

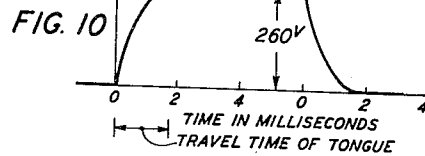
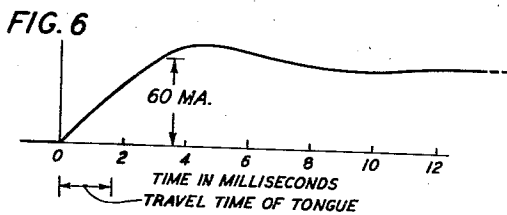
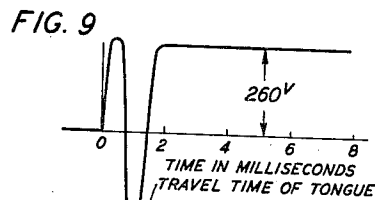
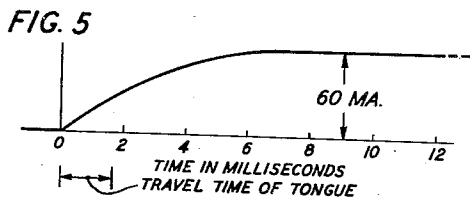
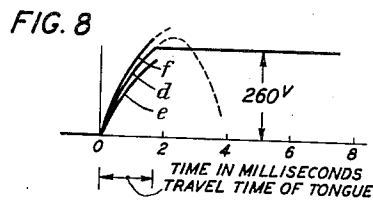
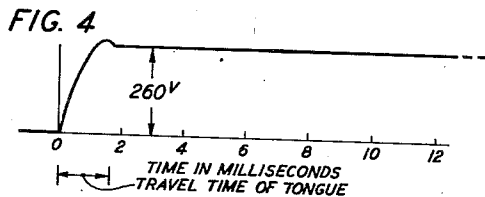
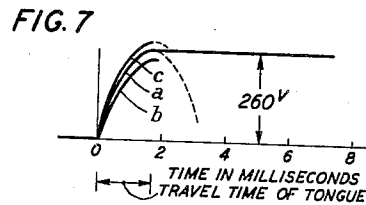
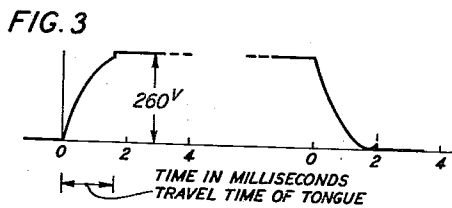
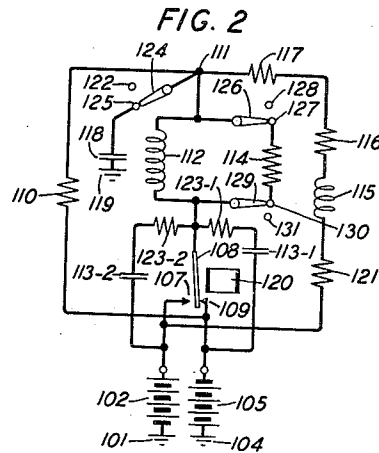
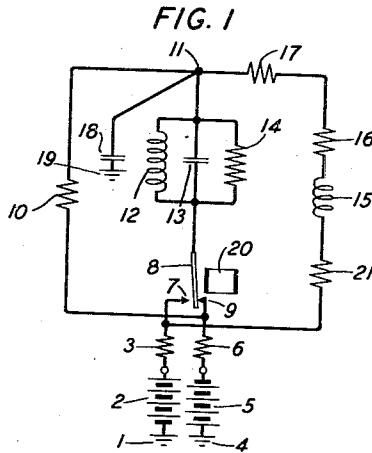
July 16, 1940.

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2,207,969

ELECTRICAL CONTACT PROTECTION

Filed Dec. 30, 1937



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ELECTRICAL CONTACT PROTECTION

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16 Claims. (Cl. 175—294)

This invention relates to electrical contact protection generally, and more particularly to relay contact protection with special reference to telegraph relays comprising an armature swinging between two contacts and to the protection of electric switch contacts.

