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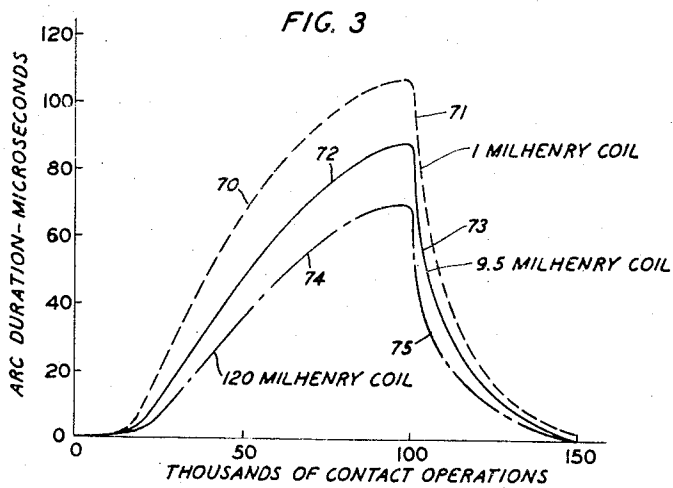
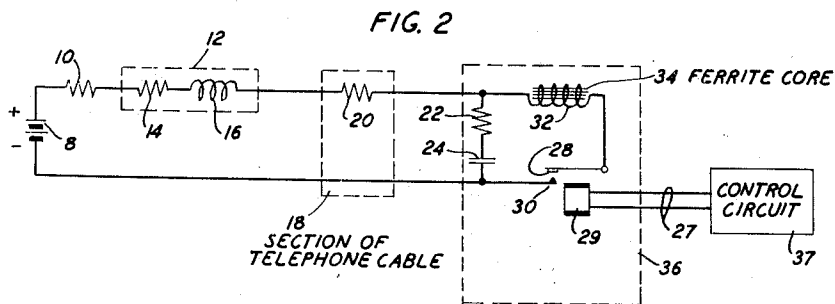
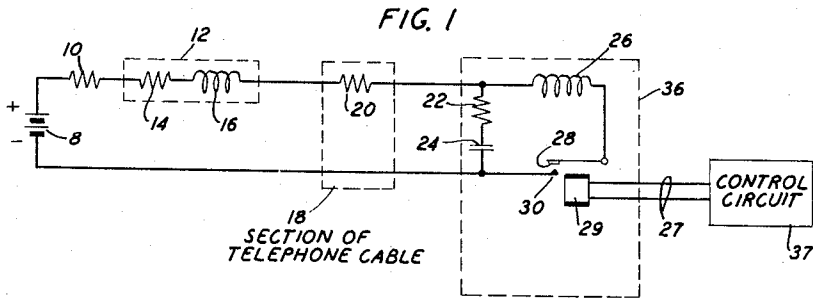
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PROTECTION CIRCUITS FOR ACTIVATED CONTACTS

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## PROTECTION CIRCUITS FOR ACTIVATED CONTACTS

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This invention relates to the protection of the switching contacts of communication, signaling and/or control switching devices such as relays, circuit selecting switches and the like, employed in circuits in which the current in the circuit being closed or opened is normally less than an ampere. A large current for such circuits is, for example, one in the order of eight-tenths ampere.

More particularly, this invention relates to the protection of switching contacts of the above types that must operate in the presence of organic vapors such as those which emanate from numerous types of paints, lubricants and the newer insulating materials such as cellulose acetate, phenol fiber and the like, being widely used in the manufacture of relays and similar switching devices. When said contacts are operated to open and/or close current carrying circuits in the presence of even relatively small concentrations of the organic vapors above mentioned, a film of organic material forms on the contact surfaces and the contact surfaces contaminated by such a film are then characterized by those skilled in the art as being "activated."

The invention further relates to a convenient method and apparatus for cleaning contacts which have become "activated" or contaminated as a result of operation in the presence of the above mentioned organic vapors, or contaminated from other causes.

The phenomenon of "activation" has, for example, been observed to take place when such contacts have been operated in the presence of the organic vapors where the pressure of the organic vapors was only five-thousandths millimeter of mercury.

The public telephone facilities of the United States probably include in the neighborhood of a million switching devices, many of which devices each employ several pairs of switching contacts.

The various pairs of contacts may be assigned various functions. For example, a particular pair of contacts may serve to both open (or "break") and to close (or "make") a current carrying circuit, or it may be assigned to "make" only, or to "break" only, the current carrying circuit, a second pair of contacts being provided to "break" or "make" the circuit, respectively, so that the first pair of contacts can perform one or the other of its operations while no current is flowing in the circuit. Still other contacts may perform both of their respective operations while no current flows in the circuit. This last mentioned situation is known in the art as "dry" operation and involves other considerations than those of immediate interest in connection with the present invention. See, for example, the copending application of T. F. Egan, Serial No. 413,633 filed March 2, 1954 and assigned to applicant's assignee. This application matured into Patent 2,812,406 granted November 5, 1957. The "brown powder" deposit reported by Egan as occurring on contacts of the platinum group of metals used in "dry" circuits is distinctly different from the film of organic material causing the form of contamination designated "activation" of contacts used in "wet" or current carry-

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ing circuits with which the present invention is concerned. Accordingly, the two types of deposits should not be confused. It should be understood, however, that the phenomenon of glow discharge to be described below will also clean contact surfaces upon which a "brown powder" deposit has been formed.

