March 10, 1953 D. M. UMPHREY 2,631,190

CIRCUIT BREAKER LATCH MECHANISM

Filed April 17, 1950 2 SHEETS—SHEET 1

Fig. 1.

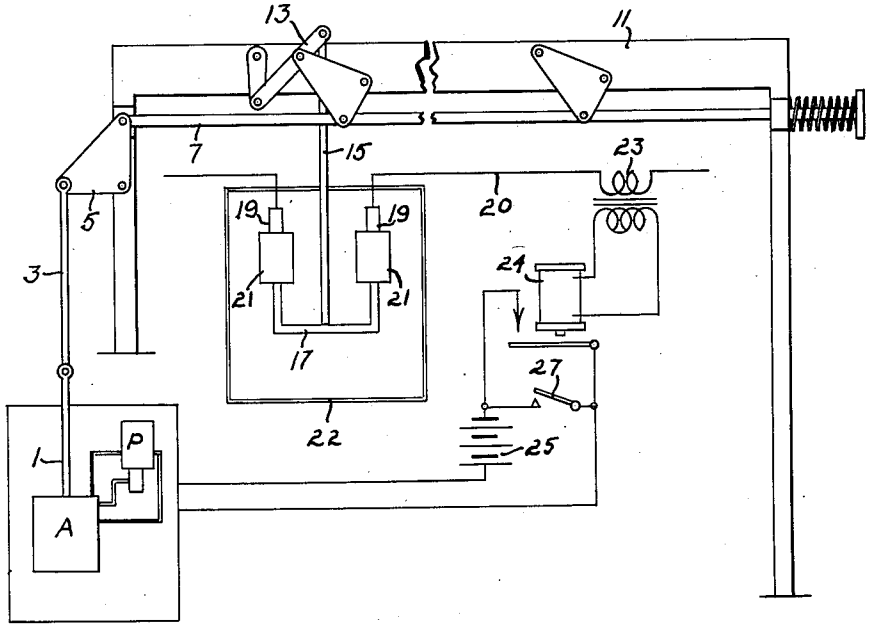
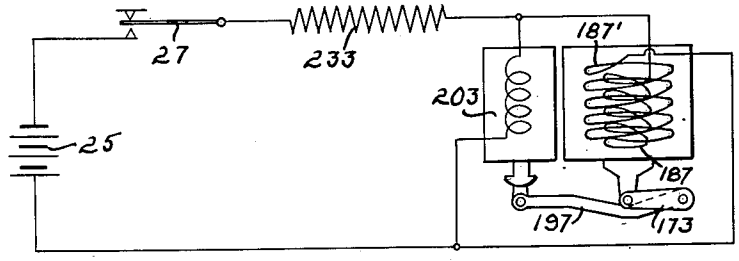


Fig. 3.



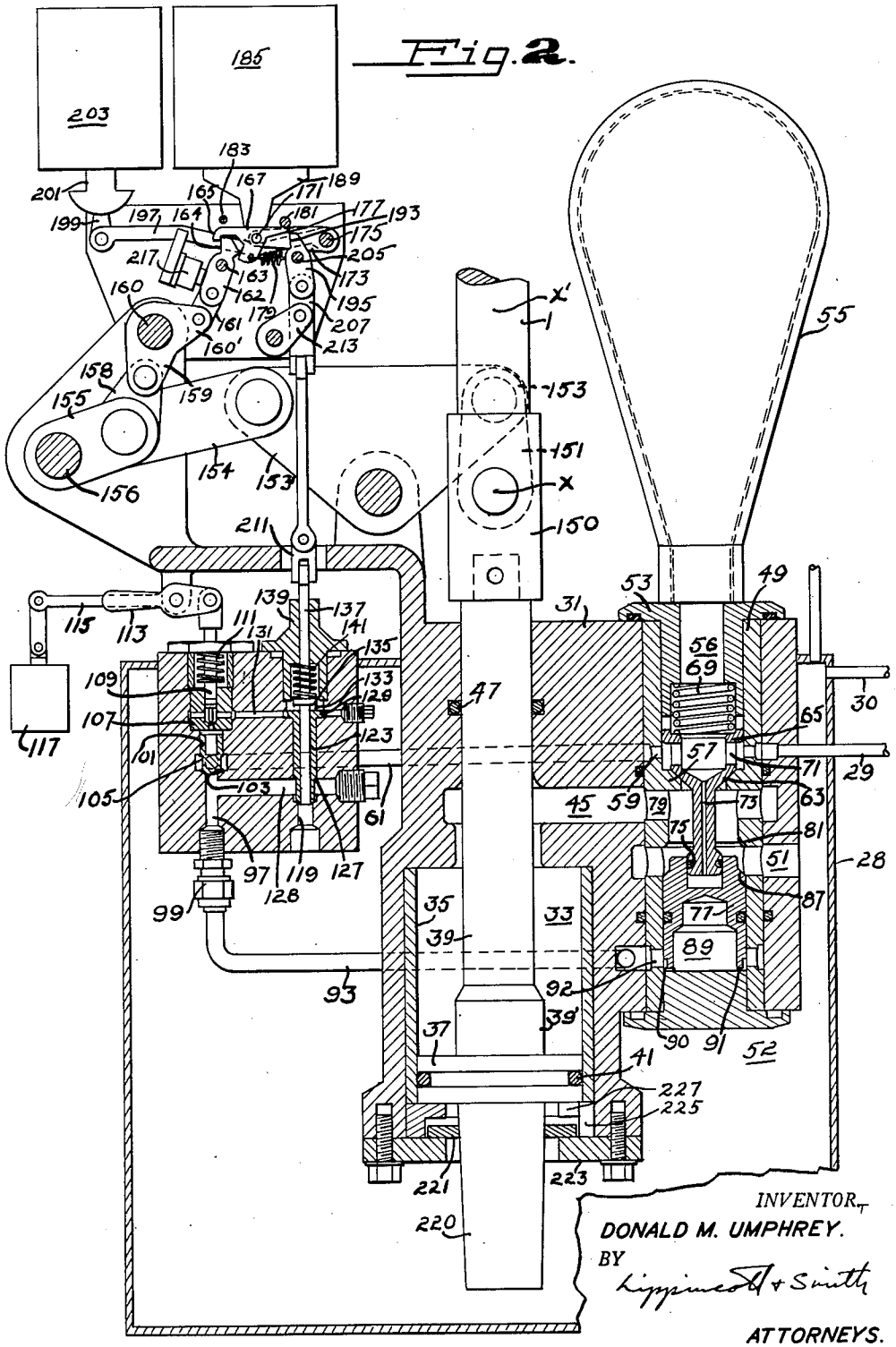
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Fig. 2.



