Prospect on Desalination by Nuclear Energy in Indonesia

Geni Rina Sunaryo and Puradwi Ismu Wahyono

National Nuclear Energy Agency (BATAN), Indonesia
genirina@batan.go.id

Content

1. Introduction

- 5,120 km from east to west
- 1,760 km from north to south
- 18,000 islands, 6,000 are inhabited by 215 million people

Map of Indonesia

- About 60% of the inhabited regions receive plenty of annual precipitations in the range of 2,000 mm to 3,500 mm, whereas some areas see greater than 5,000 mm and some less than 1,000 mm.
- In reality, however, Indonesia is suffering from clean water shortages due to ever-increasing demand for water to support growing population, developing industry and agriculture

Water Inventory in Indonesia: Surface Water and Ground Water

Island(s)	Area	Population	Water Resource	Water Demand		Water Resource	
	Million-km^2	Million	(mill.m^3/yr.)	(mill.m^3/yr.)		(Thousand m^3/yr.)	
				2000	2015	Per-km^2	Per-capita
Java	0.133	113.6	187,000	83,378	164,672	1,406	1.6
Lesser Sunda	0.086	10.8	60,000	13,827	42,274	698	5.5
Celebes	0.187	13.5	247,000	25,555	77,305	1,321	18.3
Sumatra	0.471	40.1	738,000	25,298	49,583	1,567	18.4
Borneo	0.535	10.2	1,008,000	8,204	23,093	1,884	98.8
Mollucas+Papua	0.492	3.9	981,000	589	1,886	1,994	251.5
Indonesia	**1.905**	**192.2**	**3,221,000**	**156,850** →	**358,813**	**1,690**	**16.8**

1. MACHBUB, Pengelolaan Sumberdaya Air Berwawasan Lingkungan pada Pengembangan Wilayah
2. PANGESTI, Pengelolaan dan Pemanfaatan Sungai Menyongsong Abad 21 (2000)

- Indonesia initiated and carried out Nuclear Power Plant (NPP) programs in the early 1990s
- Suspended following the epidemic economic crisis in Asia in 1997.
- Building grass-root knowledge on NPP for future constructions by IAEA Extra Budgetary Programs.
- The Presidential Decree Number 5 (Year 2006) on National Energy Policy specified a target of achieving great than 5% energy mix from new and renewable energies by 2025 using biomass, nuclear, hydro, solar and wind.
- Indonesia is now planning to construct a nuclear power plant in Muria area (Ujung Lemah Abang, Ujung Watu and Ujung Grenggengan) by 2016.
- Other plans include the continuation of feasibility studies and evaluation of desalination plants for Muria.

2. Plan for Desalination in Indonesia

- There are 12,500 desalination plants in the world
- Half of which are located in the Middle East
- Total capacity is approaching 30 million m^3/day with the single largest unit producing 454,000 m^3/day

- Most of the desalination plants today use fossil fuels
- Type of desalination :
  - MSF - the most commonly adopted technology- 25 to 200 kWh/m^3
  - RO - 6 kWh/m^3
  - MED
  - VC
  - MSF- RO hybrid plants exploit the best features of each technology

2. Plan for Desalination in Indonesia (Cont'd)

- Single-effect desalination processes are suitable for remote and small population areas
- They are based on various types of Mechanical Vapour Compression (MVC) techniques
- Comprising mechanical compression
  - steam jet ejector
  - solute-water vapour absorption
  - solid-water vapour adsorption.
- The single effect MVC desalination process is most attractive
- The MVC system, driven by electric power, is compact and confined, and does not require external heating source.
- As such, it is suitable for remote population areas with access to power grid lines.
- Operating at low temperatures around 70°C
- Only limited literature studies on MVC modelling and analyses have been made.

3. Mechanical Vapour Compression Desalination

The MVC desalination process design is based on:

- material balance
- energy balance
- heat transfer for evaporator/condenser and preheater
- specific power consumption

The main parameters considered that affect the power consumption and unit cost of the product are:

- thermo physics
- Thermodynamics
- heat exchange process for the whole system.
- Operating temperatures
- salt concentration

3. Mechanical Vapour Compression Desalination (Cont'd)

5 main functional parts:

