

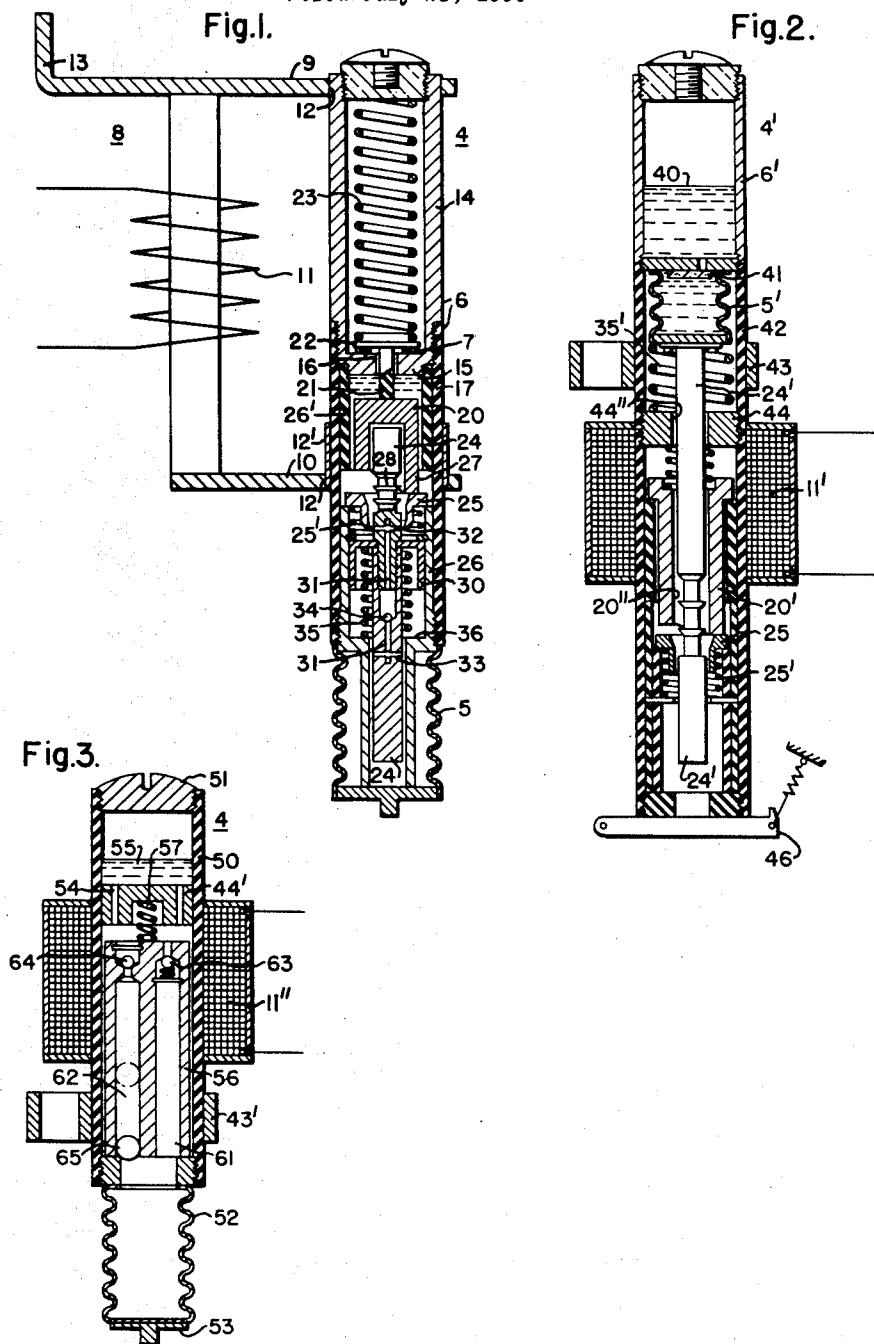
Dec. 28, 1954

A. W. EDWARDS

2,698,404

LINE-SECTIONALIZER INTEGRATOR-MECHANISM

Filed July 21, 1950



WITNESSES:

H. F. Sussner.
Leon J. Taya

INVENTOR

Andrew W. Edwards

BY *O. B. Buchanan*

ATTORNEY

1

2,698,404

LINE-SECTIONALIZER INTEGRATOR-MECHANISM

Andrew W. Edwards, East McKeesport, Pa., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Application July 21, 1950, Serial No. 175,275

20 Claims. (Cl. 317—178)

My invention relates to line-sectionalizer integrator-mechanism having liquid-restrained resetting-means for slowly returning the counter-member to its initial position. The general purpose of line-sectionalizers is to cooperate with a recloser, which energizes a rural distribution-line, so that the sectionalizer will cut out of service only the faulted section of the line, in the event of a fault which persists after a predetermined number of openings and closings of the recloser, thus leaving the rest of the line in service. The recloser counts a predetermined number of times, usually four, before locking itself out, with its contacts permanently open; and each sectionalizer counts a smaller number of rapidly repeated overcurrent conditions, and then opens up its line-contact during a no-current period of the recloser.

In case the integrator or counting-mechanism of either the recloser or the sectionalizer counts a number less than its predetermined number, it is necessary for that integrator or counting-mechanism to return slowly back to its initial position, thus automatically resetting itself, ready for another counting of a succession of rapidly repeated overcurrent-conditions.