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CIRCUIT BREAKER LATCH MECHANISM

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8 Claims. (Cl. 175—335)

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This invention relates to mechanisms for actuating circuit breakers, and while it is particularly applicable to circuit breakers of the largest size, as utilized for breaking high voltage circuits of large power-carrying capacity, it is also applicable to breakers of smaller types.

Among the objects of this invention are to provide a mechanism which will close a circuit breaker quickly and positively upon the application of either a local or remote control, to provide a mechanism wherein the break can be accomplished with extreme rapidity, i. e., in from one and one-half to two cycles following the application of a fault current of sufficient magnitude to cause the breaker to trip instead of requiring three cycles as is the case in more conventional breakers, to provide a mechanism which will trip free of the closing mechanism and break the circuit with substantially equal speed and positiveness in case a short circuit or other fault is either already present or occurs at the instant when the breaker is being closed, to provide a circuit breaker which will operate without failure if an attempt is made to reclose it while the fault still exists, to provide a circuit breaker mechanism employing a latching mechanism of the toggle type having a large mechanical advantage, but which has, at the same time, a minimum effective inertia, and, generally, to provide a circuit breaker mechanism of maximum reliability and simplicity.

The operating mechanism of this invention may be used in substantially any of the known types of circuit breakers, which, generally speaking, comprise one or more stationary contacts which are engageable by one or more moveable contacts. Trip mechanisms, operable either manually or in response to an overload or fault current, release means to separate the stationary and movable contacts, the separation usually being accomplished by means of a powerful spring in order that the circuit may be broken as rapidly as possible.

The equipment which is the subject of the present invention is for the purpose of closing the breaker against the action of the spring and includes the latch and trip elements referred to. Broadly speaking it comprises a source of hydraulic pressure, preferably a high-pressure pump plus a hydraulic accumulator. The latter may be of the type comprising a chamber to which the pump is connected, which chamber contains a bag or "balloon" containing, preferably, an inert gas such as nitrogen and formed of oil-resistant synthetic rubber or elastomer such

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as neoprene, since the actuating fluid is frequently an oil. By the use of the accumulator the primary pressure source may be a high pressure pump of small capacity, the normal function of which is merely to maintain the proper pressure in the accumulator which acts as a secondary pressure source.

The operating element for compressing the opening spring and thus closing the circuit breaker comprises a hydraulic cylinder and piston, the cylinder being connected by a conduit system both to the pressure source and to a sump into which the cylinder discharges the fluid contained therein when the circuit breaker opens, the fluid thus discharged being recirculated back to the accumulator. A hydraulically-operated valve in the conduit system connects the cylinder alternatively to the pressure source or, through an exit port, to the sump, this valve being so constructed that when hydraulic pressure is applied thereto it operates first to cut off the passage from the cylinder to the sump and then to open the conduit from the pressure source into the cylinder and thus operate the piston.

Where a breaker of the type here under consideration is used it is obvious that the possibility always exists that an attempt may be made to close it when a fault, such as a short circuit, exists on the line which it feeds. When this occurs it is important that the breaker should trip open as positively and substantially as rapidly as would be the case if the fault occurred with the breaker in its latched-closed condition and no hydraulic pressure applied thereto. This is particularly the case in self-reclosing circuit breakers which are designed to attempt to re-close the circuit automatically one or more times after a fault occurs, in the hope that such fault may be of a purely transient nature which will clear itself.

The mechanism for actuating the main valve while permitting the breaker to trip free when closed under a faulty line condition comprises a pilot valve interposed in a connection from the pressure source to the hydraulically-operated main valve and a dump valve which normally closes a bypass to the sump positioned between the pilot valve and the main valve, the dump valve being so constructed that it tends to open when pressure is applied through the pilot valve to the main valve line but is normally prevented from operating in response to such pressure by mechanical means which may be disabled by the operation of trip mechanism operating coordinately with the trip of the latch holding the circuit breaker closed.

The pilot valve, besides controlling the application of pressure from the source to the main valve, is preferably operated by pressure from the same source. It is, however, externally operable either by direct manual or by remote control. In its preferred form the pilot valve comprises a moveable valve element which, when subjected to pressure on one side, tends to close the pilot valve and when subject to pressure on the other side tends to open it, the area exposed to the closing pressure being greater than that exposed to the opening pressure so that when pressure is applied to both sides the valve tends to remain closed. The pressure is applied continuously and at full force to the side which tends to open the valve, but there is a leak or high-resistance passage to the closing side. Accordingly, under static conditions when there is no flow from the pressure source, the hydrostatic pressure on the two sides of the valve equalizes and because of the larger area tending to close the valve it remains tightly shut.

A passageway leads from the closing side of the valve element into the sump, this passage being normally blocked by an auxiliary valve which can be externally operated to actuate the mechanism. When this latter valve is opened the pressure tending to hold the valve closed is relieved and the pilot valve at once opens, actuating the main valve and closing the circuit breaker. If, however, the trip is actuated while this condition obtains the dump valve operates, relieving the pressure both upon the main valve and the opening side of the pilot valve element, the latter closes and the breaker trips free. Such process is speeded and made more positive by the fact that the operation of the dump valve also closes the passage into the sump from the closing side of the pilot valve, permitting the pressure to build up and, what is equally important, preventing the wasting of oil from the pressure source into the sump.

The pressures used within the mechanism to operate the various valves are preferably high—of the order of a few thousand pounds per square inch. To withstand these pressures the various parts of the valves are necessarily sturdy but their actual sizes are not large and their masses are relatively small. It will have been noted from the foregoing general description that differential pressures operate throughout and, as will be seen in the more detailed description which follows, the areas over which these pressures act are so computed that even the differential pressures are large and, acting upon the relatively small masses of the moving parts, operate them with extreme rapidity.

