

TITLE OF THE INVENTION

Safety Mechanism Employable in Abrasive Suspension Jet Machine

BACKGROUND OF THE INVENTION

Field of the Invention

5 The present invention relates to a safety mechanism employable in an abrasive suspension jet machine.

Description of the Background Art

 A water jet machine machining a workpiece by spraying high-pressure water onto the workpiece is employed in general. Throughout the specification, it is assumed
10 that "machining" includes chipping, perforation, cutting, polishing and the like. In machining with the water jet machine employing high-pressure water, the pressure of the high-pressure water must be reduced for safety reasons in case of emergency.

 A machine using high-pressure water containing an abrasive (abrasive grains), i.e., the so-called abrasive water jet machine is also employed. This abrasive water jet
15 machine has been so developed as to solve problems in a machine spraying high-pressure water containing no abrasive onto a workpiece, and can improve machining efficiency by employing high-pressure water containing an abrasive as machining water. This machine employs garnet, silica or aluminum oxide as the abrasive (refer to page 9 and Fig. 4 of Japanese Patent Laying-Open No. 3-066600 (1991), for example).

20 Various types of abrasive water jet machines have been proposed. Three types of such machines are now described. The first type of machine is a machine employing a method referred to as an abrasive injection jet system (refer to "Development of Water Jet Polishing Machine" by Shuko Munehiro and eight others, Hiroshima Prefectural Technology Research Institute Report No. 15 (2002), August 29, 2002, p. 31, for
25 example). According to this machine, an abrasive is supplied to a mixing chamber of an abrasive nozzle, and mixed into high-pressure water in this mixing chamber. The high-pressure water containing the abrasive is sprayed from the forward end of the abrasive nozzle at a high speed. Also in this machine, the pressure of the high-pressure

water must be reduced for safety reasons in case of emergency. Further, a valve and a discharge path connected to this valve are provided as safeguards connected to a pipe immediately upstream of the abrasive nozzle, in order to reduce the pressure of the high-pressure water (refer to an on-off valve 30 and a dump (disposal) nozzle assembly 28 in the lower left to lower right columns in page 9 and Fig. 4 of Japanese Patent Laying-Open No. 3-066600 (1991), for example). According to this structure, the valve is opened in case of emergency, upon completion of an operation etc. Therefore, the pressure of the high-pressure water can be reduced by discharging the high-pressure water through the discharge path. In this machine, the high-pressure water discharged through the discharge path contains no abrasive.

The second type of machine is a machine, included in abrasive suspension jet machines, employing a method referred to as indirect pumping (refer to "Development of Water Jet Polishing Machine" by Shuko Munehiro and eight others, Hiroshima Prefectural Technology Research Institute Report No. 15 (2002), August 29, 2002, p. 31 and Fig. 2, for example). In this machine, an isolator provided in a storage vessel in a reciprocative manner partitions the storage vessel. Machining water (suspension) containing an abrasive in a dispersed state is stored in a lower portion of the storage vessel. High-pressure water supplied from an upper portion of the storage vessel presses the isolator. Thus, the machining water is sprayed from a nozzle at a high speed.

The third type of machine is a machine, included in abrasive suspension jet machines, employing a method referred to as a bypass-principle (refer to "Development of Water Jet Polishing Machine" by Shuko Munehiro and eight others, Hiroshima Prefectural Technology Research Institute Report No. 15 (2002), August 29, 2002, p. 31 and Fig. 2, for example). In this machine, no isolator is provided in a storage vessel. Abrasives are stored in a lower portion of the storage vessel in a sedimented and deposited state (precipitated state). High-pressure water supplied from an upper portion of the storage vessel through a bypass presses the deposited abrasives. Thus,

the abrasives extruded from the lower portion of the storage vessel are sucked into the bypass and mixed into the high-pressure water in this bypass, for forming mixed water. Thereafter the mixed water is sprayed from a nozzle at a high speed, for functioning as machining water.

5 Also in each of the aforementioned second and third types of machines, the pressure of the high-pressure water stored in the storage vessel must be reduced for safety reasons in case of emergency. Therefore, a valve and a discharge path connected to this valve are provided as safeguards connected to a pipe immediately upstream of the nozzle, similarly to the first type of machine.

