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Yoshioka et al.

[11] **3,740,506**

[45] **June 19, 1973**

[54] **FLUID OPERATED PISTON CIRCUIT BREAKER WITH FLOATING POSITION VALVE ACTUATOR**

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[52] **U.S. Cl.** ..... **200/82 B,** 200/148 F, 91/461, 251/65

[51] **Int. Cl.** **H01h 35/38**

[58] **Field of Search** ..... 200/148 A, 82 B, 200/148 E, 148 F, 82 D, 82 R; 251/65; 92/6 R, 183; 91/392, 461

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Assistant Examiner—Robert A. Vanderhye
Attorney—Paul M. Craig, Jr., Donald R. Antonelli, David T. Terry et al.

[57] **ABSTRACT**

A circuit breaker having an actuating system comprising a signal responsive valve member of large diameter and a making force imparting valve member of small diameter connected to each other by an actuating rod so that a first differential force relationship can be established therebetween. A movable valve seat of diameter smaller than that of the making force imparting valve member is movable toward and away from the signal responsive valve member so that a second differential force relationship can be established between the two valve members when the movable valve seat engages the signal responsive valve member to limit the effective area of the latter. The movable valve seat is moved toward and away from the signal responsive valve member and fluid under pressure applied to the signal responsive valve member is suitably controlled so as to selectively bias the actuating rod in one of the making and breaking directions. A control valve member is disposed in proximity to the movable valve seat so that it moves in response to the movement of the actuating rod in the breaking direction for controlling the application of the fluid pressure to the signal responsive valve member. This control valve member acts to reduce the moving distance of the movable valve seat following the movement of the signal responsive valve member so that the movable valve seat can take a floating position ready to move in the making direction.

28 Claims, 7 Drawing Figures

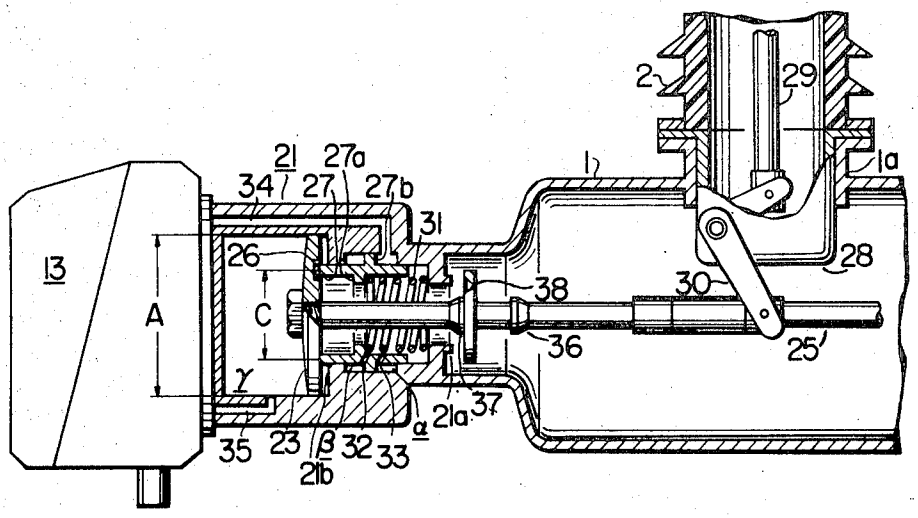
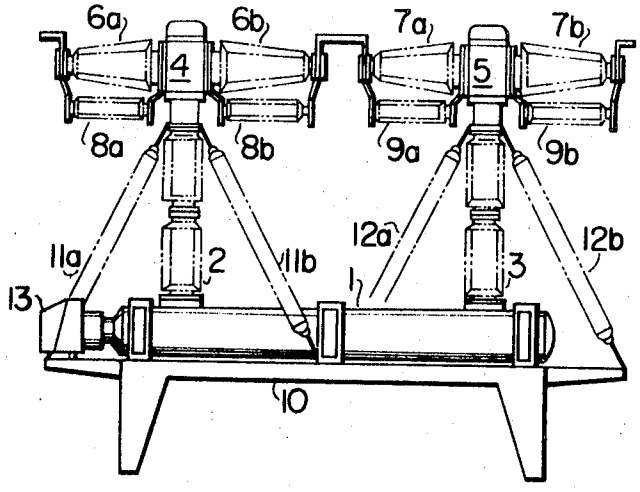


FIG. 1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6b
7a
7b
4
5
8a
8b
9a
9b
11a
2
11b
12a
3
12b
13
1
10

FIG. 2a

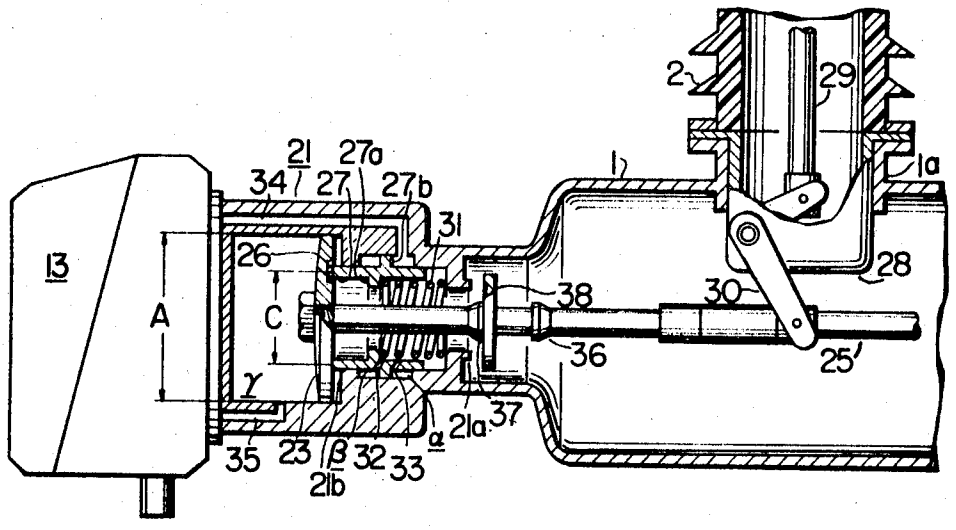

2
29
1a
21
27a
34
27
27b
31
13
26
A
C
γ
38
30
28
36
25
37
21a
35
23
β
32
33
α
21b

FIG. 2b

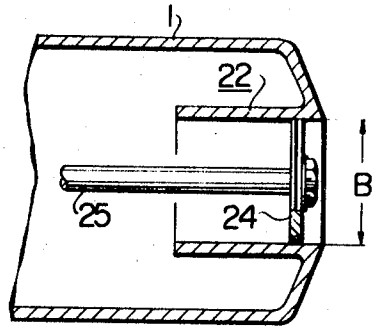
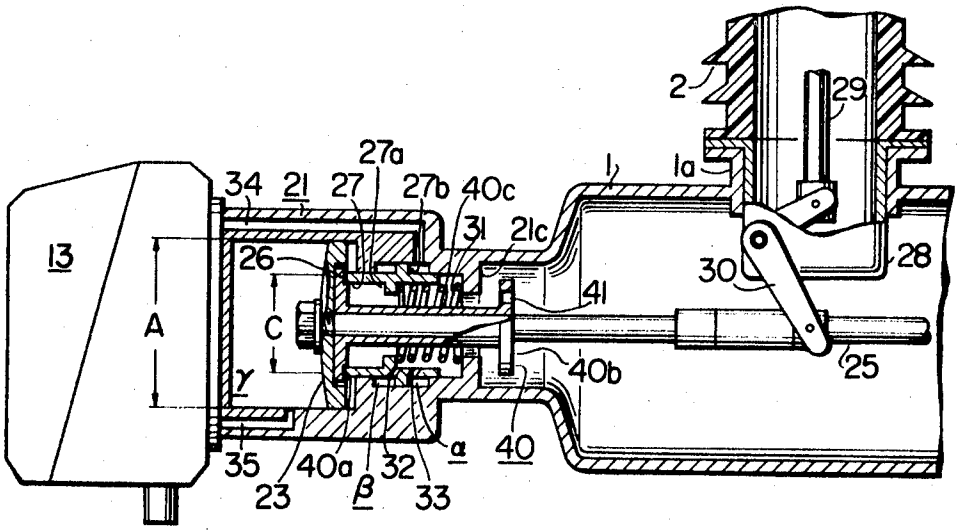

1
22
B
25
24

FIG. 3


2
29
27a
34
21
27
27b
40c
1
1a
13
31
21c
26
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C
γ
40b
25
35
40a
32
α
40
23
β
33