Various difficulties have been encountered in using liquid-type time-delay resetting-means for such integrators or counter-mechanisms. In general, I provide, in one form or another, a liquid-filled hermetically sealed tubular capsule, the lower portion of said capsule being an axially expandible portion having flexible side walls, an electromagnetically operated armature, means for causing a measured advance of a counting-means each time the armature moves in one direction, and means for finally advancing the flexible end of the capsule far enough to effect a desired integrator-response at the end of a predetermined number of measured advances of the counting-means.

While my present invention was particularly designed for integrators or counting-mechanisms for line-sectionalizers, and will be so described, it is also susceptible of application of reclosers and in other applications where similar self-resetting counting-operations are required.

In like manner, while my invention was particularly designed, and is particularly adapted, for the use of a liquid, rather than air or gas, certain features of my invention are also generally applicable, whatever may be the retarding-fluid. The use of a suitably chosen liquid, rather than air or gas, has the general advantage of permitting easily maintainable working tolerances between slidably fitting parts, in the manufacturing operation, with no danger of service-trouble due to corrosion, dirt, or thermal distortion of the parts; and it also makes possible a considerable choice of the variation of the resetting-time with temperature, by choosing a liquid having suitable temperature-viscosity characteristics, thus compensating for unequal thermal expansions of the fitted parts of the mechanism.

With the foregoing and other objects in view, my invention consists in the apparatus, systems, combinations, parts, and methods of design and operation, several specific illustrative forms of which are hereinafter described and claimed, and illustrated in the accompanying drawing, wherein Figures 1, 2 and 3 are somewhat diagrammatic vertical sectional views showing different illustrative forms of embodiment of my integrator-mechanism.

In Fig. 1, I show a self-resetting integrator-mechanism which uses a normally upstanding, long, tubular capsule 4, the lowermost portion of which is an axially expandible

2

portion having flexible side walls like Sylphon bellows 5, while all the rest of the capsule has stiff side walls 6. In the illustrated example, about 60% of this capsule is filled with a liquid of suitable temperature-viscosity characteristics, which extends up to about the level of a washer or gasket 7 which will be subsequently described.

In the device shown in Fig. 1, the top portion of the tubular capsule 4 is supported from an electromagnet-device 8 having upper and lower spaced pole-piece plates 9 and 10, which are energized by means of a coil 11, for causing a magnetic flux to flow axially in the upper portion of the tubular capsule 4, between the two pole-piece plates 9 and 10. This coil 11 is the coil which is adapted to be connected in series with a distribution-line (not shown) for responding to over-current-conditions therein. Each of the pole-piece plates 9 and 10 has an opening 12 which at least partially surrounds the tubular capsule 4, and supports the same in an essentially vertical position. The opening 12 in the lower pole-face plate 10 is lined with a magnetizable sleeve 12' which surrounds a portion of the tubular capsule 4, so that the top of this magnetizable sleeve 12' actually forms the top face of the lower pole of the electromagnet-device.

The electromagnet-device 8 is supported by any suitable means, such as a supporting-bracket 13 which may form a part of an upper pole-plate 9.

In Fig. 1, the upper end of the tubular capsule 4 consists of a magnetizable tube 14 which is closed at both ends, the bottom 15 of this magnetizable tube having an axial hole 16 therethrough. This bottom 15 of the magnetizable tube 14 underlies the previously mentioned washer or gasket 7. The bottom 15 of the magnetizable tube 14 thus in effect becomes the lower end of the top pole of the electromagnet-device.

In Fig. 1, the lower half of the stiff side walls 6 of the tubular capsule consists of an insulating tube 17, or at least a tube of non-magnetizable material, which is hermetically secured to the bottom of the magnetizable tube 14 to constitute a tubular extension thereof. An intermediate portion of this insulating tube 17 is surrounded by the magnetizable sleeve 12' which constitutes the lower pole of the electromagnet-device.

Within the insulating tube 17 at about the level of the upper end of the magnetizable sleeve 12', there is disposed an axially movable armature 20, which is freely movable axially between a predetermined unattracted lowermost position, which is shown in Fig. 1, and a predetermined elevated attracted position, in which the top end of the armature moves up into contact (or near-contact) with the bottom 15 of the magnetizable tube 14. In the lowermost position of the armature 20, there is a vertical space between the top of the armature and the bottom of the magnetizable top-pole tube 14, this vertical space corresponding to the stroke or extent of axial movement of the armature.

Secured to, or resting upon, the top of the armature 20 is an axially extending insulating or non-magnetizable pressure-rod 21, which extends up through the hole 16 in the bottom of the magnetizable tube 14. The top of this pressure-rod 21 is secured to a shoulder or plate 22 which is pressed downward by a compression-spring 23. This spring 23 thus biases the armature 20 to its lowermost position, and at the same time it compresses the washer 7 between the plate 22 and the bottom 15 of the magnetizable tube 14.

Underneath the armature 20 there is an axially disposed movable counter-rod 24 which is freely axially movable within the tubular capsule 4, so that the lower end of said counter-rod is advanceable and retractible away from and toward the lower end of the armature. Below the armature 20, there is a one-way drive-mechanism, shown in the form of a tiltable pawl or clutch 25, which is pressed up against the armature 20, by a spring 25'. In the lowermost position of the armature 20, said armature presses the pawl or clutch 25 down against the level or horizontal top of a sleeve 26 in the tubular member 4.

