design also provides the opportunity for stepwise expansion of the total production capacity of the desalination system during the lifetime of the subsea plant.

Lifting connectors mounted on the module frames, a guiding system, the module zones on the template or templates, use of an installation or service vessel, etc. provide a quick, robust and reliable means to install and retrieve modules (and in some cases templates and/or base templates). The intervention can be done at specific intervals or is triggered by events based on monitored parameters.

Short description of the enclosed figures:

Fig. 1 is a schematic representation of a first step of an installation of a part of a subsea desalination system of the invention on a seabed;

Fig. 2 is a schematic representation of a second step of the installation initiated in fig. 1;

Fig. 3 is a schematic representation of an installed subsea desalination system of the invention;

Fig. 4 is a schematic representation of a first step of an installation of a complete subsea desalination system of the invention;

Fig. 5 is a schematic representation of a subsea desalination system of the invention with twelve desalination system templates;

Fig. 5b is a subsea desalination control flow chart;

Fig. 6 shows a detail of fig. 5 with three templates;

Fig 6b is a subsea desalination flow chart;

Fig. 7 is schematic representation of an alternative configuration of a desalination system of the invention with a separate pumping template;

Fig. 8 is schematic representation of a desalination system in an alternative embodiment with a floating desalinated water receiving facility;

Fig. 9 shows the embodiment of fig. 8 during a module exchange step;

Fig. 10 shows the embodiment of fig. 8 further including a floating power generation unit;

Fig. 11 shows an alternative embodiment of the invention with a seawater inlet at a remote location relative to a template;

Fig. 12 shows an alternative embodiment of the invention with a seawater inlet at a remote location above a template;
Fig. 13 shows an alternative embodiment of the invention with a seawater inlet at a separate filtering and pumping station;
Fig. 13b is a subsea desalination flow chart;
Fig. 14 shows an alternative embodiment of the invention with a desalinated water transport pump template separate from a water desalination template;
Figs. 15a-15d show details of desalination modules for the desalination system of the invention;
Figs. 16a-16c show details of alternative desalination modules for the desalination system of the invention;
Fig. 17 is a schematic representation of a subsea template in a 3x3 configuration for 9 modules in an elevation and from the side;
Fig. 18 is a schematic representation of a subsea template in a 3x6 configuration for 18 modules in an elevation and from the side;
Fig. 19a-c are schematic representations of water pump modules of the invention;
Fig. 20 is a schematic representation of a flow between a template, a desalination module, a circulation module and a transport module;
Fig. 21 is a schematic representation of a subsea desalination system with template on permanent seabed foundation and jumpers between modules;
Fig. 22 is a schematic representation of a subsea desalination system with a desalination template and a pump template on a base template located on a permanent seabed foundation; and
Fig. 23 is a schematic representation of a subsea desalination system with a desalination template located on a permanent seabed foundation.

Detailed description of embodiments of the invention with reference to the enclosed drawings:

The installation sequences shown in the figures 1, 2, 4 are relevant for the installation of all templates and modules.

Fig. 1 shows a first installation step of a subsea desalination template 1. The subsea desalination template 1 is lowered from an installation/service vessel 6 towards a seabed.

5 illustrates that the plant is easily scalable to and adaptable to different applications. The pump module 17 include both the transport pump for desalinated water and the circulation pump for pumping seawater through the desalination modules

The control module 18 includes the electronic and logic circuits to monitor and control the desalination system, communicate with a topside control room and execute commands. The control module 18 includes electrical connectors connecting the control cable/s for I/O (Input/Output) to the surface and connectors for I/O to sensors and equipment on the template. Each control function, e.g. open and close a valve, will have a dedicated control loop.
This could be a simple open loop control, or a more advanced closed loop control with sensor feedback.

