

DESCRIPTION

MOLTEN SALT CIRCULATION APPARATUS AND CIRCULATION METHOD

TECHNICAL FIELD

[0001]

The present invention relates to an apparatus and a method for circulating a molten salt as a heat-transfer medium, and more specifically relates to a molten salt circulation apparatus and circulation method that make it possible to facilitate handling of the molten salt by lowering the freezing point of the molten salt and reduce heating energy for maintaining the molten salt in a liquid state when operation is stopped.

BACKGROUND ART

[0002]

Molten salts are salts composed of cations and anions, and are substances that are normally coagulated but melted at a certain temperature or more to be turned into a molten state. Among molten salts, there are substances called HTS (Heat Transfer Salt) which are used to heat a heat exchanger, a reactor, or the like as a sensible heat-type heat-transfer medium for conducting heat accumulation or heat release without involving phase change. Examples of HTS include a mixture of sodium nitrite (NaNO_2), sodium nitrate (NaNO_3), and potassium nitrate (KNO_3) (for example, see Patent Document 1). This mixture is also called Niter derived from the English name of a crystal of potassium nitrate.

[0003]

In the case of using a molten salt such as HTS as a heat-transfer medium, a molten salt circulation apparatus generally includes: a tank for reserving the molten salt; a

heater for heating the molten salt in the tank; a pump for sending out the molten salt from the tank; and a circulation path for circulating the molten salt sent out from the tank and returning the molten salt to the tank.

[0004]

However, since the freezing point of a molten salt containing 40% by weight of sodium nitrite, 7% by weight of sodium nitrate, and 53% by weight of potassium nitrate is about 142°C, for example, it is necessary to heat the molten salt in the tank to the freezing point (about 142°C) or more to maintain the molten salt in a liquid state when handling the molten salt. For this reason, there is a disadvantage that heating energy for maintaining the molten salt in the liquid state is large even when operation is stopped.

[0005]

In addition, molten salts having high freezing points are difficult to handle. Specifically, since a molten salt has hardness like a ceramic in a solidified state, in the case where a molten salt is solidified in a pipe to cause clogging of the pipe or the like, the entire facility inevitably has to be replaced. For this reason, a molten salt needs to be maintained always at a high temperature so as not to cause the clogging of a pipe. In addition, there is a possibility that when operation is started, if a high-temperature molten salt flows into a device or pipe included in a molten salt circulation apparatus in a state where a small amount of water is present in the device or pipe, water evaporates instantly to cause steam explosion. Hence, extreme caution is required to avoid such situation.

PRIOR ART DOCUMENT

PATENT DOCUMENT

[0006]

Patent Document 1: Japanese patent application Kokai publication No. 2015-67670

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0007]

An object of the present invention is to provide a molten salt circulation apparatus and circulation method that make it possible to facilitate handling of a molten salt by lowering the freezing point of the molten salt and reduce heating energy for maintaining the molten salt in a liquid state when operation is stopped.

MEANS FOR SOLVING THE PROBLEM

[0008]

A molten salt circulation apparatus of the present invention for achieving the above-described object comprises: a tank for reserving a molten salt composed of at least one of sodium nitrite, sodium nitrate, and potassium nitrate; a heater for heating the molten salt in the tank; a pump for sending out the molten salt from the tank; a circulation path for circulating the molten salt sent out from the tank and returning the molten salt to the tank; and a water supply source for supplying water into the tank.

[0009]

In addition, a molten salt circulation method of the present invention for achieving the above-described object is a molten salt circulation method using a circulation apparatus including: a tank for reserving a molten salt composed of at least one of sodium nitrite, sodium nitrate, and potassium

nitrate; a heater for heating the molten salt in the tank; a pump for sending out the molten salt from the tank; a circulation path for circulating the molten salt sent out from the tank and returning the molten salt to the tank; and a water supply source for supplying water into the tank,

the molten salt circulation method comprising: diluting the molten salt with water supplied from the water supply source to lower the freezing point of the molten salt; heating the molten salt diluted with the water by using the heater to maintain a liquid state of the molten salt; and circulating the molten salt through the circulation path by driving the pump.