Speed of operation is, of course, of primary importance in circuit breakers. In order to obtain high operating speeds high rates of acceleration are necessary, which means either that the masses moved must be small, their velocities must be small or the actuating forces must be large. In high power circuit breakers the breaking mechanisms themselves have to be sturdy and to move through considerable distances and since this involves a considerable mass, large operating forces, i. e., powerful springs, are required, and this in turn necessitates that large forces be used to compress (or extend) the springs. In the past either mechanical methods have been used to close the circuit breakers, or, alternatively, pneumatic methods. The forces used to trip the circuit breakers, however, must be relatively small since these devices should be

sensitive and therefore the control equipment must be light in weight and move through reasonably small distances so that the accelerating forces do not become too high. Owing to the low inertia of gases and their relative ease of control, pneumatic circuit breaker operation is, on the surface, quite attractive and hydraulic methods have not been generally used because of the greater masses which must be moved. A careful examination of the problem, however, develops the fact that because of the compressibility of gases and their necessity of expanding into the operating cylinders or other equivalent chambers where they can exert their forces, a material lag is introduced in pneumatic devices. No such time for expansion is necessary when hydraulic actuation is used. Changes in pressure are propagated between control valves and any mechanism which such valves operate with the speed of sound in the medium which may well be several times that of the sound in air. The passages through which the pressure acts may be made short and the friction losses correspondingly low so that much quicker operation may be achieved through hydraulic means than through pneumatic.

Pneumatic breakers are, moreover, subject to a number of disdavantages which do not at first appear. Gases are hard to retain, leaks readily occur and are hard to detect, and therefore closed pneumatic systems are not used. With an open pneumatic system losses, due to leakage or to the release of gas when the pressure rises above the desired limit due to expansion from changing temperature, are supplied from the surrounding air by a pump which is electrically driven under the control of an electrically-operated switch. There is also, in such cases, inevitably a loss of compressed air every time that the breaker is actuated, which loss must also be made up by the pump. The power required for make-up of this character is not particularly important, but what is important is the fact that the air to be compressed always contains some water vapor and almost always is contaminated by carbon dioxide, sulphur dioxide, and frequently other even more corrosive materials. The water vapor condenses in the receiver of the system and must be blown out from time to time. It is always carried, to some extent, into the connecting lines and valves. Corrosion always takes place within the air receiver and frequently within the control valves. Particles of rust or other corrosion products may be carried through the air passages of the system into the valves causing them to stick, and because of the chances of actual perforation of the receivers or the pipes connecting the latter with the operating mechanism the whole device must be subject to constant inspection. Therefore, although the pneumatic operating system may be simpler and lighter in weight than the mechanical system and cheaper than a hydraulic system in first cost, it is, in the long run, more expensive and less reliable as well as slower in operation than the hydraulic system which is the subject of this application.

The above considerations may be more fully appreciated, and the invention and its various objects and advantages more fully understood, from the following detailed description of a preferred embodiment thereof, taken in connection with the accompanying drawings wherein:

Fig. 1 is a diagrammatic representation of a circuit breaker embodying a preferred form of the invention;

Fig. 2 is a sectional view of the closing, latching and release mechanism of such a breaker, the accumulator and main valve mechanism being shown, for the purposes of illustration, as being rotated 120 degrees from their actual position in order that the entire operating mechanism may be illustrated in a single diagram; and

Fig. 3 is a schematic circuit diagram of the electrical portion of the trip mechanism.

Figure 1 is a schematic diagram of one form of circuit breaker which may be operated by the subject mechanism of this invention. The type of breaker shown is merely illustrative since the invention may be modified to actuate almost any of the known types of breaker, of which there are many. In the figure the block A represents the mechanism more fully illustrated in Figure 2, the projecting plunger 1 representing the operating member which is driven downward hydraulically in order to close the breaker contact. The plunger 1 connects through a link 3 to a bell crank 5, the bell crank in turn operating a pull rod 7 which moves towards the left of the diagram and compresses an opening spring 9 when the plunger 1 is retracted or pulled downward. Bell crank 5 and pull rod 7 are mounted upon a suitable supporting framework 11.

Pivoted to the frame 11 and the pull rod 7 is a parallel motion linkage 13 of known type to which is connected a vertical bar 15. A transverse drop bar 17, carrying the movable contacts of the breaker, is secured to the lower end of the bar 15. The latter, as well as the pull rod 7, is preferably made of insulating material such as impregnated wood, porcelain, Bakelite, or other material having the requisite dielectric strength. When in the closed position shown in the diagram the moving contacts carried by the drop bar 17 make contact with fixed contacts 19 in the transmission line 20 which is to be controlled by the breaker. Connection between the fixed and movable contacts is made within interrupter structures 21 for extinguishing the arc. Fixed contacts, moving contacts, and interrupter are all preferably immersed in oil or other arc-quenching dielectric liquid within a tank 22.

Means are provided for tripping the breaker, either manually or in response to an overload, such means comprising, for example, a current transformer 23 in the line 20 which actuates a marginal relay 24, closing the relay contacts and completing a circuit, including a storage battery 25, to the trip mechanism of the breaker which will be described later. Alternatively the trip circuit may be actuated by closing a manually-operated switch or key 27.

As has been indicated, all of the parts referred to, with the exception of the mechanism A itself, are well-known in the art and might be taken for granted, but are shown here for the sake of completeness. It is to be noted that the one mechanism may operate a number of drop bar elements, for example, one set in each leg of a three-phase line. Under other circumstances separate mechanisms may be used in each phase so that if a fault occurs in one line only that particular line may be deenergized and the load carried, at least in part, by the other two phases. All such expedients are well known and need not be further considered here.

The block A of Fig. 1 represents a tank-like housing within which the actual operating mechanism is encased. Within this housing is a high-pressure motor-driven pump P, controlled by a pressure-actuated switch, which develops the hydraulic pressures for operating the device. The pump P withdraws hydraulic fluid from a tank or sump 28 and delivers it to the accumulator through a conduit 29. For protection against excess pressures a by-pass 30, controlled by a relief valve (not shown) returns excess fluid to the sump.

