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Gregg

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[54] **SPARK DETECTOR APPARATUS AND METHOD**

[75] Inventor: **Paul S. Gregg,** Indianapolis, Ind.

[73] Assignee: **Ransburg Electro-Coacting Corp.,** Indianapolis, Ind.

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Related U.S. Application Data

[63] Continuation of Ser. No. 77,299, Oct. 1, 1970, abandoned.

[52] **U.S. Cl.** ..... **317/9 R,** 317/3, 317/51

[51] **Int. Cl.** **H02h 3/14**

[58] **Field of Search** ..... 317/3, 4, 51, 262 A, 9 R

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Primary Examiner—James D. Trammell

Attorney, Agent, or Firm—Hofgren, Wegner, Allen, Stellman & McCord

[57] **ABSTRACT**

A spark detector for electrostatic coating apparatus which distinguishes disruptive discharges in the electrostatic system from a corona discharge or random sparking of other electrical equipment. A frequency selective radio wave receiver is connected with an envelope detector, the output of which is analyzed to detect the presence of repetitive discharges.

7 Claims, 5 Drawing Figures

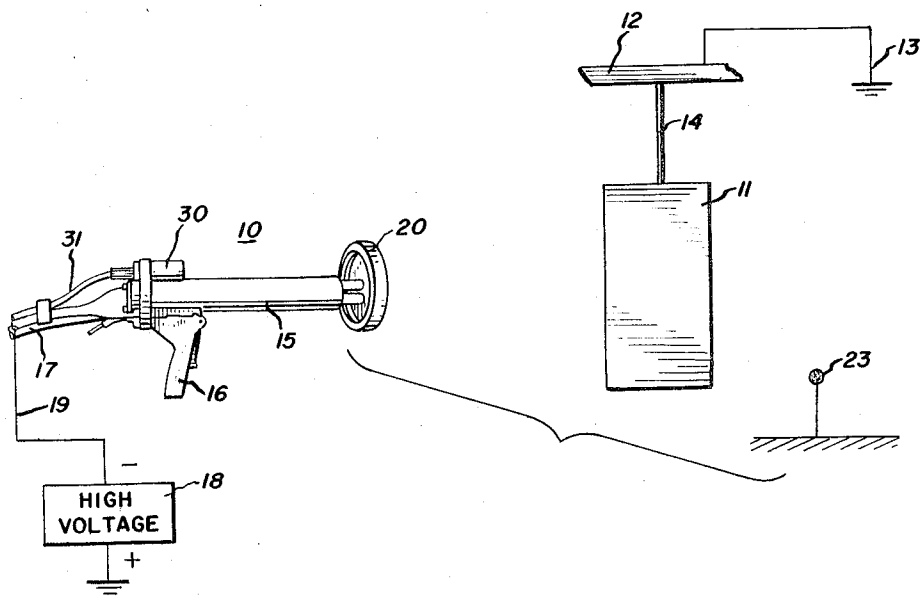


Fig. 1

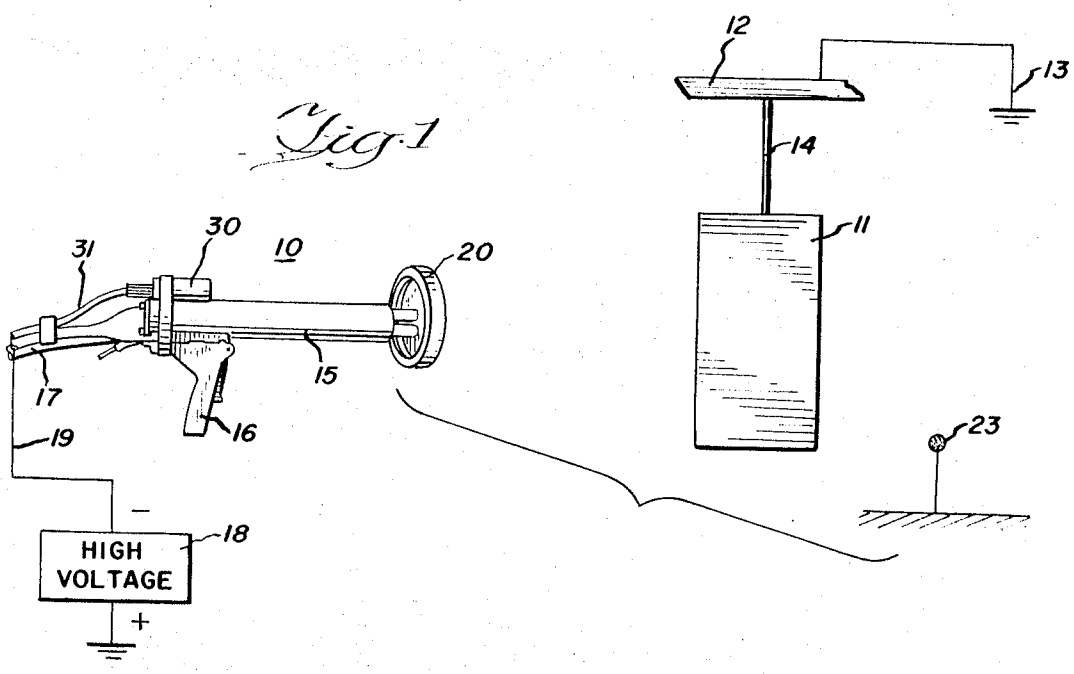


Fig. 2

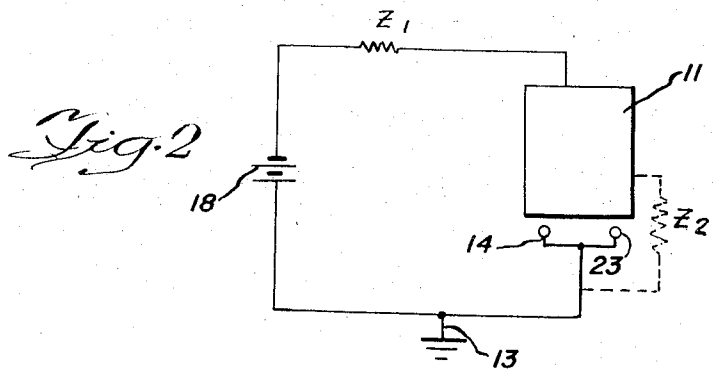
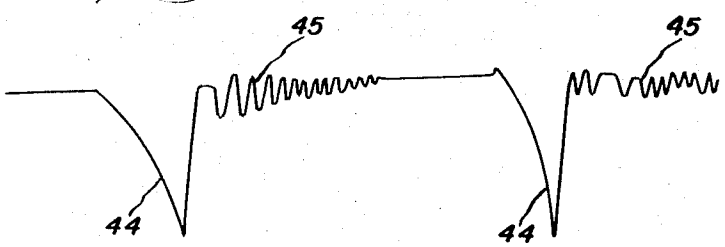


