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STORAGE CALORIFIER DESIGN FOR DOMESTIC WATER HEATING SYSTEM ONBOARD PKR SHIP

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APPROVAL SHEET

STORAGE CALORIFIER DESIGN FOR DOMESTIC WATER HEATING SYSTEM ONBOARD PKR SHIP

BACHELOR THESIS

Submitted to Comply One of the Requirements to Obtain a Bachelor of Engineering Degree
In
Double Degree of Marine Engineering (DDME) Program
Department of Marine Engineering-faculty of Marine Technology
Institut Teknologi Sepuluh Nopember (ITS)
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January, 2017
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I hereby who signed below declare that:

This final project has written and developed independently without any plagiarism act. All contents and ideas drawn directly from internal and external sources are indicated such as cited sources, literatures, and other professional sources.

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STORAGE CALORIFIER DESIGN FOR DOMESTIC WATER HEATING SYSTEM ONBOARD PKR SHIP

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ABSTRACT

Air pollution is the main cause of global warming effect that is a main issue nowadays in the modern era. Today almost all goods are transported via sea by using ships worldwide. Diesel engine is used mostly as their prime mover. Among all types of vehicles in the world, ship is the biggest producer of air pollution based on the quantity of fuel consumption. According to MARPOL 73/78 Annex VI, air pollution must be prevented either by utilizing exhaust gas from the engine.

Thermodynamically and mechanically, the maximum efficiency of diesel engine is around 60%. While the rest 40% remains as wasted heat, and approximately 25-30% of it is in the form of exhaust gas. There are possibilities to reuse this heat for certain system on the ship.

In this study, storage calorifier is studied as the part of wasted heat recovery system. The aim of this study is to design storage calorifier on board PKR (perusak kawal rudal) ship, and to conduct technical studies on the designed domestic system. The methodology that is used is thermodynamic calculation based design and software based design using HTRI Software. The results will be compared to determine the performance of the system and then used to acquire the economic analysis from saving fuel oil of auxiliary engine. One of the final results is
comparison between software based and calculation based design, with the obtained over design is 6.13 %. Heat Exchanger Research Inc. (HTRI) 6.0 the results obtained are not too much difference. From calculation based design, the obtained area is 640.076 ft$^2$ while the obtained area of software based design is 494,406 ft$^2$. For Overall Coefficient from manual calculation be obtained 6.5 btu/ft$^2$.h.F and from HTRI software is 6.96 btu/ft$^2$.h.F. For over design from calculation manual and htri software is 6.13 %. The economic analysis results that is after using the storage calorifier, fuel consumption of auxiliary engine at 50%MCR can save 139659 liter/years.

**Keywords** – Air pollution, Waste Heat Recovery, Storage Calorifier, Calculation based design, software based design, Economic Analysis.
ABSTRAK


Secara termodinamik dan mekanik, efisiensi maksimum dari mesin disel adalah sekitar 60%. Sementara 40% sisanya sebagai panas buang dan diperkirakan 25-30% nya berupa gas buang. Banyak kemungkinan untuk menggunakan kembali panas buang ini untuk sistem tertentu di atas kapal.

Di tugas akhir ini, tangki calorifier dipelajari sebagai salah satu bagian dari sistem pemanfaatan panas buang. Tujuan dari tugas akhir ini adalah mendesain tangki calorifier diatas kapal PKR (perusak kawal rudal) dan analisa teknik desain sistem
pemanas air. Metode yang digunakan oleh penulis dalam tugas akhir ini adalah perhitungan desain secara manual dan desain menggunakan software HTRI kemudian dibandingkan untuk menentukan kinerja sistem dan untuk menganalisa segi ekonomi dari konsumsi bahan bakar dari auxilary. Dari hasil perbandingan perhitungan manual area perpindahan panas 640,076 ft2 sementara area perpindahan panas dari software HTRI adalah 494,406 ft2. Untuk koefisien perpindahan panas keseluruhan dari perhitungan manual diperoleh 6,5 btu / ft2.h.F dan dari software HTRI adalah 6,96 btu / ft2.h.F serta kelebigan desain 6,13%. Berdasarkan analisa ekonomi setelah menggunakan tangki calorifier fuel oil consumption dari auxilary pada 50%MCR dapat disimpan sebanyak 139659 liter/tahun.

Kata Kunci – Polusi Udara, Pemanfaatan Gas Buang, Tangki Calorifier, Perhitungan Desain, software HTRI, Analisa Ekonomi.
PREFACE

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# TABLE OF CONTENTS

- APPROVAL SHEET .......................................................................................... i
- DECLARATION OF HONOUR ....................................................................... vi
- ABSTRACT ....................................................................................................... ix
- ABSTRAK ......................................................................................................... xi
- PREFACE .......................................................................................................... xiii
- TABLE OF CONTENTS ................................................................................. xv
- TABLE OF FIGURE ......................................................................................... xix
- LIST OF TABLE .............................................................................................. xxi
- CHAPTER 1 ...................................................................................................... 1
  1.1 Background ............................................................................................... 1
  1.2 Statement Of Problems ............................................................................ 1
  1.3 Research Limitation .................................................................................. 2
  1.4 Research Objectives ................................................................................ 2
  1.5 Research Benefits .................................................................................... 2
- LITERATURE REVIEW ................................................................................... 5
  2.1 Overview .................................................................................................... 5
  2.2 Waste Heat Recovery System (WHRS) .................................................. 6
  2.3 Storage Calorifier .................................................................................... 7
  2.4 *Perusak Kawal Rudal (PKR) SHIP* ...................................................... 9
  2.5 Htri Software .......................................................................................... 10
  2.6 Paper Review ........................................................................................... 11
  2.7 Estimating The Engine %MCR Based On RPM ................................. 12
2.8  Find Out The Kw At Certain Rpm Or Certain Load .....13
2.9  Mass Flow Rate Of Exhaust Gas ..........................13
2.8.1 Mass Flow Rate Of Fuel ...............................13
2.8.2 Intake Air Mass Flow Rate .............................14
2.10 The Rules Of Hot Water Needs At Ship ..................14
2.11 The Calculation Rules From Hot Water Needs At Ship.15
2.12 Heat Balance ..............................................16
2.13 Heat Transfer ...............................................16
   2.12.1 LMTD ..................................................17
   2.12.2 Overall Heat Transfer Coefficient ( U ) ..............21
   2.12.3 Heat Transfer Area ..................................22
2.13 Calculation of Heat Exchanger Performance ............23
   2.13.1 Flow Area ............................................23
   2.13.2 Mass Velocity .........................................24
   2.13.3 Reynolds Number ....................................24
   2.13.4 Heat Transfer Factor ( jH ) ..........................25
   2.13.5 Heat Transfer Coefficien ...............................26
   2.13.6 Clean Overall Heat Transfer Coefficient Design .26
   Clean Overall Heat Transfer Coefficient Design (Uc) is the heat transfer coefficient when the heat exchanger is clean and yet there are deposits or dirt .............26
   2.13.7 Overall Heat Transfer Coefficient Design ..........26
   2.13.8 Dirt/Fouling Factor ....................................26
   2.13.9 Pressure Drop .........................................27
2.14 Back Pressure ..............................................28
2.15 Heat Insulation Material ........................................ 28
2.16 Pipe Insulation ...................................................... 29
2.17 Heat Loss .............................................................. 30

CHAPTER 3 ........................................................................ 34
METHODOLOGY .............................................................. 35
  3.1 Identification and Statement of Problems .................. 35
  3.2 Literature Review .................................................... 35
  3.3 Data Collection ......................................................... 35
  3.4 Study Empiris .......................................................... 36
  3.5 Design System .......................................................... 36
    3.5.1 Design System to HTRI ....................................... 36
    3.5.2 Calculation Design ............................................. 36
  3.6 Comparing ............................................................... 36
  3.7 Result and Discussion .............................................. 37
  3.8 Conclusions and Recommendations ....................... 37
  3.9 Flowchart of Research Method ................................. 38

CHAPTER 4 ........................................................................ 41
DATA ANALYSIS .............................................................. 41
  4.1 Ship Data ................................................................. 41
  4.2 Design Planning of the Storage Calorifier ................ 42
  4.3 Data Analysis ........................................................... 44
    4.3.1 Estimating The Auxiliary Engine %MCR Based on RPM ......................................................... 44
    4.3.2 Find Out the KW of Auxiliary Engine Certain RPM or Certain %MCR ........................................... 45

xvii
### TABLE OF FIGURE

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Characterized compounds of emissions from marine vessel engines</td>
<td>5</td>
</tr>
<tr>
<td>2.2</td>
<td>Heat balance diagram of the nominally rated 12K98ME/MC engine</td>
<td>7</td>
</tr>
<tr>
<td>2.3</td>
<td>Calorifier</td>
<td>8</td>
</tr>
<tr>
<td>2.4</td>
<td>PKR ship</td>
<td>9</td>
</tr>
<tr>
<td>2.5</td>
<td>CODOE system</td>
<td>10</td>
</tr>
<tr>
<td>2.6</td>
<td>HTRI Simulation</td>
<td>11</td>
</tr>
<tr>
<td>2.7</td>
<td>Parallel-Flow Heat Exchanger</td>
<td>18</td>
</tr>
<tr>
<td>2.8</td>
<td>Counter-flow heat exchangers</td>
<td>19</td>
</tr>
<tr>
<td>2.9</td>
<td>One-shell pass and 2,4,6,etc (any multiple of 2), tube passes</td>
<td>20</td>
</tr>
<tr>
<td>2.10</td>
<td>Two-shell passes and 4, 8, 12, etc. (any multiple of 4), tube passes</td>
<td>20</td>
</tr>
<tr>
<td>2.11</td>
<td>Single-pass cross-flow with both fluids <em>unmixed</em></td>
<td>21</td>
</tr>
<tr>
<td>2.12</td>
<td>Single-pass cross-flow with one fluid <em>mixed</em> and the other <em>unmixed</em></td>
<td>21</td>
</tr>
<tr>
<td>2.13</td>
<td>Graphic of Heat Transfer Factor (<em>jH</em>)</td>
<td>25</td>
</tr>
<tr>
<td>2.14</td>
<td>Cross Section of Insulated Pipe</td>
<td>29</td>
</tr>
<tr>
<td>4.1</td>
<td>Design Planning of the System Storage Calorifier</td>
<td>42</td>
</tr>
<tr>
<td>4.2</td>
<td>Design Storage Calorifier</td>
<td>43</td>
</tr>
<tr>
<td>4.3</td>
<td>The Tube Layout Planning</td>
<td>43</td>
</tr>
<tr>
<td>4.4</td>
<td>Baffle Cutting Planning</td>
<td>44</td>
</tr>
<tr>
<td>4.5</td>
<td>Schematic of Hot fluid and Cold Fluid</td>
<td>48</td>
</tr>
<tr>
<td>4.6</td>
<td>Input Summary HTRI 6.0</td>
<td>58</td>
</tr>
</tbody>
</table>
Figure 4. 7 Nozzle Location HTRI 6.0 ........................................59
Figure 4. 8 Tube Layout ..........................................................59
Figure 4. 9 Output Summary HTRI 6.0 .................................60
Figure 4. 10 Heat Exchanger Specification Result ..............60
Figure 4. 11 Operational of Exhaust System on a storage calorifier from starboard side .......................67
Figure 4. 12 Operational of Exhaust System on a storage calorifier from Port Side .................................68
Figure 4. 13 Operational of Exhaust System on a storage calorifier from top view .................................69
Figure 4. 14 Water operational on a storage calorifier system .................................................................70
Figure 4. 15 Grafic of %MCR vs SFOC .................................74
Figure 4. 16 Grafic of %MCR and FOC after-before adding the storage ......................................................77
LIST OF TABLE

Table 2.1 Material Insulation Low Temperature ............. 31
Table 2.2 Material Insulation Intermediate Temperature .. 32
Table 2.3 Material Insulation High Temperature .......... 33

Table 4.1 Specification of Tube ................................ 48
Table 4.2 Comparison Calculation Manual and Software 61
Table 4.3 Price of Storage Calorifier system Equipment .. 71
Table 4.4 Total Price of Storage Calorifier system
  Equipment........................................................................ 72
Table 4.5 Storage Calorifier System Equipment
  Maintenance & Installation............................................. 72
Table 4.6 SFOC of the auxiliary engine....................... 73
Table 4.7 Power, %MCR ,SFOC after adding the storage
  calorifier................................................................. 75
Table 4.8 Fuel oil consumption before storage added ..... 76
Table 4.9 Fuel oil consumption after storage added ....... 76
Table 4.10 Fuel oil saving after storage calorifier added .. 78
Table 4.11 Fuel Saving per year..................................... 79
Table 4.12 MDO Price every year ................................. 80
Table 4.13 Payback Period.............................................. 80

xxi
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CHAPTER 1
INTRODUCTION

1.1 Background
Air pollution is the main cause of global warming effect that is a main issue nowadays in the modern era. Today almost all goods are transported via sea by using ships worldwide. Diesel engine is used mostly as their prime mover. Among all types of vehicles in the world, ship is the biggest producer of air pollution based on the quantity of fuel consumption. According to MARPOL 73/78 Annex VI, air pollution must be prevented either by utilizing exhaust gas from the engine.

Thermodynamically and mechanically, the maximum efficiency of diesel engine is around 60%. While the rest 40% remains as wasted heat, and approximately 25-30% of it is in the form of exhaust gas. There are possibilities to reuse this heat for certain system on the ship.

From the planning that had been made, the writer could know Storage Calorifier technology which is normally applied to the building is suitable for domestic water heating system on the ship PKR or not, and could determine the performance of the system.

1.2 Statement Of Problems.
Based on the description above the statement problem of this thesis are:

a. How many the amount of required of exhaust gas for hot water in the domestic systems PKR ship?
b. How the comparison design calculation with software HTRI?
b. How is the back pressure of exhaust gas system due to the modification of exhaust gas system?
d. How the operational of domestic water heating system with storage calorifier?
f. How the system analysis in terms of economic?

1.3 Research Limitation
a. Design Storage Calorifier will be made only used for domestic systems only.
b. System design using existing domestic systems on PKR ship.
c. The analysis were performed on fresh water system (hot water) for bathing in PKR ship at a temperature of 38º C.

1.4 Research Objectives
1. Technical Analysis
   a. To know the amount of required exhaust gas for hot water in the domestic systems of PKR ship.
   b. To know the comparison design of manual calculation with software HTRI.
   c. To know the back pressure result from the modification of Auxilary Engine’s exhaust gas system.
   d. To know the operational of domestic water heating system with storage calorifier.
2. Economic Analysis
   a. To know the fuel oil saving after adding the storage calorifier system.

1.5 Research Benefits
a. Knowing whether the use of waste heat can be applied to the domestic systems on PKR ships or not.
b. Getting the appropriate design for design planning Storage Calorifier Storage Calorifier applied to the domestic systems on ships PKR.
c. Knowing the modified keyplan (PID including detail specification of all equipment), and modified E/R arrangement / layout.

d. Knowing performance and best design of Storage Calorifier Storage Calorifier that applied at domestic systems on PKR ships.

e. Knowing the economic analysis of Storage Calorifier using waste heat recovery system
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CHAPTER 2
LITERATURE REVIEW

2.1 Overview

There are many type of the Air pollutants, such as carbon monoxide (CO), sulfur dioxide (SO2), nitrogen oxides (NOx), volatile organic compounds (VOCs), ozone (O3), and reaction from this pollutant will be decomposition in long time. [1]

Maritime transport is the fifth largest contributor to air pollution and carbon emissions, and the growth rate of trade makes the problem even more pressing. Figure 2.1 show that the emissions from marine engines with per - cylinder displacement at or above 30 litres (also called Category 3 marine diesel engines) are considered to be significant contributors to air pollution [2].