EFFECTS OF THE INVENTION

[0010]

In the present invention, a circulation apparatus comprising: a tank for reserving a molten salt (HTS) composed of at least one of sodium nitrite (NaNO_2), sodium nitrate (NaNO_3), and potassium nitrate (KNO_3); a heater for heating the molten salt in the tank; a pump for sending out the molten salt from the tank; a circulation path for circulating the molten salt sent out from the tank and returning the molten salt to the tank, and a water supply source for supplying water into the tank is configured, thus making it possible to supply water from the water supply source to dilute the molten salt with the water, thus lowering the freezing point of the molten salt. Hence, it is possible to reduce heating energy for maintaining the diluted molten salt in a liquid state when operation is stopped. In addition, since the temperature of the molten salt is lowered when operation is started and when operation is stopped, the handling of the molten salt is facilitated. That is, since the circulation of the molten salt can be started at a relatively

low temperature, even if the molten salt flows into a device or pipe included in the molten salt circulation apparatus in a state where a small amount of water is present in the device or pipe, steam explosion does not occur. In addition, since the molten salt having a lowered freezing point is unlikely to be solidified in the pipe, it is possible to prevent the clogging of the pipe.

[0011]

It is preferable that the above-described circulation apparatus include a gas supply source for supplying an air shutting gas composed of an inert gas or steam into the tank to supply the air shutting gas from the gas supply source into the tank when the pump is driven. Although a molten salt (HTS) is chemically stable, if the molten salt (HTS) is used at a high temperature over a long period of time, NaNO_2 is thermally decomposed to generate NaNO_3 or Na_2O , and if Na_2O reacts with carbon dioxide gas (CO_2) in the air, Na_2CO_3 is generated. Na_2CO_3 forms a eutectic mixture with the molten salt, and the freezing point of the eutectic mixture exceeds 300°C . In addition, when the molten salt comes into contact with oxygen in the air at a high temperature, NaNO_3 is generated by the oxidation of NaNO_2 . Then, when the concentration of NaNO_3 increases, the freezing point of the molten salt increases, making the clogging of the pipe likely to occur. However, by supplying the air shutting gas from the gas supply source into the tank when the pump is driven as mentioned above, it is possible to shut down contact between the molten salt and oxygen or carbon dioxide gas to suppress an increase of the freezing point of the molten salt.

[0012]

It is preferable that in the above-described circulation

apparatus, a pipe of the circulation path be inclined toward the tank such that the molten salt in the circulation path returns to the tank at the time of stopping the pump to recover the molten salt into the tank when the pump is stopped. This makes it possible to more surely prevent the clogging of the pipe.

[0013]

It is preferable that the molten salt circulation method of the present invention comprise: when operation is stopped, maintaining the driving of the pump, and when a temperature of the molten salt has been decreased to a threshold set in advance, supplying water from the water supply source into the tank. Since the water content mixed in the molten salt when operation is started evaporates due to the heating and is released to the outside, it is necessary to supply water into the tank when operation is stopped. Such water is gradually supplied into the tank after the temperature of the molten salt has decreased to the threshold set in advance. This makes it possible to lower the freezing point of the molten salt for the next time of starting the operation.

[0014]

It is preferable that the molten salt circulation method of the present invention comprise: measuring a concentration of sodium oxide (Na_2O) in the molten salt periodically; and when the concentration of sodium oxide (Na_2O) in the molten salt has reached to a threshold set in advance, adding nitric acid to the molten salt. By conducting neutralization by adding nitric acid to the molten salt, sodium oxide is converted to sodium nitrate (NaNO_3), so that the alkalinity decreases, and corrosion of a steel material in the system can be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

[Fig. 1] Fig. 1 is a schematic diagram showing a molten salt circulation apparatus according to an embodiment of the present invention.

