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(71) Applicant: **Jokoh Co., Ltd**  
**Tokyo 113-0033 (JP)**

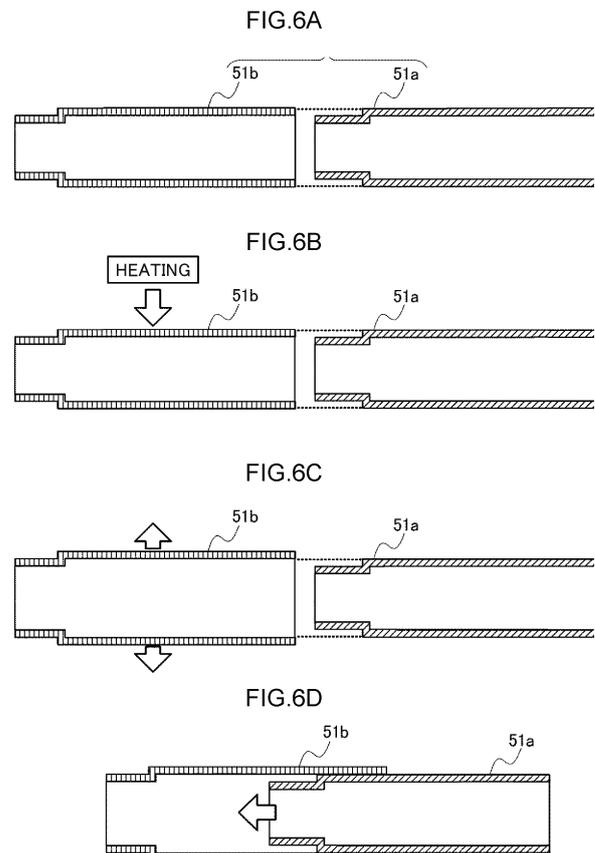
(72) Inventor: **SANO, Keiichi**  
**Kawasaki-shi, Kanagawa 213-8588 (JP)**

(74) Representative: **Berggren Oy**  
**P.O. Box 16**  
**Eteläinen Rautatiekatu 10A**  
**00101 Helsinki (FI)**

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(54) **METHOD FOR MANUFACTURING PLUNGER PUMP AND PLUNGER PUMP**

(57) A method of manufacturing a plunger pump includes a temperature difference generation process of generating a difference in temperature with respect to a normal temperature state for either one of an outer cylinder or an inner cylinder, a cylinder insertion process of inserting the inner cylinder inside the outer cylinder in a state in which the inner cylinder has a smaller outer diameter than an inner diameter of the outer cylinder as a result of the temperature difference generated by the temperature difference generation process, an elimination process of eliminating the generated temperature difference, and a plunger placement process of placing a circular tube-shaped plunger in a pressure chamber of the inner cylinder so as to enable of reciprocating motion by the plunger.



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## Description

### Technical Field

**[0001]** The present disclosure relates to a method of manufacturing a plunger pump and a plunger pump.

### Background Art

**[0002]** Known homogenizer units used to pulverize and homogenize a preparation include pulverizer units.

**[0003]** As an example of such a pulverizer unit, Japanese Patent No. 3149371 discloses a configuration including a pulverizer formed with an internal pulverization flow path. A preparation fed from a container is fed into and passed through the pulverization flow path of the pulverizer by a high pressure pump in order to homogenize the preparation.

## SUMMARY OF INVENTION

### Technical Problem

**[0004]** However, in the invention disclosed in the above-described literature, a cylinder configuring the pump may be subject to deterioration fatigue due to the pump applying pressure to the preparation.

**[0005]** In consideration of the above circumstances, an object of the present disclosure is to provide a method of manufacturing a plunger pump that improves the durability of a pump with respect to internal pressure from a preparation, and a plunger pump manufactured using this method of manufacturing.

### Solution to Problem

**[0006]** In order to address the above issue, a method of manufacturing a plunger pump according to one aspect of the present disclosure is a method of manufacturing a plunger pump for connection to a pulverizer. The pulverizer includes a pulverization flow path through which a preparation is passed in order to pulverize the preparation, and the plunger pump is configured to feed the preparation into the pulverizer under high pressure and is configured from an outer cylinder and an inner cylinder formed with a circular tube-shaped pressure chamber. The method includes a temperature difference generation process of generating a difference in temperature with respect to a normal temperature state for either one of the outer cylinder or the inner cylinder, a cylinder insertion process of inserting the inner cylinder inside the outer cylinder in a state in which the inner cylinder has a smaller outer diameter than an inner diameter of the outer cylinder as a result of the temperature difference generated by the temperature difference generation process, an elimination process of eliminating the generated temperature difference, and a plunger placement process of placing a circular tube-shaped plunger in the pressure

chamber of the inner cylinder so as to enable of reciprocating motion by the plunger.

**[0007]** The method of manufacturing described above may be configured such that the temperature difference generation process includes a heating process of heating the outer cylinder, in the cylinder insertion process, the inner cylinder is inserted into the outer cylinder in a state in which the inner diameter of the outer cylinder has become larger than the outer diameter of the inner cylinder, and the elimination process includes a cooling process of cooling the outer cylinder.

**[0008]** The method of manufacturing described above may be configured such that the temperature difference generation process includes a cooling process of cooling the inner cylinder, in the cylinder insertion process, the inner cylinder is inserted into the outer cylinder in a state in which the outer diameter of the inner cylinder has become smaller than the inner diameter of the outer cylinder, and the elimination process includes a heating process of heating the inner cylinder.

**[0009]** The method of manufacturing described above may be configured such that the temperature difference generation process includes a heating process of heating the outer cylinder, and a cooling process of cooling the inner cylinder, in the cylinder insertion process, the inner cylinder is inserted into the outer cylinder in a state in which the inner diameter of the outer cylinder has become larger than the outer diameter of the inner cylinder, and the elimination process includes a cooling process of cooling the outer cylinder, and a heating process of heating the inner cylinder.

**[0010]** The method of manufacturing described above may be configured such that the inner cylinder is press-fitted inside the outer cylinder in the cylinder insertion process.

**[0011]** Furthermore, in order to address the above issue, a plunger pump according to one aspect of the present disclosure is a plunger pump for connection to a pulverizer, the pulverizer including a pulverization flow path through which a preparation is passed in order to pulverize the preparation, and the plunger pump being configured to feed the preparation into the pulverizer under high pressure. The plunger pump includes an outer cylinder, an inner cylinder that is inserted inside the outer cylinder and that is formed with a circular tube-shaped internal pressure chamber, and a circular tube-shaped plunger that is placed in the pressure chamber of the inner cylinder so as to be capable of reciprocating motion. The inner cylinder is configured so as to be compressed by the outer cylinder.

**[0012]** Advantageous Effects of Invention

**[0013]** The method of manufacturing the plunger pump of the present disclosure is used to manufacture the plunger pump including the cylinder configured from the outer cylinder and the inner cylinder. Placing either the outer cylinder or the inner cylinder at a different temperature to a normal temperature state causes a change in size. While the size is changed, the inner cylinder is in-

serted into the outer cylinder. On returning to the normal temperature state, the cylinder can thereby be configured in a state in which the outer cylinder constantly applies external pressure to the inner cylinder. Internal pressure from the preparation passing through the cylinder under high pressure can accordingly be counteracted, enabling metal fatigue in the cylinder configuring the plunger to be suppressed.

#### BRIEF DESCRIPTION OF DRAWINGS

##### [0014]

Fig. 1 is a conceptual diagram illustrating an example of configuration of a pulverizer unit.

Fig. 2 is a cross-section illustrating a structure of an orifice homogenizer.

Fig. 3A to Fig. 3C are radial direction cross-sections of an orifice homogenizer.

Fig. 4 is an enlarged illustration of a plunger pump.

Fig. 5 is a flowchart illustrating a method of manufacturing a plunger pump.

Fig. 6A to Fig. 6D illustrate manufacturing processes of a plunger pump.

Fig. 7A to Fig. 7C illustrate manufacturing processes of a plunger pump as a continuation from Figs. 6D.

Fig. 8 is a flowchart illustrating an alternative method of manufacturing a plunger pump.

Fig. 9A to Fig. 9D illustrate alternative manufacturing processes of a plunger pump.

Fig. 10A to Fig. 10C illustrate alternative manufacturing processes of a plunger pump as a continuation from Figs. 9D.

#### DESCRIPTION OF EMBODIMENTS

[0015] Detailed explanation follows regarding embodiments of a plunger pump and a method of manufacturing a plunger pump according to the present disclosure, with reference to the drawings.

