(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 October 2015 (29.10.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/162185 A1

(51) International Patent Classification:
A61M 5/24 (2006.01) *H01H 36/00* (2006.01)
G04F 13/06 (2006.01) *A61M 5/31* (2006.01)

(21) International Application Number:
PCT/EP2015/058730

(22) International Filing Date:
22 April 2015 (22.04.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
14165509.2 22 April 2014 (22.04.2014) EP

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) **Title**: A MAGNETIC TIME DELAY INDICATOR AND AN INJECTION DEVICE INCORPORATING SUCH INDICATOR

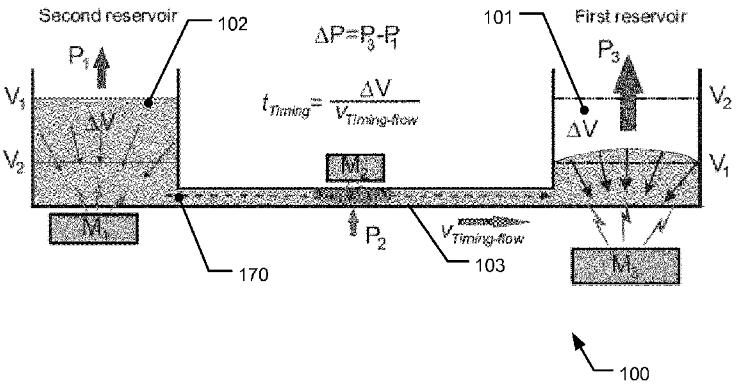

Fig. 2

(57) **Abstract**: A magnetic time delay indicator (100, 100') comprises: - a first reservoir (101, 101') and a second reservoir (102, 102'), the first reservoir (101, 101') and the second reservoir (102, 102') being interconnected by a fluid communicator (103, 103'), - a magnetic liquid (170, 170') arranged to be at least partly accommodated within the second reservoir (102, 102') and configured to flow towards the first reservoir (101, 101') through the fluid communicator (103, 103') for providing an indication of elapsed time. The magnetic time delay indicator (100, 100') defines a magnetic field generator arrangement (M_1, M_2, M_3, 150, 160) configured for applying a magnetic field on the magnetic fluid (170, 170') and comprising a first magnetic field generator (M2, 150') arranged at the fluid communicator (103, 103') to predominantly apply a magnetic field on magnetic liquid (170, 170') present in the fluid communicator (103, 103') to control the viscosity of the magnetic liquid (170, 170') present in the fluid communicator (103, 103') when flowing from the second reservoir (102, 102') to the first reservoir (101, 101').

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A MAGNETIC TIME DELAY INDICATOR AND AN INJECTION DEVICE INCORPORATING SUCH INDICATOR

FIELD OF THE INVENTION

The present invention relates to magnetic time delay indicators and to medical injection devices for administering a drug into the body of a subject user wherein the medical injection devices incorporate such magnetic time delay indicators.

BACKGROUND OF THE INVENTION

Some medication, such as insulin, is typically self-administered using a medical delivery device such as an injection pen. The typical diabetes patient will require injections of insulin several times during the course of a week or a day. However, typical injection devices, such as the one disclosed in WO 2006/076921, do not address the problem of a user not remembering when the last injection was administered.

Even shortly after administering a dose of insulin, the user now and then will be in doubt as to whether or not an injection has actually been carried out. This could be minutes or even hours after the intended time for performing an administration. Thus, there is a potential risk that the patient chooses not to take his medication or that he takes it twice.

Some prior art devices, such as the electronic syringe disclosed in WO 97/30742, are provided with an electronic monitoring system adapted to automatically start an electronic timer when a selected dose is injected and to show the progress in time on an electronic display. Such injection devices generally provide an acceptable solution to the problem addressed above. However, for simpler devices such as disposable injection devices, i.e. the so-called pre-filled devices, the solution with integrated electronics will in most cases not be economically viable. In addition, such a solution may not be environmentally acceptable due to the potential increase in the disposal of electronic components such as batteries etc.

WO 2010/127995 and WO 2010/023303 include disclosure of medical injection devices that incorporate lapsed time indicators of a type that makes them suitable to be used as pre-filled devices. The particular embodiment shown in fig. 2 of WO 2010/023303 relates to a type of lapsed time indicator that makes use of a mechanical time delay device. A spring is tensed as part of the initial injection procedure. The spring is utilized to operate the mechanical time delay device during lapse of the pre-defined time interval. In such a design it is a challenge to ensure optimal operation both during injection and during lapse of the pre-defined time interval to provide time indication signals that fully reflects the history of use of the device.

WO 2011/123515 discloses a reversible timer system that includes a liquid disposed within a cavity defined by first and second substrates where the fluid spreads from an equilibrium state to an active state upon application of a force to the system and wherein the liquid contracts upon relief of said force. Further related timer devices are disclosed in WO 2011/050128. Still further, WO 2013/072412 discloses magnetic time delay indicators wherein a magnetic liquid is physically moved by a magnet.

Some applications require a reversal time for the time delay indicator to lie in the order of several minutes or even in the order of hours. For liquid based time delay indicators wherein activation of the time delay indicator activates a liquid that slowly reverses back into an initial configuration, it is a challenge to ensure that the time delay indicator exhibits a reversal time having a sufficient length. Furthermore, for these types of time delay indicators, it is a challenge to ensure that a desired reversal time is accurately and consistently obtained even when subjected to a variety of different ambient conditions.

BRIEF DESCRIPTION OF THE INVENTION

Having regard to the above-identified prior art, it is an object of the present invention to provide a timer device solution, suitable for use in medical injection devices, that is improved having regard to timing precision and that works consistently at various ambient conditions.

In a first aspect the present invention relates to a magnetic time delay indicator comprising:

- a first reservoir and a second reservoir, the first reservoir and the second reservoir being interconnected by a fluid communicator,
- a magnetic liquid arranged to be at least partly accommodated within the second reservoir and configured to flow towards the first reservoir through the fluid communicator,
- pressure generating means configured for generating a driving pressure on the magnetic liquid for urging the magnetic liquid to flow from the second reservoir towards the first reservoir, and

- an activator being activatable to enable flow of magnetic liquid from the second reservoir to the first reservoir, wherein the duration for an amount of magnetic liquid to flow from the second reservoir to the first reservoir provides an indication of elapsed time since activation of the activator,

wherein:

- the magnetic time delay indicator defines a magnetic field generator arrangement configured for applying a magnetic field on the magnetic fluid, the magnetic field generator arrangement comprising a first magnetic field generator arranged at the fluid communicator to predominantly apply a magnetic field on magnetic liquid present in the fluid communicator to control the viscosity of the magnetic liquid present in the fluid communicator.

In accordance with such time delay indicator, the presence of the first magnetic field generator to apply a magnetic field on the magnetic liquid at or in the fluid communicator enables increased control of the flow through the communicator. Once the time delay indicator has been activated for allowing the timer function to operate, the time delay indicator is allowed to operate for a prolonged time and with an improved accuracy having regard to the duration of the timing operation. Hence the length of the timing interval is predictable even for large variations in ambient temperature and/or ambient pressure. Hence, the overall reliability of operation of the time delay indicator is improved.

The magnetic liquid may be selected as a ferrofluid and/or a magnetorheological fluid. In other embodiments, the magnetic liquid may comprise a ferrofluid and/or a magnetorheological fluid.

The magnetic field generator arrangement of the magnetic time delay indicator may provide a magnetic force on the magnetic liquid to cause at least a portion of the magnetic liquid present in the second reservoir to flow through the fluid communicator towards the first reservoir.

The magnetic field generator arrangement may comprise at least one magnet, such as a permanent magnet. The magnetic field generator arrangement may in some embodiments incorporate a single magnet. In other embodiments, the magnetic field generator arrangement defines two, three or more magnets.

In some embodiments, the magnetic field generator arrangement defines a self-compensating temperature compensated field strength regulator configured to regulate the flow from the second reservoir towards the first reservoir.

In one embodiment the self-compensating temperature compensated field strength regulator comprises a mounting device for the magnetic field generator arrangement so that at least a part of the magnetic field generator arrangement is movable relative to the first reservoir and/or the second reservoir to regulate magnetic field strength applied on the magnetic liquid. Said movability of the magnetic field generator arrangement may be caused by thermal expansion and/or contraction of said mounting device or by thermal expansion and/or contraction of the magnetic field generator arrangement itself.

In other embodiments the self-compensating temperature compensated field strength regulator comprises an electrically controlled magnetic field strength regulator that is controlled by signals that correlates with detected values provided by a temperature sensing element.

The magnetic field generator arrangement may comprise a second magnetic field generator arranged at the second reservoir configured to predominantly apply a magnetic field on magnetic liquid present in the second reservoir.

In some embodiments, the second magnetic field generator is mounted movable relative to the second reservoir by means of a mounting device, where the temperature coefficient of expansion of said mounting device is selected so that it compensates for temperature induced variations in the flow of the magnetic liquid through the fluid communicator during the timing operation.

The first magnetic field generator arranged at the fluid communicator may provide a braking force on the magnetic liquid flowing through the fluid communicator to restrict the flow through the fluid communicator.

In some embodiments the first magnetic field generator is movably positioned relative to the fluid communicator to regulate magnetic field strength in the fluid communicator to regulate the viscosity of the magnetic liquid present in the fluid communicator. Said movability of the first magnetic field generator may be caused by thermal expansion and/or contraction of a mounting device of the first magnetic field generator or by thermal expansion and/or contraction of the first magnetic field generator itself.

As an alternative to the first and second magnetic field generators, or in combination with the first and second magnetic field generators, the magnetic field generator arrangement may comprise a third magnetic field generator positionable at the first reservoir to apply a magnetic field on the magnetic liquid for urging the magnetic liquid to flow towards the first reservoir. When the third magnetic field generator is positioned at the first reservoir it may be configured to predominantly apply a magnetic field on magnetic liquid present in the first reservoir.

The third magnetic field generator may be arranged movable from a first position at the second reservoir to a second position at the first reservoir, and wherein the third magnetic field generator when positioned in the second position generates a magnetic pressure for causing the magnetic liquid present in the second reservoir to flow towards the first reservoir.

The magnetic time delay indicator may be configured for being reset by allowing fluid present in the first reservoir to flow towards the second reservoir.

In some embodiments, when the third magnetic field generator is positioned in the first position magnetic liquid present in the first reservoir is caused to flow towards the second reservoir for resetting the time delay indicator.

In some embodiments, the third magnetic field generator is mounted movable relative to the first reservoir by means of a mounting device, where the temperature coefficient of expansion of said mounting device is selected so that it compensates for temperature induced variations in the flow of the magnetic liquid through the fluid communicator during the timing operation.

The magnetic time delay indicator may include a visual indicator enabling a user of the device to visually observe the status of the magnetic time delay indicator.

In some embodiments, the magnetic time delay indicator includes at least a portion of one or more of the first reservoir, the second reservoir and the fluid communicator that is made from a material that is optically transparent allowing a user of the device to visually inspect the magnetic liquid and hence visually observe the status of the magnetic time delay indicator.

Alternatively, the magnetic properties of the liquid present in any of the first reservoir, the second reservoir and the fluid communicator may be configured to magnetically couple and operate a visual indicator that is operated by the magnetic field strength induced by the magnetic liquid. Still alternatively, other means for providing an indication of the status of the magnetic time delay indicator may be incorporated.

In some embodiments the magnetic time delay indicator includes a bypass section coupling the first reservoir with the second reservoir for allowing fluid present in the first reservoir to quickly escape to the second reservoir enabling resetting of the magnetic time delay device to be quickly performed. Such bypass section may include a valve, such as a one-way valve, for allowing flow through the bypass section during resetting but preventing flow through the bypass section when the timer runs.

The activator may be configured so that prior to activation, the activator prevents flow of magnetic liquid from the second reservoir to the first reservoir.

In some embodiments the magnetic time delay indicator may be so configured that, after activation of the activator, i.e. when the timer runs, the duration of time for a predefined amount of magnetic liquid to flow through the fluid communicator indicates the lapse of a pre-defined time interval since activation of the activator.

In particular embodiments, the pre-defined time interval is longer than15 minutes, such as longer than 30 minutes, such as longer than 1 hour, such as longer than 2 hours, such as longer than 3 hours, such as longer than 5 hours, such as longer than 12 hours, such as longer than 24 hours, such as longer than 36 hours.

In certain embodiments the time delay indicator comprises a magnetic liquid that is reversibly flowable between a first configuration and a second configuration wherein the first configuration defines a first visual indication and the second configuration defines a second visual indication of the time delay indicator. The first and second visual indications provide an indication of the status of the time delay indicator.

The time delay indicator may be configured so as to re-initialize the timing function if a renewed activation of the activator occurs during lapse of a previously initiated pre-defined time interval.

