How to define the Thermal Efficiency of Evaporators for Cruise Ships

This very short description shows – in a simplified manner and with typical data – how to specify the thermal efficiency of a fresh water generator in dependence of the design philosophy of a cruise ship.

The first step is the design of the engine power and the required fresh water production. According to the cruise profile, it has to be defined at which speed of the vessel the nominal required water production has to be maintained only by using the exhaust heat of the HT motor water (19 knots/hr in this example). The recoverable heat at this operating point defines the thermal efficiency of the evaporator (as kWh/kg of water produced).

Nominal Speed:	22 knots/hr
Power for Propulsion at nominal Speed:	40000 kW
Base Load Power Plant (zero speed):	5000 kW
Power Requirements at nominal speed:	45000 kW
100% Engine Load:	50000 kW
Engine Load at nominal Speed:	90 %
Number of Engines:	2 x 3
Water Production:	2 x 600 t/d
Critical Speed for 100% Water Production:	19,0 knots/hr = 30800 kW Power (incl. Base Load)

3 Engines are linked to one evaporator via a common cooling water circuit

Diagram 1 shows the approximate operating characteristics of the vessel as kw of electric power versus the speed, considering a base load of 5000 kW for the ship.

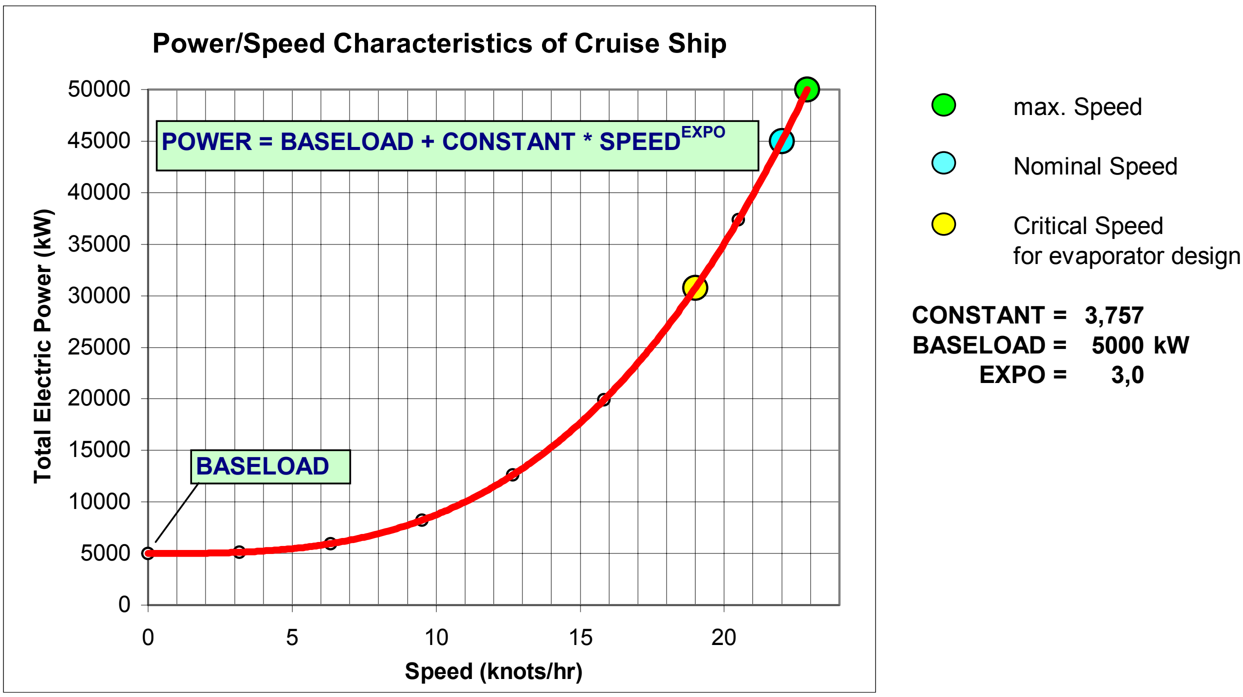


Diagram 1: Typical Speed / Power-Characteristics of a Cruise Ship

Diagram 2 shows the typical exhaust heat characteristics of a Diesel Engine, as the dimensionless relation between recoverable HT motor water heat and shaft power.

