

June 14, 1938.

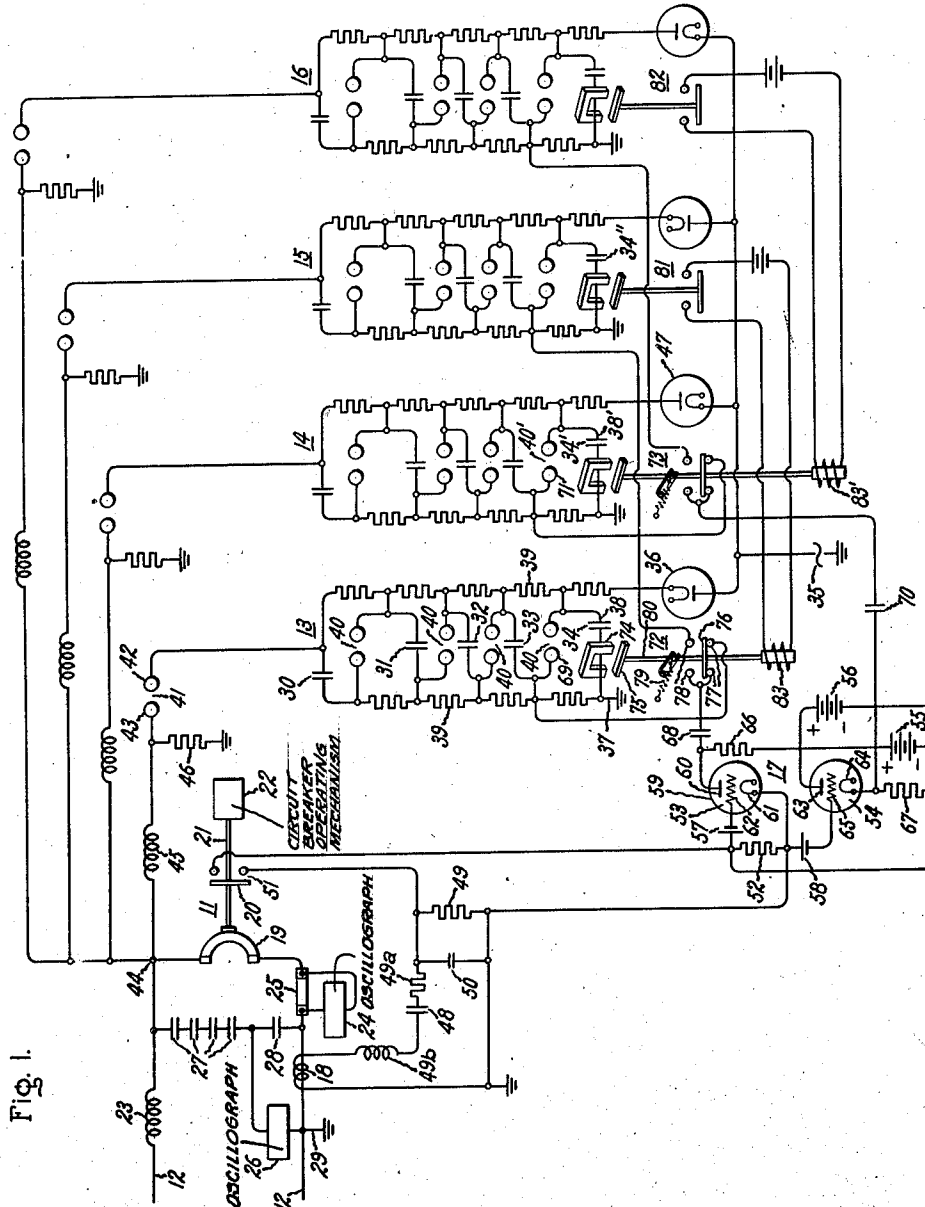
W. F. SKEATS

2,120,873

CIRCUIT BREAKER TESTER

Filed Feb. 27, 1937

3 Sheets-Sheet 1



Inventor:
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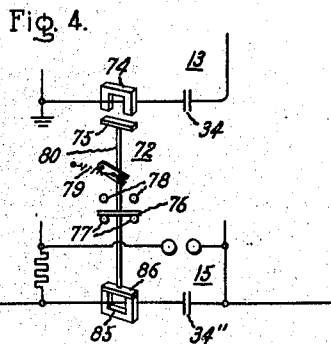
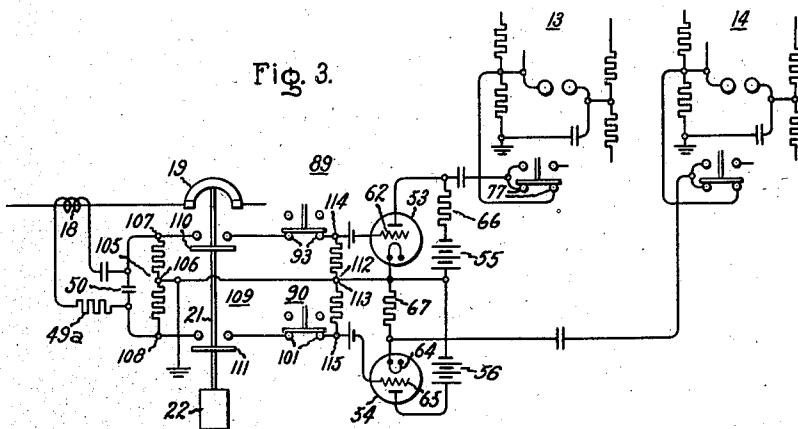
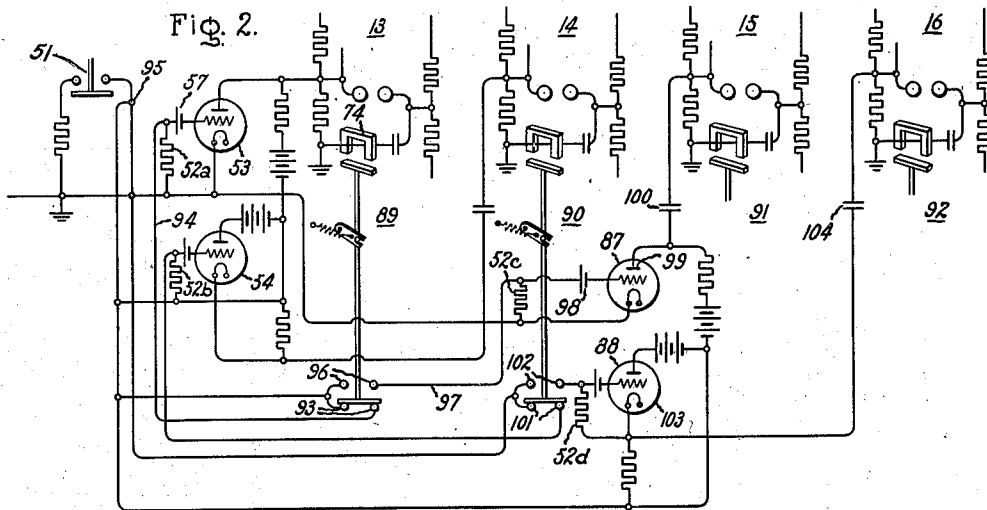
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CIRCUIT BREAKER TESTER