The normal currents in telephone switching circuits will range in amplitude between one-tenth and eight-tenths ampere. The "average" current in such circuits can, in general, be assumed to be in the order of one half ampere.

To insure long periods of reliable service and to keep maintenance charges within reasonable bounds, it is necessary, in the majority of cases, that each pair of contacts should be capable of operating a very large number of times without failure or fault. Many such contact pairs, for example, should have a normal "life" expectancy of several hundred million fault-free operations. For such service conditions it is, obviously, important that all phenomena involving any tendencies toward contact impairment should be most carefully analyzed. Likewise, remedial measures must be carefully gauged and controlled to produce precisely the required degree of compensation for the deleterious propensities of all such phenomena.

In addition to public telephone facilities, numerous other private and/or governmental communication, signaling, and/or electrical control circuits are being extensively used for which operating conditions closely paralleling those described above are encountered.

The "sparking," or discharge, across the gap which occurs at a pair of contacts when the contacts are separated to interrupt or "break" a current carrying circuit, may involve either or both of two phenomena which have been designated as "arcing" and "glow discharge," respectively.

Because of the phenomenon known in the art as "chatter," a pair of contacts is virtually certain to open and close a number of times for each occasion on which they perform either a "break" or a "make" operation.

An "arc," as distinguished from a "glow discharge," is a highly localized, "high current" discharge, requiring only a very modest voltage (under twenty volts for most metals). "Arcing," if sustained for any appreciable interval, results in "pitting," "mounding" (i. e., the formation of "pits" and "mounds" on the surfaces of the contacts) and serious erosion and impairment of the surfaces of the contacts. With clean contact surfaces and suitable prior art contact protecting arrangements, however, no appreciable sustained arcing will occur and consequently there will be no serious contact surface impairment as a result of "arcing" in switching circuits having clean contacts suitably protected by conventional contact protecting arrangements provided that the maximum current is less than one ampere.

A "glow discharge," on the other hand, is, as its name implies, diffused and is substantially uniformly distributed over the entire adjacent areas of the pair of contacts. It can take place where the current is very small, i. e., even as small as one-tenth ampere or less, but requires a minimum voltage of approximately 300 volts. Erosion of the contact surfaces resulting from a "glow discharge" of limited duration is normally uniform over the entire contact surfaces, particularly where it can, as will be described below, be readily controlled. If unduly prolonged "glow discharge" may produce a phenomenon known as "showering" which can result in serious erosion and pitting of the contact surfaces.

As is also pointed out above, the majority of communication circuits and large numbers of signaling and control circuits operate with currents of not more than eight-tenths of an ampere, so that, if the contact surfaces are clean and remain substantially clean under

their normal operating conditions, entirely satisfactory contact protection circuits can be devised to afford, in many instances, "life" expectancies of several hundred million fault-free operations.

During a period of several decades just passed, numerous and varied contact protecting circuits have been developed for meeting a like number and variety of specific operating conditions and many of such circuits effectively protect and suitably prolong the "life" of contacts operating under the specific respective operating conditions for which the circuits were designed. A typical conventional protection circuit, the use of which will be described more fully below, comprises the series combination of a resistor and a capacitance shunted directly across the contacts to be protected.

As indicated above, however, and particularly with the advent, during recent years, of the use, in telephone switching devices, of newer types of insulating materials such as cellulose acetate in coil windings and phenol fiber for winding-spool heads, a source of serious difficulty, namely a species of contamination by a film of organic material, which those skilled in the art have designated as "activation" of the surfaces of the contacts, has been encountered to an increasing degree, notwithstanding the fact that the newer insulating materials are in many respects very appreciably superior to those which they have replaced. Many types of paints, lubricants, and the like, have also been found to contribute seriously to the contamination by "activation" of contact surfaces.

This difficulty arises from the combination of the two facts that the newer types of insulating materials and the paints, lubricants, et cetera, give off organic vapors, and that it is deemed necessary to enclose the majority of these switching devices within dust-proof cabinets or closely fitting covers to shield the devices mechanically (particularly from airborne dust) and, in some instances, to afford shielding from electrical or magnetic interference with adjacent apparatus. In some instances, also, it is necessary to employ moisture-proof enclosures.

Such combinations of circumstances result in the early accumulation around the contacts of an appreciable amount of organic vapors and, following a relatively small number of contact operations, say fifty thousand or less) in the presence of these vapors, there develops a coating, or filming over, of the contact surfaces by organic material, which latter condition is designated by those skilled in the art as "activation" of the contacts.

With the degree of contamination resulting from "activation" which usually takes place it has been found that sustained arcing can occur at current values as low as fifty milliamperes, rather than only above the minimum value of one ampere normally required when the contacts are clean. The "pitting," "mounding" and erosion which results from this low-current arcing encountered across the "activated" contacts when breaking a current carrying circuit proves to be substantially as harmful as that caused by arcing at currents in excess of one ampere with clean contacts. The useful "life" of the contacts is thus very materially reduced.

