June 5, 1951 R. G. GEHLSEN ET AL 2,555,689

SPARK LIMITING CONTROL CIRCUITS

Filed May 15, 1947 2 Sheets-Sheet 1

FIG. 1.

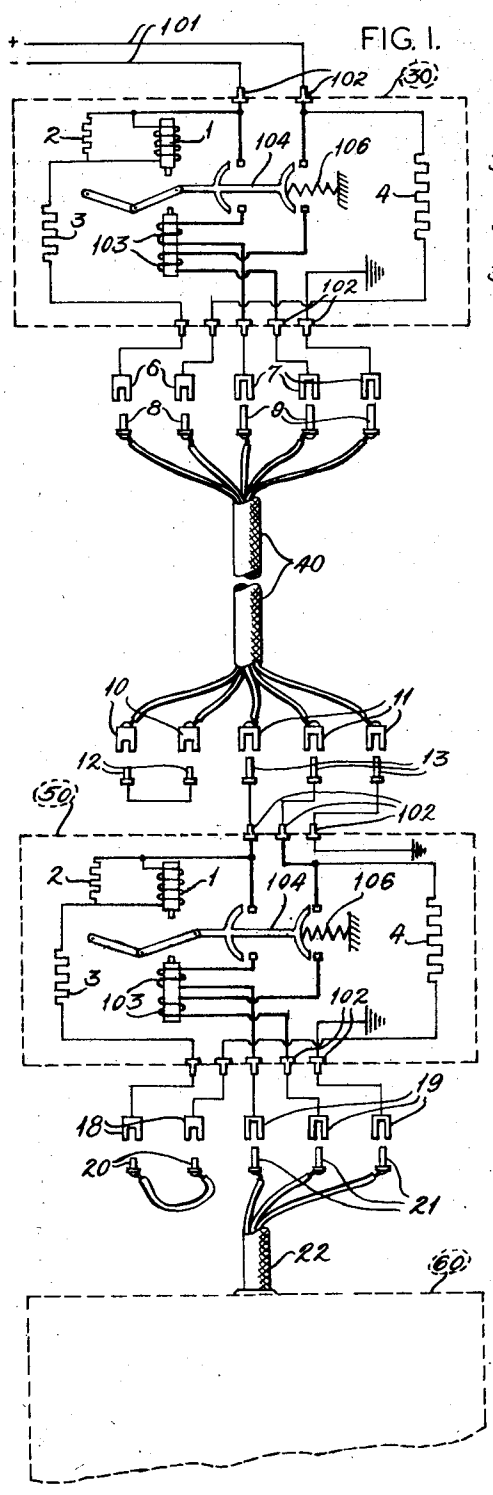
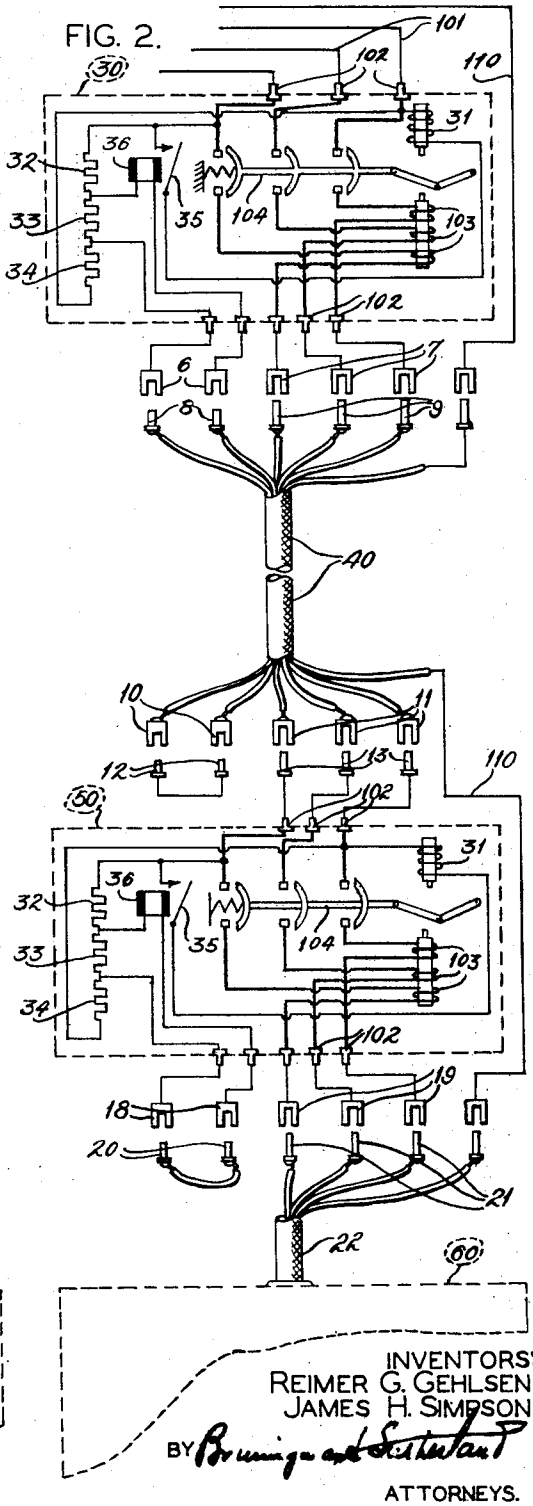