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3 Sheets-Sheet 2



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Fig. 5.

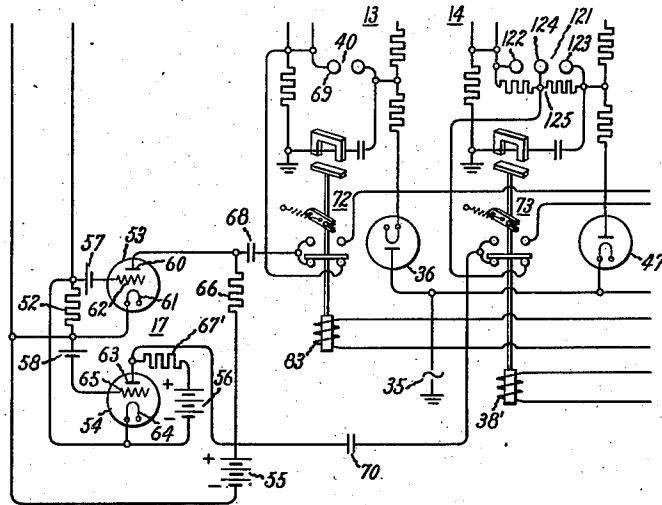
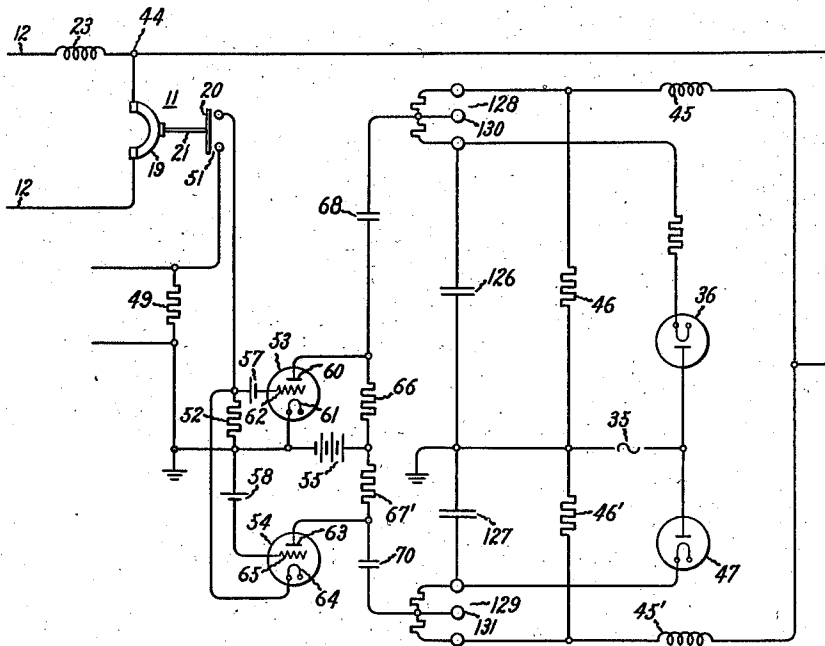


Fig. 6.



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UNITED STATES PATENT OFFICE

2,120,873

CIRCUIT BREAKER TESTER

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Application February 27, 1937, Serial No. 128,217

17 Claims. (Cl. 175-183)

My invention relates to testing devices and concerns particularly methods and devices for testing circuit-interrupting devices at high apparent power on a low-power source.

5 It is an object of my invention to provide improved, simply operating apparatus for testing circuit breakers under conditions simulating the conditions of short circuit at rated apparent power as they occur in actual operation.

10 It is an object of my invention to provide an arrangement which is suitable for testing a single breaker, whether or not the breaker is of the type having positive operating characteristics, and without the necessity of synchronizing other and independent circuit operations with the inter-
15 ruption time with high precision.

It is an object of my invention to provide an arrangement for simulating a given recovery voltage transient and to provide an arrangement
20 in which the wave shape of the voltage surge can be modified with comparative ease.

Furthermore, it is an object of my invention to provide a testing arrangement that will continue to simulate actual operating conditions al-
25 though the current may be reestablished in successive half cycles.

Other and further objects and advantages will become apparent as the description proceeds.

In accordance with my invention in its pre-
30 ferred form, I provide a low-voltage source for supplying normal load current to a circuit breaker to be tested. The source need have comparatively little power owing to its low voltage. One or more surge generators are provided and they are ar-
35 ranged to be released in succession, one of them being released after each current interruption of the breaker in cases where the current is reestablished and more than one current interruption occurs. The voltages of the surge gener-
40 ators are applied to the breaker contacts to simulate the recovery voltages produced when the breaker is operating under actual voltage and power conditions. For tripping the surge gener-
45 ators, electric valve apparatus may be employed having control circuits inductively connected to the circuit supplying current to the breaker.