This explains the fact that although a number of prior art contact protection arrangements have been found entirely effective to protect clean (or "inactive") contacts and to enable them to fulfill the requirement of several hundred million fault-free operations, if the contacts become "activated," as above described, the normally employed prior art contact protection arrangements appear to hasten, rather than to defer, the deterioration of the contacts. In many instances, for example, "activated" contacts, with conventional protecting arrangements, fail to function satisfactorily after a relatively small number of operations, such as fifty thousand or less operations.

A discovery upon which the operation of arrangements of the present invention depends is that the above described phenomenon known as "glow discharge" has a very definite tendency to "deactivate" or remove the film of organic material and thus to clean the surfaces of contacts which have become contaminated or "activated" as a result of being operated in an atmosphere which includes organic vapors of the types mentioned above. This discovery, of course, provides a basis for cleaning or "deactivating" the surfaces of contacts.

Another discovery of importance in connection with the contact protecting arrangements of the present invention is that, for contacts subjected continuously to the conditions which usually produce a harmful degree of contamination or "activation," the least erosion takes place if the contacts are maintained in a not quite completely "deactivated" (or clean) condition.

A principal object of the present invention is to eliminate the deleterious effects which result from the contamination or "activation," by organic vapors, of the contacts in communication switching devices.

A further object is to provide a method and means for cleaning and "deactivating" contact surfaces.

The contact protecting arrangements of the present invention are based upon the above mentioned discovery that where the contact surfaces of communication switching devices are operated under conditions tending to contaminate them, that is to produce the phenomenon known as "activation" (as also described above), a normal "life" expectancy of the contacts (several hundred million fault-free operations) can be achieved if at each operation the contact surfaces can be partially, but not quite completely cleaned of the organic film or "deactivated."

It has long been known that for current carrying circuits including an appreciable inductive component of impedance, the phenomenon known as "glow discharge" is likely to occur each time the contacts break the circuit. The duration of the glow discharge is approximately proportional to the current amplitude and the inductive component for the specific circuit being opened. Indeed, one objective in the use of the conventional resistance-capacitance contact protective circuit shunted across the contacts is to convert the impedance effective across the contacts into a virtually resistive impedance and thus eliminate the prolonged glow discharge which the very substantial inductive component, usually contributed by the winding of a switching device being actuated, would otherwise cause.

It should further be borne in mind that, as has been previously mentioned, in view of the phenomenon well known to those skilled in the art as "chatter," the large majority of contact pairs of communication switching devices actually open and close numerous times for each individual "make" or "break" operation. In view of this, if the circuit is "live" or "wet," i. e., if current flows or is interrupted depending upon whether the particular pair of contacts under consideration are closed or opened, there is an opportunity for numerous glow discharges to take place whether the particular operation is a "make" or a "break" operation. In general, for any specific circuit, the phenomenon of "glow discharge," if present, is very much more pronounced for a "break" than a "make" operation.

Since, as above described, it has been found that the phenomenon of "glow discharge" tends to clean or remove the film from "activated" contact surfaces, the problem here involved is that of causing an appropriate amount of "glow discharge" to effect the desired degree of contact cleaning or deactivation for each of the contemplated purposes of the invention.

If of sufficient duration the "glow discharge" will not only completely "deactivate" the contact surfaces but may also cause "showering" and serious erosion, which will tend to seriously diminish the number of fault-free

operations of which the particular pair of contacts is capable.

A specific problem sought to be solved in connection with contact protecting arrangements of the present invention is that of producing just an appropriate duration of glow discharge at each operation of any particular pair of contacts to effect a not quite complete "deactivation" of the contacts, since actual tests have indicated that a longer contact life can thus be realized where the contacts are to be operated under the conditions which tend to contaminate or "activate" them. From the standpoint of a particular circuit, under specified operating conditions such as normal or average current and "break only," "make only" or both "break" and "make" requirements for the particular pair of contacts, the problem usually resolves itself into the question of how much inductive reactance should be added closely adjacent to the contacts and in series therewith to produce a duration of "glow discharge" just sufficient to effect the desired, not quite complete, "deactivation" of the contacts at each operation. In the case of the majority of contaminated or "activated" contact conditions encountered in telephone switching circuits, a glow discharge duration in the order of one half microsecond has been found to produce excellent results.

Where the current in the particular circuit under consideration has a relatively small, substantially constant closed-circuit value, say two-tenths ampere, the desired glow-discharge-inducing inductive reactance can conveniently comprise a simple air core retardation coil of appropriate inductance value to produce a glow discharge having a duration of substantially one half microsecond.

For telephone switching circuits of the type which, for clean or deactivated contacts, operate satisfactorily with the conventional type of resistance-capacitance protective circuit shunted across the contacts, the glow discharge duration  $t_g$  may be found from the formula

$$t_g = \frac{L}{R} \left( 1 - \sqrt{1 - \frac{2RI_0}{V}} \right) \quad (1)$$

where  $L$  is the inductance in henries of the cleaning or deactivating coil placed immediately in series with the active contacts,  $R$  is the protective circuit resistance in ohms,  $I_0$  is the current in amperes, and  $V$  is the glow discharge voltage. Since glow discharge is a constant current density phenomenon the voltage  $V$  will be stabilized at substantially 300 volts. It is further assumed that the value of resistance  $R$  will lie between the quantity

$$\sqrt{\frac{L}{C}}$$

(where  $C$  is the capacity in microfarads of the protective circuit capacitance) and 300 ohms.