FIG. 2.



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FIG. 3.

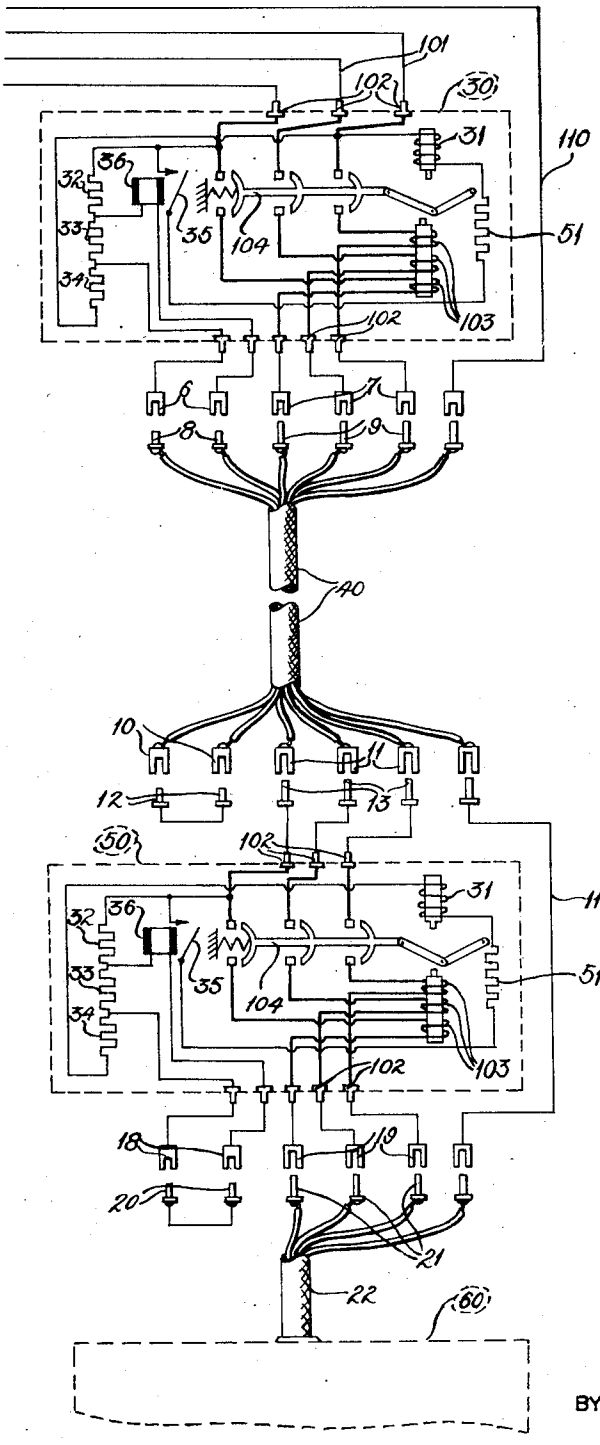


FIG. 4.

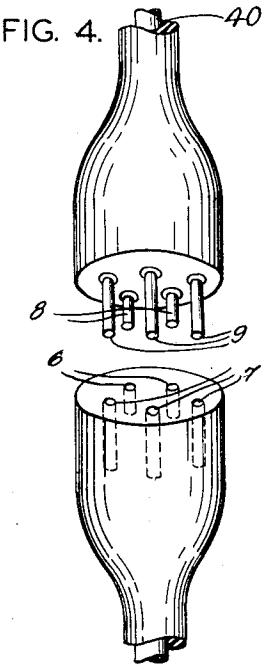
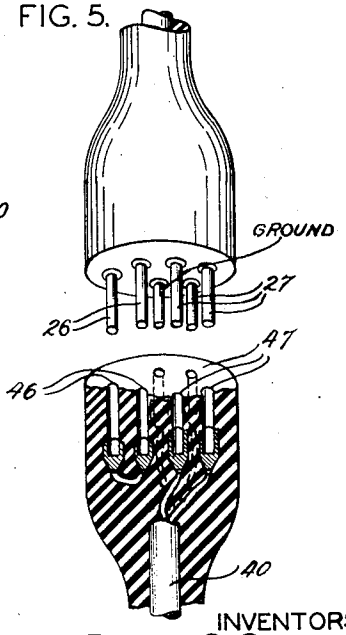


FIG. 5.