An object of this invention is to provide protection for contacts which make and break in electric circuits against arcing, sparking, burning, melting, pitting, building out, depositing residue, discoloring and in general all of the difficulties inherent in such operation.

A more specific object of this invention is to extend the useful life of electric relays, particularly telegraph relays as well as switches, both manually and electrically operated.

A further object of this invention is to prevent or reduce inductive and capacitative interference in neighboring wired circuits or the radiation of interfering waves to neighboring radio apparatus, such as receivers.

As is generally known, when two contacts having current flowing through them or voltage applied to them in an electric circuit make or break, under ordinary circumstances, sparking or arcing occurs which is more or less severe, depending on the character and constants of the circuit. This is indicative of a variety of objectionable conditions, causing shortened useful contact life and service failures.

The present invention involves a method of eliminating this difficulty applied specifically to a telegraph relay.

It is understood that the protection methods disclosed herein may find direct application to many other cases wherein an electric circuit is made and broken.

One of the essential ideas of the invention is the following: To protect contacts, generate a transient potential in one contact which approximately matches the potential of the other contact in value and in sign while the contacts are in close proximity on make and break; by proper choice of the transient voltage wave shape, maintain the potentials of the two contacts at such level, as they approach and as they separate, that the potential difference between them is insufficient to support an arc through the changing distance intervening between the contacts.

The method of applying this principle consists in generating a transient potential by means of electrical apparatus directly connected to a moving armature. The electrical constants of this apparatus are so chosen that during the travel time of the armature the voltage is changed, so

that at all times the difference between it and the contact which it is approaching or from which it is separating is insufficient to support an arc or cause a spark through the changing distances intervening between said armature and said contacts. On making or breaking, the potentials of the armature and the contact are the same in sign and are essentially matched in level.

The use of the transient voltage generating apparatus is disclosed herein as applied to a telegraph relay comprising an armature swinging between two contacts at different potentials. The specific apparatus for generating said transient voltage used herein comprises an inductance in the form of a coil with a magnetic core tuned with a capacitance in the form of a condenser, both connected to said armature. The constants of the various units are so chosen that the surge appearing at the beginning of the armature travel time swings the armature voltage gradually from that of one side contact to that of the other. Break and subsequent make, therefore, occur with little or no potential difference between the armature and the contact involved. The current wave fronts are rounded, the wave rising or falling gradually during the time of armature travel and for a short time thereafter. Very long contact lives result when this method of protection is used. Further, interference in neighboring circuits including radio receivers is reduced.

The various figures on the drawing will now be described.

Fig. 1 shows a telegraph subscriber's line circuit including the transient voltage generating apparatus of this invention;

Fig. 2 shows the same telegraph subscriber's line circuit, with the transient voltage generating apparatus arranged in a manner different from that in Fig. 1;

Fig. 3 is a curve showing the armature voltage change plotted against time for Fig. 2, using an inductance of 2.7 henries and two tuning condensers of .15 microfarad capacity;

Fig. 4 is a curve showing the armature voltage change plotted against time for Fig. 2, using the same inductance but with two tuning condensers each of .10 microfarad capacity;

Fig. 5 is a curve showing armature current plotted against time corresponding to the voltage wave of Fig. 4;

Fig. 6 is a curve showing a current wave with a faster current build-up, obtained by inserting condenser 118 in the circuit of Fig. 2;

Fig. 7 is a curve showing voltage plotted against

time with the armature travel time equal to one-fourth the period of the generated transient;

Fig. 8 is a curve showing voltage plotted against time with the armature travel time less than one-fourth the period of the generated transient;

Fig. 9 is a curve showing voltage plotted against time with the armature travel time equal to five-fourths the period of the generated transient;

Fig. 10 is a curve showing an ideal armature voltage swing and match with the engaging contact.

