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Project: Solar Desalination Plant

Capacity: 10 /20 KLPD

General Description

Typical MED Desalination unit such as the one shown above uses waste heat from the engine of European cruise line- AIDA to provide drinking water of 100 KLPD.

Note: This document has been prepared for understanding various components and the system requirements of the Modular MED concept using Solar Energy/Waste heat. All parameters mentioned are indicative. The actual design may vary depending on site conditions.

Nomenclature

MED	Multi Effect Distillation
SW	Sea Water
SWS	Sea Water Supply
SWR	Sea Water Return
HT	High Temperature Water system
HTR -	Return (to Boiler / Storage Tank / Diesels)
HTS -	Supply (from Diesels)
Q	Heat Duty [kW]

Process description

The project envisages a **solar driven desalination system** with a daily water delivery capacity of **10 m³/20 m³ per day (10000 – 20000 LPD)** to convert Sea water/Brackish water to safe drinking water.

The proposed process combines a Multi-Effect-Distillation (MED) Desalination unit running at 47°C top brine temperature based on vacuum distillation with a solar thermal collector field.

The solar collector field is to be designed such that the heat produced by the collector field is sufficient for continuous operation of the desalination unit.

A hot water tank serves as energy storage for night time operation.

Waste heat from any existing Diesel Generators or any other source such as Biomass gassifiers, etc. will serve as a backup for rainy seasons or half-sunny days and will be stored in the heat storage tanks by an integrated control system.

An **optional upgrade** of the solar supply system is possible at a later stage in order to increase the system-capacity up to a possible 20 m³ per day simply by increasing the heat supply temperature.

The upgrade unit can be installed at a later stage without any major modification to the MED unit. It might be necessary to include raw water pre-treatment (e.g. 0.8 ppm dosing of anti-scalant) in case **of the** temperature increase.

As such the entire system provides a very high overall performance.

Key technical data of the system- MED Unit

- 5 effects , one final condenser stage **capacity 10 m³/d** when heated with hot water 62/48°C
- innovative design by combining identical heat-exchanger cells for each of the stages
- 3 individual trains assure high availability
- multiple effect distillation process
- entirely fabricated from sea water resistant stainless steel
- no risk of corrosion by sea water

Thermal energy storage system

- hot water tank made from reinforced glass fiber mounted in place
- not pressurized
- transportation in rolled sheets for installation on site
- proven and reliable system design

Solar collector field

- highly efficient flat plate collectors using highly selective absorber coatings /patented Technology)

- corrosion proof design, can be used in rough climates and under maritime conditions

- generously sized to produce the average heat required by the MED unit in the summer period.

- operating temperature 68 / 55°C

Sea water intake and outfall (in the case of Sea water)

— a filter pipe buried in the sea floor is proposed as the intake system in order to ensure e**nvironmentally** friendly and safe intake without use of chemicals

— Outfall will be taken off-shore to a distance of roughly 50 m

Sea Water Intake

The MED unit will require sea water to feed the desalination process and heat rejection.
The sea water shall preferably be taken from a beach well.

A layer of approximately 1 m of sand usually provides enough filtering capacity to avoid any negative effect on the equipment.

In addition the sand layer protects the system form shellfish and seaweed.

The sea water kit which is offered includes the major equipment which has to be installed in the well.

- 5 m of slit filter pipe to be buried in the sea floor
- 6 m of riser pipe which houses the pump
- a sea water pump which can be submerged in the riser section of the intake pipe
- a connection box for power and control cables

The filter pipe can also be laid on the sea floor and covered by properly selected sand and gravel.

Note:

If there is no possibility of installing the pumps in a beach well, installation on a platform of a jetty is the preferred solution. In this case the pumps must be installed in caissons which act as primary filters.

Preferably the caissons shall be made of CuNi alloy to reduce the growth of marine organisms.
Also an open (or caisson) intake requires some additional equipment and more chemicals to control fouling; for example, shock chlorination must be performed more frequently.

Basic MED Process Description

A multi effect distillation plant consists of several stages of evaporators under vacuum. Sea water is distributed on the tubular heat exchange surface of Evaporator 1 and partially evaporated.