FIG. 4

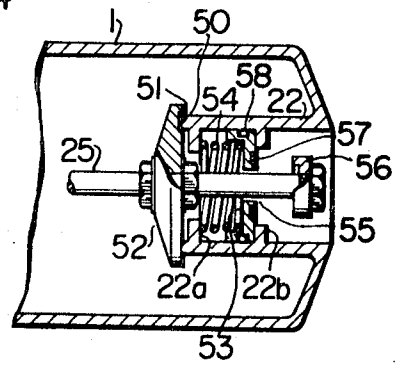


FIG. 5

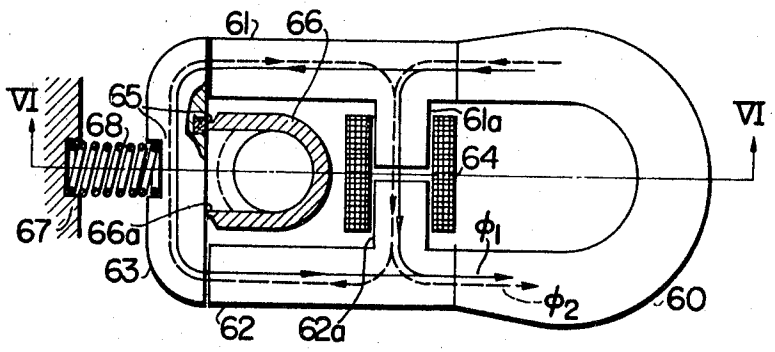
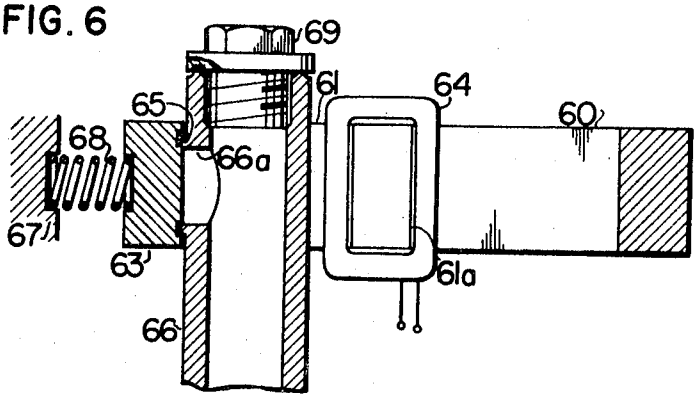


FIG. 6



FLUID OPERATED PISTON CIRCUIT BREAKER WITH FLOATING POSITION VALVE ACTUATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to circuit breakers and more particularly to a high-speed actuating system for use in a circuit breaker operating with a heavy load and having a large contact parting distance.

2. Description of the Prior Art

In a compressed-gas circuit breaker of the puffer type commonly known in the art, compression of an arc extinguishing gas is started substantially simultaneously with the contact parting operation and the compressed gas thus obtained is utilized to extinguish the arc across the contacts. A strong force of the order of 6 tons is generally required for compressing the gas in the circuit breaker of this kind rated at, for example, 168 kilovolts. The stroke of the piston in the cylinder for attaining the gas compression is relatively long or of the order of 100 to 200 millimeters although it varies depending on the current capacity. Since the compressing means and the movable contact are generally secured to a common actuating rod, the compression stroke of the piston is equal to the contact parting distance and this is considerably large compared with that of another kind of circuit breaker, for example, a compressed-air circuit breaker.

On the other hand, with the increase in the power demand, short-circuit current tends to appear more and more in many portions of large power transmission networks, and a high-speed operation is demanded more and more for circuit breakers in order to quickly deal with such short-circuit current.

U.S. Pat. application Ser. No. 199,194 filed Nov. 16, 1971 discloses an improved circuit breaker having an actuating system capable of quickly responding to short-circuit current and producing a strong actuating force. The actuating system in the patent application above described comprises a signal responsive valve member acted upon by a fluid under pressure, means for imparting a making force, an actuating rod connecting the signal responsive valve member and the making force imparting means with each other so that a first differential force relationship can be established therebetween due to the fact that the force of the fluid under pressure is imparted to the signal responsive valve member in a direction opposite to the direction of the making force relative to the actuating rod and the force imparted to the signal responsive valve member is greater than the making force, and a valve seat movable toward and away from the signal responsive valve member so as to limit the force of the fluid under pressure imparted to the signal responsive valve member when brought into engagement with the signal responsive valve member thereby establishing a second differential force relationship between the signal responsive valve member and the making force imparting means due to the fact that the limited force is imparted to the signal responsive valve member in a direction opposite to the direction of the making force and the making force is greater than the limited force imparted to the signal responsive valve member. In this actuating system, the movable valve seat is moved toward and away from the signal responsive valve member to control the force of the fluid under pressure acting upon the signal responsive valve member for selectively establishing one of the two differential force relationship thereby selectively biasing the actuating rod in one of the making and breaking directions so as to correspondingly actuate the breaker section operatively connected to the actuating rod.

While this actuating system is effective for use in a circuit breaker of the kind having a short contact parting distance, hence a short actuating distance, it is difficult to fully exhibit its technical merits in a circuit breaker of the kind having a long contact parting distance. More precisely, when the movable valve seat is moved slightly away from the signal responsive valve member, the fluid pressure is applied to the entire surface of the signal responsive valve member and the first differential force is established between this valve member and the making force imparting means, with the result that the signal responsive valve member is urged in the breaking direction. After disengaged from the signal responsive valve member, the movable valve seat follows the movement of the signal responsive valve member until finally it engages the signal responsive valve member, and in such a position, the movable valve seat stands by to move in the making direction again. However, a long contact parting distance leads inevitably to a long distance over which the movable valve seat must move following the movement of the signal responsive valve member. This necessitates a large size and an increase in the mass of the movable valve seat, resulting in a reduction of the speed with which the movable valve seat moves away from the signal responsive valve member and in a delayed application of the fluid pressure to the entire surface of the signal responsive valve member. Thus, not only the desired high-speed operation cannot be expected, but also the large size leads to an unstable operation of the movable valve seat itself, giving rise to an undesirable degradation of the reliability of the actuating system.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a circuit breaker having an improved actuating system which can actuate a breaker section operating with a heavy load and having a large contact parting distance at a high speed.

Another object of the present invention is to provide a circuit breaker having an improved actuating system which can be reliably and stably operated by small control energy.

A further object of the present invention is to provide a circuit breaker having an improved actuating system in which the loss of fluid under pressure applied to the signal responsive valve member during the breaking operation is reduced to a minimum and thus the operation can be carried out at a high speed.

The present invention provides improvements of the actuating system disclosed in U.S. Pat. application Ser. No. 199,194 in which the signal responsive valve member and the making force imparting means are connected to each other by the actuating rod, and the movable valve seat is moved toward and away from the signal responsive valve member to control the force of fluid under pressure acting upon the signal responsive valve member thereby selectively biasing the actuating rod in one of the making and breaking directions so as to correspondingly actuate the breaker section operatively connected to the actuating rod. According to the

present invention, a control valve member is disposed in proximity to the movable valve seat on the side remote from the signal responsive valve member so that it moves in response to the movement of the actuating rod in the breaking direction for controlling the application of the fluid pressure to the signal responsive valve member. The passage of the fluid under pressure to the signal responsive valve member is closed by this control valve member after the movable valve seat has been disengaged from the signal responsive valve member during the breaking operation and the fluid pressure has been applied to the entire surface of the signal responsive valve member. After having been disengaged from the signal responsive valve member, the movable valve seat follows the movement of the signal responsive valve member in the breaking direction. However, the distance over which the movable valve seat follows the signal responsive valve member is sufficiently short compared with the moving distance of the signal responsive valve member due to the fact that the control valve member closes the passage of the fluid under pressure leading to the signal responsive valve member and establishes a preparatory condition for a subsequent making operation. Thus, the movable valve seat takes a floating position spaced from the signal responsive valve member. In response to the application of a making instruction signal, the fluid under pressure acting upon the signal responsive valve member is discharged and the signal responsive valve member starts to be urged in the making direction by the making force imparted to the actuating rod by the making force imparting means. The movable valve seat in the floating position is brought into engagement with the signal responsive valve member again and the control valve member responsive to the movement of the actuating rod opens the passage of the fluid under pressure. The control valve member stands by in such a position and is now ready to respond to a breaking instruction signal.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a side elevation of a circuit breaker according to the present invention.

FIGS. **2***a* and **2***b* are enlarged longitudinal sections of parts of a grounded reservoir and associated means in the circuit breaker shown in FIG. **1**.

FIG. **3** is a view similar to FIG. **2***a*, but showing a modification of the arrangement shown in FIG. **2***a*.

FIG. **4** is a view similar to FIG. **2***b*, but showing a modification of the arrangement shown in FIG. **2***b*.

FIG. **5** is an enlarged partly sectional elevation of electromagnetic valve means employed in the circuit breaker shown in FIG. **1**.

