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(54) Title: PROCESS FOR COVERING A WIRE WITH A LAYER OF POLYMER

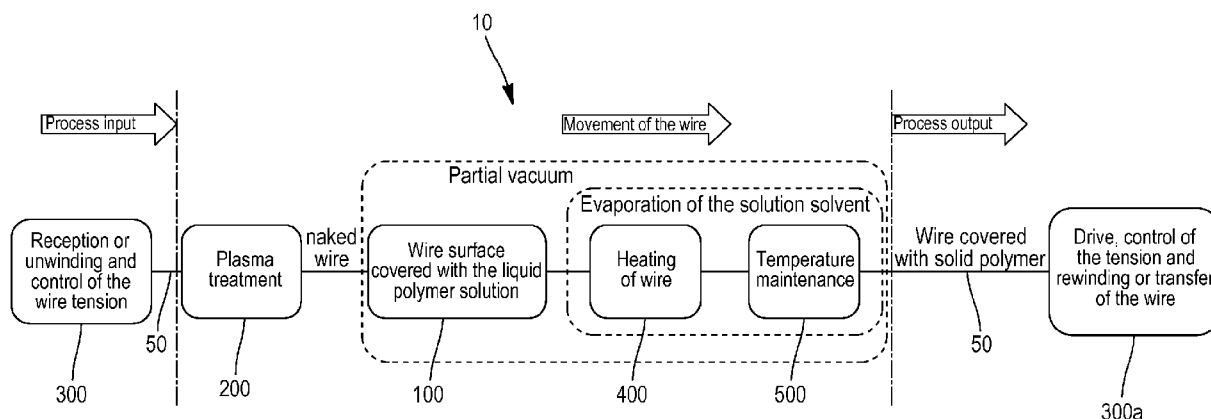


FIG. 1

(57) **Abstract:** The invention relates to a process for coating the surface of a moving wire (50) with a thin solid polymer layer. The process includes the step of providing a deposition device (100) having a compartment (108d') of a chamber (108) that contains two rotatable rings (110) and two wheels including an upper wheel (114) and a lower wheel (114') having circumferential grooves (114b, 114b') in which the two rings (110) are lodged. The wheels (114, 114') are placed vertically on either side of the wire (50) by means of the grooves (114c, 114c') such that a predetermined contact force between the wheels (114, 114') and the wire (50) makes it possible, by friction, when the wire (50) moves at constant speed, to rotate the wheels (114, 114') and the rings (110) too. The device also includes a tank (106) containing a liquid polymer solution (75). The wire (50) is conveyed at a predetermined constant speed, and the rotatable rings (110) are rotated, these conveying an amount of the liquid polymer solution (75). The process also includes the step of evaporating the solvent from the liquid polymer solution (75) deposited at the surface of the wire (50).



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PROCESS FOR COVERING A WIRE
WITH A LAYER OF POLYMER

TECHNICAL FIELD

- 5 The invention relates generally to a process for covering the surface of a wire moving continuously at constant speed with a thin solid polymer layer using a liquid polymer solution.

CONTEXT

- 10 The coating of the surface of a wire with a material of different nature in order to modify or improve certain properties thereof is known and widely used in industry. Depending on the nature and the use of the wire, the coating may be used, for example, to improve the corrosion resistance, to provide electrical insulation, to modify the tribological properties, to enable adhesion to another material or simply
- 15 for decoration. In many cases, the coating material is deposited in the liquid state and then undergoes a treatment or a transformation intended to convert it to the solid state such as, for example, a temperature change, a polymerization, the evaporation of a solvent or other. The nature of the wire and the nature of the liquid are chosen as a function of the desired final characteristics. For the invention
- 20 described here, the term “wire” applies to wires having properties of electrical conductors and the term “liquid” applies to a liquid solution of polymer dissolved in a solvent.

SUMMARY

- 25 The invention relates to a process for coating the surface of a moving wire with a thin solid polymer layer, wherein the process includes the following steps: providing a deposition device having a compartment of a chamber that contains two rotatable rings and two wheels including an upper wheel and a lower wheel having circumferential grooves in which the two rings are lodged, and in which
- 30 compartment the wheels are placed vertically on either side of the wire by means of the grooves such that a predetermined contact force between the wheels and the wire makes it possible, by friction, when the wire moves at constant speed, to rotate the wheels and, by means of the lower wheel, the rings too, and a tank containing a liquid polymer solution; conveying the wire at a predetermined

constant speed; rotating the rotatable rings, these rings conveying an amount of the liquid polymer solution, and these rings bringing it to a point of tangential contact between the grooves of the wheels and the wire, which at the same time passes through an orifice formed by the grooves and located between the grooves, in order
5 to coat the surface of the wire while it is moving; and evaporating the solvent from the liquid polymer solution deposited at the surface of the wire.

In certain embodiments, the step of evaporating the solvent from the liquid polymer solution deposited at the surface of the wire includes a process for increasing the temperature of the wire in a heating device until an evaporation
10 temperature of the solvent is attained, and a process for maintaining the temperature of the wire in a temperature maintaining device until the complete evaporation of the solvent is obtained. In certain embodiments, the process for increasing the temperature of the wire is carried out by means of an induction coil in the heating device.

15 In certain embodiments, the system also includes the step of creating a partial vacuum simultaneously in the spaces surrounding the wire of the deposition device, of the heating device and of the temperature maintaining device.

In certain embodiments, a surplus of the polymer solution is conveyed to the tank.

20 In certain embodiments, the surplus of the polymer solution is conveyed to the tank by the rotation of the rings and by the effect of gravity.

In certain embodiments, the system also includes a step of calibrating the thickness of the deposited layer of the polymer solution by means of a calibration bushing provided with an orifice at its centre and mounted in the compartment of
25 the chamber in order to make the surplus of the polymer solution fall into the tank.

