

SEAWATER DESALTING APPARATUS AND METHOD USING SOLAR ENERGY FOR CONTINUOUSLY SUPPLYING HEAT

FIELD OF THE INVENTION

[0001] The invention relates to an apparatus and a method for desalting seawater using solar energy for continuously supplying heat, belonging to the technical field of seawater desalting (including desalting of inland brackish water). The invention can also be applied to the field of wastewater treatment.

BACKGROUND OF THE INVENTION

[0002] With China's rapid economic development, the shortage of freshwater resources becomes a serious problem in the economically developed southeast coastal regions. Land subsidence has occurred in Beijing, Shanghai, Tianjin, Qingdao and other places due to excessive extraction of groundwater. Thus, since the beginning of the 1980s, China has launched water diversion projects such as water diversion project from Luan River to Tianjin, and water diversion project from Yellow River to Qingdao, and South-North water transfer project.

[0003] Remote water diversion project not only costs huge investment but also occupies a lot of arable land, and at the same time causes environmental hazards in the water supplying regions. For example, in the water diversion project from Yellow River to Qingdao, 62 thousand mu of area have been occupied, and ecological problems, such as discontinuous flow of Yellow River and vegetation destruction, are resulted. The destruction of the ecological environment is incalculable in the economy.

[0004] In addition, some coastal cities, such as Qingdao, Haikou, Lingshui, are formed

because of its close proximity to the freshwater river. However, the seawater invades the river about 30-50 km from the estuaries in the circumstances of tide fluctuation and typhoon, and the water in the freshwater rivers in the coastal cities is actually diluted seawater, or freshwater with lowered quality.

[0005] The shortage of the freshwater resource has been the crisis in the 21th century, in addition to the energy crisis and CO₂ emissions. To possess more freshwater by scientific and environmentally friendly ways stands for sustainable development of the national economy as well as the affluence of the national living standard.

[0006] It has been an important way for a long time for residents living along the coast and people in ocean-going vessels to acquire freshwater by utilizing various heat energy to heat the seawater to produce vapor and condensing the vapor into the freshwater. As a renewable resource, solar energy has a wide distribution, limitless reserves, cleanness in collection and utilization, and zero-CO₂ emission. Thus, the solar energy has been concerned by more and more people. However, the utilization of the solar power energy has been largely restricted due to problems such as decentralization of the solar energy, strong dependence on weather, and instability and discontinuity of the thermal concentration.

[0007] Thus, it has been an effective method to solve the shortage of the freshwater resource by finding a technical way including efficiently collecting the solar heat energy and operating continuously day and night for desalting the seawater.

SUMMARY OF THE INVENTION

[0008] It is one objective of the invention to provide an apparatus and a method for desalting seawater using solar energy for continuously supplying heat. The apparatus and the method of the invention are capable of continuously producing freshwater much

environmentally friendly in the coastal regions or in inland brackish water regions to solve the freshwater scarcity.

[0009] Technical scheme of the invention is as follows:

[0010] A seawater desalting apparatus using solar energy for continuously supplying heat comprising: a seawater purifying system, and a seawater desalting system. The seawater desalting system comprises: a solar thermal apparatus for concentrating solar energy and collecting heat, a solar energy heat storage tank, a purified seawater heater, and at least one stage of seawater flash evaporator. The seawater flash evaporator comprises a flash evaporator body and a seawater cooler. A heat transfer medium chamber of the solar thermal apparatus, the solar energy heat storage tank, a first heat exchanger of the purified seawater heater utilizing a heat transfer medium as a heat source are connected in sequence to form a sealed route for circulating the heat transfer medium. A purified seawater output main pipe of a purified seawater transporting pump in the seawater purifying system communicates with an inlet of the purified seawater heater and the seawater cooler. A seawater outlet of the purified seawater heater communicates with an inlet of a throttling device of the first-stage flash evaporator body via a heated seawater pump. The flash evaporator body comprises: a concentrated brine outlet, a freshwater outlet, and a vapor outlet. Vapor discharged from the vapor outlet passes through a second heat exchanger of the seawater cooler using vapor as a heat source and is accumulated with a freshwater in a freshwater main pipe. A sealed freshwater storage tank disposed at an end of the freshwater main pipe communicates with a vacuum pump. The concentrated brine outlet communicates with a pipe of a salt plant via a concentrated brine pump. A seawater outlet of the seawater cooler communicates with an inlet main pipe of the purified seawater heater via a condenser body of the flash evaporator body. When at least two stage seawater flash evaporators are employed, the purified seawater output main pipe of the purified seawater pump in the seawater purifying system communicates with the seawater outlets of the condenser

bodies of each stage seawater flash evaporator. The concentrated brine outlet of a former stage flash evaporator body communicates with an inlet of the throttling device of a next stage flash evaporator body, and the concentrated brine outlet of a last stage flash evaporator body communicates with the pipe of the salt plant via the concentrated brine pump. Pressures in the flash evaporator bodies of each stage are gradually decreased whereby forming negative pressures.

