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F. KESSELRING

3,215,804

SYNCHRONOUS-TYPE FLUID-BLAST CIRCUIT INTERRUPTERS

Filed March 27, 1961

2 Sheets-Sheet 1

Fig. 1.

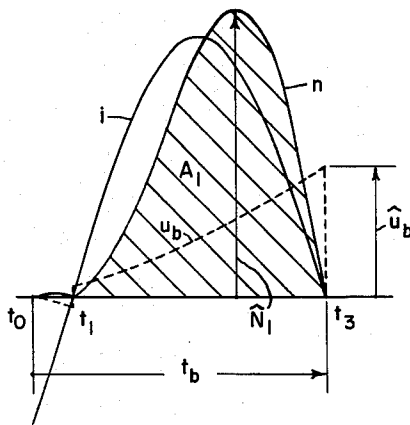


Fig. 2.

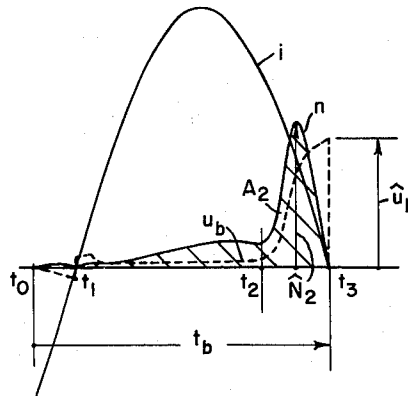
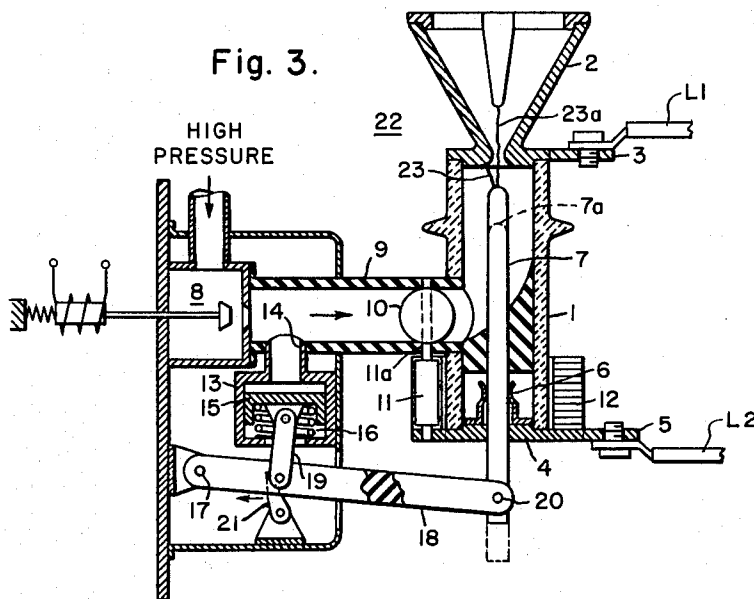


Fig. 3.



WITNESSES

WITNESSES
Robert Baird
James F. Young

INVENTOR

Fritz Kesselring.

