

SEAWATER COOLING SYSTEM AND COOLING METHOD

Cross-Reference To Related Application

5 **[0001]** This application claims the benefit of priority of Singapore patent application No. 10202108377T, filed 30 July 2021, the content of it being hereby incorporated by reference in its entirety for all purposes.

Technical Field

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[0002] Various embodiments relate to a seawater cooling system or apparatus, and a cooling method.

Background

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[0003] Offshore facilities often require air conditioning with pre-cooling pressurization system and are also loaded with electrical equipment such as transformers, switchgears, servers, GIS equipment and controllers at respective rooms, which require cooling systems to operate safely. The costs of operating these cooling systems have contributed to the operational expenses and energy consumption of these facilities.

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[0004] While highly efficient cooling solutions such as Seawater Air Conditioning (SWAC) has already been developed for shoreside application, implementation of SWAC has not been seen in offshore applications. SWAC uses cold water from lakes or deep sea to provide cooling for air conditioning system of shoreside infrastructures. Similar use of cold seawater has been used for cooling of hydrocarbons on Floating Production Storage & Offloading (FPSO) units, but cold seawater has not been utilized for air conditioning of FPSO units so far.

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[0005] In a prior publication, a cooling device that utilizes cold seawater at deep parts of the ocean was disclosed. The cooling device may be configured to provide alternative operations of a heat exchanger or a standby chiller unit, but rarely both at the same time, to render backup for the cooling.

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[0006] Thus, there is a need for a cooling system and method that utilize cold seawater more efficiently at least for air conditioning purposes, while providing technical solutions to address at least the problems mentioned above.

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Summary

[0007] According to an embodiment, a seawater cooling system is provided. The seawater cooling system may include a seawater cooling device; and an adjunct chiller, wherein the seawater cooling device is in serial fluid communication with the adjunct chiller within a seawater loop; and the seawater cooling device is further in serial fluid communication with the adjunct chiller within a chilled water loop, in absence of a bypass or partial bypass path in the chilled water loop, and the seawater loop and the chilled water loop being fluidically independent of each other.

[0008] According to an embodiment, a cooling method is provided. The cooling method may include operating a seawater cooling device in serial fluid communication with an adjunct chiller within a seawater loop; and further operating the seawater cooling device in serial fluid communication with the adjunct chiller within a chilled water loop, in absence of a bypass or partial bypass path in the chilled water loop, wherein the seawater loop and the chilled water loop is fluidically independent of each other.

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Brief Description of the Drawings

[0009] In the drawings, like reference characters generally refer to like parts throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the following description, various embodiments of the invention are described with reference to the following drawings, in which:

[0010] FIG. 1A shows a schematic diagram illustrating a seawater cooling system, according to various embodiments.

[0011] FIG. 1B shows a flow chart illustrating a cooling method, according to various embodiments.

[0012] FIG. 2 shows a schematic diagram representing an Offshore Seawater Air Conditioning (OSWAC) system or a two-fold cooling system in operation, according to one embodiment.

5 **[0013]** FIG. 3A shows a schematic diagram illustrating a deployment of an exemplary riser system, according to one embodiment.

[0014] FIG. 3B shows a front view of a floating platform or sub-station of the riser system of FIG. 3A.

[0015] FIG. 3C shows an expanded side view of an assembly including a flange connection and a bend restrictor/stiffener used in the riser system of FIG. 3A.

10 **[0016]** FIG. 3D shows an expanded side view of a debris strainer used in the riser system of FIG. 3A.

Detailed Description

15 **[0017]** The following detailed description refers to the accompanying drawings that show, by way of illustration, specific details and embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. Other embodiments may be utilized and structural, logical, and electrical changes may be made without departing from the scope of the invention. The
20 various embodiments are not necessarily mutually exclusive, as some embodiments can be combined with one or more other embodiments to form new embodiments.

[0018] Embodiments described in the context of one of the methods or devices are analogously valid for the other methods or devices. Similarly, embodiments described in the context of a method are analogously valid for a device, and vice versa.

25 **[0019]** Features that are described in the context of an embodiment may correspondingly be applicable to the same or similar features in the other embodiments. Features that are described in the context of an embodiment may correspondingly be applicable to the other embodiments, even if not explicitly described in these other embodiments. Furthermore, additions and/or combinations and/or alternatives as described for a feature in the context
30 of an embodiment may correspondingly be applicable to the same or similar feature in the other embodiments.