[0011] According to the above technical solution, a heated seawater pump having adjustable rotational speed is disposed between the seawater outlet of the purified seawater heater and the flash evaporator body. The seawater outlet of the purified seawater heater communicates with the throttling device disposed on the flash evaporator body via the heated seawater pump, and the throttling device is disposed above a seawater surface in the flash evaporator body. In the flash evaporator body, a foam breaker is disposed above the throttling device, a freshwater collecting disc is disposed above the foam breaker, and the condenser body is disposed on the freshwater collecting disc. The vapor outlet is disposed at a top of the flash evaporator body, and the freshwater outlet is disposed above the freshwater collecting disc, and the concentrated brine outlet is disposed beneath the throttling device.

[0012] According to the above technical solution, a seawater temperature sensor and a spare heat exchanger are disposed in the purified seawater heater; and the spare heat exchanger adopts a thermal oil furnace, an electric heating furnace, exhaust heat of flue gas from a boiler, or exhaust heat of waste heat from a turbine as a heat source.

[0013] According to the above technical solution, a heat transfer medium pump is disposed between the solar energy heat storage tank and the first heat exchanger of the purified seawater heater.

[0014] According to the above technical solution, the solar power filed is a tower type solar thermal collector, a parabolic trough type evacuated tubular collector, a glass type evacuated tubular collector, or a heat pipe type evacuated tubular collector.

[0015] According to the above technical solution, the seawater purifying system is a multi-stage purifying system comprising a seawater extraction well for coarse filtration, a seawater sterilizing clarifier, a multi-stage ultra-filter provided with an active carbon filter layer and a multi-fiber filter core layer, and a deoxygenating-decarbonizing tower for deoxygenation and decarbonization arranged in sequence. A purified seawater tank is disposed between the multi-stage ultra-filter and the deoxygenating-decarbonizing tower. The deoxygenating-decarbonizing tower communicates with a purified seawater main outlet. The seawater extraction well communicates with the seawater sterilizing clarifier via a seawater lifting pump. The seawater sterilizing clarifier communicates with the multi-stage ultra-filter via a first seawater transporting pump. The multi-stage ultra-filter communicates with the purified seawater tank via a second seawater transporting pump. The purified seawater tank communicates with the deoxygenating-decarbonizing tower via a third seawater transporting pump. The deoxygenating-decarbonizing tower communicates with the purified seawater main outlet via a purified seawater pump. The seawater sterilizing clarifier is added with a microbicide and a flocculant.

[0016] According to the above technical solution, the seawater extraction well is constructed at a sea beach. A well opening is disposed above a sea level at the highest tide, and a well bottom is disposed multiple meters beneath a sea level at low tides. A well wall adopts a porous concrete structure, rubbles are arranged outside the well wall, and sands are filled in the periphery of the rubbles.

[0017] A method for desalting seawater using the above seawater desalting apparatus comprises: multi-stage purifying the seawater to produce a purified seawater; collecting solar energy by the solar thermal apparatus to heat the heat transfer medium whereby converting the solar energy into heat energy of the heat transfer medium; continuously heating the purified seawater to a preset temperature by the heat energy of the heat transfer medium, and transporting the heated purified seawater to at least one-stage flash evaporator for flash evaporation; allowing pressures in the flash evaporator bodies of

each stage to gradually decrease to form a negative pressure during the flash evaporation; condensing a vapor after the flash evaporation to separate the freshwater, and converting remaining vapor into the freshwater by the seawater cooler; and transporting a non-vaporized concentrated brine from a bottom of the flash evaporator to the salt plant.

[0018] When multi-stage flash evaporators are employed, the concentrated brine at the bottom of the former stage flash evaporator successively flow into a next stage flash evaporator, and the freshwater is gradually condensed and separated out during the multi-stage evaporation process, and the non-vaporized concentrated brine is transported to the salt plant. At the same time the heat energy of the sunlight is collected by the solar thermal apparatus and the heat transfer medium is utilized to heat the purified seawater, the heat energy of the heat transfer medium is stored in the solar energy heat storage tank so as to continuously heat the purified seawater using the stored heat transfer medium during nocturnal periods or cloudy days.

[0019] According to the above technical solution, the preset temperature of the purified seawater heated by the heat transfer medium is 55°C-70°C or 70°C-120°C, and the heat transfer medium is heated to a temperature of 178°C-600°C by the solar thermal apparatus.

[0020] According to the above technical solution, the preset temperature of the purified seawater heated by the heat transfer medium is $\pm 70^{\circ}\text{C}$, and the heat transfer medium is heated to the temperature of 275°C-395°C by the solar thermal apparatus.