The activator may in some embodiments be configured for operating the resetting of the magnetic time delay indicator. For example, the activator may define an activation button which is manually activatable by a user. In some embodiments, the activation button may operate the resetting as well as the activation that enables flow of magnetic liquid from the second reservoir to the first reservoir.

In one embodiment, the activation button may be so configured that upon the activation button being moved from a first position to a second position, the activation button initially causes a resetting of the timer and subsequently activates the time delay indicator for allowing it to run throughout the pre-defined time-interval. In other embodiments, the activation button may be so configured that upon the activation button being moved from a first position towards a second position, the time delay indicator is reset. When the activation button is moved further towards a third position, or alternatively reversed into the first position, the movement of the activation button causes activation of the time delay indicator allowing it to run throughout the pre-defined time interval.

In some embodiments the fluid communicator defines a channel that connects the first reservoir and the second reservoir. In some embodiments, the channel may be designed to extend between the first and second reservoir along a linear path or along a curved path. In some embodiments the fluid communicator defines a single channel or alternatively multiple channels.

In other embodiments, the fluid communicator defines an orifice between the first reservoir and the second reservoir. In such systems, the orifice may be arranged at the interface between the first reservoir and the second reservoir, such as at a separating wall that separates the first and the second reservoir.

In a second aspect the present invention relates to a magnetic time delay indicator comprising:

- a first reservoir and a second reservoir, the first reservoir and the second reservoir being interconnected by a fluid communicator,
- a magnetic liquid at least partly accommodated within the second reservoir and configured to flow towards the first reservoir through the fluid communicator, and
- a magnetic field generator arrangement providing a magnetic force on the magnetic liquid to cause at least a portion of the magnetic liquid present in the second reservoir to flow through the fluid communicator towards the first reservoir, the flow of the magnetic liquid through the fluid communicator towards the first reservoir providing an indication of elapsed time,

wherein the magnetic field generator comprises a self-compensating temperature compensated field strength regulator configured to regulate the flow from the second reservoir towards the first reservoir.

The self-compensating temperature compensated field strength regulator may be so configured that at least a part of the magnetic field generator arrangement is configured to be moved relative to the first reservoir and/or second reservoir in response to variations in temperature to regulate magnetic field strength applied on the magnetic liquid.

The magnetic field generator arrangement may comprise a first magnetic field generator disposed at the fluid communicator to predominantly apply a magnetic field on magnetic liquid present in the fluid communicator. The first magnetic field generator may be configured to be moved relative to the fluid communicator in response to variations in temperature to regulate magnetic field strength applied on the magnetic liquid present in the fluid communicator.

In further embodiments, the time delay indicator according to the second aspect may include any of the features described in accordance with the first aspect.

In a further aspect the present invention relates to a medical delivery device, such as a medical injection device, having a time delay indicator either attached to or integrated within the device. The time delay indicator of the medical delivery device may include any of the features described in accordance with the first and/or the second aspect.

The time delay indicator of such device incorporates an activator configured for being activated to enable flow of magnetic liquid from the second reservoir to the first reservoir.

The activator may in some embodiments further define an expelling activator to control expelling a dose of drug from the medical delivery device. The activator may be adapted for manual activation by a subject user to cause expelling of a dose of drug. In one embodiment of such an injection device, when the user of the device operates the dose expelling activator for expelling a dose of a medicament, the time delay indicator is automatically activated for causing the time delay indicator to operate for a predefined duration of time.

In another embodiment of such an injection device, when the user of the injection device operates the injection device for insertion of a needle of the device into a target site, the time delay indicator is automatically activated for causing the time delay indicator to operate for a predefined duration of time. Such device may include a needle shielding portion and a held injection needle and wherein these components move relative to each other as the injection needle is inserted into the target site. The time delay indicator may be configured to be automatically activated when the needle shielding portion and the needle move relative to each other.

The medical delivery device may for example be in the form of an injection pen, either of the durable type where a medicine filled reservoir or cartridge is removably attached or of the pre-filled type where a medicine filled reservoir or cartridge is irremovably arranged in the pen. Alternatively, instead of a pen, the medical delivery device may be in the form of a doser. The medical delivery device may be of the manual type, where a user, during injection, supplies the force necessary for expelling medicine from the reservoir. Such device may include an injection button that is so configured that the injection button is forced to continuously move from a pre-injection position into a post-injection condition as a dose expelling operation progresses. Alternatively, the medical delivery device may be of the kind commonly known as a wind-up pen or AutoPen®, where energy accumulated in a spring device is released by pressing on an injection button to automatically expel a dose of the medicine. Such device may be configured e.g. as an injection device where the user, during an initial procedure such as dose setting, supplies the mechanical energy required for the expelling operation, the mechanical energy being stored as potential energy for example in a spring member. Also, the injection device may be of a kind where the mechanical energy required for expelling the total usable content of a container is stored in the device during manufacture thereof. In such devices an injection button may be configured so as to move from a rest position to an activated or pushed in position, where the activated position is maintained as a dose expelling operation progresses.

In the context of the present invention, the term “medical injection device” shall be understood as any device capable of actively bringing a medicament-containing drug into the body of a user by means of an appropriate delivery mechanism such as by using a cannula or by a needle-less jet-stream. A non-exhaustive list of medical injection devices within the context of the present invention comprises pre-filled or durable injectors such as pen-shaped injectors or dosers. The drug may be flowable or solid such as drugs forming medicine pegs for insertion through the derma. Representative medicaments includes pharmaceuticals such as peptides, proteins (e.g. insulin, insulin analogues and C-peptide), and hormones, biologically derived or active agents, hormonal and gene based agents, nutritional formulas and other substances in both solid (dispensed) or liquid form.

DETAILED DESCRIPTION OF THE INVENTION

Aspects of the invention will now be described in further detail with reference to the drawings in which:

Fig. 1 shows a schematic representation of a first embodiment of a time delay indicator during resetting of the timer,

Fig. 2 shows the time delay indicator of fig. 1 during operation of the timer,

Fig. 3 shows the basic principle of a flow reducing magnetic brake during operation of the timer,

Fig. 4 shows the same system but where not brake magnet is applied,

Fig. 5 is a graph showing pressure loss and magnetic drive pressure along the connecting channel for the system of fig. 4,

Fig. 6 shows an example of a timer system with a brake magnet applied,

Fig. 7 is a graph showing pressure loss and magnetic drive pressure along the connecting channel for the system of fig. 6,

Fig. 8 is a graph illustrating the excess pressure being build up between positions 1 and 2 and insufficient pressure being available to overcome flow resistance between 2 and 3,

Fig. 9 is a schematic illustration of frictional shear forces between particles and carrier fluid in section 1 and section 2,

Fig. 10 is a schematic representation of a second embodiment of a timer system having temperature compensation,

Fig. 11 is a schematic representation of a third embodiment of a timer system having temperature compensation,

Fig. 12 shows a schematic representation of a prior art medical injection device,

Fig. 13 shows a schematic representation of an injection pen including a time delay indicator in accordance with one aspect of the present invention,

Figs. 14a and 14b show detailed views of selected components of the time delay indicator of the embodiment shown in fig. 13, and

Fig. 15 shows the activating sequence of the embodiment of the injection device shown in fig. 13.

In the following different working principles of timer systems in form of liquid based time delay indicators will be described. The working principle of the time delay indicators is based on the behaviour and properties of magnetic liquids such as ferrofluids, which are fluids with small paramagnetic particles in it. The shown embodiments utilises several features of the unique properties of ferrofluids. The purpose of the cited illustrations is to illustrate the principles and not a preferred embodiment.

The working principle is based on a flow of a fluid between two reservoirs through a narrow channel connecting the two reservoirs. When a certain amount of fluid in one reservoir moves from this reservoir to the other due to a pressure difference the flow velocity is determined by the pressure difference between the reservoirs and the pressure drop of the flow between the reservoirs.

The pressure drop depends upon the cross sectional area of the connecting channel and the viscosity of the fluid. Both the viscosity of the fluid and the cross section area of a pipe or channel are depending on the temperature. In normal, simple situations, the viscosity drops and the cross sectional area of a pipe increases with rising temperature, both of which causes the flow velocity to increase and thus the time to move a certain volume from one reservoir to another through a channel will decrease with rising temperature.

According to an aspect of the invention, since the timer is required to be practically independent of temperature, one solution is to use a ferrofluid as the fluid in the channel between the two reservoirs, since the viscosity of a ferrofluid can be adjusted and varied by application of a magnetic field. Furthermore, the properties of ferrofluids enable the use of magnets to provide driving pressure for the system as well as generating a variable viscosity.

The pressure necessary to drive the flow between the two reservoirs are created by use of magnetic pressure in ferrofluids. Magnetic pressure occurs when a ferrofluid is subjected to a magnetic field. The magnetic forces pull the particles within the fluid towards the magnet and along with the particles, the fluid. The pressure created is thus a negative pressure in the sense that it “pulls” rather than “push” as a conventionally pressurized fluid would. Thus a magnetic driving pressure difference between two interconnected reservoirs will create a flow towards the higher pressure instead of towards the lower pressure, as a normal fluid would.

As depicted in fig. 1, a first embodiment of a time delay indicator 100 is schematically shown. The time delay indicator 100 includes a first reservoir 101 and a second reservoir 102 that are interconnected by a channel 103 through which a quantity of a ferrofluid 170 is adapted to flow. The time delay indicator further includes magnetic field generators in the form of a plurality of magnets. In the inactivated state a first magnet M_1 is positioned near the second reservoir. A second magnet M_2 is positioned near the channel whereas a third magnet M_3 is positioned near the first reservoir. As will be described later, either the first and/or the second reservoir may be used as a display providing visual feedback to the user of the status of the time delay indicator, in particular when the timer runs and when the time-out has occurred.

Referring to fig. 1, which shows the time delay indicator 100 during reset/activation of the system, the magnet M_3 is moved from the position under the first reservoir to a position under the second reservoir, thereby significantly increasing the magnetic pressure in the second reservoir to allow quick reset of timer, through the connecting channel and into the second reservoir.

During reset both of the two stronger magnets M_1 and M_3 contribute to creating the driving pressure for resetting the system and the fluid flow is only countered by the flow resistance and the much weaker magnet M_2.

When the required amount of fluid has entered the second reservoir, corresponding to a complete reset of the system, the magnet M_3 may be moved back to its position under the first reservoir. This condition, as shown in fig. 2, activates the time delay indicator enabling the time delay indicator to run. Magnet M_3 is slightly stronger than magnet M_1, which is significantly stronger than the magnet M_2.

The flow of the system is now driven by a pressure difference between the second reservoir and the first reservoir of magnitude $\Delta P_{13}=P_3-P_1$. The magnet M_2 does not contribute to the hydraulic pressure as such. It does however introduce a “mismatch” between hydraulic pressure and magnetic pressure along the interconnecting channel. This will be explained more thoroughly below.

This mismatch between hydraulic pressure and magnetic pressure cause an apparent increase of viscosity in the area below magnet M_2 acting as a constriction slowing down the flow and thus allowing both a long time-out time and a short reset-time.

The viscosity and cross sectional area of the channel between both the reservoirs are both of significant influence on the flow resistance and thus the time-out time. Both of these are influenced by the system temperature in such a way that both parameters contribute to reduced flow resistance at increased temperatures and thus reduced time-out time. In accordance with an aspect of the present invention, this influence needs to be cancelled out. The properties of ferrofluids allow several different approaches for that. These will be addressed further below.

In the following the magnetic brake effect caused by a mismatch between hydraulic and magnetic pressures will be described further. Fig. 3 schematically illustrates the basic principle of a flow reducing magnetic brake that acts during timer operation of the time delay indicator.

The flow of the system is driven by a magnetic pressure difference equalling the hydraulic pressure drop between second reservoir and first reservoir of $\Delta P_{13}=P_3-P_1$.

Assuming the magnet M_2 is positioned $1/x$ of the length of the connecting channel from second reservoir and applying a magnetic pressure of:

$$P_2 = \frac{1}{y} \cdot (P_3 - P_1) = \frac{P_3 - P_1}{y}$$

The total pressure drop between the first and the second reservoir is $\Delta P_{13}=P_3-P_1$ and the hydraulic pressure drop is linearly depending on flow length. Thus,

$$\Delta P_{12} = \frac{1}{x} \cdot (P_3 - P_1) + P_2 = \frac{(P_3 - P_1)}{x} + \frac{(P_3 - P_1)}{y} = \left(\frac{1}{x} + \frac{1}{y}\right)(P_3 - P_1) = \left(\frac{x+y}{x \cdot y}\right)(P_3 - P_1)$$

and

$$\Delta P_{23} = \left(1 - \frac{1}{x}\right) \cdot (P_3 - P_1) - P_2 = \left(1 - \frac{1}{x}\right) \cdot (P_3 - P_1) - \frac{1}{y}(P_3 - P_1) = \frac{x \cdot y - (x+y)}{x \cdot y} \cdot (P_3 - P_1)$$
$$= \left(1 - \left(\frac{x+y}{x \cdot y}\right)\right) \cdot (P_3 - P_1)$$

We then define *f* as:

$$\frac{x+y}{x \cdot y} = f$$

And we get:

$$\Delta P_{12} = f \cdot (P_3 - P_1) = f \cdot \Delta P_{13}$$

$$\Delta P_{23} = (1 - f) \cdot (P_3 - P_1) = (1 - f) \cdot \Delta P_{13}$$

This means that the magnetic pressure drop is asymmetrically distributed on each side of M_2, depending on the position of M_2 and size of the magnetic pressure generated by M_2.

