Feb. 7, 1956 L. R. RANSON 2,734,152

ELECTROMAGNETIC TIMING DEVICES

Original Filed Nov. 9, 1945 3 Sheets-Sheet 1

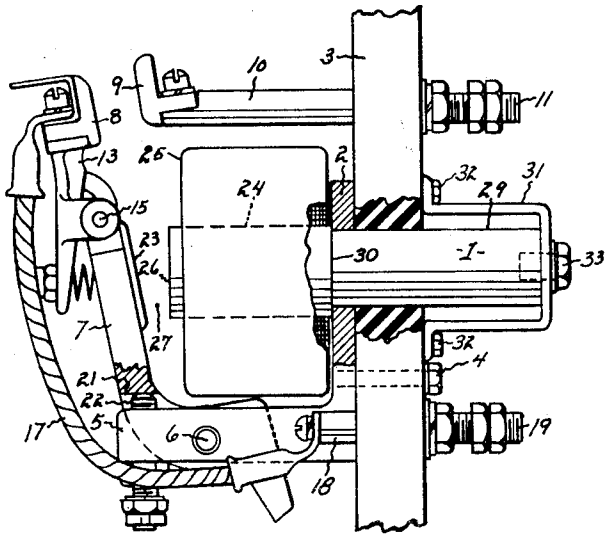


Fig. 1

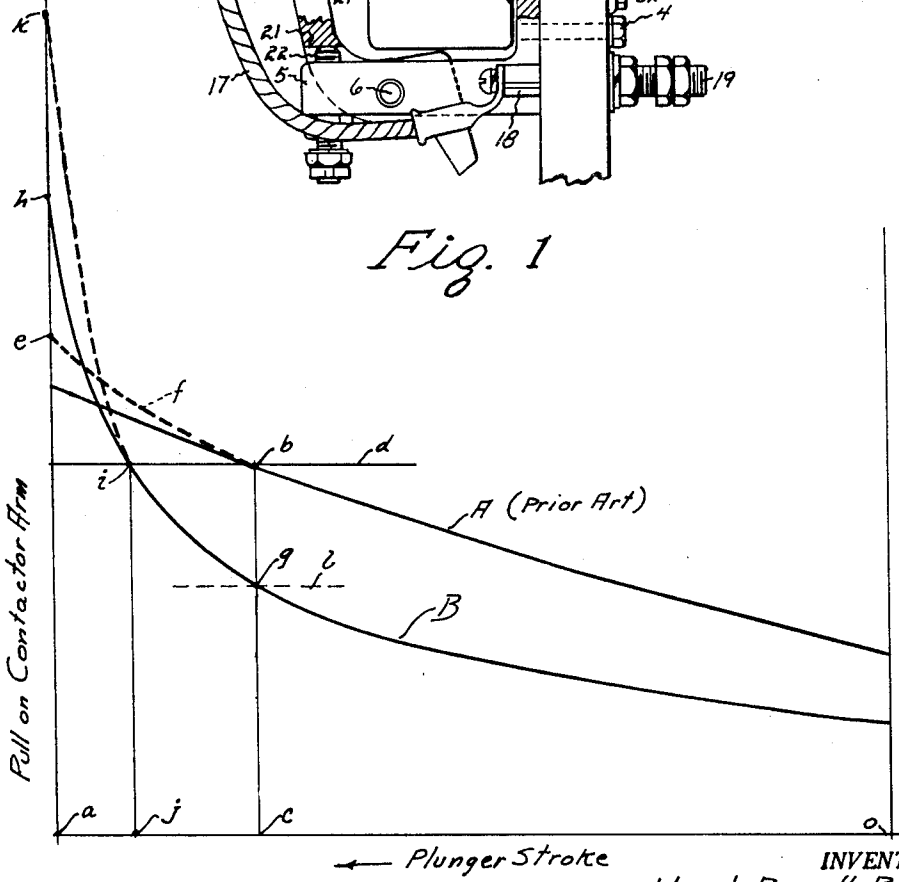


Fig. 6

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ELECTROMAGNETIC TIMING DEVICES