[0021] Advantages of the invention are summarized as follows:

[0022] The high efficient solar thermal apparatus is utilized to heat the heat transfer medium (such as the conduction oil, the silicone oil, the paraffin wax, and the molten salt), and the heat transfer medium is then employed to heat the purified seawater to a preset temperature. Thus, the scale formation resulted from seawater heating directly by the solar thermal apparatus is avoided, the seawater desalting system is enabled to operate at the best temperature parameters, and the solar thermal apparatus is also enable to

operate at its best parameters (the heat transfer medium is heated to 275°C-395°C or 178°C-600°C), thereby realizing efficiency for collecting the heat energy of the solar power to the utmost.

[0023] In addition, the freshwater plant is generally required to continuously supply water for 24 hrs. The heat energy of the sunlight is stored by the heat transfer medium, so that the seawater can be heated in nocturnal periods, and the freshwater is continuously produced.

[0024] The solar energy heat storage tank is designed for the purpose of maintaining a stable output of the heat energy of the solar power in nocturnal periods and cloudy days as well as continuously supplying freshwater to civil use or industrial use for 24 hrs. The function of the solar energy heat storage tank is storing the solar energy during daytime as much as possible and using the stored solar energy during the night.

[0025] The seawater extraction well is constructed in a sea beach, a position of a well opening being above the sea level at the highest tide, a well depth is several meters lower than the sea level at the lowest tide, the diameter of the well satisfies the extracted seawater volume. Thus, the seawater accommodated in the well has been preliminarily naturally filtered by the sands of the beach thereby being excluded from marine organisms and impurities. In addition, since the sea beach is washed every day by the seawater at the high tide and the low tide, the sea beach always keeps the natural cleaning and filtering functions. The method for constructing a well on the beach is that a well wall adopts porous concrete structure with multiple pores, rubbles are arranged in the periphery of the well wall, and sands of the beach are filled outside the rubbers.

[0026] The seawater sterilizing clarifier is added with a microbicide (such as chlorine) for killing planktons, microbes, or bacteria in the seawater, and then added with the flocculant (such as FeCl_2 and alum) so as to precipitate mass substances and clarify the seawater. A supernatant in the upper part of the clarifier is transferred by the first

seawater transporting pump to the multi-stage ultra-filter where the supernatant is treated with multi-stage ultra-filtration and a purified seawater is then stored in the purified seawater tank. Sediments in the bottom of the seawater sterilizing clarifier (beneath the inlet of the first seawater transporting pump) is required to be flushed and cleaned periodically (using a small volume of purified seawater) to discharge sewage to a wastewater treatment plant. The multi-stage ultra-filter is also periodically backwashed by seawater so as to recover the cleaning and filtering functions of each filter layer.

[0027] When the seawater desalting system is started, the purified seawater is driven by the seawater pump to enter the deoxygenating-decarbonizing tower to remove oxygen and CO₂ therein because that the seawater generally contains 3.5 wt. % of salts and has strong corrosivity, and the existence of the oxygen and CO₂ facilitates the corrosion of the seawater on the apparatus.

[0028] The purified seawater heater comprises a heating container, and the first heat exchanger and a spare heat exchanger disposed in the heating container. The first heat exchanger is employed for the purpose of heating the seawater to a certain temperature, thus, the purified seawater heater is also provided with the seawater temperature sensor for measuring the temperature of the heated seawater. However, in conditions of successive cloudy or rainy days, it may be difficult to ensure 24 hrs of continuous freshwater supplying, thus, the purified seawater heater is provided with the spare heat exchanger, and various auxiliary heat sources (such as thermal oil furnace, electric heating furnace, exhaust heat of flue gas from boilers, and exhaust heat of waste heat from turbines) are employed to heat the seawater in cloudy rainy seasons so as to continuously produce the freshwater.

[0029] The flash evaporator comprises the flash evaporator body and the seawater cooler. The flash evaporator body comprises: the throttling device, the foam breaker, and the freshwater collecting disc bottom-up. The arrangement of the throttling device on the

flash evaporator body enables the pressure of the seawater to sharply decrease when entering the flash evaporator. A large amount of the seawater is evaporated. During the raise of the vapor, large seawater drops carried in the vapor is obstructed by the foam breaker (the foam breaker is made of steel wire meshes with small areolae, such as 200-mesh, 300-mesh, or 400-mesh, the material is anticorrosive, such as stainless steel, titanium alloy wire, or carbon fibers). The vapor passing through the foam breaker reaches the condenser body where one part of the vapor is condensed into the freshwater and fall into the freshwater collecting disc and is transported to the freshwater tank, while the other part of the vapor passes through the top of the flash evaporator and enters the seawater cooler where the vapor is condensed again because the seawater is sprayed onto the second heat exchanger in the seawater cooler, thus, the latent heat is further released, and the condensed freshwater is transported to the freshwater tank.