FIG. **6** is a section taken on the line VI—VI in FIG. **5**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. **1**, there is shown a compressed-gas circuit breaker of the puffer type based on the principle according to the present invention. Referring to FIG. **1**, a pair of tubular porcelain insulators **2** and **3** extend upward from a grounded compressed fluid reservoir **1**, and a pair of puffer type breaker sections **4** and **5** at a high potential are secured to the top of the respective tubular insulators **2** and **3**. The tubular insulators **2** and **3** act to support the respective breaker sections **4** and **5** thereon, and at the same time, serve to electrically insulate the breaker sections **4** and **5** from the grounded reservoir **1**. Two pairs of bushings **6***a*, **6***b* and **7***a*, **7***b* constitute a path of current through the breaker sections **4** and **5**. In this manner, the breaker sections **4** and **5** are constructed to break the circuit at two points respectively and are connected in series with each other. In order to equalize the breaking capacity at the four breaking points, voltage dividing capacitors **8***a*, **8***b*, **9***a* and **9***b* are disposed in parallel with the four breaking points of the breaker sections **4** and **5** connected in series. In a circuit breaker operating with a high voltage, a making or breaking resistor is frequently added to each breaking point as required. However, in the embodiment of the present invention illustrated in FIG. **1**, these resistors are not employed.

The puffer type circuit breaker having such a construction is situated in a horizontal position spaced by a predetermined distance or height from the ground level by means of a base **10** supporting the grounded reservoir **1**, and the breaker sections **4** and **5** are securely fixed to the base **10** by a plurality of strain insulators **11***a*, **11***b*, **12***a* and **12***b* so that the breaker sections **4** and **5** may not fall down.

Means for actuating these two breaker sections **4** and **5** are contained within the grounded reservoir **1**, and a control unit therefor is contained within an actuating valve box **13** disposed adjacent to one of the axial ends of the grounded reservoir **1** so that the actuating means can be urged in one of the making and breaking directions under control of the control unit.

The actuating means contained within the grounded reservoir **1** will now be described in detail with reference to FIGS. **2***a* and **2***b*. A valve box **21** is formed in one of the axial ends of the grounded reservoir **1** as shown in FIG. **2***a*, and another valve box **22** is defined by a flange portion in the other axial end of the grounded reservoir **1** as shown in FIG. **2***b*. A signal responsive valve member **23** having a diameter A is disposed axially slidably within the valve box **21** in fluid-tight relation, and a making force imparting valve member **24** having a diameter B is similarly disposed within the valve box **22**. There is a relation A > B between the diameter A of the signal responsive valve member **23** and the diameter B of the making force imparting valve member **24**. These two valve members **23** and **24** are connected to each other by an actuating rod **25** extending through the space within the grounded reservoir **1**, and a fluid under pressure or herein compressed air acts uniformly upon these two valve members **23** and **24**. Thus, a first differential force relationship is established between these two valve members **23** and **24**.

The signal responsive valve member **23** is provided with a valve seat engaging packing **26** whose diameter C is smaller than the diameter B of the making force imparting valve member **24**, and a substantially annular valve seat **27** is disposed movably within the valve box **21** so as to engage and disengage the valve seat engaging packing **26**. This valve seat **27** acts as a means for limiting the effective area of the signal responsive valve member **23** to which the pressure of compressed air is applied. In the state in which the movable valve seat **27** engages the signal responsive valve member **23**, the diameter C of the valve seat engaging packing **26** engaging the movable valve seat **27** defines the effective area of the signal responsive valve member **23**. When com-

pressed air acting upon the portion of the signal responsive valve member 23 around the engaging end of the movable valve seat 27 is exhausted as will be described later, a second differential force relationship is established between the signal responsive valve member 23 and the making force imparting valve member 24 due to the difference between the diameters B and C. The first differential force relationship and the second differential force relationship are selectively established depending on the making operation and breaking operation in a manner as will be described later so that the actuating rod 25 is selectively urged rightward and leftward in FIG. 2*a*.

The tubular insulator 2 supporting the breaker section 4 is secured at its lower end portion to a flange portion 1*a* of the grounded reservoir 1 by a mounting fixture 28 as seen in FIG. 2*a*, and this mounting fixture 28 has a closed end extending into the grounded reservoir 1 so as to form a closed vessel together with the tubular insulator 2, the casing of the breaker section 4 and the bushings 6*a* and 6*b*. The interior of the closed vessel is filled with gaseous sulfur hexafluoride (SF_6) at a predetermined pressure which is excellent in the electrically insulating and arc extinguishing properties over compressed air. The breaker section 4 is connected to the actuating rod 25 by an actuating rod 29 of an electrical insulator extending through the tubular insulator 2 and a lever means 30 connected in fluid-tight relation to the actuating rod 29 so that the breaker section 4 is actuated for making or breaking operation through the actuating rod 29 and lever means 30 with the movement of the actuating rod 25 in either direction.

The movable valve seat 27 is provided with a pair of flange portions 27*a* and 27*b* on the inner and outer peripheral surfaces respectively. A spring 31 is disposed between a flanged portion of the valve box 21 and the inner flange portion 27*a* of the valve seat 27 so as to normally bias the movable valve seat 27 toward the signal responsive valve member 23. The outer flange portion 27*b* of the valve seat 27 is in intimate contact with the inner wall of the valve box 21 to serve as a piston.

The space defined between the inner wall of the valve box 21 and the outer peripheral surface of the movable valve seat 27 is divided into two chambers α and β by the outer flange portion 27*b* of the movable valve seat 27. Compressed air can flow from the grounded reservoir 1 into these chambers α and β through respective ports 33 and 32 formed in the movable valve seat 27. The chamber α nearer to the making force imparting valve member 24 communicates through a communication passage 34 with the control unit in the actuating valve box 13. A space or chamber γ is defined between the inner and end walls of the valve box 21 and the outer or left-hand surface of the signal responsive valve member 23. This chamber γ communicates similarly with the control unit in the actuating valve box 13 through a communication passage 35.

The actuating rod 25 is provided with a pair of spaced stoppers 36 and 37 at positions near the signal responsive valve member 23 in the valve box 21, and a control valve member 38 is loosely mounted on the actuating rod 25 at a position intermediate between the stoppers 36 and 37 so as to openably close the passage of compressed air supplied from the grounded reservoir 1 into the space within the annular movable valve seat 27 to act upon the signal responsive valve member 23.

Actually, the interior of the grounded reservoir 1 is filled with air compressed to about 15 to 30 atmospheres and a portion of the compressed air acts upon the signal responsive valve member 23 and making force imparting valve member 24. In the state shown in FIG. 2*a*, the movable valve seat 27 is pressed against the valve seat engaging packing 26 on the signal responsive valve member 23 by the force of the spring 31 since the same air pressure is applied to the chambers α and β. Due to the fact that a pressure substantially equal to the atmospheric pressure is applied to the area of the signal responsive valve member 23 outside the outer peripheral portion of the movable valve seat 27 and that the atmospheric pressure is normally applied to the outer surface of the making force imparting valve member 24, the second differential force relationship is established between these two valve members 23 and 24 and the actuating system is in the making position.

Upon application of a breaking instruction signal, compressed air in the chamber α is discharged to the atmosphere through the communication passage 34 by the action of breaking electromagnetic valve means (described later with reference to FIGS. 5 and 6) in the control unit contained in the actuating valve box 13. Due to the fact that the difference between the air pressures in the chambers α and β acts upon the outer flange portion 27*b* of the movable valve seat 27, the movable valve seat 27 is urged in the making direction or rightward in FIG. 2*a* against the force of the spring 31 to move away from the valve seat engaging packing 26 on the signal responsive valve member 23. As a result, compressed air within the grounded reservoir 1 acts upon the entire area of the signal responsive valve member 23 and the first differential force relationship is now established between the signal responsive valve member 23 and the making force imparting valve member 24. Thus, the force of compressed air acting upon the signal responsive valve member 23 urges quickly the actuating rod 25 and making force imparting valve member 24 in the breaking direction or leftward in FIGS. 2*a* and 2*b*. With the above movement of the actuating rod 25, the movable contact in the breaker section 4 (5) having been in contact with the stationary contacts is urged by the actuating rod 29 and lever means 30 to be disengaged from the stationary contacts while producing an arc therebetween and the arc is extinguished by a suitable arc extinguishing means such as a puffer type arc extinguishing means for breaking the circuit at the zero current point. The greater the difference between the diameter A of the signal responsive valve member 23 and the diameter B of the making force imparting valve member 24, the greater the differential force imparted to these valve members 23 and 24 and the greater the force imparted to the actuating rod 25 for urging same more quickly in the breaking direction.