Original Filed Nov. 9, 1945 3 Sheets-Sheet 2

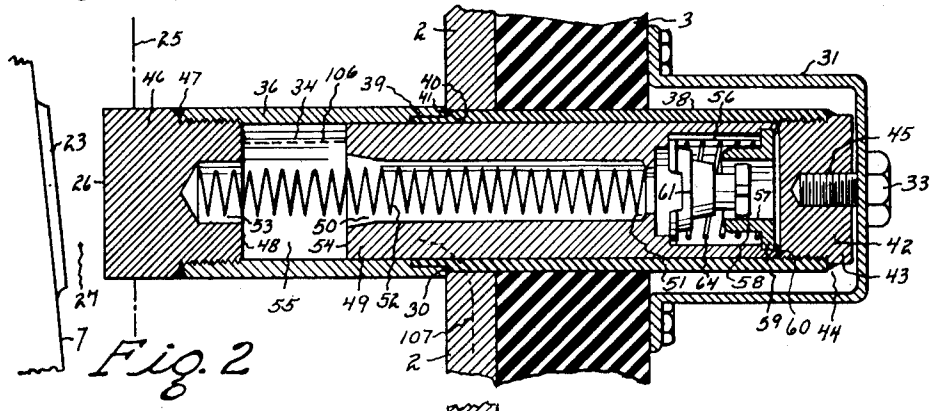


Fig. 2

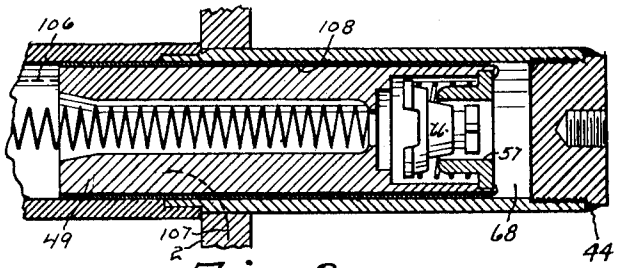


Fig. 3

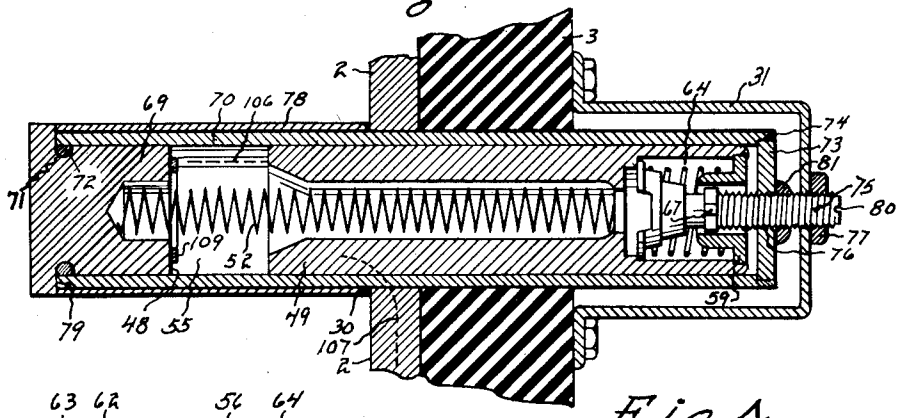


Fig. 4

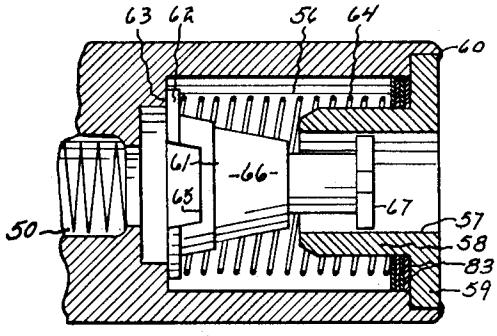


Fig. 5

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ELECTROMAGNETIC TIMING DEVICES

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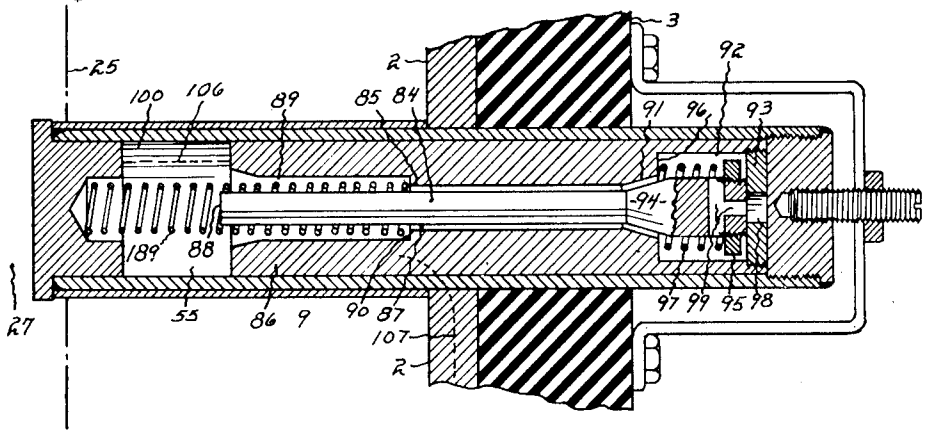


Fig. 7

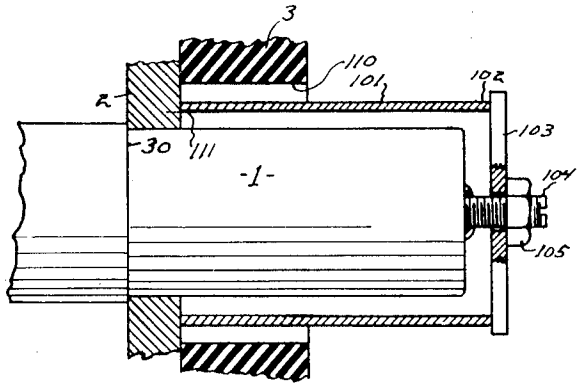


Fig. 8

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2,734,152

ELECTROMAGNETIC TIMING DEVICES

Lloyd Russell Ranson, Charlotte, N. C., assignor to The Clark Controller Company, Cleveland, Ohio, a corporation of Ohio

Original application November 9, 1945, Serial No. 627,735. Divided and this application July 17, 1952, Serial No. 299,470

6 Claims. (Cl. 317—178)

This invention relates to electro-magnetically operated timing devices, and particularly to electro-magnetic timing devices by which a time interval is introduced between the moment of energizing an electro-magnetic winding and the moment at which the magnetism produced by the winding performs a useful function or operation.

In general the embodiment of the invention comprises an electro-magnetic winding; and an air gap or work gap through which magnetism, or magnetic flux produced by the winding, acts to perform a useful operation; and means to cause the magnetic flux in the work gap to be too weak to perform the operation at the moment when the winding is first energized and to cause the strength of the flux in the work gap to gradually increase to the operating value at a controlled or timed rate.

The invention is applicable to numerous uses in various arts; but one of its most important uses or functions is to time or delay the operation of electro-magnetically operated electric switches or contactors; and for that reason it will be illustrated and described herein as applied to that use.

It is among the objects of the invention:

To provide generally an improved timing and operating device of the class referred to above;

To provide generally an improved electro-magnetically operated apparatus timed to operate with delay in an improved manner;

To provide an improved electro-magnetically actuated apparatus in which an operation is magnetically performed after the elapse of a time interval following energization of an electromagnetic winding, by magnetic pull on a movable element; and in which the magnetic pull increases at an accelerating rate having improved characteristics as the time interval goes on.

Other objects will become apparent to those skilled in the art to which the invention appertains.