[0030] The multi-stage flash evaporator comprises N signal stage flash evaporators. N is a positive integer. The freshwater output pipe of each single stage flash evaporator communicates with the sealed freshwater storage tank via a freshwater main pipe. An inlet pipe of the vacuum pump is connected to a top of the sealed freshwater storage tank, so that pressures in each stage flash evaporator gradually decrease to form a negative pressure during the operation of the vacuum pump, and the heated seawater in each stage flash evaporator tends to be vaporized. The produced vapor releases the latent heat and is condensed into the freshwater when it transfers heat with relatively cold seawater. The concentrated seawater in the bottom of each flash evaporator is gradually cooled and flows into the next stage flash evaporator where the concentrated seawater is flash vaporized and then condensed into the freshwater while the remaining un-vaporized concentrated brine is transported to the salt plant.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] The invention is described hereinbelow with reference to the accompanying drawings, in which:

[0032] FIG. **1** is a structure diagram of a seawater desalting apparatus using solar energy for continuously supplying heat; and

[0033] FIG. **2** is a structure diagram of a local part of a seawater extraction well.

[0034] In FIG. **1**, **1** is a solar thermal field for concentrating solar energy and collecting heat, **1a** is a delivery main pipe of the solar thermal field, a heat transfer medium is accommodated in the main pipe. **2** is a solar heat storage tank, **2a** is a heat transfer medium pump. **3** is a seawater heater, **3b** is a heat exchanger using the heat transfer medium, **3a** is a heated seawater pump with adjustable rotational speed, and **T3e** is a temperature sensor disposed in the seawater heater **3**. **4** is a single-stage flash evaporator, N represents a positive integer, when N=1, the flash evaporator is a 1-stage flash evaporator; when N=2, the flash evaporator is a 2-stage flash evaporator, and similarly N refers to a N-stage flash evaporator. Generally, N=3-9, and when N=9 in a best mode to carry out the invention, the last at the most right side is the 9-stage flash evaporator. **4a** is a throttling device disposed in a bottom of the flash evaporator, **4b** is a foam breaker, and **4c** is a freshwater collecting disc, **4d** is a condenser body, **4e** is a seawater cooler, and a vapor heat exchanger **4f** is disposed therein. **5** is a sealed freshwater storage tank, a top of the tank is connected to a vacuum pump **5a** via a pipe. **5b** is a concentrated brine pump disposed at a concentrated brine output pipe of the flash evaporator of the last stage. **6** is a seawater sterilizing clarifier, **6a** is a seawater extraction well constructed with a top above a highest sea level at high tides, a depth of the well is several meters lower than a sea level at low tides, and a diameter of the well is appropriate (which satisfies the extraction of a certain amount of seawater). **6b** is a seawater lifting pump, **6d** is a switch valve at a purified seawater inlet, and **6e** is a blowoff valve of the seawater sterilizing clarifier **6** (when the switch valve **6d** at the and the blowoff valve **6e** are turned on, the purified

seawater is introduced to the bottom of the seawater sterilizing clarifier **6** to flush a sludge, and an output pipe of the blowoff valve **6e** communicates with a wastewater treatment plant). **7** is a multi-stage ultra-filter, **7b** is an active carbon filter layer, **7c** is a multi-fiber filter core layer, **7d** is a first backwashing valve for introducing purified seawater, **7e** is a second backwashing valve for discharging sludge (the first backwashing valve **7d** and the second backwashing valve **7e** are periodically opened to introduce the purified seawater to bluish the filter layers within the multi-stage ultra-filter **7** so as to recover the cleaning and filtering functions of each filter layer). **8** is a purified seawater tank, **9** is a deoxygenating-decarbonizing tower, **7a**, **8a** are seawater transporting pumps, and **9a** is a purified seawater pump.

[0035] As shown in FIG. **2**, **6b** is a seawater lift pump, **6a** is a seawater extraction well, **6a1** is a seaside beach, **6a2** is a highest sea level at high tide, **6a3** is a lowest sea level, **6a4** is a porous concrete wall, **6a5** is rubbles, **6a6** is sea sand at a well bottom which will be elevated along with the time and are required to removed periodically.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0036] As shown in FIGs. **1-2**, seawater desalting apparatus using solar energy for continuously supplying heat comprises: a seawater purifying system, and a seawater desalting system. The seawater desalting system comprises: a solar thermal apparatus **1** for concentrating solar energy and collecting heat, a solar energy heat storage tank **2**, a purified seawater heater **3**, and at least one stage of seawater flash evaporator. The seawater flash evaporator comprises: a flash evaporator body **4** and a seawater cooler **4e**. A heat transfer medium chamber of the solar thermal apparatus **1**, the solar energy heat storage tank **2**, a first heat exchanger **3b** of the purified seawater heater **3** utilizing a heat transfer medium as a heat source are connected in sequence to form a sealed route for circulating the heat transfer medium. A purified seawater output main pipe of a purified