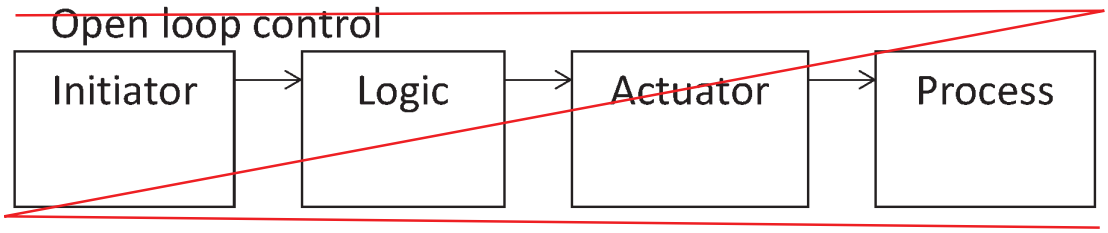

fig. 5b

The subsea desalination control flow chart ~~above~~ shows how an open loop control can be set up.

Control functions are usually initiated from the topside control room by a human operator but can alternatively be fully automated and executed by the control system. The control module 18 houses all electronics in one atmosphere pressure vessels, designed to withstand the hydrostatic pressure at the installation depth. Control modules 18 are retrievable, interchangeable and replaceable.

Chemicals for cleaning can be supplied through the chemical line 12 extending from a chemical reservoir on land or on the service vessel.
In some cases, local chemical supply could be an advantage or necessary. In these cases, a chemical injection module 29 contains one or several chemical

containers and required pumps, piping/ducting, instrumentations and control systems for cleaning, maintenance and disinfection purposes. Chemicals are injected into, and mixed with the desalinated water flow for cleaning, maintenance and disinfection purposes. Different types of chemicals are used in “clean-in-place solution” to backflush desalination modules with RO-cartridges or pre-filter assemblies. The chemical injection modules 29 are retrievable, interchangeable and replaceable.

The control functions may be integrated in at least one module to omit a separate control module.

Fig. 6 largely corresponds to a detail of fig. 5 with three desalination templates 1 each including a desalinated water line coupling 32 connecting the desalinated water pipeline 2, a power line coupling 34 connecting a power line 14, a chemical line coupling 33 connecting a chemical line 12, and a concentrated seawater outlet 3 with a discharge line. In fig. 6 however there is a separate retrievable transport pump module 17a and a separate retrievable seawater circulation pump module 17b. The chemical injection module 29 is provided for cleaning the desalination system. The six open squares represent desalination modules 5. A control system may include sensors monitoring pressures, volumetric flows, salinity, power consumption, temperatures etc.

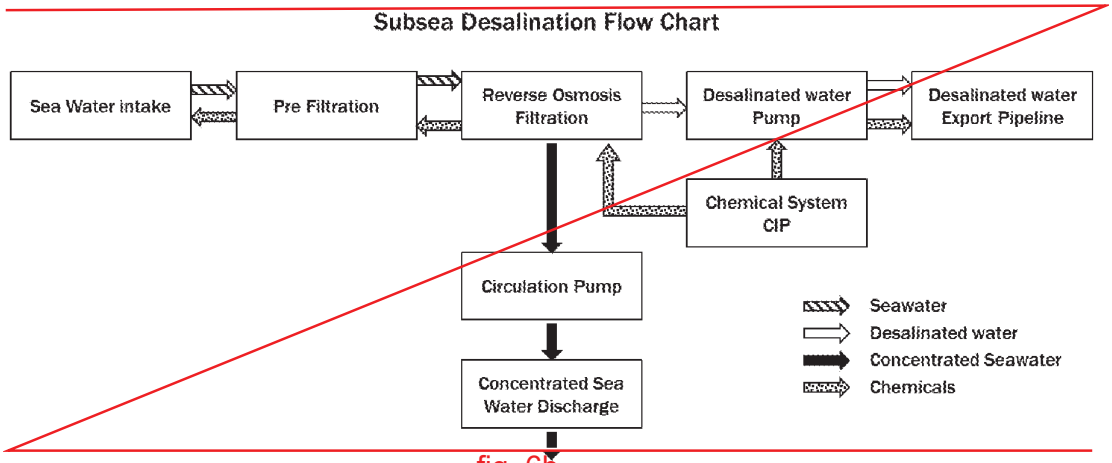

fig. 6b

The subsea desalination flow chart ~~above~~ shows how the water flows through the various elements of the desalination system in a specific embodiment with a

