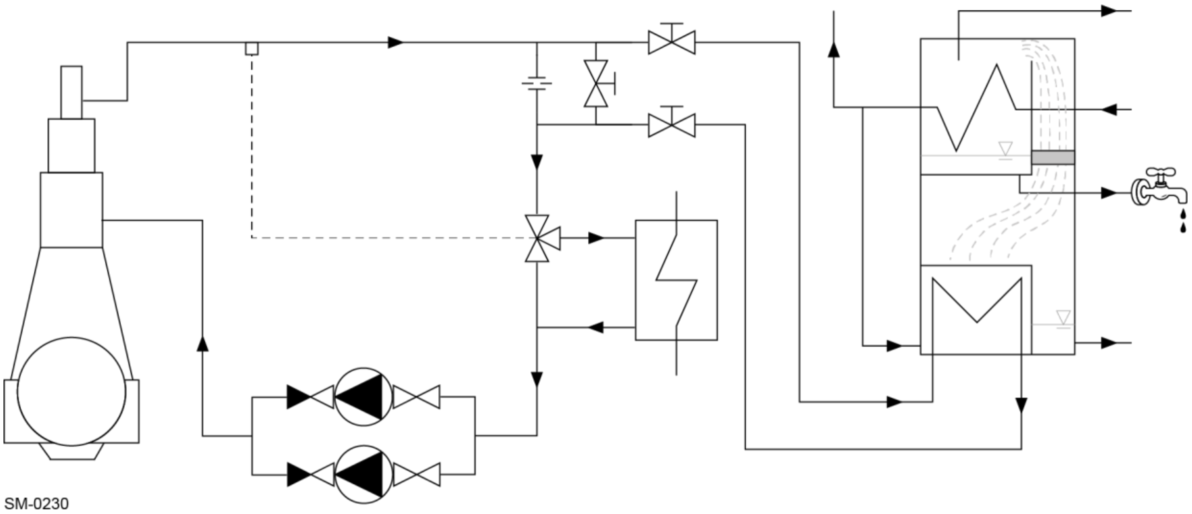
System Engineering
Concept Guidance

Fresh water generators: installation options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Valid for RT-flex / W-X / DF engines

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Table of contents

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Introduction

Production of fresh water on board of sea going vessels is a well-established requirement. However, nowadays a trend to install fresh water generators (FWG) with larger capacities can be seen. Most fresh water generators work according to the operating principle of distillation by utilising part of the engine waste heat. For very high water production, heat-independent fresh water generators are also employed, as described in section 4.

This Concept Guidance assists in designing the FWG arrangement in cooling water system which best fits the fresh water production demand while ensuring safe main engine operation. The formula in section 2.1 allows the initial ship designer to roughly estimate the potential fresh water production corresponding to the installed engine power in kilowatts [kW]. In section 2.2, 2.3, 2.4 and 2.5, the detailed specifications of the maximum heat capacity of the FWG are given based on variation of the FWG installation alternatives, the ME CSR power, and the additional AE arrangement.

The available heat from the high temperature (HT) cooling water circuit depends on the main engine load[1] and the ambient conditions. At lower engine load and in colder ambient conditions the available heat decreases. The FWG's heat requirement also depends on the ambient conditions, mainly on sea-water (SW) temperature: in colder ambient conditions the heat requirement increases. Therefore, the FWG design must be determined in accordance with the vessel's operational profile.

In case of any doubt, please do not hesitate to contact Winterthur Gas & Diesel Ltd.

If other high-temperature cooling water heat consumers are to be installed, the total heat requirement of all heat consumers has to be considered.

The system drawings in this Concept Guidance show only installations with separated HT cooling water circuits, i.e. the HT and the LT cooling water circuits are separated by the HT cooling water cooler (HTC). However, this Guidance is also valid for installations with an integrated HT cooling water circuit. In integrated HT cooling water systems, LT cooling water is mixed to the HT circuit to maintain the required temperature at the engine inlet.

[1] And auxiliary engine load for installations as described in sections **Error! Reference source not found.** and **Error! Reference source not found.**.

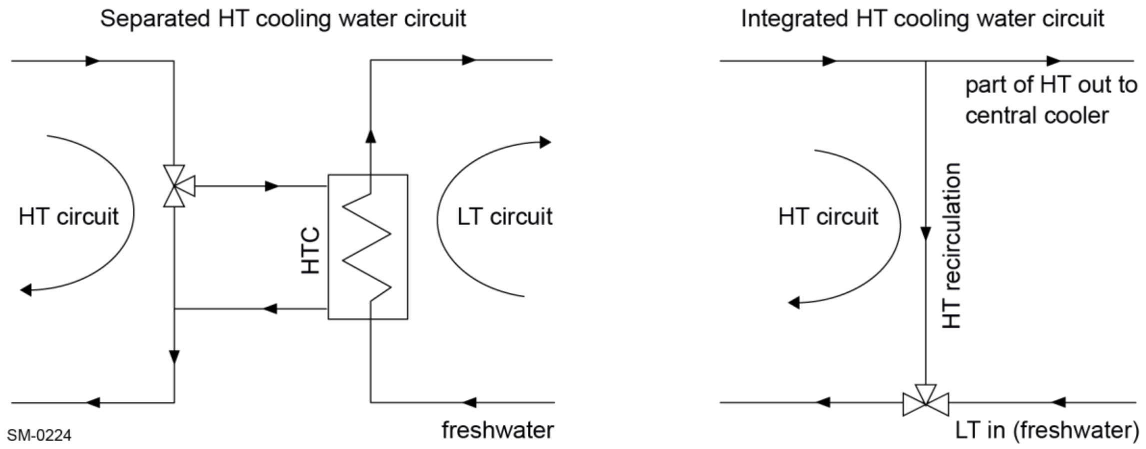

Figure 1: The two principal types of cooling water systems

1 Safe engine operation

To avoid negative impacts on the engine when operating the FWG, the following principles must be observed:

