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(54) **METHOD FOR INCREASING INTERNAL PRESSURE OF HOLLOW BALL AND DEVICE THEREFOR**

(57) [Object] To provide a method for easily increasing the internal pressure of a hollow ball in a practical time.

[Solution] A method for increasing the internal pressure of a hollow ball according to the present invention includes the steps of (1) putting a hollow ball 18 including an outer shell and a space surrounded by the outer shell, into a housing portion 4;

(2) filling the housing portion 4 with a gas which is more

excellent in permeability relative to the outer shell than oxygen gas and nitrogen gas; and

(3) causing the gas to pass through the outer shell. When the outer shell contains natural rubber, preferably, in the step (2), the housing portion is filled with a gas having a permeability coefficient of $20 \times 10^{-17} \text{ m}^4/(\text{N} \cdot \text{s})$ at 25°C for the natural rubber. Preferably, in the step (2), the housing portion is filled with carbon dioxide gas.

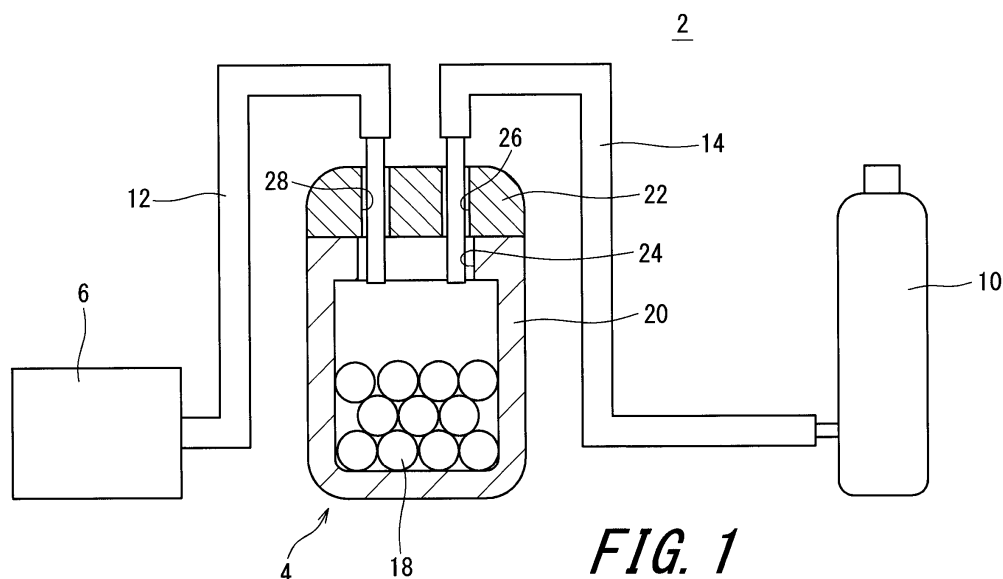


FIG. 1

Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to methods for increasing the internal pressures of hollow balls such as a regulation tennis ball, a soft tennis ball, and the like, and apparatuses therefor.

BACKGROUND ART

10 **[0002]** In order to obtain appropriate elasticity of hollow balls such as a regulation tennis ball, a soft tennis ball, and the like, the internal pressures of the balls are kept higher than the atmospheric pressure. For example, the internal pressure of a regulation tennis ball is set to be about 1.6 times to 1.9 times of the atmospheric pressure. If a ball has an internal pressure higher than this, a user feels that the ball is too hard or flies too far. If a ball has an internal pressure lower than this, the user feels that the ball is too soft or has insufficient resilience. A hollow ball needs to be manufactured
15 such that the internal pressure thereof has an appropriate value, and the internal pressure of the manufactured ball needs to be kept in an appropriate range.

[0003] In order to increase the internal pressure of a ball, for example, in manufacturing a regulation tennis ball, there are a case where a method of generating gas by a chemical reaction is used and a case where air is compressed and injected. The ball includes a core which is a hollow sphere made of rubber; and two felt portions (also referred to as
20 "melton") which cover the surface of the core. The core is obtained by attaching together two half shells. In the case where the internal pressure is increased by a chemical reaction, prior to attaching together the two half shells, a tablet of ammonium chloride, a tablet of sodium nitrite, and water (or aqueous solutions thereof) are put into the core. In crosslinking the core, they are heated, so that ammonium chloride and sodium nitrite cause a chemical reaction. Nitrogen gas is generated by the chemical reaction. The internal pressure of the core is increased by the nitrogen gas.

25 **[0004]** In a ball having an internal pressure higher than the atmospheric pressure, the gas within the ball passes through an outer shell to come out of the ball due to the difference between the internal pressure and the atmospheric pressure. That is, even when a ball is manufactured so as to have an appropriate internal pressure, the internal pressure decreases over time. For example, when a regulation tennis ball is left in the atmospheric pressure for about two months, the internal pressure thereof decreases to such a degree that a user recognizes the decrease in the internal pressure.

30 **[0005]** Results of examination of storage containers for suppressing a decrease in the internal pressures of tennis balls are disclosed in JP7-155406, JP7-187252, and JP8-89600. These storage containers are all airtight containers. After tennis balls are stored in these containers, the air pressures within the containers are increased to a pressure equal to or higher than the atmospheric pressure. By decreasing the difference between the internal pressure of each tennis ball and the air pressure of each container outside the tennis ball, a speed at which the gas within the ball passes
35 through an outer shell can be decreased. By eliminating the difference between the internal pressure of each tennis ball and the air pressure of the container, the gas within the ball does not come out. In other words, the internal pressure of the tennis ball does not decrease. By making the air pressure of the container higher than the internal pressure of the tennis ball, the internal pressure of each tennis ball can be increased reversely.

40 CITATION LIST

PATENT LITERATURE

[0006]

45 Patent Literature 1: JP7-155406
Patent Literature 2: JP7-187252
Patent Literature 3: JP8-89600

50 SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

55 **[0007]** Regarding each of the storage containers in JP7-155406, JP7-187252, and JP8-89600, while balls are stored in the container, a decrease in the internal pressure of each ball can be suppressed. However, when these balls are taken out from the container, the balls are exposed to the atmospheric pressure, and the internal pressure of each ball decreases. When each ball is used, the internal pressure thereof further quickly decreases. Then, once the internal pressure of each ball decreases, it is difficult to restore the internal pressure of the ball with these storage containers.

As described above, theoretically, if the air pressure within the container is made higher than the internal pressure of the ball, the internal pressure of the ball is restored. However, for example, even if a regulation tennis ball whose internal pressure has decreased by 10% is put into a container filled with air pressurized to a pressure which is about 2.5 times of the atmospheric pressure, it takes about one month to two months to restore the internal pressure. By increasing the air pressure within the container, the restoring speed can be increased. However, an expensive pressure container is required. Eventually, a regulation tennis ball whose internal pressure has decreased is thrown away, even when the felt portions of the ball are in a usable condition.

[0008] A soft tennis ball includes a valve for restoring a decreased internal pressure thereof. By supplying air through the valve with a dedicated air pump, the internal pressure is restored. However, the valve is thicker and harder than rubber surrounding the valve, and thus may be broken during use. The valve impairs the durability of the ball. In addition, if the valve hits against a racket when the ball is hit with the racket, the hit ball becomes unstable. Furthermore, it is necessary to supply air into balls one by one, and thus it takes much time and effort to restore the internal pressures of the balls.

[0009] An object of the present invention is to provide a method for easily increasing the internal pressure of a hollow ball in a practical time.

SOLUTION TO THE PROBLEMS

[0010] A method for increasing an internal pressure of a hollow ball according to the present invention includes the steps of:

- (1) putting a hollow ball including an outer shell and a space surrounded by the outer shell, into a housing portion;
- (2) filling the housing portion with a gas which is more excellent in permeability relative to the outer shell than oxygen gas and nitrogen gas; and
- (3) causing the gas to pass through the outer shell.

[0011] When the outer shell contains natural rubber, preferably, in the step (2), the housing portion is filled with a gas having a permeability coefficient of $20 \times 10^{-17} \text{ m}^4/(\text{N}\cdot\text{s})$ at 25°C for the natural rubber.

[0012] Preferably, in the step (2), the housing portion is filled with carbon dioxide gas or a gaseous mixture of carbon dioxide gas and air.

[0013] Preferably, the method further includes, between the steps (1) and (2), a step (4) of discharging air within the housing portion.

[0014] Preferably, a temperature within the housing portion in the step (3) is not lower than 35°C and not higher than 60°C .

[0015] Preferably, a difference between an internal pressure of the housing portion and an atmospheric pressure immediately after end of the step (2) is equal to or lower than 1.84 kgf/cm^2 .

[0016] Preferably, the difference between the internal pressure of the housing portion and the atmospheric pressure immediately after the end of the step (2) is equal to or lower than 0.9 kgf/cm^2 .

[0017] Preferably, a partial pressure of the air within the housing portion immediately after the end of the step (2) is higher than the atmospheric pressure.

[0018] Preferably, the difference between the internal pressure of the housing portion and the atmospheric pressure immediately after the end of the step (2) is equal to or lower than 0.1 kgf/cm^2 .

[0019] Preferably, the housing portion is a bag formed from a resin composition.

[0020] Preferably, a ratio (V_g/V_b) of a volume V_g of the gas with which the housing portion is filled in the step (2), relative to a sum V_b of capacities of all hollow balls put into the housing portion in the step (1), is equal to or greater than 1.0.

[0021] The housing portion may be a container formed from a metal.

[0022] An apparatus for increasing an internal pressure of a hollow ball according to the present invention includes: a housing portion into which a hollow ball including an outer shell and a space surrounded by the outer shell can be put; and a feed portion configured to feed a gas to the housing portion. The gas is more excellent in permeability relative to the outer shell than oxygen gas and nitrogen gas.

[0023] A soft tennis ball according to the present invention has an internal pressure which is increased by a method for increasing an internal pressure, the method including the steps of:

- (1) putting a soft tennis ball into a housing portion;
- (2) filling the housing portion with a gas which is more excellent in permeability relative to an outer shell of the soft tennis ball than oxygen gas and nitrogen gas; and
- (3) causing the gas to pass through the outer shell of the soft tennis ball.

The soft tennis ball does not include a valve.

[0024] A housing container for a method for increasing an internal pressure of a hollow ball according to the present invention includes a main body and an opening/closing tool mounted to the main body. The main body includes therein an intake port for feeding gas into an interior thereof and an exhaust port for discharging gas from the interior thereof. A portion of the main body is capable of being opened/closed by the opening/closing tool. When the portion of the main body is opened, a hollow ball can be taken in and out through an opening of the portion; and when the portion of the main body is closed, the main body enters an airtight state.

[0025] Preferably, the main body is composed of nylon.

[0026] Preferably, the opening/closing tool is an airtight fastener.

[0027] Preferably, the intake port is located below the exhaust port.

[0028] Preferably, when a height from a lower end of the main body to a center of the exhaust port is denoted by H_o , a ratio (H_o/H) of the height H_o relative to a height H of the main body is equal to or greater than 90%.

[0029] Preferably, when a height from the lower end of the main body to a center of the intake port is denoted by H_i , a ratio (H_i/H) of the height H_i relative to the height H of the main body is equal to or less than 10%.

[0030] The housing container may further include a hose. Within the main body, the hose is mounted to the main body such that an opening of a first end of the hose overlaps the intake port. A second end of the hose is located below the exhaust port.

[0031] Preferably, when a height from the lower end of the main body to the second end of the hose is denoted by H_h , a ratio (H_h/H) of the height H_h relative to the height H of the main body is equal to or less than 10%.

[0032] Preferably, the housing tool further includes, within the main body, a frame for reinforcing the main body.

[0033] A pressure container for a method for increasing an internal pressure of a hollow ball according to the present invention includes: a housing portion configured to house a hollow ball; and a heater configured to heat the housing portion. The housing portion includes: a trunk portion having an input port through which the hollow ball is taken in and out; a lid configured to cover the input port; and an intake port through which a gas is fed into an interior of the housing portion.

[0034] Preferably, the heater is mounted on an outer side of the housing portion.

[0035] The heater may be mounted within the housing portion.

[0036] Preferably, each of the trunk portion and the lid is formed from a metal.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0037] In the method for increasing an internal pressure of a hollow ball according to the present invention, the housing portion in which the hollow ball is housed is filled with a gas having a higher permeability relative to the outer shell of the hollow ball than those of oxygen gas and nitrogen gas. A speed at which the gas enters from the housing portion into the interior of the ball is higher than a speed at which air enters into the interior of the ball. Thus, the internal pressure of the hollow ball can be increased in a short time as compared to a conventional method for filling a container with air. According to this method, it is possible to easily reuse a ball whose internal pressure has decreased.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038]

[FIG. 1] FIG. 1 is a conceptual diagram showing an apparatus for a method for increasing the internal pressure of a hollow ball according to an embodiment of the present invention.

[FIG. 2] FIG. 2 is a conceptual diagram showing an apparatus for a method for increasing the internal pressure of a hollow ball according to a second embodiment of the present invention.

[FIG. 3] FIG. 3 is a conceptual diagram showing an apparatus for a method for increasing the internal pressure of a hollow ball according to a third embodiment of the present invention.

[FIG. 4] FIG. 4 is a perspective view of a housing container for a method for increasing the internal pressure of a hollow ball according to an embodiment of the present invention.

[FIG. 5] FIG. 5 is a perspective view of a housing container for a method for increasing the internal pressure of a hollow ball according to another embodiment of the present invention.

[FIG. 6] FIG. 6 is a conceptual diagram showing a state where the housing container in FIG. 5 is used.

[FIG. 7] FIG. 7 is a perspective view showing a state where a housing container for a method for increasing the internal pressure of a hollow ball according to still another embodiment of the present invention is used.

[FIG. 8] FIG. 8 is a perspective view of a housing container for a method for increasing the internal pressure of a hollow ball according to still another embodiment of the present invention.

[FIG. 9] FIG. 9 is a conceptual diagram showing a state where the housing container in FIG. 8 is used.

[FIG. 10] FIG. 10 is a front view of a pressure container for a method for increasing the internal pressure of a hollow ball according to an embodiment of the present invention.

[FIG. 11] FIG. 11 is a right side view of the pressure container in FIG. 10.

[FIG. 12] FIG. 12 is a plan view of the pressure container in FIG. 10.

[FIG. 13] FIG. 13 is a portion of a cross-sectional view taken along a line XIII-XIII in FIG. 12.

DESCRIPTION OF EMBODIMENTS

[0039] The following will describe in detail the present invention based on preferred embodiments with appropriate reference to the drawings.

[0040] FIG. 1 shows an apparatus 2 for a method for increasing the internal pressure of a hollow ball according to an embodiment of the present invention. The apparatus 2 includes a pressure container 4, a vacuum pump 6, a gas cylinder 10, an exhaust pipe 12, and an intake pipe 14.

[0041] The pressure container 4 houses hollow balls 18 each of which includes an outer shell and a space surrounded by the outer shell. The pressure container 4 is typically made from a metal. The pressure container 4 may be made of a resin composition. The pressure container 4 is kept airtight.

[0042] The pressure container 4 includes a main body 20 and a lid 22. The main body 20 has, at an upper portion thereof, an input port 24 for putting in the hollow balls 18 therethrough. The lid 22 is provided with an intake hole 26 and an exhaust hole 28. The exhaust hole 28 extends through the lid 22. One end of the exhaust pipe 12 is passed through the exhaust hole 28. The other end of the exhaust pipe 12 is connected to the vacuum pump 6. The pressure container 4 and the vacuum pump 6 are connected to each other by the exhaust pipe 12.

[0043] The intake hole 26 of the pressure container 4 extends through the lid 22. One end of the intake pipe 14 is passed through the intake hole 26. The other end of the intake pipe 14 is connected to the gas cylinder 10. The pressure container 4 and the gas cylinder 10 are connected to each other by the intake pipe 14.

[0044] The vacuum pump 6 sucks the gas within the pressure container 4 through the exhaust pipe 12. The interior of the pressure container 4 can be substantially evacuated by the vacuum pump 6.

[0045] The gas cylinder 10 has stored therein a gas to be fed into the pressure container 4. The gas is more excellent in permeability relative to the outer shell of each hollow ball 18 than oxygen gas and nitrogen gas. The gas cylinder 10 feeds the stored gas through the intake pipe 14 into the pressure container 4. The gas cylinder 10 can cause the pressure of the gas within the pressure container 4 to be equal to or higher than the atmospheric pressure.