The control valve member 38 is freely movable between the stoppers 36 and 37 provided on the actuating rod 25 during the movement of the actuating rod 25 in the breaking direction. In the state shown in FIG. 2*a*, all the elements are urged in the making direction and the stopper 37 is engaged by the control valve member 38. Thus, the rapid movement of the actuating rod 25 in the breaking direction imparts inertia to the control valve member 38 in such a manner as to maintain same stationary so that the control valve member 38 makes

a sliding movement relative to the actuating rod **25** to move apparently toward the stopper **36.** The control valve member **38** moving relative to the actuating rod **25** is driven in the breaking direction due to the friction between it and the actuating rod **25** and engages a valve seat **21***a* in the valve box **21** before the actuating rod **25** is urged completely in the breaking direction. The control valve member **38** closes the passage of compressed air supplied from the grounded reservoir **1** into the space within the valve seat **27** to act upon the signal responsive valve member **23.** Finally, the control valve member **38** is engaged by the stopper **36** to ensure the complete closure of the compressed air passage and stop further movement of the actuating rod **25** in the breaking direction. It is desirable that the control valve member **38** engages the valve seat **21***a* in the valve box **21,** hence, the passage of compressed air leading to the signal responsive valve member **23** is closed in a phase within the entire moving stroke of the signal responsive valve member **23.** This is because a powerful braking means must be provided in order to forcedly stop the movement of the signal responsive valve member **23** if compressed air is continuously applied to the signal responsive valve member **23** even after it has been urged to its leftmost position in FIG. **2***a*. The closure of the compressed air supply passage at a position midway of the entire moving stroke of the signal responsive valve member **23** is advantageous in that such a powerful braking means need not be provided due to the fact that the signal responsive valve member **23** is moved merely by the energy accummulated in the actuating rod **25** and other elements in the actuating system.

The movable valve seat **27** is disengaged from the signal responsive valve member **23** when the actuating rod **25** is urged in the breaking direction. With the subsequent closure of the breaking electromagnetic valve means in the control unit communicating with the communication passage **34,** compressed air is re-charged into the chamber α and the communication passage **34** through the port **33** until finally the force of the spring **31** overcomes the differential pressure of compressed air acting upon the outer flange portion **27***b* of the movable valve seat **27.** As a result, the movable valve seat **27** is urged toward the signal responsive valve member **23** to follow the movement of the signal responsive valve member **23.** This movement of the movable valve seat **27** is limited by the fact that the outer flange portion **27***b* is engaged by a flange portion **21***b* of the valve box **21,** and thus, in the state in which the actuating system is in the breaking position, the movable valve seat **27** does not engage the valve seat engaging packing **26** and is maintained in a floating position spaced from the signal responsive valve member **23.** The communication passage **35** opens desirably into the chamber γ within the valve box **21** at such a position that the opening is located intermediate between the extreme position taken by the signal responsive valve member **23** in response to the making instruction signal and the extreme position taken by the signal responsive valve member **23** in response to the breaking instruction signal. Such a position of the opening of the communication passage **35** is preferred in that, when the movable valve seat **27** is disengaged from the valve seat engaging packing **26,** compressed air acts upon the entire area of the signal responsive valve member **23** without being charged into the communication passage **35,** thereby rapidly establishing the first differential force relationship for quickly urging the signal responsive valve member **23** in the breaking direction. During the movement of the signal responsive valve member **23** in the breaking direction, compressed air is also supplied into the communication passage **35** and the pressure of compressed air acting upon the signal responsive valve member **23** is reduced thereby ensuring reliable closure of the compressed air supply passage by the control valve member **38** and effectively reducing the scale of means for applying the brake.

In the state in which the actuating system is in the breaking position, the control valve member **38** shuts off the supply of compressed air from the grounded reservoir **1** into the valve box **21,** and the communication passages **34** and **35** are completely closed by the electromagnetic valve means in the control unit communicating with these passages **34** and **35.** Thus, the interior of the valve box **21** is filled with compressed air of the same pressure as that in the grounded reservoir **1.**

Upon application of a making instruction signal, making electromagnetic valve means (described later with reference to FIGS. **5** and **6**) in the control unit communicating with the communication passage **35** is actuated to discharge the compressed air in the chamber γ to the atmosphere. As a result, the force of compressed air having been imparted to the signal responsive valve member **23** disappears and the first differential force relationship is cancelled. Thus, the actuating rod **25** is urged in the making direction or rightward by the force of compressed air imparted to the making force imparting valve member **24** so as to urge the movable contact in the making direction through the actuating rod **29** and lever means **30** connected thereto.

In this case, the control valve member **38** is kept in seating engagement with the valve seat **21***a* in the valve box **21** by the difference between the pressure in the exhausted chamber γ in the valve box **21** and the pressure of compressed air in the grounded reservoir **1** although it tends to be moved in the making direction together with the actuating rod **25** by the friction therebetween. When finally the control valve member **38** is engaged by the stopper **37,** the control valve member **38** is forcedly disengaged from the valve seat **21**a in the valve box **21.** The floating position of the movable valve seat **27** in the breaking position of the actuating system is so selected that the movable valve seat **27** engages the valve seat engaging packing **26** before the control valve member **38** is disengaged from the valve seat **21***a*. Therefore, a limited amount of compressed air is merely discharged to the atmosphere through the communication passage **35** when the making operation takes place. That is, compressed air filled in the space ranging from the valve seat **21***a* closed by the control valve member **38** to the chamber γ in the valve box **21** is merely discharged to the atmosphere. When the signal responsive valve member **23** has moved in the making direction beyond the opening of the communication passage **35** into the valve box **21,** exhaust of compressed air through the communication passage **35** is completed, and thereafter, the valve seat engaging packing **26** engages the movable valve seat **27,** finally the control valve member **38** being disengaged from the valve seat **21***a*. Thus, the combination establishing the second differential force relationship has been set already at the time the control valve member **38** has been disengaged from the valve seat **21***a* and the compressed air supply passage from the grounded reservoir

1 to the signal responsive valve member 23 has been re-opened. Although the pressure of compressed air is applied to the signal responsive valve member 23, it augments substantially the second differential force relationship and no transfer to the first differential force relationship would occur.

It will be understood from the above description given with reference to a preferred embodiment of the present invention that the movable valve seat need not follow the entire stroke of the signal responsive valve member in the breaking direction in response to the application of a breaking instruction signal and may only move over a short range relative to the signal responsive valve member to remain in a floating position spaced from the signal responsive valve member so that it is ready to move in the making direction in response to a subsequent making instruction signal. Therefore, the movable valve seat may be quite small in size and the energy required for driving the movable valve seat, that is, the energy required for the breaking operation may be quite small. Further, by virtue of the small size, the movable valve seat can be reliably driven in response to a breaking instruction signal.

FIG. 3 shows a modification of the present invention and like reference numerals are used therein to denote like parts appearing in FIG. 2*a*.

In the embodiment shown in FIG. 2*a*, the operation of the control valve member 38 is substantially regulated by the stoppers 36 and 37 provided on the actuating rod 25. The modification shown in FIG. 3 differs from the structure shown in FIG. 2*a* in that it comprises a control valve member 40 which operates in response to the action of the compressed air together with the signal responsive valve member 23 thereby closing the compressed air supply passage leading to the signal responsive valve member 23 while moving in response to the movement of the signal responsive valve member 23 carried by the actuating rod 25. More precisely, the control valve member 40 is composed of a valve portion 40*a* releasably received in a recess of the signal responsive valve member 23, an abutment portion 40*b* engaging a flange portion 21*c* of the valve box 21 during breaking operation, and a sleeve portion 40*c* connecting the valve portion 40*a* with the abutment portion 40*b* and disposed concentrically around the actuating rod 25. The movable valve seat 27 is engageable with the valve seat engaging packing 26 which is provided, in this case, on the valve portion 40*a* of the control valve member 40 so that the area of the signal responsive valve member 23 acted upon by compressed air can be limited by the movable valve seat 27 through the valve portion 40*a* of the control valve member 40.

Upon application of a breaking instruction signal, the movable valve seat 27 is disengaged from the valve seat engaging packing 26 on the control valve member 40, and the control valve member 40 is urged together with the signal responsive valve member 23 in the breaking direction or leftward in FIG. 3 by the pressure of compressed air until finally the control valve member 40 is stopped from further movement due to the engagement of the abutment portion 40*b* thereof with the flange portion 21*c* of the valve box 21. At this position of the control valve member 40, compressed air is continuously and gradually supplied into the valve box 21 through an orifice 41 formed in the abutment portion 40*b*. Thus, the signal responsive valve member 23 is continuously urged in the breaking direction by the pressure of compressed air passing through the orifice 41 even after the control valve member 40 has ceased its movement. However, the signal responsive valve member 23 is not excessively accelerated due to the flow control by the orifice 41, and the actuating system is continuously moved in the breaking direction by the inertia force applied thereto at the beginning of the breaking operation until it is stopped at the breaking position. The movable valve seat 27 is urged by the spring 31 with a slight delay relative to the movement of the signal responsive valve member 23 carried by the actuating rod 25 to follow the movement of the signal responsive valve member 23 until it is brought into fluid-tight engagement with the valve seat engaging packing 26 on the control valve member 40. The movable valve seat 27 engaging the valve seat engaging packing 26 on the control valve member 40 cannot move any further to follow the movement of the signal responsive valve member 23 and is maintained in a floating position spaced from the signal responsive valve member 23. The movable valve seat 27 is maintained in such a floating position so that it is ready to move in the making direction in response to a subsequent making instruction signal.