The operation of the circuit of Fig. 1 will now be described in detail:

Fig. 1 represents a telegraph subscriber's line circuit to which this invention is applied. The actuating mechanism of a telegraph repeating relay 20 operates armature 8 alternately between relay contacts 7 and 9. The tuned retard protecting apparatus used in combination to generate the transient which matches the potential of armature 8 with contacts 7 and 9 comprises the inductance coil 12 and its tuning condenser 13. The subscriber's line relay winding 15 is located at the subscriber's station. The resistances of the two loop conductors connecting the subscriber's line relay to the central station are indicated by resistances 16 and 21. All apparatus other than the subscriber's relay 15 and the two loop conductors is located at the central telegraph station. Resistance 17 is used to adjust the current in the subscriber's loop. A dummy resistive load 10 equal to the resistance of the subscriber's loop circuit is connected into the circuit at the central station as indicated and its function, together with the function of other apparatus units, will be understood from the detailed description which follows:

In Fig. 1, when the armature 8 is on contact 7, a circuit is closed from ground 1 to the negative terminal of battery 2, battery 2, positive terminal of battery 2 through resistance 3. Here the circuit branches into parallel paths. One branch passes through armature 8 in series with the transient voltage generating device, consisting of inductance coil 12 and condenser 13 together with damping resistance 14, all three in parallel, and then to terminal 11. The second branch passes through the subscriber's loop, consisting of resistance 21, relay winding 15, resistance 16, resistance 17 to a terminal 11 where the branches join, thence the circuit continues through the dummy load 10 to resistance 6, negative terminal battery 5, battery 5, positive terminal battery 5 to ground 4. It will be observed that battery 2 and battery 5 are in series aiding. The relative resistances of the two branch circuits traced above are such that the steady state current through the subscriber's loop under these circumstances is negligible as far as its influence on circuit operation is concerned. The major portion of the steady state current passes through the contact 8 and returns through the dummy load.

When the armature 8 has been operated to engage contact 9, a path is closed which may be traced from ground 4, positive terminal battery 5, battery 5, negative terminal battery 5 through resistance 6. Here the circuit branches into parallel paths. One branch passes through armature 8 to terminal 11, the same as described above. The second branch is through the dummy load 10 to terminal 11. Thence the circuit continues through resistance 17, resistance 16, relay winding 15, resistance 21, resistance 3, positive terminal battery 2, battery 2, negative terminal battery 2 to ground. It will again be observed

that battery 2 and battery 5 are in series aiding. Here again the relative resistances of the two branch circuits traced are such that the steady state current through the dummy load is negligible as far as its influence on circuit operation is concerned. The major portion of the steady state current passes through the armature contact and all of it passes through the subscriber's loop.

If the armature were to stand free between the contacts, the steady state voltage of terminal 11 to ground, since it is the mid-point between the balanced loads and equal batteries in series to ground, would be zero.

The magnitude of current passing through the armature is the same when in engagement with either contact. The voltage across the transient voltage generating device due to the steady state current is, therefore, the same in magnitude when the armature breaks with either contact. Assuming a direction of steady state current flow from the positive battery terminal to the negative battery terminal, it will be observed that when the armature 8 is on contact 7 the direction of the current flow is from armature 8 through coil 12 to terminal 11. When armature 8 is on terminal 9 positive battery is applied through the subscriber's loop to terminal 11 and thence through the coil in the reverse direction to armature 8. When the armature is in engagement with either contact its voltage level will be essentially the same as that of the contact. As it breaks from either contact and the current through the coil diminishes, an electromotive force is set up in the coil, tending to maintain the current. The value of the electromotive force, as is well known, is not limited directly by the voltage of the batteries 2 and 4 but is dependent on the rate at which the current in the coil changes, and the inductance of the coil. The electromotive force forces a charge into the condenser. While the armature is in engagement with either contact the voltage on the particular condenser plate directly connected to the armature is of the same polarity and value as the contact. Immediately after break, as the energy stored in the inductance coil is transferred to the condenser plate by the electromotive force, the voltage will change passing through zero and a voltage of sign opposite to that of the contact which has been broken will be built up to a peak on the plate connected to the armature. If allowed to continue after the coil energy had been transferred to the condenser, the process would be reversed and the condenser energy transferred to the coil following which the condenser voltage would change to a peak of opposite sign. This process would be repeated until the energy was dissipated. If the armature were stopped free between the contacts, an oscillatory voltage would be impressed on the armature with diminishing voltage peaks until the effect of the transient was spent. If, however, the travel time of the armature is such that it engages the opposite contact at some time before the transient is dissipated, the armature will have a voltage on it depending on the value of the transient at the instant. By a proper choice of constants in the transient generating device in relation to the armature travel time, it is possible to match the voltages at the instant of contact and also to regulate the respective voltages during the travel so that the voltage difference between them will not support an arc or cause a spark between the armature and either contact as it makes and breaks.

