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NASA Case [redacted]. ~~8981~~ XAC-8981

INVENTION ABSTRACT

PROTECTIVE CIRCUIT OF THE SPARK GAP TYPE

The protective circuit arrangement senses an overvoltage condition and removes the supply voltage from the load before the voltage reaches a level at which insulation breakdown of the load occurs. The arrangement provides a fast, positive, response and has a high current handling capacity.

The arrangement comprises a pair of spaced electrodes 20 and 22 connected across a load 10 which is supplied by a high voltage source 12 through contacts 14 of a relay 16. A third electrode 24 is positioned intermediate the electrodes 20 and 22. Upon occurrence of an overvoltage, the gaps 26 and 28 between the electrodes break down for current flow between the electrodes. The control winding 38 of the relay and relay energization source 40 are connected in shunt circuit with the gap 28, whereby the relay energization circuit is completed through the gap 28 upon breakdown for energization of the relay 16 to open the contacts 14. Adjustment of the voltage level at which the spark gap device conducts is made by loosening the nut 34 and sliding the mounting rod 30 along the arcuate slot 36 in the support 32. The slot 36 has a center of radius at the mounting of the electrode 22 to permit adjustment of the gap 26 while maintaining a constant gap 28.

Novelty resides in the inclusion of the relay control winding and relay energization source 40 in shunt with the gap 28, for completion of the relay energization circuit upon breakdown of the gap 28. The large breakdown current does not flow through the relay winding 38. A second feature includes the mounting of the electrodes 20, 22 and 24 which permits adjustment of the level at which the spark gap device conducts while maintaining a fixed gap 28 across which the relay control winding and energization source are connected.

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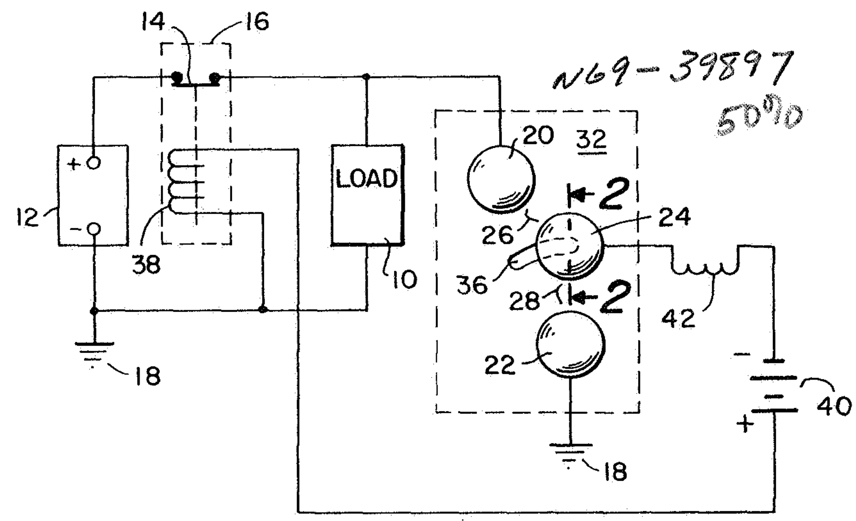

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FIG. 1.

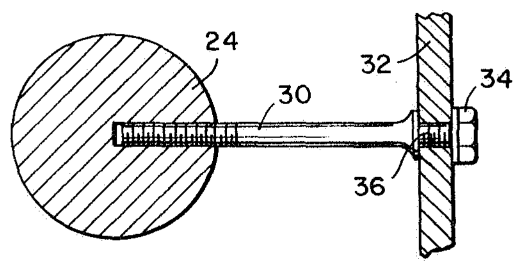

FIG. 2.