seawater transporting pump **9a** in the seawater purifying system communicates with an inlet of the purified seawater heater **3** and the seawater cooler **4e**. A seawater outlet of the purified seawater heater **3** communicates with an inlet of a throttling device **4a** of the first-stage flash evaporator body via a heated seawater pump **3a**. The flash evaporator body **4** comprises: a concentrated brine outlet, a freshwater outlet, and a vapor outlet. Vapor discharged from the vapor outlet passes through a second heat exchanger **4f** of the seawater cooler **4e** using vapor as a heat source and is accumulated with a freshwater in a freshwater main pipe. A sealed freshwater storage tank **5** disposed at an end of the freshwater main pipe communicates with a vacuum pump **5a**. The concentrated brine outlet communicates with a pipe of a salt plant via a concentrated brine pump **5b**. A seawater outlet of the seawater cooler **4e** communicates with an inlet main pipe of the purified seawater heater **3** via a condenser body **4d** of the flash evaporator body **4**. When at least two stage seawater flash evaporators are employed, the purified seawater output main pipe of the purified seawater pump **9a** in the seawater purifying system communicates with the seawater outlets of the condenser bodies **4d** of each stage seawater flash evaporator. The concentrated brine outlet of a former stage flash evaporator body **4** communicates with an inlet of the throttling device **4a** of a next stage flash evaporator body **4**, and the concentrated brine outlet of a last stage flash evaporator body **4** communicates with the pipe of the salt plant via the concentrated brine pump **5b**. Pressures in the flash evaporator bodies **4** of each stage are gradually decreased whereby forming negative pressures.

[0037] The seawater purifying system is a multi-stage purifying system comprising a seawater extraction well **6a** for coarse filtration, a seawater sterilizing clarifier **6**, a multi-stage ultra-filter **7** provided with an active carbon filter layer and a multi-fiber filter core layer, and a deoxygenating-decarbonizing tower **9** for deoxygenation and decarbonization. A purified seawater tank **8** is disposed between the multi-stage ultra-filter **7** and the deoxygenating-decarbonizing tower **9**. The deoxygenating-decarbonizing

tower **9** communicates with a purified seawater main outlet. The seawater extraction well **6a** communicates with the seawater sterilizing clarifier **6** via a seawater lifting pump **6b**. The seawater sterilizing clarifier **6** communicates with the multi-stage ultra-filter **7** via a first seawater transporting pump **7a**. The multi-stage ultra-filter **7** communicates with the purified seawater tank **8** via a second seawater transporting pump **8a**. The purified seawater tank **8** communicates with the deoxygenating-decarbonizing tower **9** via a third seawater transporting pump **8a**. The deoxygenating-decarbonizing tower **9** communicates with the purified seawater main outlet via a purified seawater pump **9a**. The seawater sterilizing clarifier **6** is added with a microbicide and a flocculant.

[0038] A method for desalting seawater by applying the above seawater desalting apparatus comprises: multi-stage purifying the seawater to produce a purified seawater; collecting solar energy by the solar thermal apparatus to heat the heat transfer medium whereby converting the solar energy into heat energy of the heat transfer medium; continuously heating the purified seawater to a preset temperature by the heat energy of the heat transfer medium, and transporting the heated purified seawater to at least one-stage flash evaporator for flash evaporation; allowing pressures in the flash evaporator bodies of each stage to gradually decrease to form a negative pressure during the flash evaporation; condensing a vapor after the flash evaporation to separate the freshwater, and converting remaining vapor into the freshwater by the seawater cooler; and transporting a non-vaporized concentrated brine from a bottom of the flash evaporator to the salt plant.

[0039] When multi-stage flash evaporators are employed, the concentrated brine at the bottom of the former stage flash evaporator successively flow into a next stage flash evaporator, and the freshwater is gradually condensed and separated out during the multi-stage evaporation process, and the non-vaporized concentrated brine is transported to the salt plant. At the same time the heat energy of the sunlight is collected by the solar thermal apparatus and the heat transfer medium is utilized to heat the purified seawater,

the heat energy of the heat transfer medium is stored in the solar energy heat storage tank so as to continuously heat the purified seawater using the stored heat transfer medium during nocturnal periods or cloudy days.

[0040] The preset temperature of the purified seawater heated by the heat transfer medium is 55°C-70°C or 70°C-120°C, and the heat transfer medium is heated to a temperature of 178°C-600°C by the solar thermal apparatus.