When the coil 11 is energized with a sufficient over-current, it draws the armature 20 into its upward position, and this upward movement of the armature is fol-

3

lowed by the pawl or clutch 25, under the force of its spring 25'. At the end of this upward movement, the top of the pawl 25 is leveled off by engagement with the level or horizontal bottom of a sleeve 26' in the tube 17, thus disengaging said pawl from the counter-bar 24.

When the coil 11 is deenergized, by which I mean, when said coil is not sufficiently energized, as a result, for example, of the tripping of the recloser (not shown), the armature 20 drops down to its lowermost position, carrying the pawl or clutch 25 with it. The bottom edge of the armature 20 is uneven, having a downwardly projecting extension 27 on one side, thus causing the pawl 25 to cant sideways, when said pawl is pushed down away from the level bottom of the sleeve 26', thus making the pawl engage in one of a series of notches 28 on the counter-bar 24, and thus pushing the counter-bar down a little further than the distance between successive notches 28. Just as the armature 20 reaches its lowermost position, the pawl or clutch 25 is leveled off by engagement with the level top of the sleeve 26, thus again disengaging said pawl or clutch from the counter-bar 24.

This releasing of the counter-advancing pawl 25 at each end of its stroke is described and claimed in an application of J. M. Wallace and myself, Serial No. 175,271, for Line-Sectionalizers, filed concurrently herewith.

An intermediate portion of the counter-rod 24, below the notches 28, carries a piston 30 which fits within the sleeve 26; and this portion of the counter-rod is provided with an axially extending hole 31 having lateral ports 32 and 33 above and below said piston. Included in the axial hole 31 is a liquid-flow valve 34 for opposing the sudden return-movement of the counter-rod. Thus the counter-rod 24 can freely advance downwardly, as fast as the armature 20 moves, but the resetting upward-return of the counter-rod is limited to the rate at which the liquid can leak downwardly past the valve 34 or past the piston 30.

The counter-rod 24 is biased upwardly, in its resetting direction, by means of a compression-spring 35 which is disposed between the bottom of the piston 30 and the top of a shoulder 36 which is provided in the sleeve 26.

Thus, the pawl 25 acts as a one-way drive-mechanism for imparting one step of a step-by-step downward advance to the counter-rod 24, each time the armature 20 moves in a downward direction in response to the interruption of an adequate current-flow in the coil 11; and when there is a succession of rapidly repeated overcurrent and undercurrent conditions, the counter-rod 24 will be progressively advanced downwardly in a succession of steps, as covered in the previously mentioned application of J. M. Wallace and myself.

After a predetermined number of downward advance-steps of the counter-rod 24 have been obtained, the bottom of this rod strikes the lower end of the bellows of flexible-walled portion 5 of the tubular capsule, and pushes this end of the capsule downwardly to effect whatever control-response may be desired, such as the opening of a sectionalizer line-contact (not shown).

It will be noted that the normally compressed washer or gasket 7 in Fig. 1 is disposed at just about the liquid-level in the capsule 4, or a trifle below said liquid-level, thus making it possible for the capsule to be handled, or to be upended, when the integrator-mechanism is in its normal reset condition, waiting for the occurrence of an overcurrent-condition in the coil 11. The washer or gasket 7 thus materially reduces the likelihood that air-bubbles will be introduced or trapped within the liquid, with their resultant erratic effect upon the behavior of the timing-means.

Another advantage of the arrangement shown in Fig. 1 is that the bellows or flexible-wall portion 5 is not deflected until the very last moment, when it is desired to have a response to the final advancing-movement of the counter-rod. Furthermore, the bellows is deflected only an absolute minimum, thus reducing the total amount of energy required to deflect the bellows. This results in a much smaller coil 11 and a less expensive bellows 5.

In Fig. 2, I show a second form of self-resetting integrator-mechanism embodying the general principles of my invention. In this form of the invention, the normally upstanding tubular capsule 4' occupies only the upper portion of the tubular integrator-mechanism. The

4

lower portion of this capsule 4' is an axially expandible portion having flexible side walls 5', while the upper portion of said capsule has stiff side walls 6'. There is a partial-filling of a liquid 40 of suitable temperature-viscosity characteristics within the capsule 4', and a liquid-flow valve 41 for opposing the rapid flow of liquid from the flexible-walled portion to the stiff-walled portion of the capsule, thus making the capsule operate, in effect, like a liquid dashpot.

Below the sealed capsule 4' in Fig. 2, there is disposed an insulating or non-magnetizable tube 42 which constitutes the main portion of the tubular housing or guide-member for the counter-mechanism. The tubular structure is supported in any desired manner, such as by means of a bracket 43. The upper end of the tube 42 is joined to the stiff-walled portion 6' of the capsule, with the flexible-walled portion 5' of the capsule extending into the top of the tube 42.