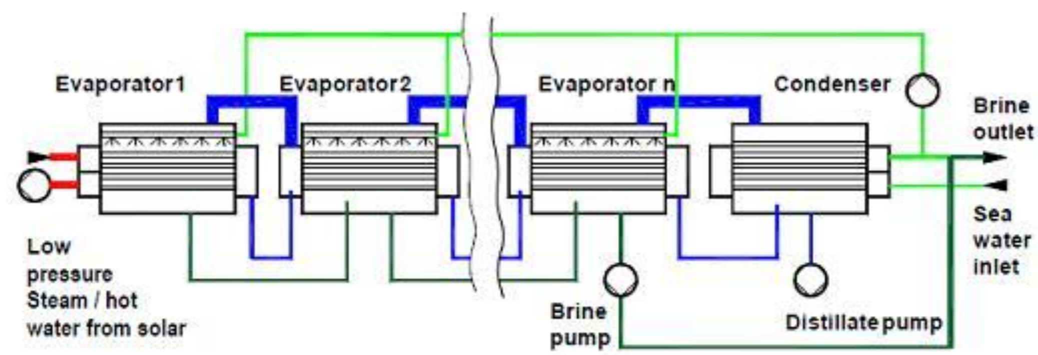
The generated steam is drawn up into the next stage of the process and condenses inside the tubes of Evaporator 2, being cooled by the sea water evaporating from outside of the tubes in this section at a slightly reduced pressure and temperature. Finally, the steam of the 5th stage will be condensed by a tubular heat exchanger bundle in stage 6 which serves as a final condenser.

This system consists of 6 stages, each being placed vertically on top each other. In the last stage those gases that could not be condensed, are extracted by a simple ejector.

In all MED processes the sea water feed is first preheated by being used as cooling device for the condenser. The driving heat of the first evaporator is usually low pressure steam or hot water from an external source with a maximum temperature of 70°C.

In this application the heat source is hot water heated in the solar collectors and stored in a tank for night operation. All other evaporators use the evaporated water vapor of the previous stage as their heat source.

The steam from the last evaporator condenses in the condenser. Condensates from each stage and from the condenser will be used as process or drinking water. Evaporation temperatures decrease in each stage. .



picture 1: MED desalination process. Thick blue line: low pressure steam, slim blue: distillate, light green: sea water, dark green: brine

The temperatures of the sea water and brine are extremely low (< 47°C in the first stage). In conjunction with a low concentration factor of less than 1.3 this almost completely eliminates the risk of scaling.

The non-condensable gases, mainly CO_2, N_2 and O_2 from the sea water will be removed from the system by a vacuum pump installed on the skid of the evaporator.

The exhaust gases from the vacuum system will be injected into the product water to add CO_2 which is required to dissolve small quantities of limestone in the re-mineralization tank.

MED Plant Configuration

Modular MED plants are scalable, each system being designed to suit customers´ requirements.

Each plant consists of single cell comprising tubular heat exchangers made from 315 stainless steel tubes.

The cells are combined in either a single or compound arrangement (stages) according to design requirements. The photograph below shows a 6 cells unit comprising a tubular heat exchanger, a spraying unit; the brine collection and a multi-fin demister are combined in a single unit.

picture 2: one of the stages out of the MED cellular system for combination of Modular MED Desalination system

MED Performance Data

Hot water flow to cell 1
- Hot Water supply / return Temperature 68 / 55°C
- Flow 3.3 m³/h

Total brine outlet
- Temperature 37°C
- Flow will be mixed with cooling water outlet

Sea water inlet
- Temperature 28°C
- Flow 5 m³/h
- required filter mesh 0.5 mm (see Sea water intake for details)

Sea water outlet
- Temperature 35°C
- Flow 5 m³/h

Water outlet
- Temperature 36°C
- Flow 10 m³/d, 420 liters/h
- Distillate to be remineralized for utilization as drinking water
- TDS < 10 ppm.

Electrical Power Consumption
- Power supply 3 x 400 V / 50Hz
- MED Unit: 1 kVA max.
- Sea water pump: on design