The general method of determining the values of the coil inductance and condenser capacity will

now be demonstrated and solved for a particular theoretical case in which circuit resistance is disregarded.

In order to match the contact voltage with the first peak of the transient voltage on the armature, which occurs at approximately one-quarter of the transient cycle period after break, it is necessary that the time of travel of the armature from contact to contact be equal to one-quarter cycle of the tuned circuit or

$$F = \frac{1}{4T} = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

where:

F=the frequency
T=the travel time
L=the inductance in henries
C=the capacity in farads

Further, the energy stored in the magnetic circuit of the coil must be transferred to the condenser and develop therein the required potential change, or

$$\frac{LI^2}{2} = \frac{CE^2}{2} \quad (2)$$

In a specific case, the relay used in Fig. 1 has a travel time T of 2 milliseconds. The current I through the coil is 60 milliamperes. The voltage across the coil E is 130 volts.

From the first equation:

$$L = \frac{4T^2}{\pi^2 C} \quad (3)$$

$$C = \frac{4T^2}{\pi^2 L} \quad (4)$$

From the second equation

$$L = \frac{CE^2}{I^2} \quad (5)$$

$$C = \frac{LI^2}{E^2} \quad (6)$$

From Equations 4 and 6

$$L = \frac{2T}{\pi} \times \frac{E}{I}$$

From Equations 3 and 5

$$C = \frac{2T}{\pi} \times \frac{I}{E}$$

substituting the values

$$C = \frac{2 \times .002}{\pi} \times \frac{.060}{130} \times 10^6 = 0.58 \text{ microfarad}$$

$$L = \frac{2 \times .002}{\pi} \times \frac{130}{.06} = 2.7 \text{ henries}$$

In practice, due to the impedance of the attached circuit which is effectively in series with the oscillating circuit, the practical value of C is somewhat lower and that of L is somewhat higher than indicated by the above equations.

It has been found desirable in the operation of this circuit to delay the change in voltage of terminal 11 to zero and to dampen the oscillations in the tuned circuit. Condenser 18 and resistance 14, respectively, perform these functions.

Fig. 2 is another embodiment of the invention showing a slight variation in the arrangement of the tuning condenser. Apparatus units corresponding to those in Fig. 1 are numbered one hundred greater than in Fig. 1. The tuning condenser in Fig. 2 is divided into two units, 113-1 and 113-2, each in series with a resistance, 123-1 and 123-2 shunted around the contacts. Condenser 118 may be cut into or out of the

circuit by the operation of switch 124 to contacts 125 or 122, respectively. The capacity of each condenser, 113-1 and 113-2, is half of the value figured from the above formula. Resistance 114 may also be cut into the circuit by the operation of switches 126 and 129 to contact 127 and 130. It may be cut out by operating the switches to contacts 128 and 131.

Fig. 3 is a reproduction of an oscillograph curve showing voltage-time characteristics of the armature for Fig. 2. The horizontal ordinate represents time. The vertical ordinate represents voltage change. Resistance 114 and condenser 118 are disconnected from the circuit by the operation of the associated switches. Starting at the break or zero time, and at the voltage of the contact from which the armature separates, it may be observed that the voltage change is 260 volts, the voltage difference between the contacts, in the travel time, which is .002 of a second. The contacts are in engagement for an interval, and then, after the break shown again at zero time, the voltage swings back 260 volts in the opposite direction, during the .002 of a second, while the armature is traveling back again to the first contact. The very small vertical rise at the top of the left-hand curved portion of Fig. 3 indicates that the voltage peak has not been quite reached at the termination of the travel, indicating that the frequency of the tuning is too low. This mismatching of voltage is representative of conditions which may occur in practice. The effect of such small mismatches are of minor importance under service conditions and may be neglected.