BY

BY
Willard R. Crout
ATTORNEY

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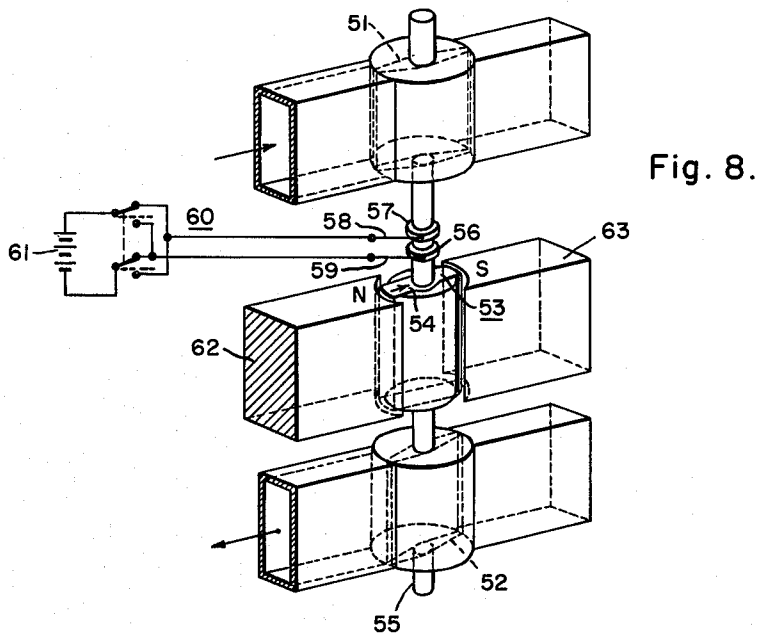
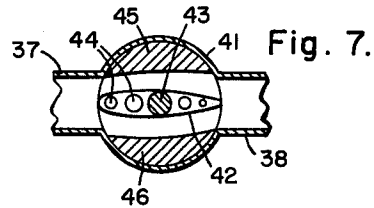
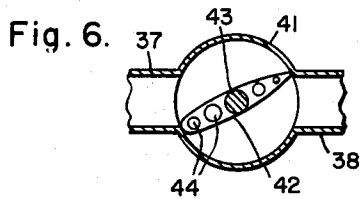
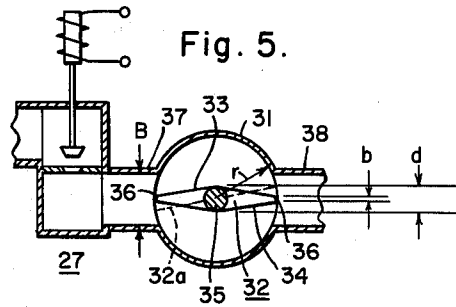
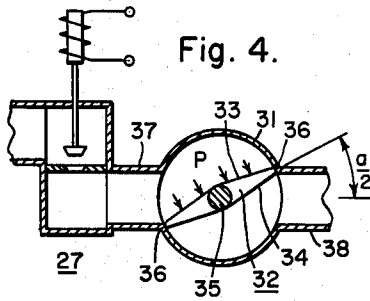
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2 Sheets-Sheet 2



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SYNCHRONOUS-TYPE FLUID-BLAST CIRCUIT INTERRUPTERS

Fritz Kesselring, Kunsnacht, Zurich, Switzerland, assignor to Siemens-Schuckertwerke Aktiengesellschaft, Erlangen, Germany, a corporation of Germany

Filed Mar. 27, 1961, Ser. No. 98,522

Claims priority, application Germany, Mar. 30, 1960,

S 67,800, S 67,801, S 67,802

3 Claims. (Cl. 200—148)

This invention relates to synchronous-type fluid-blast circuit interrupters in general and, more particularly, to improved interrupting structures therefor.

A general object of the present invention is to provide an improved synchronous-type fluid-blast circuit interrupter which will be high efficient and which will utilize a minimum quantity of arc-extinguishing fluid.

Another object of the present invention is to provide an improved compressed-gas circuit interrupter in which the application of the arc-extinguishing medium is dependent upon a predetermined reduction in magnitude of the value of the instantaneous current being interrupted.

Still a further object of the present invention is the provision of improved compressed-gas circuit-interrupting structures in which more effective use of the gas-blast medium is obtained by the employment of synchronously-operated valve structures.

In United States patent application filed March 22, 1965, Serial No. 97,656 by Fritz Kesselring and Lutz Seguin and assigned to the assignee of the instant application, there are disclosed and claimed novel-type synchronous operators particularly suitable for synchronously-operated circuit-interrupting devices. It is a further object of the present invention to utilize the principles set forth in the aforesaid patent application rendering them highly efficient as applied to circuit-interrupting devices.

Additional objects and advantages will readily become apparent upon reading the following specification, taken in conjunction with the drawings, in which:

FIGS. 1 and 2 illustrate time graphs of energy input into circuit interrupters of conventional type and those embodying features of the present invention during the circuit-interrupting operation;

FIG. 3 is a somewhat diagrammatic view taken in vertical cross-section through a compressed-gas-type of circuit interrupter embodying features of the present invention, the contact structure being illustrated in the partially open circuit position;

FIGS. 4-7 illustrate novel types of blast-valve arrangements embodying features of the present invention; and,

FIG. 8 illustrates a perspective view of a double-valve arrangement embodying features of the present invention.