Upon application of a making instruction signal, compressed air in the chamber γ of the valve box 21 is discharged to the atmosphere through the communication passage 35 by the action of the making electromagnetic valve means in the control unit and the first differential force relationship is now cancelled so that the signal responsive valve member 23 starts to move in the making direction or rightward in FIG. 3. Due to the fact that the movable valve seat 27 engages the control valve member 40 and the compressed air supply passage leading to the signal responsive valve member 23 from the grounded reservoir 1 is closed at this portion, a limited amount of compressed air is merely discharged, that is, compressed air existing in the range between the control valve member 40 ready to move in the making direction and the signal responsive valve member 23 in the breaking position is discharged from the valve box 21. On the other hand, compressed air existing in the range between the control valve member 40 in such a position and the flange portion 21*c* of the valve box 21 is not discharged from the valve box 21. Therefore, a great degree of reduction occurs in the pressure of compressed air in the former space and the first differential force relationship is rapidly cancelled. Thus, the making operation is started immediately. Thereafter, the signal responsive valve member 23 is moved to the making position shown in FIG. 3 in unitary relation with the control valve member 40.

Suppose that a breaking instruction signal is applied due to free tripping after the making operation for urging the signal responsive valve member 23 to the making position has been started. Since compressed air is continuously supplied to the valve portion 40*a* of the control valve member 40 through the orifice 41 in the abutment portion 40*b* even in the breaking position, compressed air acts immediately on all the area of the signal responsive valve member 23 as soon as the movable valve seat 27 is disengaged from the valve portion 40*a* of the control valve member 40, and the signal responsive valve member 23 carried by the actuating rod 25 starts to move in the breaking direction again.

When free tripping is done during the making operation, the control valve member 40 may take an inter-

mediate position intermediate between the breaking position or the position ready to move in the making direction and the making position shown in FIG. 3. However, due to the fact that the interior of the valve box 21 is filled with compressed air and no differential force of compressed air is imparted to the control valve member 40 in the breaking position of the actuating system, the movable valve seat 27 is urged to follow the movement of the signal responsive valve member 23 and the control valve member 40 is urged by the force of the spring 31 to the position at which it is ready to respond to a subsequent making instruction signal.

It will be easily understood that the making operation and free tripping operation can be carried out rapidly in the modification shown in FIG. 3.

In FIG. 2*b*, the making force imparting valve member 24 is illustrated as a means for imparting the making force. However, entirely the same effect can be exhibited by employing a spring in place of the making force imparting valve member 24 provided that the spring biases normally the actuating rod 25 in the making direction.

FIG. 4 shows a modification of the making force imparting valve member 24 shown in FIG. 2*b*. The making force imparting valve member 24 shown in FIG. 2*b* biases normally the actuating rod 25 in the making direction by being urged by the pressure of compressed air in the grounded reservoir 1. In the modification shown in FIG. 4, a making force imparting valve member consisting of two valve elements is used so that a force biasing the actuating rod 25 in the making direction is imparted to the actuating rod 25 only when the actuating system is in the breaking and making positions and so that any force biasing the actuating rod 25 in the making direction may not be imparted to the actuating rod 25 for a suitable period of time during the breaking or making operation.

Referring to FIG. 4, the inner end of the valve box 22 forms a valve seat 50, and a valve element 52 having a valve seat engaging packing 51 thereon is mounted on the actuating rod 25 so that the valve seat 50 is engageable with the valve seat engaging packing 51. A floating valve seat 53 is slidable in fluid-tight relation between a pair of spaced flange portions 22*a* and 22*b* formed on the inner wall surface of the valve box 22. This floating or movable valve seat 53 is normally biased toward the flange portion 22*b* by the force of a spring 54. An auxiliary valve element 56 is mounted on the end of the actuating rod 25 so as to engage the movable valve seat 53 in response to the movement of the actuating rod 25 in the breaking direction thereby closing an orifice 55 formed in the movable valve seat 53. Thus, the pressure of compressed air in the grounded reservoir 1 is applied to the movable valve seat 53 when the orifice 55 is closed by the auxiliary valve element 56. The movable valve seat 53 is provided with an O-ring 58 and a valve seat packing 57 in order to ensure fluid-tightness between the inner wall of the valve box 22 and the movable valve seat 53 and between the movable valve seat 53 and the auxiliary valve element 56 respectively.

In FIG. 4, the making force imparting valve member is shown in the making position as in FIG. 2b. The valve element 52 is in engagement with the valve seat 50 and the second differential force relationship is established between the valve element 52 and the signal responsive valve member 23 shown in FIG. 2*a* or 3.

Upon application of a breaking instruction signal, the movable valve seat 27 is disengaged from the signal responsive valve member 23 and the pressure of compressed air is applied to the entire area of the signal responsive valve member 23, thereby cancelling the second differential force relationship above described and establishing the first differential force relationship between the signal responsive valve member 23 and the valve element 52. Thus, the valve element 52 is urged in the breaking direction or leftward in FIG. 4 by the actuating rod 25. The fluid-tight seal between the valve seat engaging packing 51 and the valve seat 50 is now lost and compressed air in the grounded reservoir 1 passes through the gap between the valve element 52 and the valve seat 50 and through the space of the flange portion 22*a* to act upon the movable valve seat 53, a portion of compressed air being discharged to the atmosphere through the orifice 55. With the movement of the actuating rod 25 in the breaking direction, the auxiliary valve element 56 engages the valve seat packing 57 to completely close the orifice 55 so that the movable valve seat 53 is now subjected to the full pressure of compressed air in the grounded reservoir 1. Thereafter, the movable valve seat 53 is engaged by the flange portion 22*a* and the actuating rod 25 ceases to move any further in the breaking direction.

In the breaking operation above described, the pressure of compressed air is not applied to the auxiliary valve element 56 until the auxiliary valve element 56 engages the valve seat packing 57 to maintain fluid-tightness therebetween after the valve seat engaging packing 51 on the valve element 52 has been disengaged from the valve seat 50. Thus, no force tending to bias the actuating rod 25 in the making direction appears during the breaking operation. Therefore, the signal responsive valve member 23 can satisfactorily carry out the breaking operation without being encountered with the force tending to bias same in the making direction. This is advantageous in that the actuating rod 25 can be quickly urged in the breaking direction by that much and the diameter A of the signal responsive valve member 23, hence the size of the valve box 21 can be considerably reduced to deal with the required contact parting speed.

Upon application of a making instruction signal, compressed air having acted upon the signal responsive valve member 23 is discharged to the atmosphere and the first differential force relationship having been established between the signal responsive valve member 23 and the movable valve seat 53 engaged by the auxiliary valve element 56 is now cancelled. The movable valve seat 53 is urged in the making direction thereby urging the auxiliary valve element 56, hence the actuating rod 25 in the making direction until it is engaged by the flange portion 22*b*. During the above movement, the movable valve seat 53 imparts the inertia force to the actuating system so that the actuating system including the actuating rod 25 is restored to the making position shown in FIG. 4 by the inertia force imparted thereto. Due to the fluid-tight engagement between the valve seat 50 and the valve seat engaging packing 51 on the valve element 52, the pressure of compressed air in the grounded reservoir 1 is applied to the entire area of the valve element 52 thereby reliably maintaining the actuating system in the making position.

During the making operation above described, no making force is imparted to the actuating system any

more when the movable valve seat 53 engages the flange portion 23*b*, and the actuating system including the actuating rod 25 continues to move in the making direction by the inertia. Therefore, the making force is not imparted to the actuating system in the final step of the making operation, and a braking means of very small size suffices to stop the movement of the actuating system in the making direction. The amount of compressed air which is discharged to the atmosphere through the orifice 55 during the breaking and making operations can be reduced by reducing the area of the orifice 55.

FIGS. 5 and 6 show one form of the electromagnetic valve means in the control unit contained in the actuating valve box 13. There are a pair of such electromagnetic valve means to deal with the making operation and breaking operation respectively. The breaking electromagnetic valve means is disposed to be connected with the communication passage 34 in the valve box shown in FIG. 2*a* or 3, while the making electromagnetic valve means is disposed to be connected with the communication passage 35 in the valve box 21.