[0020] In the context of various embodiments, the articles “a”, “an” and “the” as used with regard to a feature or element include a reference to one or more of the features or elements.

[0021] In the context of various embodiments, the phrase “substantially” may include “exactly” and a reasonable variance.

5 **[0022]** In the context of various embodiments, the term “about” as applied to a numeric value encompasses the exact value and a reasonable variance.

[0023] As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0024] As used herein, the phrase of the form of “at least one of A or B” may include
10 A or B or both A and B. Correspondingly, the phrase of the form of “at least one of A or B or C”, or including further listed items, may include any and all combinations of one or more of the associated listed items.

[0025] As used herein, the expression “configured to” may mean “constructed to” or “arranged to”.

15 **[0026]** Various embodiments may relate to a cooling apparatus, or a cooling system, and a cooling method for offshore seawater air conditioning. A configuration and control system may be introduced to allow the utilization of a single subsea riser assembly to draw seawater from ocean depth where water temperature reaches 5 degree Celsius and below for use in air conditioning system, as well as other secondary cooling functions, unlike in
20 the conventional Centralised Cooling Systems (CCS). The cooling system and method according to various embodiments specifically address challenges in offshore application of SWAC.

[0027] FIG. 1A shows a schematic view of a seawater cooling system 100, in accordance with various embodiments. In FIG. 1A, the seawater cooling system 100 includes a
25 seawater cooling device 102 and an adjunct chiller 104. The seawater cooling device 102 may be in serial fluid communication with the adjunct chiller 104 within a seawater loop 106. The seawater cooling device 102 may further be in serial fluid communication with the adjunct chiller 104 within a chilled water loop 108, in absence of a bypass or partial bypass path in the chilled water loop 108. The seawater loop 106 and the chilled water loop
30 108 may be fluidically independent of each other.

[0028] The seawater cooling system 100 may interchangeably be referred to as a seawater cooling apparatus, a cooling system, a cooling apparatus or the like.

[0029] In other words, the seawater cooling system 100 may include the seawater cooling device 102, and the adjunct chiller 104 coupled in series with the seawater cooling device

5 102. The seawater loop 106 may allow a first fluid, for example but not limited to, seawater to run through the seawater cooling device 102 and the adjunct chiller 104. For example, the first fluid may flow into the seawater cooling device 102 and then out of the seawater cooling device 102 to continue to flow into the adjunct chiller 104 and then out of the adjunct chiller 104. In one example, the first fluid may flow consecutively into the seawater

10 cooling device 102 and the adjunct chiller 104 within the seawater loop 106. The chilled water loop 108 may allow a second fluid, for example but not limited to, chilled water to run through the seawater cooling device 102 and the adjunct chiller 104. For example, the second fluid may flow into the seawater cooling device 102 and then out of the seawater cooling device 102 to continue to flow into the adjunct chiller 104 and then out of the

15 adjunct chiller 104. In one example, the second fluid may flow consecutively into the seawater cooling device 102 and the adjunct chiller 104 within the chilled water loop 108.

The seawater loop 106 and the chilled water loop 108 are separate and different paths. The

first fluid and the second fluid are separate fluids and are not mixed with each other. In some examples, the first fluid and the second fluid may be of the same fluid type. In other

20 examples, the first fluid and the second fluid may be of different fluid type. In the chilled water loop 108, there may be no path connected in parallel to each of the seawater cooling device 102 or the adjunct chiller 104 to bypass in full or partially the seawater cooling device 102 or the adjunct chiller 104. There may also be no path connected in parallel to

both the seawater cooling device 102 and the adjunct chiller 104 to bypass in full or partially the seawater cooling device 102 and the adjunct chiller 104. The direction of flow

25 of the first fluid may be having the first fluid enter the seawater cooling device 102, followed by the adjunct chiller 104. The direction of flow of the second fluid may be having the second fluid enter the seawater cooling device 102, followed by the adjunct chiller 104.

[0030] In the context of various embodiments, the term “loop” may refer to a path that may

30 be open-ended or close-ended. The loop or path may involve the use of conduits coupled

to components of the loop or path to connect the components. Such components may include the seawater cooling device 102 and the adjunct chiller 104, amongst others.