- To avoid thermal shock to the engine the FWG inlet and outlet butterfly valves for the HT water are to be opened and closed slowly. The valves actuated by timer controlled progressive servomotor is the preferred solution. However, manually actuated valves with a large reduction ratio can be used. If the valves are manually operated, a conspicuous warning notice must be positioned next to them. Please keep in mind that 50% to 100% of the cooling function may be taken over by the FWG, depending on the FWG design and the main engine load.

- The water flow to the main engine must be constant. Therefore, it is forbidden to control the water flow in main water flow line by installing stop valves.

2 Single-stage fresh water generator

On board cargo vessels, the fresh water is usually produced by evaporating sea water under vacuum conditions. The most common installation is a single-stage FWG. Different designs are possible, basically divided between those with tube or plate heat exchangers. However, the working principles are the same. Sea water is pre-heated by condensing the vapour in the FWG and heated by HT cooling water. About one third of the sea water evaporates. The vapour flows through the so-called demister which separates water droplets from the vapour. In the sea-water cooled condenser the vapour condensates as so-called distillate. The distillate is pumped to the storage tank. The non-evaporated two thirds of the sea water are removed as brine and pumped overboard. To obtain the vacuum in the FWG, the air has to be removed by an ejector.

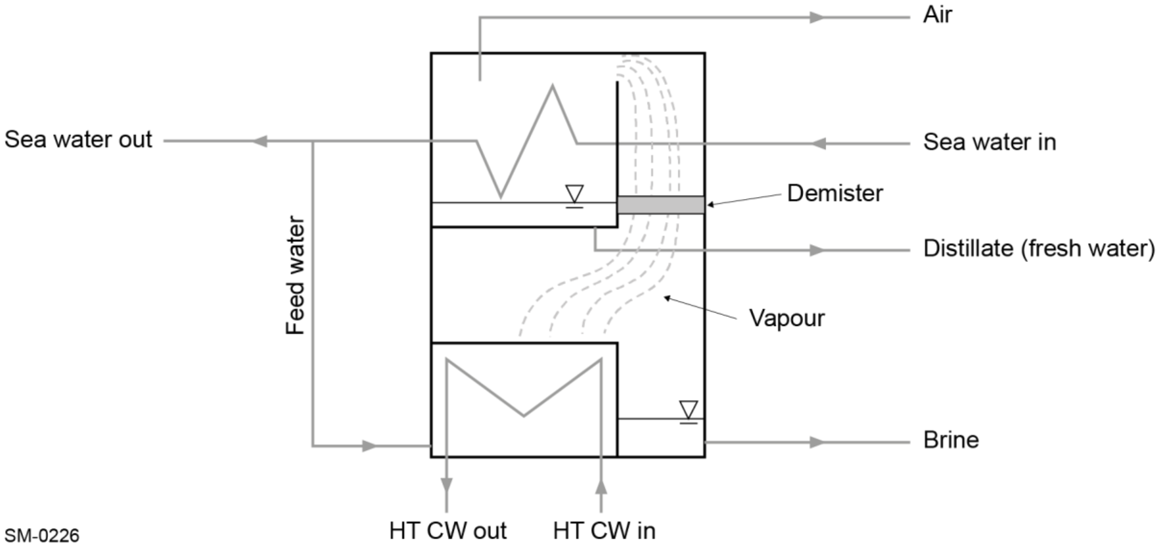

Figure 2: General flow diagram of a single-stage evaporator

2.1 Rough estimation of FWG capacity for ship initial designer

In the early stage of ship design, the initial designer can use the following formulas to roughly estimate fresh water production with the respective FWG installation alternatives.

If the FWG is designed with installation alternative 'A' as described in section 2.2, the fresh water production can be estimated as:

$$Fresh\ water\ production = 2.2 \times 10^{-3} \times Power\ of\ ME\ at\ CMCR\ [ton/day]$$

If the FWG is designed with installation alternative 'B' as described in section 2.3, the fresh water production can be estimated as:

$$Fresh\ water\ production = 3.7 \times 10^{-3} \times Power\ of\ ME\ at\ CMCR\ [ton/day]$$

If the FWG is designed with installation of utilizing heat from ME and AE, as described in section 2.4, the fresh water production can be estimated as:

$$Fresh\ water\ production = 3.7 \times 10^{-3} \times Power\ of\ ME\ at\ CMCR + 5.3 \times 10^{-3} \times Power\ of\ AE\ at\ base\ load\ [ton/day]$$

The simplified calculation methods in this section can only be used for the purpose of fresh water production estimation. For the detail design and selection of the FWG, the ship designer shall select the FWG heat capacity within the recommended limit specified in section 2.2, 2.3 and 2.4 regarding the respective FWG installation variations.

2.2 Installation alternative 'A' and the FWG capacity

The installation alternative 'A' integrates the fresh water generator directly into the HT circuit. The FWG works as an additional cooler, but without any control valve, i.e. at a constant water flow and heat requirement. Subsequently, the FWG cannot control the heat usage from the CCW system. Therefore, the FWG heat capacity must be defined so that the FWG work does not affect the ME work or that the FWG is shut off when the ME works in certain load range.

