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Inoue

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[54] **SMOKE AND FIRE ALARM SYSTEM**

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[73] Assignees: **Inoue-Japax Research (IJR) Inc.**, Midoriku, Yokohama, Japan

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[52] **U.S. Cl.** .... **340/237 S,** 313/325, 340/227.1

[51] **Int. Cl.** **G08b 17/10,** G08b 17/06

[58] **Field of Search** .... 340/237 S, 237 R, 227.1, 340/227; 200/61.03; 313/325; 324/71 PC

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Assistant Examiner—Glen R. Swann, III
Attorney, Agent, or Firm—Karl F. Ross; Herbert Dubno

[57] **ABSTRACT**

A system for of detecting smoke or fire at a protected site, comprising a spark gap connected against the source of breakdown potential and exposed to the ambient air at the site. The improvement is based upon the discovery that particles present in smoke or the products of combustion induce a premature breakdown of the normally dielectric gas in the gap to initiate a signal which can be used to control a device or to alarm personnel in the region of the protected site.

30 Claims, 10 Drawing Figures

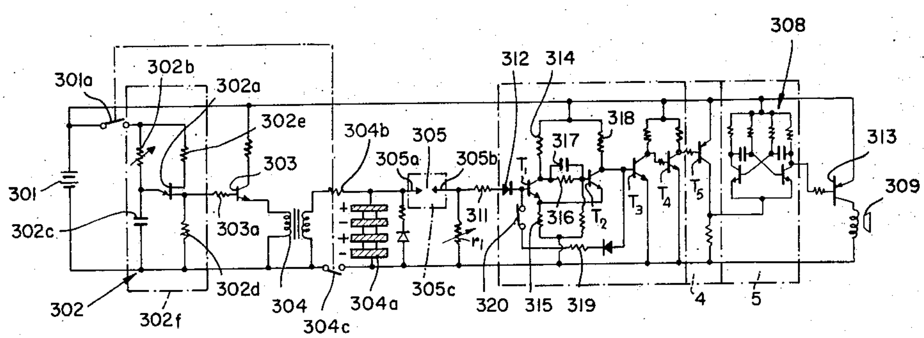
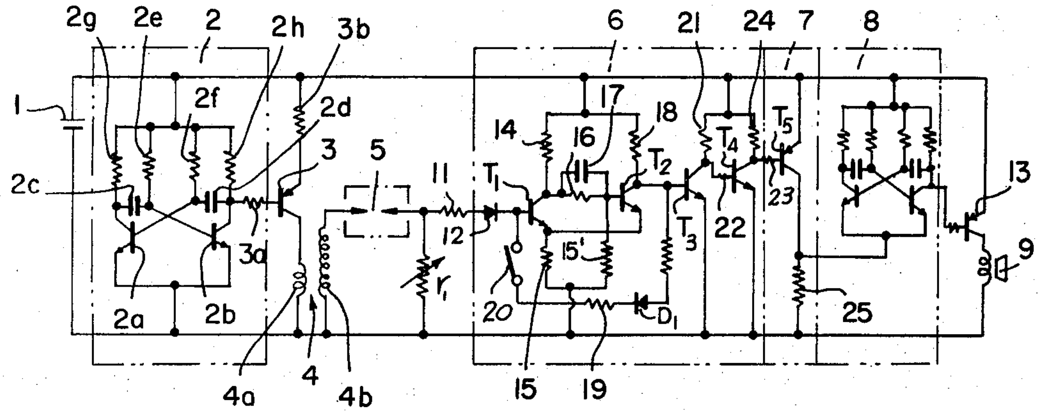