An intermediate portion of the tube 42, in Fig. 2, is surrounded by a magnetizable coil 11', which causes an axial flow of magnetic flux in the tubular portion which is surrounded by said coil. An armature 20' is disposed within the tubular member 42, so as to be freely movable axially between an illustrated lower unattracted position, and an upper attracted position to which it is attracted by the magnetic flux of the coil 11'. When the armature 20' is drawn upwardly by the magnetic flux, the top end of said armature is brought up against a (preferably magnetizable) plug 44 which is disposed within the tube 42 at about the top of the coil 11', thus acting as an upper pole-piece for the coil.

In Fig. 2, the counter-rod 24' extends axially all the way through both the armature 20' and the magnetizable plug 44', being freely slidable through holes 20'' and 44'' in these members. The counter-rod 24' is advanced downwardly, in a step-by-step manner, by the same one-way drive-mechanism or pawl 25 as in Fig. 1, but the time-delayed resetting-bias of the counter-rod 24' is different, in Fig. 2.

Thus, as shown in Fig. 2, the upwardly extending end of the counter-rod 24' is secured to the bottom of the bellows or flexible-walled portion 5' of the oil-filled capsule 4'. In this arrangement, therefore, the bellows 5' has to be extended for a distance corresponding to the total axial movement of the counter-rod 24'. The bellows permits the counter-rod to move freely downwardly, with only the impedance necessary to overcome the stiffness of the flexible side-walls 5', but the valve 41 restricts the rate at which the resetting upward movement can take place. The counter-rod 24', in Fig. 2, is biased in a resetting direction, as by a compression-spring 35' which is interposed between the bottom of the bellows 5' and the top of the magnetizable plug 44, or by a reduction in pressure inside the closed space within the tube 6, or by the spring-characteristics of the bellows 5'.

The final response of the integrator-mechanism shown in Fig. 2 is obtained by means of the lower end of the counter-rod 24', which projects down below the open bottom end of the tubular housing 42, to displace a latch 46 or other device which is to be operated in response to a predetermined count-number of the mechanism.

In Fig. 3, all of the parts of my liquid-actuated self-resetting integrator-mechanism are included in a liquid-filled hermetically sealed tubular capsule which is similar, in general principles, to the capsule 4 in Fig. 1. In Fig. 3, this capsule consists of an upper tube 50 of stiff insulating or non-magnetic material, having a hermetically closed upper end 51. The lower end of the tube 50 is hermetically joined to the upper end of a flexible-walled portion or bellows 52, having a hermetically closed bottom end 53. The tube 50 is supported by any suitable supporting-bracket 43'.

An intermediate portion of the tube 50 in Fig. 3 is surrounded by a magnetizing coil 11'', as in Fig. 2, and as in Fig. 2, an upper pole-piece is provided in the form of a magnetizable plug 44' which is disposed at about the level of the top of the coil 11''. This magnetizable plug 44' is provided with one or more holes 54 therethrough so that fluid may flow freely in either direction, either to or from the space above the magnetizable plug 44'. The oil-level in the tube 50, in Fig. 3, is at a point somewhat above this magnetizable plug 44', as shown at 55.

In Fig. 3, a different sort of armature is provided, and a different sort of operating-means for counting the successive back-and-forth axial movements of the armature, and for finally transmitting information as to the completion of a predetermined number or count of such rapidly recurring movements.

In Fig. 3, normally spaced below the bottom of the magnetizable plug 44', there is an armature 56 which fits within the tube 50 with a fit which is sufficiently liquid-tight to oppose rapid liquid-flow through said fit in the direction of the axis, the width of this fit being exaggerated in the drawing, for clearness of illustration. The armature is biased to its illustrated extreme downward limit of movement, by its own weight, and also by a compression-spring 57 which is disposed between the top of the armature and the bottom of the magnetizable plug 44'. When the coil 11'' is adequately energized, its magnetic flux draws up the armature until the top of the armature hits the magnetizable plug 44'.

In Fig. 3, the armature 56 has two holes 61 and 62 extending therethrough in the direction of the axis. In the first hole 61, a liquid-valve 63 is provided, for opposing rapid liquid-flow through said hole in the upward direction; whereas the second hole 62 has an oppositely disposed valve 64 therein, for opposing rapid liquid-flow through this second hole in the downward direction. Disposed in the second hole 62, a floating piston-means 65 is also provided, which normally rests near the bottom of this second hole 62, being biased towards this bottom position by any suitable biasing-means, such as its own weight.

When the coil 11'' is first energized with a suitable overcurrent, in Fig. 3, the armature 56 makes its first upward stroke during which a measured quantity of the liquid passes downwardly freely through the first hole 61, and no liquid-pressures are developed. When the overcurrent-condition is removed, the armature 56 drops downwardly, and the liquid which was trapped below the armature, in the closed lower end of the capsule, begins to rise upwardly in the second hole 62 in the armature, carrying along the floating piston 65 during this process. The relative diameters of the holes 61 and 62, the lengths of these holes, and the length of the armature-stroke, are so chosen that it requires a plurality of armature strokes to drive said floating piston-means 65 all the way up to the top of the second hole 62 in the armature 56. This floating piston-means 65 thus acts as a counter-member, which advances in a step-by-step fashion, until a predetermined desired number of steps or counts have been obtained. When the floating piston-means 65 reaches the top of the hole 62 its further upward progress in said hole is stopped, so that it then acts as a plug which substantially prevents any further upward liquid-flow in this hole 62. Therefore, the next time the armature 56 moves downwardly, driving a no-current period, the downward stroke of the armature pumps oil into the bellows-portion 52 of the capsule, because the valve 63 prevents upward liquid-flow in the first hole 61, while the floating piston 65 prevents any further upward liquid-flow in the second hole 62, while the armature is making this downward stroke. The expansion of the bellows-portion 52 results in a lowering of the bottom end 53, thus tripping any response-means (not shown) which may be provided for being controlled by the integrator or counting-mechanism.