For the WinGD RT-flex and W-X engines, the FWG heat capacity can be specified to utilise up to 50% of the available CCW heat dissipation at 100% of CMCR.

$$FWG\ heat\ capacity \leq 50\% \times CCW\ heat\ dissipation\ at\ 100\%\ of\ CMCR$$

For the WinGD DF engines, the FWG heat capacity can be specified to utilise up to 50% of the available CCW heat dissipation in 'Diesel Mode' at 100% of CMCR.

$$FWG\ heat\ capacity \leq 50\% \times CCW\ heat\ dissipation\ in\ Diesel\ Mode\ at\ 100\%\ of\ CMCR$$

Where the 'CCW heat dissipation' data at 100% of CMCR can be found in the contracted GTD document of each specific project.

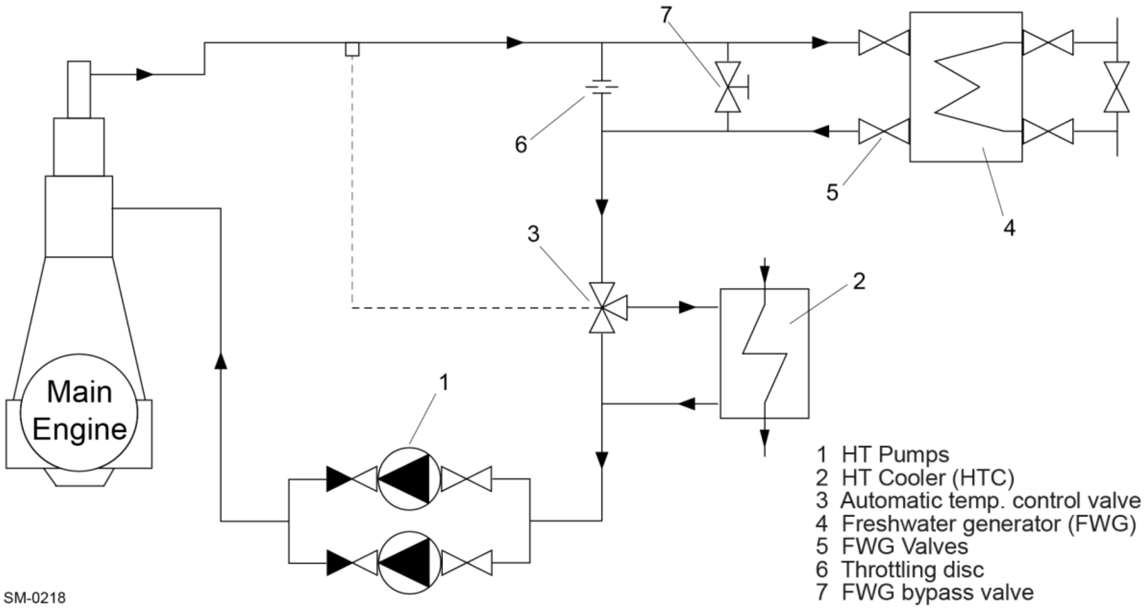

Figure 3: FWG with installation alternative 'A'

Substitute for:											PC	Q-Code
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Moreover, the FWG must be shut off when engine load is lower than 50% of CMCR.

In cold environments, the FWG heat demand increases, but the engine heat dissipation decreases, i.e. the FWG can only be operated at higher engine loads.

As described in section 1 (Safe engine operation), **the cooling water flow to the engine has always to be kept constant.** For this purpose, an FWG by-pass line must be installed to simulate the flow and pressure drop of the FWG when the FWG is not in use. The design and commissioning adjustment of this system are described as follows:

1. Open or close the FWG by slowly switching the valves (pos. 5 in Figure 3) before and after the FWG.
2. The throttling disc (pos. 6 in Figure 3) is designed so that the FWG receives the design flow when the FWG is fully open and the bypass line (pos. 7 in Figure 3) is fully closed. In the case where the total flow of the CCW is the design flow of the FWG, this orifice and branch can be omitted.
3. The bypass line with valve (pos. 7 in Figure 3) shall be adjusted to produce the same pressure drop as the FWG under its design flow condition. The commissioning engineer shall adjust the valve position to correspond with the aforementioned pressure drop set point. A physical barrier shall be added to the valve to ensure it can only be operated between the fully closed and pressure drop set point position.
4. Summary of valve operation for ship crewmember:

Operation	Valve before and after the FWG	Valve on bypass line
FWG running	Fully open	Fully closed
FWG stopping	Fully closed	Fixed position defined in point 3

2.3 Installation alternative ‘B’ and the FWG capacity

For higher fresh water demands, it is possible to install an FWG which is designed to utilise up to 85% of the maximum available heat dissipation at CSR. The remaining 15% of heat shall be reserved for heat transfer loss, radiation loss and component efficiency etc.

For the WinGD RT-flex and W-X engines, the FWG heat capacity can be specified according to the available heat in CCW at CSR:

$$FWG\ heat\ capacity\ \leq\ 85\% \times CCW\ heat\ dissipation\ at\ CSR$$

For the WinGD DF engines, the FWG heat capacity can be specified according to the available heat in CCW in diesel mode at CSR:

$$FWG\ heat\ capacity\ \leq\ 85\% \times CCW\ heat\ dissipation\ in\ diesel\ mode\ at\ CSR$$

Where the ‘CCW heat dissipation’ data can be found in the contracted GTD document of each specific project.