FIG.1



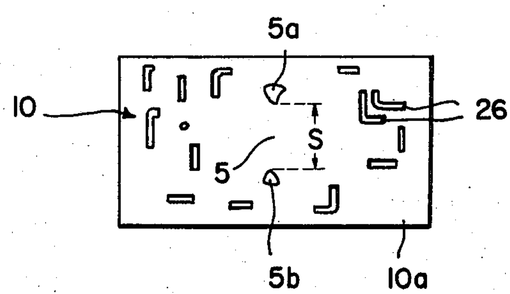


FIG.2

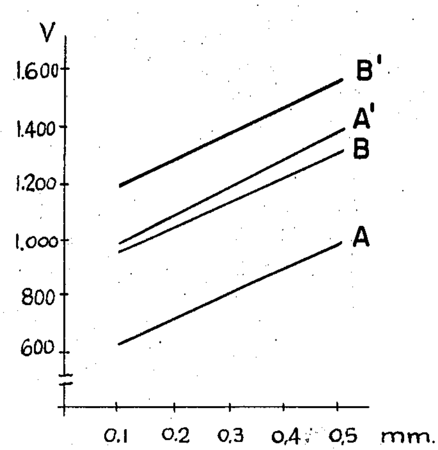


FIG.3

FIG. 4

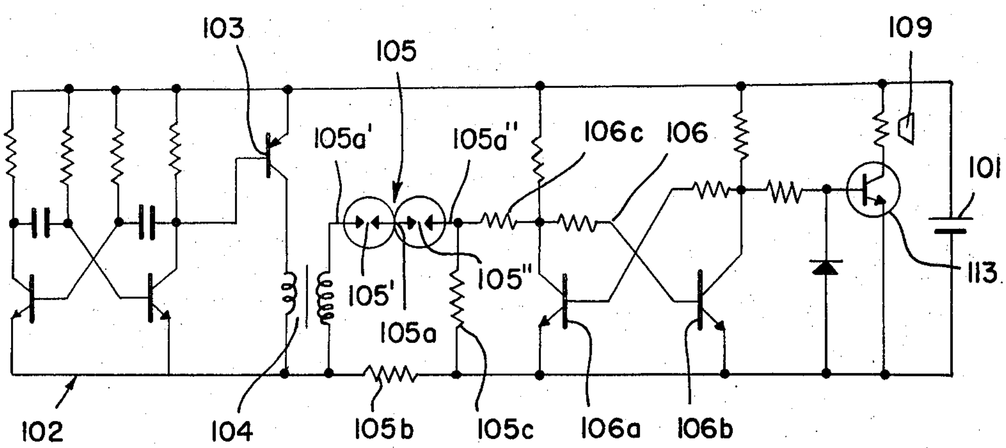
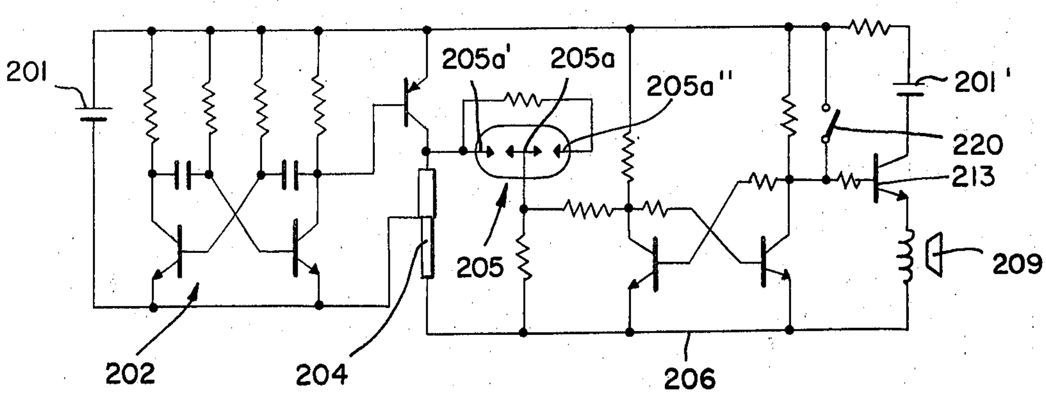


FIG. 5



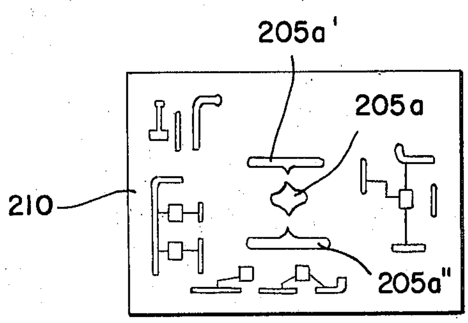


FIG. 10

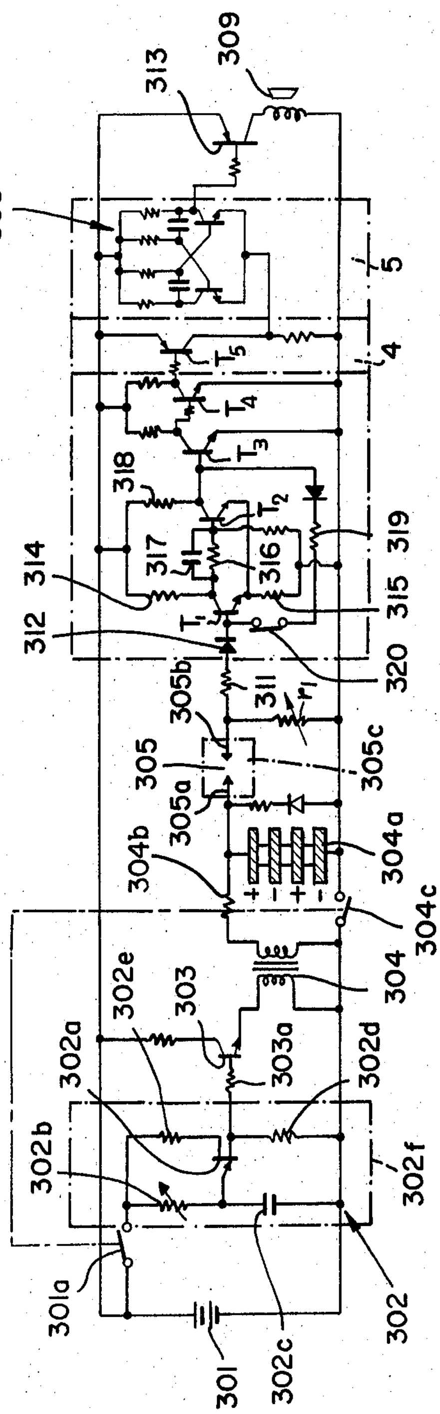

301
301a
302
302a
302b
302c
302d
302e
302f
303
303a
304
304a
304b
304c
305
305a
305b
305c
308
309
311
312
313
314
315
316
317
318
319
320
T_1
T_2
T_3
T_4
T_5
r_1
4
5