Fig. 7 shows an alternative configuration of a desalination system of the invention with a separate pumping template 16 serving several desalination templates 20 without pumps or control modules. The pumping template 16 includes a retrievable chemical injection module 29, a retrievable transport desalinated water pumping module 17a, a retrievable seawater circulation pump module 17b and a retrievable control module 18. The retrievable seawater circulation pump module 17b and the transport pump module 17a are shown in separate retrievable circulation pump modules but could have been located in the same module as shown in fig 5. In the latter case can the pumping template with four zones accommodate two pumping modules 17 each with both a seawater circulation pump and a transport pump to provide a failsafe system with built in redundancy allowing components to be exchanged without stopping production. The desalination templates 20 only include desalination modules 5. Concentrated seawater outlet 3 with discharge tubulars lead concentrated seawater away from the system as explained above. The line for electric power 14, the control cable 19 and the connection line with the desalinated water pipeline 2 runs to the desalinated water receiving facility on a service vessel or a topside facility. The pumping template 16 provides a flow path between the seawater entrance 383 and the seawater circulation pump 11. The inlet tubular 8 provides the flow path for seawater from the separate pumping template 16 and to the desalination templates 20. Seawater is pumped from the seawater inlet 9, through the pumping template 16, through the seawater circulation pump 11, through the pumping template 16, through the inlet tubular 8, through the desalination template 20, through the seawater filter in the desalination module 5, past and partly through the RO-cartridges to be separated into concentrated seawater and desalinated water, whereby the concentrated seawater flows through the template and out of the concentrated seawater outlet 3. The desalinated water flows into the desalination template 20, the connection line with the desalinated water pipeline 2, through the pump template 16, through the transport pump module 17a, through the pump template 16, through the desalinated water pipeline 2 and to the desalinated water receiving facility (not shown in fig. 7).

retrievable, interchangeable and replaceable. The filtering and pumping station 21 also includes a feed pump. The feed pump operates as a circulation pump for the desalination system and enables discharge of concentrated seawater from the desalination system. The feed pump may be built into a retrievable and replaceable feed pump module.

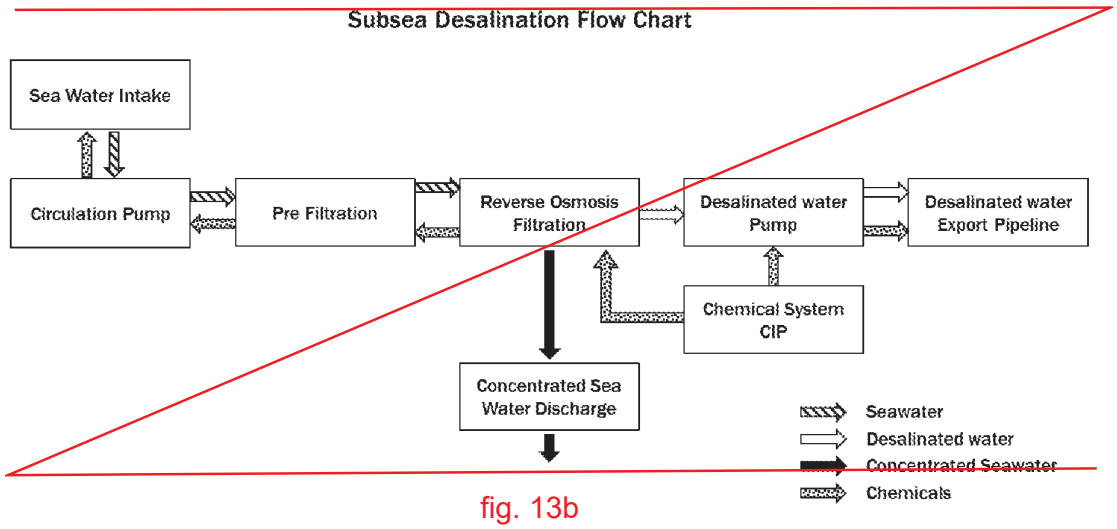

fig. 13b

The subsea desalination flow chart ~~above~~ shows how the water flows through the various elements of the desalination system in a specific embodiment with a seawater intake/entrance and a circulation pump upstream of the pre circulation filter and the desalination filter / the reverse osmosis filtration.