Referring to the drawings, and more particularly to FIGS. 1 and 2 thereof, it will be noted that the stresses exerted upon the interrupting chambers of electric circuit interrupters are determined in accordance with their design by the maximum interrupting arc power or the maximum arc work dissipated. The latter case occurs when the pressure produced by the arc cannot be continuously equalized throughout the breaker, as it happens to be, for example, in oil circuit breakers. As it is known, the interrupting work A_s is given by the equation:

$$A_s = \int_0^{t_b} \mu_b i dt$$

where:

μ_b = instantaneous value of the arcing voltage,

i = instantaneous value of the current, and

t_b = arcing time.

It has been found that the mean value of the current i

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and, most importantly, the arcing time t can be reduced by control of synchronization. In single-phase circuit breakers the control of synchronization is applied in a relatively easy manner. On the other hand, in the case of polyphase circuit breakers, for frequencies of 50 or 60 cycles, considerable difficulties are often encountered. This fact can be seen at once in that the mass of the moving system necessary for large rated currents cannot be brought satisfactorily to the separated distance necessary for arc-extinguishing action in a sufficiently short time, for example, in 1 millisecond. Also, the current wave is not as singularly defined as in the case of single-phase circuit breakers. When, for example, a two-phase arcing short circuit changes shortly, before passage through current zero, into a three-phase short circuit, the current wave changes considerably, which may lead to faulty switching. Furthermore, the maintenance of so-called flashover interruptions under control presents considerable difficulties because of the then resulting extraordinary high arc power.

It is known that the value of the arc voltage depends very much on what kind of effect the quenching medium has upon the arc. If the arc is drawn in a still atmosphere, then the arc-voltage gradient is approximately 20 to 30 volts/centimeter. On the other hand, if the arc is subjected to, for example, intensive axial blasting, or, if in the gas-vapor atmosphere surrounding the arc under high pressure, there occurs a sudden expansion, then the arc-voltage gradient reaches 200 volts/centimeter, and more. In the case of the transition from little, or only slightly affected arcs, to strongly affected arcs, the arc-voltage gradient and the corresponding arc voltage changes by a factor of approximately 10.

The present invention, in part is concerned with a fluid-blast circuit breaker, especially suitable for alternating-current interruptions, in which, as contracted with known breakers, the interrupting work to be dissipated is considerably reduced. The present invention is, in part, distinguished by the fact that there is provided a control, which makes the quenching medium, serving for arc-extinguishing action in the case of arbitrary interruption times, effective only when the current is decreasing, specifically 0.5 to 2.0 milliseconds before the current passes through current zero.

The advantages of fluid-blast circuit breakers constructed in accordance with the present invention can be seen clearly from a comparison of FIGS. 1 and 2 of the drawings. In both figures i is the interrupted current, μ_b is the arc voltage, and t_b is the arcing time. The contact separation follows arbitrarily at instant t_0 . At instant t_1 there occurs the first passage of the current through current zero. However, the contact separation is still so small that the interruption of the arc does not take place. At the instant t_3 the necessary separation distance is assumed to be reached and, therefore, the arc-quenching action should follow, whereby it is assumed that in both cases the maximum arc voltage μ_b occurs. Breakers of known design provide, shortly after the contact separation, immediately intensive arc-extinguishing action, which leads to increased arc voltage μ_b . On the contrary, in the case of circuit breakers constructed according to the present invention, intensive effect upon the arc can be found only in intervals t_0-t_1 and t_2-t_3 . The arc voltage will, therefore, remain very small in magnitude up to the instant t_2 and increase correspondingly only toward the passage through current zero t_3 . This results in that the interrupting work, represented by the shaded area A_2 , as illustrated in FIG. 2, is only a fraction of the interrupting work A_1 , as shown in FIG. 1, being approximately $\frac{1}{2}$ in the illustrated example taken from an actual case. In addition, there exists also a considerably lower maxi-

imum arc power $\hat{N}_2$, which amounts to approximately one-half of $\hat{N}_1$. Correspondingly, the stresses from pressure in the case of circuit breakers, constructed in accordance with the present invention, are considerably lower, which makes possible a lighter design of the interrupting chamber and leads consequently to lower production costs.