FIG. 6

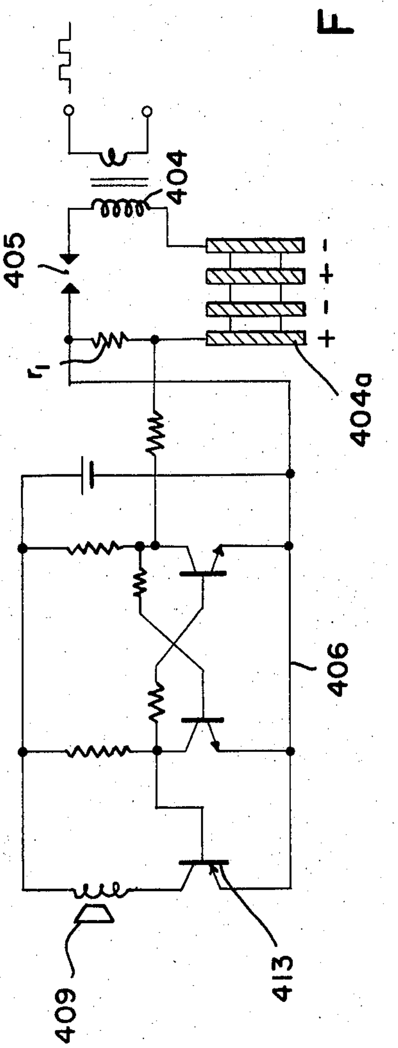
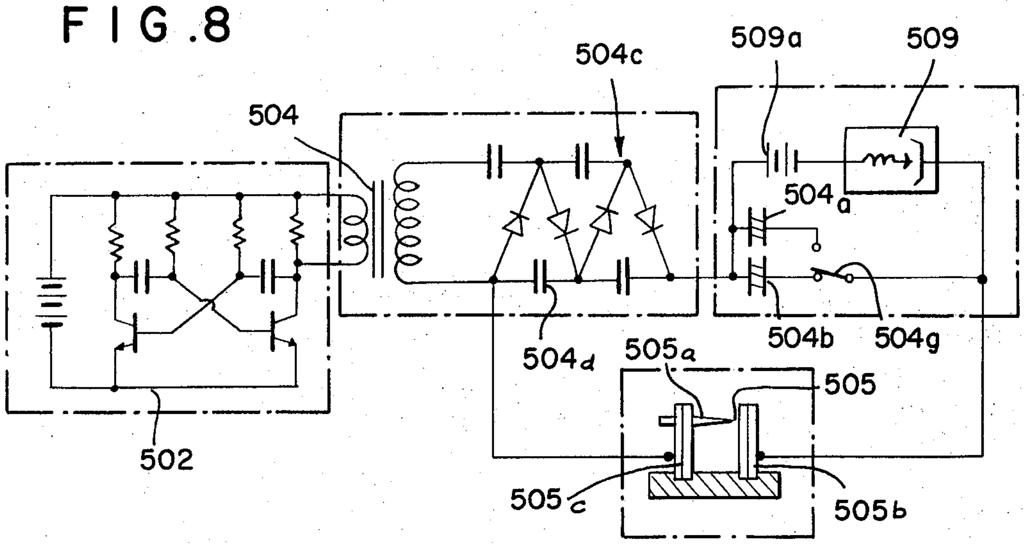

404
404a
405
406
409
413
r_1

FIG. 7

FIG. 8


504
504c
509a
509
504a
504b
504g
504d
505a
505
502
505c
505b

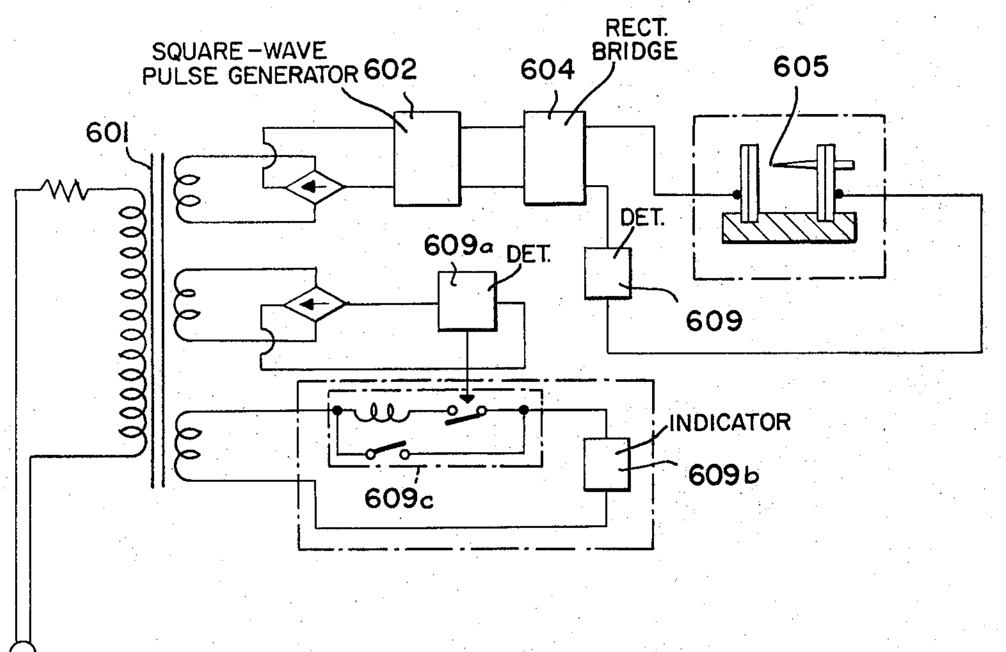

SQUARE-WAVE PULSE GENERATOR
602
RECT. BRIDGE
604
605
601
DET.
609a
DET.
609
INDICATOR
609b
609c

FIG. 9

SMOKE AND FIRE ALARM SYSTEM

FIELD OF THE INVENTION

My present invention relates to a system for detecting the presence of smoke and/or the existence of a fire at a protected site. The invention also relates to an alarm arrangement for warning of fire and smoke hazards at a protected site.

BACKGROUND OF THE INVENTION

Various alarm devices have been proposed heretofore in order to respond to the existence of a fire at a protected location or site and to trigger an alarm device capable of remote or proximal warning of personnel and other individuals in the vicinity. A typical fire alarm, for example, may include a temperature-sensitive mechanism responsive to a rise in temperature beyond a predetermined level (generally considered to be the maximum attributable to weather conditions and environmental considerations) to operate a switch mechanism which, in turn, is connected to an alarm circuit providing an audible, visible and graphic representation of the temperature rise and initiating, if desired, a suitable response.