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SPARK LIMITING CONTROL CIRCUITS

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Application May 15, 1947, Serial No. 748,308

3 Claims. (Cl. 175—294)

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This invention relates to an electrical mine feeder circuit for preventing incendiary arcing or sparking at electrical terminals or circuit breaks in mines. More particularly, it relates to an arrangement of electrical parts in a power-feeder system whereby a power delivery circuit, a superimposed secondary or control circuit, and the electrical connectors from such circuits to electrically-powered machinery all cooperate to eliminate incendiary electrical sparks at any make and break contact points in the system, and under all conditions of operation.

The difficult conditions under which mining operations are conducted make mining hazardous. Roof-falls, the presence of explosive air, mine-gas mixtures, combustible dust-air mixtures, moisture, the necessity of using high-powered equipment in cramped quarters, these and many other factors, obviate normal safety precautions, and fatal disasters are not uncommon. Electrical circuits are charged with having caused more than forty percent of the mine accidents occurring throughout the past twenty years. Peculiarly, despite the myriad safety features hitherto made part of such circuits, the percent relationship of accidents referred to has remained unchanged in comparison to other causes. Electrical arc or spark at circuit connections often ignites explosive mine gas mixtures and has proven difficult to control.

The United States Bureau of Mines conducts rigid tests directed to determining the arc or spark formed at circuit breaks, and its effect upon explosive gas-dust mixtures. An incendiary spark or arc, in view of these tests, can be defined as one which will produce an arc temperature of 650° F. or higher, or one which is sufficient to ignite a 5 to 10% methane-content, air mixture. An electrical circuit incorporating many separate parts must fail to produce such a spark over extended periods during which the circuit is rapidly made and broken under maximum conditions of load. Manufacturers of the separate electrical parts subjected to successful test receive a letter of suitability from the Bureau of Mines permitting their product to be sold for use in mines and such parts are thereafter called "permissible" or "approved" parts.

While physical tests with particular equipment under conditions approximating those to be found is a gaseous mine are, perhaps, the best means of gaining insight into arc or spark tendency in electrical equipment, since the variables attending that phenomena are many and more or less impractical of reduction to empirical formula,

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such tests do have the failing that due to the number of separate manufacturers, and the variety of "permissible" equipment available, it is seldom that the intrinsic safety of an entire electrical circuit as utilized in a mine is established.

An object of this invention is to provide a control circuit for an electrical feeder system which will operate to break the power circuit when the voltage falls below a predetermined minimum without producing an incendiary spark at any point between the power source and electrically operated machinery.

A second object of this invention is to provide an electrical control circuit for a mine feeder circuit so balanced electrically that the potential and current relationship at all points in that circuit is such as to fail to cause an arc sufficient to ignite an explosive air, methane-gas mixture when the circuit connections are made and broken.

Another object of this invention is to provide a control circuit for a mine feeder circuit which fulfills Bureau of Mines Standards of Operation and which even in the event of accidental crushing, mangling, severing or otherwise disrupting the power line circuit between the power source and the mining machinery will measurably reduce the usual instantaneous arc or spark when cable connections are so severed and prevent the ignition of explosive mine gas, air mixtures in contact with such broken connection.

Another object is to provide a control circuit for an electrical feeder circuit so intrinsically safe as to obviate the necessity for precautions in joining and separating feeder line connectors or even the necessity for a fuse.

A further object of this invention is to so combine a number of Bureau of Mines "permissible" parts so as to extend electrical feeder lines through a series of portable switch boxes and power cables to a point adjacent a mine machine so that making and breaking the circuit at any point along the feeder line from the stationary source of power connection to the equipment will be protected against the occurrence of an incendiary spark.

Other objects will be apparent from the detail description given in connection with the accompanying drawings in which:

Figure 1 is a schematic drawing of a mine feeder circuit embodying this invention, as applied to a direct current power source;

Figures 2 and 3 are schematic drawings of a mine feeder circuit embodying this invention,

adapted to a three-phase, alternating current source of power;

Figure 4 is a perspective drawing of a cable connector of the circuits embodying this invention.