[0031] In various embodiments, the seawater cooling device 102 and the adjunct chiller 104 may be configured to allow seawater to flow substantially simultaneously within the seawater loop 106. For example, the seawater cooling device 102 and the adjunct chiller 104 may be arranged adjacent to each other, and that the seawater may flow consecutively through the seawater cooling device 102 and the adjunct chiller 104. In other words, the seawater loop 106 may run successively or in tandem through the seawater cooling device 102 and the adjunct chiller 104. It should be appreciated that the seawater cooling device 102 and the adjunct chiller 104 do not operate in alternates as backup for each other, which may be adopted in some existing systems. The seawater may be drawn from a source, e.g. deep ocean, into the seawater cooling system 100. Instead of seawater, in other example, water from a lake may be drawn into the seawater cooling system 100 if the seawater cooling system 100 were to operate on an offshore facility disposed on a lake.

[0032] It should be appreciated and understood that the term “seawater” appended to the cooling system, the cooling device and the loop does not limit these components to the use of seawater only. The term “seawater” may merely allow for better referencing and distinction of the components.

[0033] The seawater cooling device 102 may include a plate heat exchanger. For example, the plate heat exchanger may be a compact plate fin heat exchanger that advantageously provides space saving and avoids large foot print, as compared to a large shell and tube heat exchanger, as well as flexibility to alter or adjust required heat transfer area that may be achieved by increasing or decreasing the number of heat exchanger plates. In other words, the configuration of the plate heat exchanger may be a flexible paving way for modification of heat transfer area in the future if needed, and benefits from easy installation. The relatively tall plate may make this type fit for long temperature programs and when high heat recovery is valued. Such compact design feature is important because space availability or space restriction has always been a problem in offshore industry. Thus, usage of less principal components has technical as well as commercial benefits.

[0034] The adjunct chiller 104 may include a condenser arranged in the seawater loop 106. For example, the condenser may include tubes made of copper-nickel. This enables the condenser to operate with corrosion resistance in the presence of seawater.

[0035] The adjunct chiller 104 may give more flexibility to the seawater cooling system 100 in terms of enabling operations where there may be a wider temperature range of deep seawater available depending on locations. With the adjunct chiller 104 being part of the seawater loop 106, water temperature may be increased before discharging to the sea surface. The water temperature may also be increased further as required, for example, by cooling additional equipment as available onboard an offshore facility.

[0036] This may be advantageously superior to existing systems where a supplemental chiller and/or a stand-by (backup) air-conditioner, which do not run simultaneously with the main system, may be used.

[0037] In various embodiments, the seawater cooling system 100 may further include a control panel configured to obtain a temperature measurement from the chilled water loop 108 to control the operation of the seawater loop 106. The operation of the seawater loop 106 may involve facilitating partial bypass of the seawater through the seawater cooling device 102, and/or facilitating at least partial bypass of the seawater through the adjunct chiller 104 and into additional equipment as available onboard an offshore facility that may require cooling, amongst others.

[0038] For example, the control panel may further be configured to operate a three-way valve to enable constant flow rate of seawater intake from the deep sea, therefore eliminating the need of a VFD (Variable frequency drive) control. In cases with VFD usage, whenever the required temperature is attained, the main seawater flow rate is reduced accordingly and this in turn affects the additional equipment that requires seawater to be cooled, as in various embodiments of the present invention. So, the three-way valve is used to control seawater flow through the seawater cooling device 102, or to at least partially bypass the seawater cooling device 102 in the seawater loop 106. In operation, the three-way valve allows seawater through the seawater cooling device 102 in the seawater loop 106 all the time. The three-way valve may be operable to control the amount of seawater flowing through the seawater cooling device 102 in the seawater loop 106.

[0039] In various embodiments, the seawater cooling system 100 may further include a riser configured to direct the seawater from an external source into the seawater loop 106. The seawater cooling system 100 may further include a main seawater pump configured to draw the seawater from an external source into the seawater loop 106. For example, the external source may include a deep ocean. The seawater pump may include or work with a submersible booster pump to provide sufficient Net Positive Suction Head. Additional individual booster pumps may also be used for the adjunct chiller 104 as well as for cooling additional equipment depending on the pressure drop of the respective device/equipment. This may reduce the main pump head and increase the pumping efficiency. Within the group of available equipment onboard, each equipment has its own pressure drop and the selection of a pump may be based on the equipment with the highest pressure drop among the group of equipment. The usage of individual booster pump shares the workload of the main seawater pump and takes away the strain of selecting the main seawater pump with high discharge head resulting in one big main pump with a high operating power. The usage of individual booster pump significantly reduces the power consumption of the main seawater pump, thereby saving energy.