The invention may be understood more readily from the following detailed description when con- sidered in connection with the accompanying
50 drawings and those features of the invention which are believed to be novel and patentable will be pointed out in the claims appended hereto. In the drawings, Fig. 1 is a circuit diagram of one embodiment of my invention having a plurality
55 of surge generators with electric valve apparatus

for controlling the tripping of the surge gener- ators, and an arrangement for causing the trip- controlling apparatus to be connected to different surge generators in succession after each current interruption of the breaker; Fig. 2 is a frag-
5 mentary circuit diagram representing in part a modification of the arrangement of Fig. 1 in which a plurality of electric valve devices is employed for controlling the tripping of the surge generators and the arrangement is such that the
10 trip-controlling devices are successively connected to be responsive to circuit interruption by the circuit breaker instead of connecting the same trip-controlling apparatus to the surge generators in succession as in the apparatus of Fig. 1; Fig. 3
15 is a fragmentary circuit diagram representing in part a further modification of the arrangement of Fig. 1 or Fig. 2 in which the trip-controlling circuits responsive to the polarity of the current interrupted are symmetrical; Fig. 4 is a fragmen-
20 tary circuit diagram of an alternative arrangement for reconnecting surge generator control circuits after the generators have operated; Fig. 5 is a fragmentary diagram of a modification in the arrangement of Fig. 1; and Fig. 6 is a simpli-
25 fied arrangement for use when exceptionally high voltage surges are not needed. Like reference characters are utilized throughout the drawings to designate like parts.

Referring now more in detail to the arrange-
30 ment illustrated in Fig. 1, I have shown by way of example one form of apparatus for testing a circuit interrupting device or circuit breaker 11 at high apparent power although the actual kilo-
35 volt-ampere input to the testing apparatus is relatively small. The current to be interrupted by the circuit breaker 11 is supplied by a source 12 and the recovery voltages are supplied by one or more surge generators 13, 14, 15, 16, etc., de-
40 pending upon how many times the circuit breaker 11 is expected to reestablish the current after having broken it. The surge generators 13 to 16 are of the type which may be charged com-
45 paratively slowly from a source at a moderately high voltage and released to supply energy rela- tively quickly at considerably higher voltage, al- though the power for charging them may be rela-
50 tively small. Electric valve apparatus 17 is employed for releasing the surge generators 13 to 16, and relays, which will be described more in de-
55 tail hereinafter are provided for connecting the re- lease or trip-controlling apparatus 17 to the surge generators in succession. In order to make the electric valve apparatus 17 responsive to the in-
terruption of current by a circuit breaker 11, a 55

coil 18 is provided in inductive relation to the circuit of the source 12 and the breaker 11, and the coil 18 is connected to control circuits of the electric valve apparatus 17.

5 The circuit breaker 11 to be tested may be of any of the types now in commercial use, such as oil-immersed circuit breakers, and is schematically represented as having a pair of relatively movable contacts 19. In the arrangement shown, 10 there is an operating rod 21 for opening and closing the contacts 19, and there is an operating mechanism 22 of any desired type for moving the rod 21.

The supply circuit 12 is one of sufficient current-carrying capacity to furnish any desired 15 current to the breaker 11 but is of low voltage since it need furnish only the voltage drop across the contacts 19. Preferably, a reactor 23 is interposed in the circuit 12 in order to prevent 20 surges produced by the surge generators 13 to 16 from damaging the supply source 12 or from being dissipated therein instead of in the circuit breaker 11. However, in case the supply source 12 has sufficient inherent reactance, it will obviously not be necessary to utilize an independent concentrated inductance, such as shown at 23.

For the purpose of obtaining an indication or a record of the behavior of the circuit breaker 11 under test, oscillographs are preferably 30 provided which are connected in a suitable manner. For example, for measuring the current through the breaker 11, an oscillograph 24 may be employed, which is connected across a shunt 25 connected in series with the supply source 12 and 35 the circuit breaker 11 and, for measuring the voltage across the contacts 19, an oscillograph 26 may be provided which may, if desired, be connected through a step-down capacitive potentiometer consisting of a plurality of condensers 40 27 connected in series across the contacts 19, the oscillograph 26 being connected across one of the condensers 28. The oscillographs 24 and 26 should be so arranged that their records can be synchronized. This may be done by having the 45 two of them record on the same rotating film, or by superimposing on each record a brief, sharp transient which will, by the time of its occurrence, indicate corresponding instants on the two time scales. The oscillographs 24 and 26 may 50 be of any desired type known in the art, such as cathode ray oscillographs, for example, which are particularly useful in case of high-speed transients, but the particular type of the oscillograph does not constitute a part of my invention and the oscillographs and their connections need 55 not, therefore, be described in detail. Preferably, for the sake of safety and for assuring definiteness of the potentials of various parts of the apparatus, one side of the supply source 12 is 60 grounded by means of a connection, such as the ground connection 29.

The surge generators 13 to 16 are similar in construction and may be of a type well known 65 in the art. It will, therefore, be sufficient to refer briefly to one of the surge generators, for example, the surge generator 13. There is a plurality of condensers 30, 31, 32, 33, and 34 connected in shunt to a source of charging current having a moderately high voltage of a given polarity but 70 not necessarily having a very high current capacity. The source of charging current may consist of a high-voltage alternating-current source 35 with a rectifier 36 of the two-electrode discharge-tube type for example. One side 37 of the condenser 34 is grounded and likewise one side of

the source 35 is grounded. The electrodes of the device 36 are shown as being so arranged that 75 current flows from the source 35 through the rectifier 36 and charges the side 38 of the condenser 34 positively. Relatively high resistance connections 39 are provided between the condensers 30 to 34 to join the condensers in parallel with respect to the charging source 35. A plurality of discharge gaps 40 is provided, which gaps are so connected that, with respect to the circuits 10 through the gaps 40, the condensers 30 to 34 are in series instead of in parallel. There is a gap 41, in the output circuit of the surge generator 13, having a pair of electrodes 42 and 43. The electrode 42 serves as the output terminal of the 15 surge generator and the electrode 43 is connected to the high potential terminal 44 of the circuit breaker 11.