Indirect methods of providing a warning of fire have also been suggested. A typical system of the latter type provides a thermally fusible element at the discharge side of a water-supply network, e.g., a sprinkler system, which is destroyed when elevated temperatures are detected to discharge a water spray over the region. An alarm may then respond to the operation of the sprinkler system to alert fire-fighting personnel or individuals who must, in turn, report the occurrence to the fire-fighting authority. Other systems have made use of the same or similar principles to provide direct or indirect warning of a fire condition. Associated with such systems may be remote-warning devices, triggered by an alarm system or operated independently of an acoustical or optical alarm network, for alerting fire-fighting authorities or other individuals remote from the site of the occurrence.

All of these systems are characterized by the fact that they respond to a temperature rise induced by combustion and generally must be monitored at a location remote from the actual site of combustion. Unless numerous sensors are provided, the response of a temperature-sensitive device may lag well behind the development of a fire, simply because the fire may begin at a location spaced from the sensor sufficiently to prevent detection of a significant temperature increase. Another disadvantage of existing fire-alarm systems is that their dependency upon a temperature rise to indicate the presence of a fire condition, prevents them from satisfactorily detecting smoldering fires or incipient combustion. It has long been known, for example, that spontaneous combustion may develop as a smoldering condition well before flames are of a sufficient intensity to cause a temperature-sensitive alarm remote from the smoldering site to respond. It is also known, in this connection, that one of the greatest hazards of the fire-fighting process is the occurrence of smoke and the danger is suffocation associated therewith. Furthermore, smoldering fires of low temperature may produce large quantities of smoke well before sufficient heat is developed to operate a temperature-sensitive alarm. Finally, I may point out that smoke is carried by

diffusion, convection and other air currents at high rates through open spaces and may even be present in the air before its odor is detected by personnel in the vicinity of a fire.

OBJECTS OF THE INVENTION

It is the principal object of the present invention to provide an improved smoke and fire alarm system which avoids the disadvantages of earlier alarm systems as discussed above, which responds rapidly and effectively to a fire condition before high heat levels are developed, which has an adjustable threshold substantially independently of ambient temperature maxima, which is of low cost and high efficiency, and which has little danger of malfunction.

A more specific object of the invention is to provide a system for detecting the development of a combustion condition which affords improved sensitivity and better response than earlier systems for the same purpose.

It is also an object of the invention to provide an apparatus capable of generating a warning signal of a fire condition.

SUMMARY OF THE INVENTION

These objects and others which will become apparent hereinafter are attained, in accordance with the present invention, by a method which is based upon my discovery, in connection to research related with spark-type discharges, that a spark gap including normally dielectric air and across which certain potentials are applied, can be caused to break down simply by the presence of smoke particles in the gap. In other words, the invention provides a method of warning of a fire and/or smoke condition which comprises the steps of providing a gap between a pair of electrodes in ambient air traversed by smoke particles generated by the fire, applying a potential across this gap incapable of effecting dielectric breakdown in the absence of smoke particles in the gap but sufficient to effect a discharge between the electrodes in the presence of such smoke particles, and detecting a breakdown in the gap for generating the warning signal.

While I may provide a constant potential across the gap, at least of limited duration, it has been found to be advantageous to apply the potential periodically, thereby preventing cumulative influences, such as polarization at the gap from altering the selected response threshold and triggering an undesired alert when smoke particles are not present. Preferably, the energization period is relatively long and the energization frequency relatively low (e.g., of a frequency between 0.01 and 10 Hz), while the pulse width may have a duration ranging from 1 to 100 microseconds for suitable operation.

According to the apparatus aspects of the present invention, therefore, a system for detecting the development of fire or smoke comprises a spark gap exposed to ambient gases and connected in a circuit for periodically applying a potential sufficient to effect breakdown across the gap in the presence of smoke particles but insufficient to cause breakdown in the absence of such particles and during "normal" conditions. In addition, a circuit responsive to breakdown of the gap may be provided across the latter and may be connected to a warning, signaling or alerting device for generating a visible, acoustic or remotely sensed signal indicative of the breakdown of the gap. It has been found to be desirable to constitute the system with a spark-discharge gap upon a mounting body for the electronic components of the device, e.g., on a printed circuit board, upon which the two electrodes defining the gap are permanently fixed.

In some instances it has been found to be advantageous to provide means for adjusting the gap, e.g., for advancing one of the electrodes toward the other, although practical applications using a gap width of the order of a fraction of a millimeter, e.g., between 0.1 and 1 mm, have shown that a fixed positioning of the electrodes on a printed circuit board or like support is desirable.

The circuit of the present invention advantageously comprises a multivibrator circuit connected to and across the electrode of the spark gap to provide the potential pulses as noted earlier. In one particularly advantageous construction, the multivibrator circuit is operated at relatively low voltage and is connected across the primary winding of a stepup transformer whose secondary winding is bridged across the gap. It has been found that transformer turn ratios may range between 100:1 and 10,000:1 between the secondary winding and the primary winding.

Moreover, it has been found to be advantageous to provide the breakdown detector as a transistor circuit including a pulse-shaping network, e.g., a SCHMITT trigger, one or more amplifying transistors (preferably a plurality in cascade) and a multivibrator oscillator energized by the amplifier transistors for operating the signaling device. All of these components, including the transformer and the multi-vibrator energizing the gap, which is preferably adjustable both as frequency and pulse duration, can be mounted upon the printed circuit board forming the gap or can be formed as an integrated circuit upon which the gap is provided.

In place of the transformer or in addition thereto, it has been found to be desirable to derive at least part of the voltage required across the gap from an electrolet pile which may be provided in series with a source of lower voltage pulses derived from a multivibrator. In other words, the low-current drain electrolet pile and a pulse source can be connected in series to superimpose the pulses of this source upon the constant potential of the electrolet pile which normally maintains a potential somewhat below the breakdown potential of the gap in the presence of the smoke particles. A circuit may be provided using the electrolet pile as a voltage-storage device as well and I may apply a transformer across the electrolet pile to superimpose the pulses upon the normally static direct-current potential thereof. An electrolet pile, of course, generally is constituted as a stack of closely spaced elements with a gap between the electrolet material and a metal plate with a high capacity. Electrostatic potentials of the order of 400 volts per cell of the pile may be developed in this manner.