[0016] Fig. 1 is a conceptual diagram schematically illustrating an example of configuration of a pulverizer unit 1 in which a plunger pump is employed. As illustrated in Fig. 1, the pulverizer unit 1 is a homogenizer unit used to pulverize and homogenize a preparation. The pulverizer unit 1 includes a pulverizer 10, a feed hopper 30, a collection hopper 31, and pipes 40, 41, 42, 43 that connect these elements together.

[0017] The pulverizer 10 includes a pulverization flow path. The preparation is pulverized by passing the preparation through the interior of the pulverization flow path. The pulverizer 10 may also be referred to as an orifice homogenizer, or simply an orifice. Detailed explanation follows regarding the structure of the pulverizer 10, with reference to Fig. 2 and Fig. 3.

[0018] Fig. 2 is a vertical cross-section of the pulverizer 10. Fig. 3A is a cross-section along line A-A in Fig. 2, Fig. 3B is a cross-section along line B-B in Fig. 2, and Fig.

3C is a cross-section along line C-C in Fig. 2.

[0019] The pulverizer 10 is formed of a first block 21, a second block 22, and a third block 23 interposed between the first block 21 and the second block 22. Plural flow channels 11, 12 are formed in the first block 21 (see Fig. 2 and Fig. 3A). Likewise, plural flow channels 18, 19 are formed in the second block 22.

[0020] A first void 14 is intentionally formed at joined faces of the first block 21 and the third block 23. The first void 14 forms a merging area 13 where the plural flow channels 11, 12 merge into one (see Fig. 2 and Fig. 3B). The third block 23 is on the opposite side of the merging area 13 (first void 14) to the flow channels 11, 12 in the flow path direction. An orifice flow channel 15 is formed inside the third block 23 (see Fig. 2 and Fig. 3C).

[0021] A second void 16 is intentionally formed at joined faces of the third block 23 and the second block 22 at a downstream side of the orifice flow channel 15. The orifice flow channel 15 branches at the second void 16, forming a junction 17 that is connected to the plural flow channels 18, 19. Namely, the pulverization flow path is configured by the flow channels 11, 12, the orifice flow channel 15, and the flow channels 18, 19.

[0022] Each of the flow channels 11, 12 and the flow channels 18, 19 has the same internal diameter (D1), this being larger than an internal diameter (D2) of the orifice flow channel 15. Specifically, the internal diameter (D1) is five to seven times as large as the internal diameter (D2). The size (D3) of the first void 14 is set so as to be the same as the internal diameter (D1). The orifice flow channel 15 therefore configures a reduced diameter flow channel.

[0023] Next, explanation follows regarding operation of the pulverizer 10 when in use. A preparation configured by a processing target material dispersed in an organic solvent enters the merging area 13 (the first void 14) via the flow channels 11, 12. Note that since the orifice flow channel 15 is narrower than the flow channels 11, 12, the flow rate of the preparation is reduced by the orifice flow channel 15. This results in a change in the pressure of the preparation (fluid conveyed under pressure), and the preparation flowing into the merging area 13 from the respective flow channels 11, 12 collides in the merging area 13. When this occurs, the processing target material present in the preparation is broken up by the energy of these collisions. In this manner, as the preparation flows from the flow channels 11, 12 into the orifice flow channel 15, repeated collisions between the processing target material in the preparation causes the preparation to be ground down.

[0024] Although two of the flow channels 11, 12 and two of the flow channels 18, 19 are formed in the drawings, at least one of the flow channels 11, 12 and at least one of the flow channels 18, 19 would be sufficient as long as the preparation is able to flow. However, in order to promote collisions between the processing target material in the preparation, it is preferable to form two or more of the flow channels 11, 12 and two or more of the

flow channels 18, 19.

**[0025]** Returning to Fig. 1, the feed hopper 30 feeds the preparation into the pulverization flow path. The feed hopper 30 is provided at the furthestmost upstream side of the pulverization flow path, and is connected to a valve 71 via the pipe 40 as illustrated. The feed hopper 30 is filled with preparation that has not yet been pulverized, and preparation that has not yet been sufficiently pulverized after passing along the pulverization flow path, as illustrated by the arrow in Fig. 1. Note that the transfer from the collection hopper 31 to the feed hopper 30 is not illustrated in detail in Fig. 1.

**[0026]** The collection hopper 31 is a container from which the preparation is collected once the preparation has been completely homogenized.

**[0027]** Note that the pulverizer unit 1 does not necessarily have to include (may be configured with) the collection hopper 31, and homogenized preparation may be collected from a drain 86 or the like via the pipe 40. Fig. 1 illustrates a configuration in which both the collection hopper 31 and the drain 86 are provided.

**[0028]** A plunger pump 51 is connected to both the valve 71 and the pulverizer 10 through the pipe 40. Opening the valve 71 allows the preparation to flow from the feed hopper 30 into the pipe 41. Closing the valve 71 enables the preparation from the feed hopper 30 to be prevented from flowing into the pipe 41, and also enables preparation that has been pumped out from the plunger pump 51 to be prevented from flowing back toward the feed hopper 30.

**[0029]** The plunger pump 51 is configured by a cylinder 51A and a plunger 51B. The inside of the cylinder is filled with the preparation, and the preparation inside the cylinder is expelled from the cylinder, by reciprocating motion of the plunger inside the cylinder. Fig. 4 is an enlarged illustration of the plunger pump 51.

**[0030]** Fig. 4 is a partial cross-section conceptually illustrating the plunger pump. Although Fig. 4 is an enlarged schematic diagram of the plunger pump 51, plunger pumps 52, 53 also have a similar structure. As illustrated in Fig. 4, in the plunger pump according to the present exemplary embodiment, the cylinder 51A is configured of an inner cylinder 51a and an outer cylinder 51b. Namely, the cylinder 51A has a double-layered structure. The cylinder 51A is configured in a state in which the inner cylinder 51a is constantly applied with external pressure from the outer cylinder 51b. Namely, the inner cylinder 51a is configured by a member that has a larger outer diameter than an inner diameter of the outer cylinder 51b in a state in which the inner cylinder 51a has not been inserted into the outer cylinder 51b. Namely, the cylinder 51A is configured in a state in which the inner cylinder 51a is compressed by the outer cylinder 51b. Note that the inner cylinder 51a is preferably configured of a material with a greater hardness (that is harder) than the outer cylinder 51b. As an example, SUS630 may be employed for the inner cylinder 51a, although there is no limitation thereto. The outer cylinder 51b is

preferably configured of a material that is somewhat softer than the inner cylinder 51a, that has elastic properties, and that fulfills a function of constricting the inner cylinder 51a. As an example, SUS316 or the like may be employed for the outer cylinder 51b, although there is no limitation thereto.

**[0031]** The plunger 51B is inserted into and placed inside the cylinder 51A so as to undergo reciprocating motion inside the cylinder 51A. The plunger 51B undergoes reciprocating motion in the direction of the arrows in Fig. 4 due to rotation of a crank mechanism. This enables the plunger pump 51 to draw in the preparation from the pipe 41, and to pump out the preparation into the pipe 41.

**[0032]** A valve 73 and a valve 75 are also connected to the pulverizer 10 through the pipe 43. Opening the valve 73 allows the preparation to flow from the pulverizer 10 into the pipe 43. Closing the valve 73 enables preparation from the pulverizer 10 to be prevented from flowing out into the pipe 43. Opening the valve 75 allows the preparation to flow out from the pulverizer 10 through the drain 86. Closing the valve 75 enables the preparation to be prevented from flowing out from the pulverizer 10 toward the drain 86.

**[0033]** The pipe 43 is connected to the valve 73, and the pipe 43 is also connected to the collection hopper 31. A heat exchanger 80 may be provided to the pipe 43. The heat exchanger 80 has a function of removing heat in cases in which the preparation has warmed up as a result of the pulverization process by the pulverizer 10.

**[0034]** The pulverizer unit 1 may also include a control section (not illustrated in the drawings) that controls the plunger pump 51, opening and closing of the respective valves 71, 73, 75, and so on. Such a control section controls the plunger pump 51 and opening and closing of the respective valves 71, 73, 75 such that the preparation flows around the pulverization flow path of the pulverizer unit 1 in a loop until the preparation has reached a target particle size.

**[0035]** Explanation follows regarding a processing sequence for pulverizing a preparation using the pulverizer unit 1 configured as described above.

**[0036]** First, the processing target material is dispersed in an organic solvent in order to form the preparation. This dispersion is performed in the feed hopper 30.