The hydraulic operating mechanism itself is preferably mounted on and (in part) encased within a base block 31 which may conveniently be a single casting. The bottom of this casting is bored or otherwise recessed to form a hydraulic cylinder generally indicated by the reference character 33, the cylinder being provided with a steel liner 35 of high tensile strength material to withstand the hydraulic pressures used. Within the cylinder a piston 37 is mounted on a piston rod 39 to which the breaker mechanism is connected through a linkage which will be described in detail later. Suitable means are used for sealing the piston against the hydraulic pressure which it is required to bear, a preferred means being a seal comprising a ring 41, of neoprene or other oil-resisting synthetic rubber, within a groove 43 formed in the periphery of the piston. A conduit 45 opens axially from the top of the cylinder 33; if the baseblock 31 is cast the conduit may be cored in the casting. Piston rod 39 runs through the axial opening into the cylinder, this port being of ample size to admit the oil or other hydraulic fluid around the piston rod. Above where the conduit 45 opens into the cylinder the block is accurately machined to size to form a bearing for the rod and a ring seal 47 is provided to prevent leaking of the hydraulic fluid around the piston rod.

The baseblock 31 is provided with a bore or other accurately-sized opening, whose axis is parallel to that of the cylinder 33, for receiving a main valve housing 49, the bore intersecting the conduit 45 and also an exhaust conduit 51 which opens into the sump 52 in which almost the entire baseblock 31 is submerged.

The main valve housing 49 is accurately fitted within its bore in block 31 and for additional security against leakage is provided with ring seals. At its upper end it carries, upon a flanged bushing 53, an accumulator reservoir 55, seals again being provided to prevent loss of pressure around the bushing and past the flange. The accumulator opens, through channel 56 through the bushing into the interior of the generally cylindrical main valve housing 49. A centrally ported septum 57 partially closes the housing 49 above the conduit 45, a conical poppet-valve seat being formed in the upper side of the port through the septum.

Above the septum the housing is provided with ports 59, one of these ports leading through a high pressure pipe or other connection 29 to the outlet of the high-pressure pump P; the other port leads through a similar connection (which may be bored or cored in the block 31) to the pilot and dump-valve mechanism which will later be described, this second connection being indicated schematically as a pipe 61. These connections are open at all times.

A poppet-valve 63 is seated in septum 57. This valve has a cylindrical section 65 rising above its conical valve face and terminating in a flange which slides in and is guided by the valve housing 49. A spring 69 bears against the upper portion of this flange, tending to keep the valve seated. This cylindrical portion of the valve is provided with ports 71 to permit the

flow of liquid past the flange and through the septum port into the lower body of the housing when the valve is open as well as to permit the flow of oil into and out of the accumulator through the ports 59. The stem of the poppet-valve 63 is of relatively large size and is provided with a longitudinal channel 73 therethrough, and has an enlarged foot 75.

The foot 75 fits within a recess formed in the top of a floating valve piston 77 and is provided with a ring seal which prevents leakage through the stem and recess.

Below the septum 57 the housing 49 is supplied with ports 79 connecting to the conduit 45. Below these ports, again, the opening within the housing is enlarged slightly to permit the formation of a conical valve-face 81 between the portion of the housing connection to the conduit 45 and its lower-most portion which forms a cylinder within which the valve-piston 77 slides. Immediately below the valve-face 81 ports 83 open into the discharge conduit 51 and the sump.

The lower end of the housing 49 is closed by a sealed plug 85 upon which the valve-piston rests when in its lower-most position. Piston 77 is generally cylindrical, and is sized to an easily sliding fit within the cylinder formed by the lower portion of the valve housing. At its upper end, however, there is a portion of reduced diameter to form a shoulder 87 which forms a valve-face seating against the valve-face 81 when the piston is in its raised position. Above the shoulder 87 the piston is sized to a sliding fit within the housing bore, so that as the piston rises it closes off the passage to the conduit 57 sufficiently well to prevent the escape of any material amount of hydraulic fluid even under the pressures applied from above until the conical faces 81 and 87 engage and complete a tight seal.

The lower end of the piston has formed within it a recess or counterbore 89. The outer diameter of the piston is also somewhat reduced at the lower end to form a channel 90 surrounding it, and a small notch 91 in the bottom of the piston connects this channel with the recess 89 to admit an initial flow of fluid thereto when pressure is applied. Channel 90 connects through port 92 in the housing 49 through a lead schematically indicated as a pipe 93 to pilot valve mechanism through which pressure for operating the mechanism is supplied.

It will be seen that when the valve piston 77 is in the position shown, poppet-valve 63 is held closed both by the hydraulic pressure from the accumulator and the spring 69. The effective area through which this pressure is applied is the diameter of the valve seat in the septum, minus the diameter of the enlarged foot 75 on the valve stem, since other portions of the valve are subjected to an equal opposing pressure. As pressure is applied through the connection 93 below the valve piston, however, it acts on the full diameter of the piston and therefore raises it very rapidly until the piston strikes the foot 75 of the poppet-valve. The parts are so proportioned that this occurs at the same instant that the reduced upper end of the piston enters the smaller bore above it and closes off the connection between the conduit 45 and the discharge conduit 51 into the sump. At this instant the piston starts to raise the poppet-valve also, opening it fully when the valve faces 87 and 81 engage and admitting the full hydraulic pressure from the accumulator to the conduit 45 and to the cylinder 33, thereby forcing the piston 37 down to the position shown in the drawing, and closing the breaker. At no time is the area upon which the operating pressure acts to force the main valve piston 77 downward greater than that referable to the reduced diameter of the upper portion of the piston, while the area below piston 77 is always equal to the full piston diameter and is therefore enough greater to cause positive operation of the valve.

When the pressure below the valve-piston 77 is relieved, however, the pressure from above it immediately forces it downward with the result that the poppet-valve 63 first closes, and the passage from the conduit 45 into the discharge conduit 51 next opens relieving oil pressure upon the operating piston 37 so that the circuit breaker may open under the full force of the spring 9 and without being subjected to any material retarding force from the hydraulic system during the major portion of its stroke. As the stroke approaches its end, however, an enlarged portion 39' of the piston rod enters the port into channel 45, restricting the flow of liquid and bringing the mechanism to rest without excessive shock.

It is to be noted that hydraulic pressure within the cylinder 33 is not relied upon to hold the circuit breaker in the operative position; instead a latch mechanism is provided together with means for relieving the pressure beneath the valve-piston 77 as soon as the closing operation is complete. The means for accomplishing this will next be described, first the hydraulic pilot and dump valves, finally the latching and tripping mechanism.

Both of the latter two valves are mounted in bores formed within a block 95 which may either be integral with the block 31 or may be separate and secured thereto. The pilot valve bore consists of a lower portion 97 of minimum diameter which connects, through a coupling 98 and a suitable hydraulic conduit 93 already mentioned, with the port 92 in the main valve cylinder. Above the portion 97 is a cylindrical bore 101 of somewhat larger diameter which connects with the bore 97 through a conical valve seat 103. The lower portion of the bore 101 communicates directly through the schematically indicated connection 61 and the port 59 with the high pressure source.