[0040] The offshore facility may be disposed on the external source. The offshore facility may accommodate the seawater cooling system 100 or at least part thereof. The offshore facility may include equipment and rooms/spaces that may require cooling by the seawater cooling system 100.

[0041] In various embodiments, the seawater cooling system 100 may further include at least one of the following: one or more backup seawater pumps configured to draw the seawater into the seawater loop 106; one or more backup chilled water pumps configured to regulate a flow of chilled water in the chilled water loop 108; one or more backup adjunct chillers; and/or the seawater cooling device 102 including more than one plate heat exchanger. The one or more backup seawater pumps may be arranged in parallel to a duty or main seawater pump so as to be operable when the duty seawater pump is under replacement, repair or maintenance. The one or more chilled water pumps may be arranged in parallel to a duty or main chilled water pump so as to be operable when the duty chilled water pump is under replacement, repair or maintenance. The one or more backup adjunct chillers may be arranged in parallel to a duty or main adjunct chiller so as to be operable

when the duty adjunct chiller is under replacement, repair or maintenance. The more than one plate heat exchanger may be arranged in parallel to a duty or main plate heat exchanger so as to be operable when the duty plate heat exchanger is under replacement, repair or maintenance.

5 **[0042]** In various embodiments, the seawater cooling system 100 may further include a temperature monitoring means configured to measure a temperature of seawater downstream in the seawater loop 106. The measured temperature may be used to facilitate the discharge of the seawater out of the seawater loop 106 in an appropriate manner.

10 **[0043]** With the seawater being dispensed from the seawater loop 106 in an appropriate manner, for example by dispensing the seawater near the sea surface where the temperature may be close to the dispensed seawater temperature, the seawater cooling system 100 may advantageously cause minimal or even prevention of any disruption to the ecosystem.

15 **[0044]** In various embodiments, the seawater cooling system 100 may further include an equipment being in serial fluid communication with the seawater cooling device 102 and the adjunct chiller 104 within the seawater loop 106, wherein the equipment is operable by using a cold energy provided by the seawater loop 106. Such equipment may include equipment disposed on an offshore facility that requires cooling. For example, such equipment may include, but is not limited to, oil cooler for transformer, seawater cooled generator(s) and seawater cooled air compressor(s).

20 **[0045]** FIG. 1B shows a flow chart illustrating a cooling method 120, in accordance with various embodiments. At Step 122, a seawater cooling device (e.g. 102 of FIG. 1A) in serial fluid communication with an adjunct chiller (e.g. 104 of FIG. 1A) within a seawater loop (e.g. 106 of FIG. 1A) is operated. At Step 124, the seawater cooling device 102 in serial fluid communication with the adjunct chiller 104 within a chilled water loop (e.g. 25 108 of FIG. 1A) is further operated, in absence of a bypass or partial bypass path in the chilled water loop 108. The seawater loop 106 and the chilled water loop 108 may be fluidically independent of each other.

30 **[0046]** The seawater cooling device, the adjunct chiller, the seawater loop and the chilled water loop discussed in context of the cooling method 120 may include the same or like elements or components as those of the seawater cooling device 102, the adjunct chiller 104, the seawater loop 106 and the chilled water loop 108 of FIG. 1A, respectively. As

such, the same numerals are assigned and the like elements may be as described in the context of the seawater cooling device 102, the adjunct chiller 104, the seawater loop 106 and the chilled water loop 108 of FIG. 1A, respectively, and therefore the corresponding descriptions are omitted here.

5 **[0047]** The step 122 of operating the seawater cooling device 102 in serial fluid communication with the adjunct chiller 104 within the seawater loop 106 may include allowing seawater to flow substantially simultaneously through the seawater cooling device 102 and the adjunct chiller 104 within the seawater loop 106. In other words, when in operation, the seawater may flow through the seawater cooling device 102 and the
10 adjunct chiller 104 within the seawater loop 106 almost at the same time. If the temperature of the chilled water in the chilled water loop 108 exceeds a pre-defined temperature, rendering the chilled water temperature to be too high, the compressor of the adjunct chiller 104 would run to provide enhanced cooling in additional to the cooling provided by the seawater cooling device 102.