In certain embodiments, the system also includes the dipping of a lower portion of each ring in the liquid polymer solution by means of an opening in the bottom of the compartment of the chamber that corresponds with at least one portion of the tank.

30 The invention also relates to a system for producing a wire coated with a layer of solid polymer using a chosen polymer dissolved in a liquid solvent. The system includes a series of devices that together define a process as described.

The invention also relates to a wire formed according to a process as described.

Other aspects of the present invention will become obvious by means of the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

5 The nature and various advantages of the present invention will be better understood from reading the detailed description that follows, and from studying the attached drawings, in which the same reference numerals denote identical parts throughout, and in which:

 Figure 1 represents a schematic view of an embodiment of a process for
10 covering a wire.

 Figure 2 represents a front view, in the direction of movement of a wire, of a device for depositing liquid on the surface of the wire.

 Figure 3 represents a side view of the deposition device from Figure 2.

 Figure 4 represents a cross-sectional view of the deposition device from
15 Figure 2 along the line A-A.

 Figure 5 represents a cross-sectional view of the deposition device from Figure 3 along the line B-B.

 Figure 6 represents an enlarged view of the portion I from Figure 5.

 Figure 7 represents a rear view of the deposition device from Figure 3, with
20 the wall 108b removed.

DETAILED DESCRIPTION

 Detailed reference will now be made to some embodiments of the invention, one or more examples of which are illustrated in the drawings. Each
25 example is given for the purposes of explaining, rather than limiting, the invention described. A person skilled in the art will appreciate that various modifications and alternative forms may be made to the invention without departing either from the scope or from the spirit of the invention. Thus, provision is made for the invention to cover these modifications and alternative forms in so far as they fall within the
30 scope of the attached claims and equivalents thereof.

 With reference now to the figures, in which the same numerals identify elements that are identical, Figure 1 represents an example of a system 10 for carrying out a process that enables the homogeneous and continuous coverage of the surface of a wire 50, in particular a wire having a small diameter (for example,

a diameter of the order of 0.2 mm to 1 mm) with a thin solid polymer layer using a solution of polymer in the liquid state. In the process carried out, a wire 50 is obtained from a reel or another process and moves continuously and at constant speed and tension through a succession of devices that carry out the operations necessary for obtaining a wire covered with a thin solid polymer layer so that the wire has the desired properties, which properties are variable and can be adapted depending on the subsequent use of the wire. The movement of the wire 50 at a constant speed and the adjustment of its tension are carried out by means of the systems 300, 300a selected from varieties of systems that are commercially available and known by a person skilled in the art. In certain embodiments, the wire may move at a speed of several metres per minute up to 100 metres per minute.

The constituents of the polymer solution in the liquid state that is deposited on the wire and the respective proportions thereof must be chosen and respectively adjusted in order to obtain the deposition conditions (for example the viscosity) that enable a complete final coating of the desired thickness on the wire.

With reference again to Figure 1, a wire 50 obtained from an unwinding system 300 is transported to a plasma treatment device 200. The plasma treatment device 200 is an element of the system 10 that carries out a surface treatment of the wire 50. The plasma treatment modifies the surface properties of the wire 50 in order to improve its wettability and the subsequent adhesion between the wire and the polymer. The plasma treatment device may be selected from varieties of devices that are commercially available and the plasma treatments are known by a person skilled in the art.

With reference again to Figure 1 and to Figures 2 to 7, a wire 50 obtained from the plasma treatment device 200 is transported to a deposition device 100. The deposition device 100 enables the homogeneous and continuous deposition of a thin layer of liquid polymer solution on a wire moving at constant speed that has a small diameter.

The device 100 for depositing a thin layer of liquid on a wire 50 moving linearly at constant speed includes at least one bottle 102 having a predetermined volume for storing a liquid 75. The bottle 102 has an open end 102a where a valve 104, with a relief valve 104a, establishes the fluidic communication with a tank 106. The valve 104 regulates the supply of the liquid 75 between the bottle 102 and

the tank 106 in order to preserve a minimum level of liquid 75 in the tank during the deposition (see Figures 4 and 5). During the deposition, it is necessary to respect an upper limit and a lower limit of the level 75a of the liquid 75 in order to ensure the complete coverage of the wire 50.

5 The valve 104 is fastened to the bottle 102 by means of the cap 102b that has a thread adapted to that of the bottle 102. The valve 104 enables the removable fastening of the bottle 102 to the tank 106. Thus, the bottle 102 is easily replaceable in order to re-establish the level 75a of the liquid 75 if required, or in order to change the chosen liquid.

10 In addition to establishing the fluidic communication with the bottle 102, the tank 106 containing the liquid 75 is surmounted by a chamber 108 having two compartments 108d' and 108d''. The compartment 108d' contains two rotatable rings 110. The chamber 108 has a front cover 108a, a rear cover 108b, side walls 108c and an internal wall 108d that together define the internal volumes of the two
15 compartments 108d' and 108d''. The side walls 108c of the chamber 108 are opposed and include an inlet wall 108c' for the wire 50 and an outlet wall 108c'' for the wire. At the bottom of the compartment 108d', there is an opening 108e corresponding with at least one portion of the tank 106 so that the dipping of a lower portion 110a of each ring 110 in the liquid 75 is ensured.

20 With reference again to Figures 2 to 7, the wire 50 enters the compartment 108d' by passing through an assembly 112 that is mounted on the outside of the inlet wall 108c'. The assembly 112 includes a barrel 112a that engages a tightening screw 112b (for example, via known complementary threads). The wire 50 passes through an opening all along the tightening screw 112b, and is guided to the
25 internal volume of the compartment 108d' by at least one tightness bushing 112c.

By additionally referring to Figures 4, 5 and 6, there are two rings 110 that are rotated by the lower wheel 114' of the set of two wheels that includes an upper wheel 114 and a lower wheel 114'. Each wheel 114, 114' includes a respective circumferential periphery 114a, 114a' having grooves 114b, 114b' in which the
30 two rings 110 are housed and also a central groove 114c, 114c' that forms an orifice 126 for the passage of the wire 50. The wheels 114, 114' may have identical diameters, although this feature is not essential, in order to ensure uniform and reproducible performances during the deposition of the liquid.