Fig. 4



INVENTOR

Paul S. Gregg

BY Hofgren, Wegner, Allen, Stellman & McCord

ATTORNEYS

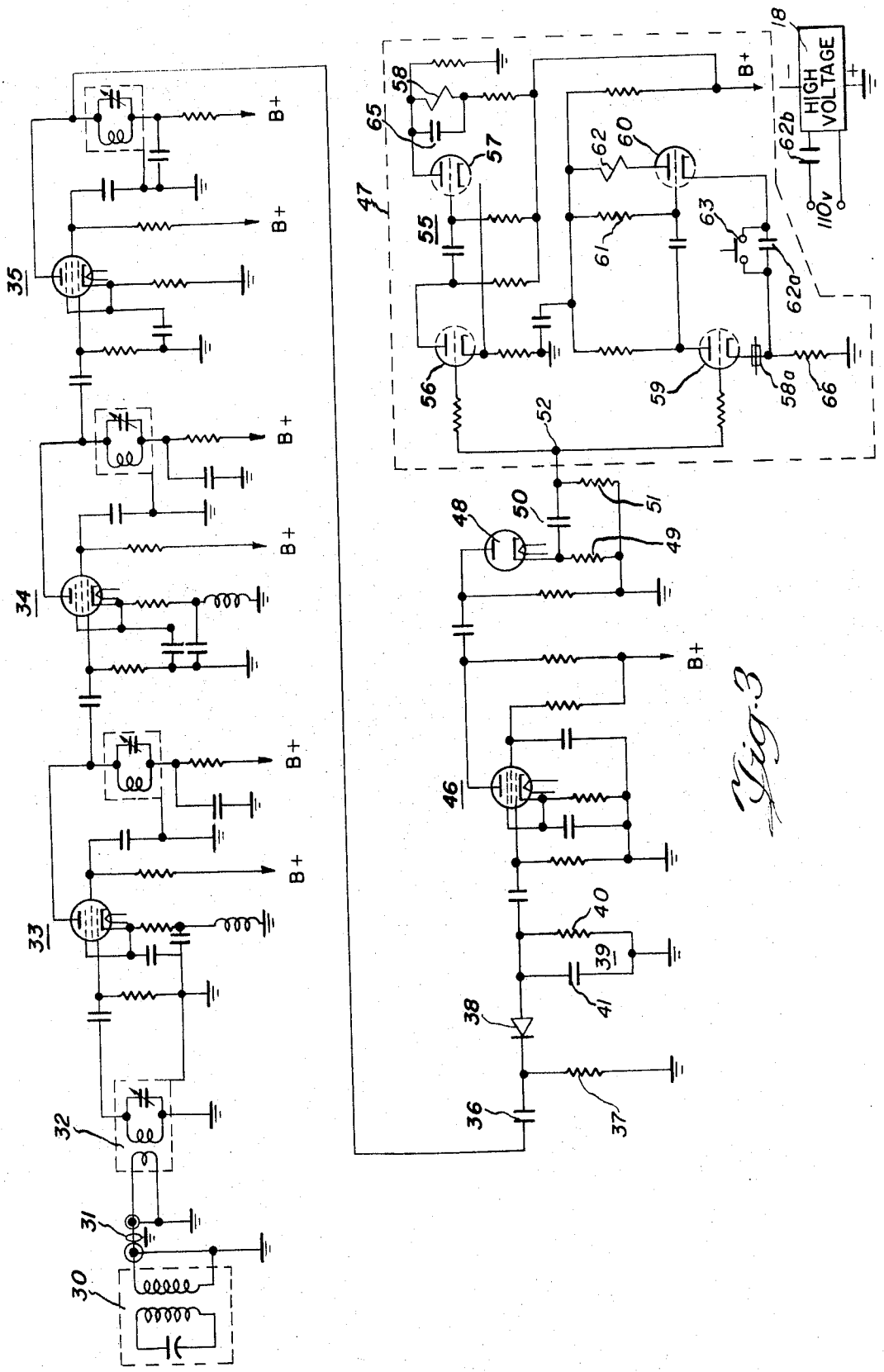
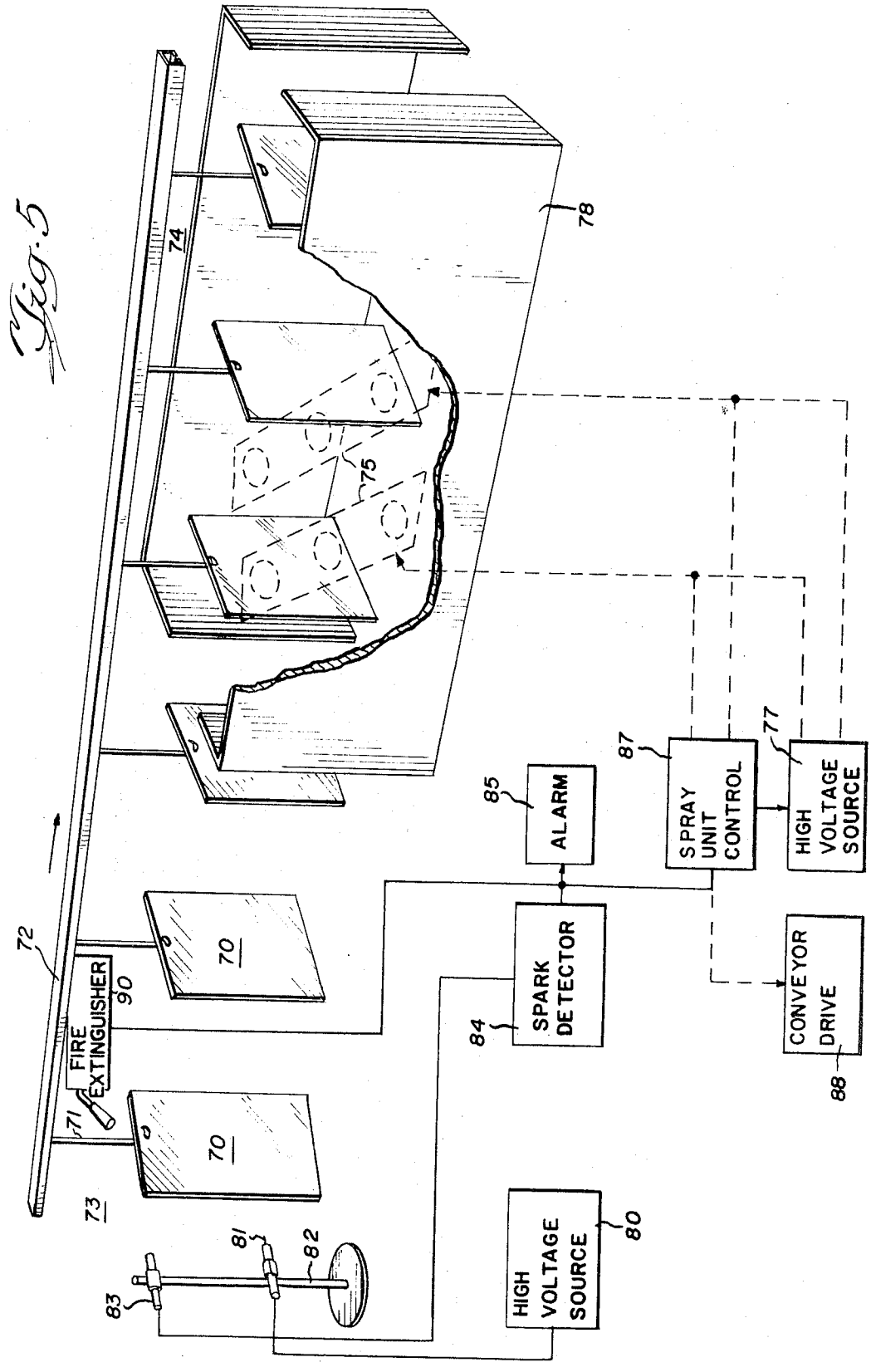