To illustrate the consequences of this, we consider the following example. Fig. 4 illustrates a time delay system with no brake magnet applied. Note that the magnetic pressure should be regarded as negative pressures and flow does consequently go from low to higher magnetic pressure.

A magnet M_3 is placed under the first reservoir, creating a magnetic pressure P_3 of 100% (Reference value). A second magnet M_1 is placed under second reservoir, creating a magnetic pressure of 30% of P_3. Since no brake magnet is applied, the pressure drop must be linearly distributed along the connecting channel having the length *l*.

The hydraulic pressure loss along *l* is then equal to the magnetic drive pressure ΔP_{13}.

Fig. 5 is an illustration of pressure loss and magnetic drive pressure along the connecting channel. The drive pressure and pressure loss are coinciding, which means that the drive pressure just balances out the flow resistance and thus the flow rate is constant.

Fig. 6 schematically illustrates a time delay system where a brake magnet M_2 is applied. If the magnet M_2 is introduced at a position of 25% of *l* from second reservoir, creating a magnetic pressure of 40% (of P_3-P_1) we get x=4 and y=2.5.

From the formula above, we get:

$$f = \frac{4 + 2{,}5}{4 \cdot 2{,}5} = \frac{6{,}5}{10} = 0{,}65$$

The resulting magnetic pressure along *l* is shown in fig. 7, illustrating the pressure loss and magnetic drive pressure along the connecting channel. The drive pressure between the second reservoir (*l*=0) and the position of magnet M_2 is increasing more rapidly than the pressure loss in the channel. Between the position of magnet M_2 and the first reservoir the pressure difference diminishes and ends at 0 in the first reservoir.

What can be seen from fig. 7 is that 65% of the total drive pressure is available between second reservoir and the position of magnet M_2, where only 25% of the pressure loss occurs. This is only possible because only 35% of the drive pressure is available between the position of M_2 and first reservoir (*l*=1), but 75% of the pressure loss occurs.

Thus there is actually an insufficient drive pressure to overcome flow resistance between position 2 and 3 (i.e. between the position of M_2 and the first reservoir) which would cause the flow to stop, if not for the excess of hydraulic pressure gained between position 1 and 2 (i.e. between the second reservoir and the position of magnet M_2). This is illustrated in fig. 8 which shows that excess pressure is being build up between position 1 and 2 whereas insufficient pressure is available to overcome flow resistance between position 2 and 3 (disregarding the excess pressure build-up between position 1 and 2).

In a purely hydraulic system this would not reduce flow speed, since it would normally be such that a high pressure is available at the input end and the pressure difference would gradually be reduced by the flow resistance through the pipe or channel.

In this case, however, the fluid is a ferrofluid and we in a sense have two fluids and two driving pressures and two hydraulic losses. We have a traditional hydraulic pressure, a traditional hydraulic flow resistance loss from a traditional viscous flow. We also have a magnetic pressure and a magnetic resistance of the particle flow and a viscous friction force between fluid and particles. It is the interaction between “magnetic particle flow” and hydraulic/viscous flow that creates the braking effect of the flow.

It is the magnetic force that creates the hydraulic pressure between second reservoir (position 1) and the position of magnet M_2, but the system in the example could just as well be driven by application of hydraulic pressure (of P_3 in the first reservoir and P_1 in the second reservoir).

The left-hand side of Fig. 9 is an illustration of frictional shear forces between particles and carrier fluid in section 1 (between the second reservoir and the position of M_2). The right-hand side of fig. 9 is an illustration of frictional shear forces between particles and carrier fluid in section 2 (between the position of M_2 and the first reservoir).

With the flow of first section (position 1 to 2) the carrier fluid and the particles move in the same direction (see fig. 9, left-hand side). The particles will be driven by magnetic forces aiding the flow and overcoming flow friction forces by “dragging” the carrier fluid with them (maybe aided by an applied hydraulic pressure). The carrier fluid is being “dragged” and to some extent slows down the flow of magnetic particles due to frictional shear forces between the particles and the carrier fluid.

Obviously the direction of the frictional shear forces are opposite in the two sections, but in section 1 the hydraulic pressure (or driving magnetic pressure) is driving the viscous flow to some extent and the magnetic particles are (partially) being driven by the magnetic field and shear forces between particles and carrier fluid are relatively low.

This may be best understood if thought of as three individual flows.

“First flow” is part of the particles being driven by the magnetic driving force created by the magnetic pressure difference ΔP_{13}. “Second flow” is the carrier fluid flow driven by either an external hydraulic pressure or entirely from the part of magnetic particles of “first flow”.

If driven entirely by magnetic pressure, frictional shear forces between these particles are higher than if an external hydraulic pressure induced some or all of the driving pressure, but regardless of the flow is driven entirely by magnetic force, entirely by external hydraulic pressure or a combination of both, circumstances of these two flows will be identical in both sections (on both sides of M_2).

The “third flow” is the remaining part of the particles that are driven by M_2. Since the force from M_2 on these particles in section 1 is in the same direction as the flow of the other part of the particles and the carrier fluid, these particles are being pulled by the other two flows to some extent. Therefore frictional shear forces between “third flow” and the two other flows are limited to the shear forces arising from differences in size of force being applied on them by hydraulic and magnetic forces.

In section 2, the two first flows are given the same conditions as in section 1. Both the hydraulic flow and the part of the particles are subjected to the magnetic pressure difference ΔP_{13} as in section 1. The third flow, however, being the part of particles subjected to the magnetic force from magnet M_2 is now being applied a magnetic force opposite the flow direction and frictional shear forces now not only have to transmit differences in size of force, but also in direction of force.

If for instance within a given volume of the flow in section 1 the combined flows 1 and 2 is 80% of the total flow and being driven by a force of 8N and the remaining 20% of the total flow is the “third flow” being driven by M2 is only being driven with a force of 4N, the total force driving the flow is $F_{tot,1}$=0,8 x 8N+0,2 x 4N=7,2N. Thus the “third flow” is exerting a frictional force of 0,8N on the “driving flow”.

In section 2 we get a frictional force on the “driving flow” of 8N-$F_{Tot,2}$=2,4N, where $F_{Tot,2}$=0,8 x 8N-0,2 x 4N=5,6N.

Thus, in this example the frictional shear force exerted by the “third flow” in section 2 is three times higher than the frictional shear forces exerted in section 1.

The increase in frictional shear forces is by definition an increase of the viscosity of the fluid. An increase in viscosity at a given pressure difference results in an increase of flow resistance and hence in a reduction of flow velocity.

When not exposed to a magnetic field, ferrofluids behave like other fluids and flows can be calculated from well-known formulas.

When exposing a ferrofluid to a magnetic field, the ferrofluid behaves very different than other fluids on especially two points. First of all, a magnetic pressure is introduced in the fluid and second, the viscosity of the fluid increase. The magnitude of viscosity change depends very much on the size of the paramagnetic particles in the fluid as well as of course the strength of the applied magnetic field and the direction of the applied field relative to the flow direction.

The magnetic pressure introduced in a ferrofluid when applying a magnetic field to it, is given by:

$$P_{Mag} = \mu_0 \cdot \boldsymbol{M}_s \cdot \boldsymbol{H}$$

where μ_0 is the vacuum permeability, $\boldsymbol{M_s}$ is the saturation magnetisation and $\boldsymbol{H}$ is the magnetic field strength.

Calculation of viscosity changes caused by the introduction of magnetic fields in ferrofluids with a high concentration of particles cannot be made based on theory, but must be based on empiric data.

Having regard to temperature variations of the timing parameters these factors will be described further. Even though the magnetic forces acting on ferrofluids are not temperature dependant (if sufficiently far from the paramagnetic materials Curie-point), the viscosity of a ferrofluid being controlled by magnetism may in some cases vary with temperature, due to the temperature dependant viscosity of the carrier fluid.

When using a magnetorheological fluid, viscosity can be increased until almost being a solid by applying a magnetic field. In this case, where the viscosity is multiplied by a factor 100 or so by application of a magnetic field, the viscosity of the carrier fluid and its temperature dependence is negligible and will have no practical influence.

Such fluids are based on particles in micrometer scale and due to their significantly larger particle size (compared to those of ferrofluid in nanometer scale), they are too dense for Brownian motion to keep them suspended and they are thus subject to sediment of particles and thickening over time. This can to some extend be reduced by use of proper surfactants and higher density of carrier liquid.

However, other ferrofluids have a much more limited potential of increasing viscosity by application of a magnetic field and will to some extend be influenced by variations in viscosity of the carrier fluid caused by temperature variations. The application of such fluids may require the use of means to compensate for temperature induced variations of viscosity.

At least two different principles for compensating flow velocity for temperature induced variations in viscosity can be employed, namely:
a) flow resistance compensation to counter the effects of variations in viscosity of carrier fluid by varying flow resistance of flow channel, or
b) magnetic field strength compensation to counter variations in carrier fluid viscosity by introducing an opposite variation in viscosity of the ferrofluid through temperature variations in magnetic field strength applied.

The first principle makes use of a flow restrictor wherein the hydraulic diameter is reduced to counter the effects of decrease in viscosity of the ferrofluid due to an increase of temperature decreasing the viscosity of the carrier fluid of the ferrofluid.

The second principle makes use of the characteristics of a magnets field strength decreasing with the square of the distance from the magnet. This principle relies on the magnet being mounted by a mounting device comprising a structure made of a material with a relatively high thermal expansion coefficient that causes the distance from the magnet to the ferrofluid to vary with temperature and thus the applied field strength to vary with the temperature. The variations in magnetic field strength are obtained by utilising the dependency between magnetic field strength and distance from magnet, where the field strength decreases by the square of the distance.

Fig. 10 shows a second embodiment of a time delay indicator where the driving magnetic pressure (P_3) can be reduced by increasing magnet distance from the ferrofluid with increasing temperature to compensate for reduced viscosity and/or the retaining magnetic pressure (P_1) can be increased by reducing magnet distance from the ferrofluid. Both of these options reduce the magnetic drive pressure difference to compensate for reductions in viscosity caused by an increase in temperature. In the embodiment shown in fig. 10, each of the magnets M_1 and M_3 are mounted on respective mounting devices 190. In other embodiments only one of the magnets M_1 and M_3 may be mounted on a mounting device configured for varying the applied field strength.

Shown in fig. 11 is a third embodiment of a time delay indicator. Alternatively, or in combination with aforementioned options, the distance between the brake magnet M_2 and the connecting channel can be decreased with increasing temperature to magnetically induce an increase in viscosity to compensate for a temperature induced decrease in viscosity of the carrier fluid. In the shown embodiment, to vary the relative distance between the brake magnet M_2 and the connecting channel 103, the brake magnet M_2 is disposed on a mounting device 190 which is configured to move the brake magnet M_2 by utilizing thermal expansion and thermal contraction of parts of the mounting device 190. For example, the mounting device 190 may be adapted to decrease the distance of brake magnet M_2 relative to the connecting channel 103 upon increasing temperature. This causes the magnetic field strength applied by brake magnet M_2 on the magnetic liquid 170 present in the connecting channel to increase which counteracts a decrease in viscosity which is due to the rising temperature.

The above described time delay indicators may for example be incorporated in devices wherein the occurrence of a particular activity needs to be indicated for a predetermined duration. One non-limiting example could be a medical delivery device, such as an injection pen for administration of a single or a multitude of doses of a medicament where the activity that require monitoring may be the occurrence of an expelling action and where the time delay indicator indicates for a predefined time interval the occurrence of a performed expelling action.

Fig. 12 depicts a schematic representation of a prior art medical injection system forming an injection pen 1 comprising a medicament filled cartridge 2 which is accommodated in a distal part of the injection pen. The injection pen 1 includes a housing that defines a central longitudinal axis. The proximal part 4 of the device holds a mechanism 7 for setting and injecting specific doses of a medicament from the cartridge 2. The cartridge 2 comprises a passage in a distal neck part which is sealed by a pierceable sealing member 5. Cartridge 2 further comprises a slideably mounted piston 6 which is adapted to slide towards the distal part of the container 2 when a distally directed force is exerted on the piston 6. Typically, medication is delivered through an injection needle 3 which may be releasably secured to the distal part of the injection pen. The injection pen further comprises a dose dial 9 which may be manipulated by the hand of a user for selecting a dosage, the size of the selected dosage being visible in window 10. The injection pen 1 further comprises an expelling activator in the form of an injection button 8 for injecting a selected dosage. In the depicted form, a distally directed force on the button 8, exerted by the hand of the user, activates the mechanism 7 of the pen for causing a dosing movement of the piston 6 of cartridge 2. Fig. 1 further shows a cap 11 which is adapted to be removably attached to the distal part of the injection pen. In the storage state, when the cap 11 is attached to the injection pen 1, the cap protects the cartridge 2 and the needle 3.