[0046] A compressor may be provided between the gas cylinder 10 and the pressure container 4. The compressor is used when the pressure in the gas cylinder 10 is not sufficient to increase the pressure in the pressure container 4. The compressor increases the pressure of the gas from the gas cylinder 10 and feeds the gas into the pressure container 4.

[0047] In a method for increasing the internal pressures of the hollow balls 18 according to the present invention, in an initial step, the hollow balls 18 are put into the pressure container 4, and, in addition, the air within the pressure container 4 is discharged. In this step, the intake pipe 14 is closed, and the pressure container 4 is kept airtight. The vacuum pump 6 is operated, and the air within the container is discharged through the exhaust pipe 12. When the interior of the container becomes substantially evacuated, the operation of the vacuum pump 6 is stopped.

[0048] In the next step, the pressure container 4 is filled with the gas. The gas from the gas cylinder 10 is fed through the intake pipe 14 into the pressure container 4. The pressure container 4 is filled with the gas. When the pressure within the pressure container 4 reaches a predetermined air pressure, the filling with the gas is stopped.

[0049] In the final step, the filled gas is caused to pass through the outer shells of the hollow balls 18. In this step, the hollow balls 18 are left within the pressure container 4 for a predetermined time period. Due to the difference between the pressure of the filled gas within the hollow balls 18 and the pressure of the filled gas within the pressure container 4, the gas passes through the outer shells of the hollow balls 18 to enter into the hollow balls 18. Thus, the internal pressures of the hollow balls 18 are increased.

[0050] In the method for increasing the internal pressures of the hollow balls 18 according to the present invention, the pressure container 4 is filled with the gas which is more excellent in permeability relative to the outer shell of each hollow ball 18 than oxygen gas and nitrogen gas. The speed at which the gas enters from the interior of the pressure container 4 into the interior of each hollow ball 18 is higher than the speed at which air enters into the interior of each hollow ball 18. Thus, the internal pressures of the hollow balls 18 can be increased in a short time as compared to a conventional method of filling a container with air. In addition, in this method, by merely leaving the hollow balls 18 within the pressure container 4, the internal pressures of many hollow balls 18 can be increased. According to this method, the internal pressures of the hollow balls 18 can be easily and efficiently increased.

[0051] The following will specifically describe the above-described effects with, as an example, the case where carbon dioxide is used as the gas with which the pressure container 4 is filled, to increase the internal pressures of regulation tennis balls. It should be noted that a description will be given on the assumption that the atmospheric pressure is 1.0 kgf/cm².

[0052] When: the permeability coefficient of a gas for a film is denoted by C_p ; the partial pressure difference of the gas between the outer side and the inner side across the film is denoted by P ; and the thickness of the film is denoted by W , a speed V at which the gas passes through the film is represented by:

$$V = C_p \times P/W.$$

[0053] The outer shell of each regulation tennis ball 18 is generally made from natural rubber. A description will be given on the assumption that the gas within each regulation tennis ball 18 is composed of 80% of nitrogen gas (N_2) and 20% of oxygen gas (O_2), similarly to the atmosphere. As described above, in order to increase the internal pressure during manufacturing, there are a method of generating nitrogen gas within the balls 18 and a method of compressing and injecting air. In the case where the method of generating nitrogen gas is used, the proportion of nitrogen gas is predicted to be actually higher than that in the atmosphere, but this does not have a great impact on the effects of the present invention. Similarly to the atmosphere, carbon dioxide gas (CO_2) is also present within each regulation tennis ball 18, but the amount thereof is negligibly small. The permeability coefficients C_p of nitrogen gas, oxygen gas, and carbon dioxide gas for natural rubber are shown in Table 1. In addition, a ratio C_c of each permeability coefficient obtained when the permeability coefficient of nitrogen gas at 25°C is defined as 1 is described in Table 1. The thickness W of the film can be considered constant, and thus the speed V is proportional to the ratio C_c and the partial pressure difference P . When a constant of the proportionality is denoted by C_0 , the speed V can be rewritten as follows.

$$V = C_0 \times C_c \times P$$

The following will describe the effects by using this formula.

[Table 1]

Table 1 Gas permeability coefficient for natural rubber

Temper ature	Item	Nitrogen	Oxygen	Carbon dioxide
25°C	Permeability coefficient C_p [$10^{-17} \text{ m}^4/(\text{N} \cdot \text{S})$]	6.0	17.5	98.3
	Ratio C_c	1.0	2.9	16.3
50°C	Permeability coefficient C_p [$10^{-17} \text{ m}^4/(\text{N} \cdot \text{S})$]	19.1	46.4	218
	Ratio C_c	3.2	7.7	36.3

[0054] Restoring the regulation tennis balls 18 whose internal pressures have decreased to 1.60 kgf/cm² due to use of the balls 18, by the method according to the present invention, will be considered. For this, it is assumed that after the pressure container 4 is evacuated, the pressure container 4 is filled with carbon dioxide gas until the pressure of carbon dioxide reaches 2.84 kgf/cm². Within the pressure container 4, no nitrogen gas and no oxygen gas are present. Therefore, the partial pressures of nitrogen gas, oxygen gas, and carbon dioxide gas within the pressure container 4 are as follows.

Nitrogen gas: 0.00 kgf/cm²

Oxygen gas: 0.00 kgf/cm²

Carbon dioxide gas: 2.84 kgf/cm²

[0055] As described above, the gas within each regulation tennis ball 18 is composed of 80% of nitrogen gas and 20% of oxygen gas. The internal pressure of each regulation tennis ball 18 is 1.60 kgf/cm², and carbon dioxide gas can be neglected. Thus, the partial pressures of nitrogen gas, oxygen gas, and carbon dioxide gas within the regulation tennis ball 18 are as follows.

Nitrogen gas: $1.60 \times 0.8 = 1.28 \text{ kgf/cm}^2$

Oxygen gas: $1.60 \times 0.2 = 0.32 \text{ kgf/cm}^2$

Carbon dioxide gas: 0.0 kgf/cm²

[0056] On the basis of the values of the partial pressures at the outer side and the inner side of the regulation tennis ball 18 and the values of the permeability coefficient C_c in Table 1, a speed $V(N_2)$ at which nitrogen gas passes through

the outer shell of the regulation tennis ball 18, which outer shell is made from natural rubber, from the outer side toward the inner side, a speed $V(O_2)$ at which oxygen gas passes through the outer shell of the regulation tennis ball 18, and a speed $V(CO_2)$ at which carbon dioxide gas passes through the outer shell of the regulation tennis ball 18 are as follows.

$$V(N_2) = C0 \times 1.0 \times (0.00 - 1.28) = -1.28 \times C0$$

$$V(O_2) = C0 \times 2.9 \times (0.00 - 0.32) = -0.93 \times C0$$

$$\begin{aligned} V(CO_2) &= C0 \times 16.3 \times (2.84 - 0.00) \\ &= 47.71 \times C0 \end{aligned}$$

[0057] Nitrogen gas and oxygen gas within the regulation tennis ball 18 come out of the interior of the ball 18, but carbon dioxide gas enters into the interior of the ball 18 at a speed which is equal to or higher than 20 times of that of nitrogen gas and oxygen gas. According to the present method, a speed V_{pro} at which the gas enters into the regulation tennis ball 18 as a whole is as follows.

$$\begin{aligned} V_{pro} &= (47.71 - 1.28 - 0.93) \times C0 \\ &= 45.50 \times C0 \end{aligned}$$

[0058] Meanwhile, a speed at which the gas enters into the regulation tennis ball 18 when the pressure of the air within the pressure container 4 is set to 2.84 kgf/cm² in the conventional method of filling with air, is calculated. At this time, the partial pressures of nitrogen gas and oxygen gas within the pressure container 4 are as follows.

$$\text{Nitrogen gas: } 2.84 \times 0.8 = 2.27 \text{ kgf/cm}^2$$

$$\text{Oxygen gas: } 2.84 \times 0.2 = 0.57 \text{ kgf/cm}^2$$

[0059] The partial pressures of nitrogen gas and oxygen gas within the regulation tennis ball 18 are as follows.

$$\text{Nitrogen gas: } 1.6 \times 0.8 = 1.28 \text{ kgf/cm}^2$$

$$\text{Oxygen gas: } 1.6 \times 0.2 = 0.32 \text{ kgf/cm}^2$$

[0060] Thus, a speed $V(N_2)$ at which nitrogen gas passes through the outer shell of the regulation tennis ball 18, a speed $V(O_2)$ at which oxygen gas passes through the outer shell, and a speed V_{cov} at which the gas enters into the regulation tennis ball 18 as a whole are as follows.

$$V(N_2) = C0 \times 1.0 \times (2.27 - 1.28) = 0.99 \times C0$$

$$V(O_2) = C0 \times 2.9 \times (0.57 - 0.32) = 0.72 \times C0$$

$$V_{cov} = C0 \times (0.99 + 0.72) = 1.71 \times C0$$

[0061] When the speed V_{pro} at which the gas enters into the ball 18 by the present method is compared to the speed V_{cov} at which the air enters into the ball 18 by the conventional method, the effect of the present invention is clear. That is,

$$V_{pro}/V_{cov} = 26.6.$$

[0062] Immediately after the pressure container 4 is filled with the gas at 2.84 kgf/cm², according to the present method, the gas enters into each ball 18 at a speed which is equal to or higher than 26 times of that in the conventional method. This significantly improves a speed of increasing the internal pressure of the ball 18. According to the present method,

it is possible to restore the internal pressure of the regulation tennis ball 18 whose internal pressure has decreased, and use the regulation tennis ball 18 again.

[0063] In the above, the speed at which the gas enters into the hollow ball 18 in a state immediately after the pressure container 4 is filled with the gas, is calculated. Actually, when the gas within the container enters into each hollow ball 18, the pressure of the gas within the container decreases. Furthermore, the partial pressure of the gas within the hollow ball 18 also changes. Thus, the speed at which the gas enters into each hollow ball 18 changes over time. In the present specification, a result of calculation of a speed that takes time elapse into account is not shown. This is because effectiveness of the present method becomes clear through comparison of a speed at which the gas enters into each hollow ball 18 immediately after the pressure container 4 is filled with the gas.

[0064] As described above, when the gas within the pressure container 4 enters into each hollow ball 18, the pressure within the container decreases. This causes a decrease in the speed at which the gas enters into each hollow ball 18. In order to prevent this decrease, a method of supplying again the gas from the gas cylinder 10 can be used. For example, a method can be used in which, although not shown in the drawing, a pressure monitor for observing the internal pressure of the pressure container 4 is installed, and the gas is supplied again from the gas cylinder 10 when the internal pressure has decreased to a certain value or lower. Such a method of supplying again the gas is used as appropriate depending on an intended use.

[0065] In the above-described method, in the initial step, the pressure container 4 is evacuated. The pressure container 4 may not be evacuated. Air having a certain pressure may remain therein. Air may not be discharged at all, and air having the same pressure as the atmospheric pressure may remain. In this case, in the initial step, a process of discharging air from the interior of the pressure container 4 is unnecessary. In FIG. 1, the vacuum pump 6 is unnecessary. In addition, a gas which is a mixture of carbon dioxide and air may be put in the gas cylinder 10 beforehand, whereby carbon dioxide may be fed into the container, and the partial pressure of air after the container is filled with the gas may be made equal to or higher than the atmospheric pressure. This is effective for increasing the internal pressure of each hollow ball 18 by causing carbon dioxide to enter into each hollow ball 18 while suppressing coming-out of the air within each hollow ball 18.

[0066] The following will describe the effectiveness of the present method with, as an example, the case where the air within the container is not discharged and the pressure container 4 is filled with carbon dioxide and air such that the internal pressure of the pressure container 4 is 2.84 kgf/cm². In the following example, after filling with the gas, the partial pressure of the air within the container is 1.84 kgf/cm² which is equal to or higher than the atmospheric pressure, and the partial pressure of carbon dioxide is 1.00 kgf/cm² which is equal to the atmospheric pressure. The internal pressure of the ball 18 is set to 1.60 kgf/cm² which is equal to that in the above example. At this time, the speed $V(N_2)$ at which nitrogen gas passes through the outer shell of the regulation tennis ball 18, the speed $V(O_2)$ at which oxygen gas passes through the outer shell of the regulation tennis ball 18, and the speed $V(CO_2)$ at which carbon dioxide gas passes through the outer shell of the regulation tennis ball 18 are as follows.

$$\begin{aligned} V(N_2) &= C_0 \times 1.0 \times (1.84 - 1.60) \times 80\% \\ &= 0.19 \times C_0 \end{aligned}$$

$$\begin{aligned} V(O_2) &= C_0 \times 2.9 \times (1.84 - 1.60) \times 20\% \\ &= 0.14 \times C_0 \end{aligned}$$

$$\begin{aligned} V(CO_2) &= C_0 \times 16.3 \times (1.00 - 0.00) \\ &= 16.3 \times C_0 \end{aligned}$$

The speed V_{pro} at which the gas enters into the regulation tennis ball 18 as a whole is as follows.

$$\begin{aligned} V_{pro} &= (16.30 + 0.19 + 0.14) \times C_0 \\ &= 16.63 \times C_0 \end{aligned}$$

When the speed V_{pro} is compared to the speed $V_{cov} = 1.71 \times C_0$ at which the gas enters into the ball 18 by the conventional method,

$$V_{\text{pro}}/V_{\text{cov}} = 9.7.$$

This means that the gas enters into the ball 18 at a speed which is 9.7 times of that in the conventional method.

[0067] Meanwhile, nitrogen gas and oxygen gas also enter into the interior of the ball 18 at a speed of $(0.19 + 0.14) \times C_0 = 0.33 \times C_0$. In the case where the container is evacuated, from the above-described results, nitrogen gas and oxygen gas come out of the ball 18 at a speed of $(-1.28 - 0.93) \times C_0 = -2.21 \times C_0$. In this method, as compared to the conventional method, the internal pressure of the hollow ball 18 can be increased at a high speed while suppressing coming-out of the air from the interior of the ball 18.

[0068] Table 1 shows the permeability coefficients of nitrogen gas, oxygen gas, and carbon dioxide gas for natural rubber at 25°C and 50°C. The permeability coefficients of these gases at 50°C are 2 to 3 times of the permeability coefficients thereof at 25°C. That is, by increasing the temperature within the pressure container 4 from 25°C to 50°C, the speed at which the gas enters into each hollow ball 18 can be increased by 2 times or more. This can be easily achieved, for example, when the pressure container 4 includes a heater. The temperature within the pressure container 4 may be increased by using a band heater. From the standpoint that the permeability coefficient of gas is increased to increase the speed of increasing the internal pressure of the hollow ball 18, the temperature within the pressure container 4 is preferably equal to or higher than 35°C. From the standpoint that the quality of natural rubber which is used in a large amount as the material of the outer shell of the hollow ball 18 is maintained, the temperature within the pressure container 4 is preferably equal to or lower than 60°C.

[0069] In the present method, the difference between the internal pressure of the pressure container 4 and the atmospheric pressure after the pressure container 4 is filled with the gas is preferably equal to or lower than 1.84 kgf/cm². This corresponds to the case where the internal pressure of the pressure container 4 is equal to or lower than 2.84 kgf/cm² when the atmospheric pressure is 1.00 kgf/cm². The pressure container 4 which is used at an internal pressure whose difference from the atmospheric pressure is equal to or lower than 1.84 kgf/cm² is easily handled and managed. In addition, the pressure container 4 is preferably made from a metal. The pressure container 4 made from the metal has strength sufficient to withstand an internal pressure whose difference from the atmospheric pressure is 1.84 kgf/cm². In this respect, examples of more preferable metals include stainless steel and aluminum alloys.

[0070] The permeability coefficient C_p of the gas, with which the pressure container 4 is filled, for natural rubber at 25°C is preferably equal to or greater than $20 \times 10^{-17} \text{ m}^4/(\text{N}\cdot\text{s})$. When the gas whose permeability coefficient C_p at a temperature of 25°C is equal to or greater than $20 \times 10^{-17} \text{ m}^4/(\text{N}\cdot\text{s})$ is used in the present method, the internal pressure of the hollow ball 18 can be increased in a shorter time than in the conventional method. In this respect, the permeability coefficient C_p is more preferably equal to or greater than $50 \times 10^{-17} \text{ m}^4/(\text{N}\cdot\text{s})$.