![Characterized compounds of emissions from marine vessel engines](image)

Figure 2.1 Characterized compounds of emissions from marine vessel engines

NOx emission can be reduced by primary methods such as retard injection, fuel nozzle modification, change of compression...
ratio, water direct injection, water emulsification, exhaust gas recirculation (EGR), secondary method such as selective catalytic reduction (SCR) and waste heat recovery system.

Fuel reductions of between 4-11% are possible, depending on the selected (Waste Heat Recovery System) WHRS solution, main engine power level, electric need at sea, operational profile, etc. The larger the engine power, the greater the possible fuel saving. In addition to large fuel savings, a WHRS gives large CO2, NOx, SOx and particulate reductions to the benefit of the environment. [3]

2.2 Waste Heat Recovery System (WHRS)

Waste heat recovery systems recover the thermal energy from the exhaust gas. There are many source of exhaust gas at the ship such as main engine, auxiliary engine, boiler, and etc. Waste heat recovery system is one of the best energy saving methods to increase the efficiency of fuel use. The example when sailing, the diesel engine has an efficiency of about 48-51% and the remainder of the input energy is released to the atmosphere through exhaust gas and jacket water. [4]

In diesel engines, there are many heat source with significant potential to be tapped, can be seen in the figure 2.2 such as shaft power, lubricating oil, jacket water, Exhaust gas, Air Cooler, Heat radiation. [5] All Waste heat source potential to be reused to produce energy, for example, is used as a driver generator, producing electricity and for heating purposes.
Figure 2. Heat balance diagram of the nominally rated 12K98ME/MC engine of the standard engine version operating at ISO ambient reference conditions and at 100SMCR

The amount of waste heat available in the exhaust gas is determined by temperature and mass flow rate of the exhaust gases, according to the equation:

\[
Q = \dot{m} \times C_p \times \Delta T
\]  

Where:
- \( Q \) = Heat Loss [kJ/min]
- \( \dot{m} \) = Mass flow rate exhaust gas [kg/min]
- \( C_p \) = Specific heat of exhaust gas [kJ/kg K]
- \( \Delta T \) = Temperature difference [K]

2.3 Storage Calorifier

Calorifier is a unit of equipment to move heat from steam to water or hot water. This heat transfer process using a pipe fin or pipe / tubing are placed in a tank or tube.
There are many types of calorifier dependent from heat source from calorifier, such as electric, gas burn, steam. The working principle of electric water heater tank system is almost the same as the cooking water using electricity (electric thermos). The water is collected in an insulated tank equipped with air pipe coiled electrical heating element. [6] Heat transfer / heat that occurs will be absorbed by the water in the tank. In the tank there are three main elements, namely:

1. Heating element, is used to heat water
2. Thermostat, serves to maintain the condition of the water in the tank stays hot at a certain temperature
3. Magnesium anode, serves to neutralize the positive ions in water to help prevent rust on the elements in the tank.

Further specification of the existing system on PKR ship can be seen in enclosure C.

Figure 2. 3 Calorifier
2.4 Perusak Kawal Rudal (PKR) Ship

![PKR Ship Image](image)

Perusak Kawal Rudal (PKR) or guided-missile frigates designated for the Indonesian Navy (TNI AL). Primarily, the vessel will be operated for Anti-Air Warfare, Anti-Surface Warfare, and Anti-submarine Warfare. However, it is also compatible with Maritime Security, Search and Rescue, Patrol, and Humanitarian Support tasks. TNI-AL will be strongly empowered by this state-of-the-art maritime capacity.

PKR has a length of 105.11 metres, a beam of 14.2 metres and a displacement of 2,365 tons. The vessel features a fully air-conditioned accommodation for up to 122 persons. The frigate has a speed of 28 knots, and can sail up to 5,000nm at 14 knots. The endurance is at least 20 days at sea.

PKR ship is a SIGMA class frigate. This ship propulsion system is a hybrid CODOE (Combined Diesel or Diesel-Electric) system. The CODOE system is that uses 2 main diesel engines or 4 auxiliary diesel engines to propel the ship, like the figure 2.5 below. The propulsion system of the PKR vessel utilises a combined diesel or electric (CODOE) which consists of two 10,000kW maximum continuous rating (MCR) diesel engines, two 1,300kW electric motors, two double input gearboxes and two 3.65 metre controllable pitch propellers. The vessel is equipped with a sophisticated platform management system that enables
operating, control and monitoring of the ship’s auxiliary systems. The vessel will naturally be equipped with a complete, state-of-the-art sensor and weapon package to counter air, surface and subsurface threats. For self-defence, the vessel is also equipped with comprehensive electronic warfare systems.

![Figure 2. 5 CODOE system](image)

### 2.5 Htri Software

Research conducted by the design. This design in the form of calculating the dimensions of a heat exchanger shell and tube type using computerized analysis of Heat Transfer Research Inc. (HTRI) and the method analysis of manual calculation. Calculating the dimensions of a heat exchanger is intended to determine the quality of a heat exchanger is based on the overall heat transfer coefficient, fouling factors, and the pressure drops will occur. Heat exchanger designed is a heat exchanger type shell and tube 1 (one) pass shell and one (1) pass tube counter-flow with exhaust gas and cold fluid is water. The results of calculation of dimensional analysis showed that a heat exchanger designed already meet the minimum requirements of fouling factor has been
The quality of heat exchanger increases in proportion to the declining value of fouling factor, decreasing the value of the pressure drop and the magnitude of the dimensions of a heat exchanger. [7]

![Image](image_url)

Figure 2.6 HTRI Simulation

### 2.6 Paper Review

The wasted heat on a marine vessel is primarily the fuel energy which is lost to the environment from various ongoing processes during normal operations, e.g. thermodynamic heat transfer. For a diesel powered vessel, the diesel engine is the largest source of wasted heat [8].

---

The energy balance of a 2-stroke large marine diesel engine and shows that about 50% of the total fuel heat energy is rejected to the surroundings via different streams without doing any useful work [9].

The temperature range of exhaust gas varies for two-stroke and four-stroke engines, with the latter having higher exhaust temperatures. While the exhaust temperatures vary depending on load and ambient conditions, for nominal loads the range lies between 325–345 °C for two-stroke and 400–500 °C for fourstroke engines. Together with a high mass flow rate and a reasonably high temperature the exhaust gas offers itself as the best waste heat source, both in terms of quantity and quality. The utilization of exhaust gas energy depends on the lowest temperature to which it could be cooled in a heat exchanger [10].

A WHRS can be designed to operate either on a single or a combination of different heat sources.

2.7 Estimating The Engine %MCR Based On RPM

To estimate the RPM based on engine %MCR of main engine is using a formula:

\[
\frac{P_1}{P_2} = \frac{(n_1)^3}{(n_2)^3}
\]

\[
P_1 = \frac{(n_1)^3P_2}{(n_2)^3}
\]

As per equation 2.3, the RPM of main engine can be calculated based on how much the desired %MCR.

\[
n_1 = \left(\frac{P_1(n_2)^3}{P_2}\right)^{1/3}
\]

Where:
\[
n_1 = \text{Given RPM}
\]
\[
n_2 = \text{Max RPM (100% load)}
\]
\[ P_1 = (\% \text{MCR}) \text{ at } n_1 \]
\[ P_2 = (\% \text{MCR}) \text{ at } n_2 \text{ (100\% RPM)} \]

### 2.8 Find Out The Kw At Certain Rpm Or Certain Load

To find out the kw at certain rpm or certain \%MCR of main engine is using a formula:

\[ KW = \%\text{MCR} \times \text{Max. KW of M/E} \] ............................... (2.5)

Where:
- \( KW \) = Power of Main Engine (Kw)
- \( \%\text{MCR} \) = \%MCR of Main Engine
- \( \text{Max KW of M/E} \) = Maximum Power of Main Engine (Kw)

### 2.9 Mass Flow Rate Of Exhaust Gas

To find out the mass flow rate of exhaust gas is using a formula:

\[ m_E = m_f + m_a \] .................................................................................. (2.6)

Where:
- \( m_E \) = Mass Flow Rate of Exh Gas (kg/s)
- \( m_a \) = Mass Flow Rate of Air (kg/s)
- \( m_f \) = Mass Flow Rate of Fuel (kg/s)

### 2.8.1 Mass Flow Rate Of Fuel

To find out the mass flow rate of fuel is using a formula:

\[ \dot{m}_f = s.f.c \times \text{Power} \] ................................................................. (2.7)

Where:
- \( \dot{m}_f \) = Mass Flow Rate of Fuel (kg/s)
Specific Fuel Consumption (g/kwh)  
*power* = Power (Kw)

### 2.8.2 Intake Air Mass Flow Rate

To find out the Intake Air Mass Flow Rate is using a formula:

\[ m_a = \dot{\eta}_w \times \rho_a \times n \times V_s \]  

Where:
- \( \dot{m}_a \) = Mass Flow Rate of Air (kg/s)
- \( \eta_w \) = Efficiency
- \( \rho_a \) = Air density at atmospheric Condition (kg/m³)
- \( n \) = Engine Speed (RPM)
- \( V_s \) = Displaced Volume (m³)

### 2.10 The Rules Of Hot Water Needs At Ship

Based on MLC (Marine Labour Convention) at Regulation 3.1 about Accommodation and Recreational Facilities [11]:

1. **Point A3.1 number 11 D**
   “With the exception of passenger ships, each sleeping room shall be proved with a washbasin having hot and cold running fresh water, except where such a washbasin is situated in the private bathroom provided.”

2. **Point A3.1 number 11 F**
   “Hot and cold running fresh water shall be available in all wash places.”

3. **Point B3.1.9 Other Facilities**
   “Where separate facilities for engine department personnel to change their clothes are provided, they should be:
   a. Located outside the machinery space but with easy access to it; and
b. Fitted with individual clothes lockers as well as with
tubs or showers or both and washbasins having hot
and cold running fresh water.”

2.11 The Calculation Rules From Hot Water Needs At Ship

Based on Merchant Shipping Act Chapter 179 Section 100
about Crew Accommodation Requirements Part III Sanitary
Arrangement [12]:

6) Cold fresh water and hot fresh water or means of heating
water shall be available in all communal wash places.
(a) the crew shall be provided with
   (i) fresh water of capacity sufficient to provide at least
   72 litres per man per day and drinking water of
capacity sufficient to provide at least 18 litres per
man per day; or
   (ii) drinkable water of capacity sufficient to provide at
least 90 litres per man per day if the fresh water
provided under sub-paragraph (i) is also of drinkable
quality;
(b) the number of days shall be sufficient to cover the
longest voyage the ship is expected to undertake with a
maximum of 30 days;
(c) if a distilling or evaporating plant capable of producing
   (i) at least 144 litres of fresh water per man per day
   and at least 36 litres of drinking water per man
   per day; or
   (ii) at least 180 litres of drinkable water per man
   per day, is provided, the water capacity to be
   provided for the crew may be reduced to at least
   7 days" supply, or sufficient to cover the
   longest voyage the ship is expected to
   undertake, whichever is the less, subject to sub-
   paragraph (a).
For the temperature of hot water at the ship it is based on Merchant Shipping Notice MSN 1845 (M) Maritime Labour Convention 2006 – Crew Accommodation point 18 Sanitary Accommodation [11]:

18.7 The hot water must be at a constant temperature of at least 66°C and must be heated by thermostatically controlled calorifiers of adequate capacity or by some equally safe and efficient means.

18.8 Every shower must be provided with an anti-scalding mixing valve which must be set in such a way that the temperature of the shower water can be varied by the person using it to any temperature between the ambient temperature and a temperature of at least:
(i) in the case of a thermostatically controlled mixing valve, 38°C but not more than 43°C; or
(ii) in the case of any other mixing valve, 35°C but not more than 40°C.

2.12 Heat Balance

To find mass flow rate at Hot Water at storage calorifier we can use this formula from heat balance below:

\[ Q_{\text{Hot Water}} = Q_{\text{Warm Water}} \] ................................. (2.9)

\[ \dot{m}_H \times C_p \times \Delta T_H = \dot{m}_W \times C_p \times \Delta T_W \] ................................. (2.10)

\[ \dot{m}_H = \frac{\dot{m}_W \times \Delta T_W}{\Delta T_H} \] ................................. (2.11)

2.13 Heat Transfer

The log mean temperature difference (LMTD) method is easy to use in heat exchanger analysis when the inlet and the outlet
temperatures of the hot and cold fluids are known or can be
determined from an energy balance. Once $\Delta T_{lm}$, the mass flow
rates, and the overall heat transfer coefficient are available, the heat
transfer surface area of the heat exchanger can be determined from

$$\dot{Q} = UA_s \Delta T_{lm}$$

Where :

- $\dot{Q}$ = Heat released / received (W)
- $U$ = overall heat transfer coefficient (W / m²°C)
- $A_s$ = area of heat transfer in accordance with the definition of $U$
  (m²)
- $\Delta T_{lm}$ = average temperature difference that is appropriate for use
  in a heat exchanger (°C)

### 2.12.1 LMTD

Therefore, the LMTD method is very suitable for determining
the size of a heat exchanger to realize prescribed outlet temperatures
when the mass flow rates and the inlet and outlet temperatures of the
hot and cold fluids are specified. With the LMTD method, the task is
to select a heat exchanger that will meet the prescribed heat transfer
requirements. The procedure to be followed by the selection process
is:

1. Select the type of heat exchanger suitable for the application.
2. Determine any unknown inlet or outlet temperature and the
   heat transfer rate using an energy balance.
3. Calculate the log mean temperature difference $\Delta T_{lm}$ and the
   correction factor $F$, if necessary.
4. Obtain (select or calculate) the value of the overall heat
   transfer coefficient $U$.
5. Calculate the heat transfer surface area $A_s$. 
Before determining the heat surface area \( (A_s) \), the first determined value of LMTD. It is based on the difference in temperature of the fluid in and out from the heat.

\[
\Delta T_{Im} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)} \tag{2.13}
\]

Here \( \Delta T_1 \) and \( \Delta T_2 \) represent the temperature difference between the two fluids at the two ends (inlet and outlet) of the heat exchanger. It makes no difference which end of the heat exchanger is designated as the inlet or the outlet.

a. Parallel-flow heat exchangers

\[
\Delta T_1 = T_{h,in} - T_{c,in} \tag{2.14}
\]

\[
\Delta T_2 = T_{h, out} - T_{c, out} \tag{2.15}
\]

![Parallel-Flow Heat Exchanger](image)

Figure 2. 7 Parallel-Flow Heat Exchanger

b. Counter-flow heat exchangers

\[
\Delta T_1 = T_{h,in} - T_{c, out} \tag{2.16}
\]

\[
\Delta T_2 = T_{h, out} - T_{c, in} \tag{2.17}
\]
c. Multipass and Cross-Flow Heat Exchangers: Use of a Correction Factor

Similar relations are also developed for cross-flow and multipass shell-and-tube heat exchangers, but the resulting expressions are too complicated because of the complex flow conditions. In such cases, it is convenient to relate the equivalent temperature difference to the log mean temperature difference relation for the counter-flow case as.

\[ \Delta T_{lm} = F \Delta T_{lm,CF} \]  \hspace{1cm} (2.18)

Where:
F = Correction Factor
\[ \Delta T_{lm,CF} \] = The log mean temperature difference for the case of a counter-flow heat exchanger with the same inlet and outlet temperatures

\[ \Delta T_{lm,CF} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)} \]  \hspace{1cm} (2.19)

\[ \Delta T_1 = T_{h,\text{in}} - T_{c,\text{out}} \]  \hspace{1cm} (2.20)
\[ \Delta T_2 = T_{h,\text{out}} - T_{c,\text{in}} \] ................................. (2.21)

The determination of the heat transfer rate for cross-flow and multipass shell-and-tube heat exchangers using the correction factor. The correction factor is \( F = 1 \) for both of these limiting cases. Therefore, the correction factor for a condenser or boiler is \( F = 1 \), regardless of the configuration of the heat exchanger.