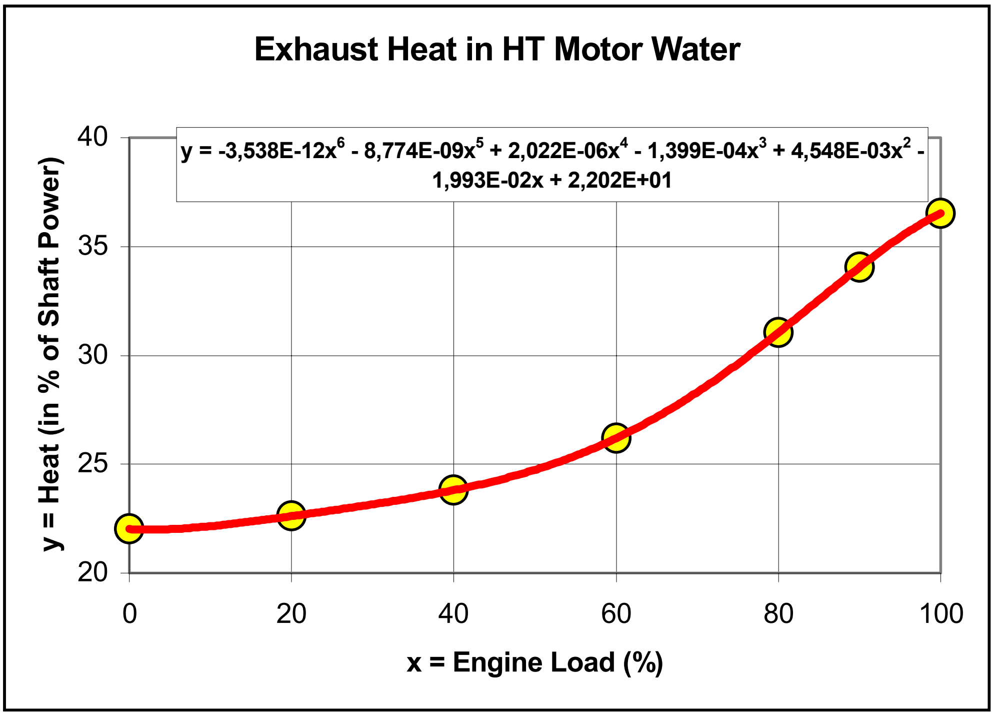
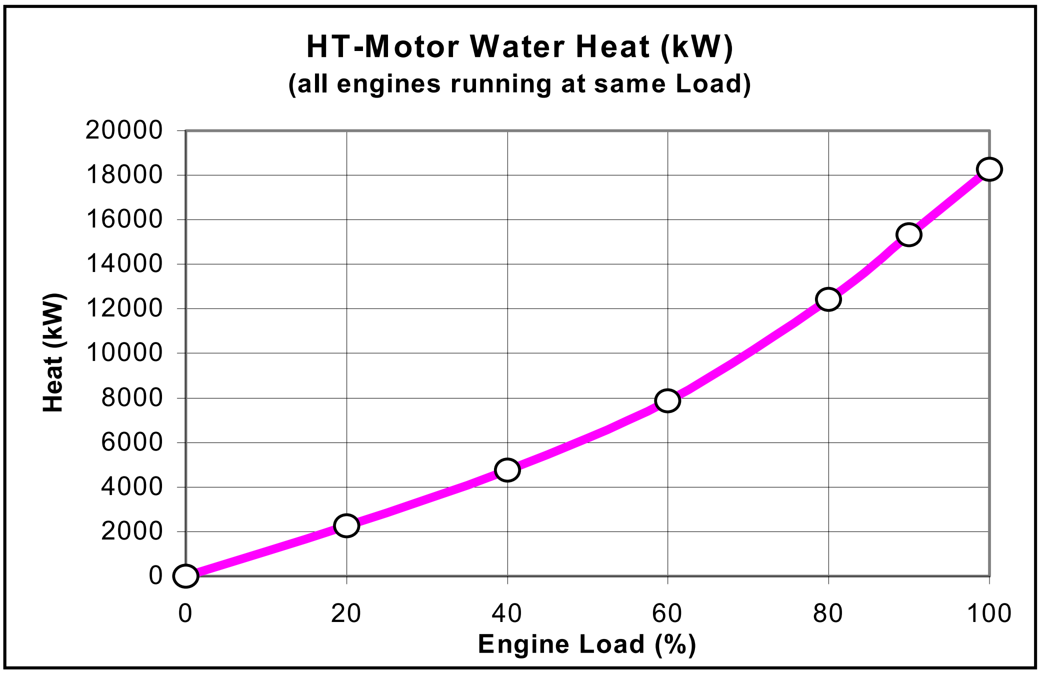


Diagram 2: Typical Exhaust Heat Charcteristics of Diesel Engine

After knowing the capacity of the installed engines, the diagram 3 can be provided, showing the heat as kW versus the load of the engines.



