My invention relates to a fluid actuated operating mechanism for an electric circuit breaker, and more particularly is an improvement on my copending application Serial No. 512,179, filed November 29, 1943, now Patent No. 2,381,336, issued August 7, 1945, and assigned to the same assignee as the present application.

Fluid actuated operating mechanisms have become quite popular in recent years particularly since the extensive use of the gas blast circuit breaker. As a matter of fact, such fluid actuated operating mechanisms are now being generally used, whether the circuit breakers are of the gas blast type or not, due to numerous advantages thereof. It is essential that such fluid actuated operating mechanisms be tripped free so that the means to be actuated, such as the circuit breaker, can be released with respect to the actuating means during the course of the closing stroke and prior to completion thereof. The trend in operating circuit breakers is continually toward higher operating speeds and today a three-cycle breaker is a common thing. Accordingly, it is desirable that an operating mechanism capable of very high speed operation be available for high speed circuit breakers.

It is an object of my invention, therefore, to provide a new and improved high speed fluid actuated operating mechanism for an electric circuit breaker.

It is another object of my invention to provide a new and improved trip-latch arrangement for an operating mechanism of an electric circuit breaker.

Further objects and advantages of my invention will become apparent as the following description proceeds and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of my invention reference may be had to the accompanying drawing in which the single figure thereof diagrammatically illustrates an electric switch or circuit breaker embodying the fluid actuated operating mechanism of my invention.

Referring now to the drawing, I have illustrated my invention in connection with an electric switch such as a circuit breaker having a contact structure 1, whose operating mechanism generally indicated at 2 is fluid pressure actuated to close the circuit breaker. This circuit breaker is schematically illustrated as a three-pole switch biased to the open position by suitable means, such for example as suitable opening springs not shown. The contact structure 1 of the circuit breaker is arranged to control an electric circuit comprising conductors 3, 4 and 5. As shown in elevation, the operating mechanism 2 is of the roller toggle type and comprises an operating or output crank 6 and a pivotally mounted cam lever 7. The crank 6 is mounted on a stationary pivot 8 and is pivotally connected to 9 to a circuit breaker operating rod 10 indicated schematically in part by the dash-dot line 11'. For actuating the crank 6 in a clockwise direction to close the circuit breaker comprising the contact structure 1, the cam lever 7 is pivotally mounted on a stationary pivot 12 and provided at its free end with a cam 13. The cam 13 is adapted to engage with a roller 14 mounted on the free end of crank 6. The cam 12 is so designed that the closing force curve substantially approximates the curve representing the opposing breaker forces that successively increase in magnitude as means such as opening springs (not shown) are compressed, as short circuit stresses are encountered, and as the abutting spring-biased breaker contacts are closed. A predetermined cam contour can be selected that produces quite rapid and exact changes in mechanical advantage which cannot be obtained as satisfactorily by prior art arrangements. Cam lever 7 is provided with one or more kick-off springs 15 which serve to urge cam lever 7 initially out from under output crank 6, thereby to minimize opposition to the breaker opening movement and consequently to permit very high speed operation.

The contact structure 1 of the switch or circuit breaker is restrained in the closed position by one or more prop-type trip latches, such as 16, which engage with suitable rollers such as 17, pivotally mounted at 17 to cam lever 7. Preferably two rollers 18 are provided, one on either side of cam lever 7 and consequently two prop-type trip latches 19 for engaging these rollers are also provided. In order to further increase the opening speed of the circuit breaker the surface 20 of the trip latch 18 adjacent roller 16 is not concentric relative to pivot 19 about which
trip latch 15 rotates but is made with an off-center or downhill radius so that the downward forces on the roller 16 associated with cam lever 7 tends to push trip latch 15 to its unlatched position. Consequently, as soon as latch 15 is tripped instantaneous opening movement of the contact structure 1 of the circuit breaker may occur without the slight delay that would otherwise attend thebrief dwell of the roller 16 if it engaged a concentric latch surface.