Fig. 4 shows a reproduction of an oscillograph voltage-time curve using Fig. 2 with two .10-microfarad condensers. Here the voltage swing is slightly too high and the tuned frequency is also slightly too high.

Performance of the circuit, however, with either wave shape, per Fig. 3 or per Fig. 4, is satisfactory as the variation between the armature and contact voltage is small. Reference to the curved peak of Fig. 4 discloses that the voltage curve at the period just before make is rounded. The voltage on the armature, when the armature is in the region close to the contact which it is approaching, is being maintained within a small variation plus or minus from that of the contact, thus preventing sparking or arcing between them. Reasonable variation in adjustment of relays or changes of line conditions may be tolerated without exceeding safe limits in mismatching of voltages.

Fig. 5 is a reproduction of an oscillograph curve showing the loop current variation with time. It may be observed that the full loop current of 60 milliamperes does not build up until about .007 of a second has elapsed. Such a slow build-up in certain situations might possibly adversely affect circuit operation. To correct this, the circuit is arranged so that condenser 118 may be added. It has been found advantageous under certain conditions to also add resistance 114.

Fig. 6 is a reproduction of an oscillograph curve showing an improved loop current versus time characteristic. For Fig. 6 condenser 118 and the relatively high resistance 114 are cut into the circuit by the operation of switches 124 to contact 125, 126 to contact 127 and 129 to contact 130. The curve shows that the current builds up considerably faster, reaching 60 milliamperes in less than .004 of a second. The voltage time characteristic is essentially unchanged from that shown in Fig. 3 or Fig. 4.

Fig. 7 shows curves in which armature voltage changes are plotted against time. In these curves the first peak of each transient occurs at one-fourth of the transient period and coincides with the end of the travel time. Curve *a* shows a perfect match in voltages at the end of the armature swing. In curve *b*, the peak voltage occurs at the end of the swing. The armature voltage is slightly below the contact voltage. In curve *c*, the peak voltage occurs at the end of the swing. The armature voltage is slightly above the contact voltage. Both variations are within the allowable limits.

Fig. 8 shows additional curves in which armature voltage changes are plotted against time. In each of these curves *d*, *e* and *f*, the transient peak, has not been reached at the end of the armature travel. The travel time is less than one-fourth of the transient period. In curve *d* the voltages are matched on contact at the end of the travel even though the transient has not reached its first peak. In curve *f* the armature voltage is slightly higher than the contact voltage at the end of armature travel. In curve *e* the armature voltage is slightly lower than the contact voltage at the end of armature travel. Variations from the ideal in accordance with these three curves give satisfactory operation.

Fig. 9 shows a curve in which armature voltage change is plotted against time wherein the travel time of the armature is equal to five-fourths of the transient period time. The contact voltage is matched in sign and magnitude by the second peak of the transient. It discloses in general that the travel time may equal approximately $(\frac{1}{4} + n) p$ where *n* is an integer and *p* the time for one complete cycle of the transient voltage. If f_{res} is the frequency of resonance

$$p = \frac{1}{f_{res}} \text{ where } f = \frac{1}{2\pi\sqrt{LC}}$$

These equations apply only approximately in the practical case because of the damping effect of the attached circuit.

Contact protection by means of matching voltages minimize inductive and capacitive interference in neighboring electrical circuits, especially communication circuits operating at voice frequency and the usual carrier frequencies. Interference in neighboring circuits is caused by sudden changes in voltage or current in the relay circuit. If these changes are gradual, the interference is greatly reduced. In the voltage matching arrangements disclosed herein the matching voltages are generated gradually and the interference is, therefore, greatly reduced. If the mismatching of voltage at the termination of a relay travel time is small, the sudden change of voltage and current being correspondingly small, the resulting interference is small. The interference is ordinarily of little consequence if the magnitude of the mismatching is kept small with respect to the normal battery voltage.