To protect the engine against excessive cooling in cases where insufficient heat is available, the water flow to the FWG is reduced by a temperature control valve (CVA). During FWG operation, the FWG utilises the most of available heat from the CCW. Only if the engine HT cooling water heat dissipation is higher than the heat demand of the FWG, does the High Temperature Cooler (HTC) take the remaining heat.

The FWG installation, with the by-pass pipes, is similar to that of the standard installation (installation alternative ‘A’). The FWG is integrated between the additional control valve (CVA) and the HTC control valve (CVB) as shown in Figure 4.

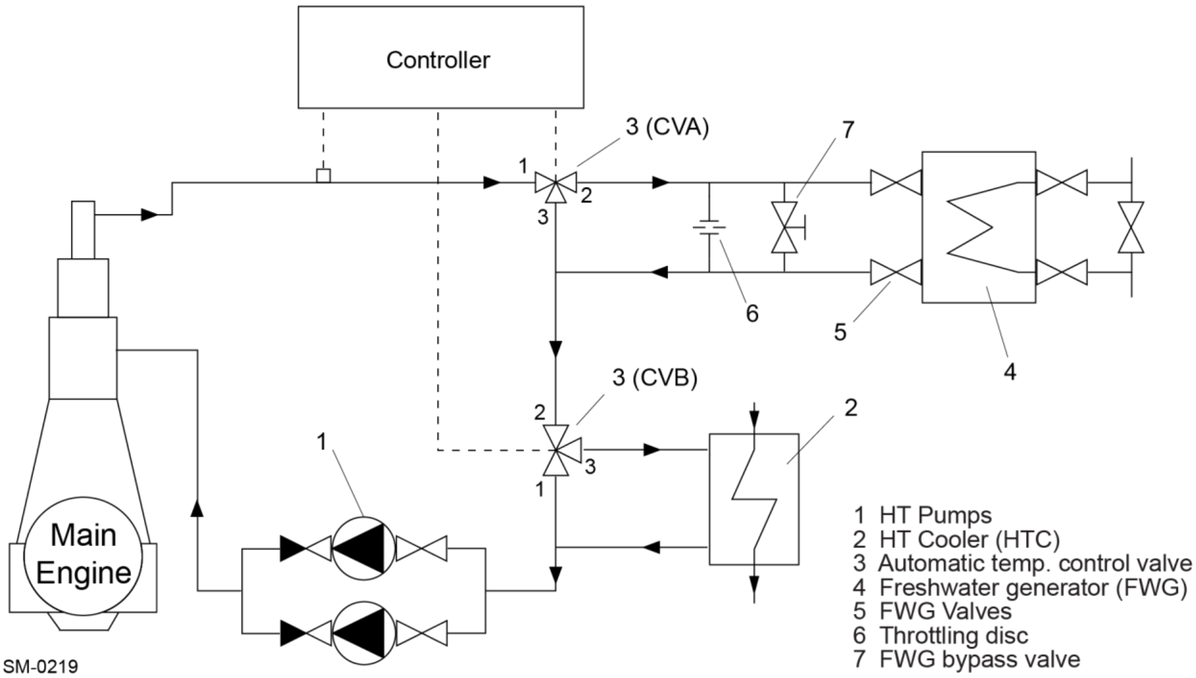

Figure 4: Optimised installation: FWG with installation alternative 'B'

The temperature control valves CVA and CVB are controlled by either:

- One controller which detects the opening position of the main temperature control valve CVA. Control valve CVB opens only if control valve CVA is already fully open in order to take the remaining heat dissipation.

Or:

- Two separate temperature controllers with different temperature set points to avoid both controllers acting at the same time.

  The set point of temperature control valve CVA shall normally be 90 °C; The set point of temperature control valve CVB shall normally be 93 °C, namely 3 °C higher than the CVA.

2.4 Installation utilising ME and AE CCW heat dissipation and the FWG capacity

A newly-developed system integrating the heat dissipation of the auxiliary engines into the HT system of the main engine is described below.

For WinGD RT-flex and W-X engines, the FWG heat capacity can be specified by adding the available heat from ME CCW at CSR and the available heat from AE CCW at base load, considering 15% of heat as margin.

$$\begin{aligned} &FWG\ heat\ capacity \\ &\qquad \leq\ 85\% \times (\ ME\ CCW\ heat\ dissipation\ at\ CSR \\ &\qquad + AE\ CCW\ heat\ dissipation\ at\ base\ load) \end{aligned}$$

For WinGD DF engines, the available heat from ME CCW shall be based on data in ‘Diesel Mode’.

$$\begin{aligned} &FWG\ heat\ capacity \\ &\qquad \leq\ 85\% \times (\ ME\ CCW\ heat\ dissipation\ in\ diesel\ mode\ at\ CSR \\ &\qquad + AE\ CCW\ heat\ dissipation\ at\ base\ load) \end{aligned}$$

Where the ME ‘CCW heat dissipation’ data can be found in the contracted GTD document of each specific project. The heat dissipation from the auxiliary engine CCW shall be checked with the auxiliary engine supplier.