15 **[0048]** Prior to the step 122 of operating the seawater cooling device 102 in serial fluid communication with the adjunct chiller 104, the cooling method 120 may further include drawing seawater from an external source. For example, the external source may include seawater at an ocean depth where water temperature reaches 5 degree Celsius and below, which may be considered as deep ocean.

20 **[0049]** In various embodiments, the cooling method 120 may further include operating a three-way valve to control seawater flow through the seawater cooling device 102, or to at least partially bypass the seawater cooling device 102 in the seawater loop 106.

25 **[0050]** The cooling method 120 may further include measuring a temperature of seawater downstream in the seawater loop 106. The measured temperature may be used to facilitate the discharge of the seawater out of the seawater loop 106 in an appropriate manner, thereby advantageously enabling the eco-friendliness of the cooling method 120 or the cooling system 100, as previously discussed.

30 **[0051]** In various embodiments, the cooling method 120 may further include operating an equipment by using cold energy provided by the seawater loop 106, wherein the equipment is in serial fluid communication with the seawater cooling device 102 and the adjunct chiller 104 within the seawater loop 106.

[0052] While the method described above is illustrated and described as a series of steps or events, it will be appreciated that any ordering of such steps or events are not to be interpreted in a limiting sense. For example, some steps may occur in different orders and/or concurrently with other steps or events apart from those illustrated and/or described herein. In addition, not all illustrated steps may be required to implement one or more aspects or embodiments described herein. Also, one or more of the steps depicted herein may be carried out in one or more separate acts and/or phases.

[0053] Examples of a cooling system and method will be described in detail below.

[0054] Various examples may provide Two-fold Cooling for Offshore Seawater Air Conditioning (OSWAC). Essentially, the use of a two-fold cooling system may be provided. FIG. 2 shows a schematic diagram representing a two-fold OSWAC system or interchangeably referred to as the two-fold cooling system 200 in operation, according to one example. The two-fold cooling system 200 and its cooling method may include the same or like elements or components as those of the seawater cooling system 100 and the cooling method 120 of FIGS. 1A and 1B, respectively. As such, the same ending numerals are assigned and the like elements may be as described in the context of the seawater cooling system 100 and the cooling method 120 of FIGS. 1A and 1B, respectively, and therefore the corresponding descriptions are omitted here.

[0055] The two-fold cooling system 200 may include a seawater cooling, e.g. a plate heat exchanger 202, and an adjunct chiller 204 which function both to further bring down the temperature of the chilled water in the chilled water loop 208 where necessary, and to further increase the seawater 214b temperature before being discharged out of the seawater loop 206 into the sea 218. The configuration is especially unique in that the return (or effluent) seawater from the plate heat exchanger 202 flows through the adjunct chiller 204 as well, to cool down the refrigerant, which in turn cools down the system 200 further. Since both the plate heat exchanger 202 and the adjunct chiller 204 may be used to cool down the chilled water, the system 200 is a two-fold cooling for the air conditioning aspect of the OSWAC.

[0056] In other words, the plate heat exchanger 202 may allow the seawater to cool down the fresh water (chilled water). The return seawater from the plate heat exchanger 202 may be handled effectively to cool down additional equipment 254 available onboard and also

for the condenser 234 usage of the adjunct chiller 204 before discharged back to the sea 218. Respective booster pumps 212, 216, controllable by a control panel 250, may be used to boost the flow of seawater through the additional equipment 254 and the condenser 234. The two-fold cooling system 200 allows the seawater 214b to be dispensed out of the seawater loop 206 in an appropriate manner. For example, the seawater 214b may be dispensed at the surface of the sea 218 where the dispensed seawater 214b temperature is close to the surface temperature, taking into consideration of minimal or no influence on ecosystem. Some seawater 214d may also be directed from the plate heat exchanger 202, after mixing with the outlet seawater from the adjunct chiller 234 as well as additional equipment 254, to be dispensed out as effluent back to the sea.