Diagrams 3: Exhaust Heat in HT Motor Water of selected Diesel Engines (typical)

The combination of diagram 1 and diagram 3 results in diagram 4, showing the exhaust heat versus the speed of the ship. The point marked in yellow colour is the critical design point of the evaporator.

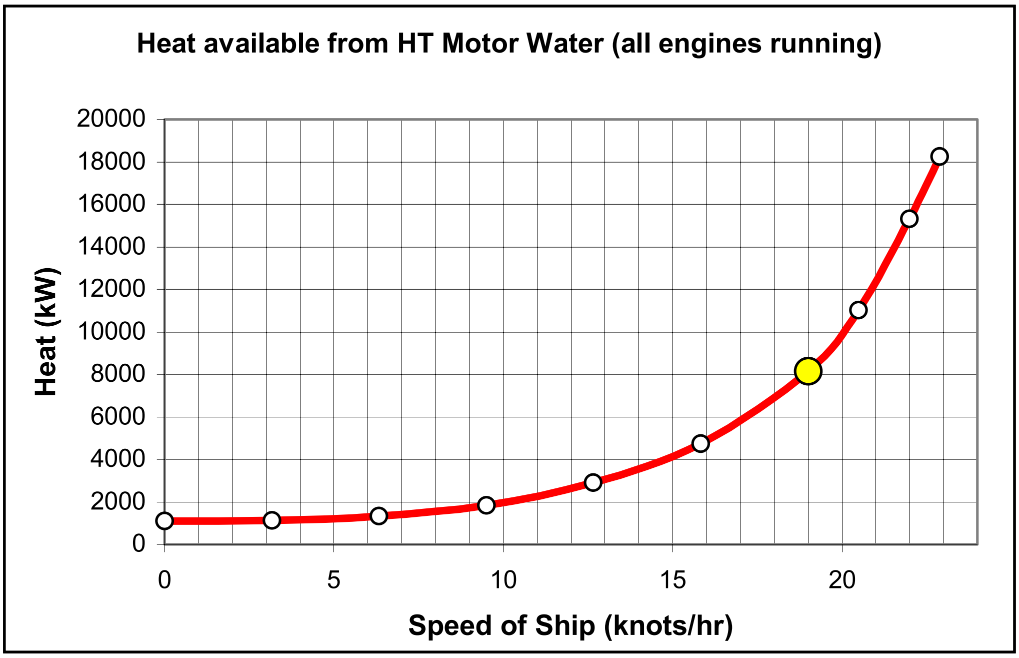


Diagram 4: Exhaust Heat in HT Motor Water versus Speed of Ship (typical)

Diagram 5 shows how 3 Diesel Engines can be combined with one evaporator via a common cooling water system. For calculation of the net utilisable motor water flow the motor water temperatures at engine outlet as well as behind engine cooler have to be considered.

The resulting design requirements for the Fresh Water Generators are as follows:

Q_{Design} = 8146 kW (from 2 x 3 engines) = 4073 kW per Engine Set

Water Production = 2 x 600 = 1200 t/d

Resulting Q_{SPEC} = 162.9 kWh/t

Motor Water Temperature: **T_{MOT} = 90 °C** (indivuídually controlled in each engine)

Motor Water return Temperature: $T_{MOT-RETURN}$ = 73 °C

Motor Water Flow at design point): **$FLOW_{MOT}$ = 206 t/h** (*) per engine set !