MODES FOR CARRYING OUT THE INVENTION

[0016]

Hereinafter, a configuration of the present invention will be described in detail with reference to the attached drawing. Fig. 1 shows a molten salt circulation apparatus according to an embodiment of the present invention.

[0017]

As shown in Fig. 1, the molten salt circulation apparatus according to the present embodiment includes: a tank 1 for reserving a molten salt S; heaters 2 and 3 for heating the molten salt S in the tank 1; a pump 4 for sending out the molten salt S from the tank 1; a water supply source 5 for supplying water into the tank 1; a gas supply source 6 for supplying an air shutting gas into the tank 1; a cyclone separator 7 disposed on an upper portion of the tank; and a circulation path 10 for circulating the molten salt S sent out from the tank 1 and returning the molten salt S to the tank 1.

[0018]

The tank 1 has a capacity that can reserve the total amount of the molten salt S to be circulated and water for dilution, and includes, in part, a deep bottom portion 1a that is deeper than the other portions. Around the deep bottom portion 1a of the tank 1, the heater 2 is disposed. This heater 2 melts or heats the molten salt S in the deep bottom portion 1a. In addition, inside the tank 1, the heater 3 is disposed. This

heater 3 melts or heats the molten salt S in the tank 1. Both of the heaters 2 and 3 use steam, but the heat source is not particularly limited.

[0019]

The pump 4 is disposed at the position of the deep bottom portion 1a of the tank 1, and sends the molten salt S in the tank 1 to the circulation path 10. In the shown example, the pump 4 is an immersion-type pump disposed in the tank 1, but may be a pump disposed outside. The water supply source 5 is connected to the tank 1 and configured to supply pure water into the tank 1 when the circulation apparatus is stopped. The gas supply source 6 is connected to the tank 1 and configured to supply the air shutting gas into the tank 1. As the air shutting gas, an inert gas represented by a nitrogen gas or steam is used. The cyclone separator 7 is an apparatus that separates the gas contained in the tank 1 and the molten salt contained in the gas and releases only the gas to the outside. The cyclone separator 7 is disposed for the purpose of separating steam generated when operation is started and when operation is stopped and the molten salt S. Such a cyclone separator 7 has a structure that does not allow rainwater to enter the discharge port.

[0020]

In Fig. 1, the circulation path 10 includes a cooler 11, a heater 12, a heating target device 13, and a break tank 14. More specifically, an ejection port of the pump 4 is connected to an inlet port of the cooler 11 through a pipe 21, an ejection port of the cooler 11 is connected to an inlet port of the heater 12 through a pipe 22, an ejection port of the heater 12 is connected to an inlet port of the heating target device 13

through a pipe 23, an ejection port of the heating target device 13 is connected to an inlet port of the break tank 14 through a pipe 24, a liquid ejection port of the break tank 14 is connected to the tank 1 through a pipe 25, and a gas ejection port of the break tank 14 is connected to the tank 1 through a pipe 26. However, the order of arrangement of the cooler 11, the heater 12, the heating target device 13, and the break tank 14 in the circulation path 10 is not limited to this.

[0021]

The cooler 11 supports the cooling of the molten salt S because it is necessary to cool the molten salt S in the case where the heating target device 13 of the user involves exothermic reaction. Representative examples of the cooler 11 include an air fin cooler, a steam generator, and the like. The shown example is an air fin cooler. A steam generator is disposed for the purpose of recovering heat, and a vertical type is preferably selected in consideration of reduction of the space. The cooler 11 does not necessarily have to be disposed.