[0071] FIG. 2 shows an apparatus 30 for a method for increasing the internal pressure of a hollow ball according to a second embodiment of the present invention. The apparatus 30 includes a storage container 32, a gas cylinder 34, and an intake pipe 38.

[0072] The storage container 32 houses hollow balls 42. The storage container 32 is typically made from a resin composition. The storage container 32 may be made from a metal. The storage container 32 is kept airtight.

[0073] The storage container 32 includes a main body 44 and a lid 46. The main body 44 includes, at an upper portion thereof, an input port for putting in the hollow balls 42 therethrough. The main body 44 includes an intake hole 48 in a lower portion thereof. One end of the intake pipe 38 is passed through the intake hole 48. The other end of the intake pipe 38 is connected to the gas cylinder 34. The storage container 32 and the gas cylinder 34 are connected to each other by the intake pipe 38.

[0074] The gas cylinder 34 has stored therein a gas to be fed into the storage container 32. The gas is more excellent in permeability relative to an outer shell of each hollow ball 42 than oxygen gas and nitrogen gas. The gas cylinder 34 feeds the stored gas through the intake pipe 38 into the storage container 32. The gas cylinder 34 can cause the pressure of the gas within the storage container 32 to be equal to or higher than the atmospheric pressure.

[0075] In a method for increasing the internal pressures of the hollow balls 42 according to the present invention, in an initial step, the lid 46 is opened, and the hollow balls 42 are put into the storage container 32.

[0076] In the next step, the storage container 32 is filled with the gas. First, while the lid 46 is opened, the gas from the gas cylinder 34 is fed into the storage container 32. The air within the storage container 32 is pushed by the gas fed through the lower portion of the main body 44, to be discharged through the input port at which the lid 46 at the upper portion of the main body 44 is kept opened. Thus, most of the air within the storage container 32 is discharged. After elapse of a certain time period, the lid 46 is closed. The storage container 32 continued to be filled with the gas. When the pressure within the storage container 32 reaches a predetermined air pressure, the filling with the gas is stopped.

[0077] In the final step, the filled gas is caused to pass through the outer shells of the hollow balls 42. In this step, the hollow balls 42 are left within the storage container 32 for a predetermined time period. Due to the difference between the pressure of the filled gas within the hollow balls 42 and the pressure of the filled gas within the storage container 32,

the gas passes through the outer shells of the hollow balls 42 to enter into the hollow balls 42. Thus, the internal pressures of the hollow balls 42 are increased.

[0078] In the method for increasing the internal pressures of the hollow balls 42 according to the present invention, the storage container 32 is filled with the gas which is more excellent in permeability relative to the outer shell of each hollow ball 42 than oxygen gas and nitrogen gas. The speed at which the gas enters from the storage container 32 into the interior of each hollow ball 42 is higher than the speed at which air enters into the interior of each hollow ball 42. Thus, the internal pressures of the hollow balls 42 can be increased in a short time as compared to the conventional method of filling a container with air. In addition, in this method, by merely leaving the hollow balls 42 within the storage container 32, the internal pressures of many hollow balls 42 can be increased. According to this method, the internal pressures of the hollow balls 42 can be easily and efficiently increased.

[0079] In the method for increasing the internal pressures of the hollow balls 42 according to the present invention, the air within the storage container 32 is discharged by the fed gas. In this method, the vacuum pump 6 is unnecessary. In this method, the internal pressures of the hollow balls 42 can be increased by the apparatus 30 which is low in cost.

[0080] In the apparatus 30 in FIG. 2, the intake hole 48 through which the gas is fed is provided in the lower portion of the main body 44. The input port through which air is discharged is located in the upper portion of the main body 44. According to the positional relationship therebetween, when the storage container 32 is filled with a gas heavier than air, such as carbon dioxide, the filled gas can efficiently push air out of the container. When the storage container 32 is filled with a gas lighter than air, preferably, the intake hole is provided in the upper portion, and the exhaust hole is provided in the lower portion.

[0081] The following will specifically describe the above-described effects with, as an example, the case where carbon dioxide is used as the gas with which the storage container 32 is filled, to increase the internal pressures of the regulation tennis balls 42.

[0082] Restoring the regulation tennis balls 42 whose internal pressures have decreased to 1.60 kgf/cm² due to use of the balls 42, by the method according to the present invention, will be considered. It is assumed that filling with carbon dioxide gas is performed until the pressure of carbon dioxide reaches 1.80 kgf/cm². It is assumed that the air within the storage container 32 is fully discharged. Therefore, the partial pressures of nitrogen gas, oxygen gas, and carbon dioxide gas within the storage container 32 are as follows.

Nitrogen gas: 0.00 kgf/cm²
Oxygen gas: 0.00 kgf/cm²
Carbon dioxide gas: 1.80 kgf/cm²

[0083] The gas within each regulation tennis ball 42 is composed of 80% of nitrogen gas and 20% of oxygen gas, substantially similarly to the atmosphere. The internal pressure of each regulation tennis ball 42 is 1.60 kgf/cm², and carbon dioxide gas can be neglected. Thus, the partial pressures of nitrogen gas, oxygen gas, and carbon dioxide gas within the regulation tennis ball 42 are as follows.

Nitrogen gas: $1.60 \times 0.8 = 1.28 \text{ kgf/cm}^2$
Oxygen gas: $1.60 \times 0.2 = 0.32 \text{ kgf/cm}^2$
Carbon dioxide gas: 0.00 kgf/cm²

[0084] On the basis of the values of the partial pressures at the outer side and the inner side of the regulation tennis ball 42 and the values of the permeability coefficient Cc in Table 1, a speed V(N₂) at which nitrogen gas passes through the outer shell of the regulation tennis ball 42, which outer shell is made from natural rubber, a speed V(O₂) at which oxygen gas passes through the outer shell of the regulation tennis ball 42, and a speed V(CO₂) at which carbon dioxide gas passes through the outer shell of the regulation tennis ball 42 are as follows.

$$V(N_2) = C_0 \times 1.0 \times (0.00 - 1.28) = -1.28 \times C_0$$

$$V(O_2) = C_0 \times 2.9 \times (0.00 - 0.32) = -0.93 \times C_0$$

$$\begin{aligned} V(CO_2) &= C_0 \times 16.3 \times (1.80 - 0.0) \\ &= 29.34 \times C_0 \end{aligned}$$

A speed V_{pro} at which the gas enters into the regulation tennis ball 42 as a whole is as follows.

$$\begin{aligned} V_{pro} &= (29.34 - 1.28 - 0.93) \times C_0 \\ &= 27.13 \times C_0 \end{aligned}$$

[0085] Meanwhile, a speed at which the gas enters into the regulation tennis ball 42 when the pressure of the air within the storage container 32 is set to 1.80 kgf/cm² in the conventional method of filling with air, is calculated. At this time, the partial pressures of nitrogen gas and oxygen gas within the storage container 32 are as follows.

$$\begin{aligned} \text{Nitrogen gas: } &1.80 \times 0.8 = 1.44 \text{ kgf/cm}^2 \\ \text{Oxygen gas: } &1.80 \times 0.2 = 0.36 \text{ kgf/cm}^2 \end{aligned}$$

The partial pressures of nitrogen gas and oxygen gas within the regulation tennis ball 42 are as follows.

$$\begin{aligned} \text{Nitrogen gas: } &1.6 \times 0.8 = 1.28 \text{ kgf/cm}^2 \\ \text{Oxygen gas: } &1.6 \times 0.2 = 0.32 \text{ kgf/cm}^2 \end{aligned}$$

Thus, a speed $V(N_2)$ at which nitrogen gas passes through the outer shell of the regulation tennis ball 42, a speed $V(O_2)$ at which oxygen gas passes through the outer shell of the regulation tennis ball 42, and a speed V_{cov} at which the gas enters into the regulation tennis ball 42 as a whole are as follows.

$$V(N_2) = C_0 \times 1.0 \times (1.44 - 1.28) = 0.16 \times C_0$$

$$V(O_2) = C_0 \times 2.9 \times (0.36 - 0.32) = 0.12 \times C_0$$

$$V_{cov} = C_0 \times (0.16 + 0.12) = 0.28 \times C_0$$

[0086] When the speed V_{pro} at which the gas enters into the regulation tennis ball 42 by the present method is compared to the speed V_{cov} at which the air enters into the regulation tennis ball 42 by the conventional method, the effects of the present invention are clear. That is,

$$V_{pro}/V_{cov} = 96.7.$$

Immediately after the storage container 32 is filled with the gas at 1.80 kgf/cm², according to the present method, the gas enters into the regulation tennis ball 42 at a speed which is 97 times of that in the conventional method. This significantly improves a speed of increasing the internal pressure of the regulation tennis ball 42. According to the present method, it is possible to restore the internal pressure of the regulation tennis ball 42 whose internal pressure has decreased, and use the regulation tennis ball 42 again.

[0087] The difference between the internal pressure of the storage container 32 and the atmospheric pressure after the storage container 32 is filled with the gas is preferably equal to or lower than 0.90 kgf/cm². For the storage container 32 which is set at an internal pressure whose difference from the atmospheric pressure is equal to or lower than 0.90 kgf/cm², a resin composition can be used as a material of the storage container 32. The storage container 32 is low in cost. The storage container 32 is lighter in weight than a metallic container. The resin composition is preferably polyethylene terephthalate. The storage container 32 made from polyethylene terephthalate has strength sufficient to withstand an internal pressure whose difference from the atmospheric pressure is 0.90 kgf/cm².

[0088] The speed at which the gas enters into the hollow ball 42 can be increased by increasing the temperature within the storage container 32. From the standpoint that the permeability coefficient of gas is increased to increase the speed of increasing the internal pressure of the hollow ball 42, the temperature within the storage container 32 is preferably equal to or higher than 35°C. From the standpoint that the quality of natural rubber which is used in a large amount as the material of the outer shell of the hollow ball 42 is maintained, the temperature within the storage container 32 is preferably equal to or lower than 60°C.

[0089] FIG. 3 shows an apparatus 50 for a method for increasing the internal pressure of a hollow ball according to a

third embodiment of the present invention. The apparatus 50 includes a housing bag 52, a gas cylinder 54, and an intake pipe 56.

[0090] The housing bag 52 houses hollow balls 58. The housing bag 52 is typically made from a resin composition. The housing bag 52 is flexible, and thus easily deforms due to an external or internal pressure. The housing bag 52 includes an input port 60 for putting in the hollow balls 58 therethrough. The input port 60 is provided with a zipper 62. By closing the zipper 62, the housing bag 52 is kept airtight.

[0091] The gas cylinder 54 has stored therein a gas to be fed into the housing bag 52. The gas is more excellent in permeability relative to an outer shell of each hollow ball 58 than oxygen gas and nitrogen gas.

[0092] In a method for increasing the internal pressures of the hollow balls 58 according to the present invention, in an initial step, the zipper 62 of the housing bag 52 is opened, and the hollow balls 58 are put into the housing bag 52. At this time, the housing bag 52 is pressed to come into close contact with the hollow balls 58, whereby the air within the housing bag 52 is discharged to the outside. The zipper 62 may be opened to a necessary degree, a suction opening of a vacuum cleaner may be inserted, and the vacuum cleaner may be operated, whereby the internal air may be discharged. The internal air may be discharged by a vacuum pump. After the air is discharged, the zipper 62 of the housing bag 52 is closed.

[0093] In the next step, the housing bag 52 is filled with the gas. The zipper 62 of the housing bag 52 is opened to a necessary degree, and the intake pipe 56 of the gas cylinder 54 is inserted into the housing bag 52. The gas is fed directly from the gas cylinder 54. After the housing bag 52 is filled with the gas, the intake pipe 56 is pulled out, and the zipper 62 is closed. The pressure of the gas within the housing bag 52 becomes substantially equal to the atmospheric pressure. By using the pressure by which the gas is fed from the gas cylinder 54, the pressure of the gas within the housing bag 52 may be made equal to or higher than the atmospheric pressure.

[0094] In the final step, the filled gas is caused to pass through the outer shells of the hollow balls 58. In this step, the hollow balls 58 are left within the housing bag 52 for a predetermined time period. Due to the difference between the pressure of the filled gas within the hollow balls 58 and the pressure of the filled gas within the housing bag 52, the gas passes through the outer shells of the hollow balls 58 to enter into the hollow balls 58. Thus, the internal pressures of the hollow balls 58 are increased.

[0095] In the method for increasing the internal pressures of the hollow balls 58 according to the present invention, the housing bag 52 is filled with the gas which is more excellent in permeability relative to the outer shell of each hollow ball 58 than oxygen gas and nitrogen gas. The speed at which the gas enters from the housing bag 52 into the interior of each hollow ball 58 is higher than the speed at which air enters into each hollow ball 58. Thus, the internal pressures of the hollow balls 58 can be increased in a short time as compared to the conventional method of filling a container with air. In addition, in this method, by merely leaving the hollow balls 58 within the housing bag 52, the internal pressures of many hollow balls 58 can be increased. According to this method, the internal pressures of the hollow balls 58 can be easily and efficiently increased.

[0096] In the method for increasing the internal pressures of the hollow balls 58 according to the present invention, the housing bag 52 is pressed to come into close contact with the hollow balls 58, whereby the air within the housing bag 52 can be discharged to the outside. In this method, a vacuum pump is unnecessary. In this method, the internal pressure of the housing bag 52 is made substantially equal to the atmospheric pressure, and thus filling with the gas is easy. In this method, the internal pressures of the hollow balls 58 can be increased by the apparatus 50 which is further low in cost.

[0097] The following will specifically describe the above-described effects with, as an example, the case where carbon dioxide is used as the gas with which the housing bag 52 is filled, to increase the internal pressures of the regulation tennis balls 58. In the following description, the air within the bag is fully discharged.

[0098] Restoring the regulation tennis balls 58 whose internal pressures have decreased to 1.60 kgf/cm² due to use of the balls 58, by the method according to the present invention, will be considered. Filling with carbon dioxide gas is performed such that the pressure of carbon dioxide gas is 1.00 kgf/cm² which is equal to the atmospheric pressure. It is assumed that the air within the housing bag is fully discharged. Therefore, the partial pressures of nitrogen gas, oxygen gas, and carbon dioxide gas within the housing bag are as follows.

Nitrogen gas: 0.00 kgf/cm²
Oxygen gas: 0.00 kgf/cm²
Carbon dioxide gas: 1.00 kgf/cm²

[0099] The gas within each regulation tennis ball 58 is composed of 80% of nitrogen gas and 20% of oxygen gas, substantially similarly to the atmosphere. The internal pressure of each regulation tennis ball 58 is 1.60 kgf/cm², and no carbon dioxide gas is present. Thus, the partial pressures of nitrogen gas, oxygen gas, and carbon dioxide gas within the regulation tennis ball 58 are as follows.

Nitrogen gas: $1.60 \times 0.8 = 1.28 \text{ kgf/cm}^2$

Oxygen gas: $1.60 \times 0.2 = 0.32 \text{ kgf/cm}^2$

Carbon dioxide gas: 0.00 kgf/cm^2

[0100] On the basis of the values of the partial pressures at the outer side and the inner side of the regulation tennis ball 58 and the values of the permeability coefficient C_0 in Table 1, a speed $V(N_2)$ at which nitrogen gas passes through the outer shell of the regulation tennis ball 58, which outer shell is made from natural rubber, a speed $V(O_2)$ at which oxygen gas passes through the outer shell of the regulation tennis ball 58, and a speed $V(CO_2)$ at which carbon dioxide gas passes through the outer shell of the regulation tennis ball 58 are as follows.

$$V(N_2) = C_0 \times 1.0 \times (0.00 - 1.28) = -1.28 \times C_0$$

$$V(O_2) = C_0 \times 2.9 \times (0.00 - 0.32) = -0.93 \times C_0$$

$$V(CO_2) = C_0 \times 16.3 \times (1.0 - 0.0) = 16.30 \times C_0$$

A speed V_{pro} at which the gas enters into the regulation tennis ball 58 as a whole is as follows.

$$\begin{aligned} V_{pro} &= (16.30 - 1.28 - 0.93) \times C_0 \\ &= 14.09 \times C_0 \end{aligned}$$

[0101] Meanwhile, in the conventional method of filling with air, the internal pressures of the regulation tennis balls 58 cannot be restored unless the pressure of the air within the housing bag 52 is equal to or higher than the internal pressure of each regulation tennis ball 58. In the conventional method, with the apparatus 50 shown in FIG. 3, it is impossible to restore the internal pressures of the regulation tennis balls 58. In addition, as described above, in the conventional method, the speed V_{cov} at which the gas enters into the regulation tennis ball 58 when the pressure container 4 is used and the pressure of the air within the pressure container 4 is set to 2.84 kgf/cm^2 is $1.71 \times C_0$. In the present method, even when the simple apparatus 50 shown in FIG. 3 is used, the gas enters into the regulation tennis ball 58 at a speed which is equal to or higher than 8 times of that in this method. The effect of the present invention is clear.