Still a further improvement can be obtained by constructing circuit breakers in accordance with the present invention in that the intensity of quenching can be made dependent upon the magnitude of rate of decrease of the interrupted current, that is, $(-di/dt)$. As well known, the quenching intensity must be the greater the greater is the instantaneous rate of change of the interrupted current immediately before the passage through current zero, and the greater is the slope of the recovery voltage. The latter is generally given by the network conditions and the magnitude of the interrupted short-circuit current. For a higher short-circuit current and thereby for a higher rate of change of the short-circuit current, there corresponds most of the time also a higher slope of the recovery voltage, because the inductance of the oscillating circuit at higher short-circuit intensities is correspondingly lower. If also the intensity of arc quenching is made greater, the greater is the rate of decrease of the interrupted current, then it can be expected that the arc quenching takes place with less possible effort, and also lowest overvoltage over the entire current range from very small currents up to full short-circuit current intensities. As well known, for example, in disconnecting a transformer running at no-load, a very high overvoltage occurs, because the quenching intensity is very often too high relative to the small no-load current, for example, only 10 amperes. The arc then interrupts too soon, which results in an instantaneous release of the large amount of magnetic energy stored in the transformer under a stronger build-up of the overvoltage. In case of compressed-gas circuit breakers, a matching of the intensity of interrupting conditions to the slope of current shortly before passage through current zero has an additional advantage in that the consumption of compressed air at normal switching operations is considerably reduced.

FIG. 3 shows by way of example a form of construction of compressed-gas circuit interrupter constructed in accordance with the present invention. With reference to FIG. 3, the reference numeral 1 indicates an interrupting chamber in the form of an insulating cylinder. At the top, the interrupting chamber 1 supports the interrupting nozzle contact 2 having a terminal lead 3. The bottom of the insulating cylinder 1 is closed by a closure cap 4 having a second terminal lead 5. The reference numeral 6 indicates cooperable sliding contacts which carry the current from the terminal lead 5 to the movable contact rod 7. The compressed gas is brought into the interrupting chamber 1 through an electrically actuated valve 8 and an insulating blast tube 9. The reference numeral 10 indicates a rotatable valve damper shown in the open position in FIG. 3. It is actuated by a moving coil or armature 11, which rotates in the field of an electromagnetic system 12 excited by the interrupting current, as set forth in the aforesaid United States patent application.

The reference numeral 13 denotes an operating cylinder, which is connected through a tube 14 with the insulating blast tube 9. A piston 15, movable within the operating cylinder 13, is acted upon by a compression spring 16. An insulating operating rod 18 is supported upon a pivot 17, and is coupled with the piston 15 through a driving link 19. The rod 18 is also connected with the movable contact rod 7 by means of a pivot pin 20. In the open-circuit position, shown by the dotted lines 7a, the insulating operating rod 18 is held by a ro-

tatable latch 21 against the biasing action exerted by the compression spring 16.

The circuit interrupter, generally designated by the reference numeral 22 and set forth in FIG. 3, functions in the following manner: At an arbitrary instant t_0 the electromagnetically actuated valve 8 is assumed to be opened. This action results in exposing the piston 15 to the entering blast of compressed gas, which will cause the piston 15 to move downwardly against the biasing action exerted by the compression spring 16 until the movable contact rod 7 reaches the illustrated open position 7a of completed interruption. Now, if the current is increasing during this process, then an induced current will flow through the moving coil of armature 11, which will, together with the flux in the magnetic system 12, produce in the air gap a torque, which causes the rotatable valve damper 10 to turn to a closed position. In this connection, it is to be noted that the magnetic circuit 12 encompasses the main current path L_1 , L_2 and consequently has flux generated therein corresponding to the line current. As a result, if at first the compressed air cannot enter the interrupting chamber 1 to blast the arc, the arc 23 burns with a much lower arc voltage than would be the case otherwise. Now, if the main current begins to decrease, then the current induced in the moving coil 11 will change its sign as set forth in the aforesaid United States patent application, Serial No. 97,656. The torque is then reversed, and the valve damper 10 will now assume the illustrated open position. By utilization of saturation of the magnetic system 12, it can be obtained that the current induced in the moving coil 11 begins to flow 0.5 to 2 milliseconds before the passage of the current through current zero. Now, at this time the compressed air may enter the interrupting chamber 1 from the blast tube 9 and act intensively upon the arc 23a drawn within the nozzle 2, thereby bringing about interruption of the arc 23a and consequent circuit interruption.