The invention is fully disclosed in the following description taken in connection with the accompanying drawing, in which:

Fig. 1 is a side elevational view partly broken away and in section of an electric contactor, and showing in side elevation a timing and operating device embodying a part of my invention applied thereto;

Fig. 2 is a view showing the timing and operating device of Fig. 1 in longitudinal section, and to a larger scale than in Fig. 1, and with parts of Fig. 1 shown fragmentarily;

Fig. 3 is a fragmentary view similar to Fig. 2 showing parts in different operative positions; and showing a modification;

Fig. 4 is a view similar to Fig. 1 showing a modification;

Fig. 5 is a view to enlarged scale of a part of Fig. 2 showing an adjustment which may be employed for a valve device of Fig. 2;

Fig. 6 is a diagrammatic view illustrating certain magneto-dynamic properties both of the invention and of certain prior art;

Fig. 7 is a view generally similar to Fig. 1 showing another kind of valve device which I may employ;

Fig. 8 is a fragmentary view showing a modification which I may employ of an attaching and securing device of Figs. 2, 4 or 7.

In the patent to Charles H. Rippl, issued October 8, 1929, No. 1,730,688, is disclosed an electric contactor provided with a delaying or timing and operating device in the same general class as that of the present invention; and the present invention when applied to an electric contactor, may be considered as an improvement over the disclosure of that patent. Referring to that patent, when the winding **20** is energized by a predetermined potential, a predetermined flux strength develops in an air gap or work gap between the contactor arm **16** and the adjacent end of a magnetic plunger **35**, enclosed in and movable in a sealed oil-containing chamber **28** made of non-magnetic material.

The magnetic pull of the flux in this gap tends to move the contactor arm **16** to close the contacts **12—14**, but is insufficient to do so, because of the length and reluctance of the long air gap and the consequent weakness of the flux.

This magnetic pull, however, is great enough to pull the plunger **35** forwardly in the chamber **28** against the opposing force of a spring **37**, and it moves forwardly, its movement being retarded by a flow restricting valve arrangement at the rear of the plunger, through which oil displaced by the moving plunger is caused to flow.

As the plunger **35** moves forwardly it reduces the length of the air gap between the plunger end and the contactor arm **16**; and this causes the flux to gradually increase in the air gap and exert increasing pulling force on the arm; and a point is reached in the movement of the plunger and after a predetermined time interval of movement, at which the pull is great enough to operate the contactor arm and close the contacts **12—14**.

The mechanical load operatively moved by the flux is in two parts; the initial load of starting the arm **16** to move against its bias; and the final load of forcing the contacts **12—14** together into pressure engagement at the end of the arm movement.

This contact engaging force must be sufficient to enable the contacts to carry the desired current; and sufficient to prevent the contacts from separating or vibrating one upon the other when they first engage with a blow or thereafter when the contactor as a whole is subjected to shocks, which vibration or separation, if it should occur, will draw momentary arcs at the contacts and weld them together.

This final load, or, the minimum force necessary to firmly engage the contacts and hold them engaged, is a fixed or pre-imposed quantity for any given size of contacts, whereas the initial load or force to start the arm **16** moving may be made large or small, and arbitrarily chosen, by adjusting the gravity or other bias holding the arm in normal open-cantact position.

Now it has been found that, with the arrangement of parts of the said patent, the magnetic pull on the arm **16** increases approximately rectilinearly with movement of the plunger **35**; that is to say, it varies approximately inversely proportionally with the length of the air gap between the arm and the plunger.

A characteristic curve of pull for such prior art arrangement is shown by the curve A in Fig. 6; ordinates representing magnetic pull on the arm, and abscissae representing different positions of the plunger as it moves through its range of movement or stroke, that is, toward the left in Fig. 6.

The curve A has been made experimentally with the arm **16** of the patent held in fully retracted, biased posi-

tion, the solid line curve A corresponding to the full stroke of the plunger from *o* to *a*.

When, as in practice, the arm **16** is held open by its bias alone and is free to move, it will start to move when the pulling force is at the point *b* on the curve A corresponding to the position *o—c* for the plunger, at which the magnetic pull crosses the bias-load line *d* and overbalances the bias. Thereafter the arm **16** moves and the plunger **35** continues to move, and the working air gap is shortened by both movements going on concurrently; and, by the time the contacts are closed, the pull holding them closed will be at the point *e*, the pull from *b* to *e* rising along the dotted line *f* due to shortening of the working air gap by arm movement.

From this pull curve A, it will be seen that in order to have at *e* sufficient magnetic pull and force to hold the contacts securely closed (for the purposes mentioned above) there will unavoidably be a relatively large magnetic pull at *b* when the arm **16** starts to move, because the pulls at *e* and *b* cannot be greatly different due to the rectilinear character of the pull curve; and to prevent the arm from moving prematurely, it must therefore be heavily biased in the open direction, with a bias equal to the force *b*, to hold it open until the timing interval of the moving plunger has run. The result is that for the sake of having ample contact engaging force, the bias of the arm **16** must be correspondingly great, and the winding must accordingly provide abnormally high ampere turns to move the arm, and the whole contactor must be of abnormally large proportions. Another way to say this is, that for a contactor, winding, etc., of given size and cost, there is a low limit to the force available to hold the contacts closed, and the current carrying rating of the contacts must be low. Satisfactory operation therefore is attained with a sacrifice of economy.

In order to overcome this economic disadvantage of the device of the patent a problem is presented.

According to the present invention this problem has been solved by causing the pull on the contactor arm to be relatively weak during the major part of the stroke of the plunger and while the arm is in the open-contact position; and to become abruptly stronger and rise rapidly to a high value near the end of the plunger movement, and near the end of its timed interval.

This enables the contactor arm to be held unmoved by any desired bias, or even small bias, and at the same time provides very great contact engaging force.

The present invention and the means by which this result is accomplished will now be described.

Referring to the drawing, I have shown in Fig. 1, a conventional electric contactor provided with an operating and timing device **1**, which constitutes part of my invention, applied thereto.