In order to cause the trip latch 15 to reset it is provided with a resetting spring 20 which is effective to reset the latch under the roller 16 but is ineffective to oppose the opening forces of the circuit breaker. The additional force required for holding prop-type latch 15 in its locking position under roller 16 is provided by a high speed release magnetic device generally indicated at 21 and described in greater detail hereinafter. Magnetic device 21 includes an armature 22 supported on a crank 23 rotatable with a shaft 24 upon which prop-type trip latch 15 is also fixedly mounted. When the armature 22 is released, as will be brought out in greater detail hereinafter in connection with the description of the magnetic or electromagnetic device 21, the breaker opening forces quickly brush aside the prop-type latch 15 which, together with crank 23, rotates in a counterclockwise direction as viewed in the drawing. The unlatching rotational movement of the trip shaft assembly including shaft 24 and crank 23 is limited and brought to rest by a suitable spring buffer 25 which is engaged by the armature crank arm 23.

If the trip latch 15, with the circuit breaker mechanism in the open position, were permitted to rotate back to its latching position under the pull of its resetting spring 20 the attractive force of the electromagnetic device 21 would again become effective to hold trip latch 15 in its latched position so that the roller 16 in its upward sweep during an ensuing closing operation, would have to rotate the latch 15 forcibly from its magnetically held position. To avoid this difficulty it is desirable to block the trip latch 15 in its unlatched position whenever the circuit breaker is in other than its closed position. To this end the cam lever 7 is provided with a projecting lug or latch guide 26 which together with the periphery of the roller 16, prevents the latch 15 from assuming its latching position except in the extreme upper position of cam lever 7 when the operating mechanism assumes its breaker closed position.

In accordance with my invention the mass of the rotatable latch assembly including trip latch 15 involves appreciable inertia forces so that the resetting spring 20 moves trip latch 15 relatively slowly from its blocked to its latched position. This resetting delay is an advantage for during a trip-free operation trip latch 15 is not speedy enough to move under the closing roller 16 where it would momentarily impede the otherwise free reversal of the mechanism including cam lever 7 and output crank 6 under the urge of the breaker forces, such as the opening springs, for example. Consequently, this slow resetting time of trip latch 15 represents a contributing factor by which fast tripping time on trip-free operations is obtained.

For actuating the operating mechanism 2 to close the circuit breaker having contact structure 1, I provide fluid pressure actuated means such as a fluid motor 27 comprising a cylinder 28 with a piston rod 29 upon the admission of fluid under pressure beneath the piston 29 engages a roller on cam lever 7, preferably between rollers 16, thereby to move the lever 7 clockwise until the parts of the operating mechanism 2 are positioned as shown in the drawing with the circuit breaker in its closed position. After the latch 15 has moved into latching engagement with roller 16 the piston 29 may return to the lower position shown in the drawing. While any suitable fluid under pressure may be utilized to actuate piston 29 to close the circuit breaker due to the fluid under pressure in a receiver or tank 31 from which the air is supplied to the cylinder 28 through control valve means 32. On the upstroke of the piston 29 suitably energy storage means, such as the spring 33, is compressed to effect a down, or return stroke, of the piston 29 to the lower position shown. This downstroke operation follows the cutting off of the air supply of the valve 32 through the medium of a dump valve generally indicated at 34.

The control valve 32, fluid motor 27 and dump valve 34 are very similar to the corresponding parts disclosed in my companion patents, Serial No. 512,179, referred to above, and Serial No. 512,180, filed November 29, 1943 and assigned to the same assignee as the present application. The control valve 32 is illustrated as a pilot differential type employing a pilot valve, which in turn controls the operation of a main valve. For opening the pilot valve there is provided electromagnetic means, generally indicated at 35, comprising an armature 36, a magnetic housing 37, a pole piece comprising the magnetic elements 38, 39 and 40, and a valve opening winding 41. As illustrated, the electromagnetic means is of the plunger and solenoid type with the armature 36 directly connected to the pilot valve (not shown). In order to hold the armature 36 in the attracted position the pole piece magnetic element 39 is of permanent magnetic material, examples of which are well known to the art. The pilot valve is normally maintained in its closed position by means of a spring 42. The electromagnetic means 35 for operating control valve 32, in addition to winding 41 for causing the valve to open, is also provided with windings 44 and 45, the energization of either one of which induces a counterflux to neutralize the effect of winding 41 thereby closing the closing valve 32.

The arrangement of the three windings 41, 44 and 45 is identical with their arrangement in the second of the prior copending applications referred to above.

The dump valve 34 is substantially identical with the arrangement disclosed and claimed in my copending applications, Serial No. 512,180, referred to above. The dump valve differs from this prior application in that the valve member 46 for controlling the exhaust port 47 to atmosphere is biased by spring means 48 to the position shown in the drawing. With this arrangement, the casting can occur by high speed movement of the dump valve when the air is first turned on through opening of valve 32, since the dump valve is already in the position for closing exhaust port 47. The dump valve includes the ports 49 and the non-return valve 50 having contact structure shown in copending application, Serial No. 512,180, referred to above.