[0041] The preset temperature of the purified seawater heated by the heat transfer medium is $\pm 70^{\circ}\text{C}$, and the heat transfer medium is heated to the temperature of 275°C-395°C by the solar thermal apparatus.

[0042] To desalt the seawater using the seawater desalting device continuously supplied with heat by the solar energy, the seawater lift pump **6b** was firstly started, and the seawater is extracted from the seawater extraction well **6a** and fed to the seawater sterilizing clarifier **6**. The seawater extraction well **6a** is constructed in a sea beach, a position of a well opening being above the sea level at the highest tide **6a2**, and a well depth is lower than the sea level at the lowest tide **6a3**, so that the seawater accommodated in the well has been preliminarily naturally filtered by the sands of the beach thereby being excluded from marine organisms and impurities. In addition, since the sea beach is washed every day by the seawater at the high tide and the low tide, the sea beach always keeps the natural cleaning and filtering functions. The method for constructing a well on the beach is that a well wall adopts porous concrete structure **6a4** with multiple pores, rubbles **6a5** are arranged in the periphery of the well wall, and sands of the beach are filled outside the rubbles.

[0043] The seawater sterilizing clarifier **6** is added with a microbicide (such as chlorine) for killing planktons, microbes, or bacteria in the seawater, and then added with the flocculant (such as FeCl_2 and alum) so as to precipitate mass substances and clarify the seawater. A supernatant in the upper part of the clarifier is transferred by the first

seawater transporting pump **7a** to the multi-stage ultra-filter **7** where the supernatant is treated with multi-stage ultra-filtration and a purified seawater is then stored in the purified seawater tank **8**. Sediments in the bottom of the seawater sterilizing clarifier **6** (beneath the inlet of the first seawater transporting pump) is required to be flushed and cleaned periodically (using a small volume of purified seawater) to discharge sewage to a wastewater treatment plant. The multi-stage ultra-filter **7** is also periodically backwashed by seawater so as to recover the cleaning and filtering functions of each filter layer.

[0044] When the seawater desalting system is started, the purified seawater is driven by the seawater pump **8a** to enter the deoxygenating-decarbonizing tower **9** to remove oxygen and CO₂ therein because that the seawater generally contains 3.5 wt. % of salts and has strong corrosivity, and the existence of the oxygen and CO₂ facilitates the corrosion of the seawater on the apparatus.

[0045] During the seawater desalting process, the solar energy collected by the solar thermal field **1** in diurnal periods is converted into heat energy of the heat transfer medium in the delivery main pipe **1a**, and the heat energy is stored in the heat storage tank **2** via the heat transfer medium. The heat transfer medium **2** flows into the first heat exchanger **3b** in the purified seawater heater **3** under the drive of a heat transfer medium pump **2a** to heat the purified seawater (generally to a temperature of 55°C-120°C). In this example, the temperature is preset to be 70°C. The heated seawater is driven by the heated seawater pump **3a** and transported to a first-stage flash evaporator body **4** (the speed of the heated seawater pump is adjusted to control the flow rate of the seawater transported to the first-stage flash evaporator thereby controlling the seawater level in the flash evaporator body **4**). Since the pressure in the flash evaporator body is negative, the pressure of the heated seawater is suddenly decreased when passing through the throttling device **4a** and is transformed into vapor. During the raise of the vapor, large seawater drops carried in the vapor is obstructed by a foam breaker and fall down to the bottom of the flash evaporator body. The vapor rises to a top of the flash evaporator body and

reaches the condenser body **4d** to release a latent heat. A part of the vapor is condensed into freshwater which falls down in the freshwater collecting disc **4c** and is accumulated into the sealed freshwater storage tank via pipes, and the remaining non-condensed vapor enters the second heat exchanger **4f** of the seawater cooler **4e** where the vapor is cooled again by the seawater with relatively low temperature to release the latent heat, the condensed freshwater flows to a freshwater main pipe and is accumulated in the sealed freshwater storage tank. In the meanwhile, the concentrated brine in the bottom of the first-stage flash evaporator body automatically enters a second-stage flash evaporator body because the operation of the vacuum pump **5a** arranged at a top of the sealed freshwater storage tank **5** forms a pressure difference between the first-stage flash evaporator body and the second-stage flash evaporator body. When the concentrated brine enters the second-stage flash evaporator, the freshwater production process from the throttling device **4a** to the second heat exchanger **4f** is repeated again. The above processes are repeated until the last stage flash evaporator body. The last stage is the ninth-stage flash evaporator. The concentrated brine from the last stage flash evaporator body is finally transported to the salt plant via the salt pump **5b** for subsequent treatment. Thus, the seawater entering the first-stage flash evaporator is treated with nine stage evaporation processes, and approximately 40% of the seawater is condensed and converted into the freshwater.