The contactor itself comprises a magnetic frame element **2**, mounted upon an insulating panel **3**, by any suitable number of screws or bolts **4**, and having a forwardly projecting leg **5**, upon which at **6** is pivoted a contactor arm **7**, carrying at its upper end a contact **8**, movable therewith, and engageable, upon movement of the arm, with a stationary contact **9**, mounted upon a post **10**, secured to the panel **3** by means of a stud **11**, to which electric circuit connection can be made. The contactor arm **7** may be in two parts as illustrated, the contact **8** being mounted upon a supplemental arm **13** pivoted as at **15** to the main arm **7**, in a well known manner, and for well known purposes.

The contact **8** is connected by a flexible cable **17** to a post **18**, secured to the panel by a stud **19**, to which electric circuit connection can be made.

The arm **7** and its contact **8** are normally biased by gravity to the open-contact position shown, the arm having a shoulder **21** resting upon a screw **22** in the leg **5**, whereby the open position of the arm may be adjustably changed.

The arm **7** is preferably provided with a flat magnetic pole face **23**.

The timing and operating device referred to hereinbefore is shown in elevation at **1** and will be more fully described in several forms, but in general it comprises a cylindrical structure **24** Fig. 1, disposed in the hollow core of an electro-magnetic energizing winding **25** and has a flat magnetic pole face **26** opposite the pole face **23** of the arm **7** and spaced therefrom, providing thereby an external working air gap **27**. Rearwardly of the winding **25** as at **29**, the device is of reduced diameter and projects through aligned bores or holes in the panel **3** and in the magnetic frame element **2** respectively; and the reduced diameter provides a shoulder **30** engaging the frame element **2** to predeterminedly position the device as a whole longitudinally. The device is held in this position by a bracket **31** mounted upon the panel **3** by screws **32—32** and overlapping the rearward end of the reduced diameter portion **29**, and by a screw **33** projected through the bracket and screwed into the device, and these parts are made so that the shoulder **30** is drawn firmly against the frame element **2**.

Meeans not shown but well understood in the art is provided to hold the winding **25** against the frame element **1** in a well known manner.

The operation of the device as a whole will be apparent. When the winding **25** is energized, magnetic flux is produced in the air gap **27** between pole faces **23** and **26**, tending to move the arm **7** clockwise, as viewed in the drawing, to engage the contacts **8** and **9**. At the time of energizing the winding the flux in the gap **27** is insufficient to overcome the bias of the arm **7** to move it, but after the passage of a time interval, determined by the timing device **1** in a manner to be described, the flux strength in the gap **27** increases sufficiently to move the arm **7** and engage the contacts. When the winding is de-energized the bias of the arm **7** restores it to its normal position and disengages the contacts.

The interior construction and mode of operation of the timing and operating device **1** will now be described and reference may be had first to the form of Fig. 2, wherein some of the parts of Fig. 1 have been reproduced fragmentarily.

A liquid-tight, tubular chamber **34** is provided preferably cylindrical in cross section as indicated in the drawing. The side wall comprises generally a forward portion **36** of non-magnetic material such as brass, and a rearward portion **38** of magnetic material such as steel, the two parts being turned down so as to telescope one within the other at an airtight liquid tight juncture indicated at **39**. The inside diameter of these two tubular portions is uniform. The outside diameter of the part **36** is somewhat greater than that of the part **38** to provide the aforesaid shoulder **30**. At the juncture **39**, the tubular part **38** may be cut back to provide a groove **40** which may be filled with solder **41** to seal the juncture. The rearward end of the tubular chamber is closed and sealed by a plug **42** of non-magnetic material such as brass, screw threaded into the end of the tubular wall **38**. The plug **42** has a flange **43** overlapping the end of the tubular wall, and the liquid tight seal effected by the end of the plug and the flange **43** may be further insured by a ring of solder **44** sealing the flange **43** and the end of the tube together.

The plug **42** has a threaded hole **45** therein into which the aforesaid screw **33** is screwed for positioning the device in connection with the bracket **31** as has already been described in connection with Fig. 1.

The forward end of the tubular wall **36** is sealed by a plug or pole piece **46** of magnetic material, screw threaded into the end of the tube as shown, and the juncture may be further sealed by providing a groove and filling it with solder as at **47**.

The pole piece **46** has the exterior transverse pole face **26** already described for Fig. 1. The forward face of

the winding 25 described for Fig. 1 is indicated diagrammatically by the broken line 25 in Fig. 2, from which it will be seen that the pole piece 46 projects forwardly out of the winding, and projects inwardly into the winding for a substantial distance. The inner end of the pole piece 46 has a transverse pole face 48 well within the winding.

The flat or planar pole face 26 extends transversely of the axis of the pole piece 46 substantially at right angles thereto; and the pole face 23 is substantially parallel to the pole face 26 and becomes parallel as it moves in operation; so that the air gap 27 between the faces 23 and 26 is of substantially uniform length in the direction of the flux coming axially out of the pole piece 46.

A plunger 49 is provided in the tubular chamber 34 and has a free-sliding piston-like fit therein. It has a longitudinal bore 50 and a shoulder 51 in the bore, and a coil compression spring 52 abuts at one end upon the shoulder 51, and extends out of the bore and into engagement with the pole piece 46. Preferably the pole piece 46 has a recess or bore 53 therein to receive and center that end of the spring. The plunger 49 is thus spring-biased toward the rear of the chamber 34. The plunger at its forward end has a transverse pole face 54 parallel to the pole face 48; and thereby is provided a magnetic air gap 55 between the pole faces 48 and 54.

The bore 50 constitutes part of a passageway extending entirely through the plunger and at its rearward end this passageway is enlarged to provide a cavity 56 in the nature of a housing for a valve structure.

At the rearward end of the valve cavity 56 is a cylindrical outlet 57, see Fig. 5, which may be provided in any suitable manner. The means shown comprises a thimble 58, having a flange 59, seated in an annular recess in the end of the plunger, the end of the plunger being peened over the flange as at 60 to retain it in position.