If, on the contrary, a transformer operating at no-load should be disconnected, and if, as a result of build-up of overvoltage causing a short circuit shortly before the no-load current of the transformer passes through current zero, then the current immediately sharply increases. This results in the situation whereby the valve damper 10 will be instantly moved into the closed position by the moving coil 11, by which action the passage of the flowing gas upon the arc 23a is stopped. The arc has a high current intensity but a very low arcing voltage. Later, when the current again begins to decrease, the valve damper 10 will then open and the arc quenching action will follow.

If the valve damper 10 is supported upon the rotatable shaft 11a of the moving armature 11, then it can be obtained in a relatively simple manner that the valve damper 10 opens wider the more quickly the line current decreases toward current zero. As a result, it is possible to match or correlate the intensity of quenching to the intensity of the interrupted current, especially to the slope with which it passes through current zero. For this purpose, it may be suitable to establish the normal "at rest" position of the valve damper 10 in such a position that the minimum intensity of quenching, necessary for interruption of currents in the normal operating range, is provided. If now higher currents are to be interrupted, then automatically a correspondingly larger movement of the valve damper 10 takes place, so that again the intensity of quenching is adjusted to the prevailing conditions.

If, for example, in the case of interrupters using liquids, an expansion should be introduced, then blocking of a valve 10 during increasing current can be released when the current begins to decrease toward current zero, in which case it may be suitable to introduce the expansion shortly before the passage of the current through current zero.

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The advantage of circuit breakers constructed according to the present invention consists largely in that the breaker mechanism itself can be built in the generally conventional manner, and does not need to move especially fast as is necessary in the case of conventional synchronized breakers. The control is limited entirely to the matching or correlating of the intensity of interrupting action to the prevailing conditions, which can be done at a small cost. The interrupting capacity of breakers of the type built according to the present invention can be, although at approximately the same production cost as conventional breakers, increased to several times the value so far obtained.

It is known in the valve art to provide arrangements including a rotatable wing-type valve adapted to be electrically operated and disposed within a cylindrical opening. With valves of this type it is desirable that the valve, when closed, have a very tight fit and, when opened, permit optimum flow conditions to take place. Opening of such valves is usually effected by rotating the valve about 90°. The electrical drive may comprise either a motor or a magnetic drive. If it is desired to provide valves which have a short operating time from closed condition to open condition, or vice versa, of less than $\frac{1}{100}$ of a second particularly less than one millisecond, certain problems are encountered at once. Such extremely fast-acting valves are needed, for example, for compressed-fluid electrical switches in which arc extinction is effected by a flowing medium. In such switches, or circuit breakers it is necessary that the valves be operated, for example, at a certain instant, within one current half-cycle. It is not absolutely necessary in circuit breakers for the valve to establish a perfect seal when closed, for a small amount of leakage is not objectionable since the quick-acting valve usually has connected in series therewith another tightly-closed valve, such as indicated by the reference numeral 27 in FIG. 4, which may be of conventional design.

According to one aspect of the present invention as shown in FIGS. 4 and 5, the valve arrangement including at least one electrically-operated rotatable wing valve disposed in a cylindrical opening is characterized in that the cross-section of the rotary wing, or wings perpendicular to the axis of rotation is biangular for obtaining opening and closing times of less than 10 milliseconds, the width "b" of the axial sealing surfaces of the rotatable wing amounting to only a fraction of the maximum wing thickness "d," and the width of the rectangular valve opening B being no more than equal to the radius "r" of the rotatable wing.