**[0037]** A wide variety of substances may be applied as the processing target material to be broken down, including cellulose, graphite, graphene, carbon nanotubes, or composite metal oxides (crystalline substances such as spinel or perovskite). Performing dispersal when breaking down results in greater uniformity of dispersion when mixing with a resin or the like. Enhanced material performance may be expected as a result.

**[0038]** Next, the valve 71 is opened and the plunger 51B is pulled out from inside the cylinder 51A, such that the preparation fills the inside of the cylinder 51A of the plunger pump 51. The valve 71 is then closed, and the plunger 51B is pushed into the cylinder 51A in this state, such that the preparation is fed (pumped out under high

pressure) into the pulverizer 10 through the pipe 41.

**[0039]** In cases in which the preparation has not yet been sufficiently pulverized, the valve 73 is placed in an open state and the valve 75 is placed in a closed state at the timing at which the plunger 51B is pushed in. After passing through the pulverizer 10 with the structure previously described, the pulverized (homogenized) preparation is fed into the collection hopper 31 through the pipe 42, the valve 73, and the pipe 43. When this occurs, heat of the preparation passing through the pipe 43 may be dissipated by the heat exchanger 80 as required. The preparation fed into the collection hopper 31 is then fed back to the feed hopper 30 to undergo another round of pulverization processing.

**[0040]** The preparation is passed through the pulverization flow path plural times by repeating the above operation plural times. Namely, the preparation is pulverized plural times, and a homogenized preparation is achieved. Note that this processing may be executed by a control section provided to the pulverizer unit 1, or executed by a control section configured to receive instructions from an operator.

**[0041]** In cases in which the preparation has been sufficiently pulverized, the preparation fed into the collection hopper 31 may be collected, or the valve 73 may be placed in a closed state and the valve 75 placed in an open state at the timing at which the plunger 51B is pushed in, in order to collect the preparation via the drain 86.

#### Method of Manufacturing Plunger Pump

**[0042]** Fig. 5 is a flowchart illustrating a method of manufacturing the plunger pump illustrated in Fig. 4. Figs. 6A to 6D and Figs. 7A to 7C illustrate the plunger pump being manufactured according to the procedure illustrated in Fig. 5. Explanation follows regarding the method of manufacturing the plunger pump 51, with reference to Fig. 5 to Figs. 7C. During manufacture of the plunger pump 51, a temperature difference with respect to a normal temperature state is generated in either one of the outer cylinder 51b or the inner cylinder 51a, such that the size of the corresponding cylinder becomes larger (or smaller) than normal, and thereby allowing the inner cylinder 51a to be inserted into the outer cylinder 51b. In a first exemplary embodiment, the outer cylinder 51b is heated so as to expand in size, thereby allowing the inner cylinder 51a to be inserted therein. Specific explanation follows regarding this.

**[0043]** First, as illustrated in Fig. 6A, the inner cylinder 51a and the outer cylinder 51b are prepared such that the outer diameter of the inner cylinder 51a is equal to or greater than the inner diameter of the outer cylinder 51b. A material that undergoes thermal expansion is employed for the outer cylinder 51b.

**[0044]** The prepared outer cylinder 51b is then subjected to heating (step S501 in Fig. 5). As illustrated in Fig. 6B, this heating is only performed with respect to the

outer cylinder 51b. During this heating, the outer cylinder 51b is heated to a level that causes the outer cylinder 51b to expand without suffering from heat damage. As illustrated by the arrows in Fig. 6C, the outer cylinder 51b undergoes thermal expansion as a result of this heating. The inner diameter of the outer cylinder 51b is enlarged (extended) as a result. This enables the inner cylinder 51a to be easily press-fitted inside the outer cylinder 51b.

**[0045]** As illustrated in Fig. 6D, the inner cylinder 51a is then inserted (press-fitted) into the outer cylinder 51b that has undergone thermal expansion (see also step S502 in Fig. 5). Fig. 7A illustrates the cylinder 51A in a state in which insertion of the inner cylinder 51a into the outer cylinder 51b is complete.

**[0046]** After insertion of the inner cylinder 51a into the outer cylinder 51b is complete, the outer cylinder 51b is then subjected to cooling to return the expanded outer cylinder 51b to its original state, namely a non-expanded state (see step S503 in Fig. 5, and Fig. 7B). In consideration of the potential for metal fatigue resulting from this heating and cooling of the outer cylinder 51b, this cooling is preferably natural cooling; however, there is no limitation thereto. Namely, the outer cylinder 51b may be cooled by artificial cooling, or may be cooled by natural cooling. One conceivable example of artificial cooling is to immerse the cylinder 51A in a water-filled tank; however, any method may be employed as long as the outer cylinder 51b can be cooled without damage.

**[0047]** The outer cylinder 51b returns to its original dimensions as a result of being cooled. The cylinder 51A therefore has a structure in which the outer cylinder 51b is constantly constricting the inner cylinder 51a from the outside thereof. During operation of the pulverizer, the preparation flows inside the cylinder 51A under high pressure. This outward-acting pressure from the preparation on the cylinder has the potential to hasten metal fatigue of the cylinder. However, in the case of the cylinder 51A of the present embodiment, external pressure from the outer cylinder 51b acts on the inner cylinder 51a. The external pressure from the outer cylinder 51b counteracts the internal pressure of the preparation flowing inside the inner cylinder 51a, thereby spreading the pressure acting on the inner cylinder 51a. As described in the present exemplary embodiment, the cylinder 51A is configured with a double-layered structure in which the outer cylinder 51b applies external pressure to the inner cylinder 51a, thereby enabling the ability of the cylinder 51A to withstand the internal pressure from the preparation flowing inside to be improved in comparison to hitherto, and also enabling the degree of fatigue to be reduced in comparison to hitherto.

**[0048]** When cooling of the outer cylinder 51b is complete, next, the plunger 51B is inserted into the cylinder 51A (see step S504 in Fig. 5, and Fig. 7C). The plunger pump 51 can be manufactured in the above manner.

## Second Exemplary Embodiment

**[0049]** In the first exemplary embodiment, the outer cylinder 51b is heated and made to expand so as to allow insertion of the inner cylinder 51a, after which the outer cylinder 51b is cooled and returned to its original size such that external pressure acts on the inner cylinder 51a. A second exemplary embodiment describes an alternative example of a method of manufacturing the cylinder 51A.

**[0050]** In the first exemplary embodiment, the outer cylinder 51b is made larger than its normal size by being heated so as to allow insertion of the inner cylinder 51a. By contrast, in the second exemplary embodiment explanation is given regarding a method of manufacturing in which the inner cylinder 51a is made smaller in size so as to enable insertion into the outer cylinder 51b.

**[0051]** Fig. 8 is a flowchart illustrating the method of manufacturing the plunger pump 51 according to the second exemplary embodiment. Fig. 9 and Fig. 10 illustrate the method of manufacturing set out in the flowchart illustrated in Fig. 8.

**[0052]** First, as illustrated in Fig. 9A, the inner cylinder 51a and the outer cylinder 51b are prepared such that the outer diameter of the inner cylinder 51a is equal to or greater than the inner diameter of the outer cylinder 51b. A material whose dimensions shrink when cooled is employed as the inner cylinder 51a.

**[0053]** The prepared inner cylinder 51a is then subjected to cooling (step S801 in Fig. 8). As illustrated in Fig. 8B, the cooling is only performed on the inner cylinder 51a. During this cooling, the inner cylinder 51a is cooled to a level that causes the inner cylinder 51a to contract without suffering damage (deterioration) as a result of the cooling. As illustrated by the arrows in Fig. 9C, the inner cylinder 51a contracts as a result of this cooling. The outer diameter of the inner cylinder 51a shrinks (becomes smaller) as a result. This enables the inner cylinder 51a to be easily press-fitted inside the outer cylinder 51b.

**[0054]** As illustrated in Fig. 9D, the contracted inner cylinder 51a is then inserted (press-fitted) into the outer cylinder 51b (see also step S802 in Fig. 8). Fig. 10A illustrates the cylinder 51A in a state in which insertion of the inner cylinder 51a into the outer cylinder 51b is complete.

**[0055]** After insertion of the inner cylinder 51a into the outer cylinder 51b is complete, the inner cylinder 51a is then subjected to heating so as to return the contracted inner cylinder 51a to its original state, namely a non-contracted state (see step S803 in Fig. 8, and Fig. 10B). In consideration of the potential for metal fatigue resulting from this cooling and heating of the inner cylinder 51a, this heating is preferably natural warming (waiting until the inner cylinder 51a naturally returns to normal temperature); however, there is no limitation thereto.