A valve shown generally at 61, is provided with a flange 62 normally resting upon a shoulder 63 at the forward end or bottom of the cavity 56 and normally retained thereon by a spring 64 abutting upon the valve flange 62 and reacting upon the said flange 59. The valve flange 62 has a transverse passageway or groove 65 therein, affording communication between the bore 50 in the plunger and the cavity 56. Rearwardly of the flange 62 the valve is provided with a slightly conical throttle portion 66 axially aligned with the cylindrical outlet 57, and guided to enter it by a flange 67 on the valve, disposed in the cylindrical outlet 57. To prevent the flange 67 from obstructing the cylindrical outlet 57, it is preferably made circular to slidingly fit the outlet and then flats are cut on its periphery as shown in the drawing.

In assembling the parts of Fig. 2, the pole piece 46 may be screwed into the chamber 34 and sealed therein as described. The valve parts may be assembled with the plunger 49, as a unit. A measured quantity of oil or other suitable liquid is put into the chamber.

The oil is not shown in cross section in Fig. 2 to avoid obscuring the parts of the structure, but is indicated by its level at 106 in the working air gap 55; and it is believed that this will make clear the presence of the oil in the gap 55, bore 50, cavity 56, etc. particularly in view of the aforesaid prior patent. The same indication of the oil has been made in Figs. 3, 4 and 7 to be referred to. The spring 52 and the assembled plunger are then put into the chamber and the end plug 4 is screwed in and sealed as described.

The operation of the device of Fig. 2, and in connection with parts of Fig. 1 fragmentarily shown therein, is as follows. The plunger 49 is normally spring-biased to the rear of the chamber 34 by the spring 52, the end 60 abutting against the plug 42. When the winding 25 is energized with predetermined ampere-turns for example by being connected across a source of potential, magnetic flux appears in the air gap 27 between the pole faces 23 and 26, and in the air gap 55 between the pole faces 48 and 54. At the predetermined ampere-turns, the pull of the flux in the gap 27 is not enough to overcome the bias of the arm 7, but the pull of the flux in the gap 55 of the plunger 49 is enough to overcome the bias produced by the spring 52, and the plunger 49 moves forwardly in the chamber 34. As it moves it displaces oil from in front of it, and rearwardly through the bore 50, where it impinges upon the valve 61; thence transversely through the groove 65, into the cavity 56, and thence through the cylindrical outlet 57, the displaced oil moving into the space 68 rearwardly of the plunger (see Fig. 3, wherein the plunger is shown in a forwardly moved position).

The movement of the plunger is retarded by the valve arrangement described above. The pressure of the displaced oil on the valve flange 62 compresses the spring 64 and moves the conical valve portion 66 into the cylindrical outlet 57, one position of which is shown in Fig. 3, throttling the flow through the outlet 57. The more rapidly the plunger tends to move the more the flow is throttled, and the result of which is that the plunger moves forwardly at a retarded timed rate.

As the plunger moves forwardly and shortens the length of the interior air gap 55 between the pole faces 48 and 54 within the winding, the reluctance of the magnetic flux path as a whole decreases, and the total flux accordingly increases, and the pull in the gap 27 on the arm 7 increases, and finally reaches a value at which the arm 7 is moved against its bias to close the contacts of the contactor as described for Fig. 1.

A characteristic curve of pull on the arm 7 is shown at the curve B in Fig. 6, the solid line curve B showing the pull on the arm in the gap 27 for the full stroke of the plunger, with the contactor arm experimentally held in open position.

It will be noted that in Fig. 6 when the plunger has moved approximately to the point *c*, the pull on the arm 7 is at the point *g* on the curve B, and that thereafter as the plunger moves the pull begins to rise very rapidly or abruptly to the point *h*.

This curve B was made with a contactor bias-load *d* the same as for the above described prior art contactor, for comparison purposes. It will be noted that the curve B in the first part of the plunger movement lies farther below the bias-load line *d* than the curve A of the prior art device; but that nevertheless the curve B because of its abrupt upward sweep, crosses the bias-load line; this occurs at *i* when the plunger has arrived at *j*.

In practice, after the plunger arrives at *j*, the contactor arm 7, moves to closed position, closing the external work gap 27; and the plunger continues to move concurrently therewith; with the joint result that the pull on the arm rises higher than the point *h*, or to the point *k*, due to the closing of the gap 27.

Thus the plunger has a longer movement for timing purposes with the curve B than with the curve A, and the final pull *k* to hold the contacts closed is much greater than that at *e* for the curve A; both due to the abrupt upward sweep for the curve B.

It will be apparent that if that part *o*—*c* of the stroke of the plunger were sufficient for timing in any given case, then a bias-load as low as the dotted line *l* could be used and the switch closing load would be made accordingly smaller, and the contactor still more economical, without any reduction in the high contact closing and holding pull *k*.

It is believed that this sudden rise of pull in the latter part of movement of the plunger may be explained as follows.

As will be apparent from the drawing, the flux produced in the core of the winding 25 when it is energized, flows serially through the end of the plunger 49, across the plunger gap 55, through the pole piece 46 across the work gap 27 and into the pole face 23 of the contactor arm 7; and thence has a magnetic path downwardly through the

contactor arm 7; and then uwardly through the frame element 2 to the rear end of the winding 25. The pole piece 46, where it projects forwardly out of and beyond the winding has no laterally extending portions that might divert flux laterally out of the said serial path, so that all of the flux in the pole piece is directed thereby to flow directly axially across the work gap 27 and into the arm 7. Because the pole piece 46 extends well into the winding 25, practically all of the flux developed by the winding will flow longitudinally through this pole piece and appear at the pole face 26 and in the gap 27. But with a large internal air gap 55, the total flux is relatively weak and there will be, accordingly, considerable dispersal or "fanning out" of the flux in the gap 27, and this weak flux, acting on a large area, produces little pull on the arm 7.

Throughout the major part of the movement of the plunger, increments of plunger movement decrease the internal air gap very little proportionally, so that the total flux increases very little proportionally; and the distribution of the flux remains substantially the same, being distributed thinly or at low density over the pole face 26, and the cross sectional area of the working flux in the gap 27 does not change materially; and the pull in the gap 27 increases very little; and the pull remains weak.