In FIGS. 4 and 5 of the drawings, a valve arrangement, according to the invention, is shown schematically in the closed and open positions, respectively. FIGS. 6 and 7 illustrate a similar valve arrangement which offers particularly little resistance to flow, and FIG. 8 shows a double valve arrangement including two rotatable wing valves actuated by a single moving-coil system.

In FIGS. 4 and 5, the reference numeral 31 designates a cylindrical valve casing and the reference numeral 32 indicates the wing-valve comprising two plates 33 and 34 rigidly connected to the shaft 35. The axial sealing surfaces are indicated at 36. The reference numeral 37 designates rectangular inlet, and the reference numeral 38 designates the rectangular outlet. In FIG. 4 of the drawings, the pressure P acts upon the upper surface 33 of the rotatable wing valve 32. Since the pressure distribution relative to the axis of rotation 35 is symmetrical, substantially no resultant torque is applied to the wing-valve 32.

FIG. 5 shows the valve in its fully opened position, and this figure also illustrates the fact that the torsional moment, or torque acting upon the wing valve 32 is zero. Contrary to the positioning of the valve 32 shown in FIG. 4 in which there exists a stable equilibrium, the equilibrium in the open position, as shown in FIG. 5 is unstable.

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As soon as the wing valve is moved somewhat from its symmetrical position, it tends to move to its closed position, and the maximum closing force is effective approximately in the position indicated by broken lines 32a in FIG. 5. Accurate measurements taken with the valve arrangement according to FIG. 4 and involving the values $r=6$ millimeters, $B=5$ millimeters, $d=3$ millimeters, and a wing height of 30 millimeters indicated at 1 to 6 atmospheres overpressure on the inlet side, result in a maximum torque in the closing direction of about 80 pond (gram weight) centimeters, that is, an extraordinarily small value which, however, is obtainable only when ball bearings are being used.

The width of the axial sealing surface of the rotatable wing valve was $b=1.2$ millimeters, and the sealing gap amounted to about $\frac{2}{100}$ millimeter. The resultant leakage loss at 6 atmospheres was 2 cm.²/ms. relative to normal pressure and normal temperature. With a gap thickness of $\frac{1}{100}$ millimeter, it was possible to reduce the leakage loss to 0.9 cm.³/ms. Sealing can further be improved by providing at least along the axial sealing surfaces of the rotatable wing sealing strips, which are biased outwardly, such as used, for example in rotary-piston type motors.

The embodiment illustrated in FIGS. 4 and 5 of the drawings has the following advantages: The moment of inertia of the rotatable wing valve 32 is very small. Despite this, however, the stability is high due to the box-type construction. In order to fully open the valve, an angular movement of the wing only of $\alpha/2$ is required. The torque necessary to move the rotatable wing is very small. The resistance to flow of the opened valve is negligible. The use of wings having a height which is substantially larger than their diameter makes it possible to obtain large cross-sectional flow areas with the valves of minimum dimensions.

FIGS. 6 and 7 illustrate an embodiment of the invention providing a valve arrangement for still better flow conditions. The rotatable wing 42, which is movable within the casing 41 has an air-foil or streamlined profile. It may be formed, together with the shaft 43, by die-casting, for example, from an aluminum or magnesium alloy, the moment of inertia being further reduced by the axial openings 44. Furthermore, the casing 41 may have disposed therein liners 45 and 46, as shown in FIG. 7, which are favorable to the streamline flow of the medium.

FIG. 8 shows an embodiment of the invention utilizing valves 51 and 52 of the type illustrated in FIGS. 4 and 5. Valve 51 is shown in its open position, whereas valve 52 is shown in its closed position. Indicated generally at 53 is a moving-coil system, the moving coil 54 of which is secured to the common shaft 55. The coil ends of coil 54 extend to the slip rings 56 and 57 and are connected through brushes 58 and 59 and a switch 60 to a battery 61. The pole pieces of the moving-coil system are indicated at 62 and 63.

