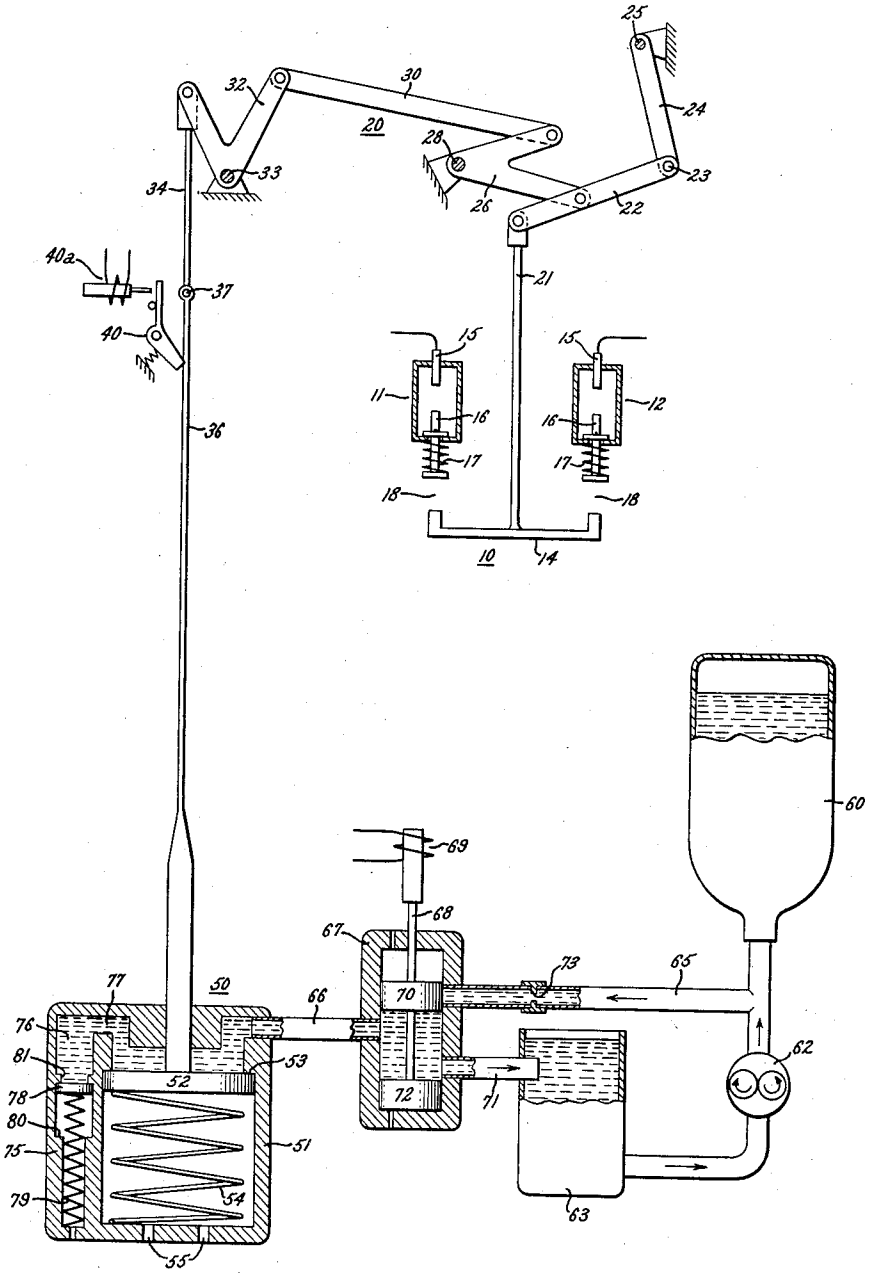
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HYDRAULICALLY-ACTUATED OPERATING MECHANISM
FOR AN ELECTRIC CIRCUIT BREAKER
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HYDRAULICALLY - ACTUATED OPERATING MECHANISM FOR AN ELECTRIC CIRCUIT BREAKER

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This invention relates to an operating mechanism for an electric circuit breaker and, more particularly, to a hydraulically-actuated mechanism for producing closing of the breaker.