There is however, a critical point in the plunger movement at which two things occur: first, the internal air gap 55 has then become so small that for small increments of plunger movement there is a rapid proportional reduction of the air gap and a rapid proportional increase of total flux and density to higher values; and second, as the flux increases to higher values, it attains the characteristic sometimes called "stiffness" and the flux in the gap 27 ceases to be "fanned out" but in effect concentrates in the gap 27 and this both further increases its density, and reduces its active area.

There is thus a critical point in the movement of the plunger at which the flux in the gap 27 begins to increase rapidly (which rapidly increases its density); and at which the flux pattern in the gap becomes less "fanned out" which latter not only still further increases the flux density, but also decreases its active area.

As is well known, the pull in a magnetic air gap is represented by the cross sectional area of the acting flux multiplied by the square of the flux density. So that this double increase of density in the air gap accompanied by a decrease in air gap area, effects an abrupt or accelerating increase in the pull as shown in the curve B, as the end of the plunger approaches closely to the pole piece 46.

The above described action is different from that in the said prior Rippl patent, as shown in the pull curve A. In the patent, when the plunger is in the rearward position, and there being no magnetic pole piece ahead of it, and accordingly no interior magnetic air gap, the flux from the end of the plunger bends laterally and flows into and through the magnetic ring 28*a*, and the flux acting on the arm 16 acts through an annular magnetic gap having the small area of the ring. This makes the pull strong, because of high density in small area. As the plunger 35 moves forwardly it is true that the flux density as a whole increases, but when the plunger moves forwardly it enters the ring 28*a*, and the greater part of the flux no longer bends laterally into the ring but goes straight ahead toward the arm 16, so that the flux then is distributed over a circular air gap of large area. The pull on the arm 16 thus does not increase at an accelerating rate due to the increased flux, because of the concurrently greatly enlarged area of the working gap.

The modification of Fig. 4 is similar to the form of Fig. 2 above described except for features of detail which in some cases may be preferred. In this form, a forward pole piece 69 is fitted into the forward end of a brass or other non-magnetic tube 70.

A groove 71 in the pole piece has a wire 72 of brazing material placed therein before the pole piece is inserted into the tube 70; and the fit at this end of the tube is made leak-proof, by heating the parts (preferably by induction heating) to melt the wire 72 and braze the parts together.

At the rearward end of the tube 70 it is closed by a metal head 73 seated in an annular recess in the end of the tube, and sealed by a ring of solder or brazing material 74. A stud 75 is threaded through the hole 76 in the axial center of the head 73 and upon its inner end the guiding head 67 of the valve abuts, and this constitutes a stop for the plunger 49 at its rearward or biased position. A nut 77 on the stud cooperates with the aforesaid bracket 31 to position the device by drawing a shoulder 30 on the tube 70 into engagement with the frame element 2 as described hereinbefore. This shoulder 30 may be formed on the outside of the tube 76 but I prefer to provide it by a separate tubular sleeve 78 loosely telescoped over the outside of the tube 70, and by providing a shoulder 79 on the pole piece 69 against which the other end of the sleeve abuts, the shoulder 79 overlapping the ends of both the tube 70 and the sleeve 78.

The provision of the threaded stud 75 provides a number of advantages.

In assembling the device, the plunger 49 and its valve structure and the spring 52 are first put into the tube 70. The head 73, and without the stud 75 therein, is then placed in position and sealed by the sealing ring 74. While as stated this ring may be made of soldering material, it is preferred to use a wire of brazing material and to heat it to a sufficiently high temperature to melt it. This may conveniently be done by electric induction heating. Because of the high temperature of such heating, the air within the tube 70 would otherwise produce pressure within the tube but because of the threaded opening 76 in the head 73, the pressure within the tube remains at atmospheric pressure.

Oil is now poured into the tube 70 through the threaded opening 76 sufficient to provide the aforesaid level 106. Then the stud 75 is screwed into the opening, and, having a close fit with the threaded opening 76, is practically oil-leak proof. The device may now be mounted in operative position in the contactor and the contactor operated and the timed delay of its operation observed. The rearward retracted position of the plunger 49 is stopped upon the stud 75 as described; and by turning the stud 75 by means of screw slot 80 in the outer end thereof, the retracted position of the plunger 49, and accordingly the length of the air gap 55, may be adjustably changed, and this obviously will effect a change in the length of the time interval required for the plunger 49 to move forwardly to the point at which the arm 7 is moved; and the period of delay of the operation may thereby be adjusted.

By means of this adjustment, a number of such devices, produced at the same time in production, may be caused to all have the same time interval of delay, and any differences in the delay time which might result from slight differences in dimensions, winding ampere turns, etc., may all be eliminated, and a quantity of such devices may all be adjusted to be uniform in operating interval.

After this adjustment has been made, then the threaded opening 76 may be finally and hermetically sealed by a ring 81 of solder or the like applied to seal the stud 75 to the head 73.

Thereafter the stud 75 may be used in connection with the bracket 31, and a nut 77 screwed on to the stud 75 as shown in Fig. 4 to finally mount the device, with the shoulder 30 drawn tight into engagement with the frame element 2, as described above.

It will be observed that the form of Fig. 4 eliminates a number of machining operations which are necessary in the form of Fig. 2.

In either of the forms of Fig. 2 or 4, the rate at which

the plunger 49 moves forwardly, under control of the valve structure, will depend upon the response of the valve to the pressure of displaced oil upon it and this in turn is determined by the strength of the spring 64. In Figs. 2 and 4, this spring is shown as abutting upon the flange 59 of the thimble 58. While this spring can in production be made in quantities of substantially uniform strength, in some cases it may be desired to provide an adjustment for it and this is shown in Fig. 5. A number of thin metal shims 83—83 are provided and placed between the spring end and the flange 59, and by selectively varying the number of the shims, the compression and strength of the spring can be adjustably varied. This is done before the end of the tube is permanently peened over at 60.

In Fig. 2 or 4, it will be observed that when the winding 25 is de-energized and the contactor arm 7 is moved to its biased position, ready for another operation, the magnetic flux in the gap 55 dies out and the spring 52 propels the plunger 49 rearwardly to its original position and displaces the oil from the rearward end of the plunger back to the forward end, and the valve is immediately opened by the spring 64 to full open position which allows the plunger to return immediately without delay.