What is claimed is:

1. The method of electric contact protection which consists in impressing a first electric potential between ground and a first contact and a second and different electric potential between ground and a second contact which second contact makes and breaks with said first contact and generating a timed transient potential in an inductance coil and a tuning condenser connected to one of said contacts to minimize the difference between said first and second potentials as said contacts make and break.

2. In a switch for transferring and interrupting the transfer of electric energy, a first electric conductor, an electric potential of a first value relative to a reference value impressed on said conductor, a second electric conductor, an electric potential of a second and different value impressed, relative to said reference value, on said second conductor, a space between said conductors, means for closing said conductors through said space, electric apparatus means comprising an inductance coil connected to said first conductor, for varying the potential of said first conductor, relative to said second conductor, as said first conductor closes through said space, to protect said conductors against deterioration.

3. In an electric relay a fixed electric contact, an electric potential of a first value above a reference value impressed on said contact, an armature, an electric potential of a second and different value relative to said reference value impressed on said armature, a space between said armature and said contact, magnetic means for closing said armature through said space, electric apparatus means comprising an inductance coil and a tuning condenser, for varying the potential of said armature relative to said contact, as said armature closes through said space, to protect said armature and said conductor against deterioration.

4. In an electric relay a fixed electric contact, an electric potential of first value above a reference value impressed on said contact, an armature, an electric potential of a second and different value relative to said reference value impressed on said armature, a space between said armature and said contact, magnetic means for closing said armature through said space, electric apparatus means comprising an inductance coil and a tuning condenser in parallel with said coil, both said coil and said condenser in series with said armature, for varying the potential of said armature relative to said contact, as said armature closes through said space, to protect said armature and said contact against deterioration.

5. In an electrical circuit, a relay comprising an armature conditioned to swing between two contacts, said contacts being at different potential levels each from the other, a first source of electric potential connected to said armature, electric apparatus comprising an inductance coil and a tuning condenser therefor permanently connected in parallel with said coil also connected to said armature conditioned to generate a second and transient electric potential as said armature moves from one of said contacts to the other of said contacts, the electric constants of said apparatus being so chosen with relation to the travel time of said armature between said contacts that there is no sparking between said armature and said contacts.

6. In an electric circuit, a relay comprising an armature conditioned to swing through space between a first contact and a second contact, said armature making direct electric contact with said first and said second contact alternately, a first source of electrical potential connected to said first contact, a second source of electrical potential connected to said second contact, a third source of electrical potential connected to said armature, said three sources maintaining said two contacts and said armature at different potential levels each from the other, varying voltage generating means comprising an inductance coil in series with said armature and a tuning

condenser in parallel with said coil conditioned to gradually change the potential of said armature relative to said contacts as said armature moves through said space to prevent sparking between said contacts and said armature.

7. In an electric circuit, a first contact, a second contact, a space between said contacts, a conductor conditioned to move in said space between said contacts and thereafter to touch one or the other of said contacts, a source of transient electric potential comprising a network including an inductance coil and a condenser, said network being tuned to a frequency having a period four times the travel time of said conductor, connected with said conductor, uninterruptedly and gradually varying the potential of said conductor as said conductor moves through said space and so conditioning the relative potential of said conductor and each of said contacts as to suppress sparking.

8. A first electrical contact, an electric potential of a fixed value E above a reference potential impressed on said contact, a second electrical contact, a space separating said contacts, means cooperating with said contacts to close said contacts during a time T , means for passing a current I through said contacts, transient potential generating means, comprising an inductance element connected in series with one of said contacts and a tuning capacitance element therefor, connected directly in parallel with said inductance element, to vary the potential of said second contact as it closes through said space, said transient potential generating means being conditioned to so vary the potential of said second contact as to prevent arcing between said contacts, by fixing the constants of said inductance and said capacitance substantially in accordance with the formulae