Fig. 14 shows the solution of fig. 7 with a separate pump module template 16 with the transport pump module 17a for desalinated water located downstream of the desalination template 1 with the with concentrated seawater outlet 3 and the desalination modules 5, and upstream of the desalinated water receiving facility 4. The retrievable circulation pump module 17b is located on the desalination template 1.

Fig. 15a, 15b, 15c show details of a desalination module 5 for the desalination system of the invention. The desalination module 5 includes a plurality of RO-cartridges 23 located in an array inside the desalination module 5. Fig 15b shows one cartridge extending the length of the module, and fig 15b shows three RO-cartridges 23 extending the length of the module. The number and size of the

cartridges depends on the commercially available RO-cartridges and the design parameters of the module. Bespoke RO-cartridges may also be used. An inlet filter 22 for ambient seawater is located on top of the modules and an inlet grid 26 protects the inlet filter 22 for seawater. The inlet filter 22 is designed to prevent premature clogging of the RO-cartridges. The desalination module 5 includes an outer frame 27 and upper lifting connectors 28 commonly used for subsea modules. A desalinated water outlet 24 and a concentrated seawater outlet 25 are located at the bottom side 37 of the module and are adapted for connection with the template. These outlets may form the template coupling 47 that is designed to stab into the module coupling in the desalination template zone of the desalination template.

The desalination module 5 with the plurality of RO-filter cartridges 23 is includes an assembly of conduits arranged in parallel where one (fig 15b) or more (fig. 15c) RO-filter cartridges 23 are connected to in each conduit in series. Seawater enters the desalination module through the inlet filter or a pre-filter assembly 22 where seawater is filtered to the desired quality. Then pre-filtered seawater is distributed over the RO assembly where it enters an assembly of the RO-filter cartridges 23 in the individual conduits. Inside the conduits, seawater is separated by the RO-filter cartridges 23 into the desalinated water part (permeate) and the concentrated seawater part (retentate). The desalinated water part and the concentrated seawater part, exits through separate outlets 24, 25 respectively and each part is collected in its own collection piping or manifold system. The desalination module 5 is connected to the template via flow connectors.

The desalinated water from the desalination modules 5 is collected and pumped to the surface by the transportation pump. The circulation pump makes sure that a enough seawater continuously enters the desalination modules 5, and that the concentrated seawater leaves the modules and is transported to a desired location where it is discharged to the sea.

The pre-filters or inlet filters 22 improving the water quality are placed upstream of the RO-filter cartridges 23. The pre-filters or inlet filters 22 are formed as an assembly including one or more

CLAIMS

1. A subsea desalination system comprising:

a subsea desalination template (1) adapted to be located on a seabed, including at least one subsea desalination module zone (41), at least one module fluid coupling (46) and template piping (36) in fluid connection with the at least one module fluid coupling (46);

at least one retrievable subsea desalination module (5) adapted to be placed in the at least one subsea desalination module zone (41) of the subsea desalination template (1), the at least one retrievable subsea desalination module (5) including a subsea template fluid coupling (47) adapted to be connected to the at least one module fluid coupling (46), and at least one reverse osmosis cartridge (23) in fluid connection with the subsea template fluid coupling (47);

at least one seawater circulation pump assembly (49) in fluid connection with a seawater side of the at least one reverse osmosis cartridge (23);

at least one desalinated water transport pump assembly (48) in fluid connection with a desalinated water side of the at least one reverse osmosis cartridge (23) in the retrievable subsea desalination module (5) and at least one desalinated water pipeline (2);

at least one retrievable subsea water pump module (17) including at least one of the desalinated water transport pump assembly (48), and the at least one seawater circulation pump assembly (49);

at least one template fluid coupling (47) on the at least one retrievable subsea water pump module (17), adapted to be connected to at least one module fluid coupling (46) on a template with a pump module zone (42); and

wherein the at least one desalinated water pipeline (2) is adapted to extend to a location above a sea level.