Dimensions and Installation

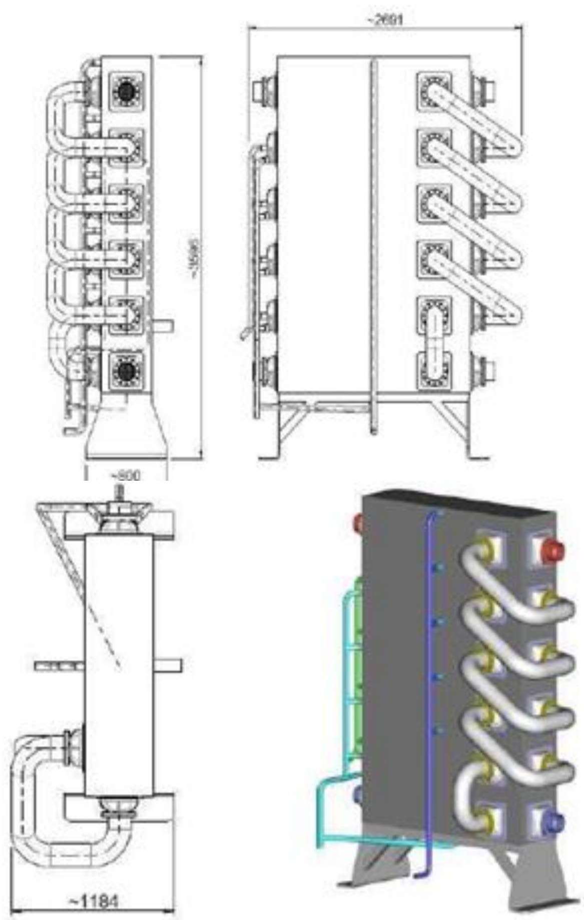
The MED modules will be mounted on a skid which must be installed on a concrete slab.

The concrete floor must be painted and inbuilt drainage to evacuate any spill water.

Preliminary overall dimensions of skid

Length	2000 mm (transportation), 2691 mm (after mounting)
Width	800 mm
Height of body	2790 mm (transportation), 3596 mm above floor (after mounting)
Weight app.	1500 kg (core part), 2500 kg (after installation)

The skid consists of pre-manufactured hot-dip galvanized steel frames which are assembled on site due to restricted transport facilities.



Sea water feed quality

Filter mesh	0.5 mm (slit pipe buried in sea floor)
Internal filter	0.1 mm (protection only)

Sea Water intake pump

The sea water intake pump has to convey the sea water from the intake to the site which is located at a distance of approx. 300m, and at max.17 m of elevation (subject to changes of design)

Flow	5 m^3/h
head	40 m WC
power consumption	1 kW

The pump will be a submergible one designed for service in sea water

Post-treatment

The water from the unit will be re-mineralized by limestone. This is accomplished through injection of the CO_2 from the MED vacuum system and subsequent dissolution of the limestone in a small tank.

Limestone	grain 5 mm
Tank	100 Liters

Chlorination

Transport chlorination of the water is not foreseen.

Cleaning

A tank with 100 l for preparation of diluted citric acid (5%) is delivered for cleaning of modules.

The tank can be temporarily connected to a module for cleaning purposes.

After the cleaning procedure the acid is drained in to the tank and the unit can be flushed with water for service.

The acid does not come into contact with product water

The citric acid is of food grade

Solar Collector Field

The solar collector field will be designed to suit site conditions.

It will be installed on pre-manufactured hot dip galvanized aluminum frames which will be assembled on site.

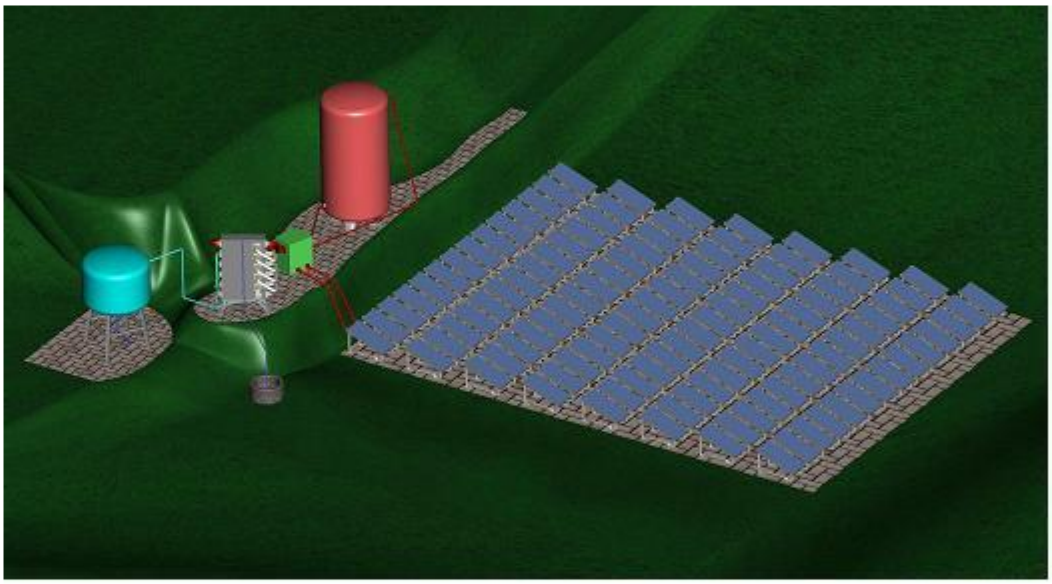
The row will be mounted on steel bars.