$$L = \frac{2T}{\pi} \times \frac{E}{I}$$

and

$$C = \frac{2T}{\pi} \times \frac{I}{E}$$

9. A first electrical contact, a second electrical contact closed against said first contact, an electric potential of a fixed value E above a reference potential, impressed on said contacts, means cooperating with said contacts to separate said contacts each from the other during a time T , to interrupt a current I through said contacts, transient potential generating means, comprising an inductance element and a tuning capacitance element therefor, connected to said second contact to impress a varying potential on said second contact as it separates from said first contact, said transient potential generating means being so conditioned as to prevent arcing as said contacts separate by fixing the constants of said inductance and said capacitance substantially in accordance with the formulae

$$L = \frac{2T}{\pi} \times \frac{E}{I}$$

and

$$C = \frac{2T}{\pi} \times \frac{I}{E}$$

10. In an electric relay, a first contact, a first electric potential above a reference potential impressed thereon, a second contact, a second electric potential below said reference potential impressed thereon, a space between said contacts,

an armature conditioned to move through said space in either direction during a time T , to interrupt currents of equal magnitudes I , passed through said armature and each of said contacts, electric apparatus means, comprising an inductance unit connected in series between said armature and a telegraph line and a tuning capacitance unit for said inductance connected to said armature for generating a transient voltage in said armature so conditioned, by fixing the inductance and capacitance constants substantially in accordance with the formulae,

$$L = \frac{2T}{\pi} \times \frac{E}{I}$$

and

$$C = \frac{2T}{\pi} \times \frac{I}{E}$$

that during the travel time of said armature the voltage of the armature is swung from the voltage of the contact from which said armature separates to substantially the voltage of the contact which said armature approaches.

11. In an electric relay, a first contact, a first electric potential impressed between said contact and ground, a second contact, a second electric potential impressed between said second contact and said ground, a space between said contacts, an armature conditioned to move through said space to touch each of said contacts alternately, electric apparatus means comprising an induction coil and a tuning condenser for said coil connected to said armature for generating a transient voltage in said armature, the constants of said apparatus so chosen that during the travel time of said armature the voltage of said armature changes gradually from the voltage of the contact from which said armature is separating to the voltage of the contact which said armature approaches.

12. In an electric relay, an armature and a contact associated with said relay, an electric potential impressed between said contact and ground, electric apparatus means, comprising an inductance coil and a tuning condenser for said coil both connected to said armature, for generating a gradually varying voltage in said armature to match said potential on said contact on make and break to suppress interference in neighboring circuits resulting from the effect of sudden voltage and current surges.

13. A contacting device conditioned to make contact and separate from each of two electrodes alternately, electric potential impressed between each of said electrodes and ground, electric potential of a level different from that of either contact impressed between said device and ground, transient voltage generating means comprising an inductance coil and a condenser connected to said device cooperating to minimize said difference in potential level between said device and each of said electrodes as said device makes contact and separates from each of said electrodes.

14. An armature conditioned to contact a first electrode and a second electrode alternately with the time of armature travel from the first electrode to the second electrode equal to the armature travel time from the second electrode to the first electrode, a first electrode potential impressed between said first electrode and ground, a second and different electric potential impressed between said second electrode and ground, an induction coil and a tuning condenser for said coil both connected to said armature, the

energy stored in said coil being transferred to said condenser to change the voltage on said condenser and said armature during said travel time in value and sign to alternately match the voltage of each of said electrodes on contact.

- 15 In an electric relay for interrupting the transfer of electric energy, a fixed electric contact, a movable armature cooperating with said contact to interrupt the transfer of electric energy through said contact and said armature, an electric potential impressed between said armature and said contact and ground, electric apparatus means comprising an inductance coil and a tuning condenser in parallel with said coil, both in series with said armature, operating to maintain the potential of said armature relative to said contact, as said armature separates from said contact at such level as to prevent sparking between said contact and said armature.

16. In a switch for interrupting the transfer of electric energy, a first electric conductor, a second electric conductor in contact with said first electric conductor, an electric potential impressed between said conductors and ground, said conductors cooperating to separate to interrupt the transfer of electric energy through said conductors, electric apparatus means, comprising an inductance coil and a tuning condenser, connected to one of said conductors, said means operating to maintain the potential of said first conductor relative to said second conductor as said conductors separate through said space at such level as to prevent sparking between said conductors.

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