Fig.13 is a schematic representation of an injection pen 1’, structurally similar to the injection pen shown in fig. 12, but having a time delay indicator 100’ arranged at the proximal end of the device 1’. The time delay indicator 100’ is a liquid based time delay indicator incorporating a magnetic liquid that is controlled by one or more magnetic field generators in accordance with the principles discussed above. The one or more magnetic field generators may be provided as one or more separate magnets. Again, in accordance with the above described principles, the time delay indicator 100’ may further include temperature compensating means that controls the magnetic field strength from one or more of the magnetic field generators to compensate for variations in viscosity of the magnetic liquid caused by variations in operating temperature.

In accordance with an embodiment of the present invention, and as schematically shown in fig 13, the time delay indicator 100’ is intended to be an integral part of an injection device 1’, such as being formed as a member that is non-separable from the remainder of the device. In the shown embodiment, the time delay indicator forms part of an injection button assembly in an auto-injector having a spring actuated dose delivery mechanism. Non-limiting examples of suitable injection device dose delivery mechanisms are disclosed in WO 2006/076921.

Fig. 14a shows the time delay indicator 100’ in a top view and in cross sectional views along lines A-A and B-B. In fig. 14a the time delay indicator is in a resting state wherein the time delay indicator has not yet been activated. Fig. 14b shows similar views of the time delay indicator 100’ but wherein the time delay indicator has been activated.

The time delay indicator 100’ is composed around a timer structure 114’ that is adapted to hold a quantity of a magnetic liquid 170’ such as a ferrofluid. The timer structure 114’ is part of a time delay body 110’ that further comprises components 111’, 112’ and 113’. In the shown embodiment the components 111’, 112’, 113’ and 114’ are components fixedly arranged relative to each other. The timer structure 114’ includes a tower portion that extends proximally along the central longitudinal axis from a distal part of timer structure 114’. Components 111’, 112’ and 113’ are configured to define a compartment that accommodates the tower portion of timer structure 114’ within the bordering walls defined by components 111’, 112’ and 113’. The components 111’, 112’, 113’ and 114’ define a first reservoir 101’ arranged proximally to the tower portion at a central top position on timer structure 114’. The components 111’, 112’, 113’ and 114’ further define a second reservoir 102’ arranged at a peripheral bottom portion of timer structure 114’.

Component 113’ forms a dome shape that is arranged on top of the timer structure 114’. Component 113’ is made from a transparent material that enables visual inspection of the timer structure 114’ and the magnetic liquid 170’ when present in the first reservoir 101’. The timer structure 114’ further comprises a fluid communicator in the form of a channel 103’ that leads from the first reservoir 101’ to the second reservoir 102’. In the shown embodiment, the channel 103’ is formed as a narrow conduit extending along an axis from the first reservoir 101’ to the second reservoir 102’. In other embodiments the shape of the channel 103’ may be formed differently, for example by forming the channel to extend along a helical path from the first reservoir 101’ to the second reservoir 102’.

The colour of the magnetic liquid 170’ and the top surface of the central top position on timer structure 114’ may be selected so that the liquid is visually distinguishable from the timer structure 114’ in a way so that a user of the device may readily inspect whether or not magnetic liquid 170’ is present in the first reservoir 101’.

The time delay body 110’ (111’, 112’, 113’ and 114’) is arranged movable relative to a time delay base 130’. Said relative movability ensures that the assembly 110’ and 130’ are able to act as an activator for operating the time delay indicator 100’ for resetting the timer and allowing the timer to run. In the shown embodiment, the time delay base 130’ is disposed on a component of the injection pen 1’ which forms part of the injection button assembly. The time delay body 110’ is thus movable relative to the time delay base 130’ along the central axis of the injection pen 1’ from a first inactivated position into a second activated position.

In the shown embodiment, a slider 140’ is coupled to the time delay body 110’ so that the slider moves axially with the time delay body and so that the slider is movable in a lateral direction between a central position and a peripheral position relative to the time delay body. The slider 140’ and the timer structure 114’ include a rail system that ensures that slider 140’ is moved axially together with the time delay body 110’ when the time delay body moves relative to the time delay base 130’ and that enables said lateral movement of the slider 140’ relative to the timer structure 114’. A spring 180’ is arranged to act on the slider 140’ to urge the slider towards the central position. A magnet 150’ is disposed on slider 140’ and hence the position of the magnet 150’ is determined by the position of the slider 140’. In accordance with the principles of the time delay indicator shown in figs. 1-2, the magnet 150’ may be referred to as magnet M_3.

The time delay base 130’ comprises a cam 135’ having a cam surface adapted to engage a corresponding cam surface of slider 140’. When an externally applied force is exerted in the distal direction on the time delay body 110’, such as when a user exerts a pressing force in the distal direction for performing an injection, the cam surfaces causes the slider 140’ to move from the central position to the peripheral position against the force provided by spring 180’. When the external applied force ceases, accumulated energy released from the spring 180’ causes slider 140’ to be moved back from the peripheral position to the central position. In accordance with the movement of the slider 140’, the magnet 150’ is moved back and forth between the central position and the peripheral position.

In the shown embodiment the time delay indicator 100’ furthermore includes brake magnets 160’. Again, in accordance with the principles of the time delay indicator shown in figs. 1-2, the brake magnets 160’ may be referred to as M_2. In this embodiment the brake magnets 160’ are formed as a series of circular concentric magnets that are disposed at a distal wall section of the time delay body 110’ and thus in close relationship with the distal part of the second reservoir 102’. The brake magnets 160’ are thus positioned along the flow path of the magnetic liquid 170’ when the magnetic liquid flows in channel 103’.

In fig. 14a the time delay indicator 100’ is in the resting state wherein the time delay indicator has not yet been activated. The magnet 150’ is located at the central position. Due to the magnetic field induced by magnet 150’ the magnetic liquid 170’ has been caused to flow into the first reservoir 101’ and the magnetic liquid is observable at a central location of the timer structure 114’.

In fig. 14b, an externally applied force is exerted on the time delay body 110’ so that it is moved from its inactivated position into its activated position. The camming action of the cammed surfaces of slider 140’ and time delay base 130’ cause the slider 140’ to be moved radially outwards against the force provided by spring 180’. In accordance with this, the magnet 150’ is moved from the central position to the peripheral position.

As shown in fig. 14b, when the magnet 150’ assumes its peripheral position, the magnetic field induced by magnet 150’ has caused a substantial portion of the magnetic liquid 170’ to be moved into the second reservoir 102’ and thus away from the from the first reservoir 101’ which is rapidly evacuated after application of the externally applied force. This condition is observable through the transparent portion of component 113’ where the timer structure 114’ can be observed unhindered. This state thus corresponds to the resetting of the time delay indicator 100’.

When the externally applied force is released, the spring 180’ urges the slider 140’ back into the central position. Due to the change of magnetic field caused by movement of magnet 150’, the magnetic liquid 170’ is forced to flow towards the first reservoir 101’. However, due to the brake magnets 160’, the duration of the return flow towards the first reservoir 101’ is relatively long. In accordance herewith the visual indication through the transparent portion of the component 113’ only slowly changes towards the initial state (i.e. the resting state). When the magnet 150’ assumes its central position, the magnetic field applied onto the magnetic liquid 170’ present in the channel 103’ acts to regulate the viscosity of the magnetic liquid 170’ thereby slowing down the flow and thus allowing a long time-out time. However, when the magnet 150’ assumes its peripheral position, the viscosity of the magnetic liquid 170’ is relatively low thereby ensuring a high flow velocity and thus enabling a short reset-time.

Fig. 15 schematically shows the injection device 1’ including the time delay indicator 100’ and the movement of the different parts of the injection button assembly of the device during the dose delivery activation procedure. In the left-hand figure, the injection pen is shown in the non-activated state, i.e. in a state corresponding to the state the device assumes between drug administering operations. As shown in the figure in the middle of fig. 15, when an externally applied force is exerted on the time delay body 110’, the time delay body 110’ is moved relative to the time delay base 130’ and the time delay indicator 100’ is reset. As the time delay base 130’ is fixedly associated with a component of the expelling activator of the dose delivery mechanism, pressing the time delay body 110’ further in the distal direction relative to the housing of the device causes the injection button assembly to activate the dose delivery mechanism for expelling the set dose (shown in the right-hand figure). Upon release of the applied force, for example when the full intended dose has been expelled from the injection pen 1’, the time delay indicator is simultaneously activated to run for the predefined time interval. During the predefined time interval the activated state of the time delay indicator is observable through the transparent section of time delay body 110’.

In accordance with the particular design of the time delay indicator, the duration of the backflow towards the initial state can be in the order of minutes or hours. Hence, for a predefined time after dose expelling, the time delay indicator of the device provides an indication that the expelling of a dose has been performed within the predefined time limit.

In other embodiments further magnetic field generators may be incorporated, for example in proximity of the first reservoir. Such magnetic field generators may be included at or in the timer structure 114’, and in particular at or in the the tower portion of the timer structure 114’.

Some preferred embodiments have been schematically shown and discussed in the foregoing, but it should be stressed that the invention is not limited to these, but may be embodied in other ways in accordance with the subject matter defined in the following claims. The figures e.g. discloses embodiments of medical delivery systems of the present invention in the form of an injection pen, however, this particular delivery device and its shape is in no way limiting for the present invention as defined in the claims. This also applies to time delay indicators being more fully integrated into an injection device than the embodiments shown in this disclosure, e.g. time delay indicators being integrated into a dose delivery mechanism within the housing of the device. Such embodiments may provide a magnetic time delay indicator viewable through a window of the housing of the device or alongside a dose amount indicator such as a dose dial scale.

While the embodiment described above relies on a design which incorporates an injection button assembly, other parts of the device may be used for cooperating with a time delay indicator in accordance with the invention. Suitable designs may include a time delay indicator which is adapted to cooperate or be operated by one or more other components which move(s) when an injection procedure is carried out. Non-limiting examples include movable components, such as a needle shield that slides relative to a needle or relative to a housing for initialising a dose administration, a cap that moves relative to a housing for gaining access to an injection needle or for covering an injection needle subsequent to an injection, a dose setting member or dose indicator that moves during dose setting, and one or more parts of the dose delivery mechanism that moves during expelling.

Apart from the disclosed magnetic field generators as discussed above, also other means for generating a driving pressure on the magnetic liquid for urging the magnetic liquid to flow from the first reservoir to the second reservoir and vice versa may be provided by alternative pressure generating means, such as by hydraulic pressure generating means.

CLAIMS

1. A magnetic time delay indicator (100, 100’) comprising:

- a first reservoir (101, 101’) and a second reservoir (102, 102’), the first reservoir (101, 101’) and the second reservoir (102, 102’) being interconnected by a fluid communicator (103, 103’),
- a magnetic liquid (170, 170’) arranged to be at least partly accommodated within the second reservoir (102, 102’) and configured to flow towards the first reservoir (101, 101’) through the fluid communicator (103, 103’), wherein the magnetic liquid (170, 170’) comprises a ferrofluid and/or a magnetorheological fluid,
- pressure generating means (M_3, 150’) configured for generating a driving pressure on the magnetic liquid (170, 170’) for urging the magnetic liquid (170, 170’) to flow from the second reservoir (102, 102’) towards the first reservoir (101, 101’), and
- an activator (M_3, 110’, 130’, 150’) configured for being activated to enable flow of magnetic liquid (170, 170’) from the second reservoir (102, 102’) to the first reservoir (101, 101’), wherein the duration for an amount of magnetic liquid (170, 170’) to flow from the second reservoir (102, 102’) to the first reservoir (101, 101’) provides an indication of elapsed time since activation of the activator (M_3, 110’, 130’, 150’),

wherein:

- the magnetic time delay indicator (100, 100’) defines a magnetic field generator arrangement (M_1, M_2, M_3, 150, 160) configured for applying a magnetic field on the magnetic fluid (170, 170’), the magnetic field generator arrangement (M_1, M_2, M_3, 150, 160) comprising a first magnetic field generator (M_2, 150’) arranged at the fluid communicator (103, 103’) to predominantly apply a magnetic field on magnetic liquid (170, 170’) present in the fluid communicator (103, 103’) to control the viscosity of the magnetic liquid (170, 170’) present in the fluid communicator (103, 103’) when flowing from the second reservoir (102, 102’) to the first reservoir (101, 101’).