Figure 2. 9 One-shell pass and 2,4,6,etc (any multiple of 2), tube passes

Figure 2. 10 Two-shell passes and 4, 8, 12, etc. (any multiple of 4), tube passes
2.12.2 Overall Heat Transfer Coefficient (U)

Heat transfer in a heat exchanger usually involves convection in each fluid and conduction through the wall separating the two fluids. In the analysis of heat exchangers, it is convenient to work with an overall heat transfer coefficient U or a total thermal resistance R, expressed as

\[
\frac{1}{UA_s} = \frac{1}{UA_i} = \frac{1}{UA_o} = R = \frac{1}{h_iA_i} + R_{wall} + \frac{1}{h_oA_o} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (2.22)
\]
where the subscripts i and o stand for the inner and outer surfaces of the wall that separates the two fluids, respectively. When the wall thickness of the tube is small and the thermal conductivity of the tube material is high, the last relation simplifies to

\[
\frac{1}{U} \approx \frac{1}{h_i} + \frac{1}{h_o} \tag{2.23}
\]

where \( U \approx U_i \approx U_o \). The effects of fouling on both the inner and the outer surfaces of the tubes of a heat exchanger can be accounted for by

\[
\frac{1}{UA_s} = \frac{1}{U_i A_i} \frac{1}{U_o A_o} \tag{2.24}
\]

\[
\frac{1}{UA_s} = \frac{1}{h_i A_i} + \frac{R_{f,i}}{A_i} + \frac{\ln\left(\frac{D_o}{D_i}\right)}{2\pi k L} + \frac{R_{f,o}}{A_o} + \frac{1}{h_o A_o} \tag{2.25}
\]

where \( A_i = \pi D_i L \) and \( A_o = \pi D_o L \) are the areas of the inner and outer surfaces and \( R_{f,i} \) and \( R_{f,o} \) are the fouling factors at those surfaces.

### 2.12.3 Heat Transfer Area

To calculate the heat transfer area, can use the following formula:

\[
A = \frac{Q}{U \times LMTD \times F_T} \tag{2.26}
\]

\[
A = \frac{M_f \times C_f \times (T_1 - T_2)}{U \times LMTD \times F_T} \tag{2.27}
\]

Where:

- \( A \) = Heat Transfer Area (ft\(^2\))
- \( M_f \) = Mass Flow rate (lb/h)
- \( C_f \) = Coefficient of Flow rate (btu/lb.\(^\circ\)F)
- \( T_1 \) = Temperature Inlet (\(^\circ\)F)
\[ T_2 \] = Temperature Outlet (°F)
\[ U \] = Overall Heat Transfer Coefficient (btu/hr.ft\(^2\).°F)
LMTD = The log mean temperature (°F)
\[ F_T \] = Correction factor

### 2.13 Calculation of Heat Exchanger Performance

Calculation of heat exchanger performance by using the following formulas:

#### 2.13.1 Flow Area

Flow area of shell and tube area can be in the calculation using the following equation:

a. Shell Area

\[
A_s = \frac{D \times C' \times B}{144 \times P_t} \tag{2.28}
\]

b. Tube Area

\[
A_t = \frac{N_t \times A_t}{144 \times n} \tag{2.29}
\]

Where:

- \( A_s \) = Flow area of Shell (ft\(^2\))
- \( D \) = Inside diameter of Shell (in)
- \( C' \) = Distance between the tube (in)
- \( B \) = Distance between the baffle plate (in)
- \( P_t \) = Distance between the tube axis (in)
- \( A_t \) = Flow area of Tube (ft\(^2\))
- \( N_t \) = Amount of Tube
- \( A_t \) = Flow area per tube (in\(^2\))
- \( n \) = Pass Amount
2.13.2 Mass Velocity

Mass velocity of shell and tube can be in the calculation using the following equation:

a. Shell Side

\[
G_s = \frac{W_s}{A_s} \tag{2.30}
\]

b. Tube Side

\[
G_t = \frac{W_t}{A_t} \tag{2.31}
\]

Where:

- \( G_s \) = Mass velocity at shell side (lb/ft\(^2\).hr)
- \( W_s \) = Mass velocity of fluid at shell side (lb/hr)
- \( A_s \) = Flow area of Shell (ft\(^2\))
- \( G_t \) = Mass velocity at tube side (lb/ft\(^2\).hr)
- \( W_t \) = Mass velocity of fluid at tube side (lb/hr)
- \( A_t \) = Flow area of tube (ft\(^2\))

2.13.3 Reynolds Number

The value of the Reynolds number permits us to determine whether the flow is laminar or turbulent. We define the Reynolds number as follows.

a. Shell Side

\[
Re_s = \frac{D_e \times G_s}{\mu} \tag{2.32}
\]

b. Tube Side
\[ Re_t = \frac{D_e \times G_t}{\mu} \] \hspace{1cm} (2.32)

Where:
- \( Re_s \) = Reynolds number at shell side
- \( G_s \) = Mass velocity at shell side (lb/ft\(^2\).hr)
- \( D_e \) = Diamater equivalent (ft)
- \( \mu \) = Fluid flow viscosity (lb/ft.hr)
- \( Re_t \) = Reynolds number at tube side
- \( G_t \) = Mass velocity at tube side (lb/ft\(^2\).hr)
- \( D \) = Diamater equivalent (ft)

2.13.4 Heat Transfer Factor (\( jH \))

Heat transfer factor on the shell side and the tube can be obtained from the table by using the value of the Reynolds number at figure 2.13.

![Figure 2.13 Graphic of Heat Transfer Factor (\( jH \))](image)

Figure 2.13 Graphic of Heat Transfer Factor (\( jH \))
2.13.5 Heat Transfer Coeffisien

Heat transfer coefficient on the outside of the tube or the inside of the shell is determined by the formula:

\[
\frac{h_o}{\varphi_s} = jH \times \left( \frac{k}{D_e} \right) \times \left( \frac{c_p \times \mu}{k} \right)^{1/3}
\] .................................................................(2.33)

Where:
- \( h_o \) = Heat Transfer Coefficient at side shell (Btu/hr.ft².of)
- \( J_h \) = Heat Transfer Factor at side shell
- \( D_e \) = Diameter equivalent (ft)
- \( K \) = Fluid Conductivity inside the shell (Btu/hr.ft².of/ft)
- \( \mu \) = Fluid flow viscosity (lb/ft.hr)
- \( C_p \) = Spesifik heat fluid inside the shell

2.13.6 Clean Overall Heat Transfer Coefficient Design

Clean Overall Heat Transfer Coefficient Design (Uc) is the heat transfer coefficient when the heat exchanger is clean and yet there are deposits or dirt.

\[
U_c = \frac{h_{i_o} \times h_o}{h_{i_o} + h_o}
\] .................................................................(2.34)

2.13.7 Overall Heat Transfer Coefficient Design

Overall Heat Transfer Coefficient Design is the heat transfer coefficient of heat exchanger which has been operated and already there are deposits or dirt.

\[
U_d = \frac{Q_t}{A \times \Delta T_{LMTD}}
\] .................................................................(2.35)

2.13.8 Dirt/Fouling Factor

Dirt/Fouling Factor is the resistance of heat transfer due to sediment or dirt on the wall when the heat transfer.
2.13.9 Pressure Drop

The value of the pressure drop on the shell side is obtained by the formula:

\[ \Delta P_s = \frac{f \times (G_s)^2 \times D \times (N+1)}{(5.22 \times 10^{10}) \times D_e \times s \times \phi_s} \]  

Where:
- \( \Delta P_s \) = Pressure difference between the fluid entrance to the fluid pressure at the exit shell (psi)
- \( f \) = Friction factor (ft\(^2\)/in\(^2\))
- \( G_s \) = Mass velocity at shell side (lb/ft\(^2\).hr)
- \( D \) = Inside diameter of shell (ft)
- \( N \) = Amount of baffle
- \( D_e \) = Diameter equivalent of shell (ft)
- \( S \) = Specific gravity fluida inside of shell
- \( \phi_s \) = Ratio Viscosity inside of shell

The value of the pressure drop on the tube side is obtained by the formula:

\[ \Delta P_t = \frac{f \times (G_t)^2 \times L \times n}{(5.22 \times 10^{10}) \times D \times s \times \phi_s} \]  

Where:
- \( \Delta P_t \) = Pressure difference between the fluid entrance to the fluid pressure at the exit tube (psi)
- \( f \) = Friction factor (ft\(^2\)/in\(^2\))
- \( G_t \) = Mass velocity at tube side (lb/ft\(^2\).hr)
- \( L \) = the length of the tube (ft)
n = Amount of Pass  
D = Diameter inside of the tube  
$\varnothing_s$ = Ratio Viscosity inside of tube  

2.14 Back Pressure  
Back pressure is defined as the exhaust gas pressure that is produced by the engine to overcome the hydraulic resistance of the exhaust system in order to discharge the gases into the atmosphere. Increased back pressure may affect the performance of the turbocharger, causing changes in the air-to-fuel ratio which may be a source of emissions and engine performance problems. All engines have a maximum allowable engine back pressure specified by the engine manufacturer. To prevent the occurrence of back pressure, the calculation by using the following formula and back pressure is allowed does not exceed 10 kPa [13]:

$$P = \frac{L \times Q^2 \times 3.6 \times 10^6}{D^5} + P_s$$

Where:  
P = Back Pressure ( kPa )  
L = Total equivalent length of pipe ( m )  
Q = Exhaust gas flow ( m$^3$/min)  
D = Inside diameter of pipe (mm)  
P_s = Pressure drop of silencer/raincap (kPa)  
S = Density of gas ( kg/m$^3$ )

2.15 Heat Insulation Material  
Insulation can be defined as a material or combination of materials that will impede the flow of heat. Their insulation can provide several benefits, including saving energy by reducing heat loss, keeping the surface temperature, preventing the flow of steam and condensation on cold surfaces. Thermal insulation is divided into three temperature ranges:
a. Low Temperature Thermal Insulation
   • Cold Water (15°C until 0°C)
   • Refrigeration or glycol (0°C until 75°C)

b. Intermediate Temperature thermal Insulation
   • Hot and steam condensate (16°C until 100°C)
   • Steam (101°C until 315°C)

c. High Temperature Thermal Insulation
   • For turbine, exhaust, incinerators, and boiler (316°C until 815°C)

As for the primary insulation material used can be seen in Table 2.1 to 2.3. Materials commonly used as insulation on pipes is a fiber glass pipe insulation covering while the tank is a glass fiber blanket. Glass fiber is often used because it is not flammable, strong and waterproof.

2.16 Pipe Insulation

Basic installation of insulation on pipelines can be seen in Figure 2.14 Cross Section of Insulated Pipe. Heat transfer coefficient of the insulation of pipes can be found using equation (Z. K. Moray, D. D. Gvozdenac, Applied Industrial Energy and Environmental Management) [14]:

Figure 2. 14 Cross Section of Insulated Pipe
\[ U = \frac{1}{D_3 \cdot \ln \left( \frac{D_4}{D_2} \right) + \frac{1}{2 \cdot K_{\text{insulation}} + h_{\text{out}}}} \] ................................................................. (2.39)

Where:

- \( U \) = Heat transfer coefficient \( (\text{W/m}^2\text{K}) \)
- \( D_3 \) = Outside diameter of insulation \( (\text{mm}) \)
- \( D_2 \) = Outside diameter of pipe \( (\text{mm}) \)
- \( K_{\text{insulation}} \) = Thermal insulation conductivity \( (\text{W/mK}) \)
- \( h_{\text{out}} \) = Heat transfer coefficient of insulation \( (\text{W/m}^2\text{K}) \)

### 2.17 Heat Loss

To calculate the heat loss can use the following formula:

\[ \frac{Q}{L} = \pi \times D_3 \times U \times (T_{\text{in}} - T_{\text{out}}) \] ......................................................... (2.40)
### Table 2. Material Insulation Low Temperature

<table>
<thead>
<tr>
<th>Type</th>
<th>Form</th>
<th>Temp. Range</th>
<th>K-Factor* Metric/Imperial</th>
<th>Mean Temp. C (°F)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLASS CELLULAR</td>
<td>Pipe Covering Block</td>
<td>-268°C to 427°C</td>
<td>.048 (.33) @</td>
<td>4° (40°)</td>
<td>Good strength, water and vapour resistant, non-combustible, poor abrasion resistance.</td>
</tr>
<tr>
<td>GLASS FIBER</td>
<td>Pipe Covering Board</td>
<td>-455°C to (850°F)</td>
<td>.036 (.24) @</td>
<td>4° (40°)</td>
<td>Good workability, non-combustible, water absorbent. Readily available. Vapour retarder required. Low compressive strength.</td>
</tr>
<tr>
<td>ELASTOMERIC FOAM</td>
<td>Pipe Sheet Roll</td>
<td>-40°C to 104°C</td>
<td>.038 (.27) @</td>
<td>10° (50°)</td>
<td>Closed cell good workability, finish not required. Limited thickness to meet flame spread/smoke. Required UV protection.</td>
</tr>
<tr>
<td>POLYSTYRENE (Extruded)</td>
<td>Pipe Covering Board</td>
<td>-183°C to 74°C</td>
<td>.035 (.24) @</td>
<td>4° (40°)</td>
<td>Lightweight, good workability. Check manufacturers' data. Combustible. Some are treated for fire retardancy. All are closed cell except polystyrene expanded.</td>
</tr>
<tr>
<td>POLYSTYRENE (Expanded)</td>
<td>Pipe Covering Board</td>
<td>-40°C to 80°C</td>
<td>.036 (.25) @</td>
<td>4° (40°)</td>
<td>K-value may change as these materials age. Combustible. High flame spread and smoke.</td>
</tr>
<tr>
<td>POLYURETHANE</td>
<td>Pipe Covering Sheet</td>
<td>-40°C to 107°C</td>
<td>.025 (.18) @</td>
<td>4° (40°)</td>
<td>Lightweight, good workability. Check manufacturers’ data. Some are treated for fire retardancy. K Values may change with age.</td>
</tr>
<tr>
<td></td>
<td>Pipe Covering Sheet</td>
<td>-70°C to 100°C</td>
<td>.036 (.25) @</td>
<td>10° (50°)</td>
<td></td>
</tr>
<tr>
<td>POLYSOCYANURATE</td>
<td>Pipe Covering Sheet</td>
<td>-183°C to 140°C</td>
<td>.025 (.18) @</td>
<td>4° (40°)</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** Special attention must be given to installation and vapour seal.