2. The subsea desalination system of claim 1, further including a permanent seabed foundation (50) secured to seabed anchoring elements (40), and wherein the subsea desalination template (1) is adapted to be located on top of the permanent seabed foundation (50).

3. The subsea desalination system of claim 1, wherein the subsea desalination template (1) is adapted to be located on a further base template (55) in fluid connection with the desalinated water pipeline (2) and a concentrated seawater outlet (3).

4. The subsea desalination system of claim 3, wherein the further subsea base template (55) is adapted to be located on top of a permanent seabed foundation (50).

5. The subsea desalination system of claim 1, wherein the subsea desalination template (1) further includes seabed anchoring elements (40) secured to the subsea desalination template (1).

6. The desalination system of any of the preceding claims, wherein the template with a pump module zone (42) is the desalination template (1).

7. The desalination system of any of the preceding claims, wherein the at least one seawater circulation pump assembly (49) and the at least one desalinated water transport pump assembly (48) are located in a common retrievable subsea water pump module (17).

8. The desalination system of any of the claims 1-6, wherein the at least one seawater circulation pump assembly (49) is located in a retrievable subsea seawater circulation pump module (17b);
the at least one desalinated water transport pump assembly (48) is located in a retrievable subsea desalinated water transport pump module (17a); and
wherein the retrievable transport pump module (17a) is located in a desalinated water transport pump module zone (42) and the retrievable subsea circulation pump module (17b) is located in a circulation pump module zone (45).

9. The desalination system of any of the preceding claims, further including at least one retrievable control module (18) located in at least one control module zone (44) on the desalination template (1).

10. The desalination system of any of the preceding claims, wherein the at least one subsea desalination module (5) includes a seawater inlet filter (22) arranged to filter seawater entering the at least one reverse osmosis cartridge (23).

11. The desalination system of claim 10, wherein the seawater inlet filter (22) is located on top of the at least one subsea desalination module (5).

12. The desalination system of any of the preceding claims, wherein the template with a pump module zone (42) is a separate pumping template (16), and wherein a desalinated water flow path extends between the separate pumping template (16) and the subsea desalination template (1).

13. The desalination system of claim 8, further including a separate filtering and pumping station (21) wherein a seawater inlet filter (22) and the circulation pump assembly (49) in a circulation pump module (17b) is located on the filtering and pumping station (21) upstream and in fluid connection with the desalination template (1), pumping seawater through the at least one subsea desalination module (5).

14. The desalination system of any of the preceding claims, wherein at least one separate pumping template (16) with the at least one pumping module (17) is located on a downstream side of the at least one subsea desalination template (1) and includes a desalinated water inlet and a desalinated water outlet, whereby the separate pumping template (16) with the at least one pumping module (17) is adapted to convey the desalinated water from the desalination template (1).

15. A subsea desalination module (5) for a desalination system of claim 1, comprising a plurality of reverse osmosis cartridges (23) and a subsea template fluid coupling (47) adapted to be connected to at least one module fluid coupling on a desalination template..

16. A method exchanging a used subsea desalination module (5) installed on a subsea desalination system of claim 1, including the steps of:

identifying that the used subsea desalination module (5) require service based on regular scheduled intervals or parameters selected from the group of parameters: desalinated water flow rate, water pressure drop over the subsea desalination module (5) and desalinated water salinity;

providing a vessel (6) above the subsea desalination system;

lowering a subsea desalination module lifting means onto the used subsea desalination module (5);

securing the subsea desalination module lifting means to the used subsea desalination module;

releasing the used subsea desalination module (5) from a subsea desalination template (1);

lifting the subsea desalination module lifting means and the used subsea desalination module on to the vessel;

lowering the subsea desalination module lifting means and an exchange subsea desalination module onto subsea the desalination template;

securing the exchange subsea desalination module (5) to the subsea desalination template (1); and

releasing the subsea desalination module lifting means from the exchange subsea desalination module (5).