(*) to be calculated as follows ($FLOW_{MOT} = Q_{MOT} * 3.6 / 4.18 / (T_{MOT} – T_{MOT-RETURN})$)

Remarks:

It has to be noted that full heat utilisation is only maintained in case of the above given motor water return temperature of 73 °C is low enough for safe cooling of the engines. Some types of engines – especially such with low motor water flow rates through the engines – require lower inlet temperatures. In such cases additional cooling takes place in the engine cooler system, the utilisable motor water flow drops, and a certain portion of the available exhaust heat thus can not be recovered !

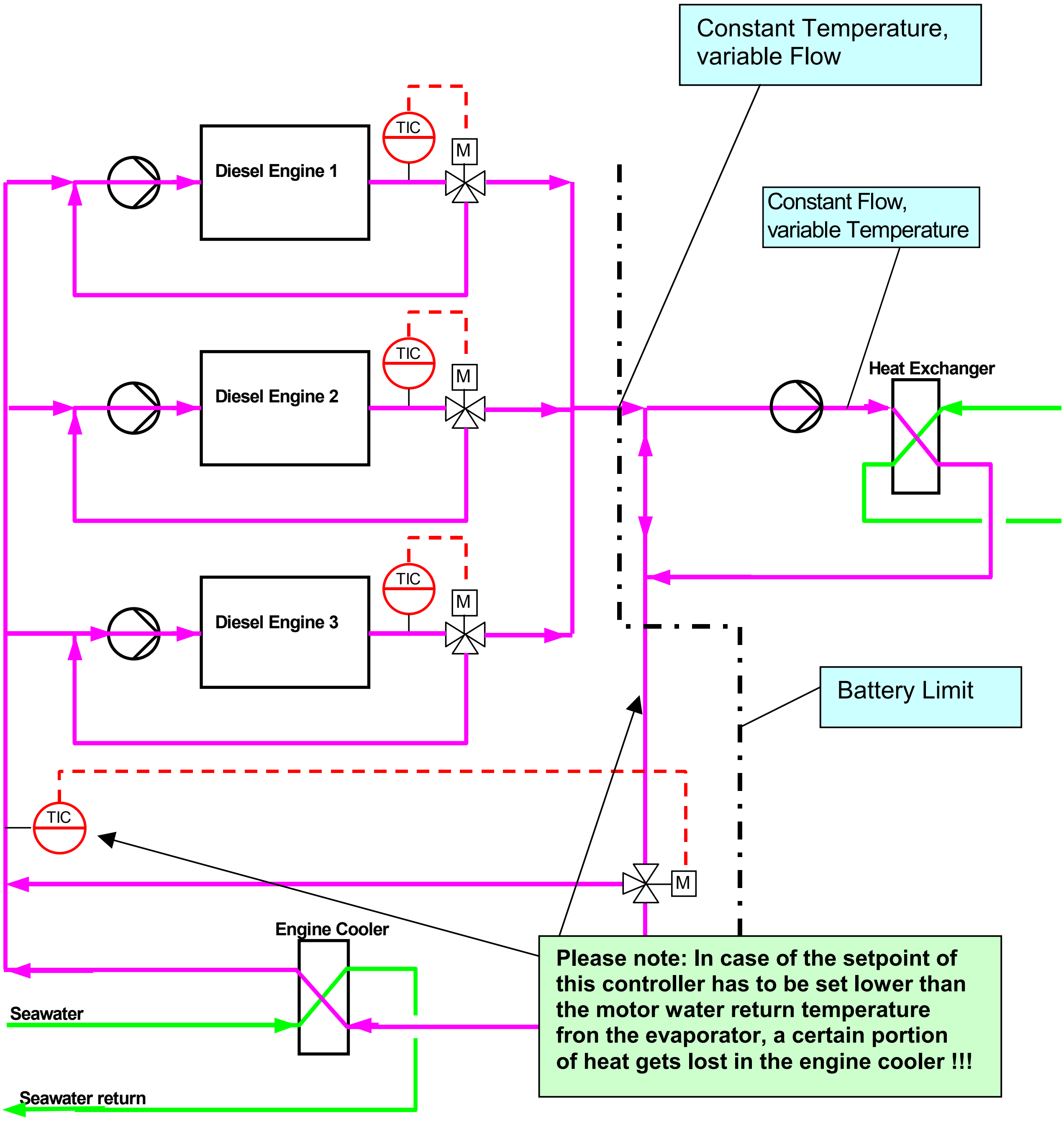


Diagram 5: **Control of Motor Water Temperatures (1 Engine set with 3 engines)**