[0046] The desalting effect of the seawater is not always in positive correlation with the temperature. When the seawater is heated to 75°C-78°C, the salts in the seawater (sodium, calcium, magnesium ions) quickly form scales in the apparatus, affecting the heat transfer and decreasing the working efficiency thereof. The addition of antisludging agent into the seawater is capable of preventing scale formation even when the seawater is heated to 120°C, but it has to pay much cost to remove the antisludging agent therefrom in the subsequent. Thus, a best temperature parameter to prevent the scale formation is approximately 70°C or $\pm 70^\circ\text{C}$. It is also operable within the temperature ranges of 55°C-

70°C, 70°C-120°C, or others to conduct the seawater desalting process, but the comprehensive benefits thereof are poorer than at the temperature of $\pm 70^\circ\text{C}$.

[0047] Advantages of the invention are as follows:

[0048] First, because a best temperature parameter to reach high efficiency of the solar thermal apparatus (the best operating parameter of the current solar thermal apparatus) is 75°C-395°C (adopting the conduction oil as the medium) or 178°C-610°C (adopting a molten salt as the medium), the high efficient heat transfer medium (such as the conduction oil, silicone oil, paraffin wax, and the molten salt) is adopted to satisfy the temperature operating parameters of the solar thermal apparatus, and the heat transfer medium is used to heat the seawater to approximately 70°C. Thus, the scale formation resulted from seawater heating directly by the solar thermal apparatus is avoided, both the seawater desalting systems and the solar power field operate at the best temperature parameters, thereby realizing efficiency for collecting the heat energy of the solar power to the utmost.

[0049] Second, the freshwater plant is generally required to continuously supply water for 24 hrs. The heat energy of the sunlight is stored by the heat transfer medium (such as the conduction oil, the silicone oil, the paraffin wax, and the molten salt), so that the seawater can be heated in nocturnal periods, and the freshwater is continuously produced.

[0050] Because of the highly efficient solar thermal apparatus is adopted, the multi-stage flash evaporator structures are capable of efficiently collecting the relatively dispersed solar energy and accomplish the heating and evaporation of the seawater. The desalting rate of the seawater reaches 40%, and the solar energy can be stored to enable the seawater desalting apparatus to continuously operate to produce the freshwater in nocturnal periods. The produced freshwater has good quality and reaches the standard of drinking water. Furthermore, the green solar energy is primarily utilized, so that the seawater desalting process is environmentally friendly, high efficient with high yield.

[0051] While particular embodiments of the invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects, and therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

CLAIMS

1. A seawater desalting apparatus using solar energy for continuously supplying heat, the apparatus comprising: a seawater purifying system, and a seawater desalting system; **characterized in that**

the seawater desalting system comprises: a solar thermal apparatus for concentrating solar energy and collecting heat, a solar energy heat storage tank, a purified seawater heater, and at least one stage of seawater flash evaporator;

the seawater flash evaporator comprises: a flash evaporator body and a seawater cooler;

a heat transfer medium chamber of the solar thermal apparatus, the solar energy heat storage tank, a first heat exchanger of the purified seawater heater utilizing a heat transfer medium as a heat source are connected in sequence to form a sealed route for circulating the heat transfer medium;

a purified seawater output main pipe of a purified seawater transporting pump in the seawater purifying system communicates with an inlet of the purified seawater heater and the seawater cooler; a seawater outlet of the purified seawater heater communicates with an inlet of a throttling device of the first-stage flash evaporator body via a heated seawater pump;

the flash evaporator body comprises: a concentrated brine outlet, a freshwater outlet, and a vapor outlet; vapor discharged from the vapor outlet passes through a second heat exchanger of the seawater cooler using vapor as a heat source and is accumulated with a freshwater in a freshwater main pipe; a sealed freshwater storage tank disposed at an end of the freshwater main pipe communicates with a vacuum pump; the concentrated brine outlet communicates with a pipe of a salt plant via a concentrated brine pump;

a seawater outlet of the seawater cooler communicates with an inlet main pipe of the purified seawater heater via a condenser body of the flash evaporator body; when at least two stage seawater flash evaporators are employed, the purified seawater output main pipe of the purified seawater pump in the seawater purifying system communicates with the seawater outlets of the condenser bodies of each stage seawater flash evaporator;

the concentrated brine outlet of a former stage flash evaporator body communicates with an inlet of the throttling device of a next stage flash evaporator body, and the concentrated brine outlet of a last stage flash evaporator body communicates with the pipe of the salt plant via the concentrated brine pump; and pressures in the flash evaporator bodies of each stage are gradually decreased whereby forming negative pressures.