*K-Factor Metric = W/m.K (Imperial = Btu.in./h.ft². °F*
Table 2. Material Insulation Intermediate Temperature

<table>
<thead>
<tr>
<th>Type</th>
<th>Form</th>
<th>Temp. Range</th>
<th>K-Factor* Metric/Imperial</th>
<th>Mean Temp. C (°F)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CALCIUM SILICATE</td>
<td>Pipe Covering Block</td>
<td>to 649°C (1200°F)</td>
<td>.065 (.45) @ .063 (.44) @</td>
<td>93° (200°)</td>
<td>High compression strength, good workability, water absorbent, non-combustible. High flexural strength. Resistant to abrasion. See manufacturers' data for shrinkage factors.</td>
</tr>
<tr>
<td></td>
<td>Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Segments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type I</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLASS CELLULAR</td>
<td>Pipe Covering Block</td>
<td>to 427°C (800°F)</td>
<td>.050 (.35) @ .063 (.44) @</td>
<td>24° (75°) @ 93° (200°)</td>
<td>Good strength, water and vapour resistant, non-combustible, poor abrasion resistance. Subject to thermal shock. For applications over 204°C (400°F) see manufacturers' specifications.</td>
</tr>
<tr>
<td></td>
<td>Blanket</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLASS FIBER</td>
<td>Pipe Covering Board</td>
<td>to 455°C (850°F)</td>
<td>.037 (.26) @ .033 (.23) @</td>
<td>24° (75°) @ 24° (75°)</td>
<td>Good workability, non-combustible, water absorbent. Low compression resistance.</td>
</tr>
<tr>
<td></td>
<td>Blanket</td>
<td>to 538°C (1000°F)</td>
<td></td>
<td></td>
<td>General purpose material, many facings available.</td>
</tr>
<tr>
<td>MINERAL FIBER</td>
<td>Pipe Covering Board</td>
<td>to 649°C (1200°F)</td>
<td>.037 (.26) @ .037 (.26) @</td>
<td>24° (75°) @ 24° (75°)</td>
<td>Good workability, non-combustible. Water absorbent. Low compression resistance.</td>
</tr>
<tr>
<td></td>
<td>Blanket</td>
<td>to 649°C (1200°F)</td>
<td>.048 (.33) @ .048 (.33) @</td>
<td>24° (75°) @ 24° (75°)</td>
<td>Good workability, non-combustible. Poor abrasion resistance. Special packaging required to protect materials. Corrosion inhibitor.</td>
</tr>
<tr>
<td>PERLITE (Expanded)</td>
<td>Pipe Covering Board</td>
<td>to 649°C (1200°F)</td>
<td>.076 (.53) @ .076 (.53) @</td>
<td>93° (200°)</td>
<td>Good workability, non-combustible. Poor abrasion resistance. Special packaging required to protect materials. Corrosion inhibitor.</td>
</tr>
<tr>
<td>ELASTOMERIC FOAM</td>
<td>Pipe Covering-I</td>
<td>-40°F to 105°C</td>
<td>.043 (.30) @ .043 (.30) @</td>
<td>24° (75°) @</td>
<td>Closed cell, finish not required, good workability. May require UV protection. Flame spread/smoke limited.</td>
</tr>
<tr>
<td></td>
<td>Sheet-II Roll</td>
<td>-40°F to 220°F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POLYSTYRENE (Extruded)</td>
<td>Pipe Covering Board</td>
<td>-183°C to 74°C</td>
<td>.037 (.26) @ .037 (.26) @</td>
<td>24° (75°) @</td>
<td>Lightweight, excellent workability, combustible although some are treated for fire retardancy. Check manufacturers' data sheets for properties. High flame spread/smoke. Check manufacturers' data sheets for values. K value may change as these materials age.</td>
</tr>
<tr>
<td></td>
<td>-29°C to 165°F</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POLYSTYRENE (Expanded)</td>
<td>Pipe Covering Board</td>
<td>-40°C to 80°C</td>
<td>.039 (.27) @ .039 (.27) @</td>
<td>24° (75°) @</td>
<td>Lightweight, excellent workability, combustible although some are treated for fire retardancy. Check manufacturers' data sheets for properties. High flame spread/smoke. Check manufacturers' data sheets for values. K value may change as these materials age.</td>
</tr>
<tr>
<td></td>
<td>-40°F to 175°F</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POLYURETHANE</td>
<td>Pipe Covering Board</td>
<td>-40°C to 105°C</td>
<td>.027 (.19) @ .027 (.19) @</td>
<td>24° (75°) @</td>
<td>Lightweight, good workability. Check manufacturers' data sheets. Some are treated for fire retardancy. K values may change with age.</td>
</tr>
<tr>
<td></td>
<td>-40°F to 225°F</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POLYETHYLENE</td>
<td>Pipe Covering</td>
<td>-70°C to 100°C</td>
<td>.037 (.26) @ .037 (.26) @</td>
<td>24° (75°) @</td>
<td>Lightweight, good workability. Check manufacturers' data sheets. Some are treated for fire retardancy. K values may change with age.</td>
</tr>
<tr>
<td></td>
<td>-94°F to 212°F</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POLYISOCYANURATE</td>
<td>Pipe Covering Board</td>
<td>-183°C to 149°C</td>
<td>.027 (.19) @ .027 (.19) @</td>
<td>24° (75°) @</td>
<td>Lightweight, good workability. Check manufacturers' data sheets. Some are treated for fire retardancy. K values may change with age.</td>
</tr>
<tr>
<td></td>
<td>-20°F to 300°F</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* K-Factor is a measure of thermal conductivity.
Table 2. 3 Material Insulation High Temperature

<table>
<thead>
<tr>
<th>Type</th>
<th>Form</th>
<th>Temp. Range</th>
<th>K-Factor* Metric/ Imperial</th>
<th>Mean Temp. C (F)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CALCIUM SILICATE</td>
<td>Pipe Covering Block</td>
<td>to 649°C (1200°F)</td>
<td>.087 (.60) @</td>
<td>260° (500°)</td>
<td>High compressive strength, good cutting characteristics, water absorbent, non-combustible. High flexural strength. Resistant to abrasion. See manufacturers' data for shrinkage factors.</td>
</tr>
<tr>
<td></td>
<td>Type I Block</td>
<td>to 871°C (1800°F)</td>
<td>.101 (.70) @</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type II Block</td>
<td>to 649°C (1200°F)</td>
<td>.087 (.60) @</td>
<td>260° (500°)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type II Block</td>
<td>to 871°C (1800°F)</td>
<td>.101 (.70) @</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLASS CELLULAR HIGH TEMP</td>
<td>Pipe Covering Block</td>
<td>to 427°C (800°F)</td>
<td>.103 (.72) @</td>
<td>260° (500°)</td>
<td>Good strength, water and vapour resistant, non-combustible, poor abrasion resistance. Subject to thermal shock. For application over 204°C (400°F), see manufacturers' specifications.</td>
</tr>
<tr>
<td></td>
<td>Type I Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type II Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLASS FIBER</td>
<td>Pipe Covering Board Blanket</td>
<td>to 455°C (850°F)</td>
<td>.083 (.58) @</td>
<td>260° (500°)</td>
<td>Good workability, water absorbent, non-combustible. Check manufacturers' data for specific properties. Low compression resistance.</td>
</tr>
<tr>
<td></td>
<td>to 538°C (1000°F)</td>
<td>.086 (.60) @</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>to 538°C (1000°F)</td>
<td>.086 (.60) @</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MINERAL FIBER</td>
<td>Pipe Covering Block</td>
<td>to 649°C (1200°F)</td>
<td>.072 (.50) @</td>
<td>260° (500°)</td>
<td>Good workability, non-combustible. Low compressive resistance. Water absorbent.</td>
</tr>
<tr>
<td></td>
<td>to 1035°C (1895°F)</td>
<td>.082 (.64) @</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>to 649°C (1200°F)</td>
<td>.101 (.70) @</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>to 1035°C (1895°F)</td>
<td>.101 (.70) @</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PERLITE (Expanded)</td>
<td>Pipe Covering Block</td>
<td>to 649°C (1200°F)</td>
<td>.106 (.74) @</td>
<td>260° (500°)</td>
<td>Good workability, non-combustible, friable. Check manufacturers' data for specific properties. Poor abrasion resistance. Special packaging required to protect material. Corrosion inhibitor.</td>
</tr>
<tr>
<td>CERAMIC FIBER (Refractory</td>
<td>Blanket</td>
<td>to 1260°C (2300°F)</td>
<td>.086 (.60) @</td>
<td>260° (500°)</td>
<td>Temperature range varies with manufacturer, style and type.</td>
</tr>
<tr>
<td>FIBER)</td>
<td>Board</td>
<td>to 1260°C (2300°F)</td>
<td>.080 (.56) @</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEMENTS</td>
<td>Hydraulic Setting Cement</td>
<td>38-649°C (100-1200°F)</td>
<td>.180 (1.05) @</td>
<td>250° (482°)</td>
<td>One coat application – insulating and finishing. Slow drying, rough texture – Pointing and insulating and filling. Used over basic insulation – Smooth finish usually 1/8” or 1/4” think application.</td>
</tr>
<tr>
<td></td>
<td>High Temperature Mineral Wool</td>
<td>38-870°C (100-1600°F)</td>
<td>.160 (1.12) @</td>
<td>250° (482°)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Finishing Cement (Mineral</td>
<td>38-880°C (100-1800°F)</td>
<td>.150 (1.26) @</td>
<td>250° (482°)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fiber or Vermiculite)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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CHAPTER 3
METHODOLOGY

The methodology used by author in this thesis is design calculation and design with HTRI Software then it will be compared to determine the performance of the system. When the author made this thesis, of course it require a process to be structured. It must exist, so that in the future the work will be more focused and easier. The phases are as follows and the flow chart diagram at figure 3.1 and be continued at figure 3.2:

3.1 Identification and Statement of Problems

Identifying the problems are occurred to determine what the problem formulation must be taken. Formulation of the problem is an early stage in the implementation of the thesis. This stage is a very important stage, because the problem in this stage must be solved and it will be used as ingredients for final work. Problem searching is done by digging information about problems that occur at this time. From this stage, the purpose for working in this thesis can be known. In this thesis, the problem to be addressed and solved is the use of technology Calorifier by utilizing the Exhaust gas.

3.2 Literature Review

After found the problem, the next step is to collect the literature that related to the final project as a reference in the work process. So that the final project does not have similarities with the previous studies.

3.3 Data Collection

At this stage there will be data collecting in the form of information about PKR vessel data that will be used for research
object, including general plan images, domestic system images also the number of crew.

3.4 Study Empiris
At this stage there are three main points, that are initial analysis, draft planning, and machining specifications selection that will be used. This initial analysis is used to analyse the waste heat recovery from the main engine exhaust gases. Furthermore, this draft plan is used to plan the system design that will be used, without ignore the safety aspects. Machining specifications must be determined in order to make it easier for the system calculation, system analysis and system design.

3.5 Design System
At this stage there will be system design that suitable for domestic applications in PKR ship using Gas Storage Calorifier Heater application. Where the system is designed according the reference to some certain aspects, such as technical, safety, reability and the convenience factor. Design system devided into two design , that is :

3.5.1 Design System to HTRI
At this stage, HTRI software will be used for design calorifier. This system modelling is made according the design system that has been made in the previous stage.

3.5.2 Calculation Design
At this stage, the system will be made by the calculation like heat transfer, flow rate, etc.

3.6 Comparing
At this stage the system that has been designed using HTRI and design by calculation will compared to know the performance of calorifier system.
3.7 Result and Discussion
At this stage the result of the comparison between designed using HTRI and design by calculation, we know how the performance calorifier with utilizing waste heat recovery system

3.8 Conclusions and Recommendations
The final step is to make the conclusion from the whole process that has been done before as well as provide answers to existing problems. The suggestions is given based on the results of the analysis which can become the base of the next research, either directly related to this research or on the data and methodology that will be referenced.
3.9 Flowchart of Research Method

```
Start

Identification and statement of Problems

Literatur Review

Data Collection

Study Empiris

Design Requirement

Design Calorifier

Design with HTRI

Calculation Design

A

B

Essay, paper, book artikel, internet about waste heat recovery system, Storage Calorifier, heat transfer, domestic system,

Preliminary Analysis

Draft Planning

Spesification Calorifier

Gas Storage Heater
```
Figure 3.2 Flowchart of Research Method (Continue)

A

Is it in accordance with design requirements?

B

COMPARING THE PERFORMANCE OF STORAGE CALORIFIER FROM CALCULATION DESIGN AND DESIGN BY HTRI SOFTWARE

RESULT AND DISCUSSION

CONCLUSION AND RECOMMENDATION

END

Figure 3.2 Flowchart of Research Method (Continue)
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CHAPTER 4
DATA ANALYSIS

4.1. Ship Data

The ship which is used for this bachelor thesis is PKR ship from PT.PAL. The ship particular of PKR Ship is described in the table below:

1. Dimension
   
<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOA</td>
<td>105.11 m</td>
</tr>
<tr>
<td>B</td>
<td>14.02 m</td>
</tr>
<tr>
<td>H</td>
<td>8.75 m</td>
</tr>
<tr>
<td>T</td>
<td>3.7 m</td>
</tr>
<tr>
<td>Displacement</td>
<td>2365 ton</td>
</tr>
</tbody>
</table>

2. Performance

<table>
<thead>
<tr>
<th>Performance</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (Main Engine)</td>
<td>28 knots</td>
</tr>
<tr>
<td>Speed (E-Propulsion)</td>
<td>15 knots</td>
</tr>
<tr>
<td>Range at 14 knots</td>
<td>&gt; 5000 NM</td>
</tr>
<tr>
<td>Endurance</td>
<td>&gt; 20 days</td>
</tr>
</tbody>
</table>

3. Propulsion system

<table>
<thead>
<tr>
<th>Propulsion system</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Combined Diesel or Electric (CODOE)</td>
</tr>
<tr>
<td>Diesel engine</td>
<td>2 x 10000 kW MCR diesel propulsion</td>
</tr>
<tr>
<td>Electric motor</td>
<td>2 x 1300 kW MCR electric propulsion</td>
</tr>
<tr>
<td>Gearbox</td>
<td>2 x double input / single output</td>
</tr>
<tr>
<td>Propeller</td>
<td>2 x CPP diameter 3.65 m</td>
</tr>
</tbody>
</table>

4. Auxiliary systems

<table>
<thead>
<tr>
<th>Auxiliary systems</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator</td>
<td>6 x 771 kWe (CAT C-32A)</td>
</tr>
<tr>
<td>Emergency gen. set</td>
<td>1 x 180 kWe</td>
</tr>
<tr>
<td>FW making capacity</td>
<td>2 x 14 m³/day (RO)</td>
</tr>
</tbody>
</table>
4.2 Design Planning of the Storage Calorifier

Before designing storage calculations, the design arrangement must be done. Design arrangement can make design calculation more easy and accurate. In figure 4.1 below is diagram system storage calorifier.

![Diagram System Storage Calorifier](image)

**Figure 4.1 Design Planning of the System Storage Calorifier**

In this design planning prefer using resource from Auxiliary Engine because if using main engine’s exhaust gas would be too much, while exhaust gas from auxiliary engine is enough to support the system. To minimize the back pressure potential, can using the whole auxiliary engine is the better option and according to general arrangement of PKR Ship the location of main engines is further to designed system location than the location of auxiliary engine (Diesel Generator room) at figure 4.13.

This PKR Ship operation schedule auxiliary engines are more often to use and main engine. The ship will operate about 200 days in port, while at sea propulsion use will be supported by main engine or auxiliary engine.
In Figure 4.2 is design storage calorifier from inside. This storage will use a tube side single-pass version for minimize the backpressure potential then the shell and tube exchanger types is Fixed-tube heat exchanger and typical TEMA (Turbular Exchanger Manufactures Association) is BEM for Provides maximum heat transfer area for a given shell and tube diameter, Provides for single tube passes to assure proper velocity, and then Less costly than removable bundle designs. In this design the exhaust through the tubes and the water will through the shell.
The design of the tube layout planning will use the triangular (30°) to find the amount of the tube, shown in the figure 4.3 above. The various types of baffles are shown in Figure 4.4. In case of cut-segmental baffle of 30%.