According to another feature of the invention, means is provided for activating the detecting circuit in the event a rise in temperature, indicative of a fire, is sensed by a suitable temperature-responsive device. This has the advantage of providing fail-safe operation of the alarm if, for some reason, the smoke-particle sensor has been contaminated or rendered inoperative for other reasons. Moreover, it guarantees early detection of a fire of smokeless or low-smoke type.

It this aspect of the invention, one or both of the smoke-detection electrodes defining the breakdown gap are provided on bimetallic members for mechanically contacting the other electrode member to form a switch which, when closed, operates the detecting circuitry.

DESCRIPTION OF THE DRAWING

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

FIG. **1** is a circuit diagram of a system according to the present invention;

FIG. **2** is a plan view of a printed circuit board carrying the gap according to the present invention;

FIG. **3** is a graph illustrating the operation of the device of FIG. **1**;

FIGS. **4, 5, 6** and **7** are circuits illustrating modifications of the invention;

FIGS. **8** and **9** illustrate embodiments of the present invention according to other principles; and

FIG. **10** shows in diagrammatic form a printed circuit board provided with another gap arrangement according to the invention.

SPECIFIC DESCRIPTION

In FIG. **1**, I have shown a circuit illustrating principles of the present invention and constituting a preferred embodiment thereof which comprises a voltage source **1**, conveniently in the form of a low-voltage, low-power dry cell or battery whose terminals are connected across a multivibrator circuit **2** for applying voltage pulses of predetermined duration and frequency to a spark gap **5** exposed to ambient gases adapted to carry smoke particles from a combustion site.

Between the multivibrator **2** and the spark gap **5**, there is provided a stepup transformer **4** having a primary: secondary turn ratio of 1:400, for example, and applied through a resistor r_1 which may be adjustable as shown.

Across the resistor r_1, is tapped an output through a resistor **11** and a rectifier diode **12** to the base of a transistor T_1 forming with transistor T_2 a SCHMITT trigger represented generally at **6**, and having an output applied to the amplifier transistor T_3 connected to a signal inverter transistor T_4. Another transistor stage T_5 is applied between the SCHMITT trigger **6** and an oscillator **8** of the multivibrator type which is connected via transistor **13** to the warning device **9**. The latter may be a bell or buzzer or may even be a transmitter signaling the response of the system to a remote location.

The multivibrator **2** comprises a pair of cross-coupled transistors **2***a*, **2***b*, the bases of which are tied to the junction between capacitors **2***c* and **2***d* and resistors **2***e* and **2***f* of respective RC networks in the collector circuits of the opposing transistor. Bias resistors **2***g* and **2***h* are bridged between the emitters and the positive terminal of the low-voltage battery **1**. Resistors **2***e*, **2***f*, **2***g* and **2***h* may be adjustable to vary the time constants of the multivibrator circuit hence the pulse duration, interval and frequency. An output transistor **3** is connected via a base-bias resistor **3***a* to the collector of transistor **2***b* and has an emitter-collector circuit including the battery **1**, a bias resistor **3***b* and a primary winding **4***a* of stepup transformer **4**. The secondary winding 4*b* of this transformer, which has a turn ratio between secondary and primary of, say, 400:1 or 500:1, is connected in series with resistor r_1 across the discharge gap **5**.

In the detector stage **6**, the transistor T_1 is provided with a collector resistor **14** and an emitter resistor **15** in series with the emitter-collector electrodes across the battery **1** while the emitter of transistor T_2 is tied to the emitter of transistor T_1 which is brought to the negative terminal of battery **1** through resistor **15**. A parallel coupling of resistor **16** and capacitor **17** connects the collector of transistor T_1 to the base of emitter T_2 and also to the negative terminal of battery **1** through resistor **15'**. A resistor **18** is provided between the collector of transistor T_2 and the positive terminal of battery **1**.

The base of transistor T_3 is energized from the collector of transistor T_2 and is also tied via a diode D_1 and a resistor **19** to the base of transistor T_1. A switch **20** in this feedback circuit can be closed to apply collector potential of transistor T_2 to the base of transistor T_1 and thus, as will be apparent, maintain operation of the alarm once a breakdown at gap **5** is detected and until it is set off.

The collector of transistor T_3, which is provided with a bias resistor **21** to the positive terminal of the battery **1**, is connected via resistor **22** to the base of transistor T_4 which is in cascade with a transistor T_5, whose base is connected by resistor **23** to the collector of transistor T_4 and is brought to positive potential when the transistor T_3 is conductive. The collector-base circuit of transistor T_4 is completed by the resistor **24** the potential drop at which governs the conduction of transistor T_5. A load resistor **25** is connected in series with the collector of transistor T_5 across the battery **1** and is tapped to the negative terminal of the multivibrator **8** which as illustrated is similar to the multivibrator **2** and provides an output in the 100 Hz to 10,000 Hz range for energizing the electro-acoustic transducer **9** through the transistor **13** when transistor T_5 is rendered nonconductive.

In operation, switch **20** is assumed to be closed and input transistor T_1 nonconductive. In this state, the second or output transistor T_2 of the Schmitt trigger is held conductive to maintain the nonconductivity of transistor T_3, and hence a positive potential is to be found at the latter's collector to maintain the conductivity of transistor T_4. Then, since transistor T_5 is likewise conductive, a potential drop appears across the load resistor **25** to hold the multivibrator **8** ineffective.