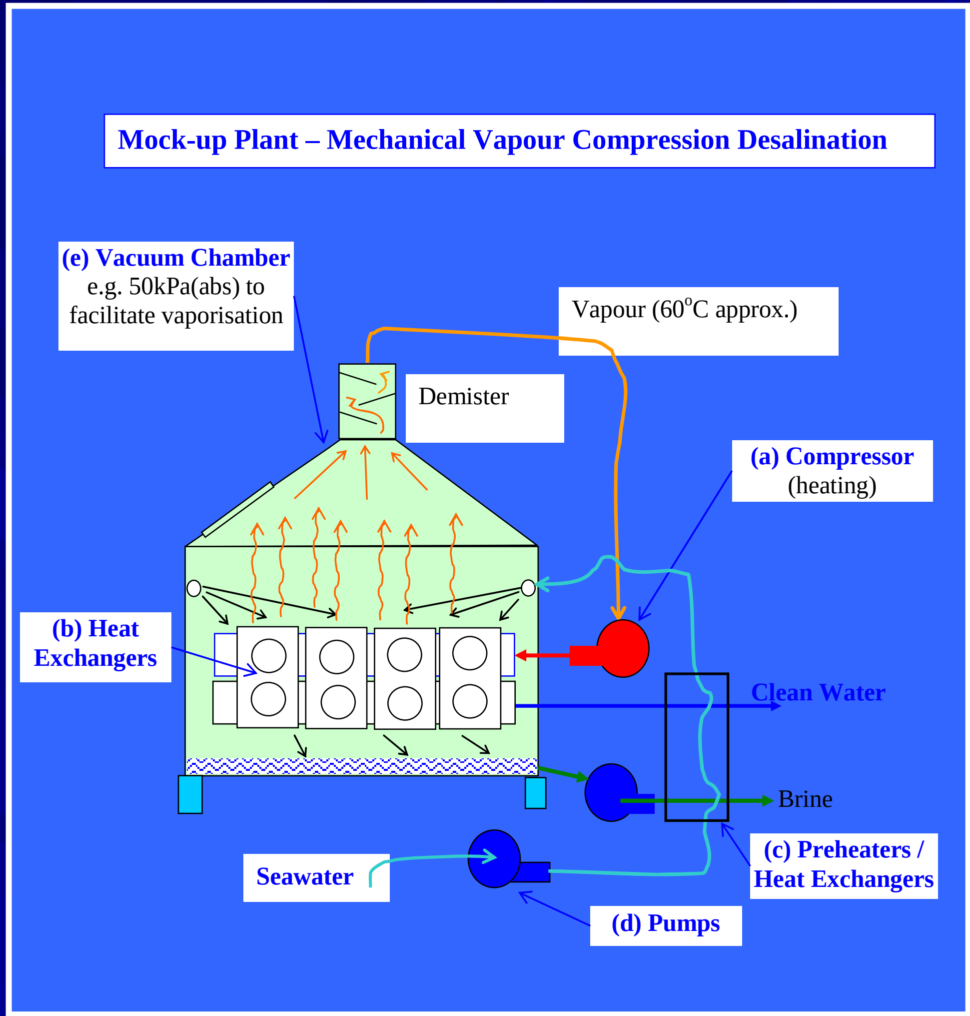
(a) Mechanical vapour compressor

(b) Evaporator/condenser heat exchangers

(c) Preheaters

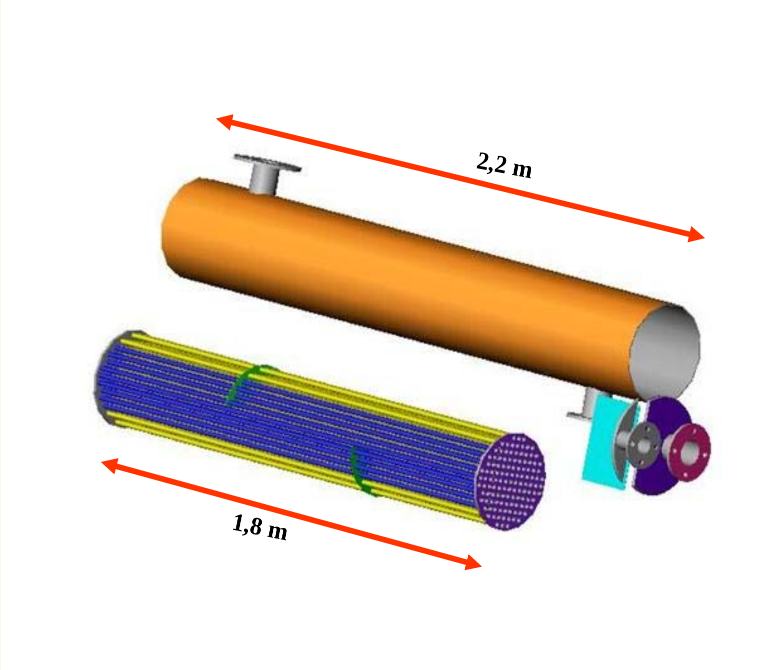
(d) Pumps

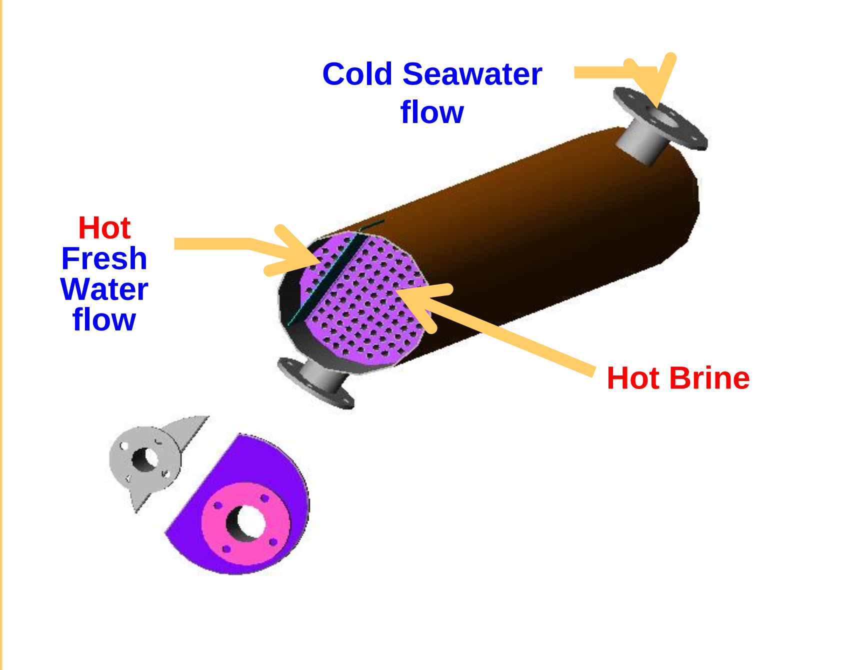
(e) Containment tank (vacuum chamber)



4. Design Description

4. 1. Preheater