The wheels 114, 114' are placed vertically on either side of the wire 50 and

in tangential contact with the wire by means of the grooves 114c, 114c'. The shafts 116, 116', upon which the wheels 114, 114' are fastened, support the rotational movement of these wheels by turning about an axis of rotation defined by the bearings 118, 118' that are fastened in cages 120, 120'. The cage 120' is rigidly
5 fastened to the wall 108d of the compartment 108d'' and imposes a fixed position on the lower wheel 114'. The cage 120 is fastened to the wall 108d of the compartment 108d'' by an axle 121 that allows the cage 120 a degree of rotational freedom about the axle 121. The wheels 114, 114' are arranged so that their rotational axes are parallel to one another.

10 With reference to Figures 4 to 7, a predetermined contact force between the wheels 114, 114' and the wire 50 is provided by a tension spring 122 that tends to move the mobile cage 120 closer to the fixed cage 120' (see Figure 7). The strength of the tension spring 122 enables the wire 50, when it moves at constant speed (as indicated by the arrow A in Figure 4), to rotate the wheels 114, 114' (as
15 indicated by the arrows B, B' in Figure 4) by means of the frictional force that exists at the tangential contact points between the wire 50 and the grooves 114c, 114c' of the wheels 114, 114'.

By friction also at their common tangential contact points, the lower wheel 114' rotates the two rings 110 that pass through the spaces 124 created by the
20 grooves 114b, 114b' (see Figure 6 which represents the portion I from Figure 5). The rings 110 turn in the direction of the arrow B' from Figure 4 and convey a certain amount of liquid to the point of contact between the wheels 114, 114' and the wire 50, which passes through an orifice 126 between the grooves 114c, 114c'. The liquid coats the wire 50 and the surplus liquid is conveyed to the tank 106 by
25 the rotation of the rings 110 and by the effect of gravity.

A uniform coating thickness is obtained on the wire 50 by the combined effects of the surface tension and the viscosity of the liquid on the one hand, and the surface energy of the wire on the other hand. The thickness of the layer of liquid measured on the wire 50, at the end of the liquid deposition process, mainly
30 depends on the viscosity of the liquid and on the run speed of the wire 50. In some embodiments, it is preferable for the thickness to be very fine (for example, around 10 μm), but the thickness of the liquid depends on the use for which the wire is intended.

If necessary, a calibration bushing 128 provided with an orifice at its centre

may be mounted in the compartment 108d' of the chamber 108 downstream of and as close as possible to the wheels 114, 114', in order to calibrate the thickness of the coating. In this case, the bushing 128 is "floatably" mounted in a housing 117 that blocks it in the direction of movement of the wire 50 but leaves it free in all
5 directions perpendicular to the movement of the wire. The hydrodynamic bearing effect ensures the centring of the calibration bushing 128 around the wire when the latter moves through the orifice of the calibration bushing. The diameter of the orifice is determined as a function of the final coating thickness that it is desired to obtain. The liquid removed by the calibration bushing falls back into the tank 106
10 by the effect of gravity.

At the inlet of the system 10, there are two different materials: a wire provided by a first system 300 and a liquid polymer solution 75 provided in a bottle 102. At the outlet of the system 10, a wire covered with a thin solid polymer layer is obtained. Besides the fact that it completely covers the wire, the polymer
15 layer has a certain degree of adhesion to the surface of the wire.

With reference to Figure 1, the wire 50 obtained from the deposition device 100 (by passing through the outlet wall 108c'') is transported to a heating device 400 in order to initiate the evaporation of the solvent from the liquid polymer layer deposited at the surface of the wire 50. The heating device 400 raises the
20 temperature of the wire 50 to a temperature sufficient to give rise to the evaporation of the solvent.

In the present invention, the evaporation of the solvent is obtained by the combined use of an increase in the temperature of the wire 50 and a reduction in the pressure in the space surrounding the wire by the creation of a partial vacuum
25 (typically between 10 mbar and 500 mbar) by means of an industrial vacuum pump (not represented). The partial vacuum makes it possible, on the one hand, to lower the boiling point of the solution and the evaporation temperature of the solvent and, on the other hand, to suck up the vapours in order to pass them, for example, into a condensation device and thus recover them for subsequent recycling. The
30 continuous movement of the wire 50 and also the existence of a partial vacuum which reduces the heat exchanges by convection between the wire and the atmosphere that surrounds it form significant difficulties for transmitting the energy necessary for increasing the temperature of the wire. To overcome these difficulties, the temperature of the wire is increased by means of an induction coil

positioned around the wire that implements the principle of induction heating known to a person skilled in the art. This heating means makes it possible to rapidly increase the temperature of the moving wire 50 without physical contact therewith and without the need for a medium between the energy source and the wire in order to transmit energy thereto by convection.

Since the complete evaporation of the solvent from the liquid polymer layer is not instantaneous, an additional supply of energy must be provided after the device 400 for the duration needed to obtain the complete evaporation of the solvent. This is why the wire obtained from the heating device 400 is transported to a temperature maintaining device 500, the role of which is to provide the necessary energy to the solvent so that it finishes evaporating (without this additional supply, the evaporation energy is taken from the wire with, as a consequence, a drop in its temperature since this portion of the wire is no longer at that moment in the zone of action of the heating device 400; if the amount of energy accumulated in the wire alone at the outlet of the heating device is insufficient, the evaporation of the solvent will not be complete). This external energy supply is transmitted to the surface of the wire by radiation and by convection of the residual molecules in the partial vacuum and is carried out by heating elements that are commercially available and known to a person skilled in the art.