[0057] Using the two-fold cooling system 200 allows for greater adaptability for different operation environment. If the cooling system 200 is only dependent on a seawater cooling, a strict temperature range of 5 degree Celsius (at present, typically below 500 m to 700 m seawater depth) may be needed to fulfil the air conditioning requirements. For example, the cooling system 200 may be applicable for offshore facilities operating in waters of around 500m in depth, D, with air conditioning as an essential part of the offshore facility. A novel configuration of the cooling system 200 takes seawater from deep ocean, where temperatures may reach 5 degree Celsius and below, to cool down a different cooling medium such as freshwater or chilled water in the cooling system 200. If the facility were to operate at slightly shallower water, the adjunct chiller 204 in the two-fold cooling system 200 may be able to compensate for the slight temperature increase to meet the air conditioning requirements. This allows for the system 200 to be applicable across a greater range of operating environment.

[0058] The cooling system 200 may make use of a flexible riser assembly 230, or simply referred to as a riser, that draws cold seawater from the required depth, D, with a seawater pump 236 providing the necessary suction. A seawater treatment system 238 may be provided, for example, prior to the seawater pump 236, to filter out unwanted materials in the seawater 214a drawn in by the riser 230. The two-fold seawater cooling system 200 may make use of a variety of pump arrangement, such as a vertical centrifugal pump or a horizontal centrifugal pump that may be used in the offshore oil and gas industry, depending on the space available at a pump room which locates the pump.

[0059] The two-fold seawater cooling system 200 may make use of a variety of riser system, such as a free-hanging or catenary riser system common in the offshore oil and gas industry. For example, the cooling system 200 may be adapting a flexible riser system for the seawater intake 214 from the depths, D.

5 **[0060]** In another example, a seawater riser may take the form of a pipe hanging freely from a point on the facility. Such free-hanging riser configuration does not require the use of seabed to secure the position of the pipe. FIG. 3A shows a schematic diagram illustrating a deployment of an exemplary riser system 300. The pipe 330 may be connected to a floating platform or sub-station 334 (having a front view as shown in FIG. 3B) through an
10 assembly 256 including a flange connection 338 and a bend restrictor/stiffener 340 (as more clearly shown in FIG. 3C), and then through a riser conduit (not shown in the figures). From the riser conduit, the flexible pipe 330 may be connected to conventional rigid and insulated pipes that leads the seawater 214a into the seawater loop 206. The rigid and insulated pipes may then be directed to the seawater treatment system 238, then the pump
15 236 in the pump room (not shown in the figures). The floating platform 334 may be positioned along the sea surface 218. The floating platform 334 may be moored to, for example, a seabed via a mooring leg or line 336. The pipe 330 may be susceptible to underwater current-induced displacements and vortices, especially when the water current is strong. Dead weights 332 may be used to hold the pipe 330 more or less in place.
20 However, there may still be a possibility for the variation in the depth as the intake strainer end of the pipe 330 may be displaced that may affect the seawater intake 214a temperature range required for the cooling system 200. FIG. 3D shows an expanded view of a strainer 232, which may be a debris strainer attached at the bottom end of the pipe 330 to prevent large debris from entering the pipe 330, and may be coupled to a weighted end. The
25 weighted end by use of a dead weight 332 may be used to keep the riser 230 in tension and fully extended. An appropriate length of the pipe 330 may depend on the seawater temperature in the specific location.

[0061] In the different exemplary case of FPSO where seawater is already extracted for use of cooling down hydrocarbon, the seawater riser and seawater pump for the air
30 conditioning may be removed or omitted. Instead, the source of cold seawater may be the

outflow from the hydrocarbon cooling system, if possibly the temperature is within suitable range and the available flow rate is sufficient.

[0062] The adjunct chiller 204 may come in handy to overcome the temperature differences, for example, caused by the riser 230 vertical movements, if used. This may be the main function and necessity of the adjunct chiller 204 to compensate for the temperature increase to meet the air conditioning requirements.

[0063] Another added benefit lies in the seawater flowing through a condenser 234 of the adjunct chiller 204 where this allows the seawater 214b to be heated up further, trying to bringing it closer to the sea surface 218 temperature. This may be important so as to allow for easier discharge of the seawater 214b out of the seawater loop 206 with minimal negative environmental impact.