2. A magnetic time delay indicator as defined in claim 1, wherein the magnetic field generator arrangement (M_1, M_2, M_3, 150, 160) applies a magnetic force on the magnetic liquid (170, 170’) to cause at least a portion of the magnetic liquid (170, 170’) present in the second reservoir (102, 102’) to flow through the fluid communicator (103, 103’) towards the first reservoir (101, 101’).

3. A magnetic time delay indicator as defined in any of claims 1-2, wherein the magnetic field generator arrangement (M_1, M_2, M_3, 150, 160) defines a self-compensating temperature compensated field strength regulator configured to regulate the flow from the second reservoir (102, 102') towards the first reservoir (101, 101').

4. A magnetic time delay indicator as defined in claim 3, wherein the self-compensating temperature compensated field strength regulator comprises a mounting device (190) for the magnetic field generator arrangement (M_1, M_2, M_3, 150, 160) so configured that at least a part of the magnetic field generator arrangement (M_1, M_2, M_3, 150, 160) moves relative to the first reservoir (101, 101') and/or second reservoir (102, 102') in response to variations in temperature to regulate magnetic field strength applied on the magnetic liquid (170, 170').

5. A magnetic time delay indicator as defined in claim 4, wherein said movement of said at least part of the magnetic field generator arrangement (M_1, M_2, M_3, 150, 160) is caused by thermal expansion and/or contraction of said mounting device (190).

6. A magnetic time delay indicator as defined in any of claims 1-5, wherein the magnetic field generator arrangement (M_1, M_2, M_3, 150, 160) comprises a second magnetic field generator (M_1) arranged at the second reservoir (102, 102') configured to predominantly apply a magnetic field on magnetic liquid (170, 170') present in the second reservoir (102, 102').

7. A magnetic time delay indicator as defined in any of the claims 1-6, wherein the first magnetic field generator (M_2) arranged at the fluid communicator (103, 103') provides a braking force on the magnetic liquid (170, 170') flowing through the fluid communicator (103, 103') to restrict the flow through the fluid communicator (103, 103').

8. A magnetic time delay indicator as defined in any of claims 1-7, wherein the first magnetic field generator (M_2) is movably positioned relative to the fluid communicator (103, 103') to regulate magnetic field strength in the fluid communicator (103, 103') to regulate the viscosity of the magnetic liquid (170, 170') present in the fluid communicator (103, 103').

9. A magnetic time delay indicator as defined in any of claims 1-8, wherein the magnetic field generator arrangement (M_1, M_2, M_3, 150, 160) comprises a third magnetic field generator

(M_3) positionable at the first reservoir (101, 101') to apply a magnetic field on the magnetic liquid (170, 170') for urging the magnetic liquid to flow towards the first reservoir (101, 101').

10. A magnetic time delay indicator as defined in claim 9, wherein the third magnetic field generator (M_3) at least partly defines said activator ($M_{3,}$), wherein the third magnetic field generator (M_3) is movable from a first position at the second reservoir (102, 102') to a second position at the first reservoir (101, 101'), and wherein the third magnetic field generator (M_3) when positioned in the second position generates a magnetic pressure for causing the magnetic liquid (170, 170') present in the second reservoir (102, 102') to flow towards the first reservoir (101, 101').

11. A magnetic time delay indicator as defined in claim 10, wherein when the third magnetic field generator (M_3) is positioned in the first position magnetic liquid (170, 170') present in the first reservoir (101, 101') is caused to flow towards the second reservoir (102, 102') for resetting the time delay indicator.

12. A magnetic time delay indicator as defined in any of claims 1-11, wherein at least a portion of one or more of the first reservoir (101, 101'), the second reservoir (102, 102') and the fluid communicator (103, 103') is transparent for allowing a user to visually inspect the magnetic liquid (170, 170') to enable a user of the device to visually observe the status of the magnetic time delay indicator.

13. A magnetic time delay indicator as defined in any of claims 1-12, wherein the fluid communicator (103, 103') defines an elongated channel that connects the first reservoir (101, 101') and the second reservoir (102, 102').

14. An injection device for expelling one or more doses of a drug, the injection device (1') comprising a magnetic time delay indicator (100, 100') as defined in any of the claims 1-13.

15. An injection device as defined in claim 14, wherein the activator (M_3, 110', 130', 150') defines an expelling activator adapted for manual activation by a subject user to cause expelling of a dose of drug.

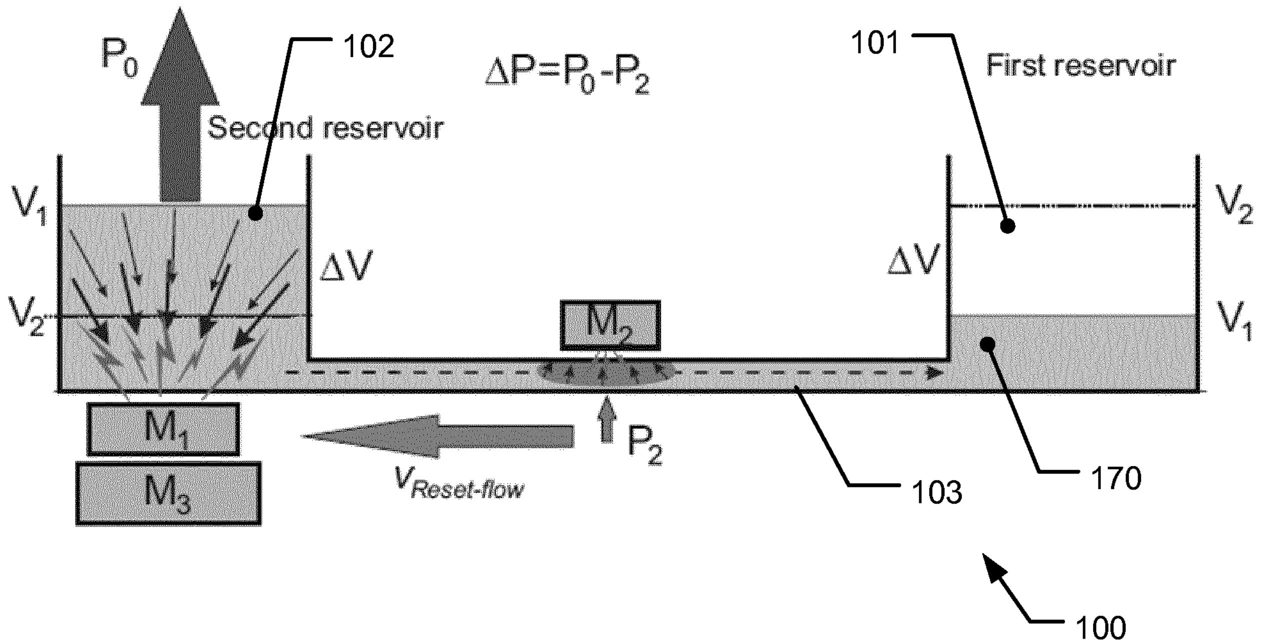

P0
102
ΔP=P0-P2
101
First reservoir
Second reservoir
V1
ΔV
ΔV
V2
V2
M2
V1
M1
P2
M3
VReset-flow
103
170
100

Fig. 1

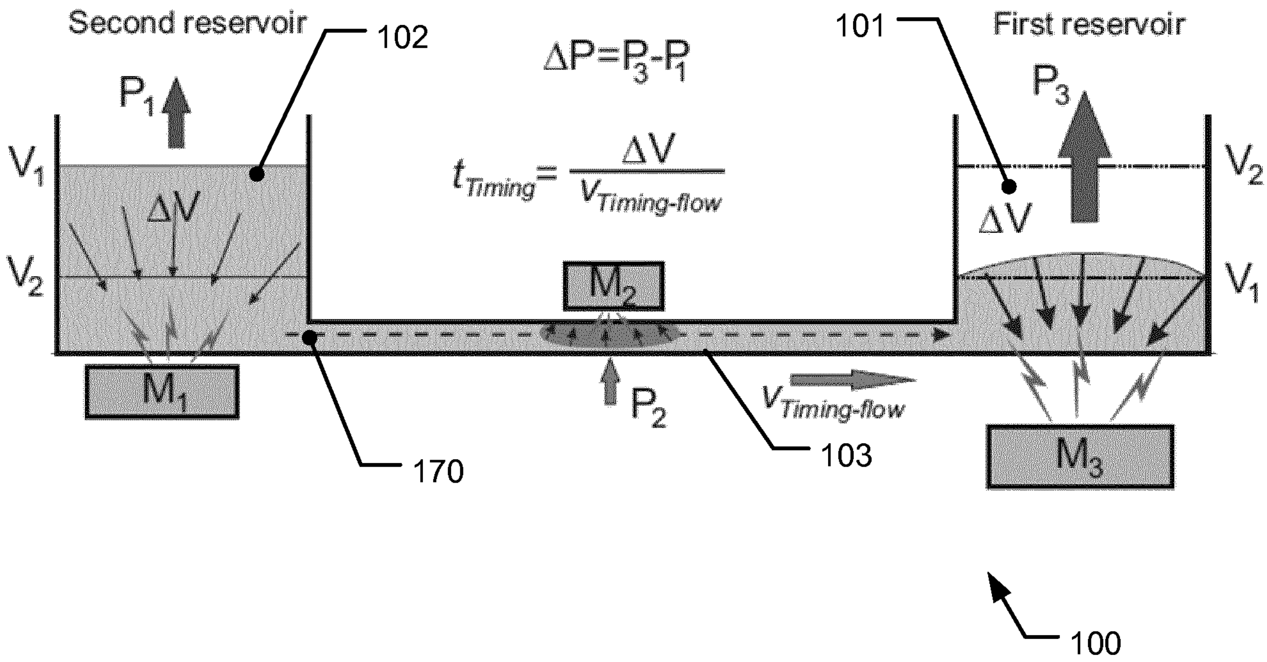
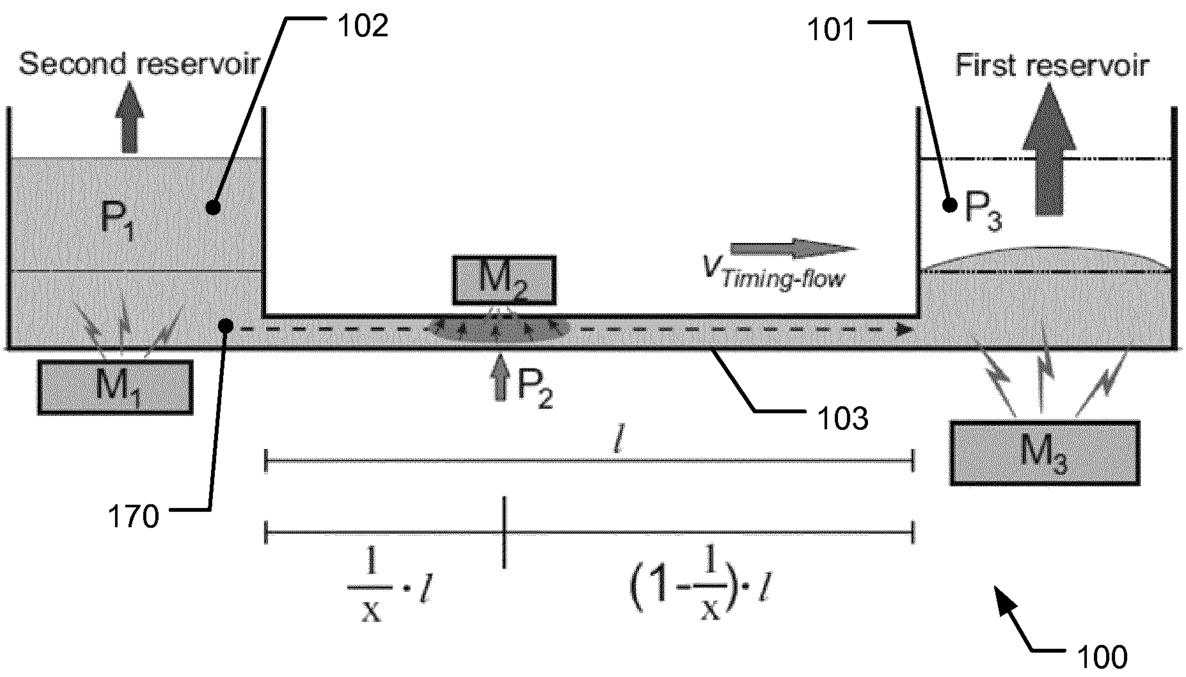
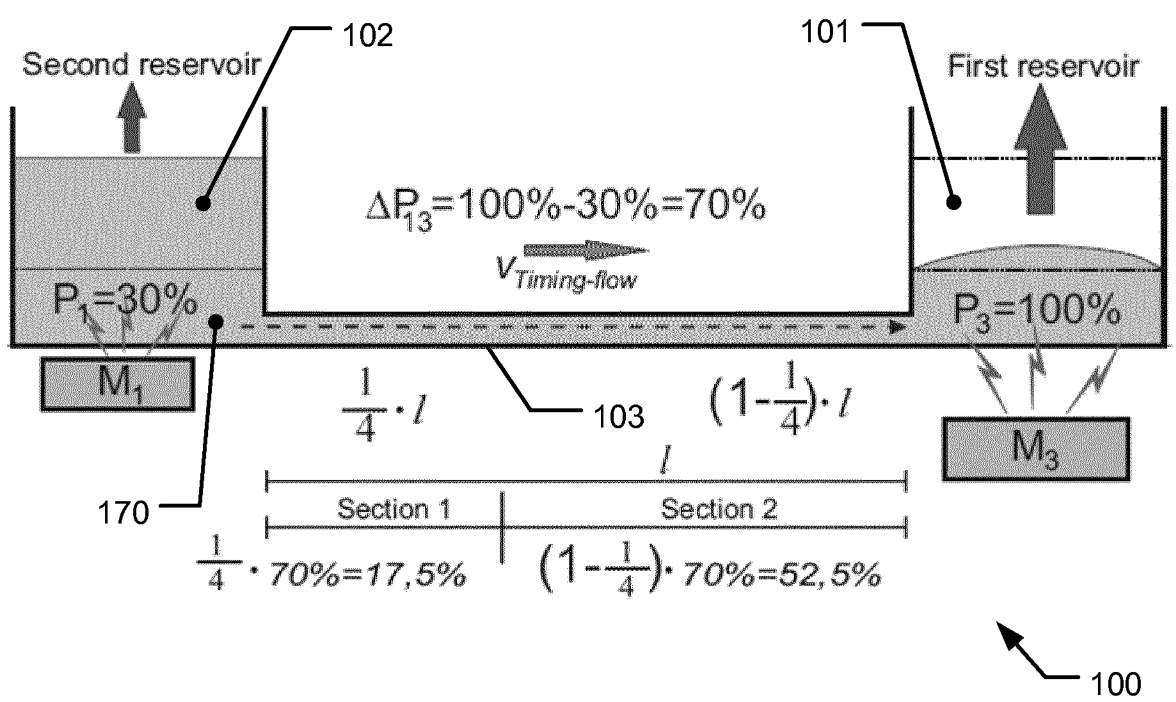