Each flat plate collector element will have the following approximate dimensions :

Length 2000 mm

Width 1050 mm

aperture 1.9 m² per module



picture 3: Principal set up of the MED desalination system

The collectors will be connected with copper piping and connected to the storage tank through a heat exchanger.

The loop will be filled with pure water in order to gain maximum performance in terms of heat capacity.

The control system will control the flow through the system such that the heat is only fed into the storage tank if the temperature is sufficiently high.

An automatic disconnection of the solar collector field from the heat supply system will avoid overheating of the supply system during any stand-still periods of the system.

The collector field will stay inherently safe through the use of pressure exchange vessels and /or an additional natural-convection emergency cooling system

The collector loop also includes pumps, expansion vessels, piping and auxiliaries.

Thermal Energy Storage

The purpose of the thermal energy storage tank is to store heat from the solar collector such that the MED unit can operate continuously without interruption during the night.

The design of the tank has to take into account limited transport facilities. Therefore a GRP tank has been considered.

Type of storage:	stratified hot water storage tank
Pressure:	atmospheric
Dimensions:	approx. 3 m dia x 5 m high
Volume (usable):	app. 30 m^3
Heat insulation	Rockwool 100 mm covered with galvanized steel sheets

The heat from the solar collector field and waste heat from the diesel generator will be fed into the tank through a heat exchanger.

Control System- Structure & Philosophy

The control system of the MED unit will perform all control operations for the MED itself, plus the collector field, the thermal energy storage and the intake pump.

All operational control actions can be performed via the Ethernet link to the PLC. Monitoring data is collected in a file stored in the filing system of the PLC from where they can be accessed via the FTP service over Ethernet

Key features of the operator interface (web visualization) are:

- detailed information about the process variables
- all parameters for controllers are visible for each user
- alarms can reset after logging-in with a password
- alarm limits can be modified individually for each relevant component
- instruments can be deactivated individually to suppress alarms from defective instruments
- set points and controller parameters can be modified
- pumps can be controlled individually
- control valves can be set manually

Any operation beyond the capabilities of the visualization must be performed through the programming interface (Ethernet).

Access to the programming interface is also password protected

Visualization:	Local:	via a panel installed on the control cabinet
	Remote:	accessible via onboard Ethernet from any location

The control cabinet will include the

- PLC
- visualization screen
- motor control blocks
- manual start/stop buttons for pumps
- interface blocks for connection to the junction box of the sea water intake pump.

Visualization

A typical visualization screen similar to that shown below will be implemented.

All measurements are available on the screen via Ethernet. Multiple clients can connect to the system. Access to controllers, set points etc. is available through a password protected page only.

The screen-print also shows the level of instrumentation typically implemented on an absorption unit.

The values shown in black boxes are direct measurements, the values in blue boxes contain values obtained through mathematical operations which may include look-up in the property data base of the fluids.

All values will be continuously stored in a text file which can be read via the ftp-server of the controller.

Delivery

All equipment will be shipped in a standard Sea shipping containers..

Erection and Site

Site preparation :
The required plot area for the MED unit and the collector field is approximately 30 x 40 m. The site for the collector field should be flat, free of obstacles and properly graveled.

Draining for rain water and deluge water shall be provided.

Fence:
The entire site shall be protected by a fence to keep animals / visitors away form the installation.

Building

The MED unit should be installed in a shelter with a floor area of 20 m² and a free height of 3.5 m
The shelter should be ventilated, preferably by natural draft;, air conditioning is not required.

The construction of the shelter can either be wood, pre-fabricated metal panels or brick. It is mainly to protect the installation from heavy rainfall and sunlight.

Solar Collectors

The solar collector will be installed on an aluminum framed structure which will be assembled locally from pre-manufactured elements.
Those elements will be connected by steel frame elements being anchored to the ground.
Depending on the quality of the ground, a concrete foundation may be required, otherwise the aluminum structure will be anchored directly to the rock underground.
Anchoring of the support structure for the solar collectors must be designed for anticipated wind loads.