The surge generator 13 is adjustable for producing transients of any desired wave shape. For 20 this purpose, the constants, such as capacity, may be variable, and adjustable shunt or series resistances, inductances, and capacitances (not shown) may be included but, since this feature is well known in the art and is not a part of my invention, it need not be described in detail. 25

In order to guard against interaction between the surge generators 13 to 16 whereby the discharge of one generator might trip the other generators, inductance coils are placed in the output 30 leads of the surge generators, and a high-resistance ground is placed in the circuit between the inductance and the surge generator, the inductance 45 being connected in series between the circuit breaker 11 and the electrode 43 of the gap 41 and a high-resistance 46 being connected from electrode 43 to ground. 35

The surge generator 14 and its connections are similar to the surge generator 13 and its connections with the exception that the discharge tube rectifier 47 of the surge generator 14 has 40 its electrodes reversed, causing the condensers of the surge generator 14 to be charged with the opposite polarity and causing a surge of the opposite polarity to be provided by the surge generator 14 when released. In a similar manner, 45 the polarities of the surge generators 15 and 16 and any additional generators which may be provided are alternately reversed.

For the purpose of tripping or releasing the surge generators, means are provided for applying 50 a voltage suddenly to one of the gaps 40, causing it to break down, whereupon the transient produced will break down all of the gaps and trip the entire surge generator. The control apparatus for tripping the surge generators is so 55 arranged that, upon the interruption of current by the breaker 11, a suitable tripping voltage is applied to the surge generator and a recovery voltage transient is applied to the contacts 19 directly following current interruption in the same 60 manner as in actual full-power operation of circuit breakers. The tripping voltage for the surge generators is provided by the electric valve apparatus 17 and the tripping voltage for the discharge tubes of the apparatus 17, in turn, is 65 produced by the circuit comprising the coil 18, a condenser 48, and a resistance 49 upon the cessation of current through the circuit of the source 12 and the breaker 11. 70

The coil 18 may be the secondary winding of a transformer having a primary winding connected in series with the circuit breaker 11, or the coil 18 may merely be so placed as to have some mutual inductance with respect to the circuit of 75

the breaker 11. The condenser 48 and the resistor 49 are connected in series with the coil 18. For the purpose of preventing the appearance of tripping voltage across the resistor 49 and consequent operation of the tripping apparatus during extremely brief discontinuities, such as may result from a current zero during the arcing period, a condenser 50 may be connected across the resistor 49 and a second resistance 49a may be connected in series with the combination, or an additional inductance 49b may be placed in the circuit in series.

In order to keep the control circuits deenergized except during the opening operation of the circuit breaker 11, an auxiliary switch 51 is provided which may be operated by independent timing means or may be connected mechanically or otherwise to the operating rod 21 of the circuit breaker 11. For example, the switch 51 may have a movable contact 20 carried by the operating rod of the circuit breaker 11. The arrangement is such that the switch 51 is closed at an early point in the opening stroke of the circuit breaker 11. For example, the flexibility of the movable contact 19 or its supports may be such that the switch 51 closes before the circuit breaker 11 actually opens. The switch 51 is interposed in a connection between the resistor 49 and the control circuits of the trip-controlling apparatus 17.

The trip-controlling apparatus 17 comprises a pair of three-element electric valves 53 and 54, which may be discharge devices or discharge tubes, having suitable sources of anode current 55 and 56 and sources of grid-biasing potential 57 and 58, respectively. The discharge tube 53 consists of a gas or vapor filled envelope 59 containing an anode 60, a cathode 61 having a source of heating current not shown, and a grid or control electrode 62. Similarly, the discharge tube 54 includes an anode 63, a cathode 64, and a grid or control electrode 65. A resistor 52 having high resistance is connected from the input side of the grid-biasing potential source 57 to the cathode 61 of the tube 53 in order to prevent accumulation of stray charges on the grid 62 which might cause false tripping of the tube.

A resistor 66 is connected between the positive terminal of the anode source 55 and the anode 60 of the tube 53. The negative side of the source 55 is connected to the cathode 61 of the tube 53 through the resistor 49 and the switch 51. The resistor 52 is in parallel with the resistor 49 but carries a relatively small proportion of the current owing to its higher resistance. The anode current source 56 has its positive terminal connected to the anode 63 of the tube 54 and its negative side is connected to the cathode 64 of the tube 54 through a resistor 67. The anode 60 of the tube 53 is connected through a condenser 68 to the negative side electrode 69 of one of the gaps 40 of the surge generator 13. In a similar manner, the cathode 64 of the discharge tube 54 is connected through a condenser 70 to the positive side electrode 71 of one of the gaps 40 of the surge generator 14. In the arrangement shown, the connections of the condensers 68 and 70 are through the contacts of relays 12 and 13, respectively, the purpose of which will be described hereinafter in connection with tests in which the circuit breaker is expected to reestablish the current more than once.

The operation of the apparatus thus far described is as follows:

Let it be assumed that the current source 12 is causing current of a predetermined value to

flow through the circuit breaker 11, the contacts of which are closed, the current flowing representing the short-circuit current for which the test is to be made. The interrupting characteristics of the circuit breaker 11 are then tested by causing the operating mechanism 22 to separate the contacts 19 whereupon the switch 51 is closed and the surge generator tripping apparatus 17 is connected in readiness to cause a recovery voltage transient to be applied between the contacts 19 when the arc is broken between these contacts.

It is obvious that, during the normal flow of current through the breaker 11, a voltage will be induced in the coil 18 by the sine wave variations in current in the circuit of the source 12, assuming this is an alternating-current circuit, and, of course, no voltage will be induced in case the test is made with a steady direct current and the source 12 is a direct-current source. The greater part of whatever voltage is induced will appear across the condenser 48. When the breaker attempts to clear, however, the rate of change of current will change suddenly from a high rate, as the current approaches zero, to zero as the current remains zero or substantially so. The voltage of the mutual inductance or coil 18 will likewise change suddenly from a high value to zero. The voltage across the condenser 48, being incapable of rapid change, a voltage will suddenly appear across the resistance 49 as well as across the resistor 52 in shunt with the resistor 49. The polarity of the induced voltage will, of course, depend upon the direction of the current interrupted by the circuit breaker 11 and a positive voltage impulse will be furnished to one or the other of the control grids 62 or 65 of the discharge tube apparatus 17.