[0022]

As the heater 12, there are 2 types, that is, a heating furnace and an electric heater. The 2 types are differently used depending on the amount of heat to be consumed in the heating target device 13, but basically in the case of endothermic reaction, since a large amount of heat is required, a "heating furnace" may be selected, while in the case of exothermic reaction, since only an amount of heat required to increase temperature is sufficient, an "electric heater" may be selected. In the shown example, the heater 12 which is composed of an electric heater is incorporated in the circulation path 10, but it is also possible to dispose such a heater 12 in the tank 1.

[0023]

As the heating target device 13, there are a heat exchanger, a reactor, and the like. The break tank 14 is disposed for the purpose of siphon break and gas-liquid separation. That is, the molten salt S having passed through the heating target device 13 is separated into gas and liquid, which are refluxed to the tank 1 through the pipes 25 and 26, respectively. The break tank 14 is disposed at the highest position in the circulation path 10. Although the break tank 14 is disposed downstream of the heating target device 13 in the shown example, it is also possible to employ a system configuration in which the break tank 14 is disposed upstream of the heating target device 13 to supply the molten salt S to the heating target device 13 of each user through the break tank 14.

[0024]

The molten salt S (HTS) used in the present invention is composed of at least one of sodium nitrite (NaNO_2), sodium nitrate (NaNO_3), and potassium nitrate (KNO_3). For example, the molten salt S (HTS) includes a mixture of three types, sodium nitrite (NaNO_2), sodium nitrate (NaNO_3), and potassium nitrate (KNO_3), a mixture of two types, sodium nitrate (NaNO_3) and potassium nitrate (KNO_3), a single substance of sodium nitrate (NaNO_3), a single substance of potassium nitrate (KNO_3), and the like. More specifically, examples of the molten salt S (HTS) include a mixture containing three types, 40% by weight of sodium nitrite (NaNO_2), 7% by weight of sodium nitrate (NaNO_3), and 53% by weight of potassium nitrate (KNO_3), a mixture containing two types, 50% by weight of sodium nitrate (NaNO_3) and 50% by weight of potassium nitrate (KNO_3), a mixture containing two types, 75% by weight of sodium nitrate (NaNO_3)

and 25% by weight of potassium nitrate (KNO_3), and the like.
[0025]

The amount of water to be added to the molten salt S is preferably 6% by weight to 50% by weight, and more preferably 15% by weight to 25% by weight of the weight of the molten salt S. For example, while the freezing point of a molten salt S containing 40% by weight of sodium nitrite, 7% by weight of sodium nitrate, and 53% by weight of potassium nitrate is about 142°C , adding 15% by weight of dilution water to the molten salt S decreases the freezing point to 70°C or less. There is a tendency that as the amount of dilution water to be added is increased, the freezing point decreases, and there is an advantage that the heating energy for maintaining the molten salt S in a liquid state when operation is stopped is reduced. However, it is necessary to increase the capacity of the tank 1 for reserving the molten salt S for this. Hence, the amount of water to be added to the molten salt S may be selected as required depending on the relation between the heating energy required to heat the tank 1 and the capacity of the tank 1.
[0026]

Next, a method for using the above-mentioned molten salt circulation apparatus will be described. First, water is supplied from the water supply source 5 into the tank 1, and this water was heated to be warm water. Then, the molten salt S is added into the warm water to dissolve the molten salt S. Such operation can be easily conducted. The freezing point of the molten salt S is lowered by this operation. When operation is started, the molten salt S diluted with the water is heated by using the heaters 2 and 3 to maintain the liquid state of the molten salt S, and the molten salt S is circulated through

the circulation path 10 by driving the pump 4. The molten salt S is cooled by the cooler 11 as necessary, further heated by the heater 12 as necessary, and then supplied to the heating target device 13 composed of a heat exchanger or a reactor. The molten salt S having passed through the heating target device 13 returns to the tank 1 through the break tank 14. While the temperature of the molten salt S is increased to an operating temperature set within a range of 300°C to 550°C, for example, the temperature of the molten salt S is gradually increased to such an operating temperature with sufficient time being taken. The dilution water evaporates at between about 140°C and about 260°C at the time of increasing the temperature of the molten salt S, and no dilution water is contained in the molten salt S in the state of normal operation.