Piston rod 30 is provided with a downwardly extending portion 51 including a kick-off spring
for quick return of piston 28 during a trip-free operation following manual closing. The fluid motor 27 also controls two switches, a cut-off switch 53 and a pressure transfer switch 54. The cut-off switch 53, which is adapted to bridge contacts 55, is normally biased to the open position and is provided with a pin 56 which extends into cylinder 28 and is engaged by piston 28 as it reaches its uppermost position whereby cut-off switch 53 is closed to perform a suitable controlling operation as the piston 28 reaches a position corresponding to the closed position of the associated circuit breaker or switch. The pressure transfer switch 54 is also a normally open switch for controlling contacts 57. Whenever fluid under pressure is supplied to cylinder 28 below piston 29 pressure transfer switch 54 is actuated to close contacts 57. Pressure transfer switch 54 includes a cylinder 58 connected to cylinder 28 and a piston 59 directly connected to switch 54 and biased to the position shown by a suitable spring 60.

For the very fast trip-free tripping time required by high speed circuit breakers spring 33 does not store energy to aid in the motion of piston 28 with sufficient speed, and the mass of the piston might impede the otherwise free reversal of the breaker connected output crank 6 and cam lever 7. Accordingly, I provide another tripping time required arranging comprising a piston return control valve generally indicated at 62. Piston return valve 62 is connected between tank 34 and cylinder 28 above piston 28 by conduits 63 and 64. Piston return valve 62 comprises a valve member 65 biased to the closed position shown in the drawing by spring means 66. The valve member 65 is provided to an armature 67 and opening of the valve is controlled by energization of a winding 68 arranged in concentric relationship with respect to armature 67. Whenever piston return valve 62 is in the position indicated the valve permits the flow of fluid to motor 27 is connected to atmosphere through a suitable exhaust port 69. As will be described hereinafter, the control circuit for winding 68 of auxiliary piston return valve 62 is such that only when the associated circuit breaker is closed and a short circuit exists 58 energized to aid in the high speed reversal of piston 28. As soon as piston return valve 62 is opened, a fully open passageway is provided through which air or gas may flow to the upper end of cylinder 28. On the other hand, the ports 49 of the non-return valve 50 throttle the flow of air into cylinder 28 below piston 29. This throttling scheme whereby the closing valve supply is handicapped in favor of the auxiliary piston return valve permits the speed of the closing stroke to be regulated as required, while the slightly increased closing time is not objectionable in view of the faster trip-free opening time that is made possible thereby.

As was mentioned above, my invention contemplates a delayed trip latch resetting characteristic to insure high speed opening in the event that the circuit breaker is closed on a short circuit. This delayed resetting of the trip latch necessitates that the upward thrust of the piston plunger 30 must be continued during a switching operation at least until the trip latch 16 is safely in its restraining position under the roller 16. This requirement is met in accordance with my invention by the provision of an additional cut-off switch 70 which controls contacts 71. Cut-off switch 70 is controlled by an arm 12 mounted to rotate with shaft 24. Latch cut-off switch 70 is moved to the position indicated in the drawing taking contacts 71 when trip latch 16 moves to its latching position with respect to roller 16. This latch cut-off switch 70 prevents closing control valve 32 from closing as will be described in conjunction with the description of the control circuits, thereby maintaining the piston 28 and plunger 30 in their uppermost position until resetting of trip latch 16 is assured.