Namely, the inner cylinder 51a may be heated by artificial heating. One conceivable method of artificial cooling is

to immerse the cylinder 51A in a tank filled with warm water; however, any method may be employed as long as the inner cylinder 51a can be heated without damage. Note that it is preferable that the outer cylinder 51b does not expand during this heating.

**[0056]** The inner cylinder 51a returns to its original dimensions as a result of being heated. On the other hand, the outer cylinder 51b remains at its original size throughout. The cylinder 51A therefore has a structure in which the outer cylinder 51b is constantly constricting the inner cylinder 51a from the outside thereof. During operation of the pulverizer, the preparation flows inside the cylinder 51A under high pressure. This outward-acting pressure from the preparation on the cylinder has the potential to hasten metal fatigue of the cylinder. However, in the case of the cylinder 51A of the present embodiment, external pressure from the outer cylinder 51b acts on the inner cylinder 51a. The external pressure from the outer cylinder 51b counteracts the internal pressure from the preparation flowing inside the inner cylinder 51a, thereby spreading the pressure acting on the inner cylinder 51a. As described in the present exemplary embodiment, the cylinder 51A is configured with a double-layered structure in which the outer cylinder 51b applies external pressure to the inner cylinder 51a, thereby enabling the ability of the cylinder 51A to withstand the internal pressure from the preparation flowing inside to be improved in comparison to hitherto, and also enabling the degree of metal fatigue in the cylinder 51A to be reduced in comparison to hitherto.

**[0057]** When heating of the inner cylinder 51a is complete, next, the plunger 51B is inserted into the cylinder 51A (see step S804 in Fig. 8, and Fig. 10C). The plunger pump 51 can be manufactured in the above manner.

## Modified Examples

**[0058]** In the first exemplary embodiment, the inner cylinder 51a is inserted into the outer cylinder 51b after causing the outer cylinder 51b to expand by heating, whereas in the second exemplary embodiment, the inner cylinder 51a is inserted into the outer cylinder 51b after causing the inner cylinder 51a to contract by cooling. However, as long as the inner cylinder 51a can be inserted into the outer cylinder 51b that has an inner diameter smaller than the outer diameter of the inner cylinder 51a, an approach other than heating or cooling may obviously be employed. For example, a robotic machine or the like may be employed to mechanically grip the outer cylinder 51b, and press-fit the inner cylinder 51a therein. Press-fitting the inner cylinder 51a into the outer cylinder 51b in this manner enables an equivalent configuration to that of the cylinder 51A of the first and second exemplary embodiments to be realized.

**[0059]** Moreover, by manufacturing the cylinder 51A using the above-described methods, a configuration is achieved in which the outer cylinder 51b applies pressure to the inner cylinder 51a in a normal state. Such a con-

figuration resists the internal pressure of the inner cylinder 51a when the pulverizer is operating as described previously. As long as external pressure is made to act on the inner cylinder 51a, other configurations may be employed. For example, an additional device may be provided in order to apply external pressure to the cylinder 51A when the pulverizer is operational. For example, a hydraulic device may be attached to the cylinder 51A so as to apply external pressure to the cylinder 51A during operation of the pulverizer, or a device such as a vice may be employed to apply external pressure to the cylinder 51A.

Summary

**[0060]** As described above, the method of manufacturing the plunger pump and the plunger pump according to the above exemplary embodiments enable the provision of a plunger pump including the cylinder 51A configured such that the outer cylinder 51b constantly applies external pressure to the inner cylinder 51a. Thus, the pressure acting on the inner cylinder 51a from the outer cylinder 51b opposes the internal pressure from the preparation flowing under high pressure inside the cylinder 51A of the plunger pump 51, thereby enabling the degree of fatigue in the cylinder 51A to be reduced in comparison to hitherto.

**[0061]** Note that although the preparation only flows in one direction in the pulverizer unit 1 in the above exemplary embodiments, a configuration in which the preparation flows back and forth through the pulverizer 10 may be applied. Namely, a separate plunger pump may be provided at the location provided with the drain 86 in Fig. 1, such that preparation can flow back and forth inside the pulverizer 10.

**[0062]** Moreover, the structure of the flow path of the pulverizer 10 may be changed as desired.

**[0063]** Moreover, there is no limitation to the modified examples described above, and these modified examples may be selectively combined as appropriate, or other modified examples may be employed.

**[0064]** The entire content of the disclosure of Japanese Patent Application No. 2019-55719 filed on March 22, 2019 is incorporated by reference in the present specification.

**[0065]** All cited documents, patent applications, and technical standards mentioned in the present specification are incorporated by reference in the present specification to the same extent as if each individual cited document, patent application, or technical standard was specifically and individually indicated to be incorporated by reference.

Claims

1. A method of manufacturing a plunger pump for connection to a pulverizer, the pulverizer including a pul-

verization flow path through which a preparation is passed in order to pulverize the preparation, the plunger pump being configured to feed the preparation into the pulverizer under high pressure and being configured from an outer cylinder and an inner cylinder formed with a circular tube-shaped pressure chamber, the method comprising:

- a temperature difference generation process of generating a difference in temperature with respect to a normal temperature state for either one of the outer cylinder or the inner cylinder;
- a cylinder insertion process of inserting the inner cylinder inside the outer cylinder in a state in which the inner cylinder has a smaller outer diameter than an inner diameter of the outer cylinder as a result of the temperature difference generated by the temperature difference generation process;
- an elimination process of eliminating the generated temperature difference; and
- a plunger placement process of placing a circular tube-shaped plunger in the pressure chamber of the inner cylinder so as to enable reciprocating motion by the plunger.

2. The method of manufacturing a plunger pump of claim 1, wherein:

- the temperature difference generation process includes a heating process of heating the outer cylinder;
- in the cylinder insertion process, the inner cylinder is inserted into the outer cylinder in a state in which the inner diameter of the outer cylinder has become larger than the outer diameter of the inner cylinder; and
- the elimination process includes a cooling process of cooling the outer cylinder.

3. The method of manufacturing a plunger pump of claim 1, wherein:

- the temperature difference generation process includes a cooling process of cooling the inner cylinder;
- in the cylinder insertion process, the inner cylinder is inserted into the outer cylinder in a state in which the outer diameter of the inner cylinder has become smaller than the inner diameter of the outer cylinder; and
- the elimination process includes a heating process of heating the inner cylinder.

4. The method of manufacturing a plunger pump of claim 1, wherein:

- the temperature difference generation process

includes:

a heating process of heating the outer cylinder, and  
 a cooling process of cooling the inner cylinder; 5

in the cylinder insertion process, the inner cylinder is inserted into the outer cylinder in a state in which the inner diameter of the outer cylinder has become larger than the outer diameter of the inner cylinder; and 10  
 the elimination process includes:

a cooling process of cooling the outer cylinder, and 15  
 a heating process of heating the inner cylinder.

5. The method of manufacturing a plunger pump of any one of claim 2 to claim 4, wherein the inner cylinder is press-fitted inside the outer cylinder in the cylinder insertion process. 20

6. A plunger pump for connection to a pulverizer, the pulverizer including a pulverization flow path through which a preparation is passed in order to pulverize the preparation, and the plunger pump being configured to feed the preparation into the pulverizer under high pressure, the plunger pump comprising: 25  
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an outer cylinder;  
 an inner cylinder that is inserted inside the outer cylinder and that is formed with a circular tube-shaped internal pressure chamber; and 35  
 a circular tube-shaped plunger that is placed in the pressure chamber of the inner cylinder so as to be capable of reciprocating motion, the inner cylinder being configured so as to be compressed by the outer cylinder. 40