A loosely fitting piston 105 slides within the bore 101. No seals are provided for this piston, as it is intended to have the high pressure hydraulic fluid leak past it. The piston 105 has at its lower end a reduced portion terminating in a valve face engaging the valve seat 103 and forming, above it, a shoulder immediately above the port into the cylinder from the connection 61. Hydraulic pressure from the accumulator therefore operates against this shoulder and tends to raise the piston and open the passage from the connection 61 into the passage 93 and the main valve piston. Normally, however, this pressure is more than counterbalanced by pressure from the hydraulic fluid flowing past the piston and operating against the full area thereof, thus tending to close the valve.

The upper end of the cylinder 101 is closed by a valve block 107 which is axially apertured for a ring-sealed needle valve 109. The needle valve is normally held closed by a spring 111 of sufficient strength to hold the needle valve closed against pressure on its point from the cylinder 101. The needle valve may, however, be externally operated either by manipulation of a handle 113 or by remote control through the lever 115

and a solenoid 117 (which is schematically indicated) or by other suitable means.

A dump valve bore is formed in the block 95 parallel to the pilot valve bore and two connections exist between the two bores. The first of these connections passes through the valve block 107 and connects the bores above the needle valve. The second of the two connections is below the valve 103.

Like the pilot valve bore, the dump valve bore has a minimum diameter portion 119 at its lower end, this portion opening above into a valve-cylinder portion of somewhat larger diameter and below into the sump. A tubular piston 123 slides within the cylinder. The lower end of the piston is reduced in diameter to form a sliding fit within the bore 119, forming a shoulder 127 above the reduced portion, and the passage 128 from the outlet of the pilot valve enters the dump valve bore below the shoulder, so that when the pilot valve is open pressure is applied beneath the shoulder tending to raise the piston and open the dump valve. The upper end of the piston is supplied with a flange 129 which limits its downward motion and, when the valve is closed, lies within an annular channel communicating through the connection 131 with the outlet side of the needle valve 109. Above the flange 129 the piston is provided with extension lugs 133 which bear against a flange 135 on a push-rod 137.

The push rod 137 slides in a ring-sealed bearing in a cap 139 which fits into the upper end of the dump valve bore. A compression spring 141 located within a recess in this cap bears against the flange 135 and thus tends to hold the valve piston 123 in its lower position and close the passage between the pilot valve bore and the sump. Moreover, during the interval when the breaker is being closed, the push rod is normally mechanically locked in this position unless the breaker trips. As will be seen from the drawing, when the dump valve is closed a passage exists from the channel 131 between the lugs 133 and down through the hollow center of the piston into the sump. When the piston rises, however, the flange 129 enters a closely-fitting portion of the bore above the channel and closes off this passage.

Turning now to the more purely mechanical parts of the apparatus including the latch and trip mechanism, the piston rod 39 connects to the breaker plunger 1 through a strut 159. A compression link 151 is hinged at one end to the strut; its other end is pivoted to one arm 153 of a bell crank which is so mounted that when the switch is in a closed position, as shown, the arm makes approximately a 45-degree angle with the axis of the piston rod 39. As the breaker opens and the piston rises the axis X, about which the link 151 turns, moves up into the position indicated in the drawing by the point X'. The link 151 swings in a counterclockwise direction during this motion, moving the bell crank in a counterclockwise direction up to the point at which the link is horizontal, after which it reverses the bell crank motion, moving it very slightly clockwise and bringing it to rest at an angle of between ten and fifteen degrees from the vertical. At this point the other arm 153' of the bell crank is approximately horizontal.

It is the aim in all circuit-breaker design to separate the breaker contacts and open the circuit as rapidly as is possible. In high-power breakers the necessity of opening a wide gap to insure rupture of the arc, of large insulating members to withstand the high voltages employed, and of relatively heavy conductors to carry the currents involved require that rather heavy masses be moved. To move such masses rapidly requires very large accelerations and a spring of great power. Trip mechanisms used to release such breakers must, however, be sensitive; i. e., small tripping forces must be used to control heavy springs. In order that this may be done, the actual latch mechanism must be given a very great mechanical advantage with respect to the spring. The inevitable result of this is that an equal mechanical advantage is given to the inertia of the latch itself. At the instant of its release the velocity of the latch bears the same ratio to the velocity of the switch mechanism itself as the ratio of the mechanical advantage which the latch possesses, and since inertial effects vary as the square of the velocity the limitation upon the opening time of the breaker is usually the inertia of the latch.

This disadvantage may be minimized by using a linkage system in which the mechanical advantages change rapidly as soon as any motion takes place. Such a system is a toggle formed of compression links; theoretically, the mechanical advantage of such a system varies between infinity when the toggle links are perfectly straight to zero when the links are fully buckled. In practice, however, no such wide range is possible, since at the position of infinite advantage the linkage is unstable and slight mechanical inaccuracies may prevent its operating in the manner intended. Gains up to a maximum of from (say) 8 to 15-fold may be obtained with a toggle linkage without incurring instability, or requiring undue accuracy of machining or adjustment.

The theory of the rapid change of mechanical advantage in a toggle link system is that the lever arm through which the restrained force acts to buckle the links when the toggle is released increases rapidly. The use of this principle in latching mechanism is old per se. In the present mechanism, however, this effect is multiplied by two expedients; first, a plurality of toggle linkages is used in cascade, and, second, compound toggle linkages are used where in the force which is used to buckle the originally nearly straight toggle links is itself applied through a pair of links which are buckled at the start of the action but which straighten as the latching links buckle. Through this latter expedient the mechanical advantage is very rapidly transferred from the latch mechanism to the breaker and breaker spring with the result that the inertial load of the latch is dropped still more rapidly and the motion of the latch mechanism itself becomes very small in spite of its initial mechanical advantage. The transfer of inertia, as regards the final links of the series may, in fact, be made so rapid, that it is only at the initial instant of the trip that it contributes to the inertia, its velocity actually decreasing while the breaker is still accelerating.