Assume that the polarity is such as to raise the voltage of the grid 62 of the tube 53 controlling the surge generator 13. The rise in potential of the grid 62 will fire the discharge tube 53, causing current to flow through the resistor 66, thereby suddenly depressing the potential of the anode 60 and causing a sudden drop in potential to be transmitted to the gap electrode 69 through the condenser 68. The side 38 of the gap 40 is normally charged to positive potential and, accordingly, a sudden drop in the potential of the electrode 69 will increase the potential difference between the electrodes and initiate a discharge across the gap which, in turn, will cause all the gaps 40 of the generator 13 to discharge and an impulse at high voltage will cross the gap 42, impressing a recovery voltage transient on the circuit breaker 11. Although the condensers 30 to 34 are in parallel with respect to current supplied through the rectifier 36 and the resistances 39, they are in series with respect to a circuit through the gaps 40. When the gaps 40 are broken down, the conductivities of the resistances 39 are negligible in comparison and a very high voltage transient is delivered by the surge generator. It will be understood that the connections are such that the polarity of the surge provided by the generator 13 corresponds to the polarity of the recovery voltage transient which would occur in the circuit breaker 11, interrupting current in a circuit operating at full power and voltage.

If the direction of the current in the circuit breaker 11 had been opposite, the potential of the grid 62 would have been depressed instead of raised, thus having no effect on the surge generator 13 but the potential of the cathode 75

64 of the discharge tube 54 would have been depressed, causing the discharge tube 54 to fire. The resultant initiation of the flow of current through the resistor 67 would suddenly have raised the potential of the cathode 64, causing a raising of the potential of the electrode 71 of the gap 40 of the surge generator 14. It will be recalled that the condensers of the surge generator 14 were so charged that the side 38' of the condenser 34' was negative with respect to electrode 71 and, consequently, raising the potential of the electrode 71 will initiate a discharge in the surge generator 14 resulting in the application of a recovery voltage transient to the circuit breaker 11 of the opposite polarity to that furnished by the surge generator 13.

Whichever of the two surge generators 13 or 14 discharges first, it will be understood that, upon the interruption of the next half cycle of current, the current direction will be the opposite and accordingly the other of the two surge generators will be released, thus simulating actual conditions under which, if the current is reestablished after the first interruption, a recovery voltage of reversed polarity will occur after the second interruption.

In response to the first surge, the tested breaker may either maintain an open circuit or break down along the previous arc path. In the former case, if the surge is made to simulate a given recovery transient in shape, the circuit has established the ability of a breaker to clear the applied current in combination with that recovery transient, which may correspond to a much higher 60 cycle voltage than that at which the current was supplied. In the latter case, the circuit is reestablished through the test breaker and current from the 60 cycle source will flow for another half cycle after which the second surge generator will be discharged, giving the test breaker a second opportunity to clear against a high voltage surge.

Should the circuit breaker 11 fail to clear on the discharge of the second surge generator, it will, as far as the circuit thus far explained, including only surge generators 13 and 14, is concerned, have lost its last opportunity to clear against the high voltage surge. Even in this case, however, the circuit may have performed a valuable function. This arises from interrupting characteristics of many circuit breakers and notably the fact that, with increase of current beyond a certain point at a given voltage, the breaker tends to interrupt with shorter and shorter arc lengths so that the consistent clearing of any current beyond this point gives a good indication of the ability of the breaker to clear any greater current at the same voltage provided the attendant mechanical forces are not so great as to cause breakage. When the rating of the breaker exceeds the current which the testing plant is able to deliver at rated voltage, it is customary to check the mechanical forces by tests at rated current or more but at reduced voltage. These forces are, to some extent, dependent upon arc duration, however, and the arc duration may decrease with reduction in test voltage so that, in many cases, such testing is either not fully effective or requires compensation for short arc lengths by increase of current beyond rating, which attempts to compensate for understress at one instant during the interruption period by overstress at another. In such a case, it is always open to question whether the compensation is insufficient or excessive or

possibly insufficient in one respect and excessive in another at the same time. The use of the circuit described with surge generators 13 and 14, however, increases the arc duration by one or two half cycles and this is usually sufficient to render it equal to that obtained at full voltage. Thus the mechanical forces, which depend directly only on current and arc duration, will be the same in these tests at reduced voltage as in full voltage tests.

Should it be required to prolong the arcing still further or actually to clear the circuit against a high voltage surge where this is not accomplished with the application of two surges, further surges may be obtained by the use of any additional number of surge generators, such as the generators 15 and 16, in combination with relaying devices, such as the devices 72 and 73. For example, the relaying device 72 may be actuated by the discharge current from the surge generator 13 to disconnect the anode 60 of the discharge tube 53 from the surge generator 13 and to connect the anode 60 to the third surge generator 15, which will operate on the third or the fourth attempt to clear, depending upon polarity. Similarly, the relaying device 73 will effect a transfer of the connection of the cathode 64 of the discharge tube 54 from the surge generator 14 to the surge generator 16 supplying a surge of polarity opposite to that of generator 15.

The relaying device 72 is of the pick-up type having a yoke 74 of magnetizable material, such as soft iron, an armature 75, a movable contact 76 mechanically connected to the armature 75, two pairs of stationary contacts 77 and 78 co-operating with the movable contact 76, and a snap-action spring 79 for holding the movable contact 76 in engagement with one of the other of the pairs of stationary contacts 77 and 78. The yoke 74 links one of the current-carrying conductors of the surge generator 13; for example, it may link one of the leads of the lowermost condenser 33 connected between the points 37 and 38. The lower stationary contacts 77 are in the connection between the condenser 38 and the surge generator 13 and, before tests are made, the apparatus is placed in its initial position with the movable contacts 76 downward engaging the contacts 77 so that the first impulse delivered through the discharge tube 53 causes the surge generator 13 to deliver a surge to the circuit breaker 11. Thereupon, the yoke 74 picks up the armature 75 and causes the movable contact 76 to engage the upper stationary contacts 78. The anode 60 of the discharge tube 53 is now connected through the condenser 38 to the surge generator 15. The connection to the surge generator 15 corresponds to that formerly existing to the surge generator 13 and accordingly, upon the next operation of the discharge tube 53, the surge generator 15 will deliver a surge.