10 The third type of machine and the safeguards thereof are now specifically described with reference to Fig. 3. Fig. 3 is a block diagram schematically showing an abrasive suspension jet machine employing the method referred to as the bypass-principle. Each of Figs. 1 to 3 related to this specification is schematically illustrated in a properly simplified or exaggerated manner, in order to simplify the
15 illustration.

As shown in Fig. 3, the machine employing the method referred to as the bypass-principle has a high-pressure pump (high-pressure water source) 1, a main pipe 2 connected to high-pressure pump 1 and a nozzle 3 connected to an end of main pipe 2. A pressure pipe 4 is so provided as to branch from main pipe 2, and connected to an
20 upper portion of a tank 5. High-pressure water for pressurization flows in pressure pipe 4. A pressure valve 6 is provided on an intermediate portion of pressure pipe 4. An end of an abrasive supply pipe 7 is connected to a lower portion of tank 5. Another end of abrasive supply pipe 7 is connected to main pipe 2 on a downstream side of the portion of main pipe 2 from which pressure pipe 4 branches. Further, a decompression
25 pipe 8 is connected to main pipe 2 on an upstream side of the portion of main pipe 2 connected with abrasive supply pipe 7, to extend toward an outlet 10 through a decompression valve 9. Decompression pipe 8, decompression valve 9 and outlet 10 constitute a decompression piping system 11.

Water containing abrasives is stored in tank 5. In general, the abrasives are stored in a lower portion of tank 5 in a deposited state. In other words, high-pressure high-concentration water 12 containing the abrasives in a high concentration is stored in the lower portion of tank 5. On the other hand, high-pressure fresh water 13 substantially containing no abrasives is stored in an upper portion of tank 5. A stage 14 movable in three directions X, Y and Z respectively is provided under nozzle 3, and a workpiece 15 is fixed to the upper surface of stage 14 by adsorption, cohesion or the like. This workpiece 15 is a resin-sealed molding or a semiconductor wafer prepared by resin-sealing a semiconductor chip mounted on a lead frame or a printed board, for example. Throughout the specification, the term "high-pressure water" indicates high-pressure water for pressurization to be supplied to tank 5, as well as either or both of high-pressure high-concentration water 12 and high-pressure fresh water 13 in tank 5.

An operation of the abrasive suspension jet machine shown in Fig. 3 is now described. While decompression valve 9 is closed, pressure valve 6 is so opened that the high-pressure water for pressurization is supplied to tank 5 through pressure pipe 4 and fresh water 13 pressurizes high-concentration water 12 in tank 5. At the same time, high-concentration water 12 is sucked into main pipe 2 through abrasive supply pipe 7 due to flowing water (not shown) flowing in main pipe 2 at a high pressure. Thus, the abrasives contained in high-concentration water 12 are mixed into the flowing water in main pipe 2, to form mixed water. This mixed water is sprayed from nozzle 3 at a high-speed, for functioning as machining water 16.

In the abrasive suspension jet machine including each of the aforementioned second and third types of machines, however, the following problems arise when the pressure of the high-pressure water is reduced in tank 5: The first problem results from the abrasives contained in the high-pressure flowing water discharged through decompression piping system 11. More specifically, decompression pipe 8, decompression valve 9 and outlet 10 are worn and damaged by the abrasives.

The second problem results from connection between decompression piping

system 11 and another piping system (main pipe 2, high-pressure pump 1 etc.) in which the high-pressure flowing water flows. This connection directly leads the high-pressure flowing water into decompression piping system 11. More specifically, abrupt change in the flow takes place when decompression valve 9 is opened (or closed), to cause
5 mechanical damage to decompression valve 9 and decompression pipe 8. Thus, decompression valve 9 and decompression pipe 8 may be broken. This problem worsens the first problem, i.e., increases the extent of wear and damage resulting from the abrasives contained in the flowing water. Further, a shock wave generated when decompression valve 9 is opened (or closed) causes mechanical damage not only to
10 decompression valve 9 and decompression pipe 8 but also to other elements, such as high-pressure pump 1, for example, connected to main pipe 2. Thus, main pipe 2 and high-pressure pump 1 may be broken. This problem arises regardless of the abrasives contained in the flowing water.