B+
HIGH VOLTAGE
110v
18
30
31
32
33
34
35
36
37
38
39
40
41
46
47
48
49
50
51
52
55
56
57
58
58a
59
60
61
62
62b
63
65
66

Fig. 3

Fig. 5


74
78
75
72
70
70
FIRE EXTINGUISHER
90
71
73
81
82
83
HIGH VOLTAGE SOURCE
80
85
ALARM
SPARK DETECTOR
84
87
SPRAY UNIT CONTROL
77
HIGH VOLTAGE SOURCE
CONVEYOR DRIVE
88

SPARK DETECTOR APPARATUS AND METHOD

This is a continuation of application Ser. No. 77,299 filed Oct. 1, 1970 now abandoned.

This invention relates to a detector for sparks which may occur in connection with the operation of electrostatic apparatus and particularly an electrostatic coating apparatus. In electrostatic coating it is common to operate a device for dispersing and charging the coating material at a potential of the order of 40,000 volts or higher. Where the coating material is a paint having a volatile solvent, the danger of an explosion or fire from sparking is quite serious. Electrostatic coating apparatus has been designed which, as a result of its physical and electrical characteristics, is incapable of causing objectionable sparking even when moved very close to a grounded conductor. Details of the design of such an apparatus are disclosed in Juvinall et al. U.S. Pat. No. 3,048,498. Such devices have greatly reduced, but not completely eliminated, the danger from sparking in an electrostatic coating operation.