The construction and connections of the relaying device 73 are similar with the exception that the relaying device 73 transfers the connection of the cathode 64 of the discharge tube 54 and the condenser 70 from the surge generator 14 to the surge generator 16. If additional surge generators are desired, additional relays corresponding to 72 and 73 may, of course, be employed so as to transfer the connection from the surge generator which has just been released to a succeeding surge generator of the set. However, the surge generators, although charged much more slowly than discharged, are capable of

of becoming charged and being ready to deliver another surge within several half cycles and, if desired, the last pair of surge generators may have relays arranged directly or indirectly to transfer connections back to the first pair of surge generators 13 and 14. For example, the surge generators 15 and 16 which, in this case, represent the last pair of surge generators, although there may be other intermediate pairs of surge generators, may have relays 81 and 82 each arranged to close a circuit through windings, such as the windings 83 and 83', respectively, for restoring the transfer relays, such as the relays 72 and 73, respectively, of all the previous surge generators of each polarity to the lower position.

With only four surge generators, however, a direct mechanical connection may be employed, as illustrated in Fig. 4, and the relay 81 of Fig. 1 may be replaced by a yoke 85 and an armature 86 connected to the contact-operating rod 80 of the relay 72. The yoke 85 will be reversed in position with respect to the yoke 74 so that, when the surge generator 15 is released, the yoke 85 will draw down the armature 86 and restore the movable contact 76 to its lower position in engagement with the stationary contacts 77. The construction and arrangement of parts replacing the relay 82 are similar to those shown in Fig. 4 and serve to restore the movable contact of the relay 73 to its lower position upon release of the surge generator 16.

In the arrangement of Fig. 2, separate pairs of discharge tubes 53 and 54, 87 and 88, etc., are employed for controlling successive pairs of surge generators 13 and 14, 15 and 16, etc. The purpose of this arrangement is to permit the transfer relays for shifting connections to successive surge generators to operate at lower voltages by having the contacts connected in the grid circuits of the discharge tubes instead of in the anode circuits. There are relay devices 89, 90, 91, and 92 corresponding to the relay devices 72, 73, 81, and 82 and having yokes 74 and so on similarly placed. The contacts, however, control the grid circuits instead of the anode circuits. The relay device 89 has a lower pair of stationary contacts interposed in the lead 94 connecting the terminal 95 of the auxiliary switch 51 to the grid-biasing potential source 57 of the discharge tube 53. The upper pair of stationary contacts 96 of the relay device 89 is interposed in a lead 97 from the terminal 95 of the auxiliary switch 51 to the grid-biasing potential source 98 of a discharge tube 87 having an anode 99 connected through a condenser 100 to a suitable control point in the surge generator 15. Thus, after the surge generator 13 has operated, the movable contact will close the stationary contacts 96 and cause the surge generator 15 to be released by the firing of the tube 87 upon the next circuit-breaker current interruption of the polarity which previously released the surge generator 13. Likewise, the relay device 90 has a lower pair of stationary contacts 101 interposed in the grid circuit of the discharge tube 54, and an upper pair of stationary contacts 102 interposed in the grid circuit of the discharge tube 88, the latter discharge tube having a cathode 103 connected through a condenser 104 to a suitable point in the surge generator 16. It will be observed that the grid leak resistor 52 of Fig. 1 is replaced by separate grid leaks 52a, 52b, 52c, and 52d, one for each tube, in Fig. 2.

Fig. 3 illustrates a modification in the arrangement of discharge tube circuits of either Fig. 1 or Fig. 2 in which both discharge tubes of a pair are controlled by raising the grid potentials with respect to ground instead of controlling one discharge tube, such as the discharge tube 53, by raising the potential of its grid 62 above ground potential and controlling the other discharge tube 54 by lowering the potential of its cathode 64 below ground potential. In the arrangement of Fig. 3, the resistor 49 of Figs. 1 and 2 is replaced by a corresponding resistor 105 having a midterminal 106 and end terminals 107 and 108, the end terminals 107 and 108 being connected across the condenser 50 of Figs. 1 and 2. The switch 51 of Fig. 1 is replaced by a double-pole switch 109 having separate blades 110 and 111 interposed in the circuits from the end terminals 107 and 108, respectively, of the resistor 105. The midterminal 106 of the resistor 105 is grounded. The resistor 52 of Figs. 1 and 2 is also replaced by a resistor 112 having a midterminal 113 connected to the midterminal 106 of resistor 105 and having end terminals 114 and 115 adapted to be connected to end terminals 107 and 108, respectively, of the resistor 105 when the switch 109 and the relaying devices 89 and 90 are closed.

The end terminal 114 of the resistor 112 is connected to the grid 62 of the discharge tube 53 analogous to the arrangement of Figs. 1 and 2. The cathode connection of the discharge tube 53, however, is made to the midpoints 106 and 113 of the resistors 105 and 112 instead of to the remaining end point of the resistor 52, as in Figs. 1 and 2, and the grid connection of the discharge tube 54 is made to the end point 115 of the resistor 112. The contacts 93 and 101 of the transfer relays 89 and 90, respectively, may be interposed, if desired, in series with the contacts 110 and 111.

It will be understood that, for the purpose of applying successive surges when current is reestablished through the breaker more than twice, the transfer relay arrangement of either Fig. 1 or Fig. 2 may be utilized in connection with the tube connection of Fig. 3. If the transfer arrangement of Fig. 2 is used, there will be a plurality of pairs of tubes, such as 53 and 54, with transfer relays including contacts 93 and 101 for transferring connections. In this case, the contacts 77 will not be employed. On the other hand, if the transfer arrangement of Fig. 1 is used, the contacts 93 and 101 will be omitted, only one pair of tubes 53 and 54 will be needed, and the transfer of connections will take place through relays connected as shown at 72, 73, 81, and 82 in Fig. 1, including contacts such as contacts 77.