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FIG.1

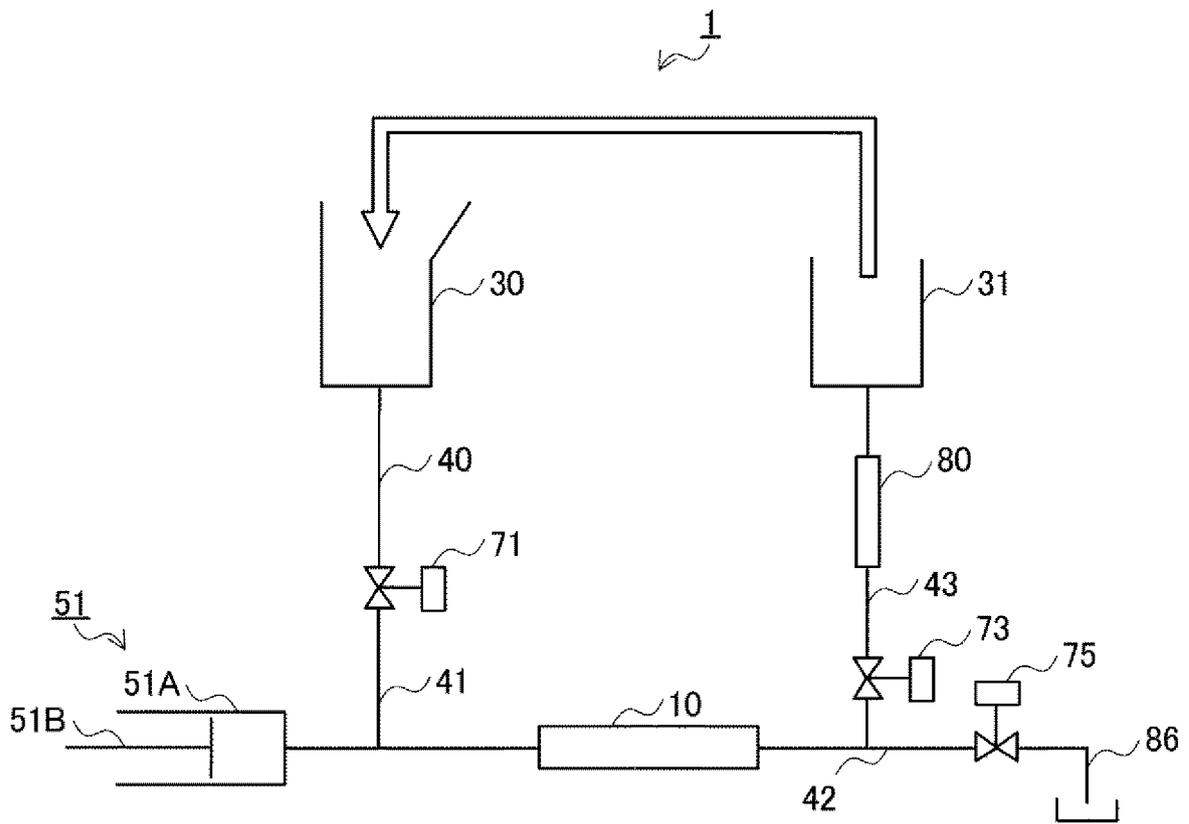


FIG.2

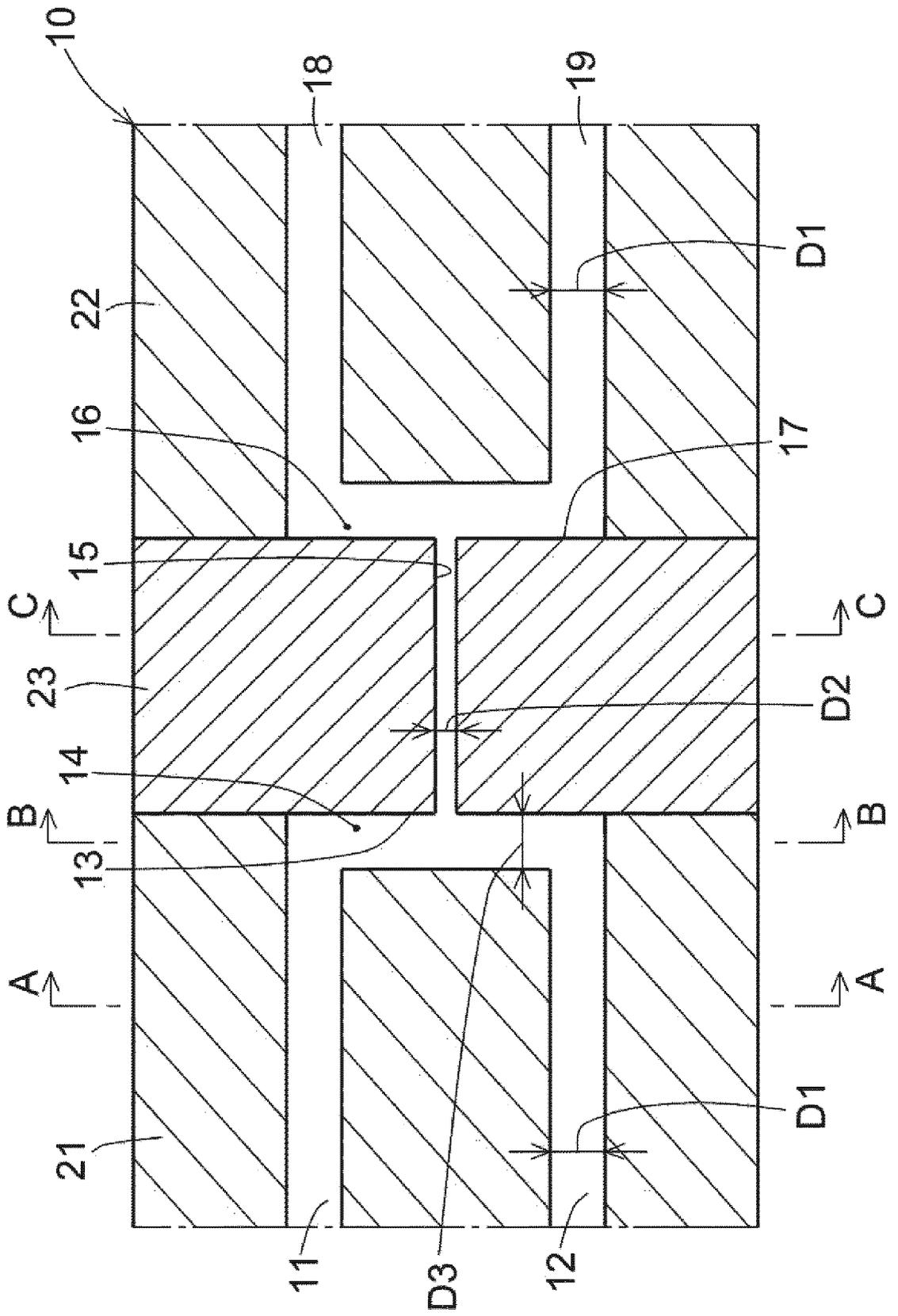


FIG.3C

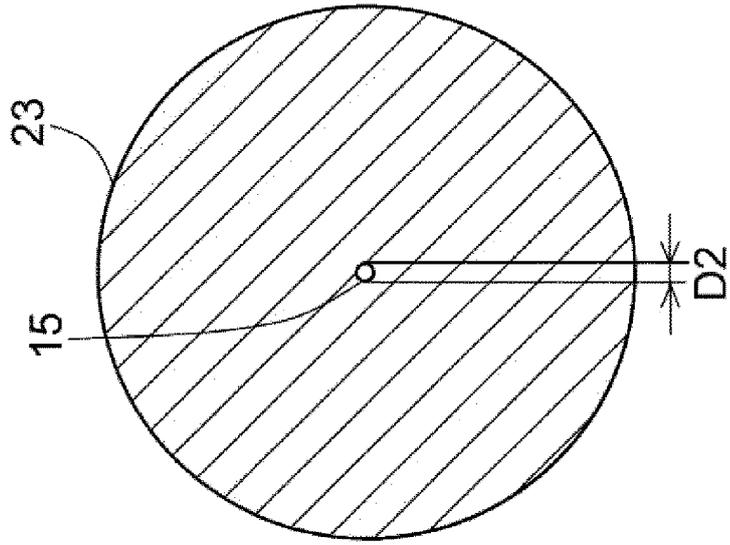


FIG.3B

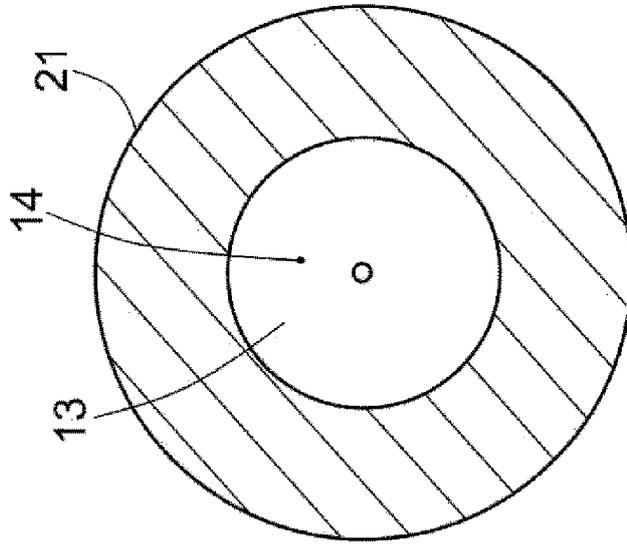


FIG.3A

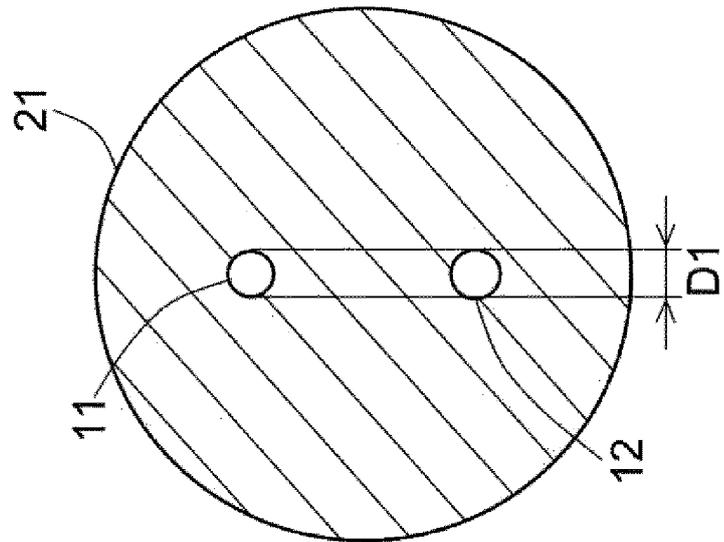


FIG.4

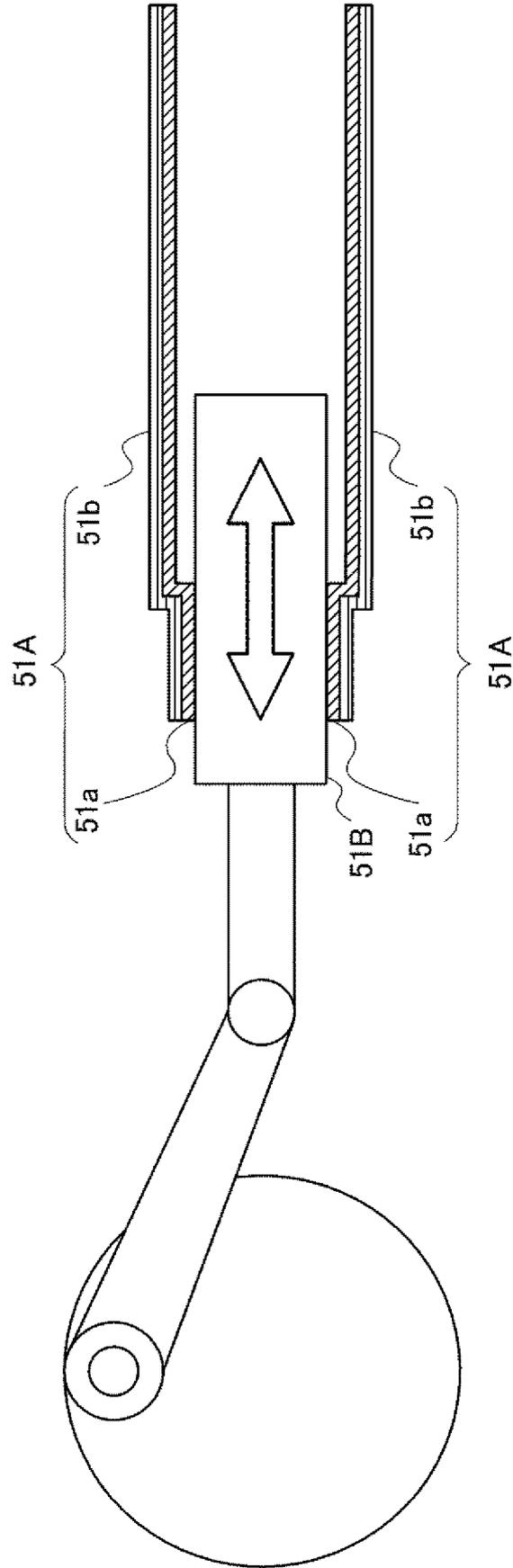


FIG.5

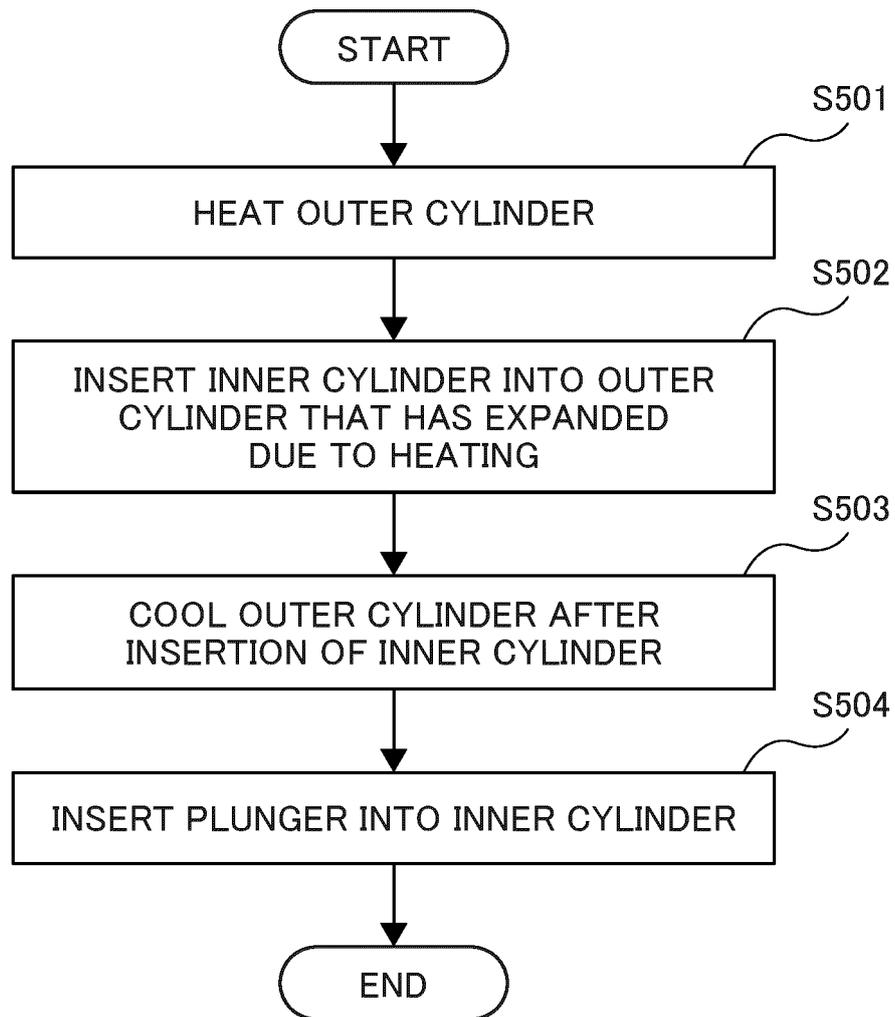


FIG.6A

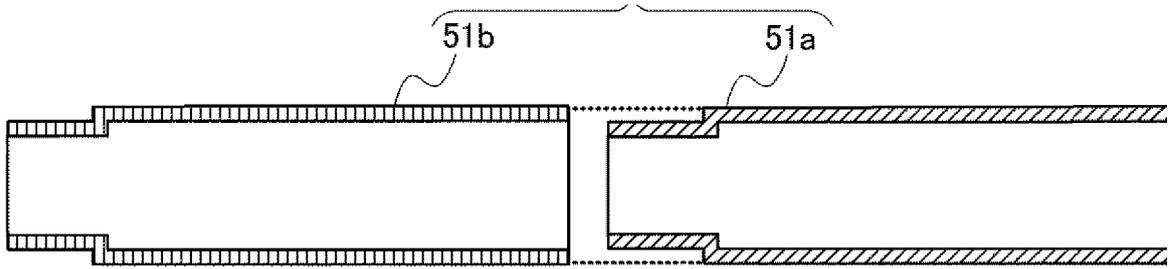


FIG.6B

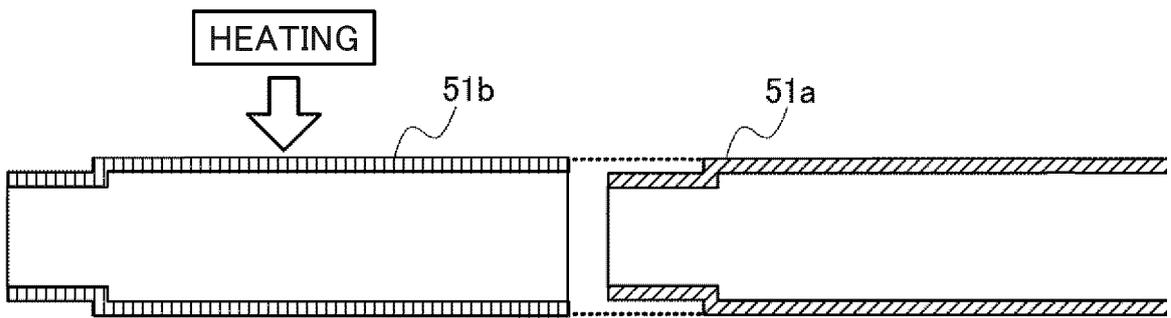


FIG.6C

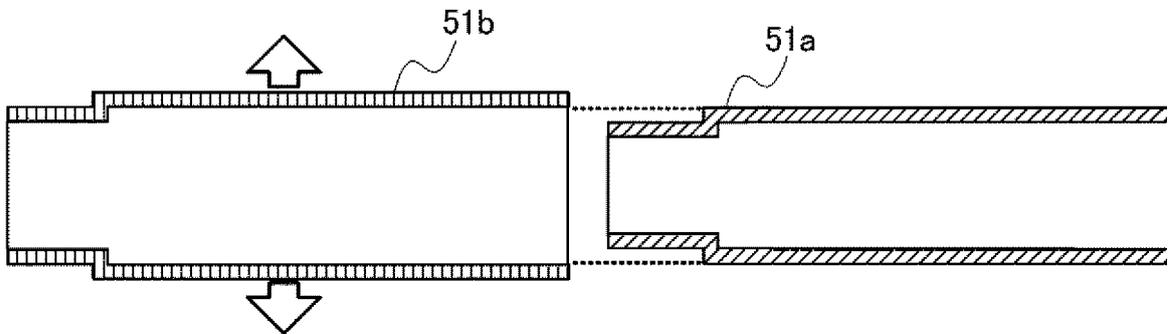


FIG.6D

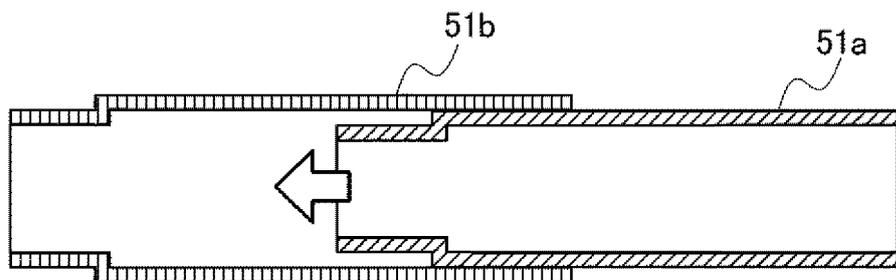


FIG.7A

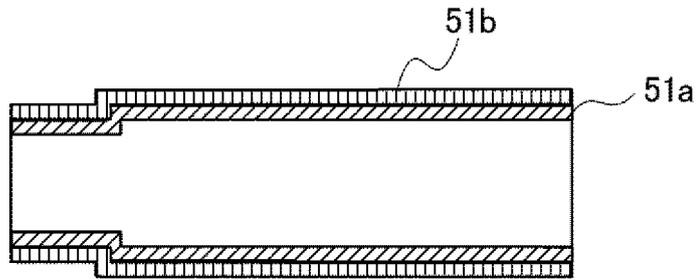


FIG.7B

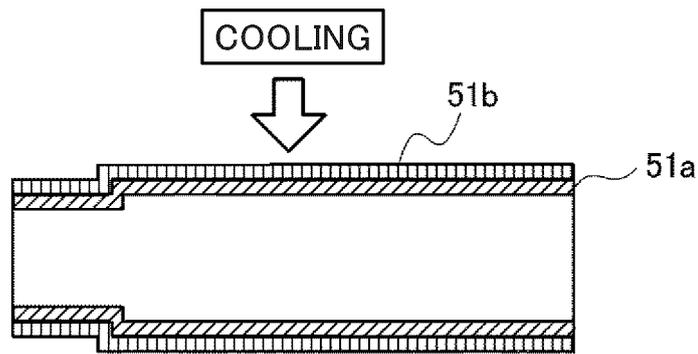


FIG.7C

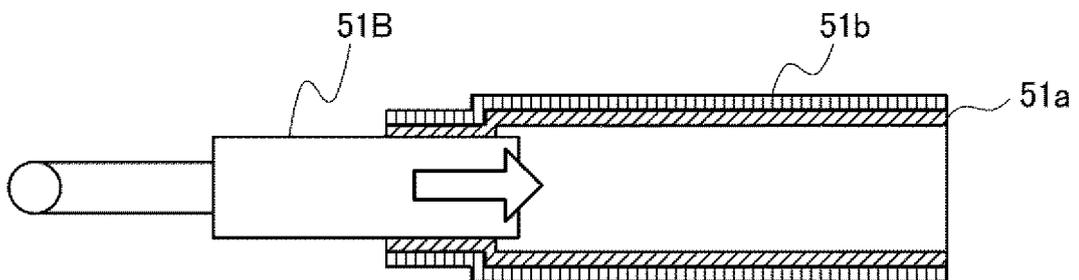


FIG.8

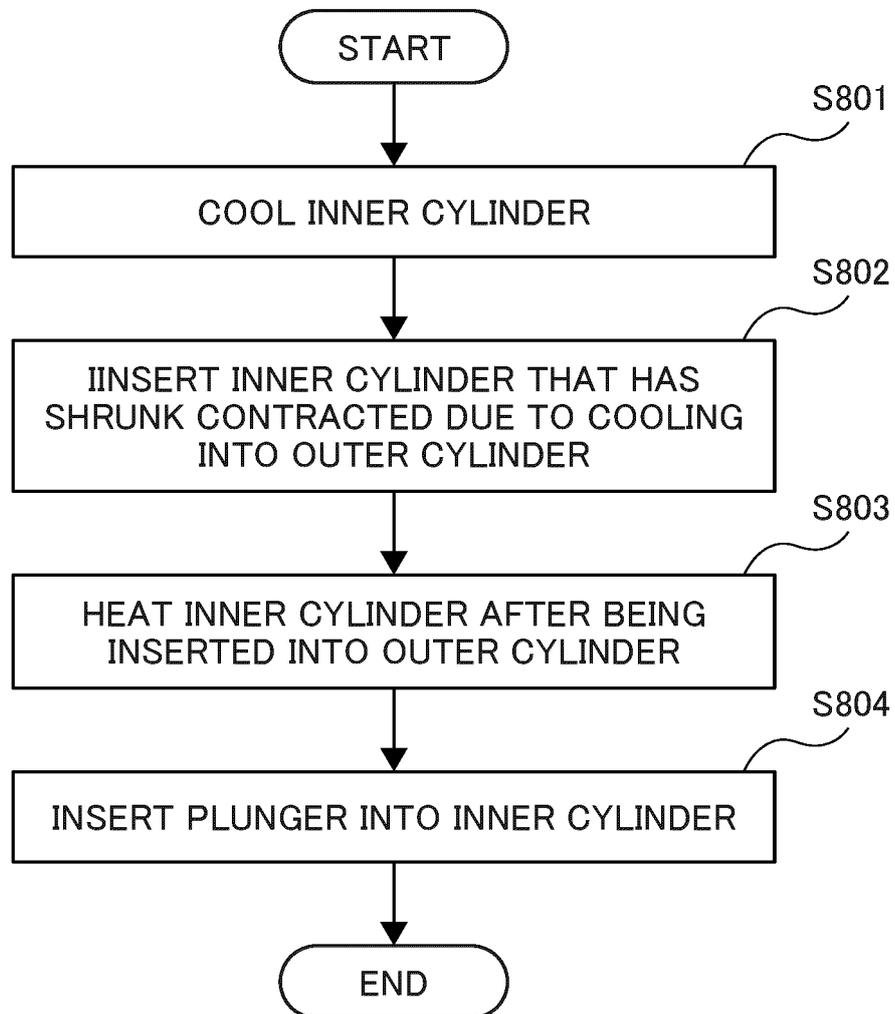


FIG.9A

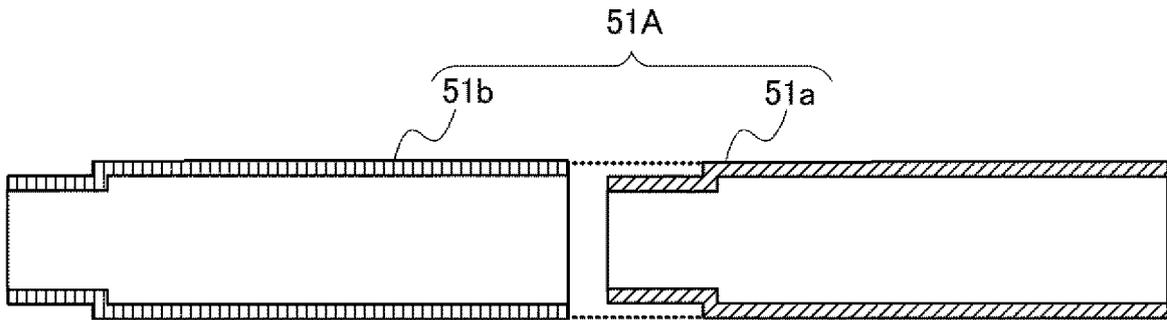


FIG.9B