The mechanism resets itself, in Fig. 3, by the slow dropping of the floating piston 65, due to fluid-leakage past said piston or through the fit between the outer walls of the armature 56 and the inner bore of the tube 50. Thus the mechanism of Fig. 3 is self-resetting.

It will be noted that the mechanism of Fig. 3 is extremely simple, it is all-fluid in its action, having no mechanical parts other than the moving armature 56, the valves 63 and 64, and the floating piston 65. It is further noted that the bellows 52 is not expanded at all until the very last moment, at which time it is expanded only the minimum amount necessary to provide the slight downward movement of the lower end 53, which is necessary to indicate a response of the counting-mechanism.

While I have shown my invention in several different forms of specific embodiments, I wish it to be understood that the general principles of my invention are not limited to these precise embodiments, as various

changes may be made, by way of the substitution of equivalents, or the omission or addition of parts, without departing from the spirit of the invention. I desire, therefore, that the appended claims shall be accorded the broadest construction consistent with their language.

I claim as my invention:

1. A fluid-actuated self-resetting integrator-mechanism comprising: a sealed capsule containing a fluid, an electromagnet-device having a magnetizing coil, and having an armature which is movable from a predetermined unattracted position to a predetermined attracted position to which it is attracted by the magnetic flux of said coil; biasing-means for returning said armature to its unattracted position each time the current falls below a predetermined value; a movable counting-means; one-way-acting means for causing each movement of the armature, in one direction, to cause a measured advance of said counting-means; biasing-means for biasing said counting-means in a resetting direction toward its unadvanced position; time delay means including one-way-acting fluid-flow means within the capsule for effecting cumulative advancement of said counting-means by impeding the fast resetting movement of said counting-means; and means freely permitting its fast advancing-movement; and means including a flexible capsule sealing member at one end of said capsule for effecting a desired integrator-response at the end of a predetermined number of repeated measured advances of the counting-means.

2. A fluid-actuated self-resetting integrator-mechanism comprising: a hermetically sealed fluid-filled capsule having flexible-wall means whereby an end of the capsule may be extended; an electromagnet-device having a magnetizing coil, and having an armature which is movable from a predetermined unattracted position to a predetermined attracted position to which it is attracted by the magnetic flux of said coil; biasing-means for returning said armature to its unattracted position each time the current falls below a predetermined value; a movable counting-means; one-way-acting means for causing each movement of the armature, in one direction, to cause a measured advance of said counting-means; biasing-means for biasing said counting-means in a resetting direction toward its unadvanced position; one-way-acting fluid-flow means within the capsule for effecting cumulative advancement of the counting-means by impeding the fast resetting movement of said counting-means while freely permitting its fast advancing-movement; and means for finally responding to a predetermined number of repeated measured advances of the counting-means for extending said end of the capsule far enough to obtain a desired integrator-response.

3. A fluid-actuated self-resetting integrator-mechanism comprising: a tubular member having a fluid therein and having an expansible flexible wall portion sealing said fluid in a portion of said tubular member; a magnetizing coil for causing a magnetic flux to flow axially in a portion of said tubular member; an armature within said tubular member, said armature being freely movable axially between a predetermined unattracted position and a predetermined attracted position to which it is attracted by the magnetic flux of said coil; biasing-means for returning said armature to its unattracted position each time the current falls below a predetermined value; an axially moving counting-means within said tubular member; one-way-acting means, within said tubular member, for causing each movement of the armature, in one direction, to cause a measured advance of said counting-means; biasing-means, within said tubular member, for biasing said counting-means in a resetting direction toward its unadvanced position; one-way-acting fluid-flow means within the sealed portion of said tubular member for effecting cumulative advancement of said counting-means by impeding the fast resetting movement of said counting-means while freely permitting its fast advancing-movement; and means connected to the flexible wall portion for effecting a desired integrator-response at the end of a predetermined number of repeated measured advances of the counting-means.

4. A fluid-actuated self-resetting integrator-mechanism comprising: a normally upstanding tubular member including a hermetically sealed fluid-filled capsule having flexible-wall means whereby an end of the capsule may be extended; a magnetizing coil for causing a magnetic flux to flow axially in a portion of said tubular member;

an armature within said tubular member, said armature being freely movable axially between a predetermined unattracted position and a predetermined attracted position to which it is attracted by the magnetic flux of said coil; biasing-means for returning said armature to its unattracted position each time the current falls below a predetermined value; an axially moving counting-means within said tubular member; one-way-acting means, within said tubular member, for causing each movement of the armature, in one direction, to cause a measured progressive advance of said counting-means; biasing-means, within said tubular member, for biasing said counting-means in a resetting direction toward its unadvanced position; one-way-acting fluid-flow means, within said tubular member, for impeding the fast resetting movement of said counting-means while freely permitting its fast advancing-movement; and means for effecting a desired integrator-response at the end of a predetermined number of repeated measured advances of the counting-means.