Figure 5 is another modification in partial section of another cable connector of the circuits embodying this invention.

While as hereinbefore set forth, the accomplishment of the invention, even without certain usual protective minutiae, viz., fuses, is possible; such additional safety factors can be and usually are incorporated in the circuit described. The present invention is not to be limited in the conjunctive use of other safety devices, nor is it to be limited to the specific circuits described, but is properly to include such modifications and adaptations thereto consonant with this specification and within the scope of the appended claims.

Referring to Figure 1, a direct current power source (not shown) is permanently connected through mains 101 to terminals 102 of a switch housing 30. Switch housing 30, an explosion resisting box (indicated in dotted outline), is preferably permanently located on the exterior of the mine but may be portable. The load side of the box 30 is provided with a separable cable connector, which may be of the type shown in Figure 4, but in Figure 1 is shown diagrammatically as a pair of female connector sockets 6, and a series of female connector sockets 7. A cable 40 having a complemental cable connector (shown diagrammatically as male prongs 8 and 9) extends from switch box 30 into the mine. Cable 40 may be composed of a plurality of lengths of cable joined at their ends by separable connectors of the character utilized adjacent switch box 30.

At a remote point from switch box 30, cable 40 terminates in a separable connection diagrammatically shown as consisting of a pair of sockets 10 and a series of sockets 11 connected to correspond respectively with sockets 6 and 7 adjacent the switch box 30. If the overall length of cable 40 is great, another switch box 50 (which may be substantially identical with switch box 30 save that it is preferably portable) is connected to terminals 11. Such connection is again accomplished by a separable connector of the type shown in Figure 4, the prongs 13 mating with sockets 11. On the load side of box 50 another separable connector is provided, sockets 18 and 19 corresponding respectively to sockets 6 and 7 adjacent box 30. Beyond box 50 a load 60, which may be a loader, conveyor, drill or other electrical machine, is connected through cable 22 which terminates in prongs 21 for mating with sockets 19. Again the connection is accomplished with a separable connector of the type shown in Figure 4.

Since the plug connectors utilized at both ends of cable 40 and at both sides of box 50 are interchangeable, it will be apparent that, if desired, cable 22 of mine machine 60, can be plugged directly into the complementary female socket 6—7, or into the complementary female socket 10—11 of power cable 40, rather than into female connection 18—19 as shown. The diagram indicates a typical arrangement of the usual plurality of feeder circuit extension parts, which advance a power outlet to a point adjacent the powered machinery in a mine. Power cable 40 might equally well be shown between housing 50, and machine 60, since its function is merely to advance the position of terminals 6—7 toward the machine 60.

The separable connectors utilized at the several stations may of course be of any suitable type provided they are interchangeable. In the form shown in Figure 4, the female sockets 6 and 7 are embedded in an insulating body such as rubber. Likewise the male prongs 8 and 9 are embedded in an insulating body. The prongs 9 are intentionally longer than prongs 8 and sockets 7 are intentionally deeper than sockets 6. The conductors attached to the long prongs 9 and deep sockets 7 constitute the power circuit while the short prongs 8 and shallow sockets 6 are in a control circuit. This arrangement assures that the power connections always to be engaged prior to the making of the control contact, and for the control circuit to be broken before the power circuit is broken.

The control circuit prongs 12 of the separable connector on the source side of switch box 50, as well as the corresponding prongs 20 immediately in advance of machine 60, are however connected together. Thereby when these prongs are engaged with any of the control sockets 6, 10 or 18, the control circuit immediately in advance thereof is activated.

Within the switch housing 30 there is provided a manually operable, trip-fee-of-the-handle, circuit breaker 104 having both a low-voltage and an overload trip mechanism (not shown) of any conventional type. The low-voltage trip is actuated by a coil 1 and the overload trip is actuated by either of coils 103 (of which there is one in each leg of the power circuit). The circuit breaker 104 is biased to its open circuit position by a spring 105 and is thus adapted to interrupt the power circuit upon the occurrence of either an overload or a low- or no-voltage condition. Said circuit breaker is movable to closed circuit position, however, only by a trip-free handle located on the exterior of switch box 30, but not shown.

The circuit through the low-voltage trip-coil 1 is herein denominated the control circuit and, under normal conditions, is energized whether circuit breaker 104 is open or closed. The control circuit extends from the negative main 101, through coil 1, which is paralleled by a resistor 2, thence through a resistor 3 connected in series, to the socket 6, from whence the control circuit extends through so much of the control conductor as may lie between the socket 6 and a station, such as 12, whereat the control conductors in the cable 40 are electrically connected together. From the opposite socket 6, the control circuit extends through a series resistor 4 and back to the positive power main. Energization of the control circuit, including coil 1, is thus impossible save when the sockets 6 are electrically connected, either immediately or remotely.