For example, in a typical coating system articles to be coated are transported through a coating zone by a mechanical conveyor. The conveyor is operated at ground potential and the articles being coated are carried from the conveyor on hangers or supports of conductive material so that the articles themselves are at ground potential. The coating device includes an electrically charged electrode, preferably at a negative potential with respect to ground. If the article support or hanger should become so coated with paint that the article is electrically insulated from the hanger, an electrostatic charge can accumulate on the article. If the charge reaches sufficient magnitude, a spark can occur from the article to the hanger, providing a path for discharge of the energy stored on the article. Such sparking may occur repetitively at a rate depending on the rate of accumulation of charge on the article, the capacitance of the article with respect to ground and the breakdown voltage of the electrical insulation between the article and the hanger. A charge can accumulate on other isolated objects in the coating zone and sparks can occur from such objects to nearby grounded objects.

The sparking may cause a fire or explosion if it occurs in a flammable atmosphere. Furthermore, many of the benefits of electrostatic coating are lost if the article is not grounded to terminate the electrostatic field.

The terms "disruptive discharge" and "spark" are used synonymously herein.

One feature of the invention is the provision in an electrostatic coating system of a means for detecting the occurrence of a disruptive discharge in the electrostatic field and a means responsive to the occurrence of a discharge for disabling the high voltage source which energizes the coating device. More specifically, the detecting means includes means for distinguishing the disruptive discharge from either a corona discharge or from a random discharge within the sensing field.

Another feature of the invention is that the detector includes an antenna, a tuned radio wave receiver having a pass band below the frequency of corona discharge and a detector. A further feature is that the receiver includes an envelope detector having a time constant longer than the period of the corona discharge.

Yet another feature of the invention is that the detector has a means connected therewith for responding to plural successive discharges, to distinguish from random discharges which may occur within the sensing field, generally from sources other than the electrostatic coating apparatus.

Another feature of the invention is a method of inspecting a conductive article to insure proper grounding, prior to the coating operation, without contacting the article. The article is placed on a grounded support which is subject to the unintended accumulation of coating material which will undesirably isolate the article from ground. Prior to moving the support and article into a coating zone, the article is subjected to an electrostatic ionizing field. An ungrounded article will acquire a charge which may spark to a grounded object. Detection of the spark indicates an unsatisfactory ground and actuates an alarm or interrupts the electrostatic coating operation.

Further features and advantages of the invention will readily be apparent from the following specification and from the drawings, in which:

FIG. 1 is a diagrammatic illustration of an electrostatic coating system;

FIG. 2 is a schematic diagram of an equivalent circuit illustrating the problem;

FIG. 3 is a schematic diagram of a preferred embodiment of the detector circuit;

FIG. 4 is a representative wave shape of the output of the envelope detector of the radio wave receiver resulting from the occurrence of successive disruptive discharges; and

FIG. 5 is a diagrammatic illustration of an electrostatic coating system in which articles are moved by a conveyor through the coating zone, with a spark detector ahead of the coating zone.

The invention is illustrated and described as incorporated in an electrostatic printing system. It is particularly suited for use in this environment as the problem of isolation of the articles being coated from ground is particularly prevalent in a painting system where the article supports may become covered with paint and interrupt the desired ground connection. Furthermore, the danger of an explosion or fire as a result of a spark discharge is particularly great in a painting system which frequently utilizes flammable and sometimes very volatile coating materials. However, certain aspects of the invention have utility in detecting the occurrence of disruptive discharges or sparking in other electrostatic systems, as for coating with powder or flock material or for providing an electrostatic treatment, for example.

In FIG. 1 of the drawings an apparatus 10 is provided for coating an article 11 transported through a coating zone by a conveyor 12 connected with a reference potential or ground 13. The article 11 is supported from the conveyor by a conductive article support or hanger 14.