Thermal energy storage tank

The tank will have a diameter of 3 m and weigh more than 30 tonnes after being filled. Therefore a proper concrete foundation is necessary. The tank will be built on site from prepared lining elements and moduled parts, the heaviest comprising a weight of app 400 kg.

Sea water intake pipeline

The sea water intake should be located a maximum distance from the site of 300 m.

It is suggested to recommended that the pipeline be protected either by the use of a protective pipe or by burying the pipe in a trench.

Sea Water outfall

The outfall is located in the sea at the remote end of the site. It is recommended that the pipeline be protected either by the use of a protective pipe or by burying the pipe in a trench. In order to ensure proper discharge, the brine discharge pipeline must be leveled appropriately with a constant slope of at least 10 mm/m.

The discharge pipe will be extended to a distance of 50m off the sea shore.

Foundations

The following equipment will require foundations

- Shelter 20 m^2 x 30 cm = 6 m^3
- Tank 4 m dia x 0,5 m = 6,5 m^3
- Intake 2 m^3
- Collectors to be defined once location is fixed

Testing

The single units will be pre-assembled in the workshop for a test of all basic functions before shipment.

No production test under solar supply will be performed.

Installation

Will be performed by GERINDTEC / local contractors

Commissioning

Cold commissioning: will be performed jointly short before heat and sea water is available

Operation and Maintenance

Normal operation of the unit does not require operator action as all systems will be fully automatic.

Daily:

However it is strongly recommended to perform a daily visual inspection visit to the units

Every six months

Regular preventive maintenance
A typical maintenance schedule includes an inspection of the unit, check of water quality and a functional test of the instruments.
The duration of the inspection is typically 72 hours

When performance starts degrading:

On the sea water side the unit can be cleaned in situ with diluted food grade citric acid . Normally this is entirely sufficient as only $CaCO_3$ may precipitate at the low temperature.

Sea Water system

The intake pump must be inspected once a year.

The sea water system needs regular inspection to prevent the system from shutdown caused by clogged intake structures.

In particular the sand and gravel cover must be inspected regularly. After heavy storms the sea floor may change and renewal of the sand/gravel may be necessary.

Operation of the intake without the sand layer may lead to malfunction and clogging after a short time

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SUMMARY of MODULES

6-stage MED-Auto Syphon-Unit,

Type **MaxDest-AS** nominal water production capacities of optionally **20, 50, 100, 250 or 500 m³ per day**, designed for production of drinking water to WHO standards.

- Thermal Energy supply from any low temperature heat source, e.g. generator waste heat, solar thermal heat
- Nominal operation temperatures 75°C heating-steam/hot water temperature, 26°C cooling water temperature
- Process cooling by seawater or alternatively by cooling tower, 50 kW @ 35/30°C
- Optionally and only if requested pre-treatment of raw water, simple stand alone operation without permanent technical supervision
- electrical power connection: app. 0.4 kWh per m³ and day, 230 V three phase

20 m³ per day	**MaxDest-AS-20**
50 m³ per day	**MaxDest-AS-50**
100 m³ per day	**MaxDest-AS-100**
250 m³ per day	**MaxDest-AS-250**
500 m³ per day	**MaxDest-AS-500**

Summary of Technical Data

	MaxDest-AS-20	MaxDest-AS-50	MaxDest-AS-100	MaxDest-AS-250	MaxDest-AS-500
Nominal water production capacity: drinking water from standard sea water @ 75°C heat supply temperature and 24 hours operation per day	20 m³/d	50 m³/d	100 m³/d	250 m³/d	500 m³/d
Thermal energy demand:	@ 75°C: 115 kWh/m³ (*GOR 6*)				
Cooling water flow: salt water *26°C/32°C , alternatively wet cooling tower possible (to be specified)*	35 m³/h	74 m³/h	145 m³/h	294 m³/h	580 m³/h
app. physical dimensions of the main module: Length x Width x Height (*mm*) (weight without aggregate- *kg*)	2000 x 570 x 2790 (2500 Kg)	2400 x 570 x 3160 (3640 kg)	2400 x 570 x 5750 (5285 kg)	2400 x 1140 x 5750 (8240 kg)	2400 x 1140 x 5750 (14150 kg)
Raw water demand / feed flow	4.9 m³/h	10.8 m³/h	17.6 m³/h	35.1 m³/h	69.8 m³/h
Maintenance: The system is designed to operate in stand alone mode on remote places. There is no daily supervision needed. The operation can be without chemical additives at lower input temperatures, reducing the daily distillate production, thus no chemicals need to be refilled					