A feature of particular importance to the present invention is the provision of a resistor in shunt relation to the coil 1. The resistor 2, thus connected, is of a relatively high order of resistance magnitude, being sufficient to absorb and dissipate the power resulting from the self-induced electromotive force in coil 1 upon interruption of the control circuit.

The invention is also characterized by a division of the total resistance in the control circuit, so as to substantially balance the total resistance in that leg of the control circuit which extends between the negative main and the socket 6 with the total resistance in the other leg

which extends between the positive leg and the socket 6. This dictates that the resistance of resistor 4 be substantially equal to the resistance of resistor 3 plus the resistance of the parallel bank consisting of resistor 2 and coil 1. With such balancing of the resistances between the two legs of the control circuit and properly proportioning them, an accidental short-circuiting of one of the legs thereof to the power main of opposite polarity will not create an arc having incendiary properties.

Insertion of the power cable connectors 9 into the complementary socket-connector 7 functions merely to extend a dead power circuit to the remote end of power cable 40 unless, at the time of insertion of connectors 9 into socket 7, the plug connections have already been made at a point therebeyond, as, for example, at the station where control sockets 10 are electrically interconnected through prongs 12.

When the interconnected prongs 12 engage the control sockets 10, however, the control circuit through coil 1 is completed and circuit breaker 104 may be moved to its closed circuit position, thus energizing the power conductors through cable 40. The latter cannot occur, however, until after prongs 13 are engaged with sockets 11 due to the differential in length between the power and control connectors, as described hereinbefore. With the connectors 6, 7, 8, and 9, as well as connectors 10, 11, 12, and 13, engaged, power is available as far as switch housing 50, but the circuit is not complete through switch housing 50.

The mechanism contained within switch housing 50 is identical in all substantial respects with the mechanism contained within switch housing 30 and consequently corresponding reference characters are applied thereto.

In identical manner, upon insertion of machine cable male plug 20—21, which places a short across the control circuit connector plugs 18 in the female socket connector of housing 50, coil 1 of housing 50 is energized, and upon the manual closing of the circuit breaker in housing 50 thereafter maintains the feeder circuit closed in this part of the circuit chain.

In operation, in the event of severed control wires between housing 30 and housing 50, coil 1 of box 30 will be de-energized and switch 104 will open. The spark or arc which may occur upon such interruption of the power circuit will be confined within the explosion resisting housing 30. Breaking a connection, as for instance, by separating the connectors 10—11 from 12—13, will break the control circuit in switch box 30 in advance of the separation of the power circuit connections, since they are still engaged when the control circuit is broken. The arc developed upon separation of the control circuit connections is minimized and maintained below incendiary proportions by the voltage current relationship in the control circuit which, as is described below, and by the absorption of induced E. M. F. in shunt resistor 2. An undervoltage condition between housing 50 and mine machine 60 will break the power circuit in 50 in manner identical to that just described.

Referring now particularly to Figures 2 and 3 which illustrate the circuits of this invention as adapted to alternating current power sources, like reference characters denote parts corresponding to the several parts of the circuit shown in Figure 1. In Figures 2 and 3 the circuit through the no-voltage release coil 31 of the circuit breaker 104 is separate from but controlled by the control circuit which extends through connectors 6—8 and 10—12. In Figure 2 the full line voltage, for example, 220 volts, is applied across the no-voltage release coil 31, but the circuit thereto is controlled by a relay 35 having a coil 36. The voltage impressed upon the relay coil 36 is reduced below line voltage by the provision of series resistors 32 and 34, one in each leg of the control circuit through relay coil 36. A non-induction resistor 33 parallels relay coil 36 and functions to markedly reduce the voltage across the circuit (including connectors 6—8) to coil 36 by increasing the current flow through resistors 32 and 34 with consequent increase in the voltage drop across the latter. The connector function of making and breaking the control circuit, respectively, after and before the power circuit connections are made and broken is identical in this circuit with that described above in connection with the direct current circuit of Figure 1.

A ground connection 110 is shown in Figures 2 and 3 by passing the housings 30 and 50. It will be readily understood that such a connection can be either through or around the breaker boxes as choice may dictate. As shown, the connecting cables of the various parts incorporate this ground wire 110 as well as the power and control circuit connections.

When the line voltages are higher than 220 volts A. C., it is desirable to interpose a resistor 51 in series with the undervoltage release coil 31, as shown in Figure 3. Otherwise the circuit shown in Figure 3 is identical in all substantial respects with that shown in Figure 2.