In Fig. 7 is illustrated a modification similar in construction and operation to either of the forms of Fig. 2 or 4 but in which the valve arrangement is operated magnetically.

In this form (for which in view of Figs. 2 and 4 a brief description will now suffice) the valve comprises a stem 84 of magnetic material, slidable in a bore 85 along the axis of the plunger 86 with ample clearance with the bore wall as at 87. The stem 84 projects forwardly from the forward end of the plunger as shown at 88. The forward end portion of the bore 85 is enlarged as at 89 providing a bore shoulder 90 and the plunger retracting spring 89 loosely surrounds the setm 84 and reacts on this shoulder.

At the rear end of the plunger bore 85 it is flared out into a conical valve seat 91; and beyond the valve seat is an enlarged cavity 92 closed at its outer end by a head 93.

The stem extends into the cavity and has a conical valve portion 94 to function as a valve, in cooperation with the valve seat 91; and beyond the valve portion the stem has a flange 95 adjustably screw threaded thereon, and between the flange 95 and the bottom 96 of the cavity 92 is a compression spring 97 the tension of which is adjustable by moving the flange 95. The head 93 has a central perforation 98 therethrough communicating with the cavity 92 through a T-shaped passageway 99 in the stem, when the stem rests on the head 93 as it normally does, or communicating with the cavity directly when the stem end is raised from the head in operation as will be described.

In operation, flux produced in the inner air gap 55 by the winding indicated at 25 as for the other forms, acts on the end 88 of the stem and pulls the stem forwardly against the tension of the spring 97, at the same time that flux in the gap 55 pulls the plunger 86 forwardly. The oil in the chamber 100 (indicated at 106) displaced by forward movement of the plunger, flows rearwardly through the bore 85 and through the conical valve 91—94 being variably throttled thereat for the purposes described for the preceding forms.

For any predetermined energizing ampere turns and flux, and corresponding adjustment of the spring 97, the valve will be pulled forwardly to a definite position and will predetermine a rate of movement for the plunger, by throttling the oil flow to a predetermined rate.

If for any reason the ampere turns should increase (or decrease) for example due to a change of energizing voltage on the winding 25, the valve stem will be pulled magnetically farther forward against increasing tension of the spring 97 (or retracted farther rearwardly by the spring 97), and will thus compensate for the change of ampere turns and maintain the rate of oil flow and rate of plunger movement unchanged.

And if the ampere turns should increase (or decrease) at different times because of a change of temperature and the resulting change of resistance of the winding, a like compensation will be effected.

This form is therefor preferred when constant timing is wanted under circumstances which may cause the ampere turns of the winding to vary. Otherwise the mode of operation and construction is the same as described for the other forms.

In general, as to the several forms, it is preferable for the main tubular chamber wall to be of non-magnetic material in order not to divert any of the magnetic flux out of the working air gap 55. The chamber wall rearwardly of the gap 55 however can be made of magnetic material, and the reluctance of the magnetic circuit as a whole will thereby be decreased with advantages of economy; and that is the purpose of the magnetic rear wall portion 38 of Fig. 2.

Obviously therefore, the entire chamber wall of Fig. 2 could be non-magnetic; or the rear portions of the chamber walls of Figs. 4 and 7 could be magnetic.

In either case, the main part of the flux from the winding and in the plunger 49 flows from the plunger into the return path provided by the frame element 2, following in general the dotted line 107 of Figs. 2, 3, 4 or 7; and there will be some magnetic attraction between the plunger 49 and the frame element 2. When the rear part of the chamber wall is non-magnetic as in Figs. 4 and 7, this attraction is negligible, because of the large gap provided by the thickness of the non-magnetic wall. But when the rear part of the wall is magnetic (for the advantages noted above) this air gap is very thin, being that only of the sliding fit clearance between the plunger 49 and the wall, and the attraction is accordingly greater and may in some cases cause the plunger to drag frictionally on the wall and make it irregular in its movement. In such cases therefore it may be desirable to artifically increase this gap, and this may be done as shown in Fig. 3 as a modification, wherein a sleeve of non-magnetic material, 108, is fitted upon and around the plunger, moving therewith. It has been found that a very thin sleeve 108 will serve the desired purposes and that it may be provided by plating non-magnetic metal on the plunger.

In Fig. 4 is shown another modification which may be utilized in all of the described forms. A thin non-magnetic washer 109 is spot welded upon the pole face 48 of the pole piece 69 to prevent magnetic sticking of the end of the plunger 49 on the pole piece after the plunger has engaged it at the end of its stroke.

In Fig. 8 is illustrated a modification which may be used in place of the above described bracket 31 to hold the timing device rearwardly against its shoulder 30 for the purposes described. A tube 101 is loosely telescoped over the rear end of the timing device 1, and projects beyond its outer end as at 102. The inner end 111 of the tube 101 extends with ample clearance through a hole 110 in the panel and abuts upon the frame element 2. A disc or transverse bar 103 lies on the outer end 102 of the tube 101. A stud or screw 104 attached to the device as above described projects through a perforation in the disc, and a nut 105 on the stud, when screwed up tight, draws the device 1 rearwardly and engages the shoulder 30 with the frame element 2 and clamps the tube 101 between the disc 103 and the frame element 2 into a rigid assembly. Means otherwise to support or mount the tube 101 and disc 103 are unnecessary. With this arrangement the same parts may be used with different thicknesses of panel 3.

My invention is not limited in all respects to the exact construction, proportion of parts, etc., illustrated and described; and certainly not to its application to an electric contactor, nor to the particular contactor of the draw-

ing; and my invention is comprehensive of all changes and modifications which come within the scope of the appended claims.

This application is a division of application Serial No. 627,735 filed by me November 9, 1945, for Retarded Electromagnet, now Patent No. 2,605,327.

I claim.