Second reservoir
102
ΔP=P3-P1
101
First reservoir
P1
P3
V1
tTiming= ΔV / VTiming-flow
V2
ΔV
ΔV
V2
M2
V1
M1
P2
VTiming-flow
M3
170
103
100

Fig. 2



102
101
Second reservoir
First reservoir
P1
P3
M2
V Timing-flow
M1
P2
103
M3
l
170
1/x · l
(1-1/x)· l
100

Fig. 3



102
101
Second reservoir
First reservoir
ΔP13=100%-30%=70%
V Timing-flow
P1=30%
P3=100%
M1
1/4 · l
103
(1-1/4)· l
M3
l
170
Section 1
Section 2
1/4 · 70%=17,5%
(1-1/4)· 70%=52,5%
100

Fig. 4

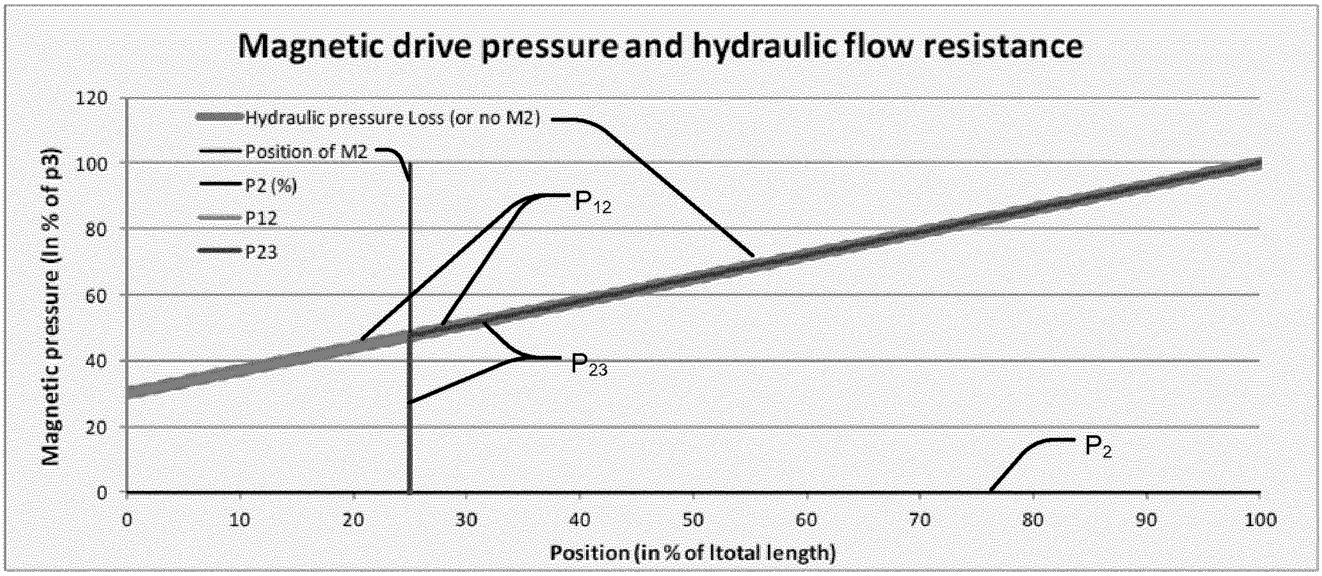

Magnetic drive pressure and hydraulic flow resistance
Hydraulic pressure Loss (or no M2)
Position of M2
P2 (%)
P12
P23
Magnetic pressure (In % of p3)
Position (in % of ltotal length)
P12
P23
P2
0
10
20
30
40
50
60
70
80
90
100
120

Fig. 5

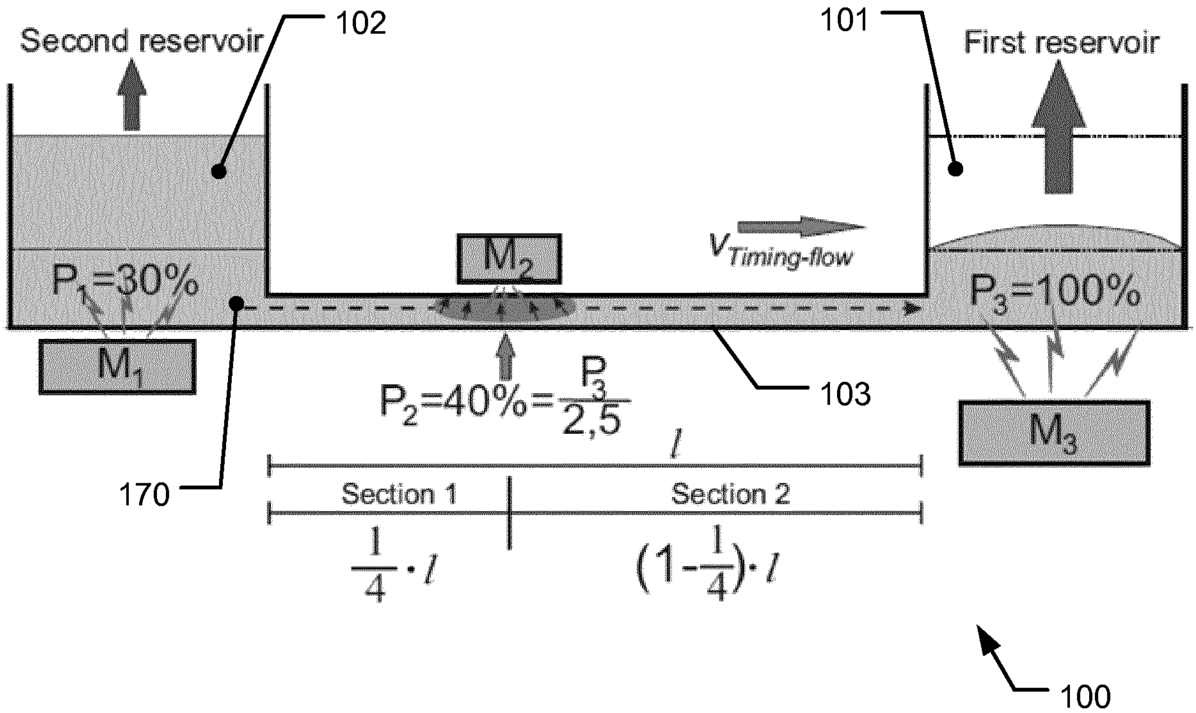

Second reservoir
102
101
First reservoir
M2
V Timing-flow
P1=30%
P3=100%
M1
M3
P2=40%=P3/2,5
103
170
l
Section 1
Section 2
1/4 · l
(1-1/4) · l
100

Fig. 6

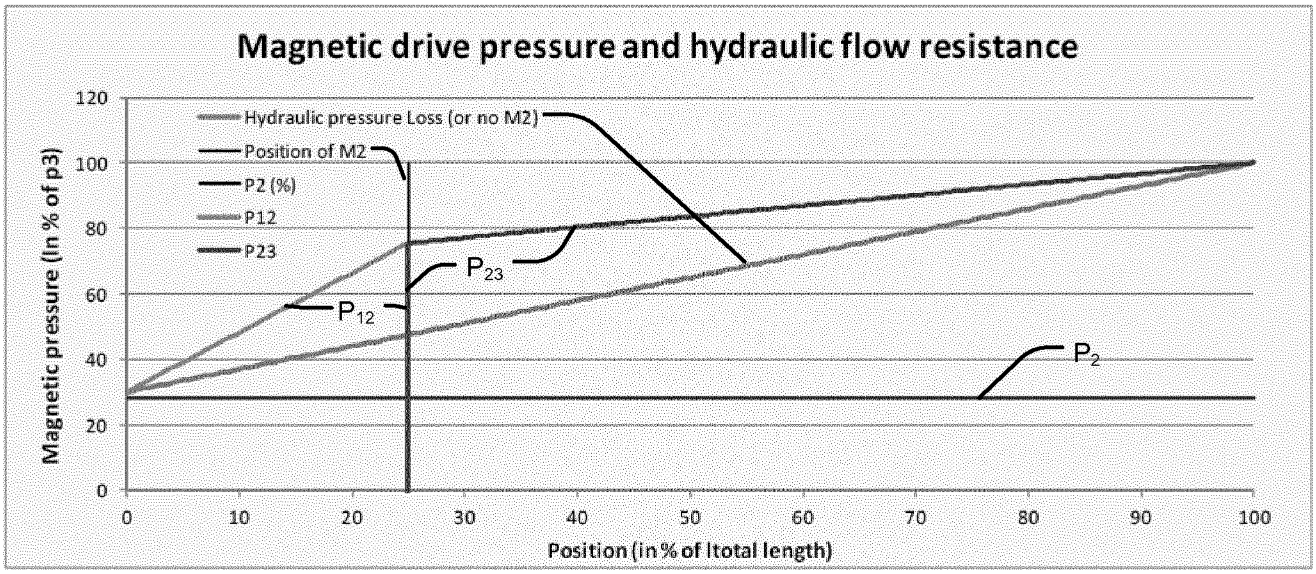

Magnetic drive pressure and hydraulic flow resistance
Magnetic pressure (In % of p3)
Hydraulic pressure Loss (or no M2)
Position of M2
P2 (%)
P12
P23
P23
P12
P2
Position (in % of ltotal length)
0
10
20
30
40
50
60
70
80
90
100
120

Fig. 7

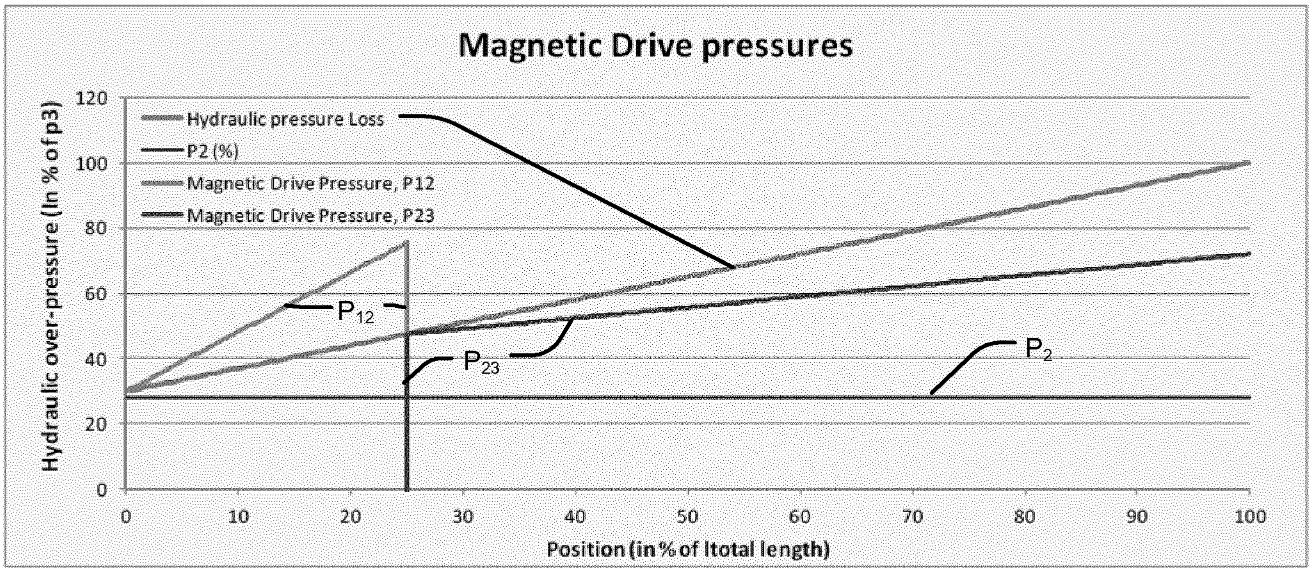

Magnetic Drive pressures
Hydraulic over-pressure (In % of p3)
Hydraulic pressure Loss
P2 (%)
Magnetic Drive Pressure, P12
Magnetic Drive Pressure, P23
P12
P23
P2
Position (in % of ltotal length)
0
10
20
30
40
50
60
70
80
90
100
120