Figure 5 illustrates a modification of the plug-socket connectors for closing the control and feeder circuits embodying this invention. It will be readily apparent that the function of the short plugs of Figure 4 in making and breaking the control circuit after and before the feeder circuit connections are made and broken is accomplished in this instance by making the control and feeder circuit terminals 26 and 27, respectively, of the same length but varying the socket contact depths in the female connector so that the male pins of the power terminals make contact on insertion into the female connector at 47 before the control pins make their contact at 46. Other modifications accomplishing the same purpose are possible and the connectors may be of any suitable design or type. The female plug of Fig. 5, in section, illustrates the manner in which the control circuit connections are shorted together in one of the connectors to close the release coil circuit within housings 30 and 50, as is the case at 12 and 20 of Figures 1, 2 and 3. Cable connectors of the character shown in Figures 4 and 5 are constituted of two separable mounting parts, each of which mounts one member of the several pairs of contacts (one pair for each conductor in the cable) so that the individual contacts concomitantly approach toward and recede from their companion contacts. As shown in Figures 4 and 5, the separable mounting parts are released from each other; when they are initially brought together so that prongs 9 make physical engagement with sockets 7 (while prongs 8 are free of sockets 6), the separable mounting parts are in partially coupled position; and when the separable mounting parts are moved completely together, all pairs of contacts have engaged and the parts are in coupled position. Connectors of the type shown in Figures 4 and 5 are

desirable, since by this means the limitation placed on mine circuits by the United States Bureau of Mines Schedule 2E of February 15, 1945, which specifies in principle "that a power connector or connection shall not be broken while alive," is met.

The electrical elements described in the control circuits of Figures 1, 2 and 3 are so grouped as to successfully operate the undervoltage release mechanism, while at the same time the current in the control circuits is limited to a minimum which fails to produce an incendiary spark at the exposed connectors when the connectors are joined and separated. Different line voltages require the resistances of the operating parts to be varied and the following examples illustrate the specific groupings of such parts adapted to particular alternating and direct current line voltages. The examples are all explanatory of the circuits in housing **30** of Figures 1, 2 and 3, it being understood that the line connections to housing **50** as shown, cause no appreciable variation in the operation of the second control circuit, and the permissible parts included therein have the same characteristics as their counterparts in housing **30**.

Example 1

With a power source furnishing 250 volts D. C. and tested at 300 volts, the permissible parts of Figure 1 demonstrated to limit the current in the control circuit to prevent incendiary sparking at the connectors possessed the following resistance characteristics: coil **1**, 1840 ohms maximum to 1660 ohms minimum; shunt resistor tube **2**, 5000 ohms plus or minus 10%; series resistor tube **3**, 2500 ohms plus or minus 1%, and series resistor tube **4**, 3000 ohms plus or minus 1%.

In the arrangement of parts, 29 volts across coil **1** successfully operated the undervoltage release mechanism to hold the circuit closed after manual setting. The current in the control circuit was about 44 milliamperes.

Resistor tube **4** can be omitted from this control circuit, in which case, however, resistor tube **3** must have at least a minimum resistance of 2447 ohms, a figure below which incendiary arcing at connectors may develop.

Making and breaking this circuit consistently failed to develop an incendiary spark, i. e. one capable of igniting an 8.6% methane in air, gas mixture at the connectors.

Example 2

With a power source for furnishing 250 volts D. C. tested at 300 volts and substituting an undervoltage release mechanism whose coil **1** had a rated resistance of 1000 ohms the resistance characteristics of the other permissible parts in the circuit of Figure 1 were: resistor tube **2**, 5000 ohms plus or minus 1%; resistor tube **3**, never less than 2930 ohms when resistor tube **4** is omitted, a condition generally satisfied when resistor tube **4** is or is not included in the circuit by using a resistor tube with a manufacturer's rating of 3000 ohms plus or minus 1%; resistor tube **4**, 3000 ohms plus or minus 1% but variable to suit circuit requirements although in no instance, when incorporated in the circuit, ought it to be less than 2000 ohms..

In this arrangement of parts, 21 volts across coil **1** successfully operated the breaker, the current in the control circuit being about 44 milliamperes with tube **4** included. With or without tube **4** this proved to be an intrinsically safe control circuit, preventing incendiary spark.