[0027]

According to the above-mentioned circulation method, the circulation apparatus includes: the tank 1 for reserving the molten salt S composed of at least one of sodium nitrite (NaNO_2), sodium nitrate (NaNO_3), and potassium nitrate (KNO_3); the heaters 2 and 3 for heating the molten salt S in the tank 1; the pump 4 for sending out the molten salt S from the tank 1; the circulation path 10 for circulating the molten salt S sent out from the tank 1 and returning the molten salt S to the tank 1; and the water supply source 5 for supplying water into the tank 1, and the freezing point of the molten salt S is lowered by diluting the molten salt S with water supplied from the water supply source 5, the molten salt S diluted with the water is heated by using the heaters 2 and 3 to maintain the liquid state of the molten salt S, and the molten salt S is circulated through the circulation path 10 by driving the pump 4. In this way,

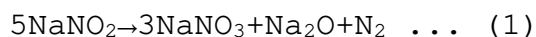
it is possible to reduce the heating energy for maintaining the molten salt S having a low freezing point in a liquid state when operation is stopped.

[0028]

In addition, since it becomes possible to lower the temperature of the molten salt S when operation is started and when operation is stopped, the handling of the molten salt S is facilitated. That is, since the circulation of the molten salt S can be started at a relatively low temperature (for example, about 70°C), even if the molten salt S flows into a device such as the cooler 11, the heater 12, the heating target device 13, or the break tank 14 or the pipe 21 to 25 included in the circulation apparatus of the molten salt S in a state where a small amount of water is present in the device or pipe, steam explosion does not occur. In addition, since the molten salt S having a lowered freezing point is unlikely to be solidified in the pipes 21 to 25, it is possible to prevent the clogging of the pipes 21 to 25.

[0029]

In the case where the above-mentioned circulation apparatus includes the gas supply source 6 for supplying an air shutting gas composed of an inert gas or steam into the tank 1, the air shutting gas can be supplied from the gas supply source 6 into the tank 1 when the pump 4 is driven. Although a molten salt (HTS) is chemically stable, if the molten salt (HTS) is used at a high temperature over a long period of time, NaNO_2 is thermally decomposed to generate NaNO_3 or Na_2O . Particularly, thermal decomposition of the formula (1) below occurs at 450°C or more, and thermal decomposition of the formula (2) below occurs at 600°C or more.



[0030]

Na₂O generated in the process of thermal decomposition reacts with carbon dioxide gas (CO₂) in the air to generate Na₂CO₃. Na₂CO₃ forms a eutectic mixture with the molten salt, and the freezing point of the eutectic mixture exceeds 300°C. In addition, when the molten salt S comes into contact with oxygen in the air at a high temperature, NaNO₃ is generated by the oxidation of NaNO₂. Then, when the concentration of NaNO₃ increases, the freezing point of the molten salt S increases, making the clogging of the pipes likely to occur. In view of this, by always supplying the air shutting gas from the gas supply source 6 into the tank 1 when the pump 4 is driven, it is possible to shut down contact between the molten salt S and oxygen or carbon dioxide gas to suppress an increase of the freezing point of the molten salt S.

[0031]

In the above-mentioned circulation apparatus, it is preferable that the pipes 21 to 25 of the circulation path 10 be inclined toward the tank 1 such that the molten salt S in the circulation path 10 returns to the tank 1 when the pump 4 is stopped. The degree of the inclination of the pipes is preferably within a range of 1/200 to 1/100. In this case, the molten salt S is recovered into the tank 1 by its own weight when the pump 4 is stopped. This makes it possible to more surely prevent the clogging of the pipes 21 to 25. However, in the case where a retention portion (for example, a horizontal portion) is inevitably formed in at least part of the pipes 21 to 25 because of the structure of the facility, it is also

possible to dispose a steam trace or an electric heater on the retention portion to heat the retention portion, thereby promoting dissolution of the molten salt S in the retention portion.