It will be apparent, in the arrangement of Fig. 3, that, when an impulse of one polarity is induced in the coil 18, one of the discharge tube grids, for example, the grid 62, will be raised in potential whereas, when an impulse of the other polarity is induced in the coil 18, the other discharge tube grid 65 will be raised in potential. In this manner, the discharge tube 54 as well as the discharge tube 53 is fired by having its grid potential raised, the cathodes of both tubes being normally grounded.

Under certain circumstances where particularly great speed of response is desired, it may be preferable to modify the arrangements of Figs. 1, 2, and 3 by changing the connections of the grid-controlled discharge tubes and using three-electrode gaps in alternate surge generators for

initiating the discharge. The modification of the circuits of the embodiment of Fig. 1 for this purpose is illustrated in Fig. 5. Corresponding changes in tube connection may likewise be made in the embodiments of Figs. 2 and 3.

In the arrangement represented by Fig. 5, negative voltage impulses are utilized to trip each of the surge generators. The negative side of the voltage source 55 is connected directly to the cathode 61 of the tube 53. The resistor 67 in the cathode lead of the tube 54 is replaced by a resistor 67' in the anode lead of the tube. The electrode 69 of the lowermost gap 40 of the surge generator 13 is connected through the condenser 68 to the anode 60 of the tube 53 as in the arrangements previously described. However, the lowermost gap 40' of the surge generator 14 or of any other surge generators 16, etc., having the same polarity, in the arrangements previously described, is replaced by a three-electrode gap 121 having an electrode 122 substantially at ground potential prior to discharge, a negative electrode 123, and a middle electrode 124. A high-resistance resistor 125 is connected between the electrodes 122 and 123, and the electrode 124 is connected to an intermediate point in the resistor 125 for the purpose of holding the middle electrode 124 normally at a potential intermediate the potentials of the electrodes 122 and 123. The anode 63 of the tube 54 is connected to the middle electrode 124 of the gap 121 through the condenser 70 and also through the contacts of the relaying device 73, if the latter is used.

The tripping of the surge generator 13 and any others of like polarity takes place as previously described. In the arrangement represented by Fig. 5, the surge generator 14 and any others of like polarity are also tripped by negative potential impulses. When the tube 54 becomes conducting, the potential of its anode 63 falls by reason of the voltage drop in the resistance 67' and the potential of the middle electrode 124 of the gap 121 is depressed. In consequence, the difference in potential between the electrodes 122 and 124 causes this portion of the gap to break down. A discharge of all the condensers of the surge generator 14 is thereby initiated and a voltage surge is applied to the circuit breaker 11.

In Figs. 1 to 5, I have illustrated arrangements in which my invention is employed in connection with surge generators suitable for delivering extremely high voltage surges. However, in cases where such high voltages are not needed, simpler types of surge generators may be employed. For example, in the arrangement illustrated in Fig. 6, two condensers 126 and 127 serve as generators for surges of opposite polarities. Two three-electrode gaps 128 and 129 are employed for controlling the surges and delivering them to the high-voltage terminal 44 of the circuit breaker 11. The middle electrode 130 of the gap 128 is connected to the anode 60 of the tube 53 through the condenser 68, and the middle terminal 131 of the gap 129 is connected to the anode 63 of the tube 54.

As in the arrangements previously described, one or the other of the tubes 53 and 54 becomes conducting upon the interruption of current by the breaker 11, depending upon the polarity of the current interrupted. When either tube 53 or 54 becomes conducting, the potential of the corresponding middle electrode 130 or 131 of the three-electrode gaps is depressed and a discharge takes place from the middle electrode to one of

the adjacent electrodes, thereby initiating a discharge of the corresponding condenser 126 or 127 and applying a voltage surge to the circuit breaker 11.

I have herein shown and particularly described certain embodiments of my invention and certain methods of operation embraced therein for the purpose of explaining its principle and showing its application but it will be obvious to those skilled in the art that many modifications and variations are possible and I aim, therefore, to cover all such modifications and variations as fall within the scope of my invention which is defined in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States, is:—

1. Apparatus for testing circuit interrupting devices comprising in combination, a supply circuit for current to be interrupted by an interrupting device under test, a coil in inductive relation to said circuit, a capacitor and a resistor in series with said coil, a surge generator connected to said circuit, and means responsive to voltage across said resistor for releasing said surge generator.

2. Apparatus for testing circuit interrupting devices comprising in combination with a circuit interrupting device under test, an operating member, means for passing test current in a circuit through said device, a surge generator with terminals connected across said device and with a control terminal, a coil in inductive relation to said circuit through said device, a condenser and a resistor in series with said coil, a second resistor, a switch so connected mechanically to said operating member as to close when said interrupting device is open and so connected electrically to said resistors as to connect them in shunt when said switch is closed, a discharge device with a grid circuit including said second resistor, a current source, a third resistor, said discharge device, third resistor, and current source being connected in series to constitute a discharge circuit, and a capacitance connection to said surge generator control terminal from a point in said discharge circuit between said third resistor and said discharge device.

3. Apparatus for testing circuit interrupting devices comprising in combination with a circuit interrupting device under test, means for passing testing current in a circuit through said device, a surge generator with terminals connected across said device and with a control terminal, impulse-producing means responsive to sudden cessation of current in the circuit through said device, a discharge tube device having a control electrode connected to said impulse-producing means and including a resistor in a discharge circuit controlled by said electrode, and means for transmitting potential variation from said resistor to the control terminal of said surge generator upon excitation of said control electrode to produce a discharge through said resistor.

4. Apparatus for testing circuit interrupting devices comprising in combination, a circuit for passing testing current through a device to be tested, impulse-producing means responsive to sudden cessation of current through said circuit, a surge generator having output terminals for connection across a circuit breaker to be tested and a control terminal, and voltage variation producing means connected to said control terminal having a control electrode connected to said impulse-producing means.

5. Apparatus for testing circuit interrupting devices comprising a circuit for passing a testing current through a circuit interrupting device, a surge generator for applying a recovery transient to a circuit interrupting device, and means responsive to sudden cessation of current in said testing circuit for releasing said surge generator.