The construction of the high speed release electromagnetic device 21, briefly mentioned above, embodies the same operating principle disclosed in Boehne Patent 2,188,803, granted January 30, 1940, and assigned to the same assignee as the present application. As in the above mentioned Boehne patent, the holding power of the high speed electromagnetic device 21 is derived from a permanent magnet while its high speed release is effected by means of a neutralizing flux path that is set up by the energization of a trip coil. As is shown in the drawing, the electromagnetic device 21 comprises an Alnico magnet core 73 suitably supported by a magnetic frame 74 so as to define a magnetic structure of a substantially E-shaped configuration with the Alnico core 73 constituting the center leg of the E. The annular space enclosing the core 73 houses an exciting coil 75 which is energized for a short period of time during each breaker operation as will become apparent as the following description proceeds, for providing additional holding force in the magnets. A suitable laminated pole piece 76 is provided which acts as an extension of the center leg of the E-shaped magnetic structure and is spaced from the outer legs of the E-shaped frame by small air gaps 78. A trip coil 77 surrounds a portion of the laminated pole piece and the armature 22 is arranged to engage the pole piece 76 as well as the outer legs of the E-shaped magnetic structure. With the armature 22 attracted against the pole piece 76 as indicated in the drawing, the trip coil 77 unenergized, two complementary low reluctance twin magnetic circuits are set up, one through each half of the E-shaped frame as shown by the arrows in the drawing. Energization of the trip coil 77 establishes two counter-neutralizing flux circuits that short circuit the main twin flux paths from the armature by shunting them across the pole piece 76 at high speed due to the bias of the forces applied to trip latch 16 to rotate the same in a counterclockwise direction.

The tripping winding 77, the energization of which permits armature 22 to be released, is connected across a control source of power through a circuit breaker a switch 78 which normally bridges contacts 80 when the contact structure 1 of the associated circuit breaker is closed and opens contact 80 when the contact structure of the associated circuit breaker is opened. Tripping winding 77 of electromagnetic device 21 is energized in response to operation of a protective relay 81 or a tripping control switch 82. The protective relay 81 is illustrated simply as an over current relay connected to be energized from a current transformer 83 in the circuit conductor 3. It will be understood of course that any number of relays may be employed in accordance with the art of circuit protection. Whenever protective relay 81 or control switch 82 are actuated, winding 44 of the electromagnetic device 35 for con-
trolling closing valve 32 is energized and also winding 68 of piston return valve 62, providing that pressure transfer switch 54 has closed its contacts. Windings 44 and 68 are connected in parallel with each other and this parallel circuit is connected in series with contacts 57 of pressure transfer switch 54, contacts 90 of a switch 19 and the contacts of either protective relay 81 or control switch 52.

For closing the circuit breaker comprising contact structure 1, there is provided a closing control circuit for the valve opening winding 41 of the electromagnetic device 35 associated with closing valve 32. As shown in the drawing, this circuit includes a closing control switch 54, contacts 85 of a minimum pressure switch 85 which opens when the pressure in tank 31 falls below a predetermined value, a conductor 86, contacts 87 of an auxiliary switch 88, open when the circuit breaker is in its latched closed position and actuated to the closed position by lever 72 when trip latch 15 moves into its unlatching position, conductor 89, the contacts 90 of a short time delay circuit opening relay 91 whose winding 92 is energized upon the closing of the closing control switch 84, and conductor 93 connected through winding 41 to one side of a source of electric potential (not shown). The opening of the circuit breaker closing control circuit by the slightly delayed contacts 90 of the relay 91 insures a positive opening of the closing control valve 32 in response to the energization of its winding 41 and also prevents reclosure of the associated circuit breaker as long as the control switch 84 is kept closed. In other words, with a single closure of the control switch 84 only one closure of the associated switch or circuit breaker comprising contact structure 1 can be effected.

The contacts 55 of the circuit breaker cutoff switch 53 control the energization of magnetizing winding 75 of high speed release electromagnetic device 21 and also through contacts 71 of latch cutoff switch 70 control the energization of winding 45 of the electromagnetic device 35 associated with closing contact 32. In other words, whenever piston 29 reaches the end of its closing stroke near the top of cylinder 28 to engage pin 56 and close switch 55, winding 75 of electromagnetic device 21 is energized to provide additional holding force, and as soon as latch cutoff switch 70 indicates that trip latch 15 is in the latch position winding 45 associated with the closing valve 32 is energized to cause valve 32 to close and permit piston 29 to return to the position indicated in the drawing.

In view of the detailed description included above, the operation of the arrangement embodying my invention will be more or less obvious to those skilled in the art. With the circuit breaker or switch comprising contact structure 1 in the closed position shown an opening operation may be initiated, either by a fault on the system causing operation of overcurrent relay 81 or by the operation of manual opening switch 82. In either case the tripping winding 17 of electromagnetic device 21 is energized to cause armature 22 to be released whereupon the forces due to the breaker opening springs (not shown) cause output crank 6 and cam lever 7 to rotate unimpeded and latch trip latch 15 out of the way. As the trip latch 15 moves out of its latching position, latch cutoff switch 10 is opened while contacts 87 are bridged by switch 88 to complete the closing control circuit. The projecting lug or latch guide 26 prevents trip latch 15 from returning to its latched position under the influence of relatively weak resetting spring 26, this action being opposed by the opening spring forces acting on the latch structure 1 of the associated circuit breaker.