[0032]

In the above-mentioned circulation apparatus, it is desirable to use carbon steel as the constituent material of the tank 1, the pipes 21 to 25, and the like in the case of using the molten salt S at 450°C or less, and to use chromium molybdenum steel as the constituent material of the tank 1, the pipes 21 to 25, and the like in the case of using the molten salt S at 450°C or more. Although the start temperature of the decomposition reaction of the molten salt S is about 450°C, in the case where there is adhesion of iron rust or organic substance inside the device or the pipes, the decomposition reaction of the molten salt S starts at around 300°C. Then, Na_2O generated by the decomposition reaction cause corrosion of a steel material. For this reason, it is effective to increase the corrosion resistance of the tank 1, the pipes 21 to 25, and the like depending on the operating temperature. As the constituent material, stainless steel can also be used besides carbon steel and chromium molybdenum steel.

[0033]

In the above-mentioned circulation method, when operation is stopped, while the heating by the heater 12 is stopped, the driving of the pump 1 is maintained, and when the temperature of the molten salt S has been decreased to a threshold set in advance, water is supplied from the water supply source 5 into the tank 1. Since the water content mixed in the molten salt S when operation is started evaporates due

to the heating and is released to the outside, it is necessary to supply water into the tank 1 when operation is stopped. Such water is gradually supplied into the tank 1 after the temperature of the molten salt S has decreased to the threshold (for example, 250°C) set in advance. The stop of supplying dilution water can be determined based on, for example, position of the liquid level. This makes it possible to lower the freezing point of the molten salt S for the next time of starting the operation.

[0034]

In the above-mentioned circulation method, it is favorable to measure the concentration of sodium oxide (Na_2O) in the molten salt S periodically (for example, around once a year), and when the concentration of sodium oxide (Na_2O) in the molten salt S has reached a threshold set in advance, to add nitric acid to the molten salt S. By conducting neutralization by adding nitric acid to the molten salt S, sodium oxide is converted to sodium nitrate (NaNO_3), so that the alkalinity decreases, and corrosion of the steel material in the system can be reduced.

EXAMPLES

[0035]

Circulation of a molten salt was conducted based on Example 1 and Comparative Example 1 described below.

[0036]

[Example 1]

A circulation apparatus comprising: a tank for reserving a molten salt; a heater for heating the molten salt in the tank; a pump for sending out the molten salt from the tank; a circulation path for circulating the molten salt sent out from

the tank and returning the molten salt to the tank; and a water supply source for supplying water into the tank (see Fig. 1) was used to dilute the molten salt with water supplied from the water supply source to lower the freezing point of the molten salt, heat the molten salt diluted with the water by using the heater to maintain the liquid state of the molten salt, and circulate the molten salt through the circulation path by driving the pump. On the circulation path, a heater for heating the molten salt, a heat exchanger as a heating target device, and a break tank were provided. As the molten salt, a mixture containing three types, 40% by weight of sodium nitrite (NaNO_2), 7% by weight of sodium nitrate (NaNO_3), and 53% by weight of potassium nitrate (KNO_3) (freezing point= 142°C) was used and diluted with 15% by weight of water. The freezing point of the molten salt diluted with water was about 70°C .

[0037]

[Comparative Example 1]

A circulation apparatus comprising: a tank for reserving a molten salt; a heater for heating the molten salt in the tank; a pump for sending out the molten salt from the tank; and a circulation path for circulating the molten salt sent out from the tank and returning the molten salt to the tank was used to heat the molten salt by using the heater to maintain the liquid state of the molten salt, and circulate the molten salt through the circulation path by driving the pump. On the circulation path, a heater for heating the molten salt, a heat exchanger as a heating target device, and a break tank were provided. As the molten salt, a mixture containing three types, 40% by weight of sodium nitrite (NaNO_2), 7% by weight of sodium nitrate (NaNO_3), and 53% by weight of potassium nitrate (KNO_3) (freezing

point=142°C) was used.