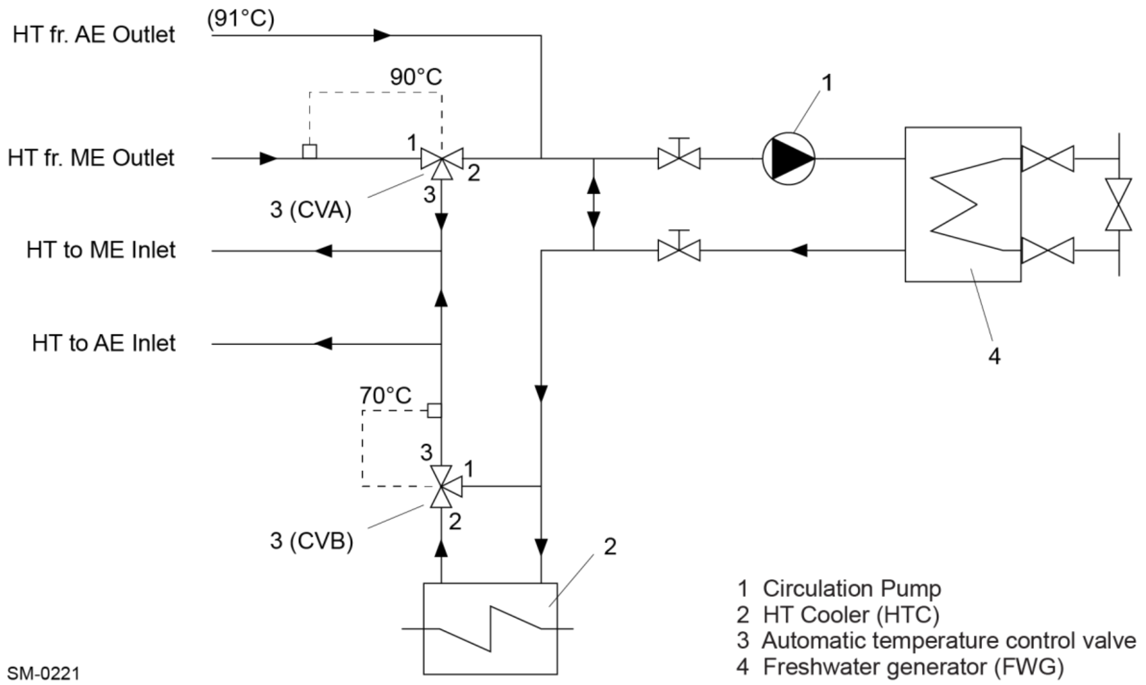

Figure 5: Installation option utilising ME and AE CCW heat dissipation

A circulation pump ensures a constant water flow to the FWG, independent of main and auxiliary engines’ load, but at different temperature levels. Depending on the opening position of temperature control valve CVA, part of the flow recirculates through the by-pass line between the FWG inlet and outlet.

Control valve CVA maintains the main engine outlet cooling water temperature at a constant 90 °C. When all the available heat cannot be dissipated by the FWG, the remaining heat is dissipated by the HT cooler.

Control valve CVB maintains the temperature of the HT cooling water at 70 °C. If the cooling water temperature downstream of the control valve CVB falls below 70 °C, the FWG circulation pump must be stopped.

The 70 °C cooling water can be directly used for pre-heating either the stopped auxiliary engines or the stopped main engine respectively.

Application of an integrated HT cooling water circuit is also possible. The HT cooler shall be replaced by adding LT cooling water at the connection No. 2 of temperature control valve CVB.

Other advantages of this installation, besides the greater fresh water production potential, are:

- Pre-heating of the ME from the AE is possible when in port.
- Pre-heating of the AE from the running ME is possible.
- Only a small pre-heater for one AE is required (not shown in above schematic drawing).

For further information on this installation please contact Winterthur Gas & Diesel Ltd.

2.5 Installation with booster heater: maximum possible FW production depending on the additional booster heater capacity

To increase the available heat for the FWG, also during lower part-load operation of the ME and in colder ambient conditions, it is possible to install a booster heater. The heater may be operated with steam or thermal oil heated by the exhaust gas boiler, enabling another source of waste heat to be used for the fresh water production.

The booster heater can be integrated in the systems as described in section 2.3 and section 2.4.

2.5.1 Booster heater integrated into the system of installation alternative ‘B’

A circulation pump provides a constant water flow to the FWG according to the FWG demand. When the available waste heat from the main engine is not sufficient, control valve CVA provides less HT cooling water to the FWG. In this case the circulation pump recirculates part of the cooled water flow through the by-pass line between the FWG inlet and outlet. The booster heater ensures a constant FWG operating temperature.