[0064] The configuration including the adjunct chiller 204 may further cool down the chilled water in the chilled water loop 208, where the seawater in the seawater loop 206 is not of a sufficiently low enough temperature, to allow for a wider temperature range. The adjunct chiller 204 may include the condenser 234, that is in fluid communication with the seawater or within the seawater loop 206, coupled to an evaporator 240, that is in fluid communication with the chilled water or within the chilled water loop 208. A refrigerant runs across the adjunct chiller 204 cycle as a cooling medium. The adjunct chiller 204 may further include an expansion valve 242 and a compressor 244. In the chilled water loop 208, the chilled water 210 may be circulated using a chilled water pump 246 through the plate heat exchanger 202 and the evaporator 240 of the adjunct chiller 204. The chilled water 210 may be used for an air conditioning system 258, that includes fan coil units, air handling units, and pressurization units.

[0065] A temperature sensor 248 is placed within the chilled water loop 208 to monitor or measure the temperature of the chilled water 210. The measured temperature may be fed to the control panel 250 that controls a three-way valve 252 coupled within the seawater loop 206 and configured to control the seawater flow through the plate heat exchanger 202.

[0066] This configuration may use the control option of constant seawater flow. The volume of seawater intake 214a may be constant and once the required temperature is achieved, the three-way valve 252 installed may bypass (at least partially) the flow of water 214c to cool down additional equipment 254 that may be available and may need cooling.

The water 214b may then discharged to the sea 218. The three-way valve 252 may be controlled, for example, by a programmable logic controller (PLC) in the control panel 250, which may use the temperature sensor 248 to sense the temperature at the chilled water loop 208 to obtain feedback signal to operate the three-way valve 252.

5 **[0067]** In conditions where the seawater is sufficiently cold, the system 200 may operate on its own using a single main heat exchanger, e.g. the plate heat exchanger 202. However, when the seawater is not sufficiently cold to provide the required cooling on its own, the adjunct chiller 204 may be required to assist in the cooling process. This adjunct chiller 204 may be especially relevant where there are significant changes in the water temperature
10 across the seasons and also adds flexibility to the OSWAC system 200 to cover wide area of applications.

[0068] Deepwater applications may be targeted in the temperature climate, where the water at the required depth, D, may be relatively consistent throughout the season.

[0069] In the two-fold OSWAC cooling system 200, seawater 214a may be pumped from
15 the depth of the sea (as deep as 600 metres to get the required temperature of 5°C) though a flexible riser (similar to FIG. 3), using one duty seawater pump 236 and one standby seawater pump (not shown in figures). The duty seawater pump 236 and the standby seawater pump may be arranged in parallel to each other. In the event where the duty seawater pump 236 is under replacement, repair or maintenance, the standby seawater
20 pump comes into operation as a backup.

[0070] Prior to the pump 236, the seawater 214a passes through a seawater treatment system 238, e.g. a Seawater Filter (SWF), capable of filtration for cooling system 200 using low-quality water. This filter may operate as an integral part of the cooling system 200 to remove debris that may foul and clog the plate heat exchanger 202. For example, the type
25 of filter may be a pressure filter with an automatic flushing arrangement. The backflushing may be carried out automatically at regular intervals without interrupting the ongoing filtering process and may be controlled by the PLC in the control panel 250, which may be installed nearer to the filter.

[0071] The seawater 214a may be then introduced into the duty plate heat exchanger 202
30 and a standby plate heat exchanger (not shown in figures). The type may be a gasketed plate-frame heat exchanger with high energy efficiency and at the same time operates at a

low cost. The duty plate heat exchanger 202 and the standby plate heat exchanger are arranged in parallel to each other. In the event where the duty plate heat exchanger 202 is under replacement, repair or maintenance, the standby plate heat exchanger comes into operation as a backup. It should be noted that the standby plate heat exchanger does not include or perform tasks of the adjunct chiller 204. If the standby plate heat exchanger is operated in place of the duty plate heat exchanger 202, the standby plate heat exchanger and the adjunct chiller 204 allow the seawater to flow substantially simultaneously within the seawater loop 206. For example, the seawater may flow consecutively through the standby plate heat exchanger and the adjunct chiller 204.

[0072] The control panel 250 may control separate three-way valves to partially bypass the seawater 214c through the respective duty plate heat exchanger 202a and standby plate heat exchanger. A duty chilled water pump 246 and a standby chilled water pump may be responsible for circulating the chilled water 210 between heat exchangers 202, air handling units and fan coil units of the air conditioning (AC) system 258 onboard. The duty chilled water pump 246 and the standby chilled water pump are arranged in parallel to each other. In the event where the duty chilled water pump 246 is under replacement, repair or maintenance, the standby chilled water pump comes into operation as a backup. The sufficiently cooled chilled water by the adjunct chiller 204, whenever needed, serves the AC system 258 (individual deck air handling unit (AHU), fan coil unit (FCU), pre-cooled pressurization unit, self contained unit (SCU) onboard).