![Figure 4. 4 Baffle Cutting Planning](image)

### 4.3 Data Analysis

Because the data from the auxiliary engine test bed (can be seen in enclosure A) is incomplete, so to find the exhaust gas mass flow rate of the auxiliary engine can use the manual calculation below:

#### 4.3.1 Estimating The Auxiliary Engine %MCR Based on RPM

The calculation process to find out the RPM at the 50% MCR by using equation 2.4:

\[
P_2(100\%) = 771 \text{ KW} \\
n_2(100\%) = 1800 \text{ RPM} \\
n_1 = \left(\frac{P_1(n_2^3)}{P_2}\right)^{1/3} \\
= \left(\frac{50 \times (1800)^3}{100}\right)^{1/3}
\]
= 1269,9 RPM

4.3.2 Find Out the KW of Auxiliary Engine Certain RPM or Certain %MCR

To find out the kw at certain rpm or certain %MCR of main engine is using a equation 2.5 :

\[ kW = Load \times Maximum\ kW\ of\ Auxiliary\ engine \]
\[ = 50\% \times 771 \quad KW \]
\[ = 391 \quad KW \]

4.3.3 Calculation of Mass Flow Rate From Exhaust Gas Auxiliary Engine

To find out the mass flow rate of exhaust gas is using This equation :

a. Mass Flow Rate of Fuel

\[ \dot{m}_f = s.f.c \times \text{power} \]
\[ = 220,8 \times 391 \]
\[ = 81144 \quad \text{gr/h} \]
\[ = 22.54 \quad \text{gr/s} \]

b. Intake Air Mass Flow Rate

\[ \eta_v = \frac{\text{Volume of air}}{\text{Sweft volume}} \]
\[ \eta_v = \frac{\dot{m}_a}{\rho_a \times n \times V_s} \]
\[ \dot{m}_a = \eta_v \times \rho_a \times n \times V_s \]

Assumption: \[ V_s = 0.321 \quad m^3 \]
\[ \eta_v = 3 \]
\[ \rho_a = 1.167 \quad \text{kg/m}^3 \]
\( N = 1800 \text{ rev/min} \)

\( \dot{m}_a = \eta v \rho_a n V_s \)

\( \dot{m}_a = 3 \times 1,167 \times 1269.9 \times 0.032 \)

\( = 142,7140 \text{ kg/min} \)

\( = 2378,5671 \text{ gram/s} \)

c. Mass Flow Rate of Exhaust Gas

\( \dot{m}_E = \dot{m}_f + \dot{m}_a \)

\( = 22.54 + 2378.5671 \)

\( = 2401,107147 \text{ gram/s} \)

\( = 2,40110 \text{ kg/s} \)

\( = 19056,7264 \text{ Lb/h} \)

4.3.4 Calculation of The Fresh Water Amount

From Merchant Shipping Act Chapter 179, fresh water of capacity sufficient to provide at least 72 litres per man per day and drinking water of capacity sufficient to provide at least 18 litres per man per day; or. [15]

In this calculation author put the assumption 72 liter per man and there are 122 crew at PKR Ship and the amount of fresh water in one day:

The amount of fresh water = 122 X 72

\( = 8784 \text{ liter/days} \)

\( = 8,784 \text{ m}^3/\text{days} \)

4.3.5 Calculation of Warm Water Masses

After find the volume of fresh water for a day, and the next calculate mass of warm water at 38°C with this equation:
\[ m = V \times \rho \quad \rho \text{ (at temperature } 38 \, ^\circ\text{C) } = 992.99 \, \text{kg/m}^3 \]
\[ = 8.784 \times 992.99 \]
\[ = 8722.42416 \, \text{kg/hari} \]

4.3.6 Calculation of Warm Water Mass Flow Rate

From Merchant Shipping Notice MSN 1884 Marine Labour Convention 2006 - Crew Accommodation point 18 Sanitary Accommodation [12]:

Design Temperature System:
- Fresh Water Temperature = 25 \, ^\circ\text{C}
- Hot Water Temperature = 70 \, ^\circ\text{C}
- Warm Water Temperature = 38 \, ^\circ\text{C}

For calculation of warm water masses we can use equation 2.7:
\[ \dot{m}_H = \dot{m}_W \frac{\Delta T_W}{\Delta T_H} \]
\[ = 8722.424 \times \frac{38 - 25}{70 - 25} \]
\[ = 2519.811 \, \text{Kg/hari} \]
\[ = 0.029164 \, \text{kg/s} \]

4.3.7 Calculation of Calor Amount for the system

\[ Q_{\text{water}} = m \times c \times (T_2 - T_1) \]
\[ = 0.029164 \times 4200 \times (70 - 25) \]
\[ = 5512 \, \text{J/s} \]
\[ = 5.51208749 \, \text{KJ/s} \]
\[ = 5.51208749 \, \text{KW} \]

4.3.8 Design Storage Calculation

And for the specification from tube inside the storage in table 4.4 below:
Table 4.1 Specifications of Tube

<table>
<thead>
<tr>
<th>OD</th>
<th>1.5 in</th>
<th>=</th>
<th>0.125 ft</th>
<th>=</th>
<th>0.0381 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lt</td>
<td>59</td>
<td>in</td>
<td>6.5</td>
<td>ft</td>
<td>1.98 m</td>
</tr>
<tr>
<td>Di</td>
<td>0.834</td>
<td>in</td>
<td>0.0695</td>
<td>ft</td>
<td>0.021184 m</td>
</tr>
<tr>
<td>Pt</td>
<td>1.875</td>
<td>in</td>
<td>0.15625</td>
<td>ft</td>
<td>0.04765 m</td>
</tr>
</tbody>
</table>

Type: 1 ½” OD Tubes (12 BWG) on 1 7/8” Triangular Pitch

After designing the system, designing the storage, and specifying the tube, the performance from the storage will be calculated in the next step below.

1. **Overall Heat Transfer Coefficient:**

   \[
   h_1 = 800 \text{ W/m}^2\text{°C} \\
   h_0 = 1200 \text{ W/m}^2\text{°C} \\
   T_{h,in} = 487.4 \text{ °F} \\
   T_{h,out} = 230 \text{ °F} \\
   T_{c,in} = 77 \text{ °F} \\
   T_{c,out} = 158 \text{ °F}
   \]

Figure 4.5 Schematic of Hot fluid and Cold Fluid
\[ A_0 = \pi \times D_0 \times L \]
\[ = 0.23687532 \, m^2 \]

\[ A_i = \pi \times D_0 \times L \]
\[ = 0.13170267 \, m^2 \]

\[ h_{rad} = \varepsilon\sigma \left( T_{hout}^2 + T_{cout}^2 \right) \left( T_{hout} + T_{cout} \right) \]
\[ = 1 \times 5.57 \times 10^{-8} \times \left( 526,15^2 + 383,15^2 \right) \times (526,15 + 158) \]
\[ = 21,84162 \, \frac{W}{m^2 \cdot ^\circ C} \]

\[ R_{conv} = \frac{1}{h_i \times A_i} \]
\[ = \frac{1}{800 \times 0.13170} \]
\[ R_{conv} = 0.00949 \, ^\circ C/W \]

\[ R_{cond} = \frac{\ln D_0/D_i}{2\pi KL} \]
\[ = \frac{\ln 0.0381/0.02118}{2 \times \pi \times 15.1 \times 1.98} \]
\[ R_{cond} = 0.0003126 ^\circ C/W \]

\[ R_{conv} = \frac{1}{h_0 \times A_0} \]
\[ = \frac{1}{200 \times 0.236875} \]
\[ R_{conv} = 0.003518 ^\circ C/W \]
\[
R_{rad} = \frac{1}{h_{rad} \times A_0} \\
= \frac{1}{21.841 \times 0.2368} \\
R_{rad} = 0.193 \, ^\circ C/W
\]

\[
\frac{1}{R_{conv} + h_{rad}} = \frac{1}{R_{conv}} + \frac{1}{R_{rad}} \\
= \frac{1}{0.00351} + \frac{1}{0.193} \\
= 284.250 + 5.173 \\
\frac{1}{R_{conv} + h_{rad}} = 289.424 \, W/^\circ C
\]

\[
R_{conv + rad} = 0.00345 \, ^\circ C/W
\]

\[
R_{total} = R_{conv} + R_{cond} + R_{conv + rad} \\
R_{total} = 0.0160 \, ^\circ C/W
\]

\[
U = \frac{1}{R_{tot} + A_{tot}} \\
= 37 \frac{W}{m^2 \cdot ^\circ C}
\]

\[
U = 6.5 \frac{Btu}{hr \cdot ft^2 \cdot ^\circ F}
\]
2. **Log Mean Temperature Difference (LMTD)**

Because the principle of storage calorifier same with the heat exchanger in this calculation, using the analysis of heat exchanger. In the analysis of heat exchangers, it is usually convenient to work with the logarithmic mean temperature difference LMTD, which is an equivalent mean temperature difference between the two fluids for the entire heat exchanger.

\[
\text{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}}
\]

\[
\Delta T_1 = 487.4 - 77
= 410.4 \degree \text{F}
\]

\[
\Delta T_2 = 230 - 158
= 72 \degree \text{F}
\]

\[
\text{LMTD} = \frac{410.4 - 72}{\ln \frac{410.4}{72}}
\]

\[
= 235.798 \degree \text{F}
\]

3. **Heat Transfer Area**

\[
A = \frac{Q}{U \times \text{LMTD} \times F_T}
\]

\[
= \frac{M_f \times C_f (T_1 - T_2)}{U \times \text{LMTD} \times F_T}
\]

\[
= \frac{19056.7 \times 0.2472 (410.4 - 72)}{6.5 \times 235.789 \times 1}
\]
\[ = 640.076 \text{ ft}^2 \]

### 4. The Amount of Tube

\[
nt = \frac{A}{\pi \times D \times L} = 246
\]

### 5. Flow Area Shell

\[
a_s = \frac{D_s \times C'' \times B}{144 \times P_T}\text{ eq. 7.1, kern} \]

Assumptions:
1. 30% cut segmental baffles
2. Baffle Spacing (B) \( = 0.5 \times D_S \)
   \[ = 0.5 \times 35 \]
   \[ = 17.5 \text{ inc} \]
   \[ = 1.45 \text{ ft} \]
3. Diameter inside shell (Ds) \( = 35 \text{ inc} \)
   \[ = 2.91667 \text{ ft} \]
4. Tube Pitch (P_T) \( = 1.875 \text{ inc} \)
   \[ = 0.15625 \text{ ft} \]
5. Clearance (C'') \( = P_T - \text{OD} \)
   \[ = 0.375 \text{ inc} \]
   \[ = 0.03125 \text{ ft} \]
6. Diameter Outside = 1.5 inc
    = 0.125 ft

\[ a_s = \frac{35 \times 0.375 \times 17.5}{144 \times 1.875} = 0.850694 \text{ in}^2 = 0.005907 \text{ ft}^2 \]

6. Mass Velocity at Shell

\[ G_s = \frac{mf}{a_s} \]
\[ = \frac{4409.24}{0.005907} \]
\[ = 746367.39 \text{ lbm/hr.ft}^2 \]

7. Reynolds Number of Shell

\[ T_c = 77 \text{ °F} \]
\[ \mu = 2.162628 \text{ lbm/ft.hr} \]
De = Diameter for the shell side

\[ \frac{4 (P_r^2 - \frac{\pi}{4} d_o^2)}{\frac{1}{2} \pi d_o} = 0.247611 \]

\[ \text{Re} = \frac{\text{De} \times G_s}{\mu} \]
\[ = 85455.80799 \]
8. Corrected Coeffisien of Shell

The value of Thermal conductivity (K) and Spesific Heat (Cₚ) and Heat Tranfer Factor (Jₜₜ) gets from kern chat at temperature 77 °F.

K = 0.072 btu/hr.ft.F (Fig. 1 Kern, 1965)
Cₚ = 0.67 btu/lbm.F (Fig 2 Kern, 1965)

\[ j_H = \frac{h_o D_e}{k_g} \left( \frac{\mu_g C_g}{k_g} \right)^{-1/3} \left( \frac{\mu}{\mu_w} \right)^{-0.14} \]

\[
190 = \frac{h_o (0.247611)}{0.072} \left( \frac{2.16263 \times 0.67}{0.072} \right)^{-1/3} \left( \frac{\mu}{\mu_w} \right)^{-0.14}
\]

\[ h_o = 3336.58 \text{ btu/hr.ft}^2.\text{F} \]

9. Flow AreaTube

at ' = 1.40 in² (table 10, kern)

at " = \frac{Nt \times at'}{144 \times n} = \frac{246 \times 1.4}{144 \times 1} = 2.39167 \text{ in}^2

= 0.0166088 \text{ ft}^2

10. Mass Velocity at Tube

\[ G_t = \frac{w}{\text{at}} \]
\[
\frac{19056.72648}{0.011875} = 147387.3 \text{ n/hr.ft}^2
\]

11. Reynold Number of Tube

\[
tc = 487.4 \text{ oF}
\]
\[
\mu = 0.7413 \text{ lbm/ft.jam}
\]
\[
\text{Re} = \frac{\text{ID x Gt}}{\mu} = 165099.1239
\]

12. Corrected Coeffisien of Tube

The value of Thermal conductivity (K) and Specific Heat (C_p) and Heat Transfer Factor (J_h) gets from kern chat at temperature 483 oF.

From Kern's Grafik fig.24 get the value \( J_h = 300 \)
\[
k = 0.0274 \text{ btu/jam.ft}^2\text{F}
\]
\[
C_p = 0.252 \text{ btu/lbm.F}
\]
\[
J_h = \frac{h_i ID}{k_g} \left( \frac{\mu_g C_g}{k_g} \right)^{-1/3} \left( \frac{\mu}{\mu_w} \right)^{-0.14} \frac{\mu}{\mu_w} = 1
\]
\[
360 = \frac{h_o (0.0695)}{0.0274} \left( \frac{0.7413 \times 0.252}{0.0274} \right)^{-1/3} \left( \frac{\mu}{\mu_w} \right)^{-0.14}
\]
\[
h_l = 269.122 \text{ btu/hr.ft}^2\text{F}
\]
\[
Hio = \text{hi x ID/OD}
\]
\[
= 269.122 \times \frac{0.0695}{0.083}
\]
\[ = 229.650 \text{ btu/hr.ft}^2.\text{F} \]

13. **Clean Over-all Coefficient**

\[
U_c = \frac{\text{hi}_0 \times \text{ho}}{\text{hi}_0 + \text{ho}}
\]

\[
= 180.996 \text{ btu/hr.ft}^2.\text{F}
\]

14. **Dirt Factor**

\[
R_d = \frac{U_c - U_d}{U_c \times U_d}
\]

\[
= 0.1483
\]

*Because from Rd Calculation > Rd Convention, 0.148321 > 0.003, Then The spesification of HE can be approve.*

15. **Pressure Drop**

1. **Shell**

   To find shell-side friction factor to do with put the renoulovd number at shell-side friction factor chart(Figure 29, Kern 1950) and Specific heat can be found at table 6 kern 1950.

   Renoulovd Number (Re) \(= 85455.80799\)
   
   shell-side friction factor \(f\) \(= 0.00017 \text{ ft}^2/\text{in}^2\)
   
   Specific Heat \(s\) \(= 1\)
   
   Diameter Shell \(D_s\) \(= 2.9167 \text{ ft}\)
   
   No. Of Crosses, N+1 \(= 12 \times \frac{\text{Tube Length}}{\text{Baffle Space}}\)
Total Pressure at Shell (ΔPs) = \frac{f \cdot G_s^2 \cdot D_s \cdot (N+1)}{5.22 \times 10^{10} \times D_e \times \rho} = \frac{0.00021 \times 111507.21^2 \times 2.91 \times 81.1}{5.22 \times 10^{10} \times 0.247} = 2.3221 \times 10^{-6} \text{ psi} = 1.6 \times 10^{-5} \text{ kpa}

2. Tube
To find shell-side friction factor to do with put the renouuld number at shell-side friction factor chart (Figure 29, Kern 1950) and Specific heat can be found at table 6 kern 1950.