In the present device three linkages are employed in cascade, the principle of each of the three linkages being the same. Each linkage comprises three elements, a driving link, a connecting link, and a driven link, pivotally connected end-to-end with the outer ends of the linkage turning on fixed pivots, plus a latch mechanism to prevent the toggle from buckling until it is released. In the first of the linkages

used the driving link is the arm 153' of the bell crank already described, the connecting link is link 154, and the driven link is link 155, the outer end of which turns upon a shaft 156 fixed to the frame of the device. As may be seen from the drawing the driving link 153' acts at an initial angle of somewhere in the neighborhood of 45° to compress the nearly straight linkage comprising the connecting link 154 and the driven link 155. Owing to the very slight angle between the connecting and driven links the lever arm against which the connecting link 154 thrusts is small; the result is a mechanical advantage of approximately 12½ to 1 in favor of the latch mechanism which prevents the driven link from rotating.

The latch mechanism in this case is another linkage of the same type, with the driven link of the first linkage forming the driving link of the second and thrusting, at a fairly large angle, against the nearly straight connecting link 158 and driven link 159. The latter forms one arm of a bell crank mounted on a fixed shaft 160 on the frame of the equipment.

The second arm, 160', of the last mentioned bell crank forms the driving link of a third and similar linkage, which constitutes a latch for the second linkage. This last linkage comprises a connecting link 161 and a driven link 162 which turns on a fixed shaft 163. The final driven link extends beyond its pivot on the shaft and is provided with a face 164 which is engaged by a hooked end 165 on a catch or latch member 167 and comprises the final latching element.

It will be seen that in each of the linkages mentioned the driving link has a relatively large lever arm with respect to a very small lever arm on the driven link. Each of the driving links is disposed at an angle of approximately 45° with the other two links in their nearly-straightened position, although this angle is not critical. It might appear that a greater advantage could be obtained by making the angle between the driving link and the connecting link approach 90° This is, in fact, the case, but in the 90° position the change in lever arm, for a small rotation of the link, is small, while beyond the 45° position it becomes increasingly rapid. The purpose of the entire linkage is to transfer the advantage from a latching mechanism to the driving mechanism as rapidly as possible and this is achieved better by decreasing the lever arm of the driving link simultaneously with the increase of lever arm of the driven link. Moreover, it will be noted that while the driving and driven links are never permitted to straighten fully, the driving and connecting links in each case may pass through the dead center position and it is, in fact, desirable that they do so since this results in minimum total motion of the succeeding linkage. Since the drive is always supplied from the breaker end of the linkage and never from the latch end, the passage of the driving linkage through the dead center position does not result in any uncertainty or instability of action.

In the linkage which has been shown for illustration the mechanical advantage of the second linkage, when locked, is 8.15 to 1, while that of the third is 9.25 to 1. The overall mechanical advantage of the catch is therefore the product of that of the three linkages taken separately, or slightly over 942 to 1. The multiplication of the inertia of the final link is, however, the square of this, or nearly 890,000 so that an effective mass of one ounce applied at the lever arm of the final link becomes the equivalent of 55,000 pounds added to the mass of the breaker arms themselves. Mechanical advantage due to the linkage is so rapid, however, that by the time the latch face has moved only 1/50 of an inch when it is released from the hook 165, the mechanical advantage has dropped by a factor of nearly 9 and its inertial effect by a factor of 80. Furthermore, owing to this shift in mechanical advantage the breaker mechanism can accelerate without any acceleration of the final link and with only moderate accelerations of the intervening links. The result is that in practice circuit breakers may be made to open in 1/600 of a second or 1/10 of a cycle where this release mechanism is used, in comparison to a half-cycle or more where conventional types of trip are employed.

The release latch 167 is centrally suspended from a pivot 171 on an arm 173 which, in turn, is pivoted on a shaft 175 on the frame of the apparatus. The end 177 of the latch member which is opposite to the hook 165 is flattened to form a sear the use of which will be explained later. A spring 179 attached to a depending arm 180 on the latch and to a fixed point on the frame tends to rotate the latch around its pivot 171 in a counterclockwise direction, this motion being limited by a fixed pin 181 on the frame. It will be seen that the effect of the spring 179 is to tend to hold the hook 165 in engagement with the latch face 164 of the link 162. A second fixed pin 183 limits the clockwise rotation of the latch.

The tripping mechanism for the breaker comprises a moving-coil type movement which is schematically illustrated as including a permanent magnet 185 having its moving coil 187 connected by a tension link 189 to the pin 171. When the moving coil 187 is excited it raises the lever 173, causing the latch 167 to rotate against the pin 181 as a fulcrum and disengage the hook 165 from the face 169, thus releasing the latch. When this has occurred and the excitation is removed from the coil 187 the lever arm 173 carrying the pin 171 drops. Under these circumstances, however, the end of the hook 165 rests upon a circumferential face formed at the end of the link 161, so that the latch 167 now pivots around this contact and drops the sear end 177 into position to engage the face 193 of a pivoted link 195 and prevent counterclockwise rotation thereof. This serves to lock the dump valve as will be described shortly.

An additional safety trip is provided in addition to the moving-coil type which has just been described. A second lever 197 is pivoted from the pin 175 and extends under the pin 171, so that when the lever 197 is raised it carries with it the pin, the lever 173, and the latch 167 irrespective of the action of the moving-coil trip. The end of the lever 197 is connected through a link 199 with the plunger 201 of a solenoid, schematically indicated at the reference character 203.

Solenoids of this character are generally used for the trips of devices of the kind described. They have, however, a considerable inductance and hence their operation is not very rapid. The inductance of the moving coil 187 can, however, be practically entirely neutralized and therefore their action may be made very fast. Normally (and in every case which has been encountered in practice) the moving coil magnet will trip the breaker a measurable time before the solenoid can come into action, but in case it should be

incapacitated for any reason, the solenoid will back it up and trip the breaker.

Returning now to the link 195, this link is loosely pivoted upon a fixed pin 205 mounted on the frame of the device. It is pivotally connected with a long link 207, the lower end of which pivots on a fitting 211 fixed to the end of the dump valve push rod 137. The upper end of the link 207 is constrained to move in an arcuate path by a guide crank 213 mounted rotatively on a fixed shaft 215 carried by the frame. It will be seen that when the dump valve is seated the linkage consisting of the elements 195, 207, and the push rod 137 is nearly but not quite straight, all of the various toggles comprised in this linkage therefore being "broken" but barely broken. When the circuit breaker is open the dump valve hook 165 rests on link 162 and the linkage is locked in its position by the engagement of the face 193 with the sear end 177 of the latch until and unless one of the trip coils operates to break this contact, when a sufficient upward force applied on the push rod will flex the linkage and permit the rod to rise.