5. A self-resetting integrator-mechanism comprising: a normally upstanding hermetically sealed tubular capsule, the lower portion of said capsule being an axially expandible portion having flexible side walls, the upper portion of said capsule having stiff side walls, a partial filling of a liquid of suitable temperature-viscosity characteristics within said capsule; a magnetizing coil for causing a magnetic flux to flow axially in a stiff-walled portion of said capsule; an armature disposed axially within a stiff-walled portion of said capsule, said armature being freely movable axially between a predetermined unattracted position and a predetermined attracted position to which it is attracted by the magnetic flux of said coil; biasing-means for returning said armature to its unattracted position each time the current falls below a predetermined value; an axially disposed movable counter-rod which is freely movable within said capsule, the lower end of said counter-rod being advanceable and retractable away from and toward the lower end of said armature; a one-way drive-mechanism for imparting one step of a step-by-step advance to said counter-rod each time the armature moves in that direction; means for biasing said counter-rod toward its retracted position; means including a liquid-flow valve for opposing the sudden return-movement of said counter-rod toward its retracted position; and means for causing said counter-rod, at the end of its predetermined step-by-step advance, to cause the lower end of said capsule to move downward below a predetermined point, whereby the integrator-mechanism responds to a predetermined number of rapidly repeated overcurrent-conditions in said coil.

6. A self-resetting integrator-mechanism comprising: a normally upstanding hermetically sealed tubular capsule, the lower portion of said capsule being an axially expandible portion having flexible side walls, the upper portion of said capsule having stiff side walls, a partial filling of a liquid of suitable temperature-viscosity characteristics within said capsule; a magnetizing coil for causing a magnetic flux to flow axially in a stiff-walled portion of said capsule; an armature disposed axially within a stiff-walled portion of said capsule, said armature being freely movable axially between a predetermined unattracted position and a predetermined attracted position to which it is attracted by the magnetic flux of said coil; biasing means for returning said armature to its unattracted position each time the current falls below a predetermined value; an axially disposed movable counter-rod which is freely movable within said capsule, the lower end of said counter-rod being advanceable and retractable away from and toward the lower end of said armature; a one-way drive-mechanism for imparting one step of a step-by-step advance to said counter-rod each time the armature moves in that direction; means for biasing said counter-rod toward its retracted position; a piston carried by an intermediate portion of said counter-rod and fitting within a stiff-walled portion of said capsule; said counter-rod having an axially extending hole having lateral ports above and below said piston; means including a liquid-flow valve in said axially extending hole for opposing the sudden return-movement of said counter-rod toward its retracted position; and means for causing said counter-rod at the end of its predetermined step-by-step advance, to cause the lower end of said capsule to move downward below a predetermined point, whereby the integrator-mechanism responds to a prede-

termined number of rapidly repeated overcurrent-conditions in said coil.

7. A self-resetting integrator-mechanism comprising: a normally upstanding hermetically sealed tubular capsule, the lower portion of said capsule being an axially expandible portion having flexible side walls, the upper portion of said capsule having stiff side walls, a partial filling of a liquid of suitable temperature-viscosity characteristics within said capsule; a magnetizing coil for causing a magnetic flux to flow axially in a stiff-walled portion of said capsule; an armature disposed axially within a stiff-walled portion of said capsule, said armature being freely movable between a predetermined lower unattracted position and a predetermined upper attracted position to which it is attracted by the magnetic flux of said coil; said capsule having an annular shoulder within its bore at a point above the armature; the armature having an upstanding axial rod, terminating in an enlarged portion disposed above said annular shoulder; a gasket disposed between said enlarged portion of the upstanding rod and the annular shoulder of said capsule; a compression-spring disposed between the top of the capsule and the enlarged portion of the upstanding rod for returning said armature to its unattracted position each time the current falls below a predetermined value; said compression-spring also normally holding said gasket tight in the unenergized condition of said coil; the division-line between the partial liquid-filling and the overlying air being sufficiently near said gasket so that said gasket materially reduces the introduction of air-bubbles in the liquid when the capsule is upended; an axially disposed movable counter-rod which is freely movable within said capsule, the lower end of said counter-rod being advanceable and retractable away from and toward the lower end of said armature; a one-way drive-mechanism for imparting one step of a step-by-step advance to said counter-rod each time the armature moves in that direction; means for biasing said counter-rod toward its retracted position; means including a liquid-flow valve for opposing the sudden return-movement of said counter-rod toward its retracted position; and means for causing said counter-rod, at the end of its predetermined step-by-step advance, to cause the lower end of said capsule to move downward below a predetermined point, whereby the integrator-mechanism responds to a predetermined number of rapidly repeated overcurrent-conditions in said coil.