As the double throw switch 60 is moved from the center position, indicated by broken lines, to the upper position, current will flow through coil 54 in the direction indicated by the arrow, said current, together with the air-gap induction producing a torque which causes the valve 51 to be moved to its closed position and valve 52 to be moved to its open position.

Referring to FIG. 8, the rotary wing of valve 51 tends to move clockwise to its closed position, whereas the rotary wing of valve 52 tends to move counterclockwise also to its closed position, as shown. It is, therefore, apparent that the two torques of the rotary wings 51, 52 substantially cancel each other. Movement of switch 60 to its lower position effects a reversal of the current flowing through coil 54, which, in turn, also reverses the torque. Thus, the two rotary wings of valves 51 and 52 return to the position shown.

Tests have proven that with an arrangement such as shown in FIG. 8, it is readily possible to effect movement

through the angle $\alpha/2$ (FIG. 4) in less than 1 millisecond. The moment of inertia of one rotary wing including the shaft amounts to only about 10% of the moment of inertia of the moving coil 54.

In one practical example, the main driving torque of the moving-coil system amounted to approximately 12 kpcm., whereas the resultant maximum counter-torque acting upon the rotary wings amounted to only about 0.03 kpcm., that is, to only 2.5% of the driving torque, at 6 atmospheres of over-pressure.

The battery 61 may be replaced by a charged condenser, which, when discharged, causes a very high impulse-like current to flow through the moving coil 54. Furthermore, the permanent magnet system 62 and 63 may be replaced by an unsaturated, or saturated alternating-current magnet. If this is the case, and if coil 54 is supplied from a source of direct current, the rotary wings will oscillate at the frequency of the alternating current.

If it is desired to use the valve arrangement according to the invention for the control of fluid-blast circuit breakers, it is desirable to energize the magnetic system 62 and 63 in dependency upon the current to be interrupted, whereas the moving coil 54 should be supplied with a current which may be proportional, for example, to the changing rate of the current to be interrupted. In this manner, it is possible to cause valve 51 to open only when the current decreases, particularly shortly before the zero passage of the current, and to be closed during the increase of the current, during which period the circuit breaker is vented by the valve 52. In view of the extraordinarily short response time of these valves 51 and 52, the valve arrangement embodying the invention may be used advantageously in connection with control and regulating systems.

Although there have been illustrated and described specific structures, it is to be clearly understood that the same were merely for the purpose of illustration, and that changes and modifications may readily be made therein by those skilled in the art, without departing from the spirit and scope of the invention.

I claim as my invention:

1. A compressed-gas circuit interrupter including a stationary nozzle-type contact and a cooperable movable rod contact separable to establish an arc, a source of high-pressure gas, blast-valve means including an electromagnetically-actuated valve (8) and a series rotatable blast-valve (10), piston means (15) interposed between said two valves and operable to effect opening motion of the movable rod contact, and a synchronous operator correlat-

ing the opening of the rotatable blast-valve (10) with the magnitude of the slope of the rate of change of currents, whereby a more intensive gas blast will be obtained for higher magnitude fault currents than for load-current interruption.

2. A compressed-gas circuit interrupter including a stationary nozzle-type contact and a cooperable movable rod contact separable to establish an arc, a source of high-pressure gas, blast-valve means including an electromagnetically-actuated valve (8) and a series rotatable blast-valve (10), piston means (15) interposed between said two valves and operable to effect opening motion of the movable rod contact, a synchronous operator correlating the opening of the rotatable blast-valve (10) with the magnitude of the slope of the rate of change of currents, whereby a more intensive gas blast will be obtained for higher magnitude fault currents than for load-current interruption, said synchronous operator including a magnetic circuit energized in dependence upon the current to be interrupted, and a moving coil element traversed by a current dependent upon the rate of change of the current to be interrupted.

3. The combination according to claim 1, wherein a pivotally-mounted operating lever (18) is connected to said movable rod contact and is actuated by the piston means, and the piston means is biased to the closed contact position.

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BERNARD A. GILHEANY, *Primary Examiner.*

MAX L. LEVY, ROBERT K. SCHAEFER, *Examiners.*