SUMMARY OF THE INVENTION

15 The present invention has been proposed in consideration of the aforementioned problems, and an object of the present invention is to provide a safety mechanism for an abrasive suspension jet machine, capable of reducing the pressure of high-pressure water stored in a tank without exerting bad influence on the machine.

An abrasive suspension jet machine according to an aspect of the present
20 invention comprises a tank. High-pressure high-concentration water containing an abrasive in a high concentration is stored in a lower portion of the tank. High-pressure fresh water substantially containing no abrasive is stored in an upper portion of the tank. A pressure pipe circulating high-pressure water for pressurization to be supplied to the tank is connected to the upper portion of the tank. The pressure pipe is provided with
25 a pressure valve. The machine further comprises an abrasive supply pipe supplying the high-concentration water to a nozzle. The machine further comprises a decompression pipe connected to the upper portion of the tank, a decompression valve provided on the decompression pipe and a decompression mechanism provided on the decompression

pipe downstream of the decompression valve, as a safety mechanism.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

5 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram schematically showing a safety mechanism in an abrasive suspension jet machine according to a first embodiment of the present invention;

10 Fig. 2 is a block diagram schematically showing a safety mechanism in an abrasive suspension jet machine according to a second embodiment of the present invention; and

Fig. 3 is a block diagram schematically showing an abrasive suspension jet machine employing a method referred to as a bypass-principle.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

15 A safety mechanism in an abrasive suspension jet machine according to each of embodiments of the present invention is now described with reference to Figs. 1 and 2. The abrasive suspension jet machine according to each embodiment comprises a tank 5, as shown in each of Figs. 1 and 2. High-pressure high-concentration water 12 containing an abrasive in a high concentration is stored in a lower portion of tank 5.

20 High-pressure fresh water 13 substantially containing no abrasive is stored in an upper portion of tank 5. A pressure pipe 4 circulating high-pressure water for pressurization to be supplied to tank 5 is connected to the upper portion of tank 5. Pressure pipe 4 is provided with a pressure valve 6. The machine further comprises an abrasive supply pipe 7 supplying high-concentration water 12 to a nozzle 3. The machine comprises a

25 decompression pipe 8 or 19 connected to the upper portion of tank 5, a decompression valve 9 provided on decompression pipe 8 or 19 and a decompression mechanism 27 provided on decompression pipe 8 or 19 upstream of decompression valve 9, as a safety mechanism.

The aforementioned decompression mechanism 27 may be provided with a small-diametral portion 17 having a smaller inner diameter than decompression pipe 8 and an outlet 10 discharging fresh water 13 passing through small-diametral portion 17, as shown in Fig. 1.

5 The aforementioned decompression mechanism 27 may be provided with a decompression cylinder 20 connected to decompression pipe 19, a piston 22 provided in decompression cylinder 20 to be pressed by high-pressure fresh water 13 flowing into decompression mechanism 27 through decompression pipe 19 and a pressure absorption mechanism 24 absorbing the pressure applied to piston 22, as shown in Fig. 2.

10 In the machine according to each of the embodiments shown in Figs. 1 and 2, high-pressure fresh water 13 substantially containing no abrasive is stored in the upper portion of tank 5. Further, decompression pipe 8 or 19 is connected to the upper portion of tank 5. Thus, high-pressure fresh water 13 substantially containing no abrasive flows into decompression mechanism 27 through decompression pipe 8 or 19 and decompression valve 9. Thus, decompression pipe 8 or 19, decompression valve 9 and decompression mechanism 27 are prevented from wear and damage resulting from the abrasive.

20 In the machine according to each of the embodiments shown in Figs. 1 and 2, further, decompression pipe 8 or 19, decompression valve 9 and decompression mechanism 27 are separated from the piping system circulating the high-pressure water for pressurization. Therefore, the pressure of the high-pressure water stored in tank 5 is reduced without exerting bad influence on the machine by the high-pressure water for pressurization.

25 In the machine shown in Fig. 1, decompression pipe 8 is provided with small-diametral portion 17. Thus, the high-pressure water so flows in small-diametral portion 17 that the pressure thereof is gradually reduced. Therefore, a safeguard having a simple structure is implemented.