Example 3

With a power source nominally furnishing 550 volts D. C., but tested at 600 volts, the release mechanism of Example 1 having a coil **1** resistance of 1840 ohms maximum and 1660 ohms minimum, manufacturer's rating, required permissible parts in circuit as shown in Figure 1 with the following resistance characteristics: shunt resistor tube **2**, 20,000 ohms plus or minus 10%; resistor tube **3**, 10,000 ohms plus or minus 1% and never less than the rated minimum when resistor tube **4** is omitted from the circuit; resistor tube **4** is somewhat variable to suit the line requirements, but a tube capable of offering 10,000 ohms plus or minus 1% is preferred.

In this circuit the resistance values were based upon 27 volts for successful operation or closing of the circuit breaker, and the current in the control circuit limiting the formation of incendiary spark was 27.9 milliamperes.

Example 4

Adapting the release mechanism of Example 2 to a control circuit or a feeder line furnishing a nominal 550 volts D. C. and tested at 600 volts, i. e. adapting the breaker requiring 21 volts across coil **1** for successfully closing the breaker across the line, the coil **1** having a resistance of 1000 ohms (manufacturer's rating), required resistance characteristics in the other permissible parts of Figure 1, as follows: shunt resistor tube **2**, 20,000 ohms plus or minus 10%; resistor tube **3**, 9000 ohms plus or minus 1%, but never less than 8760 ohms if resistor tube **4** is omitted, a limitation normally met by a tube with a manufacturer's rating of 9000 ohms plus or minus 1%; resistor tube **4**, 10,000 ohms plus or minus 1% and not less than the 9900 ohms minimum.

These permissible parts prevented incendiary sparking at connectors; the current in the control circuit with resistor **4** included in the circuit is 20.7 milliamperes.

Example 5

In the alternating current circuits of Figure 2 with a power source furnishing 220 volts, three phase, 60 cycle, A. C., the resistance characteristics of the incorporated permissible parts preventing incendiary sparking were: undervoltage release coil **31**, 661.5 ohms maximum and 598.5 ohms minimum; resistor tube **32**, 2500 ohms plus or minus 1%; resistor tube **33**, 5000 ohms plus or minus 1%; resistor tube **34**, 2500 ohms plus or minus 1%; relay coil **36**, approximately 3510 ohms, all resistances being manufacturer's tested rating and tolerance.

Relay coil **36** was a rated 115 volts A. C. 60 cycles coil with a dropout of 50% and a pickup of 65% of that operating voltage. Contacts **35** on dropout and pickup are adjustable, however, by simply changing tension of the usual spring. Release coil **31** had a coil voltage of approximately 105 volts on dropout and a coil voltage pickup of approximately 130 volts.

With this arrangement of parts the relay coil operated successfully, closing its contact **35** to complete the circuit of coil **31** with 4.7 milliamperes in coil **36**, a limited current incapable of producing an incendiary spark at the complementary, circuit-completing connectors when those contacts were made and broken. With 226 v. A. C. 60 cycles across coil **31** in series with

16,000 ohms resistance **51**, the current was 9.3 milliamperes and non-incendiary. By lowering resistance **51** to 13,000 ohms the circuit was incendiary.

Example 6

With a power source furnishing 440 volt, 3 phase, 60 cycle A. C. the permissible parts necessary to make this an intrinsically safe feeder circuit had the following resistance characteristics: release coil **31**, 661.5 ohms maximum and 598.5 ohms minimum rated resistance; relay coil **36**, 3510 ohms; resistor tube **32**, 7500 ohms plus or minus 1%; resistor tube **33**, 5000 ohms plus or minus 1%; resistor tube **34**, 7500 ohms plus or minus 1%; resistor tube **51**, 12,000 ohms plus or minus 1%.

The line voltage of the release coil and resistance **51** on dropout was approximately 250 volts and the line voltage on pickup was approximately 280 volts. The relay coil was identical with that used in Example 5, being a 115 volt A. C. coil with a dropout and a pickup of approximately 50% and 65%, respectively. As in Example 5, the dropout and pickup can be varied by changing the tension in spring **37**.

In this arrangement of parts no incendiary spark was created over long periods of testing at any connector in the feeder system when the circuits were made and broken. The current in the relay circuit was approximately **4.7** milliamperes and it was found that it was possible to vary the tube resistances to increase the current to about 6.2 milliamperes without creating incendiary spark at the connectors. In this range of currents shorting right control circuit wire **6** in Figure 3 across left feeder circuit line **7** did not create an incendiary spark. Shorting left **6** across right **7**, likewise, did not create an incendiary spark. Currents in excess of 6.2 milliamperes, however, failed in this test.