In a typical circuit breaker, the forces which oppose closing action are of a minor nature at the beginning of a closing stroke but increase very rapidly near the end of the stroke. To overcome these increasing opposing forces, it has been common to close the contacts of the breaker by means of an operating linkage so designed that it provides a mechanical advantage which increases as the closing stroke progresses.

When a hydraulic motor is relied upon for imparting driving forces to such a linkage, it is desirable to provide the inlet passage to the motor with a restriction which acts to moderate the rate at which driving pressure is established within the motor. The restriction acts to prevent full source pressure from being continuously maintained in the motor during the initial portion of the closing stroke when the opposing forces are low and, thus, acts to prevent excessive velocity of the motor-driven linkage during this interval. By limiting the initial velocity of the linkage, it is possible to materially decrease the severity of the impact occurring near the end of the closing stroke when the opposing forces suddenly become much higher.

A problem which I have discovered to be present in hydraulically-actuated mechanisms of the above type is that the operating linkage, because of its inertia and velocity combined with its increasing mechanical advantage, has a tendency to overrun the driving part of the motor during an intermediate portion of the closing stroke. My investigations indicate that in certain mechanisms where the linkage and the driving part, or piston, of the motor are positively coupled together, the linkage actually drives the piston ahead of the body of liquid therebehind. In other words, the driving, or overrunning action, of the linkage moves the piston at such a high velocity that the cylinder volume behind the piston increases at a greater rate than the rate at which liquid can be supplied through the restricted inlet to the motor. Under such conditions, a vacuum tends to be drawn in the cylinder space behind the piston with the result being that dissolved gases in the liquid come out of solution and form gas pockets, i.e., cavitation occurs. These cavitation-produced gas pockets are undesirable because, due to their compressibility, they can cause erratic motion and possible stalling of the linkage, especially near the end of the closing stroke when large opposing forces are abruptly encountered.

Having discovered the above problem, an abject of my invention is to prevent the occurrence of cavitation in a hydraulically-actuated operating mechanism for an electric circuit breaker.

Another object is to incorporate into a hydraulic motor means for overcoming any tendency of a driven linkage to produce cavitation in the motor.

In carrying out my invention in one form, I compensate for the overrunning action of the driven linkage by providing a compensating reservoir which communicates with the cylinder space behind the motor piston through a flow passage which is located downstream from the restriction in the motor supply line. Within this reservoir, there is provided means responsive to the liquid pressure within the cylinder space for forcing sufficient liquid from the reservoir into the cylinder space to maintain the pressure within the cylinder space above any value at which cavitation can occur. As a result of this action, the formation of cavitation-produced gas pockets within the cylinder space is effectively prevented despite the fact that the piston travels at such a high velocity that the cylinder volume therebehind increases at a greater rate than the rate at which liquid can be supplied through the restriction in the motor supply line.

For a better understanding of my invention, reference may be had to the following specification taken in conjunction with the accompanying sheet of drawing, wherein:

The single figure diagrammatically illustrates a circuit breaker operating mechanism embodying one form of my invention.

Referring now to the drawing, there is shown, in open-circuit position, a typical oil circuit breaker **10** comprising two identical pole units **11** and **12** which are adapted to be electrically-connected in series by a conductive cross-blade **14** when the breaker is closed. Each pole unit comprises a stationary interrupting contact **15** and a movable interrupting contact **16** which is biased away from the stationary contact by a suitable compression spring **17**. In the open-circuit position shown, the cross-blade **14** is separated from the movable contacts **16** so as to provide a pair of isolating gaps **18** between the two pole units.

To close the breaker, the cross-blade **14** is driven upwardly through its closing stroke. Only slight opposition is encountered during the first portion of the closing stroke inasmuch as the cross-blade is merely moving through the isolating gaps **18**. However, when the cross-arm encounters the movable contacts **16** and begins to compress the springs **17**, the opposing forces abruptly increase and continue to increase until the end of the closing stroke, at which time the contacts **15** and **16** are in circuit-closing engagement with the opening springs **17** fully charged. The magnetic forces which are established by closing the contacts further contribute to the greatly increased opposition which is encountered near the end of a closing stroke.