[0073] While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced.

CLAIMS

1. A seawater cooling system comprising:
a seawater cooling device; and
5 an adjunct chiller, wherein
the seawater cooling device is in serial fluid communication with the
adjunct chiller within a seawater loop; and
the seawater cooling device is further in serial fluid communication
with the adjunct chiller within a chilled water loop, in absence of a bypass
10 or partial bypass path in the chilled water loop, and the seawater loop and
the chilled water loop being fluidically independent of each other.
2. The seawater cooling system as claimed in Claim 1, wherein the seawater cooling
device and the adjunct chiller are configured to allow seawater to flow substantially
15 simultaneously within the seawater loop.
3. The seawater cooling system as claimed in Claim 1 or 2, wherein the seawater
cooling device comprises a plate heat exchanger.
- 20 4. The seawater cooling system as claimed in any one of Claims 1 to 3, wherein the
adjunct chiller comprises a condenser arranged in the seawater loop.
5. The seawater cooling system as claimed in Claim 4, wherein the condenser
comprises tubes made of copper-nickel.
25
6. The seawater cooling system as claimed in any one of Claims 1 to 5, further
comprising a control panel configured to obtain a temperature measurement from the
chilled water loop to control the operation of the seawater loop.
- 30 7. The seawater cooling system as claimed in Claim 6, wherein the control panel is
further configured to operate a three-way valve to control seawater flow through the

seawater cooling device, or to at least partially bypass the seawater cooling device in the seawater loop.

8. The seawater cooling system as claimed in any one of Claims 1 to 7, further
5 comprising a riser configured to direct the seawater from an external source into the seawater loop.

9. The seawater cooling system as claimed in any one of Claims 1 to 7, further
10 comprising a seawater pump configured to draw the seawater from an external source into the seawater loop.

10. The seawater cooling system as claimed in Claim 9, wherein the seawater pump comprises or works with a booster pump.

11. The seawater cooling system as claimed in Claim 9 or 10, wherein the seawater
15 pump is positioned in a pump room close to a sea level.

12. The seawater cooling system as claimed in any one of Claims 1 to 11, further
comprising at least one of the following:

20 one or more backup seawater pumps configured to draw the seawater into the seawater loop;

one or more backup chilled water pumps configured to regulate a flow of chilled
water in the chilled water loop;

one or more backup adjunct chillers; and/or

25 the seawater cooling device including more than one plate heat exchanger.

13. The seawater cooling system as claimed in any one of Claims 1 to 12, further
comprising an equipment being in serial fluid communication with the seawater cooling
device and the adjunct chiller within the seawater loop, wherein the equipment is operable
30 by using cold energy provided by the seawater loop.

14. A cooling method comprising:
operating a seawater cooling device in serial fluid communication with an adjunct chiller within a seawater loop; and
further operating the seawater cooling device in serial fluid communication
5 with the adjunct chiller within a chilled water loop, in absence of a bypass or partial bypass path in the chilled water loop,
wherein the seawater loop and the chilled water loop is fluidically independent of each other.

10 15. The cooling method as claimed in Claim 14, wherein the step of operating the seawater cooling device in serial fluid communication with the adjunct chiller within the seawater loop comprises allowing seawater to flow substantially simultaneously through the seawater cooling device and the adjunct chiller within the seawater loop.

15 16. The cooling method as claimed in Claim 14, further comprising prior to the step of operating the seawater cooling device in serial fluid communication with the adjunct chiller, drawing seawater from an external source.

17. The cooling method as claimed in Claim 16, wherein the external source comprises
20 seawater at an ocean depth where water temperature reaches 5 degree Celsius and below.

18. The cooling method as claimed in any one of Claims 14 to 17, further comprising operating a three-way valve to control seawater flow through the seawater cooling device, or to at least partially bypass the seawater cooling device in the seawater loop.

25 19. The cooling method as claimed in any one of Claims 14 to 18, further comprising operating an additional equipment by using cold energy provided by the seawater loop, wherein the equipment is in serial fluid communication with the seawater cooling device and the adjunct chiller within the seawater loop.

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