By way of a specific numerical example, if  $L$  is assumed to be one millihenry,  $R$  100 ohms, and  $C$  one half microfarad, the glow discharge duration  $t_g$  will be 1.6 microseconds. This is substantially three times too long for optimum results in the case of contacts which "break" the switching circuit and the value of  $L$  should therefore be reduced for such circuits to produce a duration  $t_g$  of substantially five-tenths microseconds. In a majority of telephone switching circuits in which the contacts break the switching circuit, a value of  $L$  between 100 and 200 microhenries has been found to produce optimum results.

Where the closed-circuit current in the particular circuit under consideration is relatively large, for example, from five-tenths to eight-tenths of an ampere, or is subject to amplitude variations over a wide range of values, the inductance or retardation coil provided to induce the desired degree of glow discharge is, in accordance with the principles of the invention, preferably a retardation coil having a core of initially high permeability

which, however, becomes saturated at a low value of current through the coil. Under such circumstances the coil should be designed so that the core will reach a condition of magnetic saturation at a predetermined low value of current in the circuit. A preferred material for the core of such a coil is, for example, a ferrite such as nickel-zinc ferrite.

Such a coil will, because of the high permeability of its core prior to becoming saturated, effectively "retard" the initial build-up of current upon closure, thus reducing difficulties resulting from the "chatter" of the contacts as well as producing the required glow discharge. Furthermore, as the core becomes saturated its effective inductance is reduced to a negligible value thus limiting the duration of the glow discharge to the time interval required to effect the desired degree of "deactivation" and avoiding the deleterious effects of a too prolonged glow discharge. Such a coil will operate satisfactorily over a sufficiently wide range of current values that only a few designs will suffice to cover substantially all telephone switching circuits. The necessity of providing a large number of different coil designs to include one for each current value of each particular circuit is thus avoided. Also, the use of a saturable core eliminates difficulties arising from the fact that the "chatter" openings during a "make" operation takes place while the current is building up so that an air-core coil of suitable inductance for the fully established circuit current may prove inadequate during the "chatter" openings.

In connection with the problem of cleaning or deactivating contact surfaces which have become activated to an objectionable degree, it will become apparent, during the course of the detailed description given hereunder of specific illustrative arrangements of the invention and of experiments conducted to discover the behavior of activated contact surfaces under particular conditions, that complete cleaning of the activating film from contact surfaces is merely a matter of subjecting them to a suitably controlled glow discharge cleaning process.

These and other features, objects and advantages of the arrangements of the present invention will become more readily apparent during the course of the following detailed description of preferred illustrative embodiments of the invention shown in the accompanying drawings and from the appended claims.

Fig. 1 illustrates in schematic diagram form a representative communication switching circuit modified in accordance with the principles of the present invention to avoid the deleterious effects resulting from the tendency of the contact surfaces to become contaminated or "activated."

Fig. 2 is a circuit of the type illustrated in Fig. 1 but in which the contact "cleaning" coil is provided with a core of initial high permeability, the core becoming saturated at a low value of current;

Fig. 3 shows curves of "arc duration in microseconds" versus "thousands of contact operations" for "activating" and "deactivating" cycles of three different pairs of contacts;

Fig. 4 illustrates curves showing contact erosion versus cleaning coil inductance  $L$ , for circuits of the types illustrated in Figs. 1 and 2; and

Fig. 5 illustrates a further type of circuit embodying the principles of the present invention.

In more detail, in Fig. 1 a common form of circuit employed in telephone systems, but equipped with a "cleaning" coil or inductance of the invention, is illustrated in schematic diagram form.

The circuit of Fig. 1 comprises the following: A battery 8, which has, in a typical case, a voltage of 48 volts; a current limiting resistance 10 having in a typical case a value of 90 ohms; a low resistance, high operating velocity, relay 12, the winding of which has, in a typical case, a resistance 14 of 16 ohms and an inductance 16

of approximately one henry; a section 18 of telephone cable which has, in a typical case, a substantially resistive impedance 20 of 100 ohms; a conventional resistance-capacitance contact protecting circuit, closely adjacent to and shunting the combination of cleaning coil 26 and contacts 28, 30, and comprising typically, in series relation, a resistance 22 of 100 ohms and a condenser 24 of five-tenths microfarad; a cleaning coil 26, connected immediately in series with contacts 28, 30, and comprising an air-core coil having an inductance of 100 microhenries or somewhat more, as will be explained in greater detail hereinafter; and a pair of contacts 28, 30, which upon closure complete a direct current circuit and cause current from battery 10 to operate relay 12 in conventional manner.

The contacts 28, 30, in turn, are a pair of relay contacts operated by a relay winding 29, which winding is connected by leads 27 to a control circuit 37, from which control circuit current to cause closure of contacts 28, 30, is furnished.

Contacts 28, 30, and their associated winding 29, are, further, within an enclosure 36, within which enclosure there may also be one or more other switching devices or other apparatus (not shown), the windings of all of which switching devices and apparatus utilize insulating materials, paints or lubricants which emit organic vapors in sufficient quantity to build up within said enclosure an appreciable concentration of said vapors.