Fig. 8

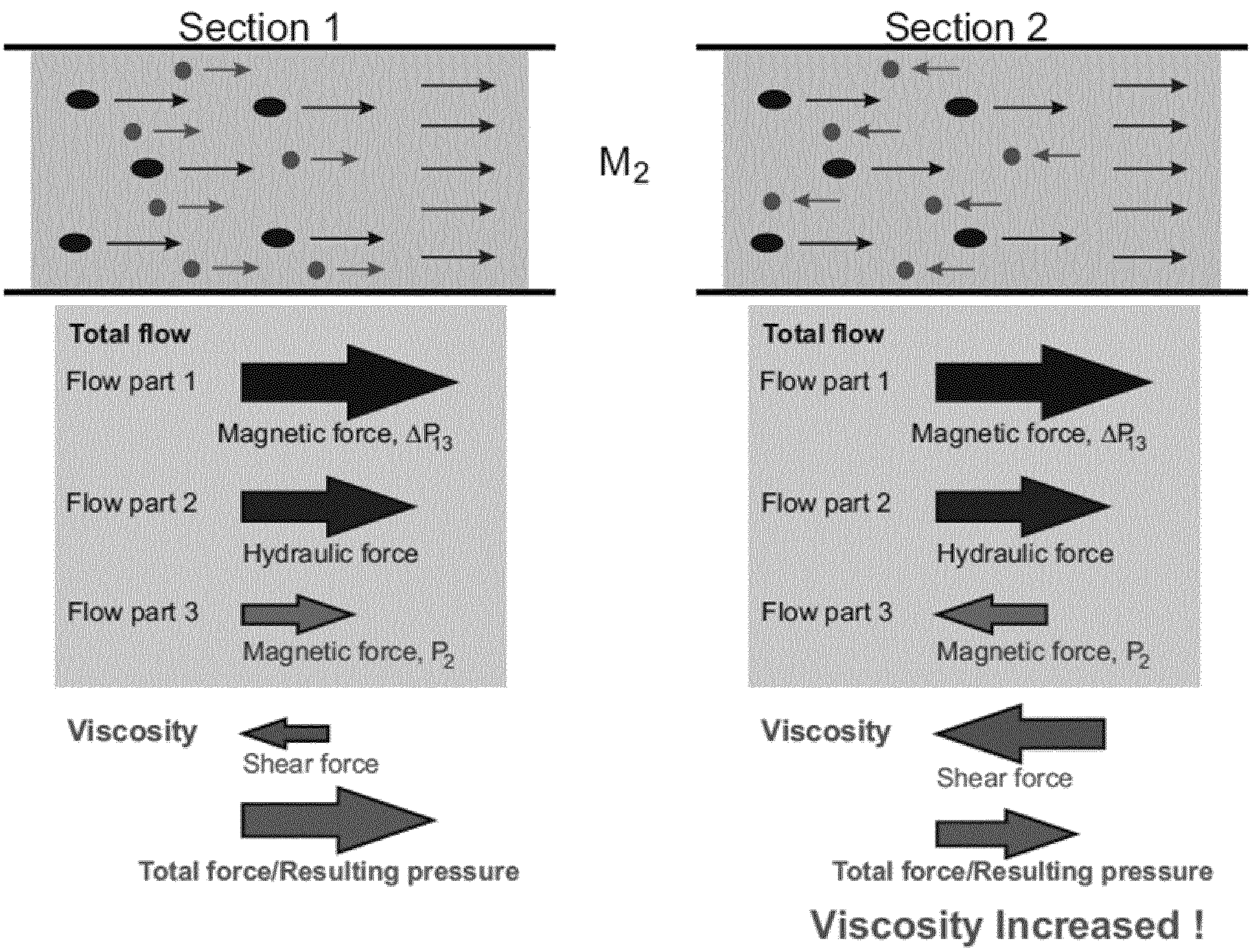

Section 1
Section 2
M2
Total flow
Flow part 1
Magnetic force, ΔP13
Flow part 2
Hydraulic force
Flow part 3
Magnetic force, P2
Viscosity
Shear force
Total force/Resulting pressure
Total flow
Flow part 1
Magnetic force, ΔP13
Flow part 2
Hydraulic force
Flow part 3
Magnetic force, P2
Viscosity
Shear force
Total force/Resulting pressure
Viscosity Increased !

Fig. 9

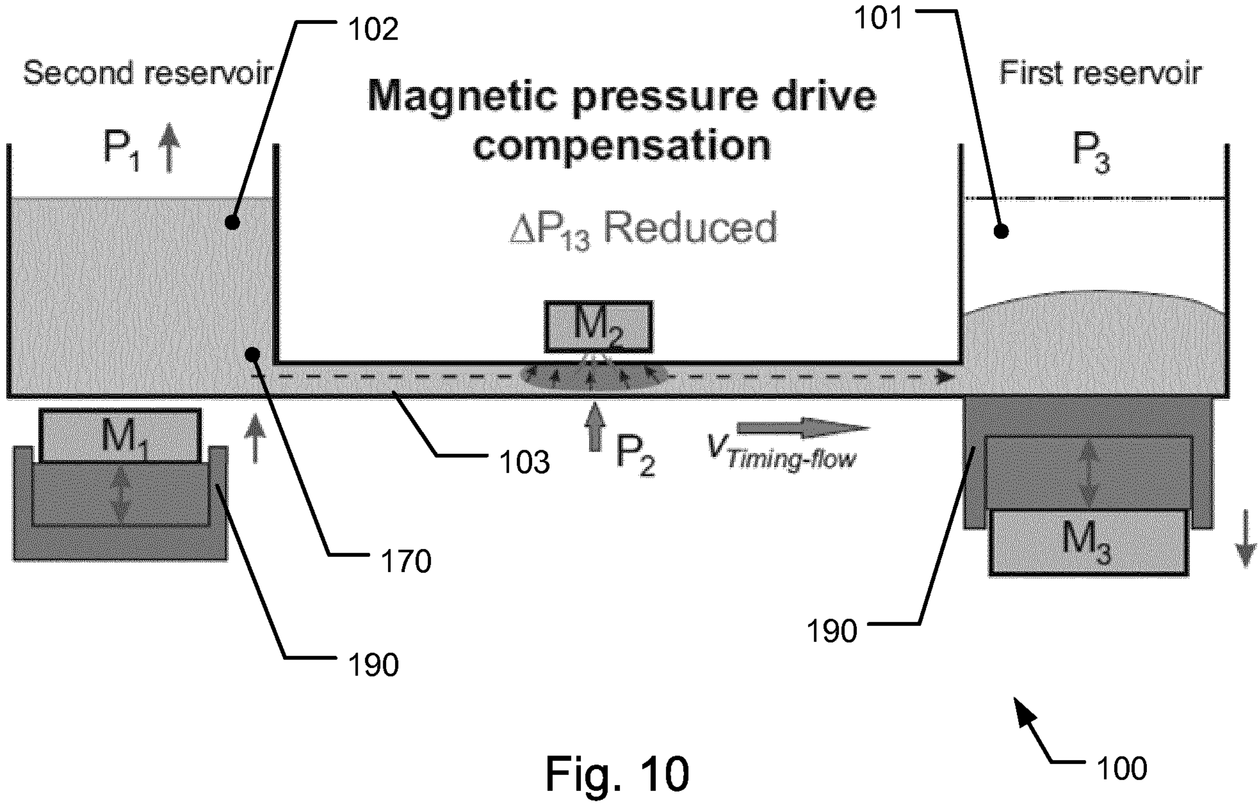

102
101
Second reservoir
Magnetic pressure drive compensation
First reservoir
P1
P3
ΔP13 Reduced
M2
M1
103
P2
VTiming-flow
M3
170
190
190
100

Fig. 10

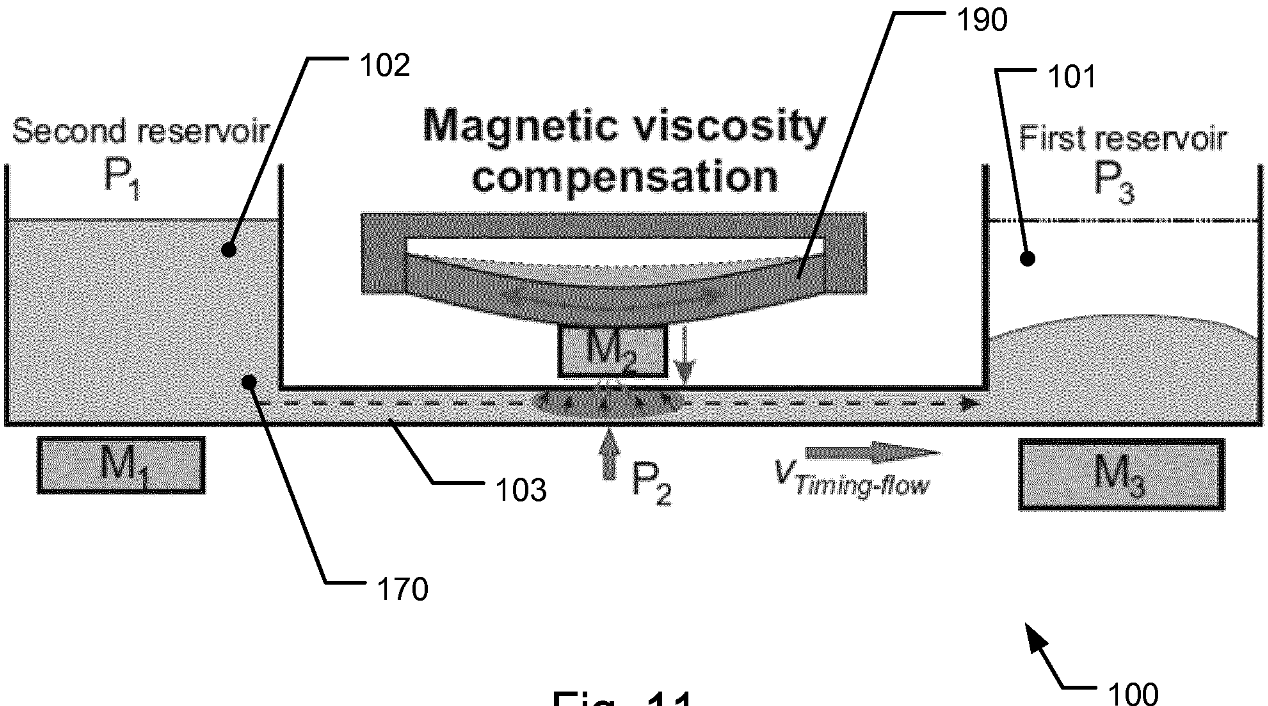

190
102
101
Second reservoir
Magnetic viscosity compensation
First reservoir
P1
P3
M2
M1
103
P2
VTiming-flow
M3
170
100