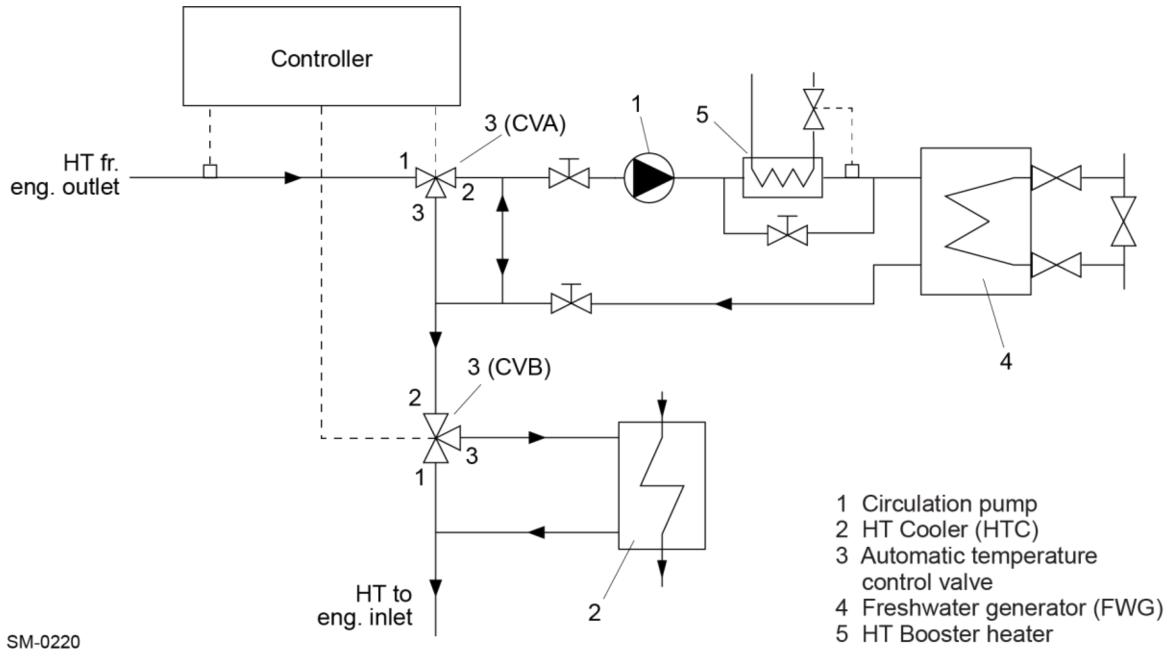

Figure 6: Booster heater integrated into the system of installation alternative 'B'

2.5.2 Booster heater integrated into the system of installation utilising ME and AE CCW heat dissipation

In the system described in section 2.4, a booster heater is integrated downstream of the circulation pump. This ensures that the FWG is always operated at a constant temperature. For an optimum recovery of the HT cooling water heat it is recommended that the FWG outlet temperature be kept at about the same level as the outlet temperature at control valve CVB, i.e. 70 °C. Therefore, the booster heater should be controlled by the FWG outlet temperature.

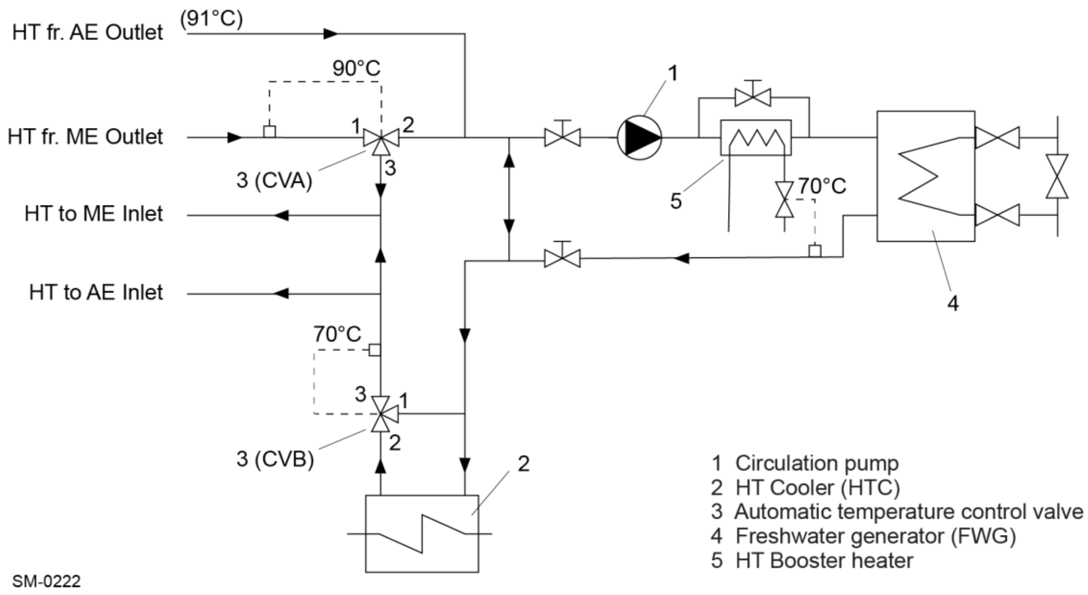

Figure 7: Booster heater integrated into the system of installation utilising ME and AE CCW heat dissipation

3 Multi-effect and multi-stage FWG: a multiple of the single-stage FWG installations

To increase the possible water production with a given amount of (waste) heat, it is possible to install fresh water generators which utilise the available heat several times. The basic principal behind the higher water production of these FWG is a better reutilisation of the latent vapour condensation heat.

3.1 Multi-effect evaporation FWG installations

The single-stage FWG installations as described in section 2 can be replaced by a multi-effect evaporation FWG.

The multi-effect distillers (MED or MEP) utilise the latent vapour heat of the previous stage for evaporation in the following stages, i.e. the vapour condenser is cooled by heating up the sea water of the following stage.

Depending on the number of stages, it is possible to produce a multiple amount of fresh water compared to a single-stage FWG installation with the same heat input.

The Figure 8 shows the working principle of a multi-effect evaporation FWG with five stages as an example.