Since, on the other hand, the multivibrator **2** is effective by virtue of its direct connection to the battery **1**, it generates a substantially square wave output in the form of low-voltage pulses which are applied to the base of transistor **3**. The latter is rendered periodically conductive for brief intervals and thus current pulses traverse the primary winding 4*a* of transformer **4** to generate high-voltage pulses in the secondary winding 4*b*. A potential is tereby applied across the gap **5** which, however, is not sufficient to break down the dielectric medium, e.g., normal air free from smoke particles and hence no change is detected by the sensing circuit **6**. The potential is chosen to lie between about 600 and 1,500 volts with a spark gap of 0.1 to 0.5 mm and is established so as to be sufficient to break down the gap at any desired threshold level of smoke-particle concentration in the air.

Should a smoldering fire (or a fire of any other type) generate sufficient smoke in the area, the smoke particles entering the gap will cause a breakdown of the dielectric and phase-reversal triggering of the sensing circuit **6** to render transistor T_3 conductive to trigger transistor T_4 and in turn transistor T_5 into non-conduction, and to eliminate the blocking bias potential across resistor **25**. The multivibrator **8** is thereby energized to provide a sonic-frequency energization of transistor **13** and of the transducer **9**. It will be apparent that an optical signal may be provided in place of an acoustical signal or in addition thereto by providing a filament of a lamp in the output circuit of multivibrator **8**. Furthermore, the latter may represent any other oscillator including that of a radio frequency, transmittor, for remote signaling of the presence of fire and smoke. In addition, it is possible to constitute transistor **13** of Germanium and the like type transistor which increases the leakage conductivity at an elevated temperature and to dispose same in the detection zone so that when such an elevated temperature is experienced, the transducer **9** is energizable independently of the operation of the smoke detector **6**.

In FIG. **2** of the drawing, I have shown a printed circuit board **10** in somewhat diagrammatic form. The spark gap **5** is provided between a pair of electrodes **5*a*** and **5*b*** permanently implanted in the board with a fixed spacing S. The other components of the system, namely, the transistors, resistors, capacitors, diode, transducer and even transformer **4** and battery **1** may be mounted upon the opposite side of the printed circuit board and interconnected by the printed circuit leads **26** in the usual manner. The printed circuit board may then be mounted in a housing with the surface **10*a*** exposed to the ambient atmosphere at the protected location.

In FIG. **3**, I have shown a graph of the relationship between the spark-discharge gap spacing (plotted along the abscissa) and the breakdown potential across the gap plotted along the ordinate using two different sets of electrode configuration for smoke present and absent in the gap area. Plots A and B were made with a needle electrode as cathode and 2 mm diameter planar disc electrode as anode while plots A' and B' were made when both anode and cathode had a needle shape. Plots B and B' represent breakdown potentials, when smoke is absent in the gap region while A and A' represent breakdown potential when smoke is present in the gap area. It can be seen that in each plot the relationship is substantially linear and it is preferably to employ a pointed electrode as cathode and a planar element as anode since this establishes a greater difference in breakdown potential level between the smoke present and absent states. The plots were made with a frequency of 10 to 0.01 Hz, a pulse width of 10 microseconds, a transformer having a turn ratio of 400:1, a potential across the multivibrator of 1.5 volts to 4.5 volts and a titanium-oxide lead transformer core.

FIG. **4** shows a circuit which represents a modification of that of FIG. **1**. In this embodiment, the discharge gap **105** is subdivided by a conductive electrode **105a** into a pair of gaps **105'** and **105''**, each associated with an electrode **105*a*'** and **105*a*''**. The multivibrator **102** is here constructed identically with the multivibrator **2** and has an output transistor **103** in series with the primary winding of the transformer **104** whose secondary is connected via resistors **105*b*** and

105*c* across the series of discharge gaps **105'** and **105''**. The detector circuit is here shown to include a monostable multivibrator **106** having transistors **106*a*** and **106*b*** of the cross-coupled type and a resistor **106*c*** connecting the gap electrode **105*a''*** across the emitter-collector network of transistor **106*a***. Conductivity of the gap system **105**, resulting from a breakdown of the dielectric medium (e.g., air) in the gap, results in the development of a potential at resistor **106*c*** which renders transistor **113** conductive and energizes the electro-acoustic transducer **109** in series therewith across the battery **101**. Here again, the multivibrator **102** provides short-duration spaced pulses of low total current drain to provide, via the transformer, periodic high-potential pulses at the gap and allows the system to operate at low cost for long durations.

The circuit of FIG. **5** differs from those already described in that the titanium-oxide lead core transformer **204** has its secondary winding connected between the central electrode **205*a*** and the outer electrodes **205*a'*** and **205*a ''*** of the gap system represented generally at **205**. A switch **220** is provided in the base circuit of transistor **213** and can be closed to terminate operation of the transducer **209** when the latter is energized by the cross-coupled coupled transistors of the network **206**. This system differs from that already described in that a separate battery **201** is provided for the multivibrator **202** generating the energization pulses. The battery **201'**, of course, energizes the transducer **209** when transistor **213** is rendered conductive.

In FIG. **10**, there is shown a printed circuit board **210** in which the central conductor **205*a*** is shown permanently positioned between the electrodes **205*a*** and **205*a''*** (fixed gap), the remaining components of the system being mounted on the opposite face of the printed circuit board as already described.

In FIG. **6**, I have shown another embodiment of the present invention wherein the voltage required across the gap **305** which is formed by a pair of electrodes **305*a*** and **305*b*** permanently mounted on a printed circuit board as represented at **305*c***, is applied by an electrolet pile **304*a*** which has been polarized semi-permanently. The polarization source for the electrolet pile **304*a*** is here constituted conveniently by a low-power pulser which includes a transformer **304** and a resistor **304*b*** connected in series with the secondary winding of the transformer **304** and is connectable via a switch **304*c*** across the pile **304*a*** when the latter requires repolarization as a result of its spontaneous release of stored charges or discharge through the smoke-detected gap **305**. An electrolet pile comprises an electrolet material spacedly juxtaposed with a plate and forming a capacitor-like voltage source. When the electrolet is a synthetic resin such as polydifluoroethylene, heated to 100° C and then while being cooled stretched under an applied voltage, and when, say, three layers of the electrolet material are used with intervening metal plates, the electrolet pile is able to deliver 100 nanocoulombs/cm^2 at 100 volts/μ. A gap of 0.5 mm may then be used in the smoke detector. The electrolet pile can maintain such capacity semipermanently, say, for a 1-year period, without spontaneous discharge, and thus permit the smoke-detection gap to continue monitoring operation without consumption of power.