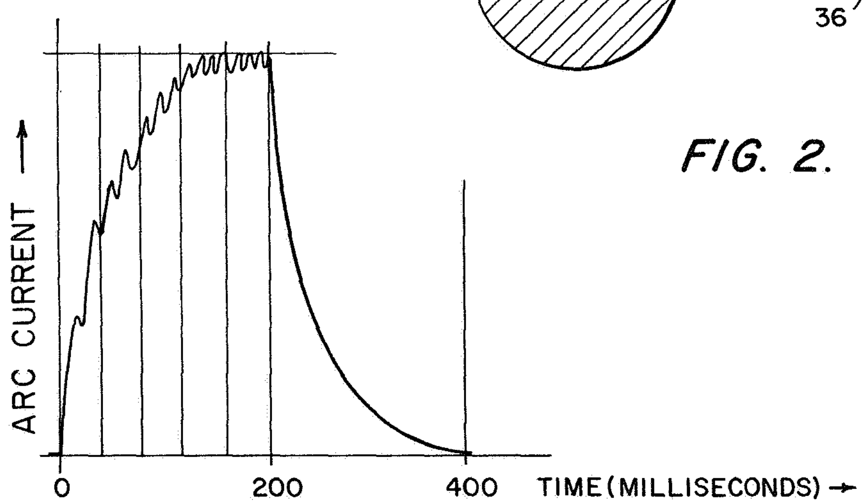

FIG. 3.

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PROTECTIVE CIRCUIT OF THE SPARK GAP TYPE

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ABSTRACT OF THE DISCLOSURE

A spark gap type protective circuit including a pair of spaced electrodes and an intermediate electrode. The spaced electrodes are connected across a load to be protected, which load is connected to a high voltage source through the contacts of a high voltage relay. The high voltage relay has a mechanical latch in the open position, in order to prevent hunting. The relay control winding is connected in shunt with a gap between the intermediate electrode and one of the pair of spaced electrodes through a series connected choke coil and a relay control winding energization source. Upon occurrence of an overvoltage of predetermined level at the load, an arc occurs between the pair of spaced electrodes through the intermediate electrode for completion of the energization circuit for the relay control winding through the spark gap without flow of the arc current through the control winding. Upon energization of the relay, the relay contacts are opened to remove the load and the protective circuit from the high voltage source. The arc thereof is extinguished and the relay control winding is deenergized. The mechanical latch on the relay can be reset after the cause of the overvoltage has been determined.

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to a protective arrangement to prevent voltage breakdown of a load supplied by a high voltage source, and more particularly to a spark gap type protective arrangement comprising a relay with contacts in the high voltage supply to the load, which relay has a control winding and energization source in shunt with a portion of the spark gap for completion of the relay energization circuit upon occurrence of a spark.

Protective circuits for high voltage use often include a spark gap which breaks down at a predetermined overvoltage. Generally, a relay control winding is included in series circuit with the spark gap for flow of the gap current therethrough and energization of the relay. The relay contacts are included in the high voltage energization circuit for removal of the high voltage source from the load. Such circuits are slow to respond to an overvoltage and are limited by the current carrying capacity of the relay control winding.

An object of this invention is the provision of an improved protective circuit which avoids the disadvantages of many prior art arrangements, including the above-described prior art circuit.

An object of this invention is the provision of a positive, quick response, high current capacity spark gap protective device for protection against overvoltage conditions.

The invention comprises a spark gap device having a pair of spaced electrodes connected across a load which is supplied by a high voltage source through contacts of a relay. A third electrode is included intermediate said pair of spaced electrodes and upon occurrence of an overvoltage, the gaps between the intermediate electrode and each of the pair of spaced electrodes break down for current flow therebetween.

The control winding of the relay and a relay energization source are connected in shunt circuit with the gap between the intermediate electrode and one of the pair of spaced electrodes. The relay energization circuit is completed through the gap upon breakdown for energization of the relay by said source of relay energization to open the relay contacts in the high voltage source circuit. Adjustment of the voltage level at which the spark gap device conducts is made by simply adjusting the gap between the intermediate electrode and the one, high voltage electrode while maintaining a fixed gap between the intermediate electrode and the other, ground electrode of the spark gap device.

The invention will be better understood from the following description taken in conjunction with the accompanying drawings. In the drawings, wherein like reference characters refer to the same parts in the several views:

FIGURE 1 is a combination diagrammatic and schematic showing of a spark gap protective arrangement embodying this invention,

FIGURE 2 is a fragmentary sectional view taken on line **2—2** of FIGURE 1, and

FIGURE 3 is a graph of arc current versus time illustrating the quick response time of the circuit.

Reference is now made to FIGURE 1 wherein there is shown a load **10** which is connected to a high voltage source **12** through contacts **14** of a high voltage relay **16**. The voltage source may be of either the alternating or direct current type. In FIGURE 1 a D-C source is shown with the negative terminal connected to a common or ground terminal **18** and the positive terminal connected to the load. A direct current source of either polarity may be used.