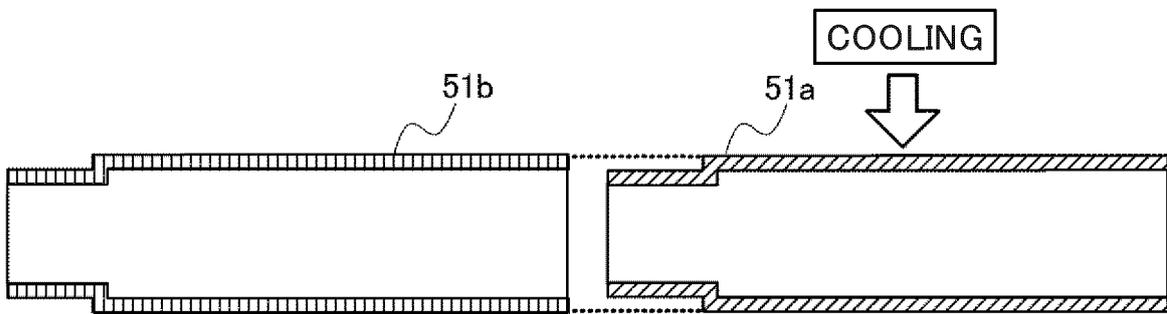


FIG.9C

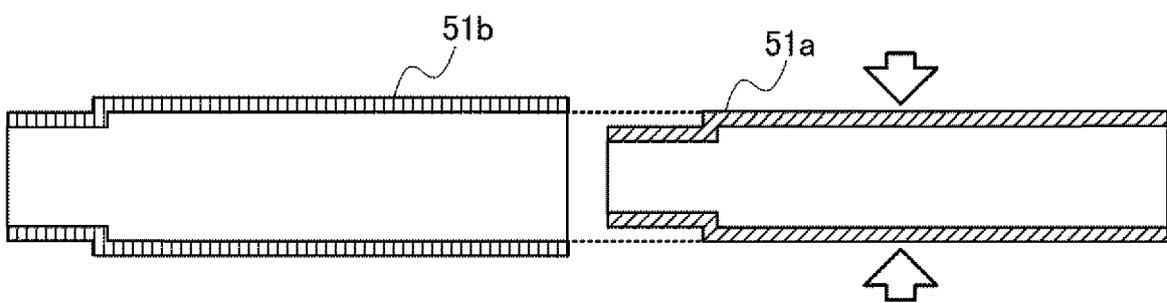


FIG.9D

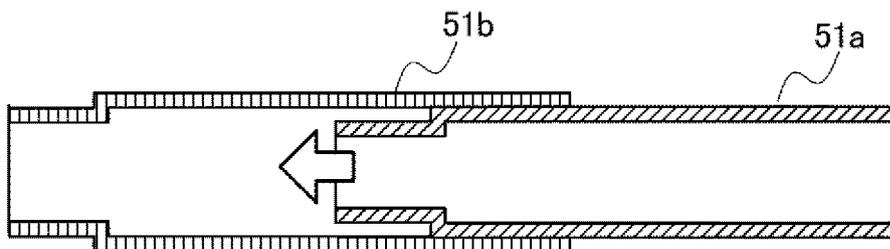


FIG.10A

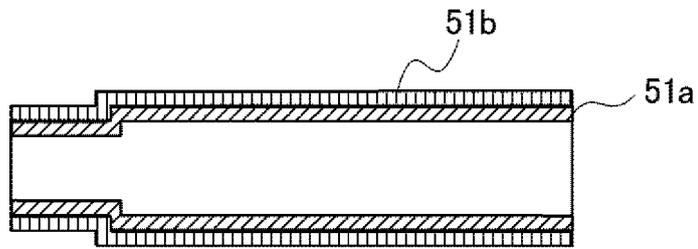


FIG.10B

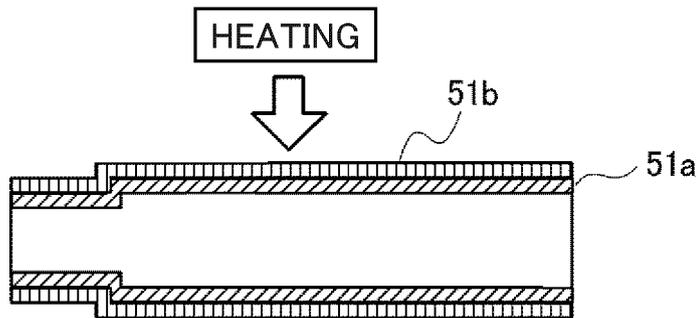
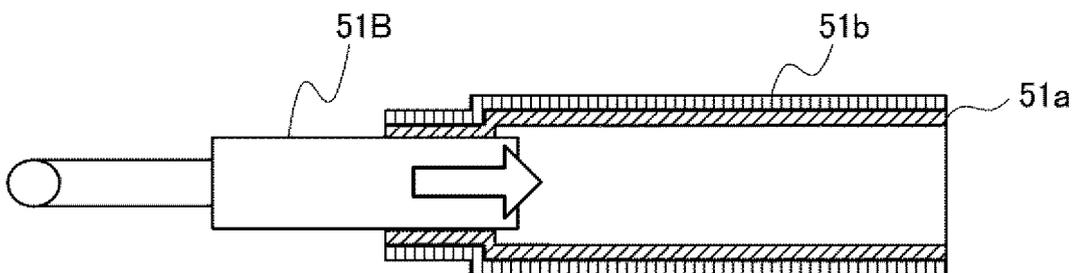


FIG.10C



INTERNATIONAL SEARCH REPORT

International application No.  
PCT/JP2020/011513

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A. CLASSIFICATION OF SUBJECT MATTER  
F04B 15/02 (2006.01) i  
FI: F04B15/02 Z

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

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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
F04B15/02

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2016-211404 A (SUGINO MACHINE LIMITED) 15.12.2016 (2016-12-15) paragraphs [0028]-[0085], fig. 1-4	1-6
Y	JP 2002-283030 A (HITACHI METALS, LTD.) 02.10.2002 (2002-10-02) claims 1-2, paragraphs [0009]-[0033], fig. 1-2	1-6
Y	JP 2009-293405 A (TOYOTA MOTOR CORP.) 17.12.2009 (2009-12-17) paragraphs [0073]-[0074], fig. 3	1-6

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Further documents are listed in the continuation of Box C.  See patent family annex.

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* Special categories of cited documents:	"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
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"E" earlier application or patent but published on or after the international filing date	"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
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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	

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Date of the actual completion of the international search 18 May 2020 (18.05.2020)	Date of mailing of the international search report 26 May 2020 (26.05.2020)
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Name and mailing address of the ISA/ Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Authorized officer  Telephone No.
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**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International application No. PCT/JP2020/011513
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Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2016-211404 A	15 Dec. 2016	EP 3088736 A1	
JP 2002-283030 A	02 Oct. 2002	paragraphs [0027]- [0084], fig. 1-4 (Family: none)	
JP 2009-293406 A	17 Dec. 2009	(Family: none)	

**REFERENCES CITED IN THE DESCRIPTION**

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- JP 3149371 B [0003]
- JP 2019055719 A [0064]