[0102] In the example of FIG. 3, the gas cylinder 54 is used for filling with carbon dioxide. For filling with carbon dioxide, dry ice may be put into the bag instead of using the gas cylinder 54. When the dry ice melts and vaporizes, the bag is filled with carbon dioxide. In this method, the gas cylinder 54 is unnecessary. In this case, the apparatus 50 can be further decreased in cost.

[0103] In the case where the internal pressures of the hollow balls 58 are increased by using a container having a fixed shape such as the pressure container 4 or the like, when the gas within the container enters into each hollow ball 58, the pressure of the gas within the container decreases. This causes a decrease in the speed at which the gas enters into each hollow ball 58. In the method shown in FIG. 3, when the gas within the housing bag 52 is absorbed by each hollow ball 58, the housing bag 52 is pressed and deformed by the external atmospheric pressure, and the capacity of the housing bag 52 decreases until the pressure within the bag 52 becomes equal to the atmospheric pressure. That is, unless all of the gas with which the housing bag 52 is filled enters into the interior of the hollow balls 58, the pressure of the gas within the bag is kept at 1 kgf/cm^2 which is equal to the atmospheric pressure. In the method shown in FIG. 3, a decrease in the speed at which the gas enters into the hollow ball 58 can be reduced without supplying again the gas from the outside.

[0104] The internal pressure of the hollow ball 58 that is left in the atmosphere decreases to the atmospheric pressure when the internal pressure is the lowest. Most of currently-used hollow balls 58 such as regulation tennis balls have an internal pressure equal to or lower than 2 times of the atmospheric pressure, when being used. Therefore, it is useful to provide a method for increasing the internal pressures of the hollow balls 58 whose internal pressures have decreased to the atmospheric pressure, to a pressure which is 2 times of the atmospheric pressure, by using the housing bag 52 filled with the gas such that the internal pressure thereof is equal to the atmospheric pressure.

[0105] In order to double the internal pressure of each hollow ball 58, the amount (molar quantity) of the gas within the hollow ball 58 needed to be doubled. This means that carbon dioxide gas is put into the hollow ball 58 in an amount equal to the amount of the gas within the hollow ball 58. Therefore, the molar quantity of the gas with which the housing bag 52 is filled is preferably equal to or greater than the sum of the molar quantities of the gas within all the hollow balls

58 stored in the housing bag 52. Since the temperature of the gas within each hollow ball 58 is equal to the temperature of the gas within the housing bag 52 and the pressures thereof are the same and equal to the atmospheric pressure as described above, the ratio of the molar quantity of the gas within each hollow ball 58 and the molar quantity of the gas within the housing bag 52 is equal to the volume ratio of these gases. Therefore, the ratio (V_g/V_b) of the volume V_g of the gas with which the housing bag 52 is filled, relative to the sum V_b of the capacities of all the hollow balls 58 (the volumes of the spaces within the hollow balls 58) put into the housing portion is preferably equal to or greater than 1.0. When the housing bag 52 is filled with the gas until the ratio (V_g/V_b) becomes equal to or greater than 1.0, the internal pressures of the hollow balls 58 whose internal pressures have decreased to the atmospheric pressure can be 2 times of the atmospheric pressure without supplying the gas in midstream. In this method, an operation of supplying the gas in midstream is unnecessary.

[0106] Each regulation tennis ball 58 typically has a capacity which is 0.5 times of the volume of the ball 58. In other words, the gas whose amount is 0.5 times of the volume of the regulation tennis ball 58 is needed to double the internal pressure of the regulation tennis ball 58. Therefore, the above condition can be rephrased as "the ratio (VC/V_t) of a capacity VC of the housing bag 52 after the regulation tennis balls 58 are put therein and the housing bag 52 is filled with the gas, relative to the sum V_t of the volumes of all the regulation tennis balls 58 put in the housing portion, is preferably equal to or greater than 1.5". By putting the regulation tennis balls 58 and the gas into the housing bag 52 such that the ratio (VC/V_t) is equal to or greater than 1.5, a user can increase the internal pressures of the regulation tennis balls 58 whose internal pressures have decreased to the atmospheric pressure, to a pressure which is 2 times of the atmospheric pressure, without supplying the gas in midstream.

[0107] In the present method, the difference between the internal pressure of the housing bag 52 and the atmospheric pressure after the housing bag 52 is filled with the gas is preferably equal to or lower than 0.1 kgf/cm^2 . For the housing bag 52 which is set at an internal pressure whose difference from the atmospheric pressure is equal to or lower than 0.1 kgf/cm^2 , a resin composition can be used as a material of the housing bag 52. The housing bag 52 is low in cost and lightweight. In addition, the permeability coefficient of this bag for nitrogen gas, oxygen gas, and carbon dioxide gas is negligibly small as compared to that of rubber. Thus, it is not necessary to take into account an effect that gas comes out of this bag. In light of being excellent in durability, low in cost, and lightweight, and having a sufficiently low permeability coefficient, the principal component of the base resin of the resin composition is preferably nylon. In this respect, the principal component of the base resin of the resin composition may be polyethylene.

[0108] By increasing the temperature in the housing bag 52, the speed at which the gas enters into each hollow ball 58 can be increased. From the standpoint that the permeability coefficient of gas is increased to increase the speed of increasing the internal pressure of the hollow ball 58, the temperature within the housing bag 52 is preferably equal to or higher than 35°C . From the standpoint that the quality of natural rubber which is used in a large amount as the material of the outer shell of the hollow ball 58 is maintained, the temperature within the housing bag 52 is preferably equal to or lower than 60°C .

[0109] A soft tennis ball includes a valve. The internal pressure of the ball is restored by supplying air through the valve with an air pump. However, the valve is harder than rubber surrounding the valve, and thus may be broken during use. The valve impairs the durability of the ball. In addition, if the valve hits against a racket when the ball is hit with the racket, the hit ball becomes unstable. Furthermore, it is necessary to supply air into balls one by one, and thus it takes much time and effort to restore the internal pressures of the balls.

[0110] When the internal pressure is restored by using the present method, a soft tennis ball does not need to have a valve. Thus, a soft tennis ball which does not have a valve can be realized. The soft tennis ball which does not have a valve is excellent in durability. When the ball is used, a racket does not hit against a valve. In addition, if the present method is used, when a plurality of balls are put into the housing portion, the internal pressures of these balls can be restored at one time. This method does not need time and effort.

[0111] The effects of the method for increasing the internal pressure of a hollow ball according to the present invention have been described above in the three types of embodiments. Embodiments of the present invention are not limited to the three types described here. For example, what to select as the housing portion, which to use as a method for discharging the air within the container, whether to discharge the air, and what pressure the internal pressure within the housing portion is set to after balls are put therein, can be determined and combined as appropriate according to a use purpose of the present method. For example, in the case where balls are used every half-day at a tennis school, in the case where balls are used in a club activity at a school only in after-school hours, or in the case where balls are used only on holidays by ordinary family, an appropriate embodiment can be realized. According to the present invention, in any of the embodiments, the internal pressures of hollow balls can be easily increased in a significantly shorter period as compared to the conventional method. Due to the above, advantages of the present invention are clear.

[0112] FIG. 4 is a perspective view of a housing container 70 for a method for increasing the internal pressure of a hollow ball according to an embodiment of the present invention. In FIG. 4, an arrow X indicates a rightward direction, and the opposite direction is a leftward direction. An arrow Y indicates an upward direction, and the opposite direction is a downward direction. The housing container 70 includes a main body 70 and an opening/closing tool 74.

[0113] The main body 70 has a box shape. The main body 70 stores hollow balls therein. The main body 70 includes an intake port 76 for feeding gas thereinto and an exhaust port 78 for discharging gas from the interior thereof. The intake port 76 is provided at the lower side of a side surface of the main body 70. The intake port 76 is provided with a cap 80. The intake port 76 can be closed by the cap 80. The exhaust port 78 is provided in an upper surface of the main body 70. The exhaust port 78 is provided with a cap 82. The exhaust port 78 can be closed by the cap 82.

[0114] The opening/closing tool 74 is located in a front surface of the main body 70. The opening/closing tool 74 is an airtight fastener. The airtight fastener 74 extends along a right side, a lower side, and a left side of the front surface of the main body 70. By opening the airtight fastener 74, the front surface of the main body 70 can be opened. Through this opening, hollow balls can be taken in and out. By closing the airtight fastener 74, the main body 70 enters an airtight state.

[0115] In order to increase the internal pressures of hollow balls by using the housing container 70, the airtight fastener 74 is opened, and the hollow balls are put through this opening into the main body 70. Next, the airtight fastener 74 is closed. In a state where the cap 80 of the intake port 76 and the cap 82 of the exhaust port 78 are opened, a gas which is more excellent in permeability relative to an outer shell of each hollow ball than oxygen gas and nitrogen gas is fed through the intake port 76 into the interior of the housing container 70. The air having been present within the main body 70 is pushed by the gas to be discharged through the exhaust port 78. After the housing container 70 is filled with the gas, the intake port 76 and the exhaust port 78 are closed. The pressure within the housing container 70 is equal to the external atmospheric pressure. The hollow balls are left in this state for a certain time period. The gas enters into the hollow balls, so that the internal pressures of the hollow balls are increased.

[0116] In the case where the internal pressures of hollow balls are increased by using the housing container 70, the air within the housing container 70 is discharged by the fed gas. When the internal pressures of the hollow balls are increased by using the container, a process of discharging the air within the container is unnecessary. In addition, the pressure within the housing container 70 is equal to the atmospheric pressure. Thus, the housing container 70 can be made from a low-cost material. In this method, the internal pressures of hollow balls can be increased with a low-cost apparatus.

[0117] As described above, in the housing container 70 in FIG. 4, the intake port 76 is located at the lower side of the side surface of the main body 70, and the exhaust port 78 is located in the upper surface of the main body 70. The exhaust port 78 is located above the intake port 76. In the case where the housing container 70 is filled with a gas heavier than air, such as carbon dioxide, the exhaust port 78 is preferably located above the intake port 76 as described above. Since the exhaust port 78 is located above the intake port 76, the filled gas can efficiently push the air out of the container.

[0118] In FIG. 4, a double-headed arrow H_i indicates a vertical height from a lower end of the main body 70 to the center of the intake port 76. A double-headed arrow H indicates the height of the main body 70. The ratio (H_i/H) of the height H_i relative to the height H is preferably equal to or less than 10%. When the ratio (H_i/H) is equal to or less than 10%, the fed gas can efficiently push out the air having been present within the main body 70.

[0119] Although not shown, a vertical height from the lower end of the main body 70 to the center of the exhaust port 78 is represented by a reference character H_o . In the housing container 70 in FIG. 4, the height H_o is equal to the height H . The ratio (H_o/H) of the height H_o relative to the height H is preferably equal to or greater than 90%. When the ratio (H_o/H) is equal to or greater than 90%, the air having been present within the main body 70 is efficiently discharged through the exhaust port 78.

[0120] In the housing container 70, the main body 70 is preferably made from a resin composition. The housing container 70 which includes the main body 70 made from the resin composition is low in cost and lightweight. The permeability coefficient of the main body 70 of the resin composition for nitrogen gas, oxygen gas, and carbon dioxide gas is negligibly small as compared to that of rubber. The container is kept airtight. In light of being excellent in durability, low in cost, and lightweight, and having a sufficiently low permeability coefficient, the principal component of the base resin of the resin composition is preferably nylon. In this respect, the principal component of the base resin of the resin composition may be polyethylene.

[0121] The opening/closing tool 74 is not limited to the airtight fastener 74. The opening/closing tool may be a zipper seal. Another type of opening/closing tool may be used as long as the tool is capable of being opened/closed and airtightness is maintained.

[0122] The housing container 70 in FIG. 4 includes the one intake port 76 and the one exhaust port 78. The housing container 70 may include two or more intake ports 76 or two or more exhaust ports 78. In this case, the air within the housing container 70 can be efficiently discharged or the housing container 70 can be efficiently filled with the gas.

[0123] The distance between the intake port 76 and the exhaust port 78 is preferably as long as possible. Thus, the gas injected through the intake port 76 can be prevented from leaking directly through the exhaust port 78. Accordingly, filling with the gas can be efficiently performed.

[0124] FIG. 5 is a perspective view of a housing container 84 for a method for increasing the internal pressure of a hollow ball according to another embodiment of the present invention. The housing container 84 includes a main body 86, an opening/closing tool 88, a hose 90, and a frame 92.

[0125] The main body 86 has a box shape. The main body 86 stores hollow balls therein. The main body 86 includes an intake port 94 for feeding gas thereinto and an exhaust port 96 for discharging gas from the interior thereof. The intake port 94 and the exhaust port 96 are provided in an upper surface of the main body 86. The intake port 94 is provided with a valve 98 and a cap 100. A feed pipe of a gas cylinder is connected to the valve 98. In addition, the intake port 94 can be closed by covering the valve 98 with the cap 100. The exhaust port 96 is provided with a cap 102. The exhaust port 96 can be closed by the cap 102.

[0126] The opening/closing tool 88 is located in a front surface of the main body 86. The opening/closing tool 88 is an airtight fastener. The airtight fastener 88 extends vertically at the center of the front surface of the main body 86. By opening the airtight fastener 88, the front surface of the main body 86 can be opened. Through this opening, hollow balls can be taken in and out. By closing the airtight fastener 88, the main body 86 enters an airtight state.

[0127] The hose 90 is located within the main body 86. The hose 90 is mounted to the main body 86. An opening of a first end of the hose 90 overlaps the intake port 94. A gas fed through the intake port 94 passes through the hose 90 to fill the main body 86. A second end 104 of the hose 90 is located below the exhaust port 96.

[0128] The frame 92 is located within the main body 86. The frame 92 supports the main body 86. In addition the frame 92 can be a rack for placing a basket containing hollow balls. The frame 92 is typically made from plastic or metal.

[0129] In order to increase the internal pressures of hollow balls by using the housing container 84, the airtight fastener 88 is opened, and the hollow balls are put through this opening into the main body 86. Next, the airtight fastener 88 is closed. As shown in FIG. 6, a gas cylinder 106 is connected to the valve 98 of the intake port 94. In a state where the valve 98 of the intake port 94 and the cap 100 of the exhaust port 96 are opened, a gas which is more excellent in permeability relative to an outer shell of each hollow ball than oxygen gas and nitrogen gas is fed through the intake port 94 into the interior of the housing container 84. The gas fed through the intake port 94 passes through the hose 90 to fill the main body 86. The air having been present within the main body 86 is pushed by the gas to be discharged through the exhaust port 96. After the housing container 84 is filled with the gas, the intake port 94 and the exhaust port 96 are closed. The pressure within the housing container 84 is equal to the external atmospheric pressure. The hollow balls are left in this state for a certain time period. The gas enters into the hollow balls, so that the internal pressures of the hollow balls are increased.

[0130] In the case where the internal pressures of hollow balls are increased by using the housing container 84, the air within the housing container 84 is discharged by the fed gas. When the internal pressures of the hollow balls are increased by using the container, a process of discharging the air within the container is unnecessary. In addition, the pressure within the housing container 84 is equal to the atmospheric pressure. Thus, the housing container 84 can be made from a low-cost material. In this method, the internal pressures of hollow balls can be increased with a low-cost apparatus.

[0131] As described above, in the housing container 84 in FIG. 5, the second end 104 of the hose 90 is located below the exhaust port 96. Thus, in the case where the housing container 84 is filled with a gas heavier than air, such as carbon dioxide, the fed gas can efficiently push the air out of the container. In the housing container 84, the intake port 94 may be located above the exhaust port 96. The intake port 94 may be located at any position in the main body 86. In this container, the intake port 94 can be located at a position where the user easily uses the intake port 94.