The protective arrangement, described below, is well suited for use with a current controlled D-C power supply **12**, in which the level of current is determined by a setting of the power supply only and not by the impedance of the load **10**. If, for any reason, the voltage across the load increases to a level where voltage breakdown of the load occurs, extensive damage to the insulation of the load may result since the entire current will flow through the breakdown path. The protective arrangement of this invention eliminates such damage caused by flashover by preventing the voltage supplied to the load from reaching the level at which breakdown occurs.

The load **10** may be of any suitable type, such as a motor, transformer, generator, arc heater or the like. For example only, but not by way of limitation, the load may comprise a high voltage electric arc heater to heat air to a high enthalpy for use in simulating reentry heating rates of space vehicles. Such a heater may comprise, for example, an anode and cathode between which a high voltage is supplied to create an arc therebetween. The arc may be initiated by use of a starting wire or a vacuum. When the arc is formed, the chamber is operated at 10 to 40 atmospheres pressure with a current of 100 to 2400 amperes. It has been found that arc heaters operate most stably if the arc voltage is approximately ½ the open circuit voltage of the voltage source. For an arc voltage of 12.5 thousand volts, which is typical for the above-mentioned heaters, an open circuit voltage of approximately 25 thousand volts is desired for arc stability.

Heater insulation which is adequate for the 12.5 kv. source under normal conditions generally is not sufficient to withstand the 25 kv. open circuit voltage without breakdown. To protect the insulation from overvoltage the protective device must operate at a voltage lower than the insulation breakdown voltage. It must be capable of carrying the current which the power supply is capable of delivery at the current setting, and must remove the high voltage source from the load without substantial delay. Also, the protective device must be operative at all times since an overvoltage may occur during start of the heater, because of insufficient vacuum or a broken starting wire, or may occur during run because of overpressure.

The protective device of this invention which meets the above requirements comprises first and second spaced spherical electrodes **20** and **22**, and a third spherical electrode **24** positioned intermediately thereof. The electrodes **20** and **22** are connected directly across the load **10**, the one electrode **20** being connected to the high voltage side of the load and the other to the common ground terminal **18**. From the high voltage electrode **20** a pair of series-connected gaps **26** an **28** are formed to ground potential, one gap being formed between the high voltage electrode **20** and intermediate electrode **24**, and the other gap being formed between the intermediate electrodes **24** and ground electrode **22**.

The voltage at which the gaps **26** and **28** break down is dependent upon the sum of the spacing of the gaps **26** and **28**. In the novel electrode mounting arrangement the gap spacing **26** is adjustable whereas the gap spacing **28** remains constant. The three electrodes comprise spheres of copper, or other suitable material, mounted on conducting rods **30** (only one of which is seen in FIGURE 2) attached to a plate of dielectric material **32**. The electrodes **20** and **22** are fixedly secured to the plate **32**, whereas the electrode **24** is movably positioned after loosening of a fastening nut **34** at the inner threaded end of the rod **30**. When the nut **34** is loosened, the rod is movable along an arcuate slot **36** in the plate **32**, the center of curvature of which slot **36** is located at the axis of the mounting rod for the sphere **22**. Consequently, a constant gap **28** (of say ½ inch) is maintained between the intermediate and ground spherical electrodes, while the spacing **26** between the intermediate and high voltage electrodes is varied. The voltage at which the gaps break down thereby is readily adjustable.

Also, in accordance with this invention, a circuit which includes the control winding, designated **38** of the high voltage relay **16** and an energization source **40** for the winding, is connected in shunt relation with the spark gap **28** between the electrodes **22** and **24**. The winding **38** and source **40**, are included in a series circuit which includes also a relatively small value choke coil **42**.

Under normal voltage conditions during which no arcing between the spherical electrodes occurs, the energization circuit for the relay control winding **38** is open and the relay contacts **14** are closed. At a predetermined overvoltage level thee two gaps **26** and **28** break down and the entire current output from the power supply **12** flows therethrough, it being assumed that the load **10** comprises an arc heater in which the arc, for some reason, is extinguished or not yet initiated. The amount of current will depend upon the current setting of the source **12**. The impedance of the choke coil **42** (together with that of the control winding **38**) prevents the current from flowing through the shunt circuit when the gap **26** breaks down. Consequently, both gaps **26** and **28** break down substantially simultaneously upon occurrence of the predetermined overvoltage.