For transmitting closing forces to the cross-blade **14**, a typical straight-line linkage **20** is provided. This linkage **20** comprises a reciprocable operating rod **21** rigidly connected at its lower end to the cross-blade **14** and pivotally connected at its upper end to a lever **22**. The lever **22** is pivotally mounted at **23** on a guide link **24** which, in turn, is supported on a stationary pivot **25**. Pivotally connected to the lever **22** in its central region is a bell-crank **26** which is mounted for angular movement about a stationary pivot **28**. Closing forces are transmitted to the bell crank **26** through a connecting link **30** which is pivotally connected at one end to the bell-crank **26** and at its other end to another bell crank **32**. This second bell crank **32** has a stationary pivot **33** about which it is driven during a closing operation by a driving link **34** pivotally connected at one end to the bell-crank **32**. The other end of the driving link **34** is pivotally connected to a reciprocable driving rod **36** by a pivot pin **37**.

Closing of the breaker is accomplished by driving the rod **36** rapidly downward to pivot the bell-crank **32** in

a counterclockwise direction. This drives the connecting link 30 to the left thereby driving the bell-crank 26 counterclockwise. Counterclockwise movement of the bell-crank 26 pivots the lever 22 in a counterclockwise direction about its pivot 23, and this acts to drive the operating rod 21 rapidly upward to produce contact-closing. At the end of the closing stroke, the linkage 20 is held in its closed-circuit position by a latch 40 which falls in behind the pivot pin 37 when the driving rod 36 nears the end of its downward stroke.

To enable the contacts to be smoothly closed against the high opposing forces which are encountered near the end of the closing stroke, it is common to design the contact-closing linkage in such a manner that its mechanical advantage increases as the closing stroke progresses. To this end, it will be apparent that, in my closing linkage 20, the bell crank 32 is so constructed that the moment arm between the pivot 33 and the driving link 34 increases as the closing stroke progresses. Similarly, the moment arm between the pivot 28 and the connecting link 30 increases as the closing stroke progresses, and also the bell crank 26 moves into a toggle position with respect to lever 22 as the closing stroke progresses. All of these relationships contribute to a mechanical advantage which increases as the closing stroke progresses.

For actuating the driving rod 36 so as to produce the above-described closing action of the linkage 20, I provide a hydraulic motor 50. This hydraulic motor 50 comprises a cylinder 51 and a piston 52, which is movable in the cylinder and is positively connected to the driving rod 36. As shown in the drawing, when the breaker is open, the piston 52 is maintained in an upper position against a shoulder 53 by means of a light compression spring 54. When pressurized liquid is admitted into the cylinder space above, or behind, the piston 52, the piston is driven rapidly downward to produce the above-described closing action. Suitable vents 55 communicating with the cylinder space ahead of the piston 52 insure that no fluid will be trapped in this space to impede the downward closing motion of the piston.

Pressurized liquid is supplied to the motor from a conventional accumulator 60, which preferably contains a pocket of highly-pressurized gas trapped above a supply of liquid contained within the accumulator. The accumulator is maintained in a charged, or pressurized, condition by means of a suitably-controlled pump 62 which forces liquid from a sump 63 into the accumulator 60 whenever the pressure in the accumulator falls below a predetermined level.

A supply line 65, 66 leads from the accumulator to the motor 50 and contains a suitable control valve 67 which is shown in the closed-position with the valve piston 70 shutting off the section 65 of the supply line. When the movable valve element 68 is operated, as by suitably-controlled electromagnetic means schematically shown at 69, the valve piston 70 is lifted to establish communication between the sections 65 and 66 of the supply line. This permits pressurized liquid to flow from the accumulator 60 to the motor 50 to effect the above-described closing action.