In the absence of suitable protection such as that afforded by coil 26 in accordance with the principles of the present invention, these vapors will cause contacts 28, 30, to become "activated," that is to become coated with a film of organic substances deposited from said vapors, after said contacts have operated in the order of twenty thousand times or more in the presence of said vapor.

In Fig. 3 are curves illustrating the "activation" and "deactivation" of three separate pairs of contacts in terms of "arc duration in microseconds" versus "thousands of contact operations."

In each instance the pair of contacts was employed to "break" or interrupt a current carrying circuit of the type illustrated by Fig. 1, except that in each instance, for operations from zero to 100,000, curves 70, 72 and 74, respectively, the contacts had no protecting or cleaning coil such as 26 of Fig. 1 connected directly in series with them. Also for operations from 100,000 to 150,000, the cleaning coil corresponding to coil 26 of Fig. 1 was given inductance values of one milhenry, 9.5 milhenries and 120 milhenries for curves 71, 73 and 75, respectively.

The arc duration in microseconds is substantially proportional to the degree of "activation."

Curve 74 represents the process of becoming "activated" starting with a pair of contacts which are virtually clean or completely "deactivated."

Curves 70 and 72 represent the process of "activation" starting with contacts not quite completely "deactivated," curve 70 representing a slightly greater initial "activation" than curve 72.

As illustrated by curves 70, 72 and 74, the arc duration in microseconds increases very moderately during the first ten thousand or so operations but thereafter increases much more rapidly, so that at fifty thousand operations all three pairs of contacts are definitely "activated" to an objectionable degree. At one hundred thousand operations all three of the curves 70, 72 and 74 indicate that a saturated or maximum degree of "activation" is being approached, and cleaning or deactivating coils, having, as above stated, values of one milhenry for curve 71, 9.5 milhenries for curve 73, and 120 milhenries for curve 75, are then inserted immediately in series with the respective pairs of contacts. The rapidity with which even the smallest of these cleaning coils deactivates its associated pair of contacts is strikingly illustrated by the curves 71, 73 and 75, so that after fifty thousand more operations all of the contact pairs have

been reduced to a degree of "activation" such that arcing of any significant duration no longer occurs. Arc durations were observed by connecting one pair of deflecting plates of an oscilloscope across the contacts and timing the sweep to coincide with the period during which the arcing, if any, occurred.

The salient features of the operation of the circuit of Fig. 1 are as follows: A few milliseconds after closure of contacts 28, 30, a direct current of approximately one half ampere will flow through the series circuit including battery 8, resistance 10, the winding of relay 12, the section of telephone cable 18, the cleaning coil 26 and said contacts. Thereafter, when contacts 28, 30 open, the cleaning coil 26 will cause a momentary voltage surge across contacts 28, 30, in excess of 300 volts, which in turn will cause a momentary glow discharge having a duration in the order of one half microsecond, to take place between contacts 28, 30. The glow discharge will tend to largely remove the contaminating or "activating" coating or film which would otherwise form on the surfaces of the contacts 28, 30.

In Fig. 4 are shown the results of a series of experiments, illustrating erosion per operation versus cleaning coil inductance, with a circuit of the type illustrated in Fig. 1, in which the cleaning coil 26 was successively given values of inductance from 50 to 1,000 microhenries. The anode is, of course, the contact connecting to the positive terminal of the battery 10 which, in Fig. 1, is contact 28. The cathode is, of course, the opposing contact 30, of Fig. 1. As is apparent from the portions 52, 53 and 62, 63 of the curves 50 (anode) and 60 (cathode), respectively, the optimum range of values for the inductance of the cleaning coil 26 of Fig. 1 is between 100 to 200 microhenries, though reasonably low erosion is still obtained with the maximum value of 1,000 microhenries. Other experiments have indicated that any further substantial increase in the inductance of the cleaning coil, in circuits in which the contacts function to "break" the circuit, would so prolong the duration of the glow discharge that appreciable "showering" would be encountered and pitting and excessive erosion of the contact surfaces would be likely to result. The portions 54 and 64 of curves 50 and 60, respectively, illustrate graphically that for values of cleaning coil inductance less than 100 microhenries, the erosion of both contacts increases sharply with decreasing inductance.

Other experiments demonstrated that the duration of the glow discharge produced by the cleaning coils within the optimum range of 100 to 200 microhenries of the inductance values was in the order of one half microsecond.

Still other experiments demonstrated that as the value of inductance of the cleaning coil was increased toward 1,000 microhenries the duration of the glow discharge increased toward a maximum in the order of 1.6 microseconds at 1,000 microhenries.

It was further found that, while a cleaning coil having an inductance in the order of 1,000 microhenries appeared to substantially clean or "deactivate" the contacts, erosion (having the descriptive designation "mound-pit" erosion) could be detected by microscopic examination and that premature failures of the contacts by mechanical locking were likely to be encountered after a relatively moderate number (less than one million) of operations.

As contrasted with the above, for cleaning coils having an inductance within the preferred or optimum range of 100 to 200 microhenries, some residual contamination or "activation" of the contacts was always found present upon microscopic examination and substantially uniform and relatively very moderate erosion or wear over the entire contact surfaces occurred. Contacts so protected were found capable of several hundred million

fault-free operations in the presence of an appreciable concentration of organic vapor equivalent to or exceeding that encountered under normal present day operating conditions.