Renouuld Number (Re) = 165099,1239
shell-side friction factor (f) = 0.00017 \text{ ft}^2/\text{in}^2
Specific Heat (s) = 1.29
Tube Length (L) = 9.8 \text{ ft}
Amount of Passes = 1
Diameter Inside (Ds) = 0.10667 \text{ ft}

Total Pressure at Tube (ΔPt) = \frac{f \cdot G_s^2 \cdot L \cdot n}{5.22 \times 10^{10} \times D_t \times s} = \frac{0.00017 \times 1147387.3 \times 6.5 \times 1}{5.22 \times 10^{10} \times 0.10667 \times 1.29} = 2.033 \times 10^{-7} \text{ psi} = 1.4017 \times 10^{-6} \text{ kpa}

Mass Velocity (G) = 1604777 \text{ lbm/hr ft}^2
\frac{v^2}{2g} = 0.03 \text{ (fig.27, Kern 1950)}
Return losses (ΔPr) \[ \Delta Pr = \frac{4nV^2}{s} \cdot g \]
\[ = 9.3 \times 10^{-2} \]

Total Pressure (ΔPt) \[ \Delta Pt = \Delta Pr + \Delta Pr \]
\[ = 1.4017 \times 10^{-6} + 9.3 \times 10^{-2} \]
\[ = 0.093 \text{ Kpa} \]

Because Pressure at shell and tube still allowable (ΔP < 10 Kpa) the specification of storage can be approved.

4.3.9 Design Storage Using HTRI Xchanger 6.0

Planning storage calorifier new ones, have been determined by performing various calculations based on a variety of books manual heat transfer. Then, after the manual calculation, then using Xchanger Suite 6.0 software HTRI same input data, the authors conducted a comparative analysis and design of heat exchangers and obtained different results. With the overall data input corresponding to the software manual calculations exchanger HTRI 6.0

![Figure 4. 6 Input Summary HTRI 6.0](image)
Figure 4. 7 Nozzle Location HTRI 6.0

Figure 4. 8 Tube Layout
Figure 4. 9 Output Summary HTRI 6.0

Figure 4. 10 Heat Exchanger Specification Result
Obtained comparison in general the comparison calculation manual and the software:

Table 4. 2 Comparison Calculation Manual and Software

<table>
<thead>
<tr>
<th>No.</th>
<th>Result</th>
<th>Manual Calculation</th>
<th>HTRI Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Overall coefficient (Btu/ft² h F)</td>
<td>6.5</td>
<td>6.96</td>
</tr>
<tr>
<td>2.</td>
<td>Area (ft²)</td>
<td>640.076</td>
<td>494.406</td>
</tr>
<tr>
<td>3.</td>
<td>Amount of the Tube</td>
<td>246</td>
<td>233</td>
</tr>
<tr>
<td>4.</td>
<td>Over Design (%)</td>
<td>6.13%</td>
<td></td>
</tr>
</tbody>
</table>

In Comparison of the calculation results to the software manual Heat Exchanger Research Inc. (HTRI) 6.0 with the corresponding input. And the results obtained are not too much difference with the manual calculation. Overdesign represents extra surface area provided beyond that required to compensate for fouling. Typical value of 10% or less is acceptable. Then from the analysis result the overdesign only 6.13% (<10%), so this design is acceptable.

4.3.10 Back Pressure Calculation

\[ P = \frac{L \times s \times Q^2 \times 3.6 \times 10^6}{D^5} + P_s \]

\[ P = \frac{16.96 \times 0.676 \times 0.144^2 \times 3.6 \times 10^6}{323.9^5} + 0.093 \]

\[ P = 2,40074 \times 10^{-7} + 0.093 \]
\[ P = 0.09300024 \text{ Kpa} \]

Because Back Pressure at Exhaust Gas still allowable \((\Delta P < 10 \text{ Kpa})\) the specification of storage can be approved.

### 4.3.11 Pipe Insulation

To calculate the heat loss that occurs in the pipeline, which has to do is look for the first heat transfer coefficient. The coefficients can be calculated using a manual calculation below. Is known:

- The outer diameter of the insulation \((D_3)\) = 60 mm = 0.06 m
- The outer diameter of the insulation \((D_4)\) = 68 mm = 0.068 m
- Outside diameter pipe \((D_2)\) = 0.03 m
- Inside diameter pipe \((D_1)\) = 0.028 m
- Pipe material = Stainless Steel
- Insulation material 1 = Glasswool
- Insulation material 2 = Aluminium Foil
- Conductivity thermal pipe \((K_1)\) = 32.8 W/m.\(^\circ\)C
- Conductivity thermal insulation \((K_2)\) = 0.05 W/m.\(^\circ\)C
- Conductivity thermal insulation \((K_3)\) = 235 W/m.\(^\circ\)C
- Heat transfer coefficient of the insulation \((h_2)\) = 6.5 W/m\(^2\).\(^\circ\)C
- Heat transfer coefficient of the pipe \((h_1)\) = 22 W/m\(^2\).\(^\circ\)C
- Ambient temperature \((T_B)\) = 28 °C
- Fluid temperature in the pipe \((T_A)\) = 70 °C

\[
R_i = R_{\text{conv}} \frac{1}{1} \\
R_i = \frac{1}{h_1 \times A_1}
\]
\[ R_i = \frac{1}{h_1 \times (2 \times \pi \times r \times L)} \]

\[ R_i = \frac{1}{22 \times (2 \times 3.14 \times 0.014 \times 1)} \]

\[ R_i = 0.5169 \, ^\circ\text{C/W} \]

\[ R_1 = R_{\text{pипa}} \]

\[ R_1 = \frac{\ln \frac{r_2}{r_1}}{2 \times \pi \times k_1 \times L} \]

\[ R_1 = \frac{\ln \frac{0.015}{0.014}}{2 \times 3.14 \times 32.87 \times 1} \]

\[ R_1 = 0.00033423 \, ^\circ\text{C/W} \]

\[ R_2 = R_{\text{insulasi}} \]

\[ R_2 = \frac{\ln \frac{r_3}{r_2}}{2 \times \pi \times k_2 \times L} \]

\[ R_2 = \frac{\ln \frac{0.03}{0.015}}{2 \times 3.14 \times 0.05 \times 1} \]

\[ R_2 = 2.2074 \, ^\circ\text{C/W} \]

\[ R_3 = R_{\text{insulasi}} \]

\[ R_3 = \frac{\ln \frac{r_4}{r_3}}{2 \times \pi \times k_3 \times L} \]
The calculation of heat loss per meter:

\[
R_3 = \frac{\ln \frac{0.07}{0.03}}{2 \times 3.14 \times 235 \times 1}
\]

\[R_3 = 0.000574 \, ^\circ\text{C}/\text{W}\]

\[R_o = R_{conv}\]

\[R_o = \frac{1}{h_2 \times A_2}\]

\[R_o = \frac{1}{6.5 \times (2 \times 3.14 \times 0.034 \times 1)}\]

\[R_o = 0.720523 \, ^\circ\text{C}/\text{W}\]

\[R_{total} = R_i + R_1 + R_2 + R_3 + R_o\]

\[R_{total} = 0.5169 + 0.0003 + 2.2074 + 0.000574 + 0.7205\]

\[R_{total} = 3.4454 \, ^\circ\text{C}/\text{W}\]

The calculation of heat loss per meter:

\[
\dot{Q} = \frac{T_1 - T_2}{R_{total}}
\]

\[\dot{Q} = \frac{70 - 28}{3.44}\]

\[\dot{Q} = 12.190 \, \text{W}\]

\[
\dot{Q} = \frac{m \times c \times \Delta T}{24 \times 3600}
\]

\[12.190 = \frac{2519.8 \times 4200 \times (70 - T_2)}{24 \times 3600}\]
\[ 0.0995 = (70 - T_2) \]
\[ T_2 = (70 - 0.0995) \]
\[ T_2 = 69.9 \, ^\circ C \]

4.3.12 Operational System

Operational of Exhaust System on the storage calorifier system will work as explained below and at figure 4.8:

1. When Temperature indicator detecting a decreasing in temperature below 158\(^\circ\) F the temperature indicator (TI) will send a signal to the control box to open the lift check valve so the exhaust gas enter the storage calorifier and water reheated.

2. But when the water temperature in storage calorifier exceeds 70\(^\circ\)C then temperature indicator automatically will send a signal to the control box to close the check valve lift and open the lift check valve at bypass exhaust manifold system.

3. A decreasing in the storage temperature due to the heat loss during the water is not used for a longer period or due to additional volume of incoming fresh water when the water level drops.

Water operational on a storage calorifier system will work as explained below and at figure 4.11:

1. When the hot water is used, the water level in the storage will be decreased so that the Level Alarm Low (LAL) will detect the drop in water level especially at 2.6 m\(^3\) and send a signal to the control box to open the valve and turn on the pump.

2. After Fresh water pump have filled the water until full the level alarm will detect high water level especially at 8,37 m\(^3\). Level Alarm High (LAH) will send a signal to the control box to close the valve and shut off the pump.
3. Back flow system will be activated when the hot water temperature have decreased coming out from the pump. Temperature indicator (TI) will detect a drop in temperature and sends a signal to the control box so that the valve on the back flow open and the water will flow back into the fresh water tank or re-enter on a storage calorifier.
Figure 4.11 Operational of Exhaust System on a storage calorifier from starboard side.
Figure 4: 12 Operational of Exhaust System on a Storage Calorifier from Port Side
Figure 4. 13 Operational of Exhaust System on a storage calorifier from top view
Figure 4.14 Water operational on a storage calorifier system

- **Fresh Water**
- **Hot Water**
- **Exhaust Gas**
4.3.13 Economic Analysis

4.3.13.1 Storage Calorifier System Equipment Price

List of Storage Calorifier System equipment are gathered from supplier manufacturers information (For the specification of equipment can be seen in ecnlosure b) and some equipment price data are gathered from estimation using website for the estimation.

Table 4. 3 Price of Storage Calorifier system Equipment

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Manufactures</th>
<th>Type</th>
<th>Price ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell Tube Heat Exchanger</td>
<td>Global Beijing Import and Export Co., Ltd</td>
<td>SS304</td>
<td>1000</td>
</tr>
<tr>
<td>Lift Check Valve</td>
<td>Westlock Controls Corp</td>
<td>2007xn-by-e45</td>
<td>200</td>
</tr>
<tr>
<td>Control Valve</td>
<td>EBARA</td>
<td>150X125</td>
<td>250</td>
</tr>
<tr>
<td>Centrifugal Pump</td>
<td></td>
<td>FS4J522</td>
<td></td>
</tr>
<tr>
<td>Butterfly Valve</td>
<td>Apollo Valve</td>
<td>LD14102BN11</td>
<td>110.31</td>
</tr>
<tr>
<td>Non-Return Valve</td>
<td>Zhejiang Lonze Valve Co., Ltd.</td>
<td>H44</td>
<td>250</td>
</tr>
<tr>
<td>Strainer</td>
<td>Vetus Marine</td>
<td>330</td>
<td>93.75</td>
</tr>
<tr>
<td>Tank High/Low Level Alarm</td>
<td>Gizmo</td>
<td>THL/TLL</td>
<td>179.00</td>
</tr>
<tr>
<td>Temperature Indicator</td>
<td>Gaimc</td>
<td>GTC701</td>
<td>108</td>
</tr>
<tr>
<td>Pressure Indicator</td>
<td>Yudian</td>
<td>AI-500</td>
<td>36.9</td>
</tr>
<tr>
<td>Pipe Insulation</td>
<td>DDL</td>
<td>DDL-R</td>
<td>1</td>
</tr>
</tbody>
</table>
After the list price of the equipment, the next is a list of the amount of equipment required in the new system.

Table 4. 4 Total Price of Storage Calorifier system Equipment

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Equipment Price ( $ )</th>
<th>Amount</th>
<th>Total Equipment Price ( $ )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell Tube Heat Exchanger</td>
<td>1000</td>
<td>1</td>
<td>1000</td>
</tr>
<tr>
<td>Lift Check Valve</td>
<td>200</td>
<td>4</td>
<td>800</td>
</tr>
<tr>
<td>Control Valve</td>
<td>110</td>
<td>13</td>
<td>1430</td>
</tr>
<tr>
<td>Centrifugal Pump</td>
<td>230</td>
<td>2</td>
<td>460</td>
</tr>
<tr>
<td>Butterfly Valve</td>
<td>130.31</td>
<td>4</td>
<td>521.24</td>
</tr>
<tr>
<td>Non-Return Valve</td>
<td>250</td>
<td>5</td>
<td>1250</td>
</tr>
<tr>
<td>Strainer</td>
<td>93.75</td>
<td>2</td>
<td>187.5</td>
</tr>
<tr>
<td>Tank High/Low Level Alarm</td>
<td>179.00</td>
<td>2</td>
<td>358</td>
</tr>
<tr>
<td>Temperature Indicator</td>
<td>108</td>
<td>1</td>
<td>108</td>
</tr>
<tr>
<td>Pressure Indicator</td>
<td>36.9</td>
<td>4</td>
<td>147.6</td>
</tr>
<tr>
<td>Pipe Insulation</td>
<td>1</td>
<td>250 m</td>
<td>250</td>
</tr>
</tbody>
</table>

According to the “Cost and Project Engineering Handbook” the maintenance cost is approximated 10% from the price of each equipment’s and the installation cost of each equipment estimated to be 20% of static equipment (valve, control valve, Strainer, LAH, LAL, TI, PI) and 25% of rotary equipment H/E, pump) (Humphreys, 2006). The list of maintenance and installation cost are listed below:

Table 4. 5Storage Calorifier System Equipment Maintenance & Installation

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Total Equipment Price ( $ )</th>
<th>Maintenance Cost ($)</th>
<th>Installation Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell Tube Heat Exchanger</td>
<td>1000</td>
<td>100</td>
<td>250</td>
</tr>
<tr>
<td>Lift Check Valve</td>
<td>800</td>
<td>80</td>
<td>160</td>
</tr>
<tr>
<td>Equipment</td>
<td>Total Equipment Price ($)</td>
<td>Maintenance Cost ($)</td>
<td>Installation Cost ($)</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>----------------------------</td>
<td>----------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Control Valve</td>
<td>1430</td>
<td>143</td>
<td>286</td>
</tr>
<tr>
<td>Centrifugal Pump</td>
<td>460</td>
<td>46</td>
<td>115</td>
</tr>
<tr>
<td>Butterfly Valve</td>
<td>521.24</td>
<td>52.124</td>
<td>104,248</td>
</tr>
<tr>
<td>Non-Return Valve</td>
<td>1250</td>
<td>125</td>
<td>250</td>
</tr>
<tr>
<td>Strainer</td>
<td>187.5</td>
<td>18.75</td>
<td>37.5</td>
</tr>
<tr>
<td>Tank High/Low Level Alarm</td>
<td>358</td>
<td>35.8</td>
<td>71.6</td>
</tr>
<tr>
<td>Temperature Indicator</td>
<td>108</td>
<td>10.8</td>
<td>21.6</td>
</tr>
<tr>
<td>Pressure Indicator</td>
<td>147.6</td>
<td>14.76</td>
<td>29.52</td>
</tr>
<tr>
<td>Pipe Insulation</td>
<td>250</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td><strong>Total Price</strong> ($ )</td>
<td><strong>6512.3</strong></td>
<td><strong>651.2</strong></td>
<td><strong>1375.46</strong></td>
</tr>
</tbody>
</table>

Total price for re-design hot water system in PKR ship need $8539.04. that is for new equipment, maintenance new system and for instalation.

### 4.3.13.2 Cost Saving in Auxiliary Engine Fuel

Specific fuel oil consumption data from specific auxiliary engine can be obtained from the project guide of its engine. The SFOC (Specific Fuel Oil Consumption) data for typical auxiliary engine load is figured at table 4.6:

<table>
<thead>
<tr>
<th>%MCR</th>
<th>Pi (kW)</th>
<th>SFOC (g/Kw.h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>77.1</td>
<td>214.58</td>
</tr>
<tr>
<td>20</td>
<td>154.2</td>
<td>210.46</td>
</tr>
<tr>
<td>25</td>
<td>192.75</td>
<td>209.075</td>
</tr>
<tr>
<td>30</td>
<td>231.3</td>
<td>208.14</td>
</tr>
</tbody>
</table>

Table 4.6 SFOC of the auxiliary engine
After the installation of the calorifier the calculation shows that there are certain amount of fuel saving due to decreasing of the load compared with the existing system. The specific amount of fuel saving can be calculated by using engine specific %MCR x SFOC graph figure 4.15 below. The point that shows the equilibrium position of engine load and SFOC can be considered as new SFOC point of the generator after installation of calorifier.