On the other hand, the machine shown in Fig. 2 has decompression cylinder 20

connected to decompression pipe 19, piston 22 provided in decompression cylinder 20 to be pressed by high-pressure fresh water 13 flowing into decompression mechanism 27 through decompression pipe 19 and pressure absorption mechanism 24 absorbing the pressure applied to piston 22. Thus, pressure absorption mechanism 24 absorbs the pressure applied through piston 22. Therefore, the pressure of the high-pressure water is gradually reduced.

[First Embodiment]

A safety mechanism in an abrasive suspension jet machine according to a first embodiment of the present invention is described with reference to Fig. 1. Fig. 1 is a block diagram schematically showing the safety mechanism in the abrasive suspension jet machine according to the first embodiment of the present invention. When elements of the machine described below have the same functions as the elements shown in Fig. 3, these elements are denoted by the same reference numerals as those shown in Fig. 3, and redundant description is not repeated.

As shown in Fig. 1, a decompression pipe 8 is connected to an upper portion (upper end surface) of a tank 5 in this embodiment. In other words, a pressure pipe 4 and decompression pipe 8 are connected to the upper end surface of tank 5. A small-diametral portion 17 having a smaller inner diameter than decompression pipe 8 is provided on a portion of decompression pipe 8 located between a decompression valve 9 and an outlet 10. Decompression pipe 8, decompression valve 9, small-diametral portion 17 and outlet 10 constitute a decompression piping system 18.

An operation of the safety mechanism shown in Fig. 1 is now described. If tank 5 must be decompressed in case of emergency, a pressure valve 6 is closed and decompression valve 9 is opened. Thus, supply of high-pressure water for pressurization to tank 5 is stopped, while high-pressure fresh water 13 flows into small-diametral portion 17 through decompression pipe 8 and decompression valve 9. High-pressure fresh water 13 is decompressed by passing through small-diametral portion 17, so that decompressed fresh water 13 is discharged from outlet 10.

The safety mechanism according to this embodiment attains the following effects: First, decompression pipe 8 is connected to the upper end surface of tank 5 while high-pressure fresh water 13 is stored in the upper portion of tank 5, whereby an abrasive is inhibited from flowing into decompression piping system 18. Therefore, decompression pipe 8, decompression valve 9, small-diametral portion 17 and outlet 10 are prevented from wear and damage resulting from the abrasive (first effect).

Second, decompression piping system 18 is not connected to another piping system (a main pipe 2, a high-pressure pump 1 etc.) circulating high-pressure flowing water, whereby the high-pressure flowing water does not directly flow into decompression piping system 18. Thus, abrupt change in the flow is suppressed when decompression valve 9 is opened (or closed). Therefore, decompression piping system 18 is hardly subjected to mechanical damage, to be prevented from breakage or the like. When decompression valve 9 is opened (or closed), further, generation of a shock wave is prevented. Thus, other elements, such as high-pressure pump 1, for example, connected to main pipe 2 are not mechanically damaged by a shock wave. Therefore, main pipe 2, high-pressure pump 1 etc. are prevented from breakage or the like. In summary, no high-pressure flowing water directly flows into decompression piping system 18, whereby decompression piping system 18, main pipe 2 and high-pressure pump 1 are prevented from breakage or the like (second effect). In the process of attaining this effect, tank 5 functions as a buffering mechanism.

Third, the high-pressure water flows out from the upper portion of tank 5 storing the same through decompression pipe 8 and decompression valve 9, to be decompressed when passing through small-diametral portion 17 and thereafter discharged from outlet 10. Thus, the high-pressure water is not abruptly but gradually decompressed. In other words, small-diametral portion 17 and outlet 10 function as decompression mechanisms in this embodiment. Therefore, the pressure of the high-pressure water is reduced without exerting bad influence on the machine (third effect).

The inner diameter and the length of small-diametral portion 17 in this embodiment may be decided in response to conditions such as the pressure of the flowing water flowing in decompression piping system 18, requirements specifications related to a decompression curve for the time and the quantity of decompression etc.

5 Between small-diametral portion 17 and outlet 10, decompression pipe 8 is preferably linearly provided for forming a linear portion, whose length is preferably increased to the utmost. The machine further comprises a U-tube (not shown) and a water tank (not shown) under the linear portion, and is filled up with water between a portion immediately downstream of decompression valve 9 and the U-tube, the water tank etc.

10 Thus, the power of the high-pressure water flowing out from small-diametral portion 17 further effectively weakened in the linear portion.