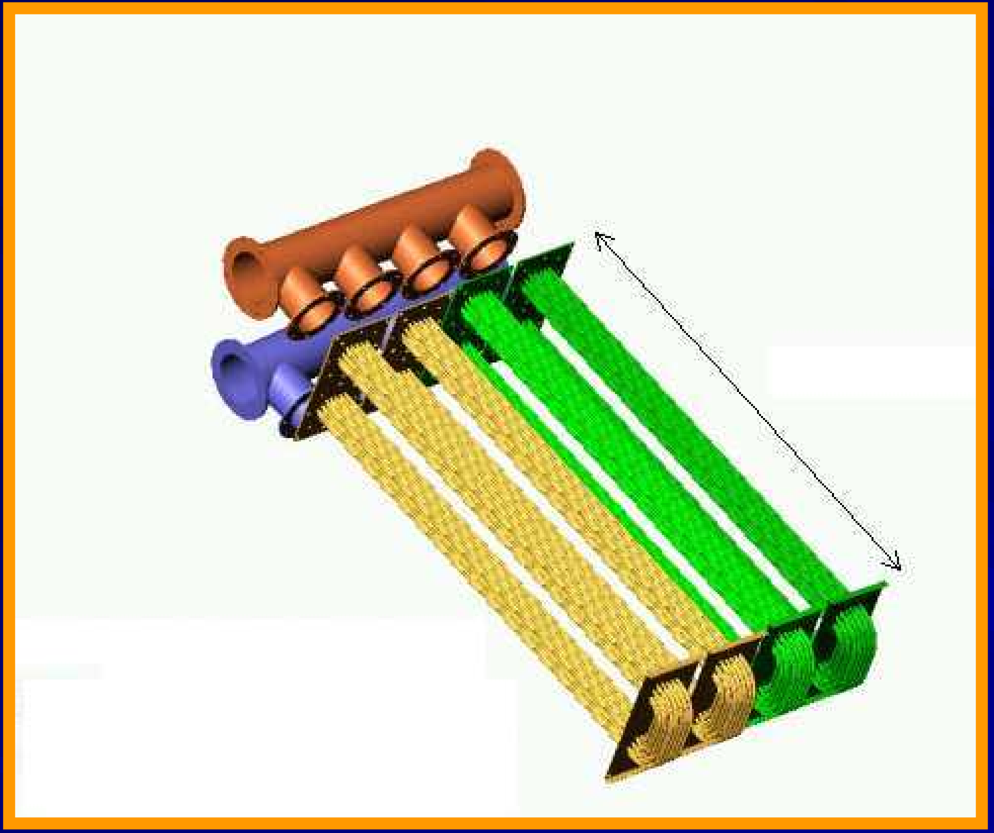


Heat exchanger has 2 separate chambers

- brine cooling (121 tubes x 1.8m long)
- fresh water cooling (19 tubes x 1.8m long)
- SS 304, 16mm od and 1.2mm thickness
- Tube bundles are cased by a SS pipe 324mm id and 4 mm d
- Ported with flange connections to flow working fluids