[0038]

As a result, in Comparative Example 1, it was necessary to heat the molten salt to 142°C or more in order to maintain the molten salt in a liquid state when operation is stopped. In contrast, in Example 1, since the freezing point of the molten salt was lowered by diluting the molten salt with water, the heating temperature for maintaining the molten salt in a liquid state when operation is stopped was able to be significantly reduced, and as a result, the heating energy was able to be significantly reduced. In addition, in Example 1, since the circulation of the molten salt was able to be started at a relatively low temperature, there was no risk of causing steam explosion when operation is started. Moreover, in Example 1, since the molten salt having a lowered freezing point was unlikely to be solidified in the pipe, there was also no risk of causing the clogging of the pipe at all.

EXPLANATION OF REFERENCE NUMERALS

[0039]

- 1 tank
- 2, 3 heater
- 4 pump
- 5 water supply source
- 6 gas supply source
- 7 cyclone separator
- 10 circulation path
- 11 cooler
- 12 heater
- 13 heating target device
- 14 break tank

21 to 26 pipe
S molten salt

CLAIMS

[Claim 1] A molten salt circulation apparatus comprising:
a tank for reserving a molten salt composed of at least one of sodium nitrite, sodium nitrate, and potassium nitrate;
a heater for heating the molten salt in the tank;
a pump for sending out the molten salt from the tank;
a circulation path for circulating the molten salt sent out from the tank and returning the molten salt to the tank;
and
a water supply source for supplying water into the tank.

[Claim 2] The molten salt circulation apparatus according to claim 1, comprising:
a gas supply source for supplying an air shutting gas composed of an inert gas or steam into the tank.

[Claim 3] The molten salt circulation apparatus according to claim 1 or 2, wherein
a pipe of the circulation path is inclined toward the tank such that the molten salt in the circulation path returns to the tank when the pump is stopped.

[Claim 4] A molten salt circulation method using a circulation apparatus including: a tank for reserving a molten salt composed of at least one of sodium nitrite, sodium nitrate, and potassium nitrate; a heater for heating the molten salt in the tank; a pump for sending out the molten salt from the tank; a circulation path for circulating the molten salt sent out from the tank and returning the molten salt to the tank; and a water supply source for supplying water into the tank,

the molten salt circulation method comprising:

diluting the molten salt with water supplied from the water supply source to lower the freezing point of the molten salt;

heating the molten salt diluted with the water by using the heater to maintain a liquid state of the molten salt; and

circulating the molten salt through the circulation path by driving the pump.

[Claim 5] The molten salt circulation method according to claim 4, wherein

the circulation apparatus includes a gas supply source for supplying an air shutting gas composed of an inert gas or steam into the tank,

the molten salt circulation method comprising:

supplying the air shutting gas from the gas supply source into the tank when the pump is driven.

[Claim 6] The molten salt circulation method according to claim 4 or 5, wherein

in the circulation apparatus, a pipe of the circulation path is inclined toward the tank such that the molten salt in the circulation path returns to the tank when the pump is stopped,

the molten salt circulation method comprising:

recovering the molten salt into the tank when the pump is stopped.

[Claim 7] The molten salt circulation method according to claim 4 or 5, comprising:

when operation is stopped, maintaining the driving of the pump, and when a temperature of the molten salt has been decreased to a threshold set in advance, supplying water from the water supply source into the tank.

[Claim 8] The molten salt circulation method according to claim 4 or 5, comprising:

measuring a concentration of sodium oxide in the molten salt periodically; and

when the concentration of sodium oxide in the molten salt has reached to a threshold set in advance, adding nitric acid to the molten salt.