[0132] In FIG. 6, a double-headed arrow Hh indicates a vertical height from a lower end of the main body 86 to the second end 104 of the hose 90. A double-headed arrow H indicates the height of the main body 86. The ratio (Hh/H) of the height Hh relative to the height H is preferably equal to or less than 10%. When the ratio (Hh/H) is equal to or less than 10%, the taken-in gas can efficiently push out the air having been present within the main body 86.

[0133] The housing container 84 includes the frame 92 therein. The frame 92 reinforces the main body 86. Even in the case where the main body 86 is made from a flexible resin composition, the housing container 84 can be stably placed. In addition, the frame 92 can be used as a rack for storing a basket containing hollow balls. This makes it easy to take in and out the hollow balls.

[0134] FIG. 7 is a conceptual diagram showing a state where a housing container 110 for a method for increasing the internal pressure of a hollow ball according to still another embodiment is used. An intake port 112 of the housing container 110 is located in an upper surface of the housing container 110. This container does not include a hose. In this container, the inner diameter of the intake port 112 is larger than the outer diameter of a pipe 116 of a gas cylinder 114. The pipe 116 of the cylinder which feeds a gas is inserted through the intake port 112 into the interior of a main body 118. A leading end of the pipe 116 is located below an exhaust port. Thus, in the case where the housing container 110 is filled with a gas heavier than air, such as carbon dioxide, the filled gas can efficiently push the air out of the container.

[0135] FIG. 8 is a perspective view of a housing container 130 for a method for increasing the internal pressure of a hollow ball according to still another embodiment of the present invention. The housing container 130 includes a main body 132 and an opening/closing tool 134.

[0136] The main body 132 has a box shape. The main body 132 stores hollow balls therein. The main body 132 includes therein an intake port 136 for feeding gas thereinto and an exhaust port 138 for discharging gas from the interior thereof. The intake port 136 and the exhaust port 138 are provided in an upper surface of the main body 132. The intake

port 136 is provided with a cap 137. The intake port 136 can be closed by the cap 137. The exhaust port 138 is provided with a cap 139. The exhaust port 138 can be closed by the cap 139.

[0137] The opening/closing tool 134 is located in a front surface, both side surfaces, and a rear surface of the main body 132. The opening/closing tool 134 extends around the main body 132 near upper sides of the front surface, both side surfaces, and the rear surface. The opening/closing tool 134 is an airtight fastener 134. As shown in FIG. 9, the entire upper side of the main body 132 can be opened by opening the airtight fastener 134. Through this opening, hollow balls can be taken in and out. By closing the airtight fastener 134, the main body 132 enters an airtight state.

[0138] In order to increase the internal pressures of hollow balls by using the housing container 130, the airtight fastener 134 is opened, and the hollow balls are put through this opening into the main body 132. Next, the airtight fastener 134 is closed. In a state where the cap 140 of the intake port 136 and the cap 139 of the exhaust port 138 are opened, a gas which is more excellent in permeability relative to an outer shell of each hollow ball than oxygen gas and nitrogen gas is fed through the intake port 136 into the interior of the housing container 130. The air having been present within the main body 132 is pushed by the gas to be discharged through the exhaust port 138. After the housing container 130 is filled with the gas, the intake port 136 and the exhaust port 138 are closed. The hollow balls are left in this state for a certain time period. The gas enters into the hollow balls, so that the internal pressures of the hollow balls are increased.

[0139] The housing container 130 may include a hose within the main body 132. Alternatively, a pipe of a gas cylinder may be inserted through the intake port 136 into the interior of the housing container 130.

[0140] As described above, in the housing container 130, the entire upper side of the main body 132 can be opened. This makes it easy to take in and out hollow balls 136. The user can put the entirety of a basket 138 containing the hollow balls 136, directly into the container 160. This greatly reduces time and effort to take in and out the hollow balls 136.

[0141] The distance between the intake port 136 and the exhaust port 138 is preferably as long as possible. Thus, the gas injected through the intake port 136 can be prevented from leaking directly through the exhaust port 138. Accordingly, filling with the gas can be efficiently performed.

[0142] FIG. 10 is a front view of a pressure container 140 for a method for increasing the internal pressure of a hollow ball according to an embodiment of the present invention. In FIG. 10, an arrow X indicates a rightward direction, and the opposite direction is a leftward direction. An arrow Y indicates an upward direction, and the opposite direction is a downward direction. A direction perpendicular to the surface of the sheet is a front-rear direction. FIG. 11 is a right side view of the pressure container 140, and FIG. 12 is a plan view of the pressure container 140. In FIG. 12, an arrow Z indicates a frontward direction, and the opposite direction is a rearward direction. The pressure container 140 includes: a housing portion 142 which houses hollow balls; and a heater 144 which heats the housing portion 142. The housing portion 142 includes a trunk portion 146, a lid 148, a clamp 150, an intake port 152, an exhaust port 154, a temperature meter 156, and a pressure meter 158.

[0143] The trunk portion 146 has a cylindrical shape with a bottom 160. The bottom 160 of the trunk portion 146 is rounded so as to be convex downward. Although not shown, the trunk portion 146 includes, in an upper portion thereof, an input port for putting in hollow balls therethrough. The inputted hollow balls are stored within the trunk portion 146.

[0144] The lid 148 is put on the trunk portion 146. An upper portion of the lid 148 is rounded so as to be convex upward. The outer diameter of the lid 148 is equal to the outer diameter of the trunk portion 146. When the lid 148 is put on the trunk portion 146, the lid 148 closes the input port of the trunk portion 146.

[0145] The clamp 150 is located at the boundary between the trunk portion 146 and the lid 148. The clamp 150 extends around the trunk portion 146 and the lid 148. The clamp 150 includes a circular arc portion 162, a bolt 164, and a nut 166. As shown in FIG. 12, the circular arc portion 162 has a circular arc shape which is opened at the front and is close to a circle. Two ends 168 of the circular arc are bent frontward.

[0146] FIG. 13 shows a portion of a cross section along a line XIII-XIII in FIG. 12. As shown in the drawing, the circular arc portion 162 has a substantially U-shaped cross section. An upper end of the trunk portion 146 and a lower end of the lid 148 are bent outward and overlap each other. The circular arc portion 162 is fitted to the overlap portion. As shown in FIG. 12, the bolt 164 is inserted through the two ends 168 of the circular arc portion 162. The bolt 164 is further inserted through the nut 166. The circular arc portion 162 strongly tightens the trunk portion 146 and the lid 148 by means of the bolt 164 and the nut 166. Thus, the trunk portion 146 firmly adheres to the lid 148. The trunk portion 146 and the lid 148 firmly adhere to the circular arc portion 162. The gas within the pressure container 140 does not leak through between the trunk portion 146 and the lid 148 to the outside. The pressure container 140 is kept airtight.

[0147] The intake port 152 is provided to the lid 148. The intake port 152 is composed of a valve capable of opening/closing. By connecting a gas cylinder to the valve and opening the valve, a gas is fed into the interior of the housing portion 142.

[0148] The exhaust port 154 is provided to the lid 148. The intake port 152 is composed of a valve capable of opening/closing. By opening the valve, the gas is released from the housing portion 142. Also when the pressure within the pressure container 140 becomes excessively high, the gas is discharged through the exhaust port 154.

[0149] The temperature meter 156 is located on the lid 148. The temperature meter 156 monitors the temperature within the pressure container 140.

[0150] The pressure meter 158 is located on the lid 148. The pressure meter 158 monitors the pressure within the pressure container 140.

[0151] The heater 144 is wound around the trunk portion 146. The heater 144 is a rubber heater. The heater 144 is mounted on the outer side of the housing portion 142. The heater 144 heats the interior of the housing portion 142 from the outside of the housing portion 142. Although not shown, the heater 144 includes a knob for temperature adjustment. Thus, the temperature within the housing portion 142 is adjusted to a desired value.

[0152] In order to increase the internal pressures of hollow balls by using the pressure container 140, first, the hollow balls are put through the input port of the trunk portion 146 into the trunk portion 146. The lid 148 is put on the trunk portion 146. The clamp 150 is mounted to the boundary between the trunk portion 146 and the lid 148, and the bolt 164 of the clamp 150 is tightened. Thus, the pressure container 140 enters an airtight state. The air within the pressure container 140 is discharged through the exhaust port 154 of the pressure container 140. A gas which is more excellent in permeability relative to an outer shell of each hollow ball than oxygen gas and nitrogen gas is fed through the intake port 152 into the interior of the pressure container 140. The gas is fed until the pressure within the pressure container 140 reaches a predetermined value. The heater 144 is operated. Thus, the pressure container 140 is heated to a predetermined temperature. The hollow balls are left in this state for a certain time period. The gas enters into the hollow balls, so that the internal pressures of the hollow balls are increased.

[0153] As described above, the permeability coefficient of each of nitrogen gas, oxygen gas, and carbon dioxide gas at 50°C for natural rubber is 2 times to 3 times of the permeability coefficient thereof at 25°C. The pressure container 140 includes the heater 144. Thus, the temperature within the pressure container 140 can be easily increased. In the case where carbon dioxide gas is used as the gas with which the pressure container 140 is filled, by increasing the temperature within the pressure container 140 from 25°C to 50°C, a speed at which the gas enters into each hollow ball is increased by substantially 2.2 times. With the pressure container 140, the internal pressures of the hollow balls can be easily increased in a shorter time.

[0154] The heater may not be a type mounted on the outer portion of the housing portion 142. The heater may be a type mounted within the housing portion 142. For example, a pocket heater which is a heat source may be provided within the housing portion 142. In this case, a partition is preferably provided so as to prevent the heat source from being in direct contact with the hollow balls.

[0155] Each of the trunk portion 146 and the lid 148 is preferably made from a metal. The pressure container 140 in which each of the trunk portion 146 and the lid 148 is the metal has favorable heat resistance. This container is not damaged even when being heated by the heater 144. Furthermore, the pressure container 140 has favorable pressure resistance. When this container is used, the pressure within the container can be made higher than the pressure of the atmosphere. With this container, the internal pressures of hollow balls can be further efficiently increased. In this respect, examples of preferable metals include aluminum alloys. The container may be made from stainless steel.

[0156] The pressure container 140 in FIG. 10 includes the one intake port 152 and the one exhaust port 154. The pressure container 140 may include two or more intake ports 152 or two or more exhaust ports 154. In this case, the air within the pressure container 140 can be efficiently discharged or the pressure container 140 can be efficiently filled with the gas.

EXAMPLES

[0157] The following will show effects of the present invention by means of examples, but the present invention should not be construed in a limited manner based on the description of these examples.

[Example 1]

[0158] In Example 1, the apparatus shown in FIG. 1 was prepared, and a method for increasing the internal pressures of hollow balls was executed with specifications shown in Table 1. At the ball type in the table, "regular TB" means that regulation tennis balls were used. Carbon dioxide was used as a gas to be filled. A ball internal pressure was measured as a difference from the atmospheric pressure. The used regulation tennis balls had an internal pressure decreased to the atmospheric pressure. Therefore, the difference between the atmospheric pressure and the ball internal pressure was 0.0 kgf/cm². The outer shells of the tennis balls were made from natural rubber. These balls were put into a pressure container made from stainless steel. In the table, "Vacuum" in the cell of deaeration operation indicates that prior to filling with carbon dioxide, the air within the pressure container was discharged by using a vacuum pump. Therefore, the partial pressure of the air within the pressure container was -1.0 kgf/cm² as a difference from the atmospheric pressure. The filling with carbon dioxide was performed until the pressure of carbon dioxide reached a pressure equal to the atmospheric pressure. Therefore, the difference between the pressure of carbon dioxide and the atmospheric pressure was 0.0 kgf/cm². The temperature within the pressure container was set at 25°C. In the table, "Container weight" indicates the weight of the container per one input ball. In the table, "1" at CO₂ supply times means that after

initial filling with carbon dioxide, no carbon dioxide gas is supplied again.

[Examples 2 and 3]

5 **[0159]** Examples 2 and 3 are the same as Example 1, except the pressure of filled carbon dioxide was as shown in Table 2.

[Comparative Example 1]

10 **[0160]** Comparative Example 1 is the same as Example 3, except the gas to be filled was air.

[Example 4]

15 **[0161]** Example 4 is the same as Example 1, except the air within the pressure container was not discharged, a gaseous mixture of carbon dioxide and air was used as the gas to be filled, and the difference between the atmospheric pressure and the partial pressure of the air within the pressure container after filling with the gas was as shown in Table 3.

[Examples 5 and 6]

20 **[0162]** Examples 5 and 6 are the same as Example 1, except the temperature within the pressure container was as shown in Table 3.

[Example 7]

25 **[0163]** Example 7 is the same as Example 1, except the ratio (V_g/V_b) was as shown in Table 3 and carbon dioxide gas was supplied in midstream once. In the table, "2" at CO₂ supply times means that after initial filling with carbon dioxide, carbon dioxide gas was supplied in midstream once until the pressure of carbon dioxide reached a pressure equal to the atmospheric pressure.

30 [Example 8]

[0164] In Table 4, "Pushing out" in the cell of deaeration operation indicates that deaeration with the vacuum pump was not performed, and air was pushed out by putting in carbon dioxide gas. Example 8 is the same as Example 1, except deaeration operation was the pushing out.

35 [Example 9]

[0165] Example 9 is the same as Example 8, except the ratio (V_g/V_b) was as shown in Table 4 and carbon dioxide gas was supplied in midstream once until the pressure of carbon dioxide reached a pressure equal to the atmospheric pressure.

40 [Example 10]

45 **[0166]** In Example 10, the apparatus shown in FIG. 2 was prepared, and a method for increasing the internal pressures of hollow balls was executed with specifications shown in Table 4. At the container in the table, "PET" indicates that the storage container was made from polyethylene terephthalate. The deaeration operation was executed through "Pushing out". Filling with carbon dioxide gas was performed such that the difference between the partial pressure of carbon dioxide within the pressure container and the atmospheric pressure was 0.9 kgf/cm².

50 [Example 11]

[0167] In Example 11, the apparatus shown in FIG. 3 was prepared, and a method for increasing the internal pressures of hollow balls was executed with specifications shown in Table 5. At the container in the table, "Nylon" indicates that the housing bag was made from nylon. At the deaeration operation, "Vacuum cleaner" indicates that after the balls were put into the housing bag, the air within the bag was discharged by a vacuum cleaner. Filling with carbon dioxide was performed until the pressure of carbon dioxide reached a pressure equal to the atmospheric pressure. Therefore, the difference between the partial pressure of carbon dioxide within the pressure container and the atmospheric pressure was 0.0 kgf/cm².

[Example 12]

[0168] Example 12 is the same as Example 11, except the ratio (V_g/V_b) was as shown in Table 5 and carbon dioxide gas was supplied in midstream until the volume of carbon dioxide reached a capacity V_g .

[Example 13]

[0169] Example 13 is the same as Example 12, except the material of the housing bag was polyethylene.

[Example 14]

[0170] Example 14 is the same as Example 12, except the internal pressures of soft tennis balls were increased. At the ball type in the table, "Soft TB" means that soft tennis balls were used.

[Evaluation of Internal Pressure Increasing Speed]

[0171] After the housing portion was filled with the gas by the method shown in each of the Examples, the balls were left within the housing portion for 24 hours. In Examples 7, 9, 12, 13, and 14, carbon dioxide gas was supplied once after 12 hours. Then, the balls were taken out from the housing portion, and the internal pressure thereof was measured. The difference between this internal pressure and the internal pressure before filling with the gas is shown as an internal pressure increasing speed in Tables 2 to 5.