4. 1. Preheater (cont'd)

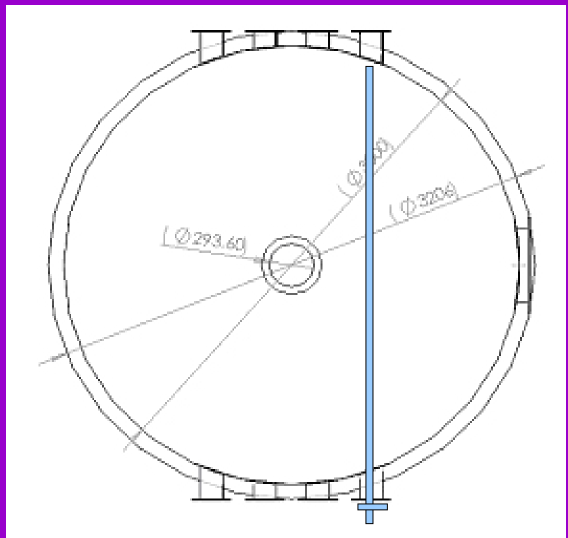
4.2. Heat Exchanger - Evaporator/Condenser



- surface area are 23.8 m^2
- 345 m of SS 304 tubes (16mm od, 1.2 mm d)
- Consists of 4 modules, each comprising 29 tubes with effective length of 1.7 m x 2 (2 passes)
- The modules are flange connected to the inlet and outlet headers
- This system allows future expansion if so desired.

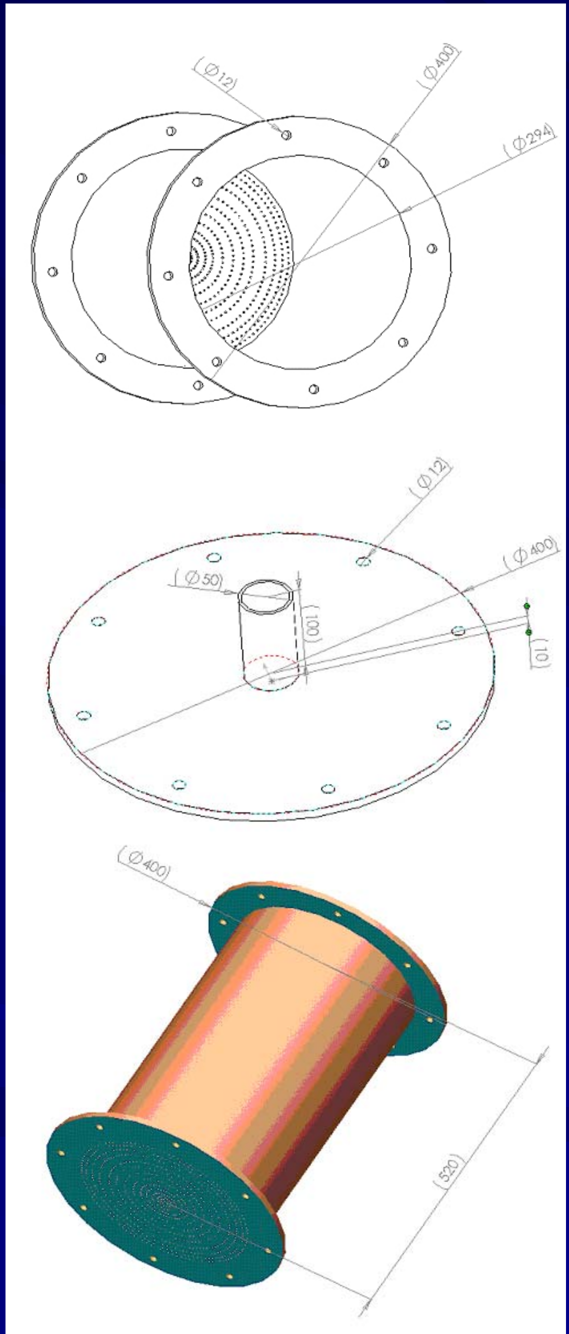
4.2. Heat Exchanger - Evaporator/Condenser (cont'd)

4.3. Sprayer



- Two stainless steel spray rails (ϕ25mm tube with series of holes along the 2.5 m length) are inserted into the containment tank.
- They are flange connected to the tank with a view to facilitating replacement with different rails to experiment various spray nozzle designs that would yield optimum atomisation and evaporation.