8. A fluid-actuated self-resetting integrator-mechanism comprising: a sealed tubular member having a fluid therein and having a flexible wall expandible member forming a seal at the lower end thereof; a magnetizing coil for causing a magnetic flux to flow axially in a portion of said tubular member; an armature within said tubular member, said armature being freely movable axially between a predetermined unattracted position and a predetermined attracted position to which it is attracted by the magnetic flux of said coil; spring biasing-means for returning said armature to its unattracted position each time the current falls below a predetermined value; means for causing each movement of the armature, in one direction, to advance a measured quantity of said fluid; valve-means for opposing the sudden return-flow of said fluid; biasing-means for causing a slow return-flow of said fluid, for resetting the integrator-mechanism; and means for responding to the displacement of a predetermined quantity of advanced fluid to cause a response-operation, said predetermined quantity being larger than the measured quantity which is advanced by one movement of the armature, whereby the integrator-mechanism responds to a predetermined number of rapidly repeated overcurrent-conditions in said coil.

9. A self-resetting integrator-mechanism comprising: a normally upstanding tubular member including a hermetically sealed tubular capsule, the lower portion of said capsule being an axially expandible portion having flexible side walls, the upper portion of said capsule having stiff side walls, a liquid of suitable temperature-viscosity characteristics within said capsule; a magnetizing coil for causing a magnetic flux to flow axially in a portion of said tubular member; an armature within said tubular member, said armature being freely movable axially between a predetermined unattracted position and a predetermined attracted position to which it is attracted by the magnetic flux of said coil; biasing-means for returning said armature to its unattracted position each time

the current falls below a predetermined value; means for causing each movement of the armature, in one direction, to advance a measured quantity of said liquid; valve-means for opposing the sudden return-flow of said liquid; biasing-means for causing a slow return-flow of said liquid, for resetting the integrator-mechanism; and means for responding to the displacement of a predetermined quantity of advanced liquid to cause the lower end of said capsule to move downward below a predetermined point, said predetermined quantity being larger than the measured quantity which is advanced by one movement of the armature, whereby the integrator-mechanism responds to a predetermined number of rapidly repeated overcurrent-conditions in said coil.

10. A self-resetting integrator-mechanism comprising: a normally upstanding hermetically sealed tubular capsule, the lower portion of said capsule being an axially expandible portion having flexible side walls, the upper portion of said capsule having stiff side walls, a liquid of suitable temperature-viscosity characteristics within said capsule; and a liquid-flow valve for opposing the rapid flow of liquid from the stiff-walled portion to the flexible-walled portion of the capsule; a tubular guide-member having its upper end joined to the stiff-walled portion of the capsule, with the flexible-walled portion of the capsule extending into the top of said tubular guide-member; a magnetizing coil for causing a magnetic flux to flow axially in a portion of said tubular guide-member; an armature within said tubular guide member, said armature being freely movable axially between a predetermined unattracted position and a predetermined attracted position to which it is attracted by the magnetic flux of said coil; biasing-means for returning said armature to its unattracted position each time the current falls below a predetermined value; said armature having an axially extending hole therethrough; a movable counter-rod which is freely movable within said hole in the armature and which extends both above and below the armature; means for securing the top of said counter-rod to the bottom of the flexible-walled portion of the capsule; a one-way drive-mechanism for imparting one step of a step-by-step downward advance to the downwardly extending portion of said counter-rod each time the armature moves downwardly; and means for biasing said counter-rod upwardly toward its return-movement; said counter-rod projecting more than a predetermined distance below the bottom of said tubular guide-member at the end of a predetermined step-by-step downward advance of said counter-rod, whereby the integrator-mechanism responds to a predetermined number of rapidly repeated overcurrent-conditions in said coil.

11. A fluid-actuated self-resetting integrator-mechanism comprising: a tubular member, a magnetizing coil for causing a magnetic flux to flow axially in a portion of said tubular member; an armature within said tubular member, said armature being freely movable axially between a predetermined unattracted position and a predetermined attracted position to which it is attracted by the magnetic flux of said coil, said armature fitting within said tubular member with a fit which is sufficiently fluid-tight to oppose rapid fluid-flow through said fit in the direction of the axis; and biasing-means for returning said armature to its unattracted position each time the current falls below a predetermined value; characterized by said armature having two holes extending therethrough in the direction of the axis; valve-means for opposing rapid fluid-flow through one of said holes in one direction; valve-means for opposing rapid fluid-flow through the other hole in the other direction; fluid-guiding passage for causing the fluid which passes freely through the first hole during one movement of the armature to pass freely back again through the second hole during the opposite movement of the armature; a floating piston-means disposed within the second hole and biased toward a position at the entrance thereof, whereby said piston-means is moved partway through said second hole during the aforesaid opposite movement of the armature; said floating piston-means operating, near the end of its movement through said second hole, as a stoppage for substantially preventing further back-passage of fluid through said second hole; the relative hole-diameters, hole-lengths, and armature-strokes being such that it requires a plurality of armature-strokes to drive said floating piston-means to its hole-

stopping position; and integrator-response means operative in response to the fluid-pressure which is produced in the fluid-guiding passage during the next armature-stroke, whereby the integrator-mechanism responds to a predetermined number of rapidly repeated overcurrent-conditions in said coil.