[Table 2]

Table 2 Evaluation Results

	Example 1	Example 2	Example 3	Comparative Example 1
Ball type	Regular TB	Regular TB	Regular TB	Regular TB
Ball internal pressure (difference from atmospheric pressure) [kgf/cm ²]	0.0	0.0	0.0	0.0
Deaeration operation	Vacuum	Vacuum	Vacuum	Not performed
CO ₂ partial pressure (difference from atmospheric pressure) [kgf/cm ²]	0.0	0.9	1.84	-1.0
Air partial pressure (difference from atmospheric pressure) [kgf/cm ²]	-1.0	-1.0	-1.0	1.84
Container	Stainless	Stainless	Stainless	Stainless
Ratio (V_g/V_b)	4.0	4.0	4.0	4.0
Storage temperature [°C]	25	25	25	25
Container weight [g/one ball]	300	300	300	300
CO ₂ supply times	1	1	1	1
Internal pressure increasing speed [kgf/cm ² day]	0.25	0.45	0.92	0.013

[Table 3]

Table 3 Evaluation Results

	Example 4	Example 5	Example 6	Example 7
Ball type	Regular TB	Regular TB	Regular TB	Regular TB
Ball internal pressure (difference from atmospheric pressure) [kgf/cm ²]	0.0	0.0	0.0	0.0
Deaeration operation	Not performed	Vacuum	Vacuum	Vacuum

(continued)

	Example 4	Example 5	Example 6	Example 7
CO ₂ partial pressure (difference from atmospheric pressure) [kgf/cm ²]	0.0	0.0	0.0	0.0
Air partial pressure (difference from atmospheric pressure) [kgf/cm ²]	0.8	-1.0	-1.0	-1.0
Container	Stainless	Stainless	Stainless	Stainless
Ratio (Vg/Vb)	4.0	4.0	4.0	2.0
Storage temperature [°C]	25	50	35	25
Container weight [g/one ball]	300	300	300	300
CO ₂ supply times	1	1	1	2
Internal pressure increasing speed [kgf/cm ² day]	0.27	0.54	0.36	0.25

[Table 4]

Table 4 Evaluation Results

	Example 8	Example 9	Example 10
Ball type	Regular TB	Regular TB	Regular TB
Ball internal pressure (difference from atmospheric pressure) [kgf/cm ²]	0.0	0.0	0.0
Deaeration operation	Pushing out	Pushing out	Pushing out
CO ₂ partial pressure (difference from atmospheric pressure) [kgf/cm ²]	0.0	0.0	0.9
Air partial pressure (difference from atmospheric pressure) [kgf/cm ²]	-1.0	-1.0	-1.0
Container	Stainless	Stainless	PET
Ratio (Vg/Vb)	4.0	2.0	4.0
Storage temperature [°C]	25	25	25
Container weight [g/one ball]	300	300	1
CO ₂ supply times	1	2	1
Internal pressure increasing speed [kgf/cm ² day]	0.25	0.25	0.45

[Table 5]

Table 5 Evaluation Results

	Example 11	Example 12	Example 13	Example 14
Ball type	Regular TB	Regular TB	Regular TB	Soft TB
Ball internal pressure (difference from atmospheric pressure) [kgf/cm ²]	0.0	0.0	0.0	0.0
Deaeration operation	Vacuum cleaner	Vacuum cleaner	Vacuum cleaner	Vacuum cleaner
CO ₂ partial pressure (difference from atmospheric pressure) [kgf/cm ²]	0.0	0.0	0.0	0.0
Air partial pressure (difference from atmospheric pressure) [kgf/cm ²]	-1.0	-1.0	-1.0	-1.0
Container	Nylon	Nylon	Polyethylene	Nylon

(continued)

	Example 11	Example 12	Example 13	Example 14
Ratio (Vg/Vb)	4.0	2.0	2.0	2.0
Storage temperature [°C]	25	25	25	25
Container weight [g/one ball]	1	1	1	1
CO ₂ supply times	1	2	2	2
Internal pressure increasing speed [kgf/cm ² day]	0.25	0.25	0.24	0.25

[0172] As shown in Tables 2 to 5, in the method for increasing the internal pressures of the balls in each Example, the internal pressures of the balls are restored at a significantly higher speed as compared to the method for increasing the internal pressures of the balls in each Comparative Example. From the evaluation results, advantages of the present invention are clear.

INDUSTRIAL APPLICABILITY

[0173] The method described above can be used for increasing the internal pressures of various hollow balls.

DESCRIPTION OF THE REFERENCE CHARACTERS

[0174]

2, 30, 50 · · · apparatus for method for increasing internal pressure of hollow ball

4, 140 · · · pressure container

6 · · · vacuum pump

10, 34, 54, 106, 114 · · · gas cylinder

12 · · · exhaust pipe

14, 38, 56 · · · intake pipe

16, 40 · · · feed pipe

18, 42, 58, 136 · · · ball

20, 44, 72, 86, 118, 132 · · · main body

22, 46, 148 · · · lid

24, 60 · · · input port

26, 28, 48 · · · hole

32 · · · storage container

52 · · · housing bag

62 · · · zipper

76, 94, 112, 136, 152 · · · intake port

84, 78, 96, 120, 138, 154 · · · exhaust port

70, 84, 110, 130 · · · housing container

74, 88, 134 · · · opening/closing tool (airtight fastener)

80, 82, 100, 102, 137, 139 · · · cap

90 · · · hose

92 · · · frame

98 · · · valve

104 · · · second end

116 · · · pipe

138 · · · basket

142 · · · housing portion

144 · · · heater

146 · · · trunk portion

150 · · · clamp

156 · · · temperature meter

158 · · · pressure meter

160 · · bottom
 162 · · circular arc portion
 164 · · bolt
 166 · · nut
 168 · · end

Claims

1. A method for increasing an internal pressure of a hollow ball, the method comprising the steps of:
 - (1) putting a hollow ball including an outer shell and a space surrounded by the outer shell, into a housing portion;
 - (2) filling the housing portion with a gas which is more excellent in permeability relative to the outer shell than oxygen gas and nitrogen gas; and
 - (3) causing the gas to pass through the outer shell.
2. The method according to claim 1, wherein the outer shell contains natural rubber, in the step (2), the housing portion is filled with a gas having a permeability coefficient of $20 \times 10^{-17} \text{ m}^4/(\text{N}\cdot\text{s})$ at 25°C for the natural rubber.
3. The method according to claim 1 or 2, wherein in the step (2), the housing portion is filled with carbon dioxide gas or a gaseous mixture of carbon dioxide gas and air.
4. The method according to any one of claims 1 to 3, further comprising, between the steps (1) and (2), a step (4) of discharging air within the housing portion.
5. The method according to any one of claims 1 to 4, wherein a temperature within the housing portion in the step (3) is not lower than 35°C and not higher than 60°C .
6. The method according to any one of claims 1 to 5, wherein a difference between an internal pressure of the housing portion and an atmospheric pressure immediately after end of the step (2) is equal to or lower than 1.84 kgf/cm^2 .
7. The method according to claim 6, wherein the difference between the internal pressure of the housing portion and the atmospheric pressure immediately after the end of the step (2) is equal to or lower than 0.9 kgf/cm^2 .
8. The method according to any one of claims 1 to 7, wherein a partial pressure of the air within the housing portion immediately after the end of the step (2) is higher than the atmospheric pressure.
9. The method according to claim 7, wherein the difference between the internal pressure of the housing portion and the atmospheric pressure immediately after the end of the step (2) is equal to or lower than 0.1 kgf/cm^2 .
10. The method according to claim 9, wherein the housing portion is a bag formed from a resin composition.
11. The method according to claim 10, wherein a principal component of a base resin of the resin composition is nylon.
12. The method according to claim 10 or 11, wherein a ratio (V_g/V_b) of a volume V_g of the gas with which the housing portion is filled in the step (2), relative to a sum V_b of capacities of all hollow balls put into the housing portion in the step (1), is equal to or greater than 1.0.
13. The method according to any one of claims 1 to 9, wherein the housing portion is a container formed from a metal.
14. An apparatus for increasing an internal pressure of a hollow ball, the apparatus comprising:
 - a housing portion into which a hollow ball including an outer shell and a space surrounded by the outer shell can be put; and
 - a feed portion configured to feed a gas to the housing portion, wherein the gas is more excellent in permeability relative to the outer shell than oxygen gas and nitrogen gas.

15. A soft tennis ball having an internal pressure which is increased by a method for increasing an internal pressure, the method including the steps of:

- (1) putting a soft tennis ball into a housing portion;
- (2) filling the housing portion with a gas which is more excellent in permeability relative to an outer shell of the soft tennis ball than oxygen gas and nitrogen gas; and
- (3) causing the gas to pass through the outer shell of the soft tennis ball, wherein

the soft tennis ball does not include a valve.

16. A housing container for a hollow ball, the housing container comprising:

- a main body; and
- an opening/closing tool mounted to the main body, wherein
- the main body includes therein an intake port for feeding gas into an interior thereof and an exhaust port for discharging gas from the interior thereof,
- a portion of the main body is capable of being opened/closed by the opening/closing tool,
- when the portion of the main body is opened, a hollow ball can be taken in and out through an opening of the portion, and
- when the portion of the main body is closed, the main body enters an airtight state.

17. The housing container according to claim 16, wherein the main body is composed of nylon.

18. The housing container according to claim 16 or 17, wherein the opening/closing tool is an airtight fastener.

19. The housing container according to any one of claims 16 to 18, wherein the intake port is located below the exhaust port.

20. The housing container according to any one of claims 16 to 19, wherein when a height from a lower end of the main body to a center of the exhaust port is denoted by H_o , a ratio (H_o/H) of the height H_o relative to a height H of the main body is equal to or greater than 90%.

21. The housing container according to any one of claims 16 to 20, wherein when a height from the lower end of the main body to a center of the intake port is denoted by H_i , a ratio (H_i/H) of the height H_i relative to the height H of the main body is equal to or less than 10%.

22. The housing container according to any one of claims 16 to 21, wherein the housing container further includes a hose, and within the main body, the hose is mounted to the main body such that an opening of a first end of the hose overlaps the intake port.

23. The housing container according to claim 22, wherein a second end of the hose is located below the exhaust port.

24. The housing container according to claim 22 or 23, wherein when a height from the lower end of the main body to the second end of the hose is denoted by H_h , a ratio (H_h/H) of the height H_h relative to the height H of the main body is equal to or less than 10%.

25. The housing container according to any one of claims 16 to 24, further comprising, within the main body, a frame for reinforcing the main body.

26. A pressure container comprising:

- a housing portion configured to house a hollow ball; and
- a heater configured to heat the housing portion, wherein
- the housing portion includes: a trunk portion having an input port through which the hollow ball is taken in and out; a lid configured to cover the input port; and an intake port through which a gas is fed into an interior of the housing portion.

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27. The pressure container according to claim 26, wherein the heater is mounted on an outer side of the housing portion.

28. The pressure container according to claim 27, wherein the heater is mounted within the housing portion.

5 **29.** The pressure container according to any one of claims 26 to 28, wherein each of the trunk portion and the lid is formed from a metal.

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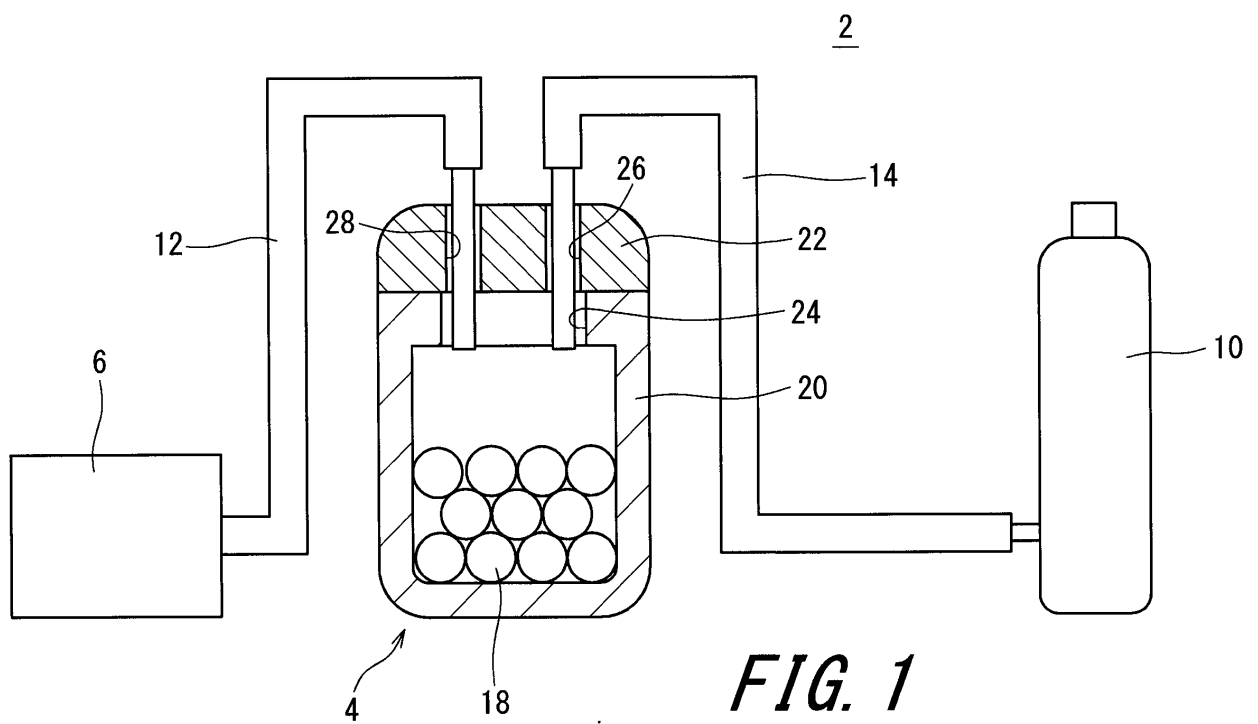
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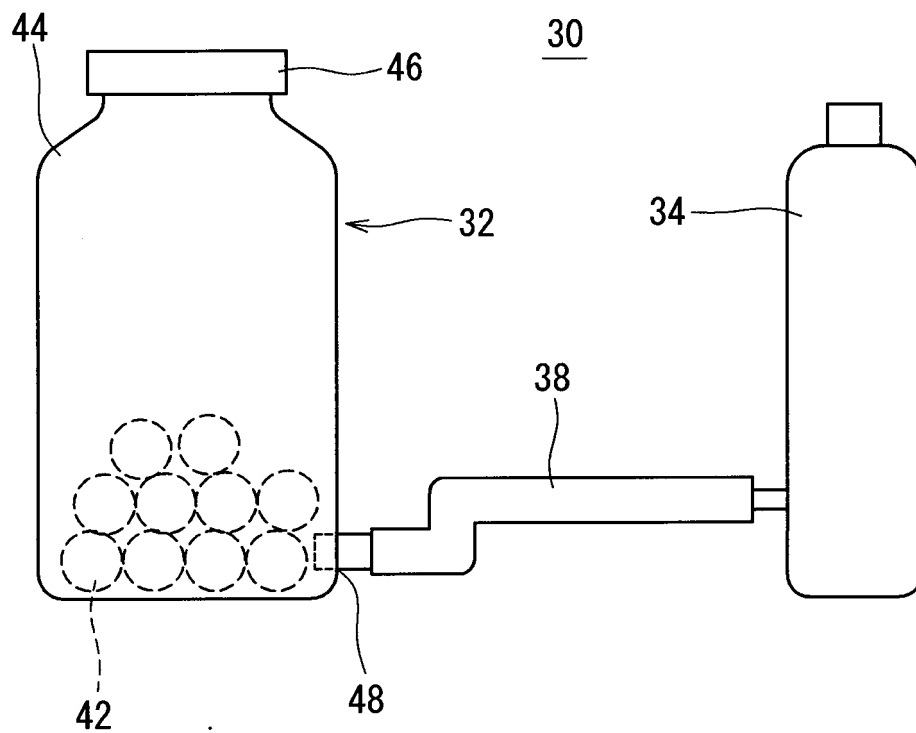