In this embodiment, the abrasive may flow into decompression pipe 8 in the following two cases: In the first case, the abrasive is not completely deposited (precipitated) in tank 5 immediately after the same is supplied to tank 5. In the second

15 case, tank 5 is so filled with the abrasive that the abrasive is easily sucked into decompression pipe 8. In each of these cases, the abrasive may remain in decompression pipe 8. Therefore, the remaining abrasive may flow into decompression valve 9, to inflict groovelike flaws on the member constituting decompression valve 9. In order to prevent this inconvenience, pressure valve 6 is preferably opened after tank 5

20 is decompressed and stabilized. Thus, tank 5 is pressurized with the high-pressure water for pressurization, whereby the fresh water stored in the upper portion of tank 5 successively flows into decompression pipe 8 and decompression valve 9. Therefore, the abrasive remaining in decompression pipe 8 and decompression valve 9 is so washed away that decompression valve 9 is prevented from breakage.

25 [Second Embodiment]

A safety mechanism in an abrasive suspension jet machine according to a second embodiment of the present invention is described with reference to Fig. 2. Fig. 2 is a block diagram schematically showing the safety mechanism in the abrasive suspension

jet machine according to the second embodiment of the present invention.

As shown in Fig. 2, a decompression pipe 19 is connected to an upper portion (upper end surface) of a tank 5 also in this embodiment, similarly to decompression pipe 8 (see Fig. 1) in the first embodiment. According to this embodiment, however,
5 decompression pipe 19 is connected to a decompression cylinder 20. Decompression cylinder 20 has a closed space 21, a piston 22 and a rod 23. Rod 23 is connected to another rod 25 provided on an air cylinder 24. An air pipe 26 is connected to air cylinder 24. Air (high-pressure air) of a prescribed pressure is supplied to air cylinder 24 through air pipe 26 at prescribed timing. According to this embodiment,
10 decompression pipe 19 and a decompression valve 9 constitute a decompression piping system 18, while decompression cylinder 20, air cylinder 24 and air pipe 26 constitute a decompression mechanism 27.

An operation of the safety mechanism in the abrasive suspension jet machine shown in Fig. 2 is now described. If tank 5 must be decompressed in case of
15 emergency, a pressure valve 6 is closed and decompression valve 9 is opened. Thus, supply of high-pressure water for pressurization to tank 5 is stopped. At the same time, high-pressure fresh water 13 flows into a portion (upper portion in Fig. 2) of closed space 21 of decompression cylinder 20 partitioned by piston 22 through decompression pipe 19 and decompression valve 9. High-pressure fresh water 13 flowing into closed
20 space 21 presses piston 22. The air (high-pressure air) of the prescribed pressure is supplied to air cylinder 24 through air pipe 26 at the prescribed timing. Thus, piston 22 of decompression cylinder 20 moves downward in Fig. 2 at a prescribed speed and the prescribed timing, whereby the pressure applied to piston 22 is absorbed through rods 23 and 25.

25 In the safety mechanism according to this embodiment, effects similar to the first and second effects in the first embodiment are attained. In addition, the following effect specific to this embodiment is attained in place of the third effect in the first embodiment: The high-pressure water flows out from the upper portion of tank 5

storing the same through decompression pipe 19 an decompression valve 9, and is gradually decompressed by decompression mechanism 27. More specifically, the high-pressure water flowing into closed space 21 of decompression cylinder 20 first presses piston 22. The pressure applied to piston 22 is absorbed by the air of the prescribed pressure supplied to air cylinder 24 at the prescribed timing. Thus, the high-pressure water is not abruptly but gradually decompressed. Thus, the pressure of the high-pressure water is reduced without exerting bad influence on the machine (third effect in the second embodiment).

In the safety mechanism according to this embodiment, the pressure of the air (high-pressure air) supplied to air cylinder 24 and the timing for supplying the air can be properly changed. Thus, the extent for reducing the pressure of the high-pressure water can be properly controlled. Therefore, a safety mechanism having the optimum decompression characteristic can be obtained in response to the pressure of the high-pressure water stored in tank 5 and a decompression curve required for decompressing the high-pressure water (fourth effect in the second embodiment).