We can now trace the operation of the device. The breaker, in the first instance, is in its open position, with the piston 37 at the top of the cylinder 33. The main valve mechanism within the housing 49 is in the position shown, with the passages from the cylinder into the sump completely open so that no pressure can exist within the cylinder other than the normal hydrostatic head of the fluid in the sump. High pressure in the accumulator is, however, at full value of a thousand or more pounds per square inch, being maintained in this condition by the pump P under the control of the pressure-actuated switch. This pressure is available in the pilot valve and is effective both above and below the floating piston 105, tending to hold it against the valve face 103.

To operate the breaker the needle valve 109 is opened, either by hand or by the remote control equipment already described. This relieves the pressure above the piston, offering free egress of the hydraulic fluid through the channel 131 and the tubular dump valve piston 123 into the sump. The pressure below the shoulder on the piston 105 immediately raises it, opening a direct passage through the connection 93 to the main valve. When this occurs, the piston 105 being forced up tightly against the block 107, it largely cuts off the flow of hydraulic fluid through this passage.

As soon as the pilot valve opens the full pressure from the source is admitted under the main valve piston 77, lifting it until its reduced upper end enters the bore above it and closes off the passage from the conduit 45 into the sump. At the instant that this occurs the piston strikes the foot 75 of the poppet-valve 63 and starts to raise it, this action continuing until the valve face 87 on the piston engages the seat 81 and completes the sealing of the exhaust port. As soon as the poppet-valve 63 start to lift the oil pressure from the source is effective through the conduit 45 into the cylinder 33 and forces the piston down until it has reached substantially the bottom of the cylinder. This straightens out the toggles in the latch mechanism until the hook 165 of the latch 167 drops, simultaneously locking the circuit breaker closed and releasing the end 177 of the latch from the push rod mechanism which holds the dump valve closed. Since at the instant of opening the latch link 162 loses acceleration rapidly, at the instant of closing it gains acceleration with equal rapidity, and a spring stop 217 is therefore provided to absorb the shock of its final closing and prevent snapping past dead center.

It may be noted here that because of the large magnitude of the forces acting upon the piston the closing action is quite violent and might be destructive were not some means provided of cushioning the final movement. Such a cushion effect can be provided by a projecting tapered end 220 on the piston 37 which projects through a ring 221, the ring being held in place by a cylinder head 223 secured to the lower end of the cylinder. The internal periphery of the ring 221 is dimensioned so that when the breaker is nearly closed there is a very small clearance between the ring and the larger end of the taper. When the breaker is open, however, and the small end of the taper lies within the ring there is a wide oil passage provided. As the breaker closes there is therefore a continually increasing dash pot action as the channel between the taper and the ring is constricted, and the final closing of the breaker is fairly gentle. When the breaker trips, however, the ring 221 rises with the piston, permitting oil to flow around the ring and through a plurality of ports 225 and 227 into the cylinder.

As soon as the latch 167 engages with the link 161 the sear end 177 disengages from the link 195, thus releasing the lock on the dump valve. Pressure through the channel 128 then becomes effective to raise the dump valve piston, opening a free passage from below the main valve through the connections 93, 97, and 119 into the sump. The pressure below the main valve piston being released, the direct pressure from the source, acting through the poppet-valve on the smaller diameter above the piston 77, becomes effective to force it down, the flow of liquid from beneath it continuing to hold the dump valve open. As soon as the poppet-valve has closed the passage between conduits 45 and 51 opens, relieving the pressure within the main cylinder 33, but the motion of the piston 77 continues until it has bottomed due to the continued flow of liquid through the hollow stem of the poppet-valve into the recess in the piston head.

In the meantime, however, the pilot valve has closed, its piston 105 dropping under its own weight, the pressure drop through the valve below it and the increasing pressure of liquid above it. This will occur whether or not the needle valve 107 has been closed in the meantime, since as soon as the dump valve rises its flange 129 will have risen into the cylinder above it to cut off the flow through the tubular dump valve piston.

In case an attempt is made to close the breaker upon a fault the trip coil will raise the lever 173 and the latch 167 will pivot around its hooked end to release the contact between the face 193 and the end 177 of the latch, permitting the dump valve to lift. The effect is then the same as that already described at the end of the normal closing operation; the pressure on the main valve piston is immediately relieved into the sump and as the main latch 165 is not engaged the main breaker spring opens the breaker in the same manner as though no attempt was being made to close it. As soon as the dump valve opens the pilot valve closes, as has already been described. Very little loss of fluid into the sump therefore occurs, so that a one gallon accumulator will effect eight or ten closures even when the accumulator is not replenished by the pump.

If a failure in the hydraulic system should occur the system will in all cases "fail safe," i. e., the breaker can always trip free, and the worst failure which can occur is an inability to close it and not the maintenance of a destructive fault.

An important, although apparently minor feature of the device is the electrical trip mechanism. The essential features of the circuit used are shown in Fig. 3. In this figure the battery 25 and pushbutton or key 27 are those shown in Fig. 1, it being apparent that as many other parallel paths as may be desired for closing the circuit may be bridged around this key. In series with the battery and key is a current-limiting resistor 233 connecting to the solenoid coil 203 and the moving coil trip in parallel, the latter comprising the moving coil 187 already identified and an equal but oppositely-wound fixed coil 187', mounted in the air gap closely surrounding or surrounded by the moving coil. The fixed coil substantially neutralizes the inductance of the moving coil but does not affect its reaction to the flux in the air gap, which is preferably provided by a permanent magnet. This method of inductance neutralization has been used in loudspeaker practice and hence in the diagram the coils only are schematically represented.