When the circuit breaker is in the open position closing contact structure 1 can be accomplished by actuating manual closing switch 56 whereupon opening winding 41 of closing valve 32 is energized through the contacts 57 of the anti-trip clamp relay 81 which opens contacts 90 with a sufficient delay to insure full opening of control valve 32. The opening of closing control valve 32 causes piston 29 to move upward to actuate the operating mechanism 2 to close the associated circuit breaker or switch containing contact structure 1. When the piston 29 reaches the almost closed position of the associated circuit breaker piston 29 strikes the pin 56 of cutoff switch 53 to set up the energization circuit for valve closing winding 45 as soon as cutoff switch 70 has bridged contacts 71, thus assuring that trip latch 15 has latched the associated breaker in the closed position winding 45 is energized and closing valve 32 is closed so that piston 29 may return to the lower position indicated in the drawing. The closing of switch 53 also completes the circuit through exciting winding 75 of high speed release electromagnetic device 21 thereby augmenting the coercive power of the permanent magnet 73 to hold armature 22 in its impact against pole piece 76. It also of course comprises a brief remagnetization of the permanent magnet 73. As the piston 29 returns to the lower position shown in the drawing the air beneath the piston discharges to atmosphere through dump valve 34.

If, during the closing operation just described above, the contact structure 1 of the circuit breaker were closed on a fault the protective relay 81 would be energized as soon as the contacts of the circuit breaker reached their almost closed position. Since fluid under pressure in such a case exists under piston 29 pressure transfer switch 54 bridges contact 57 whereupon winding 44 of closing valve 32 is energized and also winding 68 of piston return valve 62 is energized. Under these conditions closing valve 32 is quickly moved to its closed position and by virtue of the fluid under pressure provided above piston 29 through opening of piston return valve 62, which is closed when trip latch 15 is in the latch position 45 occurs thereby permitting a higher speed of operation than was possible with prior art arrangements.

While I have described what I at present consider the preferred embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention, and I therefore aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

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

1. In combination with an electric switch, an actuating device, an operating mechanism including a cam lever interrelating said switch and said actuating device, means for operating said actuating device to close said switch, latching means for holding said switch in the closed position, magnetic means for holding said latching means in latching position, a trip coil on said magnetic means, means for energizing said trip coil to render said magnetic means ineffective to hold said latching means in latching position, means for energizing said trip coil to render said magnetic means ineffective to hold said latching means in latching position...
whereby high speed release of said latching means and opening of said electric switch can occur, and means including a latch guide means for holding said latching means in movable therewith for engaging said latching means to hold said latching means out of latching position when said switch is open.

2. In combination with an electric switch, a fluid motor including a piston and a cylinder, an operating mechanism interrelating said switch and said piston, said piston being normally out of engagement with said mechanism, means for supplying fluid under pressure to act on one side of said piston to move said piston from an initial position to close said switch, latching means for holding said switch in the closed position after said piston has moved it to the closed position, means for returning said piston to said initial position while said switch remains closed, and means for supplying fluid under pressure to the other side of said piston under predetermined conditions to return said piston to its initial position said last mentioned means and cause high speed return of said piston to its initial position.

3. In combination with an electric switch, a fluid motor including a piston and a cylinder, an operating mechanism interrelating said switch and said piston, said piston being normally out of engagement with said mechanism, means for supplying fluid under pressure to act on one side of said piston to move said piston from an initial position to close said switch, latching means for holding said switch in the closed position after said piston has moved it to the closed position, spring means for returning said piston to said initial position while said switch remains closed, and means for supplying fluid under pressure to the other side of said piston only when said switch is closed during a fault condition on the circuit controlled by said switch to supplement said spring means and cause high speed return of said piston to its initial position.

4. In combination with an electric switch, a fluid motor including a piston and a cylinder, an operating mechanism interrelating said switch and said piston, means for supplying fluid under pressure to act on one side of said piston to move said piston from an initial position to close said switch, latching means for holding said switch in the closed position after said piston has moved it to the closed position, means for opening said switch, means for returning said piston to said initial position, valve means for supplying fluid under pressure to the other side of said piston, and valve control means responsive to the presence of fluid under pressure acting on said one side of said piston during a closing operation of said fluid motor for opening said valve means to cause said piston to be returned to its initial position at high speed, said valve control means being operable only after actuation of said means for opening said switch.