When the gap **28** breaks down, the electrode **24** is connected to ground potential through the arc for completion of the energization circuit for the relay control winding **38**. The completed control winding circuit may be traced from the ground terminal **18** through the control winding **38**, the battery **40**, choke coil **42** and back to ground potential through the narrow spark at gap **28**. When the relay **16** is energized the contacts **14** are opened to remove the high voltage source **12** from the load **10**.

The arcs are thereby extinguished whereup the relay energization circuit is reopened to restore it to its passive condition. The relay includes a mechanical latch, not shown, for latching the same in the open position. The relay contacts **14** are reclosed upon resetting of the mechanical latching mechanism to restore the voltage to the load. Of course, the cause of the overvoltage is eliminated before resetting. Mechanical latching relay mechanisms are well known and require no additional description.

Compared to the well-known crowbar system, the arrangement of this invention is simple and inexpensive. Also, the apparatus of this invention has a higher current capacity than many other prior art spark gap arrangements since the relay control winding is not included in series with the load to limit the load current. In addition, because of the potential difference between the intermediate and grounded spherical electrodes **24** and **22** provided by the relay energization source **40**, more accurate gap spacing is possible since the spacing must be increased to offset the electric field effect of the source **40**. The greater spacing improves the accuracy of adjustment.

The rapid response of the arrangement is illustrated in FIGURE 3 wherein there is shown a graph of arc current versus time. Time zero designates the time at which the predetermined overvoltage occurs to initiate breakdown of the spark gaps. (As noted above, the predetermined overvoltage is less than the breakdown voltage of the insulation of the load.) The relay **16** is energized within approximately 200 milliseconds from the time of the occurrence of the predetermined overvoltage for removal of the load **10** from the high voltage source **12**. The response time of prior art spark gap type protective systems is much greater. The apparatus is suitable for use with a wide range of current levels of say from 1 to 100,000 amperes, no current value being shown on the graph.

The invention having been described in detail in accordance with the requirments of the patent statutes, various changes and modifications may suggest themselves to those skilled in this art. For example, the spherical electrodes may be located in a chamber of controlled atmosphere, including a partial vacuum, if desired. Also, as suggested above, the apparatus may be used with power generation and distribution equipment, which is presently protected from voltage surges by over-insulating. Installation of this apparatus on such equipment would eliminate the need for the excess insulation thereby resulting in cost savings and/or size reduction.

I claim:

1. A protective arrangement for a load connected to a voltage source through contacts of a relay, which relay includes a control winding, said arrangement comprising:
- a pair of spaced electrodes connected across said load,
- a third electrode intermediate said pair of electrodes a spaced distance therefrom to form a first gap between one of the pair of spaced electrodes and the third electrode and a second gap between the third electrode and the other of the pair of spaced electrodes, and
- a circuit comprising said relay control winding and a relay energization source in shunt with the second gap, the conduction and nonconduction of the circuit being controlled by arcing and nonarcing conditions of the second gap.

2. The protective arrangement as defined in claim **1** wherein said relay control winding and relay energization source are connected in series circuit for completion of the circuit through said second gap upon breakdown of the gap.

3. The protective arrangement as defined in claim **2** wherein said circuit includes a choke coil in series with the relay control winding and relay energization source for substantially simultaneous breakdown of the first and second gaps when the voltage source reaches a predetermined voltage level.

4. The protective arrangement as defined in claim 1 including means for movably mounting said third electrode for adjustment of the spacing of the first gap while maintaining a substantially constant spacing of the second gap.

5. The protective arrangement as defined in claim 1 wherein the voltage source is adapted to provide a relatively constant current to the load.

6. The protective arrangement as defined in claim 5 wherein the load comprises an arc device adapted to operate with an arc.

7. In a spark gap type protective circuit which includes a pair of spaced electrodes and a third electrode intermediate said pair of electrodes,

means for mounting said pair of electrodes a spaced distance apart,

means for mounting said third electrode intermediate said pair of electrodes a spaced distance therefrom to provide first and second gaps between the third electrode and the pair of electrodes,

said means for mounting the third electrode including means for adjustably positioning said third electrode for adjustment of the length of the first gap while maintaining the length of the second gap substantially constant.

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