When the breaker is in the open position shown, the cylinder space behind the piston 52 is vented to the sump 63 by means of an exhaust passage 71 communicating with the section 66 of the supply line. When, however, the valve element 68 is lifted to establish communication between the sections 65 and 66 of the supply line for the purpose of operating the motor 50, the passage 71 is sealed-off by means of a lower piston 72 carried by the movable valve element 68. After the closing stroke has been completed the electromagnetic control means 69 acts in a conventional manner to return the valve element 68 to its open position shown in the drawing. This dumps or releases the pressure in the cylinder space above the piston 52 and allows the motor piston 52 to return to its upper position should the latch 40 be tripped, say by the solenoid 40*a* in response to a fault in the power circuit controlled by the breaker. For a more detailed showing of a valve arrangement which is suitable for controlling the motor 50, reference may be had to U.S. Patent No. 2,381,336 issued to T. R. Coggeshall and assigned to the assignee of the present invention.

Considering now a closing operation in greater detail, if the supply line 65, 66 permited full pressure from the accumulator 60 to be continually maintained behind the piston 52 upon opening of the control valve 67, then the motor 50, during the initial portion of the stroke, would drive the linkage 20 at an extremely high velocity inasmuch as the opposing forces during the initial portion of the closing stroke are very low. This extreme high velocity tends to result in objectionably severe impacts being produced when the much greater opposing forces are abruptly encountered near the end of the closing stroke.

To reduce this tendency toward excessive initial speed, the inlet passage 65, 66 is provided with a speed-governing orifice or restriction 73 which is capable of moderating the pressure build-up in the cylinder space behind the piston 52 as the piston moves through the initial portion of its stroke. The resulting lower initial speed materially lessens the severity of the impact when the opposing forces abruptly increase.

Preferably, the restriction 73 is located upstream from the control valve 67 so that it does not interfere with the above-described dumping of the liquid from the space behind the piston 52 through the valve 67 at the end of the closing stroke.

A problem which I have discovered to be present in hydraulically-actuated mechanims of the type shown is that the operating linkage 20, because of its inertia and velocity combined with its increasing mechanical advantage, has a tendency to overrun the driving piston 52 during an intermediate portion of the closing stroke. My investigations indicate that during this interval, the linkage 20 actually tends to drive the piston 52 ahead of the body of liquid therebehind. In other words, the driving, or overrunning, action of the linkage 20 moves the piston at such a high velocity that the cylinder volume behind the piston 52 increases at a greater rate than the rate at which liquid can be supplied through the orifice 73 to the cylinder 50.

Under such conditions, a vacuum tends to be drawn in the cylinder space behind the piston 52, and this vacuum, if allowed to develop sufficiently, can cause the liquid in the cylinder space to emit any dissolved gases which might be present therein. The resulting gas pockets would be highly undesirable because, due to their compressibility, they could cause erratic motion and possible stalling of the linkage 20 when the high opopsing forces are encountered near the end of the closing stroke.

For overcoming this problem, I have provided the hydraulic motor 50 with a compensator 75. This compensator comprises a cylindrical reservoir 76 communicating with the cylinder space behind the main piston 52 by means of a flow passage 77 which is located downstream from the orifice 73 with respect to flow into the cylinder space. A movable compensating piston 78 is provided within the reservoir 76 and is closely surrounded in sealed relationship by the cylindrical walls of the reservoir. A compression spring 79 acts to bias the compensating piston upwardly away from its seat 80 and into engagement with a suitable stop 81.

Under normal operating pressures, the fluid pressure within the main cylinder 51 forces the compensating piston 78 downwardly against its seat 80 thereby compressing the spring 79. When, however, the pressure in the main cylinder 51 falls to a predetermined minimum safe value as a result of the previously-described high piston velocity, the spring 79 drives the compensating piston upwardly off of its seat 80. This forces liquid from the compensating reservoir into the main cylinder

51 as such a rate as to maintain a pressure within the main cylinder which is sufficeint to prevent any tendency toward cavitation. The predetermined minimum safe value of pressure referred to above should be a pressure which is appreciably above any pressure at which cavitation can occur. For example, with most suitable types of oil, a pressure of about five pounds per square inch provides adequate protection against cavitation.