While the rated resistance of the permissible parts incorporated in the control circuits of the examples are variable within certain limits, the tolerances are such that if the maximum rated value of each manufactured part is in fact present that the additive sum will still fall within a proper operating range to control spark at the connectors. This also holds if each part were the minimum in manufacturer's rating. It will be readily understood that where such variables exist, and where the amount of arc or spark is also controlled by additional variables, such as the shape of the points at the arc, the length of time it takes to break the connection, the distance across the gap and other factors, that the building of an empirical formula must have little meaning. The examples demonstrate that it is possible to perfect control circuits which fully meet the Bureau of Mines Tests for incendiary spark and which will be intrinsically safe circuits.

In general, we have found, however, that there is a range of current in the control circuits described which varies from a minimum necessary to operate the undervoltage release, to a maximum allowable value beyond which spark or arc at make and break contacts will ignite explosive gas-mixtures. For instance, in a 250 to 300 volt D. C. circuit, a non-inductive control circuit will operate successfully, i. e., without producing an incendiary spark at the connectors in making and breaking the circuit, with less than 125 milliamperes. 125 milliamperes in such circuit is a critical figure, or approximate maximum value beyond which incendiary sparking occurs. In a partially inductive control circuit, such as that shown in Figure 1 and with the same line voltage, 80 milliamperes is an approximate maximum beyond which incendiary sparking will occur. Currents less than 80 milliamperes down to a minimum amperage necessary to operate the undervoltage release mechanism are intrinsically safe, preventing incendiary arc across the connectors when the connections are made and broken.

In a 500 to 600 volt D. C. circuit a non-inductive control circuit will operate successfully and without producing an incendiary spark at make and break contact connections in the circuit with 60.6 milliamperes. Increasing the current a few milliamperes may not result in successful operation. With the same line voltage a partially inductive control circuit (Figure 1) operates successfully with 62 milliamperes and fails when the current is increased to about 70 milliamperes. The critical current in each of these circuits, inductive and non-inductive, lies in the range from about 62 milliamperes to 70 milliamperes.

In a 115 volt, 60 cycle, A. C., power line, a control circuit, such as that of Example 5, will operate successfully, as has been said, with currents ranging from 6.2 milliamperes to 4.7 milliamperes, the latter being preferred, whereas with a current of approximately 10 to 11 milliamperes this circuit fails and will sometimes produce an incendiary spark capable of igniting explosive gas-mixtures. The critical operating current here apparently lies somewhere in the range of about 9.3 milliamperes to 10 or 11 milliamperes.

Having thus described the invention, what is claimed and desired to be secured by Letters Patent is:

1. In a power distribution system having a switch-gear enclosure including a power circuit switch and a control means therefor, a pair of control circuit contacts on the exterior of the enclosure connected respectively to opposite legs of a control circuit source, said control means being interposed in the electrical circuit between one of said contacts and the control circuit source, resistors in each of the circuits between the respective control contacts and the control circuit source, other contacts on the exterior of the enclosure connected to the power circuit behind the switch, a cable containing power conductors and control conductors, said cable being connected with said contacts and terminating in like contacts at a remote point, and means for electrically connecting the control conductors at such remote point, the total resistance of each leg of the control circuit being of such magnitude as to inhibit arcs of incendiary proportions in the event that full line voltage be impressed on either leg separately.

2. The combination of claim 1 wherein the control means includes a coil energizable only when the control conductors are electrically joined, and in which said coil is shunted by a resistance of magnitude sufficient to inhibit arcs of incendiary proportions when the control conductors are separated.

3. In a system for controlling the energization of a power circuit leading from a switch within an enclosure to a remote electrical apparatus, and wherein the position of the switch is governed by a control circuit including a coil, said control circuit being connected to a power source ahead of said switch and having a portion extending on the exterior of said enclosure for a sub-

stantial distance in a jointed cable with the power circuit, the joints in said cable being arranged so that upon coupling and uncoupling thereat the power circuit makes before and breaks after the control circuit whereby upon uncoupling the joint the breaking of the control circuit thereat opens the switch within the enclosure; the improvement which comprises: a non-inductive resistance connected in series with both said coil and said portion of the control circuit which extends in the cable on the exterior of the enclosure, said resistance being located within the enclosure, the portion of said control circuit which extends in the cable consisting of two conductors, said non-inductive resistance being divided, part being connected in series between one of said conductors and source, and part being connected between the other of said conductors and source, each divided part of said resistance being of such magnitude as to inhibit arcs of incendiary proportions in the event that full-line voltage be impressed upon either conductor separately, and said resistance having a magnitude such that the current in said control circuit is insufficient to create an incendiary arc when said control circuit is broken at a joint in the cable.

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JAMES H. SIMPSON.

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