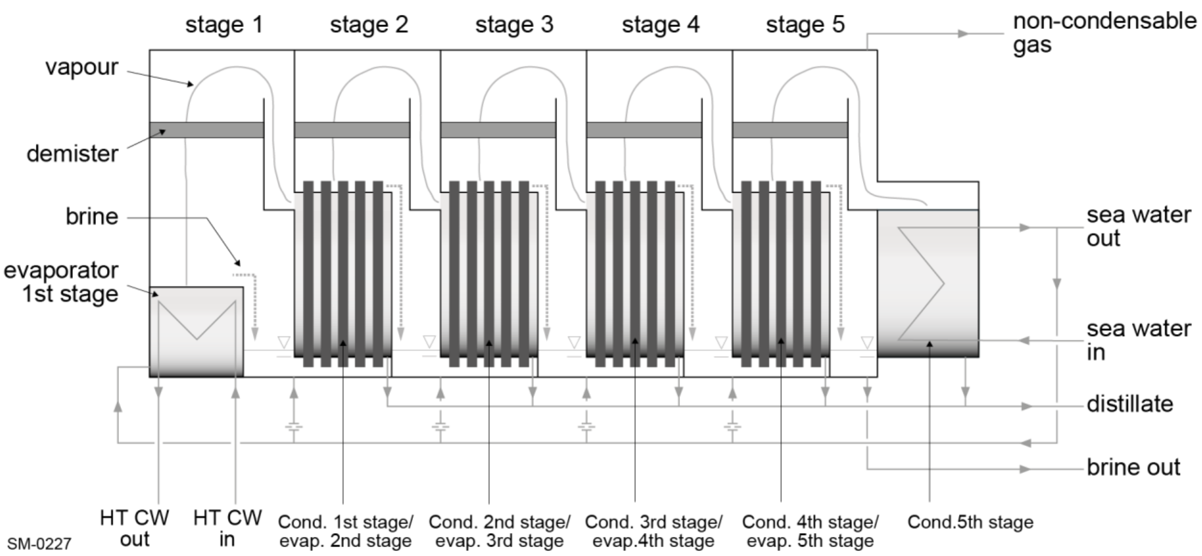

Figure 8: Principal flow diagram of a multi-stage FWG

For further information on this FWG type, please contact your FWG maker.

3.2 Multi-stage flash FWG: a multiple of the single-stage FWG installations

The multi-stage flash (MSF) FWG type also re-uses a significantly higher amount of the condensation heat compared to the single-stage FWG. The main difference compared to the multi-effect FWG is that the total heat transfer to the sea water takes place before the sea water enters the FWG. First the sea water is heated by the vapour condensation heat, beginning from the last stage up to the first one. As such, the sea water captures already 70–80% (depending on number of stages) of the total required heat. The remaining required heat is provided by the HT cooling water and/or by a booster heater. After the final heating, the sea water has enough latent heat for the multi-evaporation stages, i.e. the sea water inlet temperature is on a higher level compared to the single stage type of FWG (nearly HT cooling water outlet temperature).

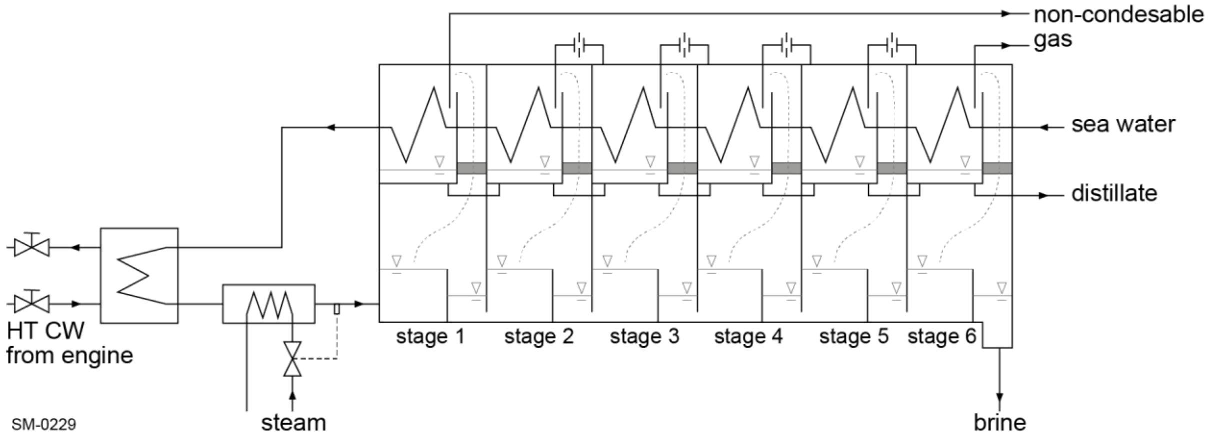

Figure 9: Principal flow diagram of a multi-stage flash evaporator

The heated sea water enters the evaporation chambers from one stage to the next. The absolute pressure decreases steadily from the first stage to the last one, so the sea water enters each chamber with a temperature about 7 °C higher than its boiling temperature in this chamber. This leads to a spontaneous controlled evaporation of the superheated sea water. The sea water (brine) cools down due to the evaporation chill and flows to the next chamber. The process goes on until the sea water has passed the last chamber.