- The objective is to create thin film on the heat exchanger tube surfaces for maximum evaporation of pure water with minimum mix of mist (liquid).

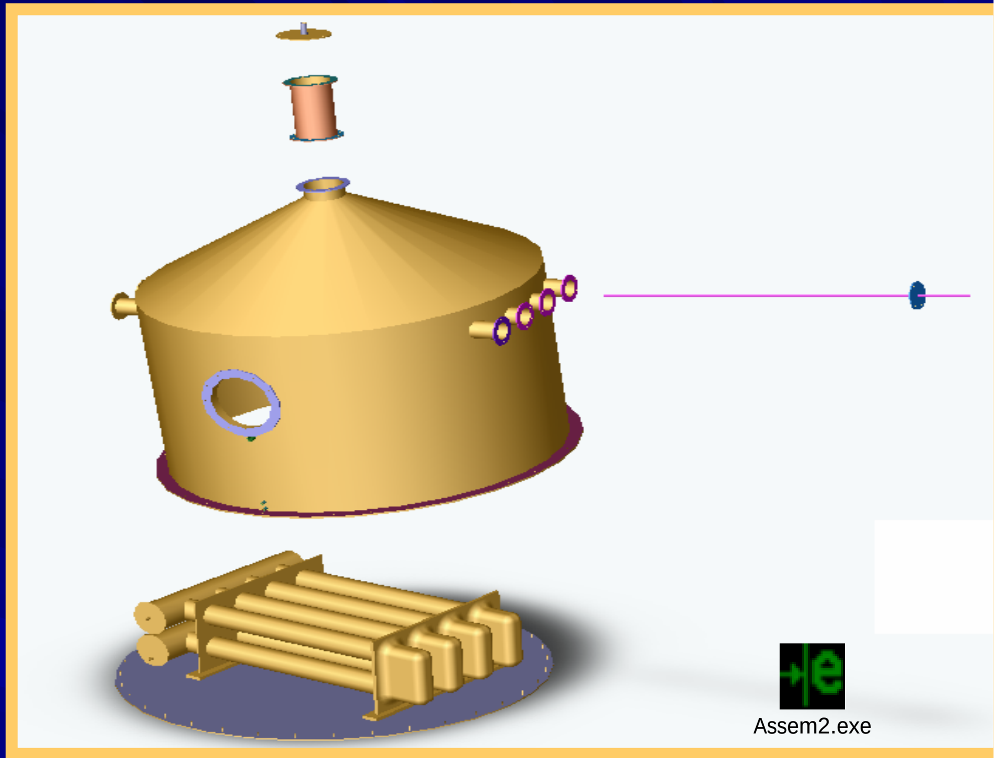


4.4. Demister

- The demister housing has been designed to facilitate experiments with various demister materials.
- It has a perforated metal base to contain demister material while allowing the vapour to pass through and coalescing mist/liquid to drain back into the tank.
- The assembly is made of SS ϕ300mm, 3mm thick shell and 500mm tall.
- The demister is flange connected to the containment tank to form a chimney.
- Its function is to segregate unwanted water mist from the vapour.
- Demister materials are yet to be determined after some trials.

4.5. Containment

- Partial vacuum.
- The conical roof of the tank is designed to facilitate vapour flows into the demister placed on top.
- Will be made of stainless steel (5 mm thick shell and 25mm thick flat base) to form 3.3m diameter and 2.5m tall containment.



- The heat exchangers are placed on the tank base. The tank shell is lifted in one piece, lowered onto the flanged base, and fastened (bolted and sealed) to contain the system. It has viewing ports, fluid inlet/outlet ports, vacuum/vent ports, and many service ports for insertion of various spray rails for experiment and other applications.

5. Results and Discussion

- A small scale MVC desalination plant has been designed to produce 0.5 m^3/day (~6 mL/s).
- Power consumption is estimated to be 322 kWh/m^3.
- The capacity of the main heat exchanger is found to be dominating the system performance and directly affects the product throughput.
- Effects of demister densities does not change flow pattens, power consumption increased from 300 to 500 kWh/m^3 as the demister density was changed from 200 to 930 kg/m^3.

6. Conclusion

- Following the completion of the concept design, the project has proceeded with prototype construction.
- The mock-up plant is currently under construction in parts.
- It is difficult to estimate completion dates due to limited project funds and resources.
- Nevertheless, research activities and procurement of system components continue whenever opportunities arise.
- Further studies and experiments will be carried out when the mock-up plant construction is completed.