Experiments with other circuits of the general type illustrated in Fig. 1, but having individual circuit element values such that their normal closed-circuit currents were appreciably greater or smaller than for the specific illustrative circuit described in detail above, clearly indicated that the inductance of the cleaning coil 26 should, in general, be such that a glow discharge having a duration of one half microsecond will be obtained. Contacts so protected are capable of fault-free operation for several hundred million operations in any concentration of organic vapors likely to be encountered in service.

A further problem in contact protection is posed by circuits in which the particular pair of contacts being considered is required to perform the operation of closing the circuit only, another pair of contacts being employed to break the circuit prior to separating the particular pair of contacts for a subsequent closing operation. In such a case the normally unwanted "openings" resulting from the inevitable "chatter" of the contacts must, as mentioned hereinabove, be relied upon to produce the desired degree of cleaning or "deactivation" at each closing operation of the particular pair of contacts. In general for contacts required only to "make" or complete the current carrying circuit, a cleaning inductance very appreciably larger than that required for contacts which are employed to "break" the circuit will be found necessary to effect the desired degree of cleaning or "deactivation." For example, where, in a circuit of the type illustrated in Fig. 1, a cleaning inductance of from 100 to 200 microhenries will be found satisfactory for contacts employed to "break" or open the circuits while normal current is flowing through the contacts, an inductance in the order of ten millihenries is necessary to satisfactorily protect contacts employed only to complete the circuit and to re-establish the flow of current.

In Fig. 2, a circuit identical with that of Fig. 1 except that in Fig. 2 the contact cleaning coil 32 is provided with a core of a ferrite, such as nickel-zinc ferrite, which at low flux densities has a high permeability, i. e., in the order of 4,000, but which becomes saturated at a low current value, such as one-hundredth ampere, whereupon its effective inductance drops to a small, substantially insignificant, value. With this type of cleaning coil a suitable inductance at low current values is always present so that the circuit will function satisfactorily over a wide range of closed-circuit current values. The relatively high inductance at low current values also functions to delay or retard the initial current surge at the instant of closing and will provide the required duration of glow discharge as the circuit is opened and the current drops below the saturation value of the core.

The ferrite core, contact cleaning coil is, by way of example, also of outstanding value in the "problem" case described above in which the particular pair of contacts under consideration are required only to "make" the circuit (i. e., to complete the current carrying path) and the function of breaking the current carrying path is performed by another pair of contacts. For the particular pair of contacts under consideration, in such a case, reliance for contact cleaning must be placed upon the inevitable and normally unwanted openings caused by "chatter" of the contacts during the circuit closing operation. The ferrite core coil will, in this instance, provide a suitably large inductance during the "unwanted" openings which occur at low current values (i. e., as the current begins to build up) but as soon as the current has reached saturation value in the coil, only an insignificant value of inductance will remain. However, sufficient energy will have been stored in the coil to pro-

vide adequate glow discharge for any subsequent "unwanted" openings. The effective duration of glow discharge for a circuit closing operation of the contacts can in this way be suitably controlled regardless of the amplitude which the current finally reaches when the contacts have ceased "chattering" and the circuit is completely established.

It should be noted that the operation of the contact cleaning coils of the present invention is readily distinguishable from that of very small inductances (from one to ten microhenries) used in the same circuit position in prior art contact protection arrangements, for example see United States Patent 2,594,890 granted April 29, 1952, to W. B. Ellwood.

As is obvious from the curves of Fig. 4 of the drawings accompanying the present application, coils of such small inductance are incapable of producing a glow discharge of sufficient duration to effect the necessary degree of cleaning of the "activated" contacts. The function of such a small inductance is merely to lessen the surge of current upon initial contact closure which tends to occur when the load circuit to which the contacts are connected has appreciable distributed capacity and becomes charged when the contacts are open. This accumulated charge, of course, tends to discharge through the contacts as they approach closure.

Conversely the larger contact cleaning inductances of the present invention will, obviously, effectively prevent the above described initial surge resulting from discharge of the energy stored in the distributed capacity of the circuit, as well as produce the appropriate duration of glow discharge required for the desired partial deactivation of the contacts in accordance with the present invention.

In Fig. 5 a further circuit of the invention is illustrated. As indicated by the use in Fig. 5 of many of the designation numbers employed in Figs. 1 and 2, a majority of the elements of Fig. 5 can be identical with those of Figs. 1 and 2 having the corresponding designation numbers, respectively, and can be as described in detail above in connection with the last mentioned figures.

The circuit of Fig. 5 differs from that of Fig. 1, however, in that the load 9, which can, for example, be a signal lamp, has a substantially purely resistive impedance 15 of, for example, 400 ohms. With a circuit having a purely resistive load, the conventional contact protective circuit comprising resistance 22 and capacitance 24 of Fig. 1 can be omitted and coil 80 which can be similar to coil 26 of Fig. 1, or alternatively similar to coil 32 of Fig. 2, can constitute the sole protective element for contacts 28, 30.