<table>
<thead>
<tr>
<th>%MCR</th>
<th>Pi (kW )</th>
<th>SFOC (g/Kw.h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>308.4</td>
<td>207,62</td>
</tr>
<tr>
<td>50</td>
<td>391</td>
<td>208,9</td>
</tr>
<tr>
<td>60</td>
<td>462.6</td>
<td>211,98</td>
</tr>
<tr>
<td>70</td>
<td>539.7</td>
<td>216,86</td>
</tr>
<tr>
<td>75</td>
<td>581</td>
<td>219,975</td>
</tr>
<tr>
<td>80</td>
<td>616.8</td>
<td>223,54</td>
</tr>
<tr>
<td>90</td>
<td>693.9</td>
<td>232,02</td>
</tr>
<tr>
<td>100</td>
<td>771</td>
<td>242,3</td>
</tr>
</tbody>
</table>

Figure 4. 15 Grafic of %MCR vs SFOC
As shown in graphic the new %MCR vs SFOC point (shown by red typing) are one example of the calculation. The complete calculation of SFOC vs Load calculation can be seen in the following table 4.7.

Table 4. 7 Power, %MCR,SFOC after adding the storage calorifier

<table>
<thead>
<tr>
<th>Po (KW)</th>
<th>% MCR</th>
<th>SFOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>18,13</td>
<td>2,4</td>
<td>218,95</td>
</tr>
<tr>
<td>95,23</td>
<td>12,4</td>
<td>213,45</td>
</tr>
<tr>
<td>133,78</td>
<td>17,4</td>
<td>211,38</td>
</tr>
<tr>
<td>172,33</td>
<td>22,4</td>
<td>209,75</td>
</tr>
<tr>
<td>249,43</td>
<td>32,4</td>
<td>207,86</td>
</tr>
<tr>
<td>332,03</td>
<td>42,5</td>
<td>207,77</td>
</tr>
<tr>
<td>403,63</td>
<td>52,4</td>
<td>209,46</td>
</tr>
<tr>
<td>480,73</td>
<td>62,4</td>
<td>212,97</td>
</tr>
<tr>
<td>522,03</td>
<td>67,4</td>
<td>215,41</td>
</tr>
<tr>
<td>557,83</td>
<td>72,4</td>
<td>218,27</td>
</tr>
<tr>
<td>634,93</td>
<td>82,4</td>
<td>225,37</td>
</tr>
<tr>
<td>712,03</td>
<td>92,4</td>
<td>234,28</td>
</tr>
</tbody>
</table>

Table 4.7 above show the fluctuation of SFOC at various load after reduction of the existing system using calorifier system. From the table at 1.6%MCR not possible to the auxilary engine to running at that point. The FOC (Fuel Oil Consumption) before storage calorifier added at the 50%MCR for 1 day can be determined as the calculation below:

\[
\text{FOC} = \text{SFOC} \times \text{Power} \times \text{Hr (Duration)} \\
= 212.89 \times 391 \times 24 \\
= 1997.76 \text{ kg/day}
\]
By using the similar process and calculation, the complete result for fuel saving at table 4.8 below:

Table 4.8 Fuel oil consumption before storage added

<table>
<thead>
<tr>
<th>%MCR</th>
<th>P (KW )</th>
<th>SFOC (g/Kw.h)</th>
<th>FOC (kg/day )</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>77,1</td>
<td>214,58</td>
<td>397,06</td>
</tr>
<tr>
<td>20</td>
<td>154,2</td>
<td>210,46</td>
<td>778,87</td>
</tr>
<tr>
<td>25</td>
<td>192,75</td>
<td>209,075</td>
<td>967,18</td>
</tr>
<tr>
<td>30</td>
<td>231,3</td>
<td>208,14</td>
<td>1155,43</td>
</tr>
<tr>
<td>40</td>
<td>308,4</td>
<td>207,62</td>
<td>1536,72</td>
</tr>
<tr>
<td>50</td>
<td>391</td>
<td>208,9</td>
<td>1960,32</td>
</tr>
<tr>
<td>60</td>
<td>462,6</td>
<td>211,98</td>
<td>2353,49</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>%MCR</th>
<th>P (KW )</th>
<th>SFOC (g/Kw.h)</th>
<th>FOC (kg/day )</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>539,7</td>
<td>216,86</td>
<td>2808,94</td>
</tr>
<tr>
<td>75</td>
<td>581</td>
<td>219,975</td>
<td>3067,33</td>
</tr>
<tr>
<td>80</td>
<td>616,8</td>
<td>223,54</td>
<td>3309,11</td>
</tr>
<tr>
<td>90</td>
<td>693,9</td>
<td>232,02</td>
<td>3863,97</td>
</tr>
<tr>
<td>100</td>
<td>771</td>
<td>242,3</td>
<td>4483,52</td>
</tr>
</tbody>
</table>

For the Fuel Oil Consumption of the auxiliary after adding the storage calorifier by using the similar process and calculation, the complete result for fuel saving at table 4.9 below:

Table 4.9 Fuel oil consumption after storage added

<table>
<thead>
<tr>
<th>%MCR</th>
<th>P (kW )</th>
<th>SFOC (g/Kw.h)</th>
<th>FOC (kg/day )</th>
</tr>
</thead>
<tbody>
<tr>
<td>18,13</td>
<td>2,4</td>
<td>218,95</td>
<td>95,27</td>
</tr>
<tr>
<td>95,23</td>
<td>12,4</td>
<td>213,45</td>
<td>487,84</td>
</tr>
<tr>
<td>133,78</td>
<td>17,4</td>
<td>211,38</td>
<td>678,67</td>
</tr>
<tr>
<td>172,33</td>
<td>22,4</td>
<td>209,75</td>
<td>867,52</td>
</tr>
<tr>
<td>249,43</td>
<td>32,4</td>
<td>207,86</td>
<td>1244,29</td>
</tr>
<tr>
<td>%MCR</td>
<td>P (kW )</td>
<td>SFOC (g/Kw.h)</td>
<td>FOC (kg/day )</td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
<td>---------------</td>
<td>---------------</td>
</tr>
<tr>
<td>332,03</td>
<td>42,5</td>
<td>207,77</td>
<td>1655,64</td>
</tr>
<tr>
<td>403,63</td>
<td>52,4</td>
<td>209,46</td>
<td>2029,09</td>
</tr>
<tr>
<td>480,73</td>
<td>62,4</td>
<td>212,97</td>
<td>2457,10</td>
</tr>
<tr>
<td>522,03</td>
<td>67,4</td>
<td>215,41</td>
<td>2698,83</td>
</tr>
<tr>
<td>557,83</td>
<td>72,4</td>
<td>218,27</td>
<td>2922,17</td>
</tr>
<tr>
<td>634,93</td>
<td>82,4</td>
<td>225,37</td>
<td>3434,29</td>
</tr>
<tr>
<td>712,03</td>
<td>92,4</td>
<td>234,28</td>
<td>4003,47</td>
</tr>
</tbody>
</table>

Figure 4. 16 Grafic of %MCR and FOC after-before adding the storage

After added the storage calorifier can be reduced the fuel oil consumption of the auxiliary engine load at Figure 4.16, then the fuel oil savings of the auxiliary engine load per days are:
Fuel Oil savings = FOC\textsubscript{before} − FOC\textsubscript{after} \\
= 1997,76 − 1665,65 \\
= 332.11 kg/day

By using the similar process and calculation, the complete result for fuel saving at table below:

Table 4. 10 Fuel oil saving after storage calorifier added

<table>
<thead>
<tr>
<th>%MCR\textsubscript{before}</th>
<th>%MCR\textsubscript{after}</th>
<th>Fuel Oil Saving (kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2,4</td>
<td>301,79</td>
</tr>
<tr>
<td>20</td>
<td>12,4</td>
<td>291,03</td>
</tr>
<tr>
<td>25</td>
<td>17,4</td>
<td>288,51</td>
</tr>
<tr>
<td>30</td>
<td>22,4</td>
<td>287,91</td>
</tr>
<tr>
<td>40</td>
<td>32,4</td>
<td>292,43</td>
</tr>
<tr>
<td>50</td>
<td>42,5</td>
<td>304,67</td>
</tr>
<tr>
<td>60</td>
<td>52,4</td>
<td>324,40</td>
</tr>
<tr>
<td>70</td>
<td>62,4</td>
<td>351,85</td>
</tr>
<tr>
<td>75</td>
<td>67,4</td>
<td>368,50</td>
</tr>
<tr>
<td>80</td>
<td>72,4</td>
<td>386,94</td>
</tr>
<tr>
<td>90</td>
<td>82,4</td>
<td>429,67</td>
</tr>
<tr>
<td>100</td>
<td>92,4</td>
<td>480,05</td>
</tr>
</tbody>
</table>

Then after 1 year the storage calorifier operated, the fuel that can be saved are :

Fuel Oil Saving = Fuel saving \times Duration \\
= 304.67 \times 365 \\
= 111205.87 kg/year

The ship is using MDO as a fuel for auxiliary engine, therefore the density of the fuel is 843 kg/m\textsuperscript{3}. 
To calculate the liters saving per year is figured below:

\[ V = \frac{m}{\rho} \]

\[ V = \frac{111205,8}{843} \]

\[ V = 139.659 \text{ m}^3/\text{years} \]

\[ V = 139659 \text{ liter/years} \]

By using the similar process and calculation, the complete result for fuel saving at table below:

<table>
<thead>
<tr>
<th>% MCR\text{before}</th>
<th>% MCR\text{after}</th>
<th>FOC (kg/years)</th>
<th>liters saving (liter/years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2,4</td>
<td>110153,73</td>
<td>130669</td>
</tr>
<tr>
<td>20</td>
<td>12,4</td>
<td>106225,11</td>
<td>126008</td>
</tr>
<tr>
<td>25</td>
<td>17,4</td>
<td>105306,86</td>
<td>124919</td>
</tr>
<tr>
<td>30</td>
<td>22,4</td>
<td>105086,00</td>
<td>124657</td>
</tr>
<tr>
<td>40</td>
<td>32,4</td>
<td>106736,42</td>
<td>126615</td>
</tr>
<tr>
<td>50</td>
<td>42,5</td>
<td>111205,87</td>
<td>131917</td>
</tr>
<tr>
<td>60</td>
<td>52,4</td>
<td>118405,79</td>
<td>140458</td>
</tr>
<tr>
<td>70</td>
<td>62,4</td>
<td>128424,76</td>
<td>152343</td>
</tr>
<tr>
<td>75</td>
<td>67,4</td>
<td>134502,86</td>
<td>159553</td>
</tr>
<tr>
<td>80</td>
<td>72,4</td>
<td>141233,24</td>
<td>167536</td>
</tr>
<tr>
<td>90</td>
<td>82,4</td>
<td>156831,24</td>
<td>186039</td>
</tr>
<tr>
<td>100</td>
<td>92,4</td>
<td>175218,75</td>
<td>207851</td>
</tr>
</tbody>
</table>

After know how much fuel oil that can be saved per years, then calculated the price of fuel saving per year. Assumed in every years the price of MDO will grow 10% from the previous year
and the dollar price is to be locked at Rp. 13,000.00 per US Dollar. The MDO price increase can be seen in the table below:

<table>
<thead>
<tr>
<th>Year</th>
<th>MDO price per liter (IDR)</th>
<th>MDO price per liter ($)</th>
<th>Profit ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>Rp 8,799</td>
<td>$0.677</td>
<td>$110,349</td>
</tr>
<tr>
<td>2018</td>
<td>Rp 9,679</td>
<td>$0.745</td>
<td>$121,384</td>
</tr>
<tr>
<td>2019</td>
<td>Rp 10,647</td>
<td>$0.819</td>
<td>$133,522</td>
</tr>
<tr>
<td>2020</td>
<td>Rp 11,711</td>
<td>$0.901</td>
<td>$146,874</td>
</tr>
<tr>
<td>2021</td>
<td>Rp 12,883</td>
<td>$0.991</td>
<td>$161,562</td>
</tr>
<tr>
<td>2022</td>
<td>Rp 14,171</td>
<td>$1,090</td>
<td>$177,718</td>
</tr>
<tr>
<td>2023</td>
<td>Rp 15,588</td>
<td>$1,199</td>
<td>$195,490</td>
</tr>
<tr>
<td>2024</td>
<td>Rp 17,147</td>
<td>$1,319</td>
<td>$215,039</td>
</tr>
<tr>
<td>2025</td>
<td>Rp 18,861</td>
<td>$1,451</td>
<td>$236,543</td>
</tr>
<tr>
<td>2026</td>
<td>Rp 20,748</td>
<td>$1,596</td>
<td>$260,197</td>
</tr>
<tr>
<td>2027</td>
<td>Rp 22,822</td>
<td>$1,756</td>
<td>$286,217</td>
</tr>
<tr>
<td>2028</td>
<td>Rp 25,105</td>
<td>$1,931</td>
<td>$314,838</td>
</tr>
<tr>
<td>2029</td>
<td>Rp 27,615</td>
<td>$2,124</td>
<td>$346,322</td>
</tr>
<tr>
<td>2030</td>
<td>Rp 30,377</td>
<td>$2,337</td>
<td>$380,955</td>
</tr>
</tbody>
</table>

Based on the calculation above, considering the capitals that is related to purchasing cost, maintenance cost, and installation cost. Payback period can be achieved in calculation below:

<table>
<thead>
<tr>
<th>Explanation</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment</td>
<td>-$6,512</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Installation</td>
<td>-$1,375</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Maintenance</td>
<td>-</td>
<td>$651</td>
<td>$716</td>
<td>$788</td>
<td>$866</td>
</tr>
<tr>
<td>Explanation</td>
<td>2016</td>
<td>2017</td>
<td>2018</td>
<td>2019</td>
<td>2020</td>
</tr>
<tr>
<td>-------------</td>
<td>------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>Saving Fuel</td>
<td>-</td>
<td>$100.318</td>
<td>$110.350</td>
<td>$121.385</td>
<td>$133.523</td>
</tr>
<tr>
<td><strong>Profit</strong></td>
<td>-$7.888</td>
<td><strong>$99.667</strong></td>
<td><strong>$109.634</strong></td>
<td><strong>$120.597</strong></td>
<td><strong>$139.363</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Explanation</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Installation</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Maintenance</td>
<td>$953</td>
<td>$1.048</td>
<td>$1.153</td>
<td>$1.269</td>
<td>$1.395</td>
</tr>
<tr>
<td>Saving Fuel</td>
<td>$146.875</td>
<td>$161.563</td>
<td>$177.719</td>
<td>$195.491</td>
<td>$215.040</td>
</tr>
<tr>
<td><strong>Profit</strong></td>
<td><strong>$153.299</strong></td>
<td><strong>$168.629</strong></td>
<td><strong>$185.492</strong></td>
<td><strong>$204.042</strong></td>
<td><strong>$224.446</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Explanation</th>
<th>2026</th>
<th>2027</th>
<th>2028</th>
<th>2029</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Installation</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Maintenance</td>
<td>$1.535</td>
<td>$1.689</td>
<td>$1.857</td>
<td>$2.043</td>
<td>$2.247</td>
</tr>
<tr>
<td>Saving Fuel</td>
<td>$236.544</td>
<td>$260.199</td>
<td>$286.219</td>
<td>$314.841</td>
<td>$346.325</td>
</tr>
<tr>
<td><strong>Profit</strong></td>
<td><strong>$246.890</strong></td>
<td><strong>$271.579</strong></td>
<td><strong>$298.737</strong></td>
<td><strong>$328.611</strong></td>
<td><strong>$361.472</strong></td>
</tr>
</tbody>
</table>

The scenario for the economy calculation above the maintenance cost will increase 10% every years and for maintenance cost start if the storage calorifier start the operation. In this thesis, it is assumed that the operational of PKR ship will be began at begining of 2017. According to my economic calculation, its turns out that the payback period is about 1 year, exactly at around the end of 2017.
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CHAPTER 5
CONCLUSION & SUGGESTION

5.1 Conclusion
Based on data analysis and result which has been done in the previous section, conclusion can be concluded as follows:

5.1.1 Technical Analysis
1. The amount of required exhaust gas for heating the 8.784 m³/day of fresh water until temperature constant at 158°F is 19056.72648 lb/h.
2. From the Comparison of the calculation results between the manual calculation and software of Heat Exchanger Research Inc. (HTRI) 6.0 with the corresponding input, it is not much with the manual calculation. From manual calculation the area is 640.076 ft² while the area from HTRI software is 494.406 ft². Overall coefficient from manual calculation is obtained 6.5 btu/ft².h.F and from HTRI software is 6.96 btu/ft².h.F. Over design from calculation manual and htri software is 6.13 %, it is acceptable because the value is less than 10%, which is the maximum value of over design.
3. The result value of the back pressure is still allowed if the value is less than 10 kPa. From calculation the value of back pressure is 0.09300024 kPa. It means that the system is still allowed (ΔP < 10 Kpa) and the specification of storage can be approved.
4. The operational of storage calorifier operational depends on temperature and the level of water. If the temperature of water is below 158°F the exhaust gas valve will be opened and re-heating the water, but when water temperature above 158°F
the exhaust gas valve will be closed because the actual water temperature already achieved the required temperature. Then when the water level in storage calorifier below the minimum amount, level alarm low will send the signal to control box to re-open the valve to fill the storage calorifier and when the water at storage calorifier is achieved the maximum amount the valve will be closed.