The creation of a partial vacuum makes it necessary to achieve a tightness seal at the inlet and at the outlet of the devices passed through by the wire 50. For practical reasons, it is difficult to achieve this tightness seal when the wire is covered with a solution of polymer in the liquid state. This is the case for the section of wire that is just downstream of the inlet of the deposition device 100 and just upstream of the outlet of the temperature maintaining device 500. This is why the three devices 100, 400 and 500 are connected together in a leaktight manner with a free passage of the wire 50 from one to the other and the tightness seals with respect to the partial vacuum are positioned at the inlet of the deposition device 100 (tightness seal on the bare wire) and at the outlet of the temperature maintaining device 500 (tightness seal on the wire covered with solid polymer).

The invention disclosed describes a continuous process, which means that all the steps are carried out without interruption on a wire, the speed of travel of which is constant. This process may be placed upstream or downstream of any

other process that aims to carry out an operation prior or subsequent to the covering of the wire with a thin layer of solid polymer (subject matter of the invention described here) on condition that the speed of travel of the wire is common to all of the processes.

5 The system 10 may follow a programmed formula. For example, a central control centre may have been programmed with data (formulae) established for a plurality of polymer solutions and a plurality of wire sizes. One or more sensors and/or sensor types may potentially be used, including, without limitation, environmental sensors (for example, for detecting atmospheric conditions such as
10 temperature, pressure and/or humidity during the course of the process) and checking sensors (for example, for detecting a deviation in relation to a setpoint value). In this way, the invention makes it possible to treat a large variety of wires as a function of the targeted application.

 The dimensions expressed in imperial units are to be understood as
15 encompassing equivalent dimensions in metric and other units (for example, a dimension given as “1 inch” is intended to denote an equivalent dimension of “2.54 cm”).

 The terms “at least one” and “one or more” are used interchangeably. Ranges given as lying “between a and b” encompass the values of “a” and “b”.

20 Although particular embodiments of the disclosed apparatus have been illustrated and described, it will be appreciated that various changes, additions and modifications can be made without departing from either the spirit or scope of the present description. Thus, no limitation should be imposed on the scope of the invention described, except for the limitations set out in the attached claims.

CLAIMS

1. A process for coating the surface of a moving wire (50) with a thin solid polymer layer, wherein the process comprises the following steps:
 - 5 providing a deposition device (100) having a compartment (108d') of a chamber (108) that contains two rotatable rings (110) and two wheels including an upper wheel (114) and a lower wheel (114') having circumferential grooves (114b, 114b') in which the two rings (110) are lodged, and in which compartment the wheels (114, 114') are placed vertically on either side of the wire (50) by means of
10 the grooves (314c, 314c') such that a predetermined contact force between the wheels (114, 114') and the wire (50) makes it possible, by friction, when the wire (50) moves at constant speed, to rotate the wheels (114, 114') and, by means of the lower wheel (114'), the rings (110) too, and a tank (106) containing a liquid polymer solution (75);
15 conveying the wire (50) at a predetermined constant speed;
rotating the rotatable rings (110), these rings conveying an amount of the liquid polymer solution (75), and these rings bringing it to a point of tangential contact between the grooves (114c, 114c') of the wheels (114, 114') and the wire (50), which at the same time passes through an orifice (126) formed by the grooves
20 (114c, 114c') and located between the grooves (114b, 114b'), in order to coat the surface of the wire (50) while it is moving; and
evaporating the solvent from the liquid polymer solution (75) deposited at the surface of the wire (50).
- 25 2. A process according to claim 1, wherein the step of evaporating the solvent from the liquid polymer solution (75) deposited at the surface of the wire (50) comprises:
 - a process for increasing the temperature of the wire (50) in a heating device (400) until an evaporation temperature of the solvent is attained; and
30 a process for maintaining the temperature of the wire (50) in a temperature maintaining device (500) until the complete evaporation of the solvent is obtained.
3. A process according to claim 2, wherein the process for increasing

the temperature of the wire (50) is carried out by means of an induction coil in the heating device (400).

4. A process according to claim 2 or claim 3, additionally comprising
5 the step of creating a partial vacuum simultaneously in the spaces surrounding the wire (50) of the deposition device (100), of the heating device (400) and of the temperature maintaining device (500).

5. A process according to any one of claims 1 to 4, wherein a
10 surplus of the polymer solution (75) is conveyed to the tank (106).

6. A process according to claim 5, wherein the surplus of the polymer solution (75) is conveyed to the tank (106) by the rotation of the rings (110) and by the effect of gravity.

15

7. A process according to claim 5 or claim 6, additionally comprising a step of calibrating the thickness of the deposited layer of the polymer solution (75) by means of a calibration bushing (128) provided with an orifice at its centre and mounted in the compartment (108d') of the chamber (108) in order to make
20 the surplus of the polymer solution (75) fall into the tank (106).

8. A process according to any one of claims 1 to 7, additionally comprising the dipping of a lower portion (110a) of each ring (110) in the liquid polymer solution (75) by means of an opening (108e) in the bottom of the compartment
25 (108d') of the chamber (108) that corresponds with at least one portion of the tank (106).

9. A system (10) for producing a wire (50) coated with a layer of solid polymer using a chosen polymer dissolved in a liquid solvent, the system (10)
30 comprising a series of devices (100, 400, 500) that together define a process according to any one of Claims 1 to 8.

10. A system (10) according to claim 9, wherein the series of devices (100, 400, 500) comprises the deposition device (100) that carries out a process for

depositing liquid polymer solution on the surface of the wire (50) while it is moving.

11. A system (10) according to claim 10, wherein the series of devices
5 comprises:
a heating device (400) that increases the temperature of the wire (50) to initiate the evaporation of the solvent from the layer deposited on the wire (50);
and
a temperature maintaining device (500) that maintains the temperature of
10 the wire (50) until the complete evaporation of the solvent is obtained.