During a normal operation of the motor **50**, leakage of pressurized liquid from the compensating reservoir **76** is effectively prevented by the coaction of piston **78** with its seat **80**. In this regard, the pressurized liquid within the reservoir **76** forces the piston **78** against the seat **80** with a high force which effectively seals the reservoir against leakage past the piston. The seat **80** also desirably serves as a stop which prevents the spring **79** from being overcompressed by the high pressures within the reservoir **76**.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects and I, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

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

1. In a circuit breaker having a contact which is movable through a predetermined closing stroke, a cylinder, a piston movable therein, and means including a supply line containing a piston-speed-governing restriction for supplying pressurized liquid to the cylinder space behind said piston, a linkage positively connected to said piston and operatively connected to said contact for transmitting closing forces to said contact in response to the admission of pressurized liquid through said restriction to said cylinder space, said linkage having a mechanical advantage which increases as said closing stroke progresses and having a mass and velocity which are of such values that the linkage acts during an intermediate portion of the closing stroke to drive said piston at a velocity which increases the cylinder volume behind said piston at a higher rate than the rate at which liquid flows through said restriction into said cylinder space, a compensating reservoir communicating with said cylinder space through a flow passage which is located downstream from said restriction with respect to flow into said cylinder, and means responsive to the liquid pressure within said cylinder space for forcing sufficient liquid from said reservoir into said cylinder space to maintain the pressure within said cylinder space above any value at which cavitation can occur.

2. The apparatus of claim 1 in combination with control valve means located in said supply line for controlling the flow of liquid into and out of said cylinder, said restriction being located in a position which is upstream from said control valve means with respect to flow into said cylinder.

3. In a circuit breaker having a contact which is movable through a predetermined closing stroke, a cylinder, a first piston movable therein, and means including a supply line containing a piston-speed governing restriction for supplying pressurized liquid to the cylinder space behind said first piston, a linkage positively connected to said first piston and operatively connected to said contact for transmitting closing forces to said contact in response to the admission of pressurized liquid through said restriction to said cylinder space, said linkage having a mechanical advantage which increases as said closing stroke progresses and having a mass and velocity

which are of such values that the linkage acts during an intermediate portion of the closing stroke to drive said first piston at a velocity which increases the cylinder volume behind said first piston at a higher rate than the rate at which liquid flows through said restriction into said cylinder space, a compensating reservoir communicating with said cylinder space through a flow passage which is located downstream from said restriction with respect to flow into said cylinder, a second piston located within said reservoir and movable in one direction to force liquid from said reservoir into said cylinder space, and biasing means responsive to the liquid pressure within said cylinder space for moving said second piston in said one direction sufficiently to maintain the pressure within said cylinder space above any value at which cavitation can occur.

4. In a circuit breaker having a contact which is movable through a predetermined closing stroke, a cylinder, a first piston movable therein, and means including a supply line containing a piston-speed-governing restriction for supplying pressurized liquid to the cylinder space behind said first piston, a linkage positively connected to said first piston and operatively connected to said contact for transmitting closing forces to said contact in response to the admission of pressurized liquid through said restriction to said cylinder space, said linkage having a mechanical advantage which increases as said closing stroke progresses and having a mass and velocity which are of such values that the linkage acts during an intermediate portion of the closing stroke to drive said first piston at a velocity which increases the cylinder volume behind said first piston at a higher rate than the rate at which liquid flows through said restriction into said cylinder space, a compensating reservoir communicating with said cylinder space through a flow passage which is located downstream from said restriction with respect to flow into said cylinder, a second piston located within said reservoir and having a seat against which said second piston is forced by pressure within said reservoir, said second piston acting when driven away from said seat to force liquid from said reservoir into said cylinder space, and biasing means operable upon reduction of the pressure in said reservoir to a predetermined value to drive said second piston away from said seat thereby forcing liquid into said cylinder space, said predetermined value being above any value at which cavitation can occur within said cylinder space and the amount of liquid forced by said second piston into said cylinder space being sufficient to maintain the pressure within said cylinder space above any value at which cavitation can occur.

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