In some instances a particular pair of contacts may be required to operate only upon rare occasions, as, for example, where the contacts are included in a spare or reserve unit. Also there are instances where the unit may be stored for a long period before it is placed in service. Under such conditions the contacts may become contaminated or dirty and the unit may fail to operate properly when it is eventually placed in service. The contacts of all such units can periodically be effectively cleaned by controlled glow discharge, utilizing, for example, a circuit of the type illustrated in Fig. 5, where the unit whose contacts are to be cleaned is connected as shown for contacts 28, 30, and actuating coil 29. Control circuit 37 can be any conventional source of appropriate control pulses such, for example, as a multi-vibrator circuit. Control circuit 37 is then operated to provide substantially fifty thousand successive operating pulses and the process of cleaning by glow discharge will have then been completed. For such cleaning operations coil 80 should preferably have an inductance between 200 and 1,000 microhenries. Stated in terms of glow discharge duration following each "break" operation, an inductance coil causing a glow discharge of between one half and one and six-tenths microseconds



duration, should be employed for cleaning contacts which have become contaminated from any of the above mentioned conditions.

Numerous and varied other arrangements embodying the principles of the present invention and within the scope of the inventive concepts involved will readily occur to those skilled in the art. It is, accordingly, to be clearly understood that the specific embodiments described above are illustrative only and are not intended to exhaustively cover all possible arrangements in accordance with the present invention.

What is claimed is:

1. Means for preventing a harmful degree of contamination in the presence of organic vapors of switching contacts employed to interrupt the current flow in a switching circuit, said circuit presenting an impedance across the contacts which is virtually resistive and carrying a maximum current of less than one ampere, said means comprising solely an inductance having a value greater than 100 microhenries and less than 1,000 microhenries connected directly in series with said contacts, the combination of said inductance and said contacts being connected directly across the remainder of said switching circuit, said inductance comprising the sole electrical connection between one of said contacts and the remainder of said circuit.

2. Means for preventing harmful contamination in the presence of organic vapors of switching contacts employed to interrupt the current flow in a switching circuit, said circuit presenting an impedance across the contacts which is virtually resistive and carrying a maximum current of less than one ampere, said means comprising solely an inductance connected directly in series with said contacts, said inductance having a value not exceeding 1,000 microhenries but sufficient to produce a glow discharge across said contacts when interrupting said current flow in said switching circuit, the combination of said inductance and said contacts being connected directly across the remainder of said switching circuit, said inductance comprising the sole electrical connection between one of said contacts and the remainder of said circuit, said glow discharge having a duration between one half microsecond and one and one half microseconds.

3. An inductance coil for cleaning switching contacts for opening and closing a circuit presenting an impedance across the contacts which is virtually resistive and carrying a maximum current of less than one ampere, said contacts operating in an appreciable concentration of organic vapors, said inductance coil having a core of a ferrite which has a large permeability at low current values through said coil but becomes saturated when currents in excess of one-hundredth ampere are passed through said coil, said coil being connected directly to one of said contacts and comprising the sole electrical connection between said contact and the remainder of said circuit, said coil having a low current inductance of not less than 100 microhenries and a high current inductance of not greater than 1,000 microhenries.

4. A device for protecting switching contacts from contamination when operating in the presence of organic vapors, said contacts being arranged to open and close a circuit which presents an impedance across the contacts which is virtually resistive, said circuit carrying a maximum current of less than one ampere, said device comprising an inductance coil having a core of a material having high permeability at low values of current through said coil, said core becoming saturated at a current of less than one-tenth ampere through said coil, said coil being connected directly to one of said contacts and comprising the sole electrical connection between said contact and the remainder of said circuit, said coil having a low current inductance of not less than 100 microhenries and a high current inductance of not greater than 1,000 microhenries.

5. In a switching circuit carrying a maximum current

of less than one ampere, contact protecting means for the switching circuit contacts for opening and closing said circuit in the presence of an appreciable concentration of organic vapors, said means comprising solely in combination, an inductance coil having an inductance between 100 and 1,000 microhenries connected directly in series with said contacts and comprising the sole electrical connection between one of said contacts and said circuit, and a second circuit directly shunted across said series circuit comprising said contacts and said coil, said second circuit comprising a resistance and a capacity connected in series, the remainder of said switching circuit being shunted by said combination, the combined impedance of said remainder of said switching circuit and said second circuit being virtually resistive.

6. The combination of claim 5 in which said coil has a core of a material having a high initial permeability, said core becoming saturated at a current of less than one-tenth ampere through said coil.

7. An electrical circuit the maximum operating current of which is less than one ampere, said circuit comprising in series a source of direct current energy, a current limiting resistance, the electrical winding of an electromagnetic switching device to be controlled by said circuit, a section of transmission line, a pair of contacts to open and close said circuit, said pair of contacts being enclosed in an atmosphere which includes an appreciable concentration of organic vapor, said concentration of vapor being sufficient to contaminate said contacts after fifty thousand operations or less, and contact protective means comprising solely the combination of a contact cleaning coil connected immediately adjacent and in series with said pair of contacts in said circuit, said coil having an inductance within the range of 100 to 200 microhenries, and an impedance corrective circuit directly shunted across the series combination of said contacts and said cleaning coil and the end of said transmission line nearer said contacts, said corrective circuit comprising a resistor and capacitor connected in series, said corrective circuit rendering the impedance at the said nearer end of said transmission line virtually resistive, whereby when said contacts open said circuit a glow discharge is produced of sufficient duration of partially clean said contacts and substantially inhibit erosion of said contacts.