6. Apparatus for testing circuit interrupting devices comprising in combination with a circuit interrupting device under test, means for passing testing current in a circuit through said device, a pair of surge generators of opposite polarity, each with terminals connected across said device and each with a control terminal, voltage impulse producing means responsive to sudden cessation of current in the circuit through said device, a pair of discharge devices having control electrodes connected to said voltage impulse producing means and responsive to impulses of opposite polarities and having resistance-including discharge circuits controlled by said electrodes, a connection between the control terminal of one of said surge generators and a point in the discharge circuit of one of said discharge devices, and a connection between the control terminal of the other of said surge generators and a point in the discharge circuit of the other of said discharge devices.

7. Apparatus for testing circuit interrupting devices comprising a circuit for passing a short-circuit simulating current through a circuit interrupting device to be tested, a pair of surge generators of opposite polarities for applying recovery voltage transients to a circuit interrupting device to be tested, voltage variation producing means having control electrodes responsive to voltage impulses of opposite polarities, connections between said voltage variation producing means and said surge generators for releasing one or the other of said generators according to which control electrode is excited, and voltage impulse producing means responsive to sudden cessation of current in said testing circuit and connected to said control electrodes.

8. Apparatus for testing circuit interrupting devices comprising a circuit for passing a current through a circuit interrupting device to be tested, a plurality of surge generators of alternately opposite polarities for applying recovery voltage transients to a circuit interrupting device to be tested, a voltage impulse producing means responsive to sudden cessation of current in the testing current circuit, discharge apparatus for producing voltage variations to release said surge generators having output terminals adapted to be connected to said surge generators and control electrodes responsive to voltages of opposite polarity connected to said voltage impulse producing means, and means for transferring the connections of said discharge apparatus from a preceding surge generator to a subsequent surge generator in response to operation of the preceding surge generator.

9. Apparatus for testing circuit interrupting devices comprising a circuit for passing a testing current through a circuit interrupting device to be tested, a plurality of surge generators for applying recovery voltage transients to a circuit interrupting device to be tested, discharge devices for releasing said surge generators, each generator having an associated discharge device for releasing it, each discharge device having a control electrode, voltage-impulse producing means responsive to sudden cessation of current in said testing circuit, and relay devices for con-

necting said impulse-producing means to successive control electrodes in response to successive operation of said surge generators.

10. A device for testing circuit interrupting devices comprising a circuit for passing a testing current through a circuit interrupting device to be tested, a plurality of surge generators for applying recovery voltage transients to the circuit interrupting device being tested, impulse-producing means responsive to sudden cessation of current in the testing circuit through a device being tested, a connection between said impulse-producing means and one of said surge generators for releasing the generator upon production of the voltage impulse, a plurality of relay devices, one less than the number of surge generators, each relay device being responsive to release of an associated surge generator to transfer the connection of the voltage impulse producing means from a preceding surge generator to a subsequent surge generator, and a relay device associated with the last surge generator responsive to release thereof to restore said first mentioned relay devices to their initial position.

11. A device for testing circuit interrupting devices comprising in combination, a circuit for passing a testing current through a circuit interrupting device to be tested, a pair of surge generators for applying recovery voltage transients to the device being tested, impulse-producing means responsive to sudden cessation of current in the testing circuit, connecting means between said impulse-producing means and said surge generators for causing release of said surge generators upon production of an impulse, a relay device having a pair of operating mechanisms, one of which is responsive to release of one surge generator and the other of which is responsive to release of the other surge generator, and a transfer element actuated by said operating elements for transferring the connection of said impulse-producing means from one surge generator to the other and vice versa.

12. Apparatus for testing circuit interrupting devices comprising in combination, a supply circuit for current to be interrupted by a circuit interrupting device under test, a coil in inductive relation to said circuit, a capacitor and a resistor in series with said coil, a surge generator connected to said circuit, and means responsive to voltage across said resistor for transferring a voltage impulse to said surge generator.

13. Apparatus for testing circuit interrupting devices comprising in combination, a supply circuit for current to be interrupted by a device under test, a surge generator for applying a recovery voltage transient to the circuit interrupting device under test, impulse-producing means responsive to a sudden cessation of current from the supply circuit, and means for transferring impulses from said impulse-producing means to said surge generator for releasing it.

14. A device for testing circuit interrupting devices comprising in combination, a circuit for passing a test current through a circuit interrupting device to be tested, a plurality of surge generators for applying recovery voltage transients to the device being tested, impulse-producing means responsive to sudden cessation of current in the testing circuit, connecting means between said impulse-producing means and said surge generators for causing release of said surge generators upon production of an impulse, and relay devices, each responsive to release of an associated surge generator to transfer the con-

nection of the voltage impulse-producing means from a preceding surge generator to a subsequent surge generator.

- 5 devices comprising, a circuit for passing a load
10 simulating current through a circuit interrupting
device to be tested, a pair of surge generators
of opposite polarities for applying recovery volt-
age transients to a circuit interrupting device
15 to be tested, a voltage impulse-producing means
responsive to sudden cessation of current in said
testing circuit, and means for selectively trans-
ferring impulses of opposite polarity from said
voltage impulse-producing means to one or the
15 other of said surge generators for releasing it.

16. Apparatus for testing circuit-interrupting
devices comprising in combination, a circuit for
passing a testing current through a circuit-inter-

rupting device, a pair of surge generators of oppo-
site polarity for applying recovery voltage tran-
sients to a circuit-interrupting device, and means
responsive to sudden cessation of current in said
testing circuits for releasing one or the other 5
of said surge generators according to the polarity
of the current flow interrupted in the testing
circuit.

17. Apparatus for testing circuit-interrupting
devices comprising in combination, a circuit for 10
passing a testing current through a circuit-inter-
rupting device, a plurality of surge generators of
alternately opposite polarity for applying recov-
ery voltage transients to a circuit-interrupting
device, and means responsive to sudden cessation 15
of current in said testing circuit for selectively
releasing said surge generators.

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