In the low-power electrolet polarization pulse supply which can be connected to the electrolet pile **304*a*** when desired, the transformer **304** is energized by a voltage source consisting of a relaxation oscillator **302** having a unijunction transistor **302*a*** and an RC network consisting of a variable resistor **302*b*** and a capacitor **302*c***. The base-bias resistors are represented at **302*d*** and **302*e*** and are mounted, together with the rest of the relaxation oscillator as an integrated circuit chip or module **302*f*** on the printed circuit board. The emitter of the unijunction transistor is tied to the junction between the resistor and capacitor of the RC network which, in turn, is bridged across a battery **301** in series with an switch **301*a*** which is ganged with switch **304*c***. The output of the unijunction transistor is applied via a resistor **303*a*** to the base of a transistor **303** in series with the primary winding of transformer **304** across the battery **301**.

The detector stage connected across the gap is similar to that previously described and comprises the variable resistor r_1 across which is connected a resistor **311** and a diode **312** which feed the base of a transistor T_1 whose collector and emitter resistors are represented at **314** and **315**, respectively. The detector is thus responsive to a surge in current across the gap and operates the transistor T_2 through an RC network **316**, **317** as previously described. The switch **320**, which is operated to cut off the warning signal after it has been triggered, is connected to the base of transistor T_1 from the collector of transistor T_2 via a diode and the resistor **319**. The collector resistor of transistor T_2 is shown at **318**. Transistor T_3 of the cascade and transistor T_4 function in the manner already described to render a transistor T_5 non-conductive to operate the multivibrator oscillator **308** and, in turn, operate the transducer **309** via the transistor **313**. In this embodiment, also, breakdown of the gap resulting from the detection of smoke particles or their presence in the region results in a breakdown of the dielectric (air) normally maintaining the gap in non-conductive condition. The transducer, of course, is thereby triggered and the potential applied across the gap derives from the electrostatic potential of the electrolet pile.

In the embodiment illustrated in FIG. **7**, the electrolet pile **404*a*** is shown to be connected in series with the secondary winding of transistor **404** across the gap **405**. Thus, the square-wave pulses can be applied to the transformer **404** by relaxation oscillator as shown at **302** or a multivibrator circuit as shown at **202**. In this embodiment, however, a portion of the potential applied across the gap derives from the electrostatic potential of the electrolet pile, while the additional voltage is supplied by the oscillator in the form of square-wave pulses stepped up at transformer **404**. The output is detected across the resistor r_1, in series with the gap and is applied to the multivibrator oscillator **406** which operates the transducer **409** through a transistor **413** as originally described.

In FIGS. **8** and **9**, I have shown still other embodiments of the present invention to which the system is applicable. In FIG. **8**, the multivibrator square-wave generator **502** applies voltage pulses at the desired level across the detection gap **505** and its series connected breakdown-type capacitor **504*a*** or **504*b*** selectively, depending upon the setting of a switch **504*g***. The transformer **504** is thus provided with a stepup rectifier bridge **504*c*** at its output, the bridge being formed with capacitor **504*d*** to produce the desired *d-c* pulse level to be applied across the detection gap **505** which is formed between a pointed cathode **505*a*** and a planar anode **505b**. When the smoke enter the gap **505**, the latter and capacitor **504b** both break down and this capacitor provides a short-circuit path for the output current of battery **509a** to energize acoustic transducer **509**. After smoke detection is accomplished in this manner, the capacitor **504b** broken down can be replaced in position by capacitor **504a** as a spare by means of switch **504g**. Either the planar anode element **505b** or the support bar **505c** for the pointed cathode element **505a** is here comprised of bimetal designed to deflect with increasing temperature to shortcircuit the gap, even if the smoke detector has not been triggered into operation and to energize the acoustic transducer **509** in series with the battery **509a**.

In FIG. **9**, there is illustrated another embodiment of the invention operating on generally similar principles wherein a transformer **601** serves as the voltage source. This transformer energizes via a full-wave rectifier bridge a square-wave pulse generator **602** whose output may be applied through a stepup rectifier bridge **604** across the gap **605**. The latter may have one or more bimetallic elements whose function has already been discussed. When low-power detector **609** is operated or as a result of entry of smoke or the temperature increase to a sufficient level, it may transmit a signal to a remote detector **609a** which, in turn, may transmit its output to a relatively high power indicator **609b** in circuit with a self-locking relay **609c** operated by the detector **609a**. In this manner, sufficient remote signaling may be provided even where the source connected across the gap may be of low power.

I claim:

1. A system for warning of a smoke or fire condition comprising:

electrode means forming a discharge gap bridged by ambient air;

a source of electric pulses with an output frequency of 0.01 to 10 Hz connected across said gap and including an electrolet pile in circuit with said gap for intermittently applying pulses thereto of a voltage insufficient to effect breakdown in said gap in the absence of smoke particles in the ambient air but sufficient to cause such breakdown in the presence of smoke particles; and

detector means connected to said gap across the electrode means and responsive to the breakdown thereof for producing a warning signal.

2. The system defined in claim **1** wherein said source produces pulses of a pulse width of 1 to 100 microseconds.

3. The system defined in claim **1** wherein said source includes a dry-cell or battery, an oscillator operated thereby and a stepup transformer having a primary winding operatively connected with the output of said oscillator and a secondary winding connected in circuit with said gap for applying thereto said voltage pulses.