The structure of the breaking electromagnetic valve means will be described with reference to FIGS. 5 and 6 by way of example. A pair of parallel yoke members 61 and 62 are joined at one end thereof to the open end portions of a horseshoe permanent magnet 60, and a valve element 63 bridges the other end of the yoke members 61 and 62. A pair of leg portions 61*a* and 62*a* extend toward each other from the respective yoke members 61 and 62 at a suitable position intermediate of the length thereof, and a reverse energizing coil 64 is wound around the leg portions 61*a* and 62*a* while being suitably electrically insulated therefrom. The valve element 63 is provided with a valve seat engaging packing 65 which engages a valve seat 66*a* formed at the peripheral edge of an opening in a communication conduit 66 connected to the communication passage 34. The communication conduit 66 communicates with the chamber α in the valve box 21, and in the making position of the actuating system, compressed air is supplied into the communication conduit 66 through the port 33 in the movable valve seat 27 and through the communication passage 34. The pressure of compressed air is applied to the valve element 63 and tends to urge the valve element 63 away from the yoke members 61 and 62. However, the holding magnetic flux ϕ_1 (shown by the solid lines) produced by the horseshoe permanent magnet 60 maintains the valve element 63 magnetically fixed to the yoke members 61 and 62 and the sealing engagement between the valve seat engaging packing 65 and the valve seat 66*a* prevents compressed air in the communication conduit 66 from being discharged to the atmosphere. The force of a return spring 68 disposed between the valve element 63 and a stationary member 67 is imparted to the valve element 63 so as to cooperate with the holding magnetic flux ϕ_1 for normally preventing compressed air in the communication conduit 66 from being discharged to the atmosphere.

In response to the application of a breaking instruction signal to the reverse energizing coil 64, this coil 64 produces a cancelling magnetic flux ϕ_2 (shown by the broken lines) which flows in a direction opposite to the direction of the holding magnetic flux ϕ_1 passing through the yoke members 61, 62 and valve element 63, thereby reducing the magnetic force fixing the valve element 63 to the yoke members 61 and 62. As a result, the pressure of compressed air in the communication conduit 66 urges the valve element 63 away from the yoke members 61 and 62 against the force of the return spring 68 and the magnetic force. Compressed air in the communication conduit 66, communication passage 34 and chamber α is discharged to the atmosphere and the movable valve seat 27 is disengaged from the signal responsive valve member 23. When the pressure of compressed air in the communication conduit 66 is reduced to a level lower than the force of the return spring 68, the valve element 63 is urged toward the yoke members 61 and 62 by the force of the return spring 68, and the valve seat engaging packing 65 engages the valve seat 66*a* again. After the breaking operation, compressed air is gradually charged into the communication conduit 66 through the port 33 in the movable valve seat 27 and through the communication passage 34 until finally the pressure of compressed air in the communication conduit 66 builds up to the level equal to that of compressed air in the grounded reservoir 1. The breaking instruction signal is applied to the reverse energizing coil 64 in the form of a pulse to instruct the starting of breaking operation. Thus, even when the interior of the communication conduit 66 is filled with compressed air again, the valve element 63 would not be disengaged from the yoke members 61 and 62 and is kept fixed to the latter by the magnetic force due to the holding magnetic flux ϕ_1 and by the force of the return spring 68.

The coiling direction of the reverse energizing coil 64 wound around the leg portions 61*a* and 62*a* of the yoke members 61 and 62 and the polarity of the breaking instruction signal are such that the cancelling magnetic flux ϕ_2 produced by the coil 64 passes through the leg portions 61*a* and 62*a* in the same direction as that of the holding magnetic flux ϕ_1 produced by the permanent magnet 60. Thus, these two magnetic fluxes ϕ_1 and ϕ_2 pass through the horseshoe permanent magnet 60 in the same direction and the magnetic force of the horseshoe permanent magnet 60 is not in any way reduced by the cancelling magnetic flux ϕ_2 produced by the coil 64.

In the electromagnetic valve means shown in FIGS. 5 and 6, the movement of the valve element 63 away from the yoke members 61 and 62 takes place in about 2/1,000 second after the application of the breaking instruction signal to the reverse energizing coil 64, and the communication conduit 66 communicates with the atmosphere as soon as the valve element 63 is moved away from the yoke members 61 and 62. Thus, the movable valve seat 27 in the valve box 21 is urged very quickly after the application of the breaking instruction signal. Further, due to the fact that compressed air in the communication conduit 66 is discharged from the opening to urge the valve element 63 away from the yoke members 61 and 62, any especial means for amplifying the breaking instruction energy is unnecessary. Thus, the electromagnetic valve means is quite simple in construction and can operate with high reliability. Further, as seen in FIG. 6, a fluid-tight plug 69 is removably inserted in the end of the communication conduit 66 so as to allow for inspection of the interior of the communication conduit 66.

The embodiment of the present invention and modifications thereof have been described with reference to the case in which compressed air is used as a fluid

under pressure acting upon the signal responsive valve member and making force imparting valve member. However, in a circuit breaker of the double pressure type employing a pressurized fluid such as gaseous sulfur hexafluoride (SF_6) in the breaker sections **4** and **5**, the grounded reservoir may be replaced by a high-pressure gas vessel, and in lieu of the compressed air discharged to the atmosphere, sulfur hexafluoride gas may be discharged into a low-pressure gas vessel. Further, any other fluid under pressure may be employed for actuating the actuating system and this fluid may be different from a fluid under pressure employed in the breaker sections for arc extinction. Furthermore, the pressure or property of the fluid under pressure acting upon the signal responsive valve member and making force imparting valve member may be suitably changed without departing from the spirit of the present invention provided that the two differential force relationships can be established between these two valve members. Moreover, the electromagnetic valve means may have any other suitable structure in lieu of that shown in FIGS. **5** and **6** provided that the fluid under pressure can be discharged within a short period of time.

We claim:

1. A circuit breaker having an actuating system comprising a pair of a first force producing means producing a large force in one direction and a second force producing means producing a smaller force in a direction opposite to the above direction, and actuating rod connecting said first and second force producing means with each other in such a manner as to establish a first differential force relationship therebetween, force reducing means adapted to move toward and away from said first force producing means for reducing the force produced by said first force producing means when brought into engagement therewith so as to establish a second differential force relationship between said first force producing means in such a state and said second force producing means, means for controlling the movement of said force reducing means toward and away from said first force producing means and controlling the application of fluid under pressure to said first force producing means for selectively establishing one of said two differential force relationships thereby selectively biasing said actuating rod in one of the making and breaking directions so as to correspondingly actuate the breaker section operatively connected to said actuating rod, and means responsive to the movement of said actuating rod for controlling the application of fluid under pressure to said first force producing, means after said force reducing means has moved away from said first force producing means and maintaining said force reducing means in a floating position spaced from said first force producing means.

2. A circuit breaker having an actuating system as claimed in claim **1**, in which the difference between the forces is larger in said first differential force relationship than that in said second differential force relationship, and said actuating rod is biased in the breaking direction when said first differential force relationship is established, while said actuating rod is biased in the making direction when said second differential force relationship is established, thereby correspondingly actuating the breaker section operatively connected thereto.

3. A circuit breaker having an actuating system comprising a signal responsive valve member mounted on one end of an actuating rod in a valve box, a movable valve seat movable in said valve box toward and away from said signal responsive valve member so as to limit the range of application of fluid under pressure to said signal responsive valve member when brought into engagement with said signal responsive valve member and to follow the movement of said signal responsive valve member in one direction after said signal responsive valve member has moved away therefrom, said movable valve seat following the movement of said signal responsive valve member taking finally a floating position spaced from said signal responsive valve member, another valve member movable in response to the movement of said actuating rod for controlling the application of fluid under pressure to said signal responsive valve member, means mounted on said actuating rod for imparting a making force thereto, means for removing the fluid under pressure applied to said movable valve seat, and means for removing the fluid under pressure applied to said signal responsive valve member, the application of fluid pressure to said signal responsive valve member being controlled for selectively biasing said actuating rod in one of the making and breaking directions thereby correspondingly actuating the breaker section operatively connected thereto.

4. A circuit breaker having an actuating system as claimed in claim **3**, in which said means for removing the fluid under pressure applied to said signal responsive valve member includes a fluid discharge passage which opens in said valve box at a position intermediate of the entire moving stroke of said signal responsive valve member.