12. A system (10) according to claim 11, wherein the devices (100, 400, 500) are connected together in a leaktight manner with a free passage of the wire (50) from one to the other, and the tightness seals with respect to a partial vacuum
15 are positioned at the inlet of the deposition device (100) and at the outlet of the temperature maintaining device (500).

13. A wire (50) coated according to a process according to any one of claims 1 to 8.
20

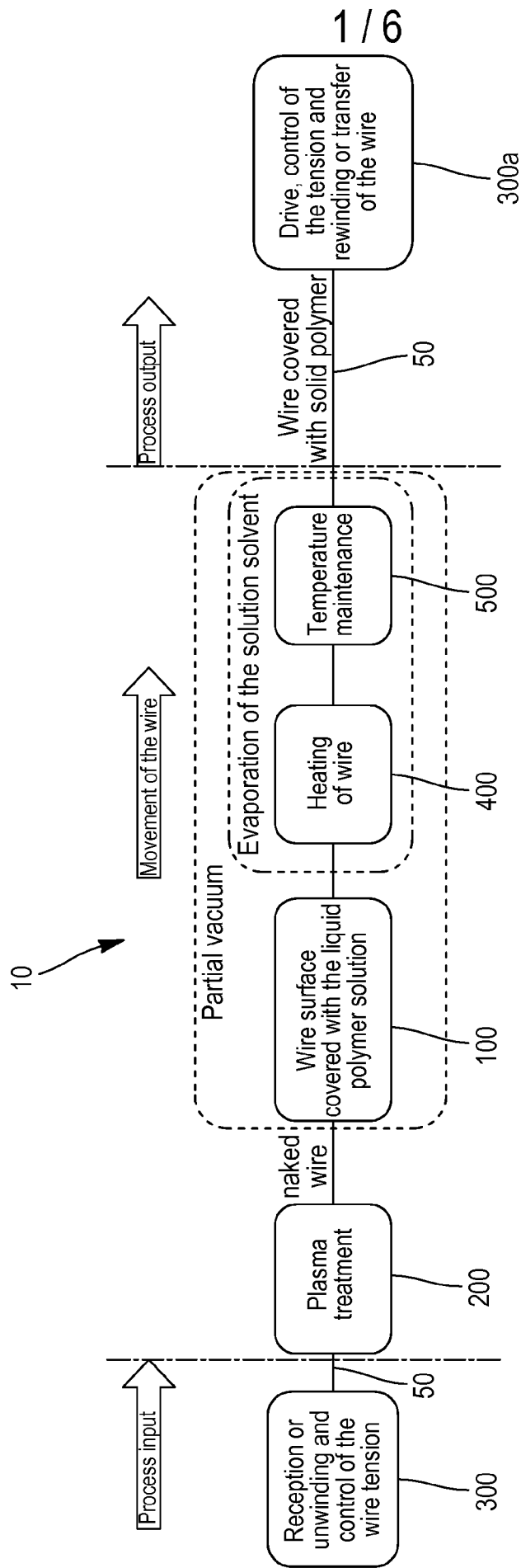


FIG. 1

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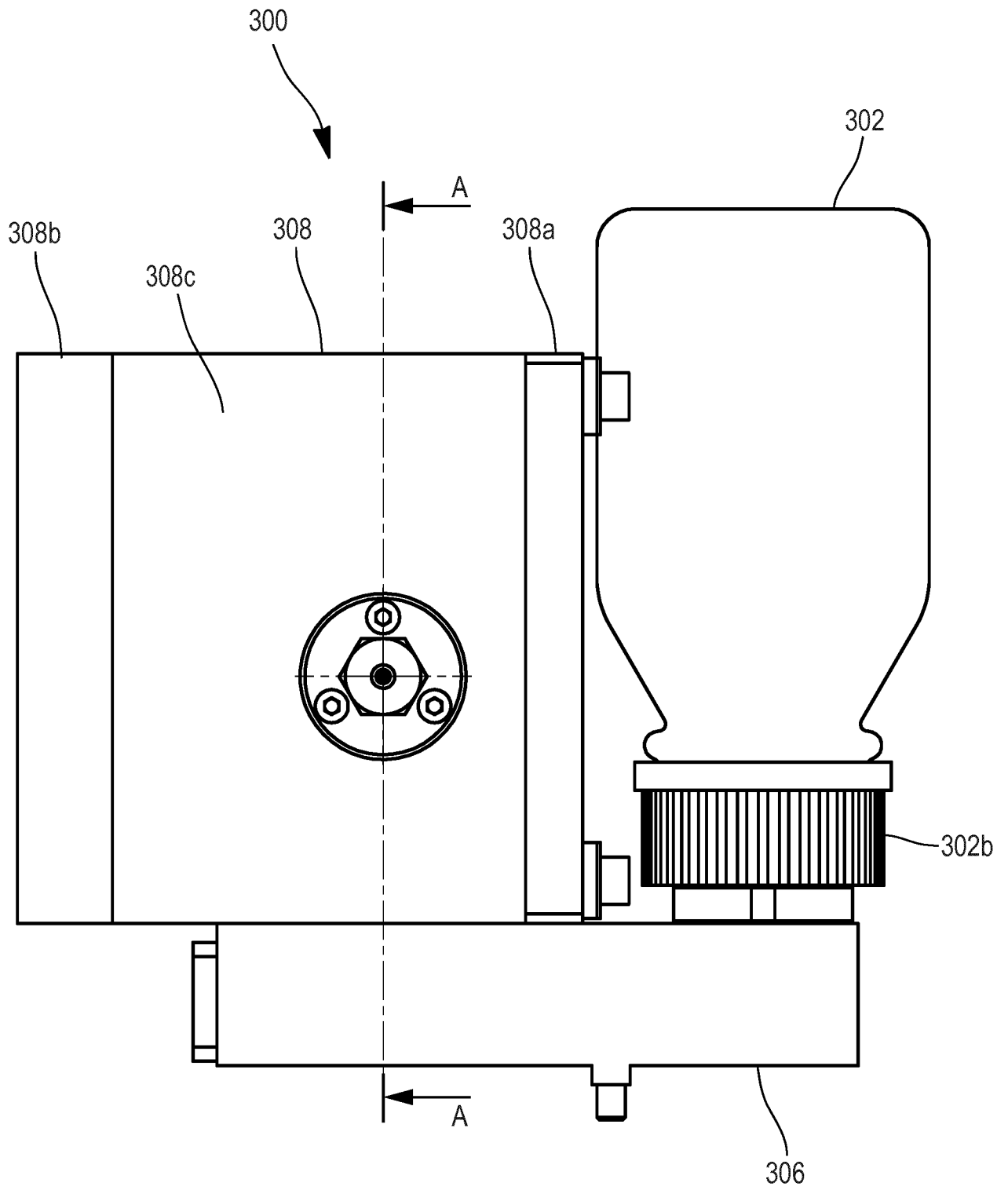
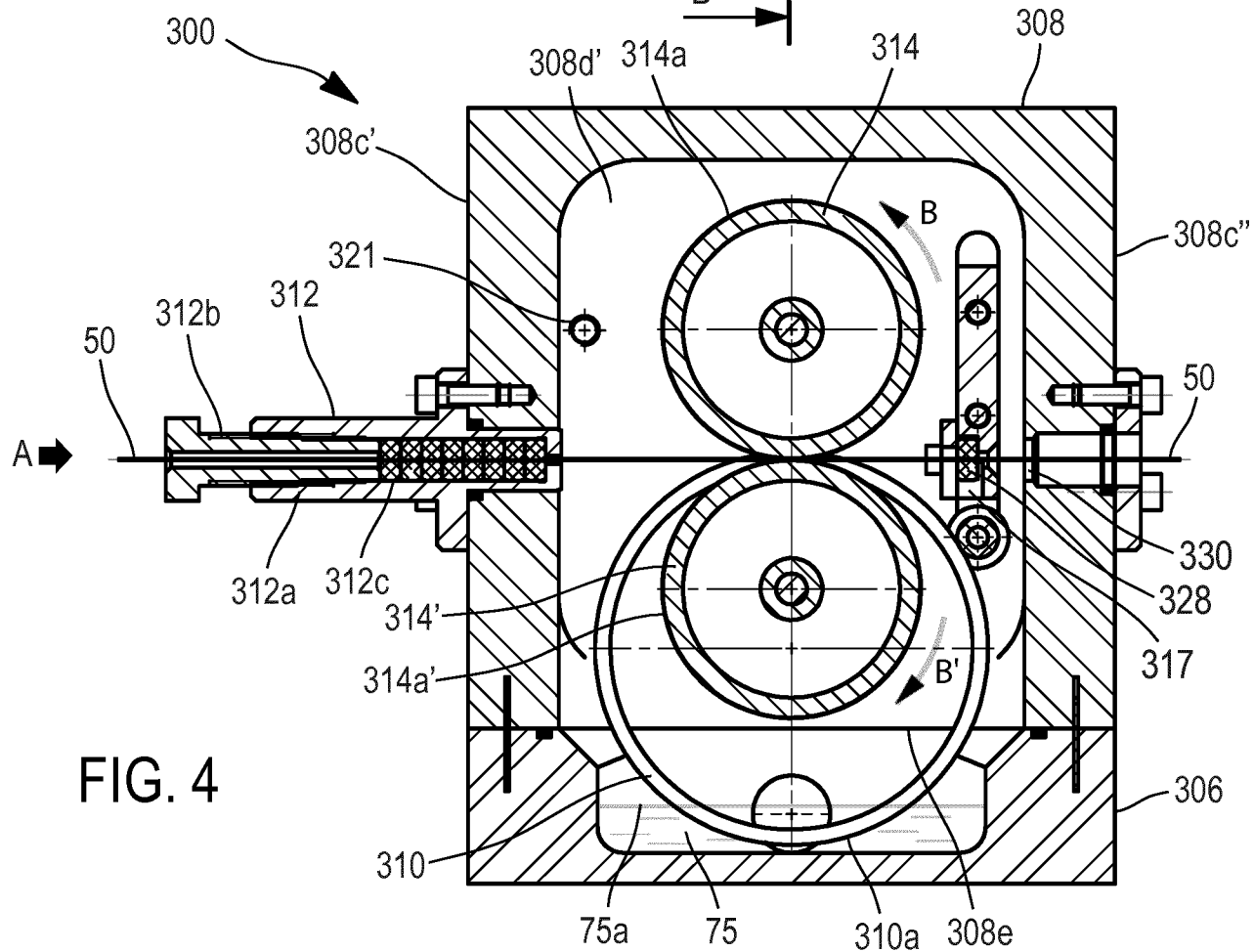
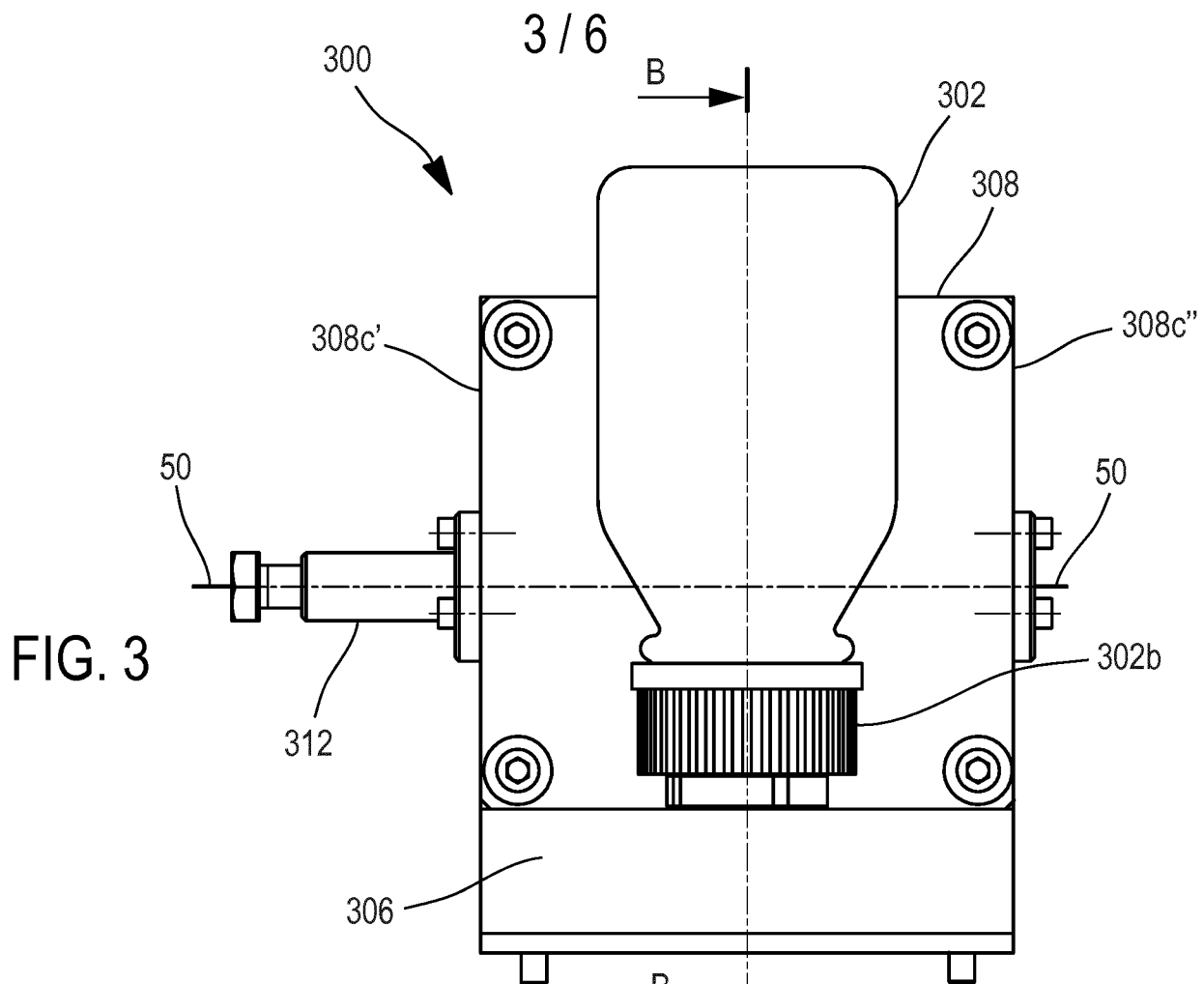