The coating apparatus 10 is here shown as a gun 15 having a handle 16 for manipulation by an operator. The gun is connected with a source of coating material through a flexible hose 17 and to a high voltage power supply 18 through a cable 19. The gun 15 has a rotating bell 20 which is electrically connected with the high voltage source 18 and to which the coating material is delivered. As the bell rotates the coating material is distributed across its surface and is electrostatically atomized from its periphery. The particles of coating material are charged and are attracted to the grounded article 11 by the electrostatic field. Further details of the

construction and operation of discharge device **10** may be found in Juvinall et al. U.S. Pat. No. 3,048,498. The system may also utilize other types of coating apparatus, as, for example, a gun having air atomization (Juvinall et al. U.S. Pat. No. 3,367,578) or a hydrostatic electrostatic device (Juvinall U.S. Pat. No. 3,169,883).

While article **11** remains electrically grounded, and so long as coating apparatus **10** is of a design in accordance with the Juvinall et al. U.S. Pat. No. 3,048,498, dangerous sparking is not a problem. However, if article **11** should become isolated from ground **13,** as by a coating of paint on hanger **14** which insulates the article from the grounded conveyor, the system has an equivalent circuit of the character illustrated in FIG. **2.** The high voltage power supply **18** is represented by a battery having its positive terminal grounded and its negative terminal connected through impedance Z1 with article **11.** Impedance Z1 is made up of a combination of the series resistance in the discharge device **10** and the "leakage resistance" of the space between the discharge device and the article. The "leakage resistance" of the space is determined by the rate at which charged atmospheric and paint particles carry charge to the article. This impedance may have a value as low as 300 megohms, for example, depending on the resistance present in the discharge device, the physical spacing between the discharge device and the article, and other physical constants of the system. The article **11** appears as one plate of a capacitor, with the other plate being grounded objects such as the hanger **14** or object **23,** in its vicinity. Article **11** accumulates an electric charge due to the flow of current through Z1 from high voltage power supply **18;** and the voltage between the article and ground **13** begins to approach the terminal voltage of the power supply at a rate determined by Z1 and the capacitance of the articles. When the voltage on the article reaches the breakdown voltage of the electrical insulation on the article support or hanger **14,** there will be a disruptive discharge between plate **11** and the grounded article support or hanger **14.** Ionization of the surrounding atmosphere will provide a low impedance Z2 indicated by broken lines, through which the energy stored on article **11** is dissipated to ground.

The voltage builds up on article **11** to the point of breakdown and discharges therefrom at rates determined by the breakdown voltage and the physical and electrical characteristics of the system as set forth above. This causes a series of disruptive discharges or sparks. The repetitive nature of the discharge provides a basis for distinguishing sparks due to the high voltage from random sparks which may be caused by switches, for example.

The circuit of the radio wave receiver and the spark discriminator is shown in FIG. **3.** A tuned antenna **30** is connected through a coaxial cable **31** with the tuned input circuit **32** of a first amplifier stage **33.** Second and third tuned amplifier stages **34** and **35** are connected in cascade. Each stage of RF amplification has essentially the same frequency characteristics with a center frequency of the order of 100 Khz and a pass band of the order of 30 Khz, well below the portion of the spectrum (above 1 Mhz) where the corona energy is concentrated. The specific circuitry of the tuned amplifier stages is not critical and will not be discussed in detail. A suitable B+ source is provided.

Antenna **30** can be mounted on the barrel **15** of the coating apparatus **10,** or otherwise mounted in the spraying area to detect the unwanted sparks.

The output of the third amplifier stage **35** is connected through coupling capacitor **36,** 0.01 μf, and across resistor **37,** 100 Kohms, to a diode **38** which, together with filter **39,** including resistor **40,** 250 Kohms, shunted by a capacitor **41,** 0.0002 μf, forms an envelope detector having an RC time constant of the order of 50 microseconds, substantially greater than the period of the corona discharge. The detected signal has a form illustrated in FIG. **4** with a negative spike **44** representing the initial spark discharge followed by a damped oscillatory wave **45** caused by ringing of the tuned amplifier circuits. The detector output is inverted by amplifier **46** so that the pulses representing the spark are positive. These pulses are utilized to actuate a spark discriminator circuit **47,** which responds to repetitive positive signals but not to signals which occur at random.