5. A circuit breaker having an actuating system as claimed in claim **3**, in which said movable valve seat is provided with a flange portion making substantially fluid-tight sliding engagement with the inner wall surface of said valve box and a spring normally biasing movable valve seat toward said signal responsive valve member, said movable valve seat being urged away from said signal responsive valve member by the difference between the fluid pressures acting upon opposite surfaces of said flange portion, and each of said means for removing the fluid under pressure applied to said movable valve seat and means for removing the fluid under pressure applied to said signal responsive valve member comprises electromagnetic valve means including a valve element in fluid-tight engagement with a fluid discharge port, a magnet producing a holding magnetic flux for attracting and holding said valve element in the port closing position against the fluid pressure acting upon said valve element in the port opening direction, and a coil producing a cancelling magnetic flux for urging said valve element to the open position in response to the application of a valve actuating signal, said cancelling magnetic flux passing through said valve element in a direction opposite to the direction of said holding magnetic flux and passing through said magnet in the same direction as that of said holding magnetic flux.

6. A circuit breaker having an actuating system comprising a signal responsive valve member mounted on one end of an actuating rod in a valve box, a movable valve seat movable in said valve box toward and away from said signal responsive valve member so as to limit the range of application of fluid under pressure to said signal responsive valve member when brought into engagement with said signal responsive valve member and

to follow the movement of said signal responsive valve member in one direction after said signal responsive valve member has moved away therefrom, said movable valve seat following the movement of said signal responsive valve member taking finally a floating position spaced from said signal responsive valve member, a control valve member movable in response to the movement of said actuating rod for shutting off the supply of the fluid under pressure to said signal responsive valve member during the movement of said actuating rod in the breaking direction, a making force imparting valve member mounted on the other end of said actuating rod in another valve box opposite to said signal responsive valve member, means for removing the fluid under pressure applied to said movable valve seat, and means for removing the fluid under pressure applied to said signal responsive valve member, the application of fluid pressure to said signal responsive vale member being controlled by disengaging said movable valve seat from said signal responsive valve member during the breaking operation, while it being controlled by said fluid removing means during the making operation for selectively biasing said actuating rod in one of the making and breaking directions thereby correspondingly actuating the breaker section operatively connected thereto.

7. A circuit breaker having an actuating system as claimed in claim **6**, in which said actuating rod extends through a grounded reservoir filled thereinside with compressed air, a portion of compressed air in said grounded reservoir being supplied to said signal responsive valve member and said making force imparting valve member accommodated in the valve boxes disposed at opposite end portions of said grounded reservoir, and the breaker section is supported on a tubular insulator upstanding from said grounded reservoir to be electrically insulated from said grounded reservoir, said breaker section being connected to said actuating rod by an actuating rod of electrical insulator.

8. A circuit breaker having an actuating system as claimed in claim **6**, in which a first differential force relationship is established between said signal responsive valve member and said making force imparting valve member connected to each other by said actuating rod due to the fact that different fluid pressures are applied to said valve members in directions opposite to each other and the total fluid pressure applied to said signal responsive valve member differs from or is higher than the total fluid pressure applied to said making force imparting valve member, while a second differential force relationship is established between said signal responsive valve member and said making force imparting valve member when said movable valve seat movable toward and away from said signal responsive valve member for controlling the total fluid pressure applied thereto is brought into engagement with said signal responsive valve member due to the fact that the total fluid pressure applied to said signal responsive valve member is now lower than the total fluid pressure applied to said making force imparting valve member, said movable valve seat being moved toward and away from said signal responsive valve member and the fluid pressure applied to said signal responsive valve member being controlled for selectively establishing one of said two differential force relationships thereby selectively biasing said actuating rod in one of the making and breaking directions so as to correspondingly actuate the breaker section operatively connected to said actuating rod.

9. A circuit breaker having an actuating system as claimed in claim **6**, in which the fluid under pressure acting upon said signal responsive valve member differs in property from the fluid under pressure acting upon said making force imparting valve member.

10. A circuit breaker having an actuating system as claimed in claim **6**, in which said making force imparting valve member imparts the force biasing said actuating rod in the making direction by being urged by the pressure difference between a high-pressure chamber and a low-pressure chamber and is composed of a pair of valve elements which engage individual valve seats in fluid-tight relation during the making and breaking operations respectively, by being urged by said pressure difference in the making direction so as to close a communication passage between said pressure chambers and act to allow for complete communication of said high-pressure chamber with said low-pressure chamber through said passage for a predetermined period of time after the making or breaking operation has started, thereby temporarily eliminating the pressure difference between said pressure chambers.

11. A circuit breaker having an actuating system as claimed in claim **6**, in which said means for removing the fluid under pressure applied to said signal responsive valve member includes a fluid discharge passage which opens in said valve box at a position intermediate the entire moving stroke of said signal responsive valve member.

12. A circuit breaker having an actuating system as claimed in claim **6**, in which said movable valve seat is provided with a flange portion making substantially fluid-tight sliding engagement with the inner wall surface of said valve box and a spring normally biasing said movable valve seat toward said signal responsive valve member, said movable valve seat being urged away from said signal responsive valve member by the difference between the fluid pressures acting upon opposite surfaces of said flange portion, and each of said means for removing the fluid under pressure applied to said movable valve seat and said means for removing the fluid under pressure applied to said signal responsive valve member comprises electromagnetic valve means including a valve element in fluid-tight engagement with a fluid discharge port, a magnet producing a holding magnetic flux for attracting and holding said valve element in the port closing position against the fluid pressure acting upon said valve element in the port opening direction, and a coil producing a cancelling magnetic flux for urging said valve element to the open position in response to the application of a valve actuating signal, said cancelling magnetic flux passing through said valve element in a direction opposite to the direction of said holding magnetic flux and passing through said magnet in the same direction as that of said holding magnetic flux.

13. A circuit breaker having an actuating system comprising a signal responsive valve member mounted on one end of an actuating rod in a valve box, a movable valve seat movable in said valve box toward and away from said signal responsive valve member so as to limit the range of application of fluid under pressure to said signal responsive valve member when brought into engagement with said signal responsive valve member and to follow the movement of said signal responsive

valve member in one direction after said signal responsive valve member has moved away therefrom, said movable valve seat following the movement of said signal responsive valve member taking finally a floating position spaced from said signal responsive valve member, a control valve member movable in response to the movement of said actuating rod for shutting off the supply of the fluid under pressure to said signal responsive valve member during the movement of said actuating rod in the breaking direction, a making force imparting spring mounted on said actuating rod opposite to said signal responsive valve member, means for removing the fluid under pressure applied to said movable valve seat, and means for removing the fluid under pressure applied to said signal responsive valve member, the application of the fluid pressure to said signal responsive valve member being controlled by disengaging said movable valve seat from said signal responsive valve member during the breaking operation, while it being controlled by said fluid removing means during the making operation for selectively biasing said actuating rod in one of the making and breaking directions thereby correspondingly actuating the breaker section operatively connected thereto.

14. A circuit breaker having an actuating system as claimed in claim **13,** in which said means for removing the fluid under pressure applied to said signal responsive valve member includes a fluid discharge passage which opens in said valve box at a position intermediate of the entire moving stroke of said signal responsive valve member.

15. A circuit breaker having an actuating system as claimed in claim **13,** in which said movable valve seat is provided with a flange portion making substantially fluid-tight sliding engagement with the inner wall surface of said valve box and a spring normally biasing said movable valve seat toward said signal responsive valve member, said movable valve seat being urged away from said signal responsive valve member by the difference between the fluid pressures acting upon opposite surfaces of said flange portion, and each of said means for removing the fluid under pressure applied to said movable valve seat and said means for removing the fluid under pressure applied to said signal responsive valve member comprises electromagnetic valve means including a valve element in fluid-tight engagement with a fluid discharge port, a magnet producing a holding magnetic flux for attracting and holding said valve element in the port closing position against the fluid pressure acting upon said valve element in the port opening direction, and a coil producing a cancelling magnetic flux for urging said valve element to the open position in response to the application of a valve actuating signal, said cancelling magnetic flux passing through said valve element in a direction opposite to the direction of said holding magnetic flux and passing through said magnet in the same direction as that of said holding magnetic flux.

16. A circuit breaker having an actuating system comprising a signal responsive valve member mounted on one end of an actuating rod in a valve box, a control valve member having a portion thereof normally engaging a recess in said signal responsive valve member in said valve box and movable while following the movement of said actuating rod in the breaking direction until it is locked in a position midway of the above movement of said actuating rod, a movable valve seat movable in said valve box toward and away from said signal responsive valve member so as to limit the range of application of fluid under pressure to said signal responsive valve member when brought into engagement with said signal responsive valve member through said control valve member and to follow the movement of said control valve member in one direction after said control valve member has moved away therefrom, said movable valve seat following the movement of said control valve member taking finally a floating position spaced from said signal responsive valve member to shut off the supply of the fluid under pressure to said signal responsive valve member, a making force imparting valve member mounted on the other end of said actuating rod in another valve box opposite to said signal responsive valve member, means for removing the fluid under pressure applied to said movable valve seat, and means for removing the fluid under pressure applied to said signal responsive valve member, the application of fluid pressure to said signal responsive valve member being controlled thereby selectively biasing said actuating rod in one of the making and breaking directions so as to correspondingly actuate the breaker section operatively connected to said actuating rod.

