source, pulsing circuit, voltage regulator and detector tube similar to the embodiment described above. The pulsing circuit, however, with the first pulse, turns on both the monostable and bistable multivibrators which then provide a signal through the AND gate No. 1 to turn on analog gate No. 1 and allow the pulse which passes through the tube 12 and a pulse forming network similar to that in the embodiment described above to pass into the Hold circuit.

The next pulse then turns off the bistable multivibrator, turns on the monostable multivibrator, which results in a signal from AND gate No. 2, in turn causing analog gate No. 2 and No. 3 to be turned on. This allows the pulse from the detector tube 12 and the pulse from the Hold circuit to be transmitted simultaneously to the differential amplifier 26, which functions to produce an amplified output corresponding to the difference in the pulses.

The output of the amplifier 26 is then fed to comparators 28 and 30 which provide an output signal to drive a relay when the voltage difference exceeds that of the reference voltages, which are set, in a similar manner to that in the above-described embodiment, to provide an output signal when a voltage difference of a magnitude indicating the presence of smoke or gas, or when a fire indicative rapid rise in ambient temperature occurs.

The next pulse then restarts the process.

From the above description, it can be seen that a detector of smoke, gaseous products of combustion, or rapid temperature rise has been provided that is simple, reliable, provides a strong output signal eliminating the need for extensive amplifier components and circuitry, requires no radioactive material or other external ionization energy source, is relatively unaffected by electrostatic precipitation of dust, and is not subject to false tripping as a result of normal ambient temperature changes.

In addition, the invention may be practiced in a variety of ways other than in the specific embodiments disclosed.

We claim:

1. An apparatus for detecting an abnormal condition in an atmosphere such as the existence of smoke, gaseous products of combustion, or increases in ambient temperature in said atmosphere, said apparatus comprising:

A. means producing periodic voltage pulses having a substantially constant voltage throughout the duration of each of said pulses;

B. first electric field means responsive to said pulses for establishing a first periodic electric field in said atmosphere in which a self-sustained avalanche current will occur for the duration of each of said pulses;

C. means providing a periodic reference current representative of a self-sustained avalanche current which would occur in an electric field in the absence of said abnormal conditions in said atmosphere; and

D. comparing means producing an output signal in response to a predetermined difference between said first electric field current and said reference current.

2. The apparatus of claim 1, wherein said means providing said periodic reference current includes:

E. second electric field means partially sealed from said atmosphere and responsive to said pulses for establishing a second periodic electric field in which said self-sustained avalanche reference current will occur.

3. The apparatus of claim 1, wherein said means providing said periodic reference current includes:

E. hold means for holding a current occurring in said first periodic electric field during said duration of one of said pulses; and

F. means transmitting the held current to said comparing means for comparison with a subsequent current occurring in said first periodic electric field.

4. The apparatus of claim 1, wherein

E. said periodic voltage pulses are positive in polarity; and wherein

F. said self-sustained avalanche current occurring for the duration of each of said pulses is a positive corona current.

5. A method of detecting an abnormal condition such as the presence of smoke, gaseous products of combustion, or increases in ambient temperature in an atmosphere, comprising the steps of:

A. producing periodic voltage pulses having a substantially constant voltage throughout the duration of each of said pulses;

B. establishing a first periodic electric field in response to said pulses in which there is a self-sustained avalanche current during each of said pulses;

C. providing a periodic reference current representative of a self-sustained avalanche current which would occur in an electric field in the absence of said abnormal conditions in said atmosphere; and

D. producing an output signal when said first electric field current and said reference current differ by a predetermined amount.

6. The method of claim 5, wherein said step providing said periodic reference current includes the steps of:

E. establishing a second periodic electric field in response to said pulses in which there is a self-sustained avalanche current representative of said reference current; and

F. shielding said second periodic electric field from the entrance of said abnormal atmospheric conditions.

7. The method of claim 5, wherein said step providing said periodic reference current includes the steps of:

E. holding a current occurring in said first periodic electric field during said duration of one of said pulses; and

F. transmitting the held current for comparison with a subsequent current occurring in said first periodic electric field during the duration of one of the subsequent pulses.

8. A method of detecting an abnormal condition such as the presence of smoke, gaseous products of combustion, or increases in ambient temperature in an atmosphere, comprising the steps of:

A. producing positive periodic voltage pulses having a substantially constant voltage throughout the duration of each of said pulses;

B. establishing a periodic electric field in response to said positive pulses in which there is a positive corona current during the duration of each of said pulses;

C. providing a periodic reference current representative of a corona current which would occur in an electric field in the absence of one of said abnormal conditions in said atmosphere;

D. comparing said first electric field current with said reference current; and

E. producing an output signal when said electric field current and said reference current differ by a predetermined amount.

9. An apparatus for detecting changes in the condition of an atmosphere such as smoke, gaseous products of combustion, or temperature, said apparatus comprising:

A. means producing positive periodic voltage pulses having substantially constant voltage throughout the duration of each of said pulses;

B. first electric field means responsive to said positive pulses for establishing a first electric field in said atmosphere in which a first positive corona current will occur during each of said pulses;

C. second electric field means partially sealed from said atmosphere and responsive to said positive pulses for establishing a second electric field in which a second positive corona current will occur during each of said pulses; and

D. comparing means producing an output signal in response to a predetermined difference between said first and second positive corona currents.

10. An apparatus for detecting changes in the condition of an atmosphere such as smoke, gaseous products of combustion, and temperature, said apparatus comprising:

A. means producing positive periodic voltage pulses having a substantially constant voltage throughout the duration of each of said pulses;

B. electric field means responsive to said positive pulses of establishing a periodic electric field in said atmosphere in which a positive corona current will occur during each of said pulses;

C. hold means for holding a current occurring in said periodic electric field during the duration of one of said pulses; and

D. comparing means producing an output signal in response to a predetermined difference between the held current and a current occurring in said electric field in response to a subsequent one of said pulses.

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