4. The system defined in claim **1** wherein said gap has a width of 0.1 to 1 mm.

5. The system defined in claim **1** wherein said detector means includes a resistor in circuit with said gap and a transistor network bridged across said resistor for changing its state in response to the passage of current therethrough.

6. The system defined in claim **1** further comprising a printed circuit board, said detector means, said source and said electrode means being mounted on said board.

7. A system forwarning of a smoke or fire condition, comprising:

electrode means forming a discharge gap bridged by ambient air;

a source of electric pulses with an output frequency of 0.01 to 10 Hz connected across said gap for intermittently applying pulses thereto of a voltage insufficient to effect breakdown in said gap in the absence of smoke particles in the ambient air but sufficient to cause such breakdown in the presence of smoke particles; and

detector means connected to said gap across the electrode means and responsive to the breakdown thereof for producing a warning signal, said electrode means including a bimetal element deflectable by temperature rise to bridge said gap and operate said detector means.

8. A system for warning of a smoke or fire condition, comprising:

electrode means forming a discharge gap bridged by ambient air;

an electrolet pile connected in circuit with said gap for applying thereto a potential of a magnitude insufficient to effect breakdown in said gap in the absence of smoke particles in the ambient air but sufficient to cause such breakdown in the presence of smoke particles; and

detector means connected to said gap and responsive to the breakdown thereof for producing a warning signal.

9. The system defined in claim **8** further comprising energization means connectable across said electrolet pile for polarizing same.

10. The system defined in claim **8** further comprising a printed circuit board, said electrolet pile, said detector means and said electrode means being mounted on said board.

11. The system defined in claim **8** wherein said detector means includes an oscillator energizable upon breakdown of said gap, transducer means energizable by said oscillator, locking means for keeping said oscillator to oscillate once gap breakdown is detected to continue said transducer to be energized independently of gap potential, and switch means associated with said locking means for terminating the operation of said oscillator.

12. A system for warning of a smoke or fire condition, comprising:

electrode means forming a discharge gap bridged by ambient air;

a source of electric pulses connected across said gap for intermittently applying pulses thereto of a voltage insufficient to effect breakdown in said gap in the absence of smoke particles in the ambient air but sufficient to cause such breakdown in the presence of smoke particles, said source including an electrolet pile in circuit with said gap; and

detector means connected to said gap and responsive to the breakdown thereof for producing a warning signal.

13. The system defined in claim **12** wherein said source has an output frequency of 0.01 to 10 Hz and produces pulses of a pulse width of 1 to 100 microseconds.

14. The system defined in claim 13 wherein said source includes a dry-cell or battery, an oscillator operated thereby and a transformer having a primary winding operatively connected with the output of said oscillator and a secondary winding connected in circuit with said gap for applying thereto said voltage pulses.

15. The system defined in claim 12 wherein said gap has a width of 0.1 to 1 mm.

16. The system defined in claim 12 wherein said electrode means includes a bimetal element deflectable by temperature rise to bridge said gap and operate said detector means.

17. The system defined in claim 12 wherein said detector means includes a resistor in circuit with said gap and a transistor network bridged across said resistor for changing its state in response to the passage of current therethrough.

18. The system defined in claim 12 wherein said detector means includes an oscillator energized upon breakdown of said gap and transducer means energizable by said oscillator.

19. The system defined in claim 12, furhter comprising a printed circuit board, said detector means, said source and said electrode means being mounted on said board.

20. A system for warning of a smoke or fire condition, comprising:

electrode means forming a discharge gap bridged by ambient air and including a pointed electrode poled as cathodic and a planar electrode poled as anodic;

a source of electric pulses connected across said gap for intermittently applying pulses thereto of a voltage insufficient to effect breakdown in said gap in the absence of smoke particles in the ambient air but sufficient to cause such breakdown in the presence of smoke particles; and

detector means connected to said gap and responsive to the breakdown thereof for producing a warning signal.

21. The system defined in claim 20 wherein said source has an output frequency of 0.01 to 10 Hz and produces pulses of a pulse width of 1 to 100 microseconds.

22. The system defined in claim 20 wherein said source includes a low-voltage dry-cell or battery, an oscillator operated thereby and a stepup transformer having a primary winding operatively connected with the output of said oscillator and a secondary winding connected in circuit with said gap for applying thereto said voltage pulses.

23. The system defined in claim 20 wherein said gap has a width of 0.1 to 1 mm.

24. The system defined in claim 20 wherein said electrode means includes a bimetal element deflectable by temperature rise to bridge said gap and operate said detector means.

25. The system defined in claim 20 wherein said detector means includes a resistor in circuit with said gap and a transistor network bridged across said resistor for changing its state in response to the passage of current therethrough.

26. The system defined in claim 20 wherein said detector means includes an oscillator energized upon breakdown of said gap and transducer means energizable by said oscillator.

27. The system defined in claim 26 wherein said detector means further includes locking means for maintaining said oscillator in oscillation once gap breakdown is detected to continue energization of said transducer independently of gap voltage, and switch means associated with said locking means for terminating the operation of said oscillator.

28. The system defined in claim 20, further comprising a printed circuit board, said detector means, said source and said electrode means being mounted on said board.

29. A system for warning of a smoke or fire condition, comprising:

electrode means forming a gap bridged by ambient air and including a pointed electrode poled as cathodic and a planar electrode poled as anodic;

a voltage source connected across said gap for applying a potential thereto to measure gap conductivity across said electrodes variable in the absence and the presence of smoke particles in the air bridging said gap; and

detector means connected to said electrodes across said gap and responsive to the gap conductivity for producing a warning signal upon detection of a gap conductivity indicative of the presence of smoke particles in said gap.

30. A system as defined in claim 29 wherein at least one of said electrodes is formed with bimetallic member for shifting said electrodes relatively upon a change in temperature.

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