12. A self-resetting integrator-mechanism comprising: a normally upstanding hermetically sealed tubular capsule, the lower portion of said capsule being an axially expandible portion having flexible side walls, the upper portion of said capsule having stiff side walls, a partial filling of a liquid of suitable temperature-viscosity characteristics within said capsule; a magnetizing coil for causing a magnetic flux to flow axially in a stiff-walled portion of said capsule; an armature disposed axially within a stiff-walled portion of said capsule, said armature being freely movable axially between a predetermined unattracted position and a predetermined attracted position to which it is attracted by the magnetic flux of said coil, said armature fitting within said capsule with a fit which is sufficiently liquid-tight to oppose rapid liquid-flow through said fit in the direction of the axis; and biasing-means for returning said armature to its unattracted position each time the current falls below a predetermined value; characterized by said armature having two holes extending therethrough in the direction of the axis; valve-means for opposing rapid liquid-flow through a first one of said holes in the upward direction; valve-means for opposing rapid liquid-flow through the other hole in the downward direction; the lower portion of the capsule causing the liquid which passes downward freely through the first hole during an upward movement of the armature to pass freely upward again through the second hole during the next downward movement of the armature; a floating piston-means disposed within the second hole and biased toward a position at the lower end thereof, whereby said piston-means is moved partway upward through said second hole during the aforesaid downward movement of the armature; said floating piston-means operating, near the end of its upward movement through said second hole, as a stoppage for substantially preventing further upward passage of liquid through said second hole; the relative hole-diameters, hole-lengths, and armature-strokes being such that it requires a plurality of armature-strokes to drive said floating piston-means to its hole-stopping position; whereby the next downward armature-movement develops a liquid-pressure in the flexible-walled portion of the capsule, pushing down the lower end of the capsule, thus causing the integrator-mechanism to respond to a predetermined number of rapidly repeated overcurrent-conditions in said coil.

13. In a counting device, a casing having a rigid wall portion and a flexible wall portion providing with at least a portion of the rigid wall portion an extensible sealed compartment, electroresponsive means including a movable magnetic core slidably disposed in a portion of said rigid wall portion, a fluid disposed within at least the flexible wall portion of the casing, and counting means progressively operable in response to movement of said core for effecting extension of said flexible wall portion to effect a response operation only after a predetermined number of closely successive movements of said core.

14. A counting device comprising, a sealed casing having a flexible wall portion disposed to be extended, a fluid in said flexible wall portion, one-way fluid valve means for retarding the flow of fluid from said flexible wall portion, electromagnetic means including a movable core in said casing, and counting means in the casing operable in response to movement of said core to mechanically operate said flexible wall portion only after a predetermined number of closely successive movements of said core.

15. In a counting device, a sealed capsule having an extensible flexible wall portion, a fluid within said capsule, one-way valve means for retarding movement of said fluid from said flexible wall portion, electroresponsive means including a movable core within said capsule, and counting means within said capsule progressively operable in response to movement of said core for effecting extension of said flexible wall portion only after a predetermined number of closely successive operations.

16. A counter comprising, a sealed container having a flexible wall portion for sealing a fluid therein, a counter

member, actuating means for said counter member, and delay means retarding movement of the counter member in one direction by retarding flow of fluid in the container from one part to another a greater amount in said one direction than in the other direction.

17. A counter comprising, a movable counting member, electroresponsive means for effecting advancement of said member in one direction in response to a predetermined condition of a circuit, said member being biased to move in the reverse direction to reset, time delay means including a sealed container having an expansible portion adjacent one end, a perforate partition in said container, said partition and at least a portion of said container comprising two parts, one of which comprises the expansible portion and is movable relative to the other to cause liquid in said container to pass from one side of said partition to the other, means associating said counting member and the movable one of said two parts at least during a part of the advance and reverse movements of said counting member, and means restricting flow of liquid through said partition during a reverse movement of said counting member to delay resetting of said counting member and cause it to be progressively advanced in response to closely successive occurrences of said predetermined circuit condition.

18. A counter comprising, a movable counting member, electroresponsive means for effecting movement of said member in one direction in response to an over-current condition, said member being biased to move in the reverse direction to reset, time delay means including a sealed container having a fluid therein and having an expansible portion, partition means in said sealed container having an aperture therein and dividing the sealed container into two parts one of which includes the expansible portion, said partition and at least one of said two parts being relatively movable to cause fluid to move from one part to the other, and means for restricting the flow of fluid through said aperture during movement of the counting member in the reverse direction.

19. A counter comprising, a movable counter member, electroresponsive means for effecting movement of said counter member in one direction, said counter member being biased to move in the reverse direction to reset, time delay means retarding said counter member including a sealed casing having an expansible portion and partition means dividing the casing into two parts one of which comprises the expansible portion, said partition means having an aperture to permit flow of fluid in the casing from one part to the other, and means for retarding the flow of fluid from said other part to said one part within the sealed container during reverse movement of the counter member.

20. An integrator comprising, a sealed casing having a flexible wall portion whereby an end of the casing may be extended for effecting an integrator response, electroresponsive means including a movable core, and means including a counting member advanceable by movement of said core, said counting member having time delayed biasing means for effecting slow resetting thereof for extending said flexible wall in response to a predetermined number of closely successive movements of said core.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,737,649	Edsall	Dec. 3, 1929
1,805,082	Edsall	May 12, 1931
2,051,938	Carlson	Aug. 25, 1936
2,053,944	Cooney	Sept. 8, 1936
2,098,331	Bowman	Nov. 9, 1937
2,455,067	Kyle	Nov. 30, 1948
2,468,851	Wallace	May 3, 1949
2,515,530	Schindler	July 18, 1950
2,573,234	Wallace	Oct. 30, 1951