Diode **48** clips the output of amplifier **44** so that only positive signal components appear at the input of discriminator **47.** Furthermore, the positive pulses which occur across cathode resistor **49** are differentiated by series capacitor **50** and shunt resistor **51** and applied to discriminator input **52.**

The spark discriminator includes a monostable multivibrator **55** having a first triode section **56** which is normally nonconducting and a second triode section **57** which normally conducts. Connected with the plate of section **57** is the coil of a relay **58** which has a normally closed contact **58***a* connected in series with the cathode of control gate triode **59.** The term "normally closed" is used with reference to the position of the contacts in the unenergized condition of relay **58.** As tube **57** conducts in the absence of a spark when the circuit is operative, relay **58** is energized and contact **58***a* is open, preventing conduction of gate tube **59.** A control tube **60** has a positive bias applied to its control grid through resistor **61.** Connected in its cathode circuit are normally open contacts **62***a*, associated with relay **62** in the plate circuit of the control tube. A momentary contact "reset" switch **63** is connected across relay contacts **62***a*. A second set of normally open contacts **62***b* is connected in series with the energizing circuit of high voltage power supply **18.**

When the system is first turned on, the operator closes switch **63,** completing the cathode circuit of control tube **60.** The tube conducts by virtue of the positive bias potential applied to the control grid, energizing relay **62,** closing contacts **62***a* and **62***b*. Contacts **62***a* serve to complete a holding circuit for the control tube while contacts **62***b* energize the high voltage power supply **18.**

On occurrence of a spark, the positive pulse at the input **52** of spark discriminator **47** drives the first section **56** of multivibrator **55** into conduction, cutting off the second section **57.** This deenergizes relay **58** and contacts **58***a* in the cathode of control tube gate **59** close. The deenergization of relay **58** is delayed by shunt connected capacitor **65** so that control gate **59** is not enabled during the occurrence of the spark which triggers the multivibrator. A delay of 0.03 seconds has been found satisfactory. After this delay, relay **58** is de-

energized, closing contacts **58***a* and permitting conduction of gate tube **59.**

The control grid of tube **59** is returned to ground through a resistive network while the cathode is at a positive potential by virtue of the current of control tube **60** flowing through common cathode resistor **66.** Accordingly, gate **59** does not conduct. This condition of the circuit is maintained for a period of the order of one second by the timing relationship of monostable multivibrator **55** which maintains tube **47** in a nonconducting state. If during this period a second spark occurs, the positive pulse at the input **52** of the spark discriminator **57** is applied to the grid of gate tube **59** through the resistive network and causes gate tube **59** to conduct, in turn cutting off control tube **60** and deenergizing relay **62.** This opens contacts **62***a* and **62***b*, deenergizing the high voltage power supply and shutting down the electrostatic system. A warning signal can also be energized.

The operator can then rectify the problem, as by cleaning the article hanger which is at fault. The high voltage system is returned to operation by closing reset switch **63.**

Preferably, the detector is used as part of an automatic inspection system to detect article supports that have collected a hazardous accumulation of material. In accordance with this aspect of the invention, articles to be coated are placed on the article supports outside of the coating zone where flammable vapors can exist. The articles on their supports are conveyed past a high voltage ionizing electrode and are subjected to an ionizing electrostatic field. If an article or a support is not adequately grounded, the accumulated charge will reach sufficient voltage to spark over to ground. This sparking is sensed by the detector and a warning is given.

The method of preinspection may be performed by the apparatus illustrated in FIG. **5.** Here, articles **70** are supported by hangers **71,** depending from conveyor **72,** which travels from left to right as viewed in FIG. **5.** The conveyor transports the articles from a loading area (not shown) through an inspection zone **73** to an automatic coating zone **74.** Following the coating operation, the conveyor may move the articles through a drying oven (not shown). In the coating zone, automatic electrostatic spraying units are provided, arranged and controlled to apply a coating on the article being processed. They may, for example, incorporate plural rotating bell discharge units **75,** such as those shown in Juvinall U.S. Pat. No. 2,839,425, with which a liquid coating material is electrostatically atomized, or may utilize guns for pneumatically or hydrostatically atomizing the coating material. Each of the discharge devices has an electrode means connected with high voltage source **77** to establish the high intensity electrostatic field which charges the coating material particles and causes them to deposit on the grounded articles. In case of apparatus utilizing rotating bells or discs, the electrostatic field also affects the dispersion of the coating material into particles. The coating zone **74** may be enclosed within a booth **78,** if desired.