17. A circuit breaker having an actuating system as claimed in claim **16,** in which said means for removing the fluid under pressure applied to said signal responsive valve member includes a fluid discharge passage which opens in said valve box at a position intermediate of the entire moving stroke of said signal responsive valve member.

18. A circuit breaker having an actuating system as claimed in claim **16,** in which said movable valve seat is provided with a flange portion making substantially fluid-tight sliding engagement with the inner wall surface of said valve box and a spring normally biasing said movable valve seat toward said signal responsive valve member, said movable valve seat being urged away from said signal responsive valve member by the difference between the fluid pressures acting upon opposite surfaces of said flange portion, and each of said means for removing the fluid under pressure applied to said movable valve seat and said means for removing the fluid under pressure applied to said signal responsive valve member comprises electromagnetic valve means including a valve element in fluid-tight engagement with a fluid discharge port, a magnet producing a holding magnetic flux for attracting and holding said valve element in the port closing position against the fluid pressure acting upon said valve element in the port opening direction, and a coil producing a cancelling magnetic flux for urging said valve element to the open position in response to the application of a valve actuating signal, said cancelling magnetic flux passing through said valve element in a direction opposite to the direction of said holding magnetic flux and passing through said magnet in the same direction as that of said holding magnetic flux.

19. A circuit breaker having an actuating system comprising a signal responsive valve member mounted on one end of an actuating rod in a valve box, a control valve member having a portion thereof normally engaging a recess in said signal responsive valve member in said valve box and movable while following the movement of said actuating rod in the breaking direction until it is locked in a position midway of the above movement of said actuating rod, a movable valve seat

movable in said valve box toward and away from said signal responsive valve member so as to limit the range of application of fluid under pressure to said signal responsive valve member when brought into engagement with said signal responsive valve member through said control valve member and to follow the movement of said control valve member in one direction after said control valve member has moved away therefrom, said movable valve seat following the movement of said control valve member taking finally a floating position spaced from said signal responsive valve member to shut off the supply of the fluid under pressure to said signal responsive valve member, means mounted on the other end of said actuating rod in another valve box for imparting a making force thereto, means for removing the fluid under pressure applied to said movable valve seat, and means for removing the fluid under pressure applied to said signal responsive valve member, the application of fluid pressure to said signal responsive valve member being controlled by disengaging said movable valve seat from said control valve member, hence from said signal responsive valve member during the breaking operation, while it being controlled by said fluid removing means during the making operation for selectively biasing said actuating rod in one of the making and breaking directions thereby correspondingly actuating the breaker section operatively connected thereto.

20. A circuit breaker having an actuating system as claimed in claim **19**, in which said actuating rod extends through a grounded reservoir filled thereinside with compressed air, a portion of compressed air in said grounded reservoir being supplied to said signal responsive valve member and said making force imparting means accommodated in the valve boxes disposed at opposite end portions of said grounded reservoir, and the breaker section is supported on a tubular insulator upstanding from said grounded reservoir to be electrically insulated from said grounded reservoir, said breaker section being connected to said actuating rod by an actuating rod of electrical insulator.

21. A circuit breaker having an actuating system as claimed in claim **19**, in which a first differential force relationship is established between said signal responsive valve member and said making force imparting means connected to each other by said actuating rod due to the fact that different fluid pressures are applied thereto in directions opposite to each other and the total fluid pressure applied to said signal responsive valve member differs from or is higher than the total fluid pressure applied to said making force imparting means, while a second differential force relationship is established between said signal responsive valve member and said making force imparting means when said movable valve seat movable toward and away from said signal responsive valve member for controlling the total fluid pressure applied thereto is brought into engagement with said signal responsive valve member through said control valve member due to the fact that the total fluid pressure applied to said signal responsive valve member is now lower than the total fluid pressure applied to said making force imparting means, said movable valve seat being moved toward and away from said signal responsive valve member and the fluid pressure applied to said signal responsive valve member being controlled for selectively establishing one of said two differential force relationships thereby selectively biasing said actuating rod in one of the making and breaking directions so as to correspondingly actuate the breaker section operatively connected to said actuating rod.

22. A circuit breaker having an actuating system as claimed in claim **19**, in which the fluid under pressure acting upon said signal responsive valve member differs in property from the fluid under pressure acting upon said making force imparting means.

23. A circuit breaker having an actuating system as claimed in claim **19**, in which said making force imparting means imparts the force biasing said actuating rod in the making direction by being urged by the pressure difference between a high-pressure chamber and a low-pressure chamber and is composed of a pair of valve elements which engage individual valve seats in fluid-tight relation during the making and breaking operations respectively by being urged by said pressure difference in the making direction so as to close a communication passage between said pressure chambers and act to allow for complete communication of said high-pressure chamber with said low-pressure chamber through said passage for a predetermined period of time after the making or breaking operation has started, thereby temporarily eliminating the pressure difference between said pressure chambers.

24. A circuit breaker having an actuating system as claimed in claim **19**, in which said means for removing the fluid under pressure applied to said signal responsive valve member includes a fluid discharge passage which opens in said valve box at a position intermediate of the entire moving stroke of said signal responsive valve member.

25. A circuit breaker having an actuating system as claimed in claim **19**, in which said movable valve seat is provided with a flange portion making substantially fluid-tight sliding engagement with the inner wall surface of said valve box and a spring normally biasing said movable valve seat toward said signal responsive valve member, said movable valve seat being urged away from said signal responsive valve member by the difference between the fluid pressures acting upon opposite surfaces of said flange portion, and each of said means for removing the fluid under pressure applied to said movable valve seat and said means for removing the fluid under pressure applied to said signal responsive valve member comprises electromagnetic valve means including a valve element in fluid-tight engagement with a fluid discharge port, a magnet producing a holding magnetic flux for attracting and holding said valve element in the port closing position against the fluid pressure acting upon said valve element in the port opening direction, and a coil producing a cancelling magnetic flux for urging said valve element to the open position in response to the application of a valve actuating signal, said cancelling magnetic flux passing through said valve element in a direction opposite to the direction of said holding magnetic flux and passing through said magnet in the same direction as that of said holding magnetic flux.

26. A circuit breaker having an actuating system comprising a signal responsive valve member mounted on one end of an actuating rod in a valve box, a control valve member having a portion thereof normally engaging a recess in said signal responsive valve member in said valve box and movable while following the movement of said actuating rod in the breaking direction

until it is locked in a position midway of the above movement of said actuating rod, a movable valve seat movable in said valve box toward and away from said signal responsive valve member so as to limit the range of application of fluid under pressure to said signal responsive valve member when brought into engagement with said signal responsive valve member through said control valve member and to follow the movement of said control valve member in one direction after said control valve member has moved away therefrom, said movable valve seat following the movement of said control valve member taking finally a floating position spaced from said signal responsive valve member to shut off the supply of the fluid under pressure to said signal responsive valve member, a making force imparting spring mounted on said actuating rod opposite to said signal responsive valve member, means for removing the fluid under pressure applied to said movable valve seat, and means for removing the fluid under pressure applied to said signal responsive valve member, the application of fluid pressure to said signal responsive valve member being controlled by disengaging said movable valve seat from said control valve member, hence from said signal responsive valve member during the breaking operation, while it being controlled by said fluid removing means during the making operation for selectively biasing said actuating rod in one of the making and breaking directions thereby correspondingly actuating the breaker section operatively connected thereto.

27. A circuit breaker having an actuating system as claimed in claim **26,** in which said means for removing the fluid under pressure applied to said signal responsive valve member includes a fluid discharge passage which opens in said valve box at a position intermediate the entire moving stroke of said signal responsive valve member.

28. A circuit breaker having an actuating system as claimed in claim **26,** in which said movable valve seat is provided with a flange portion making substantially fluid-tight sliding engagement with the inner wall surface of said valve box and a spring normally biasing said movable valve seat toward said signal responsive valve member, said movable valve seat being urged away from said signal responsive valve member by the difference between the fluid pressures acting upon opposite surfaces of said flange portion, and each of said means for removing the fluid under pressure applied to said movable valve seat and said means for removing the fluid under pressure applied to said signal responsive valve member comprises electromagnetic valve means including a valve element in fluid-tight engagement with a fluid discharge port, a magnet producing a holding magnetic flux for attracting and holding said valve element in the port closing position against the fluid pressure acting upon said valve element in the port opening direction, and a coil producing a cancelling magnetic flux for urging said valve element to the open position in response to the application of a valve actuating signal, said cancelling magnetic flux passing through said valve element in a direction opposite to the direction of said holding magnetic flux and passing through said magnet in the same direction as that of said holding magnetic flux.

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