FIG. 2



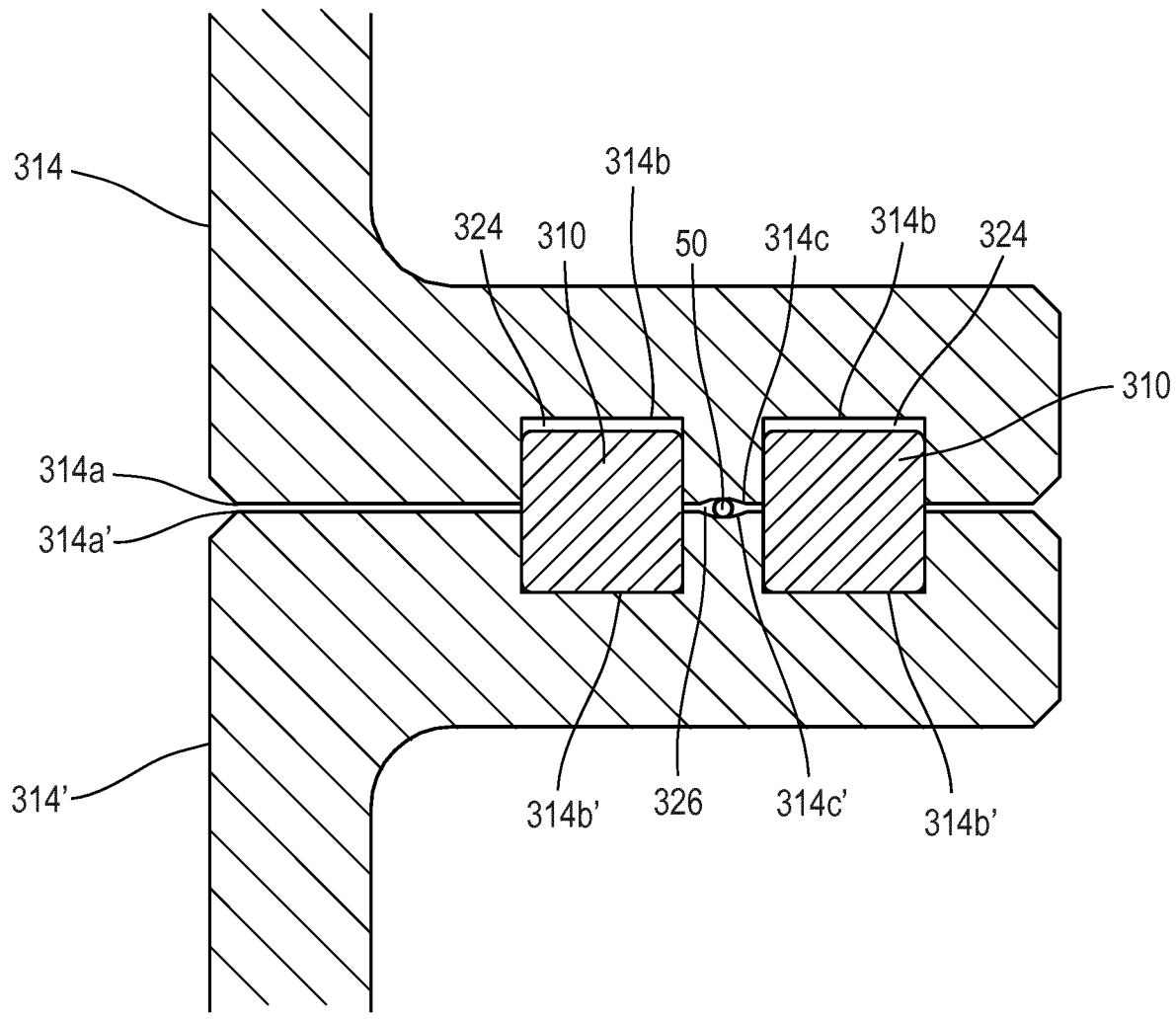


FIG. 6

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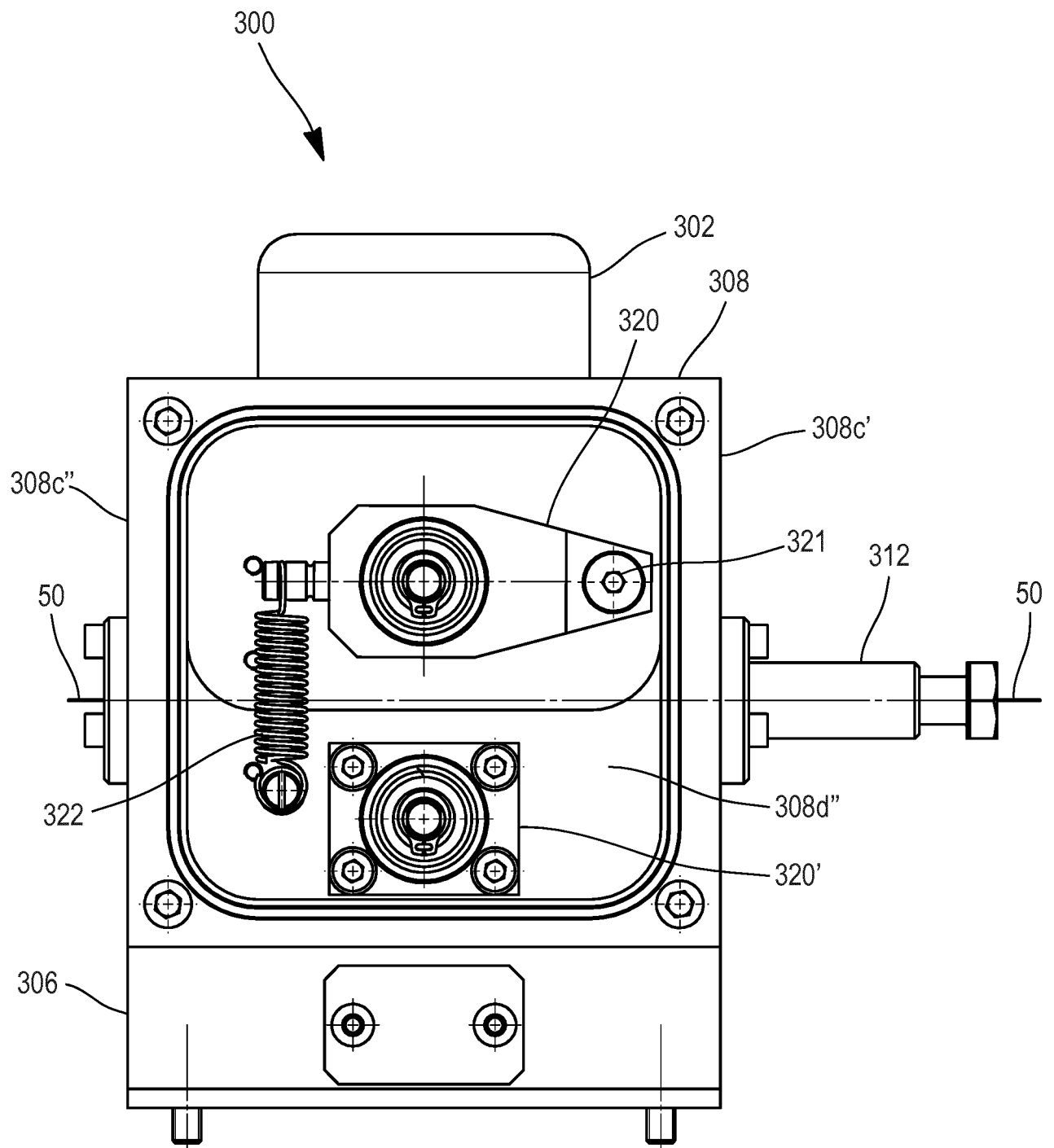


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/078551

A. CLASSIFICATION OF SUBJECT MATTER

INV. B05C1/08 B05D1/28 B05D7/20 D06B1/14 D07B7/14
B29B15/14 B05D3/02 H01B13/06 B05D3/04 B05C9/14
ADD. B05C3/12 B05C11/02

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)

B05C B65H D07B D06B B05D H01B B29B

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.
X A	BE 624 114 A (MANUFACTURE D' EPINGLES ET D'AIGUILLES) 15 February 1963 (1963-02-15) page 2 - page 4; figures -----	13 1,9
X A	FR 1 384 410 A (THOMSON HOUSTON COMP FRANCAISE) 4 January 1965 (1965-01-04) page 2, left-hand column, last line - page 2, right-hand column, paragraph 2; figures 1-2 -----	13 1,9
X A	US 2014/110147 A1 (ELIE LARRY DEAN [US] ET AL) 24 April 2014 (2014-04-24) paragraphs [0035] - [0038]; figures 3-5 -----	13 1,9



Further documents are listed in the continuation of Box C.



See patent family annex.

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Information on patent family members

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