Fig. 11

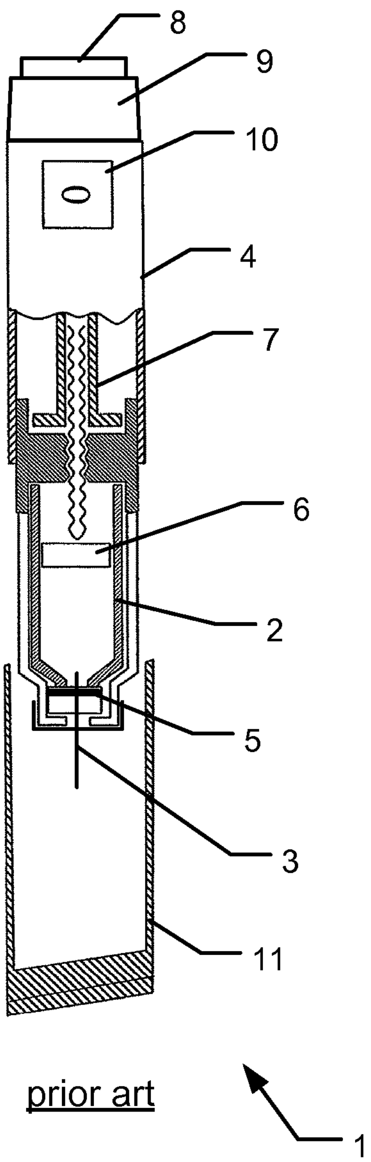


Fig. 12

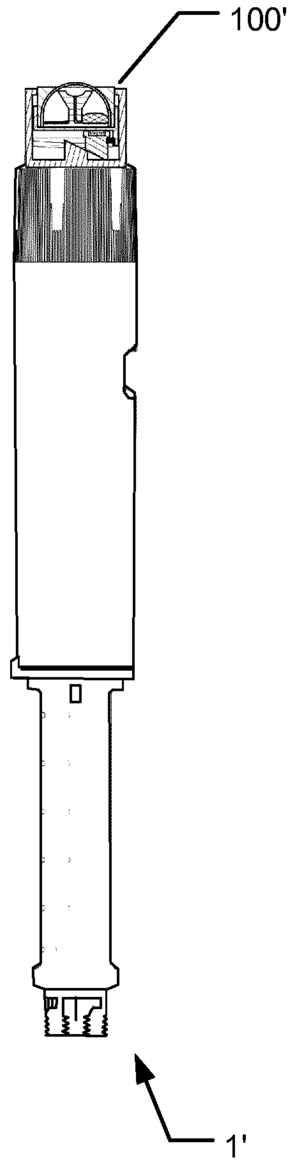


Fig. 13

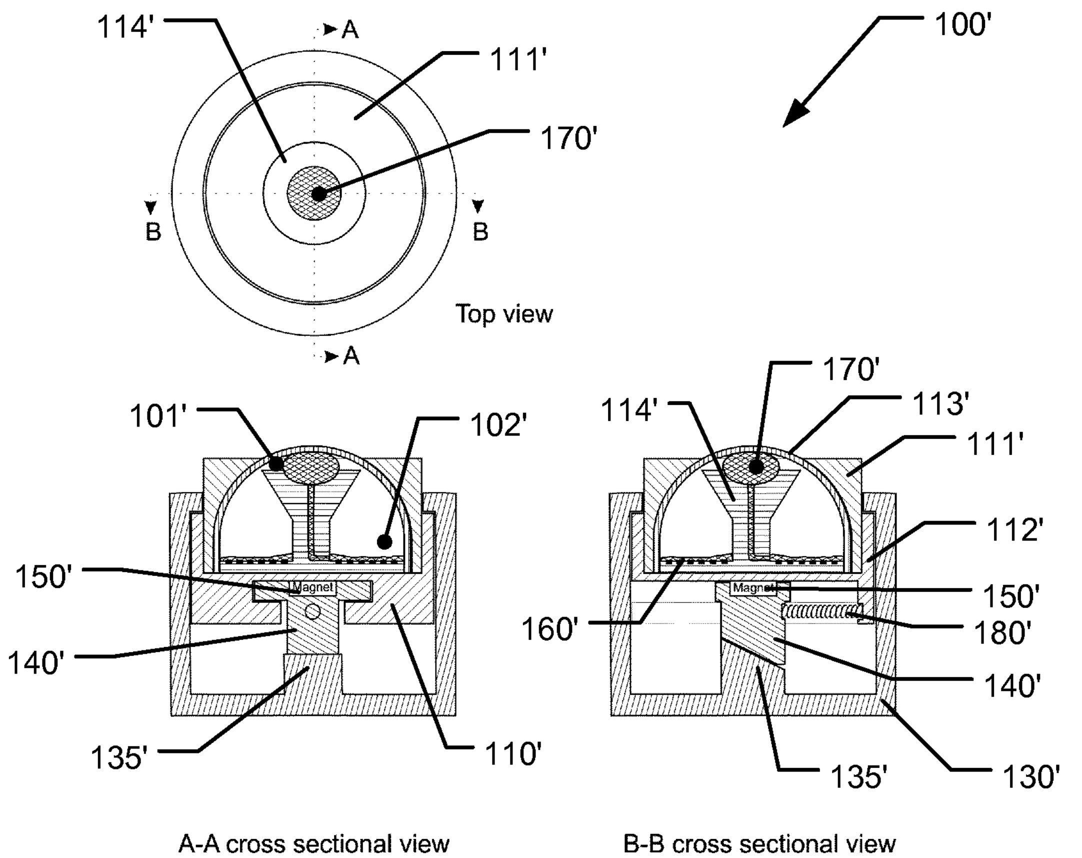


Fig. 14a

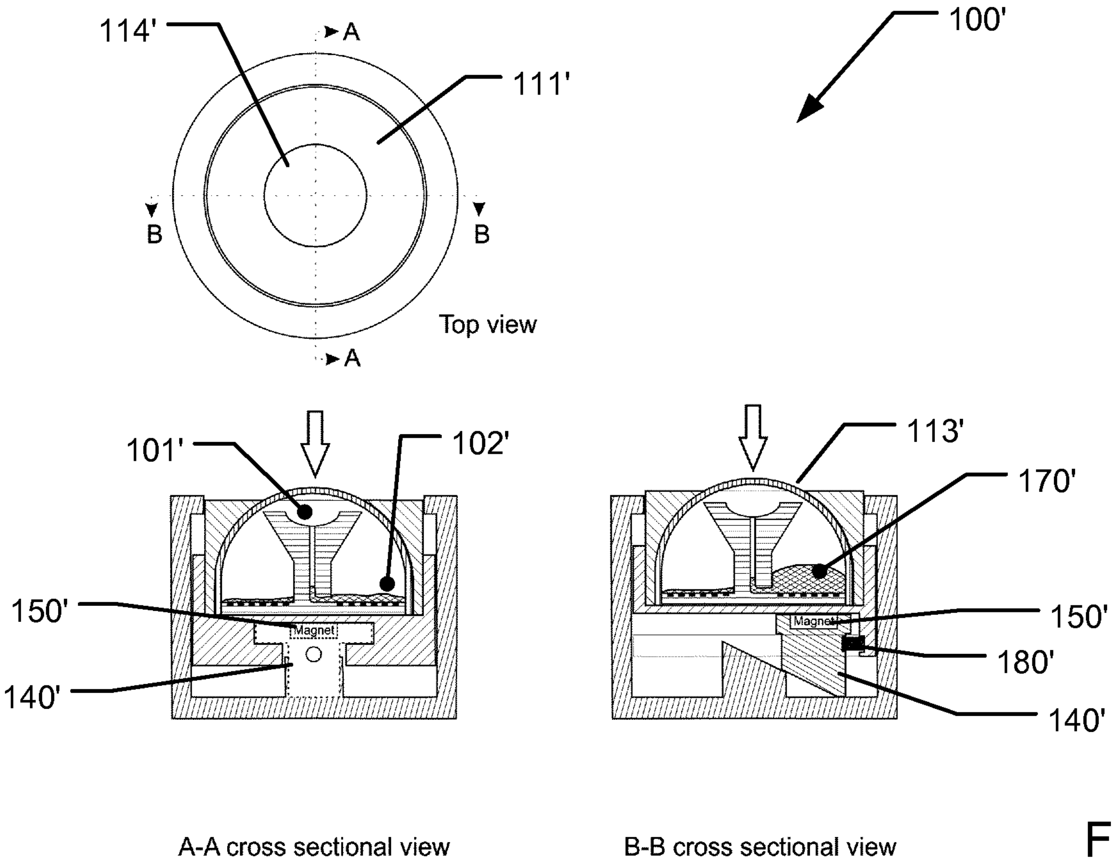


Fig. 14b

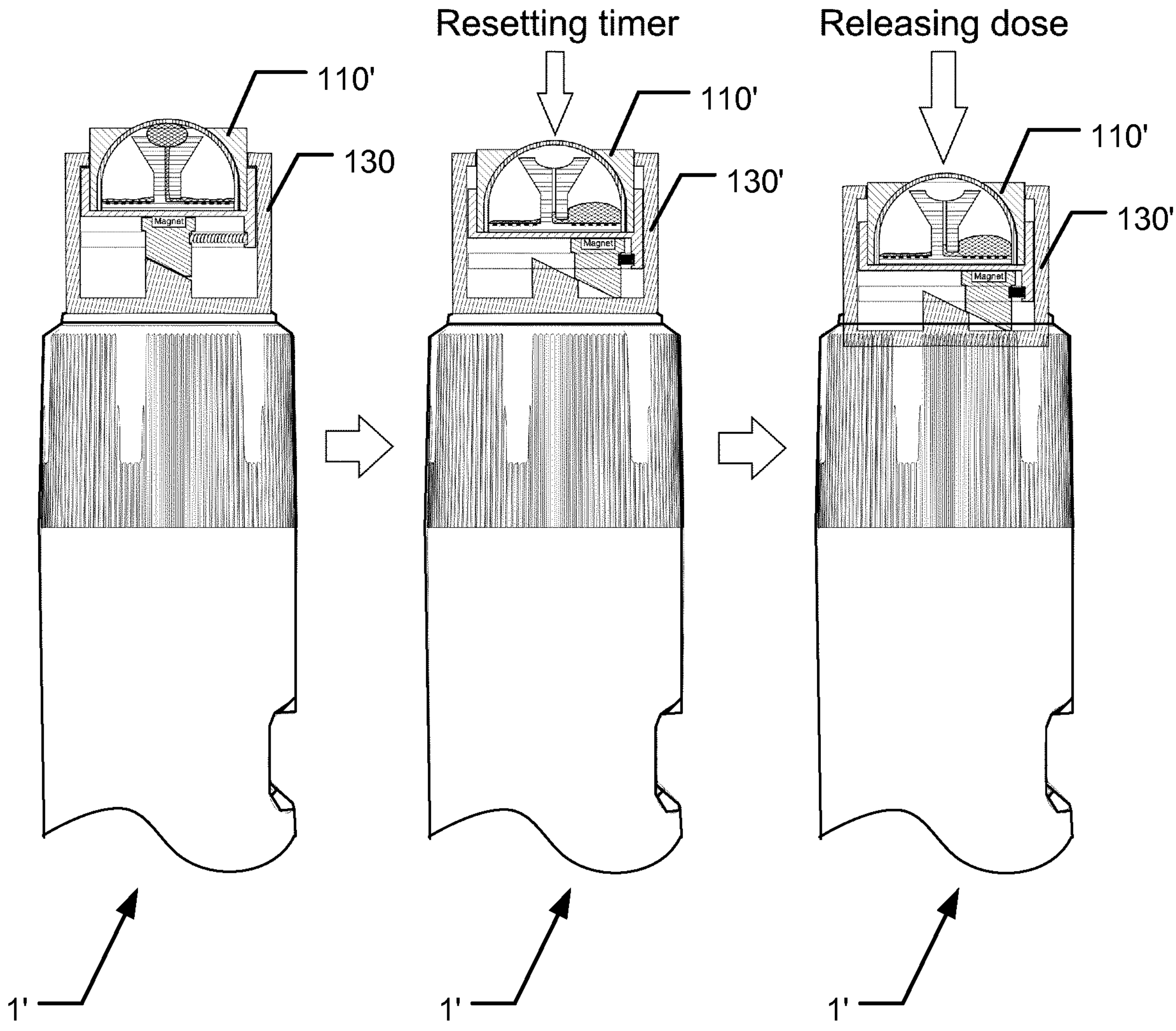

Resetting timer
Releasing dose
110'
130
110'
130'
110'
130'
Magnet
Magnet
Magnet
1'
1'
1'

Fig. 15

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/058730

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61M5/24 G04F13/06 H01H36/00
ADD. A61M5/31

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61M G04F H01H G01F A61J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2013/072412 A1 (NOVO NORDISK AS [DK]) 23 May 2013 (2013-05-23) page 3, line 7 - page 5, line 3 page 7, line 3 - page 9, line 18 figures 1-3	1-15
A	EP 1 836 945 A2 (OLYMPUS MEDICAL SYSTEMS CORP [JP]) 26 September 2007 (2007-09-26) paragraphs [0136] - [0140]; figures 15A,19	1-15
A	US 2 555 513 A (SCHWEITZER JR EDMUND O) 5 June 1951 (1951-06-05) column 1, line 4 - column 2, line 41; figures 1-3	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 June 2015	01/07/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Diamantouros, S

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2015/058730

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO 2013072412	A1	23-05-2013	EP 2780058	A1	24-09-2014
			US 2014330212	A1	06-11-2014
			WO 2013072412	A1	23-05-2013
EP 1836945	A2	26-09-2007	EP 1836945	A2	26-09-2007
			US 2007219409	A1	20-09-2007
US 2555513	A	05-06-1951	NONE		