While the air (high-pressure air) and air cylinder 24 are used as the elements of decompression mechanism 27 in this embodiment, another fluid may alternatively be employed as working fluid, in place of the air. For example, a hydraulic cylinder may be used as an element of decompression mechanism 27, in place of air cylinder 24. Alternatively, another actuator may be used as an element of decompression mechanism 27.

A combination of a ball screw connected to rod 23 of decompression cylinder 20 and an electric motor driving the ball screw may be employed. In this case, the pressure of the high-pressure water flowing into closed space 21 is preferably detected, for rotating the electric motor in response to the detected pressure. According to this structure, piston 22 of decompression cylinder 20 is so moved at a prescribed speed as to gradually reduce the pressure of the high-pressure water flowing into closed space 21 of decompression cylinder 20.

The safety mechanisms according to the aforementioned first and second embodiments are preferably selectively employed on the basis of the following criteria: According to the first embodiment, decompression piping system 18 is provided with small-diametral portion 17, whereby a small safety mechanism can be obtained at a low cost. However, the decompression performance of the safety mechanism according to the first embodiment depends on the inner diameter and the length of small-diametral portion 17. If the required decompression performance is maintained constant to some extent and implementation of a small and low-priced safety mechanism is required, therefore, the first embodiment is preferably employed. According to the second embodiment, on the other hand, the decompression characteristic can be varied by changing the pressure of the air supplied to air cylinder 24 and the time for supplying the air. In this case, closed space 21 of decompression cylinder 20 preferably has a volume comparable to (preferably substantially equal to) that of tank 5. If it is more important to obtain the optimum decompression characteristic as compared with smallness and a low cost, therefore, the safety mechanism according to the second embodiment is preferably employed.

Each of the aforementioned embodiments is applied to the machine employing the method referred to as the bypass-principle included abrasive suspension jet machines. However, the safety mechanism according to the present invention is not restricted to this but is also applicable to a machine employing a method referred to as indirect pumping employing an isolator provided in a storage vessel in a reciprocative manner included in abrasive suspension jet machines. Also in this case, high-pressure fresh water substantially containing no abrasive is stored in a portion of the storage vessel located above the isolator, i.e., in an upper portion of the storage vessel, while high-pressure high-concentration water containing an abrasive in a high concentration is stored in a portion located under the isolator, i.e., in a lower portion of the storage vessel. Also in this case, effects similar to those described with reference to the above embodiments are attained.

Decompression pipe 8 is connected to the upper end surface of tank 5 in each of the aforementioned embodiments. However, the safety mechanism according to the present invention is not restricted to this, but decompression pipe 8 may simply be connected to the upper portion of tank 5. For example, decompression pipe 8 may be
5 connected to a side surface in the upper portion of tank 5. Also according to this structure, the abrasive is inhibited from flowing into decompression piping system 18 shown in each of Figs. 1 and 2.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to
10 be taken by way of limitation, the scope of the present invention being interpreted by the terms of the appended claims.

WHAT IS CLAIMED IS:

1. A safety mechanism employable in an abrasive suspension jet machine comprising:

a tank;

high-pressure high-concentration water, stored in a lower portion of said tank,
5 containing an abrasive in a high concentration;

high-pressure fresh water, stored in an upper portion of said tank, substantially containing no said abrasive;

a pressure pipe, connected to said upper portion of said tank, circulating high-pressure water for pressurization to be supplied to said tank;

10 a pressure valve provided on said pressure pipe; and

an abrasive supply pipe supplying said high-concentration water to a nozzle, wherein

said safety mechanism includes:

a decompression pipe connected to said upper portion of said tank;

15 a decompression valve provided on said decompression pipe; and

a decompression mechanism provided on said decompression pipe downstream of said decompression valve.

2. The safety mechanism employable in an abrasive suspension jet machine according to claim 1, wherein

said decompression mechanism has:

a small-diametral portion having a smaller inner diameter than said
5 decompression pipe, and

an outlet discharging said fresh water passing through said small-diametral portion.

3. The safety mechanism employable in an abrasive suspension jet machine according to claim 1, wherein

said decompression mechanism has:

a decompression cylinder connected to said decompression pipe,

5 a piston provided in said decompression cylinder and pressed by high-pressure
said fresh water flowing into said decompression mechanism through said
decompression pipe, and

a pressure absorption mechanism absorbing the pressure applied to said piston.