FIG. 2

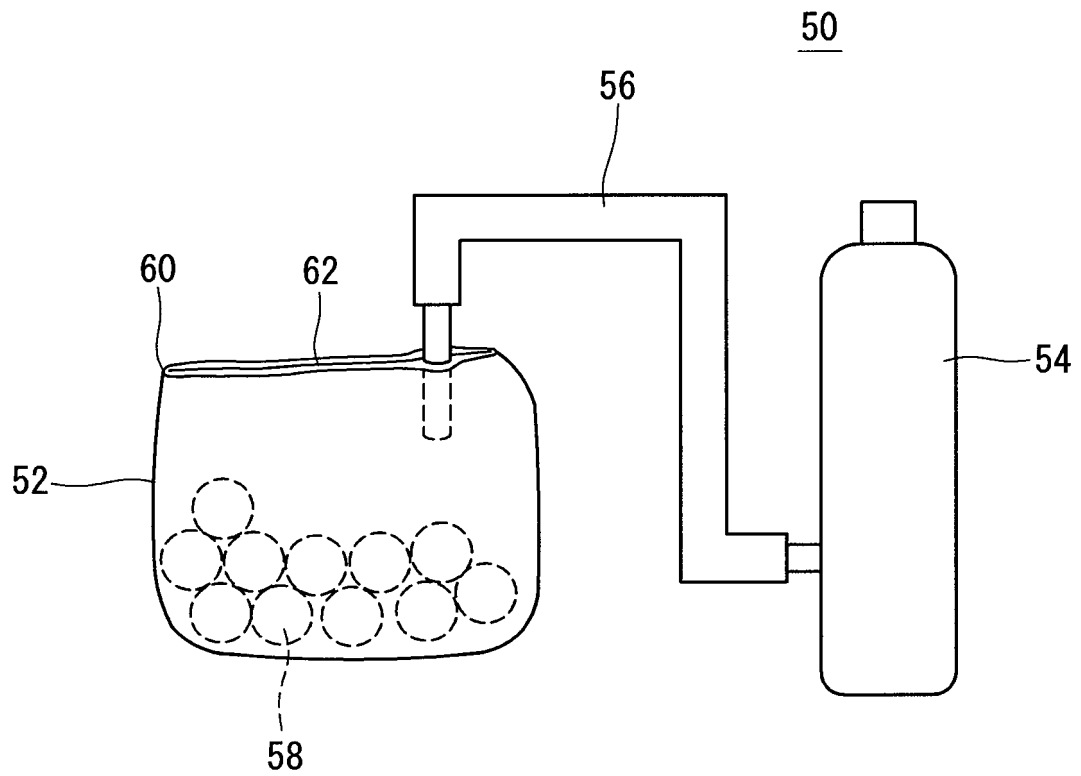
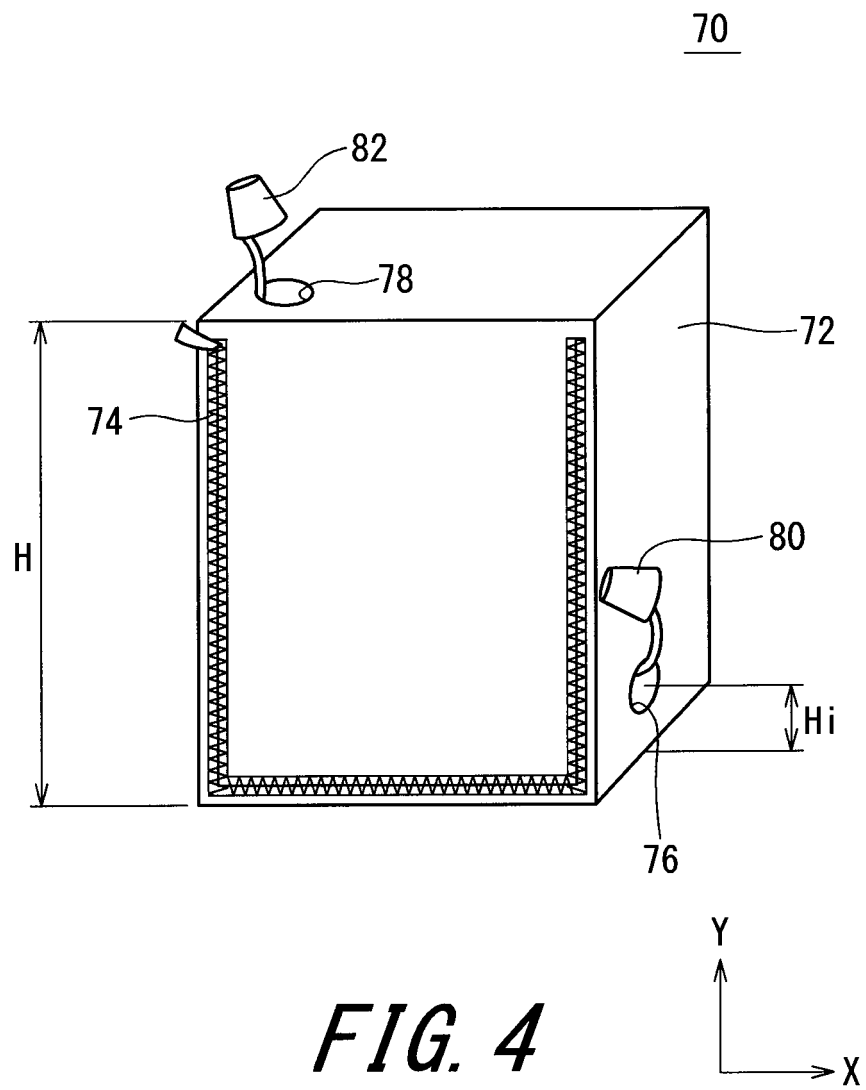