Closing the circuit by means of the key 27 or otherwise impresses a surge of voltage across the solenoid and the moving-coil trip in parallel. The resistance of the coils 187 and 187' may be equal to or even higher than that of the current-limiting resistance 233. The resistance of the solenoid 203 should be very much lower than that of the limiting resistance. The inductance of the solenoid is, however, material; it therefore requires time for current through it to build up and therefore in the first instant when the circuit is closed the moving coil carries practically the entire current and exerts a powerful pull which trips the breaker. This action ordinarily occurs so rapidly that under fault conditions the breaker opens and relay 24 releases before the solenoid can trip. If the circuit is closed by the switch 27, however, or if, for any reason, the moving coil device is incapacitated, current builds up in the solenoid and causes it also to trip. Building up of the current in the solenoid increases the drop through resistor 233. This resduces the current through the coils 187—187' very rapidly, and because of this quick drop in coil current it is possible to design the circuit so that the initial surge through the moving coils is several times the normal overload value. This makes possible a very high initial acceleration of the moving coil trip and the extremely quick action of the device without danger of damage to the coils. The rapid taking-over of the load by the solenoid permits initial trip currents through the coils which, if continued, would burn them out in a second or less.

The breaker as thus described has been proved to be capable of operating in from one-half to two-thirds of the time required by other breakers capable of rupturing comparable power. Normally circuit breakers for high power lines can be expected to operate in a minimum of three cycles, provided the actual interrupter device itself is capable of functioning to break the arc on the first or second passage of the current wave through zero. With the mechanism here described interruption can be accomplished in from one and one-half to two cycles. This improvement in operation is due to a number of factors working together. The first of these is the minimum inductance of the moving-coil trip, which sets the whole release mechanism in operation in from one-half to one cycle less than is possible with the ordinary type of solenoid trip. Use of the moving-coil release is made possible by the sensitiveness of the catch mechanisms, which in turn stems from the combination of high initial mechanical advantage with small overall acceleration and motion provided by the toggle linkages which have been described. Once the trip has been actuated the speed of the break is controlled by the force of the main opening spring, which may be made great because of the very large forces available to operate the closure. When the tripping occurs the passages from the cylinders are so large that the frictional drag of the oil through them is negligible until it is purposely increased to provide a dashpot action at the end of the stroke, the actual inertia of the oil displaced is very small indeed compared to that of the remainder of the equipment. When the trip occurs during normal operation of the circuit the main valve is already open into the sump and no delay is occasioned by it. If the trip occurs during the reclosing of the breaker some slight delay may ensue but it is very small owing to the fact that the latch mechanism has not yet reached the position where it contributes greatly to the inertia of the system, and to the very large pressure available to move the valve piston. Normal pressure in the accumulator may be from 1000 to 2500 pounds per square inch. In the breaker illustrated this pressure operates, at the instant of application, against a cylindrical face of 1½ inches diameter, making a force of over 4000 pounds effective to move a main valve piston, weighing a pound or two at most a distance of approximately half an inch before the poppet-valve closes, and the conduit from the cylinder 33 opens into the sump. As it works out, the additional time required by the breaker to trip free from a closing operation, as compared with the time of opening from a latched closed condition is, at most, less than one tenth of a cycle. In spite of this fact the presence of the hydraulic fluid between the faces of the various parts as they reach the ends of their strokes cushions the final blow. No appreciable peening takes place and the parts do not wear or deform perceptibly under operation.

It should be apparent that while the invention has been described as applied to one representative type of circuit breaker it is capable, with minor mechanical modifications, of actuating substantially all types. Moreover, it is subject to many modifications as to detail; e. g., diaphragms may be used to provide hydraulic chambers with moveable walls instead of the equivalent cylinder and piston.

Furthermore, while the various instrumentalities mentioned as contributing to the speed of operation of the equipment are most effective when combined, they can be used separately in otherwise conventional circuit breakers. The claims in this application are therefore confined to the latch and trip mechanism, claims to the hydraulic actuating features being presented in a companion application filed concurrently. I therefore do not intend to imply limitations not expressed in the following claims.

I claim:

1. A release mechanism for circuit breakers and the like wherein a relatively large operating

force is controlled by a relatively minute and easily releasable restraining force, comprising a driving member through which the operating force is applied, a fixed shaft and a driving link pivoted thereon, a mechanical connection between said driving member and said driving link for rotating the latter upon motion of said driving member, a second fixed shaft, a driven link pivotally mounted thereon, and a connecting link pivotally connecting the free ends of said driving link and said driven link, the distance between said fixed shafts being less than the combined lengths of said links as measured between the pivotal centers thereof and so disposed that when said driving member is in its restrained position there is a material angle between said driving link and said connecting link and nearly but not quite a straight angle between said connecting link and said driven link while motion of said driven member tends to straighten the connection between said driving and connecting links and thereby buckle further the connection between said connecting and driven links, latch mechanism for preventing such further buckling, and means for releasing said latch mechanism.

2. A release apparatus comprising a plurality of cascaded mechanisms in accordance with claim 1, the driven link of one of said mechanisms comprising the driving link of the second thereof and said connecting and driven links of said second mechanism comprising the latch mechanism of said first mechanism.

3. A release mechanism in accordance with claim 1 wherein said mechanical connection between said driving member and said driving link comprises a pair of compression links pivotally connected together and to said driving member and said driving link, said compression links being substantially alined when said driving member is in its restrained position and flexing through an increasing angle when released.

4. Release mechanism in accordance with claim 1 wherein said latch mechanism comprises a pair of pivotally connected compression links, one whereof is pivoted at the junction of said driving and connecting links, a fixed shaft whereon the other of said compression links is pivoted, said shaft being so positioned that said compression links also form a nearly but not quite straight angle when said driving member is in its restrained position, a hook member engaging one of said links to hold said links from buckling, and a trip coil connected to said hook to release the same.

5. A release mechanism for circuit breakers and the like wherein a relatively large operating force is controlled by a relatively minute and easily releasable restraining force, comprising the combination with an operating element of a cascade of toggle linkages each including a pair of links which form a nearly straight angle when said mechanism is in its unreleased condition, said pairs of links being so positioned that none thereof can pass through a straight angle and that buckling of any one pair requires buckling of all of said said pairs, driving connections from said operating element to said cascade of linkages, means for restraining the last of said pairs of links in said cascade from buckling, and means for releasing said restraining means.

6. Mechanism in accordance with claim 5 wherein said releasing means comprises a magnetic circuit having an air-gap therein, a coil moveable within said air-gap and connected to said restraining means, and a coil within said air-gap for effectively neutralizing the inductance of said moveable coil.

7. Mechanism in accordance with claim 6 including a circuit having relatively high inductance and low resistance connected in parallel with said moveable coil and a current limiting resistor connected in series with said coil and circuit.

8. Mechanism in accordance with claim 7 wherein said high inductance circuit comprises a magnet having an armature connected to said release and said restraining means.

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