The Figure 10 shows an example for the system integration:

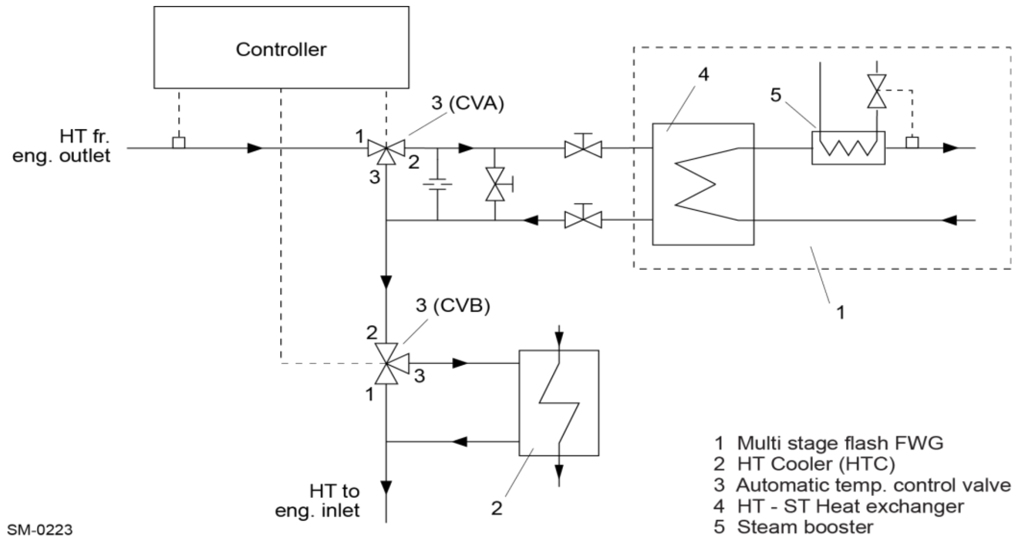

Figure 10: Multi-stage flash evaporator system integration

For further information on this FWG type, please contact your FWG maker.

4 Heat-independent FWG installations

The following FWG types are normally only applied if the available heat is absolutely insufficient. They are mentioned here for information only.

4.1 Reverse osmosis

Sea water is forced at high pressure (about 60–70 bar) to pass through an extremely fine semi-permeable filter membrane known as the diaphragm. The filter membrane is permeable to water, but only very limited to salt. The pump therefore presses water without salt through the membrane.

Owing to the different salt concentrations on both membrane sides, an osmotic pressure builds up, which tries to balance the salt concentrations on both sides of the membrane by pressing back the salt less water to the salty side. Therefore, a pump pressure higher than the osmotic pressure is required. According to an FGW maker's data, about 3–4.5 kWh of electrical energy is required for 1 m^3 fresh water production.

About 20% of the supplied sea water permeates salt less to the fresh water side of the membrane.

For further information on this FWG type, please contact your FWG maker.

4.2 Vacuum vapour compression

The vacuum vapour compression (VVC) FWG consists of only one heat exchanger. The sea water on one side of the heat exchanger is heated by the heat of condensation of the mechanically compressed vapour, which is produced by partial evaporation of the sea water. This heat exchanger operation principle is comparable to the heat exchangers in the multi-effect FWG, except for its first stage.

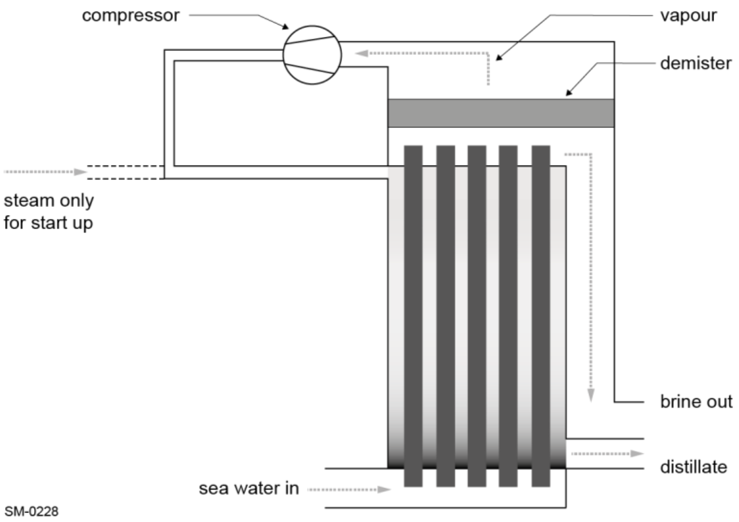

Figure 11: Principal flow diagram of a vacuum vapour compression FWG

A mechanical compressor extracts the water vapour from the evaporation chamber, creating a vacuum which is required for sea water evaporation at a low temperature level. The compressed vapour flows from the compressor to the heat exchanger and condenses. According to an FGW maker's data, about 10-17 kWh of electrical energy is required for 1 m^3 fresh water production.

Another installation option is “thermo compression” instead of mechanical compression. Steam flows at high velocity through an ejector, creating the required vacuum for sea water evaporation, like the compressor in the mechanical installation, and draws through the created vapour. The steam-vapour mixture flows to the condenser side of the heat exchanger. The reduced steam velocity at this side increases the static pressure, and the steam condenses in the heat exchanger, heating the sea water in the evaporation chamber. The boiler feed water cannot be treated with the usual chemicals, owing to the mixing of vapour and steam.

For further information on this FWG type, please contact your FWG maker.

5 Abbreviations

AE	Auxiliary Engine
CMCR	Contracted maximum Continuous Rating
CCW	Cylinder Cooling Water
CW	Cooling Water
FW	Fresh Water
FWG	Fresh Water Generator
FWG types:	
- MED	Multi-Effect Distiller (tube type)
- MEP	Multi-Effect distiller (Plate type)
- MSF	Multi-Stage Flash
- RO	Reverse Osmosis
- VVC	Vacuum Vapour Compression
GTD	General Technical Data. An application of WinGD for ME relevant data
HT	High Temperature
HTC	Hight Temperature cooling water Cooler
LT	Low Temperature
ME	Main Engine
MIM	Marine Installation Manual
SW	Sea Water

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