FIG. 3



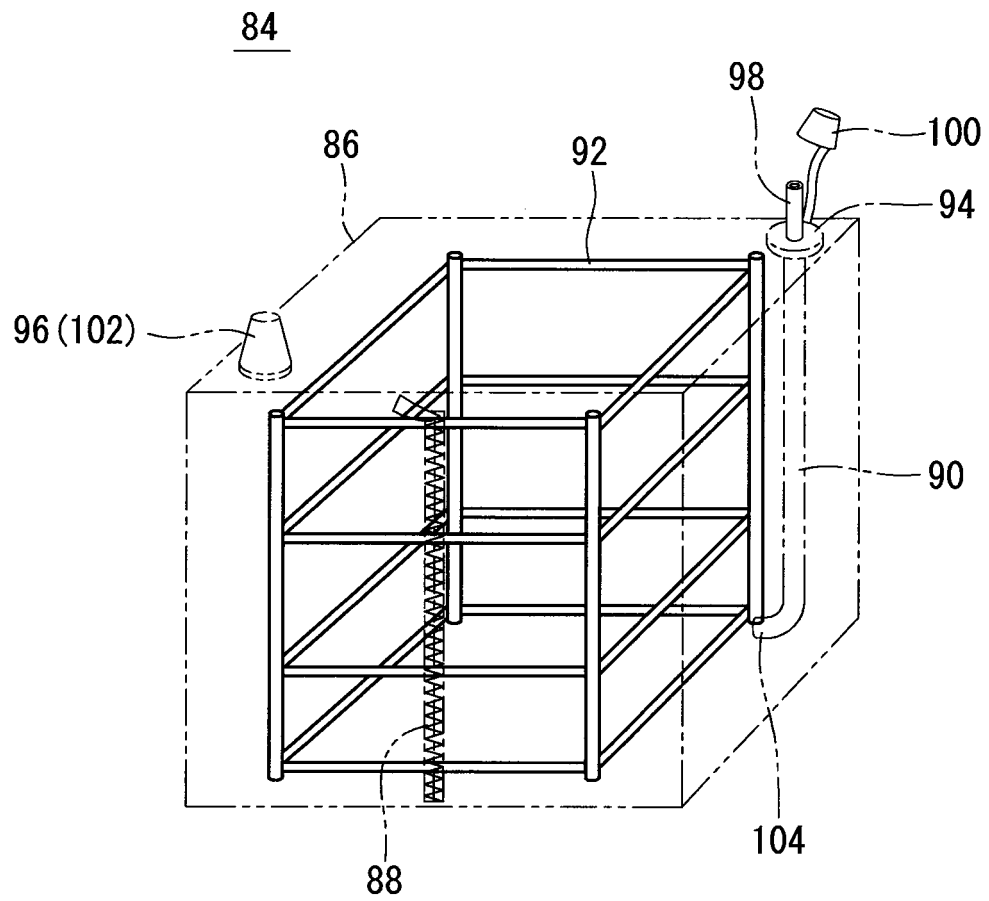


FIG. 5

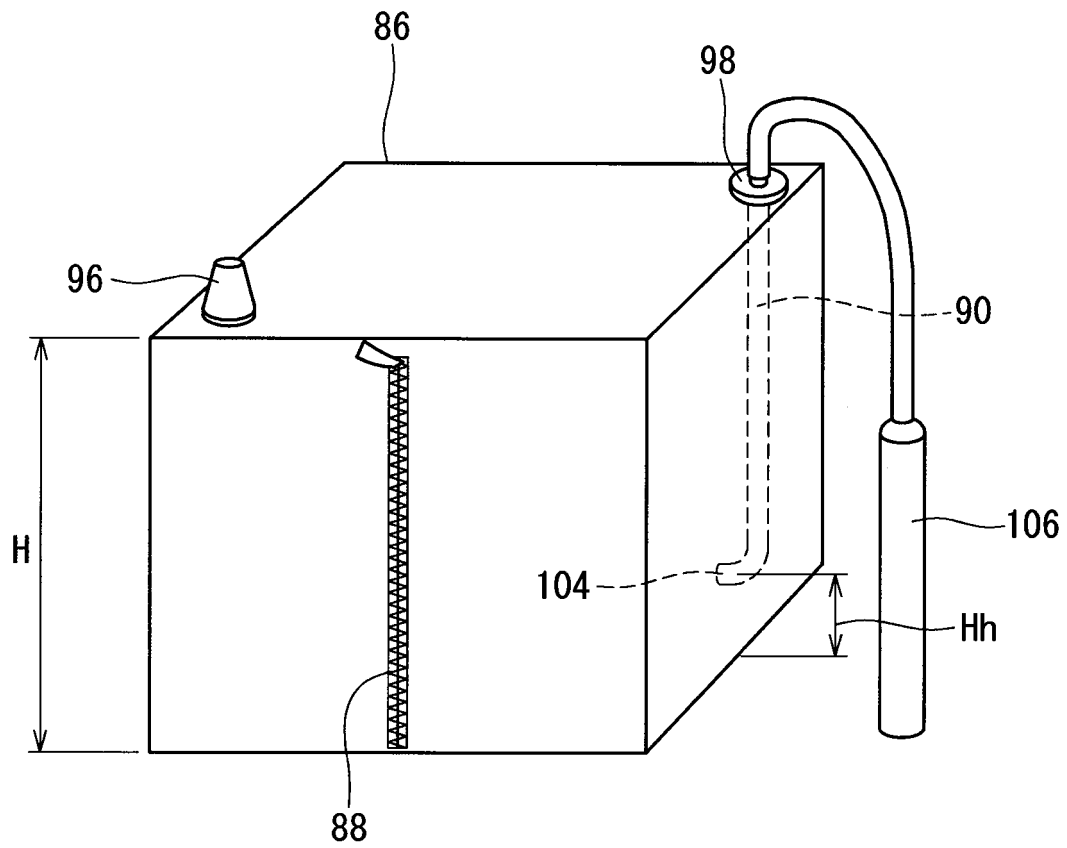


FIG. 6

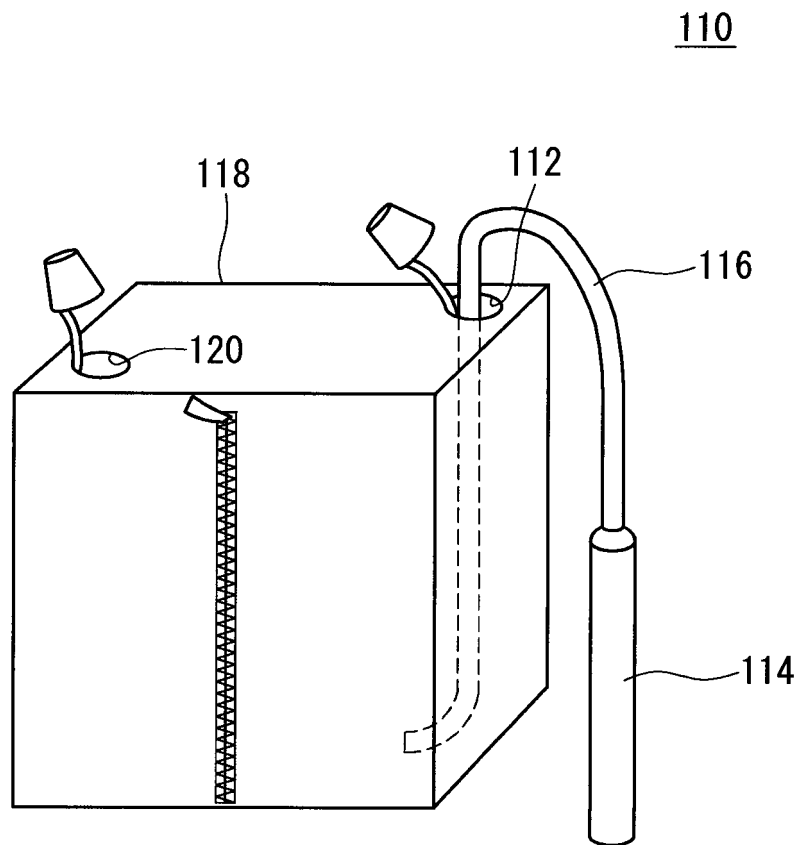


FIG. 7

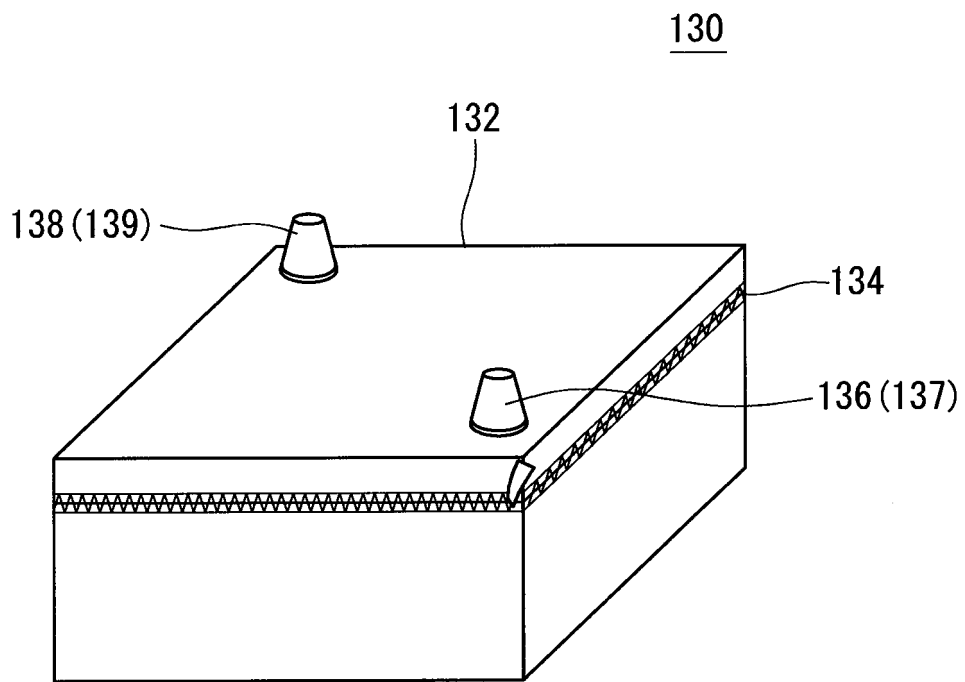


FIG. 8

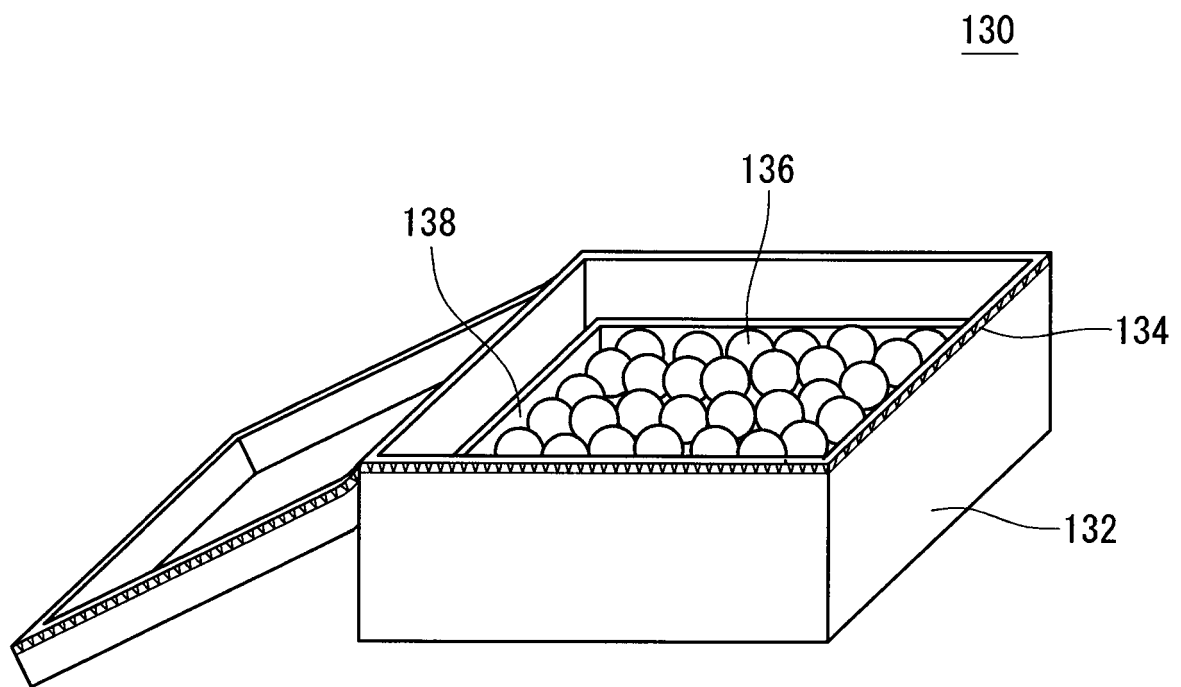


FIG. 9

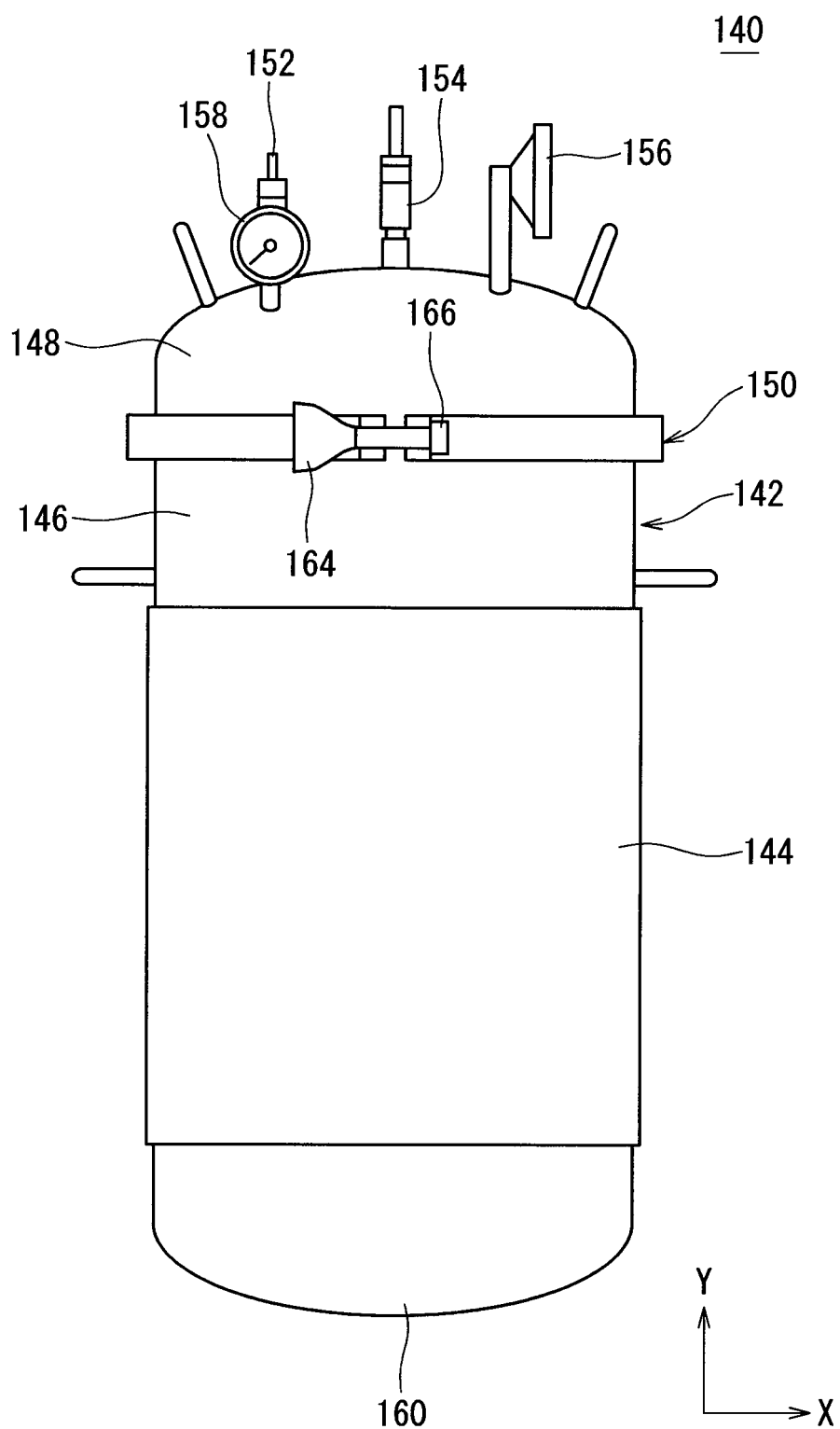


FIG. 10

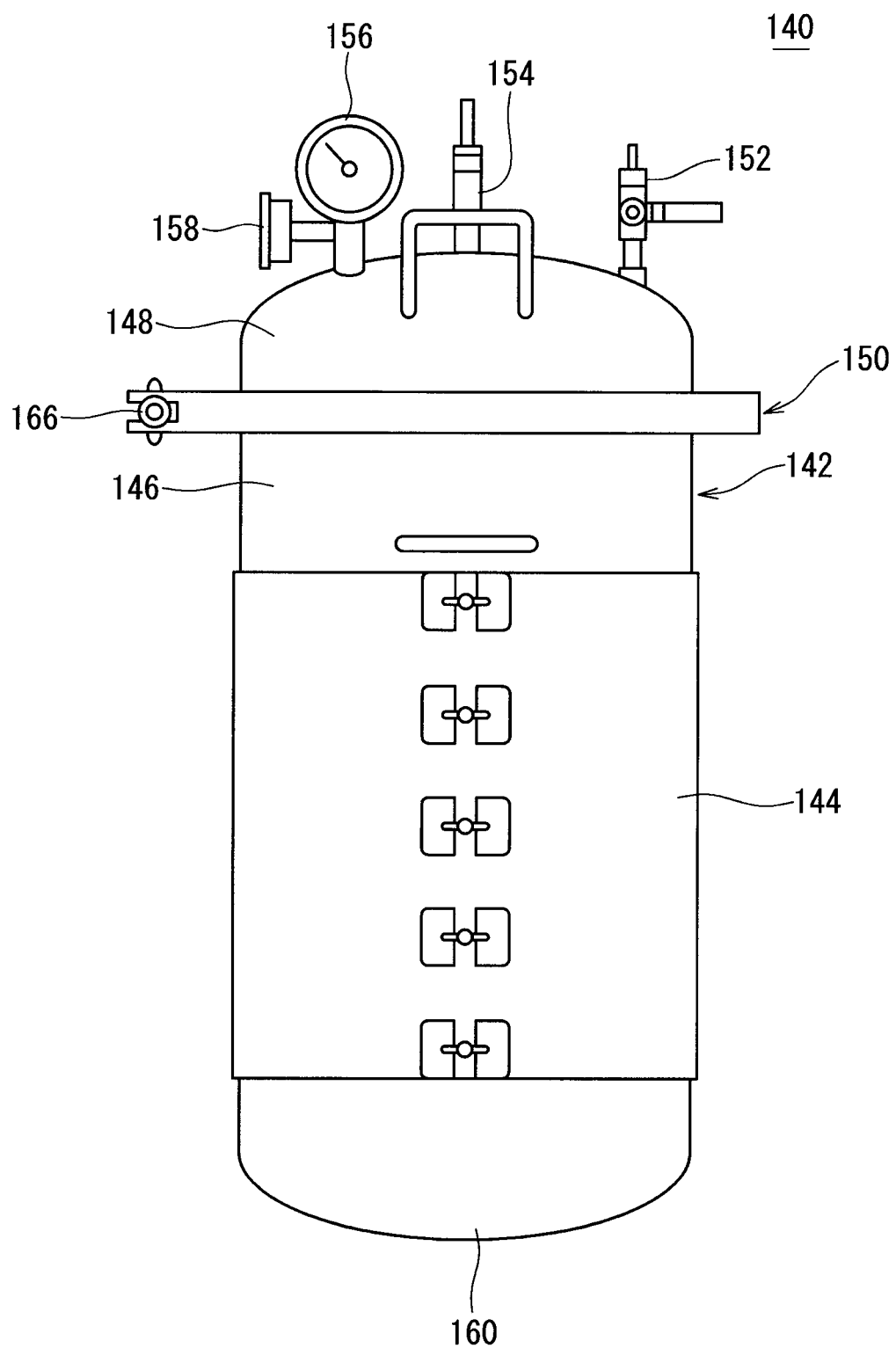


FIG. 11

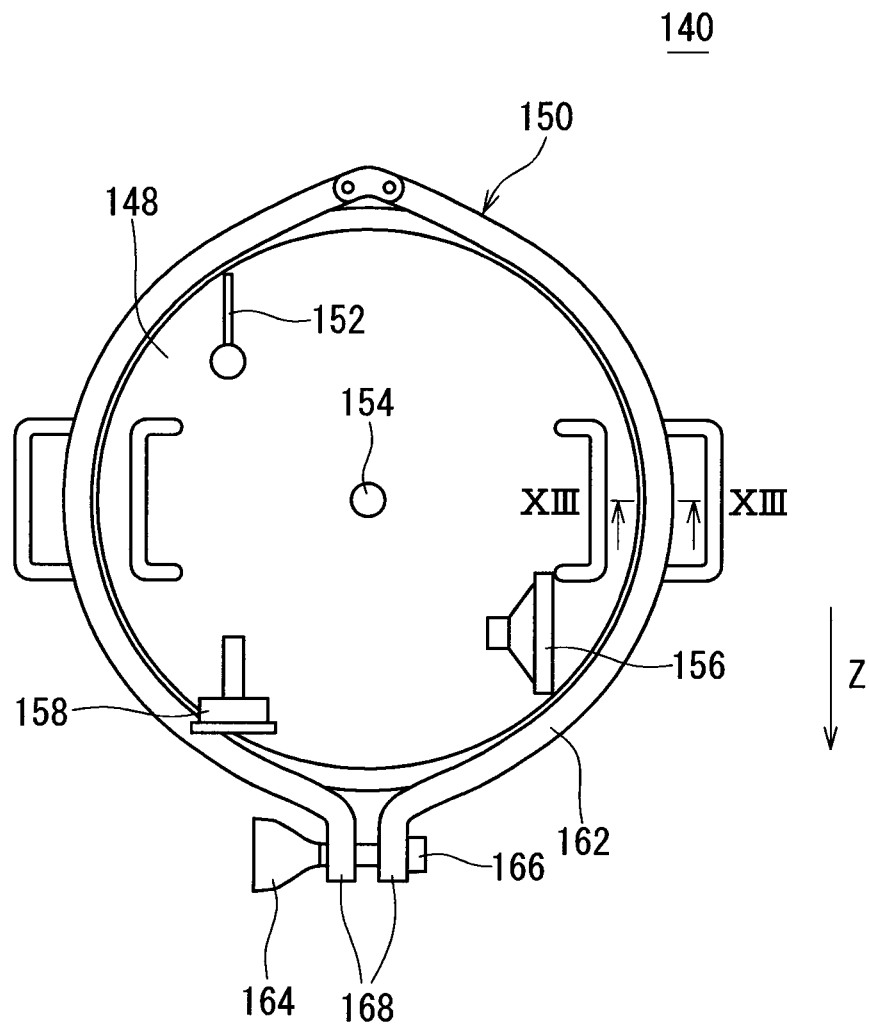


FIG. 12

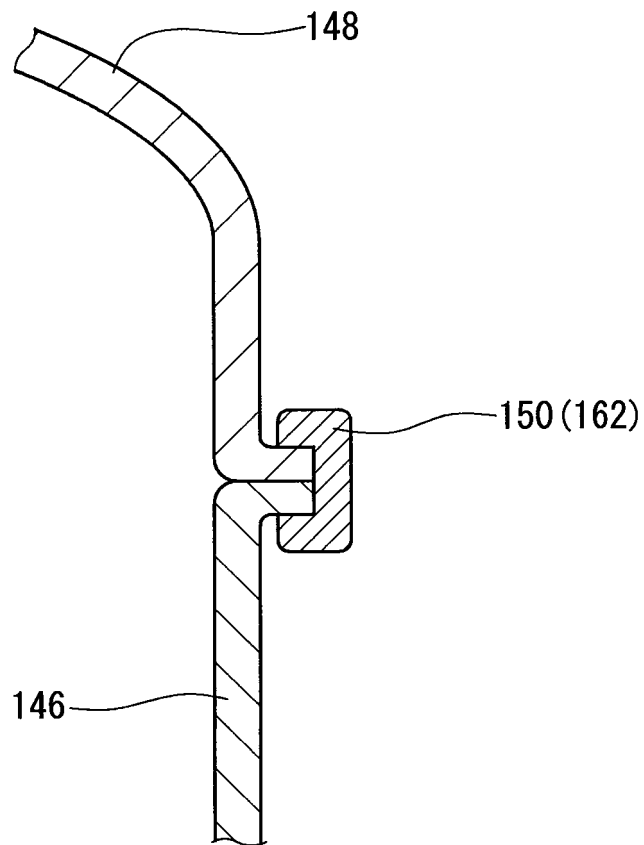


FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/063302

A. CLASSIFICATION OF SUBJECT MATTER

A63B39/02(2006.01)i, A63B47/00(2006.01)i

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)

A63B39/02, A63B47/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2014
Kokai Jitsuyo Shinan Koho	1971-2014	Toroku Jitsuyo Shinan Koho	1994-2014

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/0291914 A1 (William F.DIRST), 22 November 2012 (22.11.2012), entire text; all drawings	1-4, 6-9, 13-16
Y	& US 2010/0307637 A1 & US 7658211 B1 & WO 2011/087628 A2 & CA 2820804 A & AU 2010341694 A	5, 10-12, 17-29
Y	JP 2005-29769 A (Bridgestone Corp.), 03 February 2005 (03.02.2005), paragraph [0091] & WO 2004/113448 A1	5
Y	JP 2012-101822 A (Toppan Printing Co., Ltd.), 31 May 2012 (31.05.2012), paragraph [0041] (Family: none)	10-12, 17

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

"I" 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
20 June, 2014 (20.06.14)Date of mailing of the international search report
01 July, 2014 (01.07.14)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/063302

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2006-151428 A (Yukio HIRAHARA), 15 June 2006 (15.06.2006), claim 7 (Family: none)	18
Y	JP 7-507699 A (ESKA, Peter), 31 August 1995 (31.08.1995), fig. 1 & US 5730286 A & WO 1993/020901 A1 & DE 4212419 A & DE 59301016 C & NO 943862 A & AU 3887493 A & FI 944767 A & CA 2132443 A & AT 130521 E & ES 2085772 T & HU 75141 A & AT 130521 T & CA 2132443 A1	19-24
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 106735/1981(Laid-open No. 16215/1983) (Nihon Shokusei Corp.), 01 February 1983 (01.02.1983), claim 1; fig. 3 (Family: none)	25
Y	GB 1572813 A (John JACKSON, Brian ROWLEY, John W WOODHALL), 06 August 1980 (06.08.1980), column 2, lines 7 to 10; fig. 1 to 2 (Family: none)	26-27, 29
Y	JP 2-228979 A (Mitsuo HANYUDA), 11 September 1990 (11.09.1990), claim 1 (Family: none)	28
A	JP 8-89600 A (Kabushiki Kaisha A), 09 April 1996 (09.04.1996), entire text; all drawings (Family: none)	1-29
A	US 4101029 A (Robert S. FEINBERG), 18 July 1978 (18.07.1978), entire text; all drawings (Family: none)	1-29
A	US 4124117 A (Marion F. RUDY), 07 November 1978 (07.11.1978), entire text; all drawings (Family: none)	1-29

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/063302

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The inventions in claims 1-15 relate to the reproduction of a hollow ball.
The inventions in claims 16-25 relate to a pressure container comprising a means for sending and discharging gas.
The inventions in claims 26-29 relate to a pressure container comprising a heating means.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

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REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 7155406 A [0005] [0006] [0007]
- JP 7187252 A [0005] [0006] [0007]
- JP 8089600 A [0005] [0006] [0007]