5. In combination with an electric switch, a fluid motor including a piston and a cylinder, an operating mechanism interrelating said switch and said piston, means including a source of fluid under pressure for supplying fluid under pressure to act on one side of said piston to move said piston from an initial position to close said switch, latch means for holding said switch in the closed position after said piston has moved it to the closed position, means for opening said switch, spring means for returning said piston to said initial position, valve means for supplying fluid under pressure to the other side of said piston, and means responsive to the presence of fluid under pressure acting on said one side of said piston during a closing operation and operable upon actuation of said means for opening said switch, for opening said switch valve means to supply fluid under pressure to the other side of said piston and for simultaneously interrupting the flow of fluid from said source of fluid to said one side of said piston to cause said switch to return to its initial position at high speed.

6. In combination with an electric switch, a fluid motor, an operating mechanism including pivotally mounted cam means interrelating said switch and said fluid motor, means for operating said fluid motor to close said switch, latching means for holding said switch in the closed position, magnetic means for holding said latching means in latching position, a trip coil on said magnetic means, means for energizing said trip coil to render said magnetic means ineffective to hold said latching means in latching position, means for causing resetting of said latching means, and guide means mounted on said cam means and engaging said latching means for preventing resetting of said latching means while said switch is in other than its closed or substantially closed position.

7. In combination with an electric switch, a fluid motor including a piston and a cylinder, an operating mechanism interrelating said switch and said piston, means for supplying fluid under pressure to act on one side of said piston to move said piston from an initial position to close said switch, latching means for holding said switch in the closed position after said piston has moved it to the closed position, spring means for returning said piston to said initial position while said switch remains closed, and means for supplying fluid under pressure to the other side of said piston only when said switch is closed during a fault condition on the circuit controlled by said switch to supplement said spring means and cause high speed return of said piston to its initial position.

8. In combination with a biased open electric switch, a fluid motor, an operating mechanism including a cam lever for interrelating said switch and said fluid motor, a roller on said cam lever engageable by said fluid motor, means for operating said fluid motor to close said switch, cam means on said cam lever for causing the closing force applied by said fluid motor to said switch during a switch closing operation to increase in magnitude substantially in accordance with the increase in the forces opposing the closing of said switch, latching means cooperating with said roller for holding said switch in the closed position, means for tripping said latching means to cause opening of said switch, and a latch guide on said cam lever for preventing said latching means from occupying its latching position when said switch is open.

9. In combination with a biased open electric switch, an actuating device, an operating mechanism for interrelating said switch and said actuating device comprising a pivotally mounted lever connected to said switch at one end of said lever, a roller mounted on the other end of said lever, an independent cam lever pivotally mounted at one end, roller means and a cam mounted on the other end of said cam lever, said roller on said first mentioned lever being engageable by said cam on said cam lever during closing of said switch to cause the closing force applied by said actuating device to said switch to
increase in magnitude substantially in accordance with the increase in the forces opposing closing of said switch, and latching means for engaging said roller means to hold said switch in the closed position, said roller means being engageable by said actuating device to impart switch closing movement to said mechanism.

THELLWELL R. COGGESHALL.

REFERENCES CITED

The following references are of record in the file of this patent:

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>780,564</td>
<td>Hall</td>
<td>Jan. 24, 1905</td>
</tr>
<tr>
<td>2,163,882</td>
<td>Mercier</td>
<td>June 27, 1939</td>
</tr>
<tr>
<td>2,188,003</td>
<td>Boehme</td>
<td>Jan. 30, 1940</td>
</tr>
<tr>
<td>2,286,023</td>
<td>Strang</td>
<td>June 9, 1942</td>
</tr>
<tr>
<td>2,292,055</td>
<td>Thumin</td>
<td>Aug. 4, 1942</td>
</tr>
<tr>
<td>2,375,270</td>
<td>Westervelt</td>
<td>June 12, 1945</td>
</tr>
<tr>
<td>2,383,288</td>
<td>Boden et al.</td>
<td>Aug. 21, 1945</td>
</tr>
<tr>
<td>2,403,052</td>
<td>Hill et al.</td>
<td>July 2, 1946</td>
</tr>
</tbody>
</table>