1. In a magnetic timing device, a closed tubular chamber; liquid in the chamber; a winding surrounding at least a portion of the chamber; a magnetic plunger reciprocable in the chamber; means providing an air gap in the chamber at the forward end of the plunger causing the plunger to move forwardly responsive to winding-induced magnetic flux in the gap; a spring tending to retract the plunger; a passageway through the plunger; a valve seat at the rear of the passageway; a valve cooperable with the valve seat; a valve spring tending to hold the valve away from the valve seat; whereby forward movement of the plunger causes liquid to flow from in front of the plunger through the passageway to the rear of the plunger; a valve stem in the passageway, connected at its rearward end to the valve, and having a magnetic forward portion responsive to be pulled forwardly by said winding-induced flux to move the valve toward the valve seat in opposition to the valve spring, to throttle the liquid flow and correspondingly retard forward movement of the plunger.

2. In a magnetic timing device, a chamber comprising a non-magnetic tube, closed at its forward end by a magnetic pole piece projecting thereinto; a closure for its rearward end; liquid in the chamber; a magnetic plunger reciprocable in the chamber and normally retracted by a spring; the space between the forward end of the plunger when retracted and the pole piece providing a work gap; which by a winding surrounding the tube may induce magnetic flux in the air gap and propel the plunger forwardly; a passageway through the plunger; a conical valve seat at the rearward end of the passageway; a conical valve cooperating with the valve seat; a valve spring normally holding the valve away from the seat; whereby forward movement of the plunger causes liquid to flow from in front of the plunger through the passageway to the rear of the plunger; a valve stem of magnetic material disposed in the passageway with clearance space around it; and connected at its rear end to the valve and at its forward end projecting into the air gap, and propelled forwardly by flux in the air gap to move the valve forwardly to throttle the liquid flow and correspondingly retard forward movement of the plunger.

3. In a magnetic timing device, a closed tubular chamber; liquid in the chamber; a magnetic plunger reciprocable in the chamber; means providing a magnetic air gap at the forward end of the plunger whereby magnetic flux electromagnetically induced in the plunger will pull it forwardly; a spring tending to retract the plunger; a passageway through the plunger; a valve and valve seat disposed at a rearward portion of the passageway; spring means tending to hold the valve away from the valve seat to maintain the passageway open; whereby forward movement of the plunger causes liquid to flow from in front of the plunger through the passageway to the rear of the plunger; an element connected to the valve having a magnetic portion disposed to be pulled upon by said flux to tend to move the valve in the direction to close the passageway in opposition to the valve spring, to throttle the liquid flow and correspondingly retard forward movement of the plunger.

4. An electromagnetic structure comprising a winding and ferrous pole material, for operatively moving a biased armature load by flux produced by the winding in a work air gap between an external pole face on the pole material and a corresponding load face on the load; means effective upon energizing the winding to cause magnetic flux and pulling force to develop in the work gap and to increase during a predetermined time interval from values incapable of moving the load, to values which move the load, and to cause the increase to go on at substantially one rate during a first part of the interval and at a rapidly accelerating rate during the latter part of the interval, said means comprising a support for the winding to position it with its axis intersecting the load face, and supporting the pole material coaxially of the winding; the pole material having its said external pole face, transverse to the axis and forwardly of the forward termination of the winding; and the pole material formed to provide an inner pole face transverse to the axis and within the winding and between the ends of the winding; a normally rearwardly spring-biased forwardly movable plunger of magnetic material, and means on the support for guiding its movement axially of the winding; the plunger formed to provide a plunger face transverse to the axis and normally spaced from said inner pole face to provide a plunger flux gap; the winding when energized producing flux serially in the plunger, the plunger gap, the pole material and axially through the latter; the plunger being movable forwardly against its bias by flux in the plunger gap; means to retard forward movement of the plunger; the ferrous pole material forwardly of the winding being without lateral ferrous flux conducting portions whereby the flux therein is caused to flow through the pole material and directly across the work air gap and into the face on the load in concentrated condition without any reduction of the flux concentration by lateral ferrous conduction of flux.

5. An electromagnetic structure comprising a winding and ferrous pole material, for operatively moving a biased armature load by flux produced by the winding in a work air gap between an external pole face on the pole material and a corresponding load face on the load; means effective upon energizing the winding to cause magnetic flux and pulling force to develop in the work gap and to increase during a predetermined time interval from values incapable of moving the load, to values which move the load, and to cause the increase to go on at substantially one rate during a first part of the interval and at a rapidly accelerating rate during the latter part of the interval, said means comprising a tube sealed at both ends, and at least the forward end portion of which is of non-magnetic material; the winding telescoped over the non-magnetic portion; a support for the tube to position the winding with its axis intersecting the load face; the tube supporting the pole material coaxially of the winding; the pole material having its said external pole face transverse to the axis of the winding and forwardly of the forward termination of the winding; the pole material formed to provide an inner pole face transverse to the axis of the winding and within the winding and between the ends of the winding; a normally rearwardly spring-biased forwardly movable plunger of magnetic material slidable in the tube and formed to provide a forward plunger face transverse to the winding axis, normally axially spaced from the said inner pole face to provide a plunger flux gap; the winding when energized producing flux serially in the plunger, the plunger gap, the pole material and axially through the latter; the plunger being movable forwardly against its bias by flux in the plunger gap; a passageway extending through the plunger; a quantity of liquid in the tube some of which is in the plunger gap; the liquid in the plunger gap being displaced and flowing through the passageway by forward movement of the plunger, and means throttling the flow of liquid to retard the forward plunger movement; the ferrous pole material forwardly of the winding being without lateral ferrous flux conducting portions whereby the flux therein is caused to flow through the pole material and directly across the work air gap and into the face on the load in concentrated condition without any reduction of the flux concentration by lateral ferrous conduction of flux.

6. The apparatus described in claim 5 and in which

the means to throttle the flow of liquid is a port at the rearward end of the passageway and a spring pressed valve holding the port open and subjected to pressure of liquid in the passageway, and the valve is movable against the force of the spring by the liquid pressure to variably partly close the port.

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