8. The circuit of claim 7 in which said cleaning coil has a ferrite core.

9. An electrical communication circuit having a maximum operating current of less than one ampere, said circuit comprising a source of direct current energy, a load impedance, a pair of contacts adapted and connected to open and close a direct current path including said source and said impedance, said contacts being immersed in an atmosphere having a sufficient concentration of organic vapor to contaminate said contacts, and contact protective means comprising solely the combination of a cleaning coil connected directly in series with said contacts the inductance of said coil being sufficient to produce a glow discharge having a duration of one half microsecond when said contacts are opened, and an impedance corrective network directly shunting the series combination of said cleaning coil and said contacts and the remainder of said circuit, the combination of said corrective network and said remainder of said circuit presenting an impedance which is virtually resistive.

10. Means for cleaning contaminated contacts of an electromechanical switching device, said means comprising solely the combination of an inductance coil having an inductance of between 200 and 1,000 microhenries connected directly adjacent to and in series with said contacts, means for establishing a substantially purely resistive circuit in shunt relation across the series connected combination of said contacts and said coil in which resistive circuit a direct current of substantially one half ampere flows when said contacts are closed, and means



for operating said switching device to open and close said contacts successively fifty thousand times.

11. Contact cleaning means comprising solely an inductance directly connected in series with the contacts, the inductance having a ferrite core, said core having a large permeability at low current values but becoming saturated at current values in excess of one-hundredth of one ampere.

12. Means for preventing harmful contamination by organic vapors of switching contacts employed to close a switching circuit to establish the flow of current there-through, the maximum current in said circuit being less than one ampere, said means comprising solely an inductance connected directly in series with said contacts, said inductance being sufficient to cause a glow discharge of substantially one half microsecond duration between said contacts during their chatter open periods, the combination of said inductance and said contacts being connected directly across the remainder of said circuit, said inductance comprising the sole electrical connection between one of said contacts and the remainder of said circuit, the remainder of said circuit having an impedance which is virtually resistive.

13. The means of claim 12 in which said inductance has a core of a material having a large permeability at low current values but becoming saturated at current values in excess of one-hundredth of one ampere.

14. Contact protecting means for protecting the contacts which open and/or close a switching circuit which includes the actuating coil of an electromagnetic relay, the maximum current in said switching circuit being less than one ampere, said means comprising solely in combination a first circuit shunted across said switching circuit at a point closely adjacent said contacts, said first circuit including a resistance and a capacitance connected in series, and a second circuit shunted across the same point of said switching circuit, said second circuit comprising an inductance connected directly in series with said contacts, said inductance having a value of between 100 and 200 microhenries, said inductance comprising the sole electrical connection between one of said contacts and the remainder of said circuit, the remainder of said circuit having an impedance which is virtually resistive.

15. The combination of claim 14 in which said inductance has a core which has high permeability for low current values through said coil but becomes saturated at current values through said coil exceeding one tenth ampere.

16. Contact protecting means for protecting the contacts which open and/or close a switching circuit having a virtually purely resistive impedance, said means comprising solely an inductance coil connected directly in series with said contacts, said coil comprising the sole

electrical connection between one of said contacts and the remainder of the circuit and having a value of inductance between 100 and 1,000 microhenries.

17. The protecting means of claim 16 in which said inductance coil has a core having high permeability at low values of current through the winding of said coil and substantially unity permeability at current values through the winding of said coil which exceed one-tenth ampere.

18. Contact protecting means for protecting the contacts which open and/or close a switching circuit in the presence of organic vapors, said circuit having a virtually purely resistive impedance, said circuit carrying a maximum current of less than one ampere, said means comprising solely an inductance coil connected directly in series with said contacts, said coil comprising the sole electrical connection between one of said contacts and the remainder of the circuit and having a value of inductance between 100 and 10,000 microhenries.

19. The protecting means of claim 18 in which said inductance coil has a core having high permeability at low values of current through the winding of said coil and substantially unity permeability at current values through the winding which exceed one-tenth ampere.

20. The method of protecting a pair of contacts in a switching circuit carrying a current of less than one ampere and operating in the presence of organic vapors, said method comprising modifying the impedance of the circuit to be controlled by said contacts to present a virtually purely resistive impedance at said contacts and inserting in series relation between one of said contacts and said modified circuit an inductive impedance sufficient to produce a glow discharge across said contacts of substantially one microsecond duration whereby excessive contamination of the surfaces of said contacts is inhibited.

21. Means for cleaning contacts of switching circuits carrying a maximum current not exceeding one ampere, which contacts have become contaminated by organic vapors or contaminated from other causes, said means comprising a virtually resistive circuit connected to be controlled by said contacts, said circuit, when closed by said contacts, carrying a maximum current of less than one ampere, means for causing a glow discharge of substantially one microsecond across said contacts during a "break" operation of said contacts, and means for operating said contacts fifty thousand times.

#### References Cited in the file of this patent

##### UNITED STATES PATENTS

|           |         |               |
|-----------|---------|---------------|
| 2,020,950 | Lee     | Nov. 12, 1935 |
| 2,375,609 | Zuhlke  | May 8, 1945   |
| 2,594,890 | Ellwood | Apr. 29, 1952 |
| 2,802,149 | Germer  | Aug. 6, 1957  |