Each of the articles **70** is tested as it passes through the inspection zone to determine whether it is adequately grounded to travel through the electrostatic coating zone without acquiring a static charge which could cause sparking. Many of the coating materials used in industrial coating operations include volatile solvents which have flammable vapors. Detection of an ungrounded article which might cause sparking, before subjecting the article to the coating operation, reduces the danger of a fire or explosion.

In the inspection zone, before entry into the coating zone, each of the articles **70** is subjected to an ionizing electrostatic field. A high voltage source **80** is connected with a charging electrode **81** mounted on a stand **82** located adjacent the path of travel of the articles. The field from electrode **81** is preferably of sufficient intensity to induce a charge on an ungrounded article which is great enough, if discharged disruptively (e.g., a spark) with sufficient energy to ignite the vapors present in the coating zone. The field should be at least as strong as that to which the articles are subjected in the coating zone **74**; and in many causes high voltages sources **77** and **80** may be combined. Also mounted on stand **82** is an antenna **83** connected with spark detector **84.** The antenna and spark detector are preferably of the character illustrated in FIG. **3.** Antenna **83** is preferably located in a position closely adjacent the interengaging surfaces of the article **70** and hanger **71** to be as close as possible to the point at which sparking is most likely to occur.

When a spark is detected, an alarm **85** is actuated which may provide either a visual or audible indication to an operator. The output of spark detector **84** is also connected with spray unit control **87** which acts to disable the automatic spray units and high voltage source **77.** In addition, detection of a spark may be utilized to stop conveyor drive **88.**

Where the coating material build-up on hanger **71** is not completely dry at the time of inspection, the sparking which can occur as a result of the test procedure may cause a fire. A fire extinguisher **90** located adjacent the inspection zone is actuated by the output of spark detector **84** to direct the fire extinguishing material toward the interengaging surfaces of the hanger and article.

I claim:

1. A detector for a disruptive discharge which may occur in a zone in which a high intensity electric field is established between a charged electrode and an electrical reference, said electrode being connected with one terminal of a high voltage DC power supply which has a reference terminal connected with said electrical reference, said zone being subject to corona discharge from said electrode, said detector comprising:

an antenna having a circuit returned to said electrical reference and characterized by an absence of a connection with the path of current flow through said high voltage power supply, said antenna receiving electromagnetic energy radiated from a disruptive discharge and from said corona;

a tuned amplifier connected with said antenna circuit and having a passband excluding the frequencies of corona discharge;

an envelope detector connected with said amplifier for detecting the occurrence of a disruptive discharge in said zone; and

utilization circuit means connected with said detector and responsive to detection of a disruptive discharge.

2. The detector of claim **1** in which said envelope detector has a time constant of the order of 50 microseconds.

3. The detector of claim 1 in which the passband of said tuned amplifier has a center frequency of the order of 100 kilohertz.

4. The detector of claim 1 in which said utilization circuit means includes a timing circuit for establishing a timing period, means responsive to detection of a first discharge for actuating said timing circuit and further circuit means responsive to detection of a second disruptive discharge occurring during said timing period for causing response of said utilization circuit.

5. The detector of claim 4 in which said timing circuit means includes a monostable multivibrator having a first condition and a second condition and a gate circuit responsive to said multivibrator.

6. The detector of claim 5 in which said multivibrator includes a relay having contacts in said gate circuit.

7. The detector of claim 1 wherein there is a conductive article in said zone, nominally maintained at said reference potential, but subject to undesired isolation from the reference potential and, when so isolated, acquiring an induced electrostatic charge which may discharge to said reference potential.

* * * * *