2. The apparatus of claim 1, **characterized in that**

a heated seawater pump having adjustable rotational speed is disposed between the seawater outlet of the purified seawater heater and the flash evaporator body; the seawater outlet of the purified seawater heater communicates with the throttling device disposed on the flash evaporator body via the heated seawater pump, and the throttling device is disposed above a seawater surface in the flash evaporator body; in the flash evaporator body, a foam breaker is disposed above the throttling device, a freshwater collecting disc is disposed above the foam breaker, and the condenser body is disposed on the freshwater collecting disc; and the vapor outlet is disposed at a top of the flash evaporator body, and the freshwater outlet is disposed above the freshwater collecting disc, and the concentrated brine outlet is disposed beneath the throttling device.

3. The apparatus of claim 1 or 2, **characterized in that** a seawater temperature sensor and a spare heat exchanger are disposed in the purified seawater heater; and the spare heat exchanger adopts a thermal oil furnace, an electric heating furnace, exhaust heat of flue gas from a boiler, or exhaust heat of waste heat from a turbine as a heat source.
4. The apparatus of claim 1, **characterized in that** a heat transfer medium pump is disposed between the solar energy heat storage tank and the first heat exchanger of the purified seawater heater.
5. The apparatus of claim 1 or 4, **characterized in that** the solar power field is a tower type solar thermal collector, a parabolic trough type evacuated tubular collector, a glass type evacuated tubular collector, or a heat pipe type evacuated tubular collector.
6. The apparatus of claim 1, **characterized in that**

the seawater purifying system is a multi-stage purifying system comprising a seawater extraction well for coarse filtration, a seawater sterilizing clarifier, a multi-stage ultra-filter provided with an active carbon filter layer and a multi-fiber filter core layer, and a deoxygenating-decarbonizing tower for deoxygenation and decarbonization arranged in sequence;

a purified seawater tank is disposed between the multi-stage ultra-filter and the deoxygenating-decarbonizing tower; the deoxygenating-decarbonizing tower communicates with a purified seawater main outlet;

the seawater extraction well communicates with the seawater sterilizing

clarifier via a seawater lifting pump; the seawater sterilizing clarifier communicates with the multi-stage ultra-filter via a first seawater transporting pump; the multi-stage ultra-filter communicates with the purified seawater tank via a second seawater transporting pump; the purified seawater tank communicates with the deoxygenating-decarbonizing tower via a third seawater transporting pump; the deoxygenating-decarbonizing tower communicates with the purified seawater main outlet via a purified seawater pump; and

the seawater sterilizing clarifier is added with a microbicide and a flocculant.

7. The apparatus of claim 1 or 6, **characterized in that** the seawater extraction well is constructed at a sea beach; a well opening is disposed above a sea level at the highest tide, and a well bottom is disposed multiple meters beneath a sea level at low tides; a well wall adopts a porous concrete structure, rubbles are arranged outside the well wall, and sands are filled in the periphery of the rubbles.
8. A method for desalting seawater using the seawater desalting apparatus of any of claims 1-7, the method comprising: multi-stage purifying the seawater to produce a purified seawater; collecting solar energy by the solar thermal apparatus to heat the heat transfer medium whereby converting the solar energy into heat energy of the heat transfer medium; continuously heating the purified seawater to a preset temperature by the heat energy of the heat transfer medium, and transporting the heated purified seawater to at least one-stage flash evaporator for flash evaporation; allowing pressures in the flash evaporator bodies of each stage to gradually decrease to form a negative pressure during the flash evaporation; condensing a vapor after the flash evaporation to separate the freshwater, and converting remaining vapor into the

freshwater by the seawater cooler; and transporting a non-vaporized concentrated brine from a bottom of the flash evaporator to the salt plant;

characterized in that

when multi-stage flash evaporators are employed, the concentrated brine at the bottom of the former stage flash evaporator successively flow into a next stage flash evaporator, and the freshwater is gradually condensed and separated out during the multi-stage evaporation process, and the non-vaporized concentrated brine is transported to the salt plant; and

at the same time the heat energy of the sunlight is collected by the solar thermal apparatus and the heat transfer medium is utilized to heat the purified seawater, the heat energy of the heat transfer medium is stored in the solar energy heat storage tank so as to continuously heat the purified seawater using the stored heat transfer medium during nocturnal periods or cloudy days.

9. The method of claim 8, **characterized in that** the preset temperature of the purified seawater heated by the heat transfer medium is 55°C-70°C or 70°C-120°C, and the heat transfer medium is heated to a temperature of 178°C-600°C by the solar thermal apparatus.
10. The method of claim 8, **characterized in that** the preset temperature of the purified seawater heated by the heat transfer medium is $\pm 70^{\circ}\text{C}$, and the heat transfer medium is heated to the temperature of 275°C-395°C by the solar thermal apparatus.