5.1.2 Economic Analysis

1. Based on the economic analysis for redesign hot water in domestic system of PKR ship, it needs $94196.74 and for maintainance needs $9419.674 then for instalation new system needs $21349.07. After using storage calorifier for heating the water, the fuel oil consumption (FOC) of auxiliary at 50%MCR is 1319179 liter/year. So if operations are assumed to begin in early 2017, at the end of 2017 the primary capital to re-design can be returned.

5.2 Suggestion

As for suggestions which can be deliver incorrelate with this bachelor thesis and for the further improvement of this research are:

1. Necessary analysis in terms of safety because of the adjacent placement of storage calorifier with auxiliary engine. so the storage calorifier can work function in PKR ship safely.
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Technology Sepuluh Nopember, Surabaya, 2016.

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The author was born in Blitar on 28th September 1994, as the first child of 2 siblings. The author has completed the formal education in SDN 1 Kademangan, SMPN 2 Blitar, and SMAN 1 Blitar. The author continued her study for bachelor degree in Marine Engineering Double Degree (DDME) program of Institut Teknologi Sepuluh Nopember and Hochschule Wismar, with student id number: 4213101001 and took area of expertise in Marine Machinery and System (MMS). During the college, the author was active in marine engineering student association (HIMASISKAL), 2014-2015 period, as cabinet 2nd secretary, in the field of kepem proceed. The author was a pemandu in department level, faculty level, and also Institute level. The author has taken several trainings such as student management skill (Pra-TD) training, management activity, and management organization. The author have done on the job training in PT. Dok Perkapalan Kodja Bahari 1 Jakarta and PT. Pertamina Shipping Jakarta.
ECNLOSURE A
General Arrangement of PKR Ship
Exhasut Gas System
Domestic Water System
ECNLOSURE B
Project Guide of Auxiliary Engine
Caterpillar is leading the power generation marketplace with Power Solutions engineered to deliver unmatched flexibility, expandability, reliability, and cost-effectiveness.

## Specifications

### Generator Set Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Rating</td>
<td>830 ekW (910 kVA)</td>
</tr>
<tr>
<td>Maximum Rating</td>
<td>1000 ekW (1250 kVA)</td>
</tr>
<tr>
<td>Voltage</td>
<td>220 to 4160</td>
</tr>
<tr>
<td>Frequency</td>
<td>50 or 60 Hz</td>
</tr>
<tr>
<td>Speed</td>
<td>1500 or 1800 RPM</td>
</tr>
</tbody>
</table>

### Generator Set Configurations


### Engine Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Model</td>
<td>C32 TA, V-12, 4-Stroke Water-Cooled Diesel</td>
</tr>
<tr>
<td>Bore</td>
<td>145 mm</td>
</tr>
<tr>
<td>Displacement</td>
<td>32.1 L</td>
</tr>
<tr>
<td>Stroke</td>
<td>162 mm</td>
</tr>
<tr>
<td>Compression Ratio</td>
<td>15.0:1</td>
</tr>
<tr>
<td>Aspiration</td>
<td>TA</td>
</tr>
<tr>
<td>Governor Type</td>
<td>Adem™A4</td>
</tr>
<tr>
<td>Fuel System</td>
<td>MEUI</td>
</tr>
</tbody>
</table>
PERFORMANCE DATA[DM9933]

Performance Number: DM9933

SALES MODEL: C32
ENGINE POWER (BHP): 1,474
GEN POWER WITH FAN (ECW): 1,000.0
COMPRESSION RATIO: 15.0
RATING LEVEL: STANDBY
PUMP QUANTITY: 1
FUEL TYPE: DIESEL
MANIFOLD TYPE: DRY
GOVERNOR TYPE: ADEM
ELECTRONICS TYPE: ADEM
IGNITION TYPE: CI
INJECTOR TYPE: EUI
REF EXH STACK DIAMETER (IN): 8
MAX OPERATING ALTITUDE (FT): 997

COMBUSTION: DI
ENGINE SPEED (RPM): 1,930
HEATZ: 60
FAN POWER (HP): 56.3
ADDITIONAL PARASITIC (HP): 1.3
ASPIRATION: TA
AFTERCOOLER TYPE: ATAC
AFTERCOOLER CIRCUIT TYPE: JW-OC, ATAC
INLET MANIFOLD AIR TEMP (F): 120.5
JACKET WATER TEMP (F): 212.2
TURBO CONFIGURATION: PARALLEL
TURBO QUANTITY: 2
TURBOCHARGER MODEL: GTB45018BS-52T-1.37
CERTIFICATION YEAR: 2007
PRISN SPD @ RATED ENG SPD (FPMIN): 1,913.4

INDUSTRY
OIL AND GAS
APPLICATION
LAND PRODUCTION
PACKAGED GENSET

ELECTRIC POWER
STANDARD
PACKAGED GENSET

General Performance Data

<table>
<thead>
<tr>
<th>GENSET POWER WITH FAN</th>
<th>PERCENT LOAD</th>
<th>ENGINE POWER</th>
<th>BRAKE MEAN EFF PRES (BMEP)</th>
<th>BRAKE SPEC FUEL CONSUMPTN (BSPC)</th>
<th>VOL FUEL CONSUMPTN (VFC)</th>
<th>INLET MFLD PRES</th>
<th>INLET MFLD TEMP</th>
<th>EXH MFLD PRES</th>
<th>EXH MFLD TEMP</th>
<th>ENGINE OUTLET TEMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXW</td>
<td>%</td>
<td>BHP</td>
<td>PSI</td>
<td>LBS/HBP/HR</td>
<td>GAL/HR</td>
<td>IN-N</td>
<td>DEG F</td>
<td>DEG F</td>
<td>IN-N</td>
<td>DEG F</td>
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<tr>
<td>1,000.0</td>
<td>100</td>
<td>1,474</td>
<td>331</td>
<td>0.342</td>
<td>71.9</td>
<td>70.3</td>
<td>118.2</td>
<td>1,209.3</td>
<td>58.1</td>
<td>886.5</td>
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<tr>
<td>900.0</td>
<td>90</td>
<td>1,330</td>
<td>299</td>
<td>0.341</td>
<td>64.7</td>
<td>64.0</td>
<td>111.0</td>
<td>1,190.9</td>
<td>51.6</td>
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<td>800.0</td>
<td>80</td>
<td>1,187</td>
<td>257</td>
<td>0.349</td>
<td>59.2</td>
<td>60.4</td>
<td>106.5</td>
<td>1,116.3</td>
<td>48.6</td>
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<tr>
<td>750.0</td>
<td>75</td>
<td>1,116</td>
<td>251</td>
<td>0.354</td>
<td>56.4</td>
<td>57.9</td>
<td>103.8</td>
<td>1,190.0</td>
<td>46.6</td>
<td>921.0</td>
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<tr>
<td>700.0</td>
<td>70</td>
<td>1,046</td>
<td>235</td>
<td>0.354</td>
<td>52.9</td>
<td>53.7</td>
<td>99.5</td>
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<td>650.0</td>
<td>60</td>
<td>905.0</td>
<td>203</td>
<td>0.353</td>
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<tr>
<td>550.0</td>
<td>50</td>
<td>765.0</td>
<td>172</td>
<td>0.350</td>
<td>38.2</td>
<td>39.9</td>
<td>80.6</td>
<td>964.8</td>
<td>27.0</td>
<td>766.5</td>
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<tr>
<td>400.0</td>
<td>40</td>
<td>628.0</td>
<td>141</td>
<td>0.351</td>
<td>31.5</td>
<td>23.9</td>
<td>74.7</td>
<td>895.9</td>
<td>20.5</td>
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<tr>
<td>350.0</td>
<td>30</td>
<td>460.0</td>
<td>110</td>
<td>0.367</td>
<td>25.0</td>
<td>15.7</td>
<td>70.4</td>
<td>812.1</td>
<td>15.1</td>
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<tr>
<td>250.0</td>
<td>25</td>
<td>420.0</td>
<td>94</td>
<td>0.363</td>
<td>21.8</td>
<td>12.0</td>
<td>98.8</td>
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<td>12.7</td>
<td>543.0</td>
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<tr>
<td>200.0</td>
<td>20</td>
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<td>79</td>
<td>0.374</td>
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<td>8.7</td>
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<td>728.9</td>
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<td>200.0</td>
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<td>260.0</td>
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<td>0.425</td>
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<td>67.5</td>
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<table>
<thead>
<tr>
<th>DRY EXH VOL FLOW RATE</th>
<th>DRY EXH VOL FLOW RATE</th>
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<tbody>
<tr>
<td>DEG F</td>
<td>IN-HG</td>
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<tr>
<td>1,000.0</td>
<td>100</td>
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<tr>
<td>900.0</td>
<td>90</td>
</tr>
<tr>
<td>800.0</td>
<td>80</td>
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<tr>
<td>750.0</td>
<td>75</td>
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<tr>
<td>700.0</td>
<td>70</td>
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<tr>
<td>650.0</td>
<td>60</td>
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<td>550.0</td>
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<td>400.0</td>
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<td>250.0</td>
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<tr>
<td>200.0</td>
<td>20</td>
</tr>
<tr>
<td>100.0</td>
<td>10</td>
</tr>
</tbody>
</table>
ECNLOSURE C
Equipment selection
Temperature Indicator

Overview

Specifications
- Place of Origin: Shenzhen, China (Mainland)
- Usage: Industrial
- Temperature inputs: According to input
- Panel size: 96*96, 160*90, 80*160, 72*72...
- Communication: RS485
- Housing color: Black / gray
- Brand Name: GAIMC
- Theory: Alarm temperature indicator
- Input signal: Thermocouple, RTD, linear volt...
- Auxiliary input: Direct current
- Display: LED
- Item: GTC701 Digital thermocouple...
- Model Number: GTC701
- Accuracy: 0.3
- Alarm: Four programmable alarms
- AUX input: Relay
- Output: Linear current

Packaging & Delivery
- Packaging Details: Standard export packaging
- Delivery Details: Shipped in 10 days after payment

GTC701 Digital thermocouple alarm temperature indicator
Pressure Indicator

### Overview

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Brand Name</th>
<th>Model Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Place of Origin: Fujian, China (Mainland)</td>
<td>YUDIAN</td>
<td>AI-500</td>
</tr>
<tr>
<td>Usage: Industrial</td>
<td>Theory: Temperature Controller</td>
<td></td>
</tr>
<tr>
<td>Temperature range: 0~9999</td>
<td>Input Type: Thermocouple: K, S, R, E, J, N,...</td>
<td></td>
</tr>
<tr>
<td>Power supply: 100-240VAC/ 50-60Hz; 24VDC</td>
<td>Temperature Display: 0.1 or 1</td>
<td></td>
</tr>
<tr>
<td>Power Supply: 100-240VAC, -15%, +10% / 50...</td>
<td>Power Consumption: ≤5W</td>
<td></td>
</tr>
<tr>
<td>Color: Grey or Black</td>
<td>Name: AI-500 Pressure Indicator Supplier Digital Temperature Indicator</td>
<td></td>
</tr>
</tbody>
</table>

### Packaging & Delivery

Packaging Details: Standard Carton boxes with Yudian logo for AI-500 Pressure Indicator Supplier Digital Temperature Indicator

Delivery Detail: Shipped in 2 days after payment
Non Return Valve

Basic Info

Model NO.: H44
Connection Form: Flange
Pressure: Ordinary Pressure
Sealing Form: Gland Packings Globe Valve
Standard: DIN
Class: PN10~PN40
Media: Water
Color: as Customer's Request
Power: Manual
Trademark: Loto/OEM
Specification: DN50~DN500
HS Code: 8481300000

Material: Cast Steel
Structure: Housing
Function: Double Lobe, hair silence, bellow rubber lobe, hair silence, Norg silence
Flow Direction: Unidirectional
Application: Industrial Usage, Water Industrial Usage
Certificate: API
Painting: Epoxy Painting
Fields: Metallurgy, Light Industrial, Electric Power...
Temperature: Normal Temperature
Transport Package: Wooden Case
Origin: China
METRIC CAST STEEL
CHECK VALVES

FLANGED ENDS
DIN or JIS SPECIFICATIONS
SIZES: 40mm to 500mm

PN 16 DIN (European) SWING CHECK

<table>
<thead>
<tr>
<th>SIZE</th>
<th>40</th>
<th>50</th>
<th>65</th>
<th>80</th>
<th>100</th>
<th>125</th>
<th>150</th>
<th>200</th>
<th>250</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF</td>
<td>160</td>
<td>200</td>
<td>240</td>
<td>260</td>
<td>300</td>
<td>350</td>
<td>400</td>
<td>500</td>
<td>600</td>
</tr>
<tr>
<td>D</td>
<td>160</td>
<td>165</td>
<td>185</td>
<td>200</td>
<td>250</td>
<td>220</td>
<td>285</td>
<td>340</td>
<td>405</td>
</tr>
<tr>
<td>BC</td>
<td>110</td>
<td>125</td>
<td>145</td>
<td>160</td>
<td>180</td>
<td>210</td>
<td>240</td>
<td>295</td>
<td>355</td>
</tr>
<tr>
<td>wt(kg)</td>
<td>12</td>
<td>15</td>
<td>22</td>
<td>29</td>
<td>41</td>
<td>57</td>
<td>75</td>
<td>120</td>
<td>150</td>
</tr>
</tbody>
</table>

LN 40 DIN (European) LIFT CHECK

| SIZE | 15 | 20 | 25 | 30 | 32 | 40 | 50 | 65 | 80 | 100 | 125 | 150 | 200 | 250 | 300 |
|------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|
| FF   | 130| 150| 160| 180| 200| 230| 290| 310| 350| 430 | 480 | 500 | 720 | 850 | 500 |
| D    | 95 | 105| 115| 140| 155| 165| 200| 235| 270| 300 | 375 | 400 | 515 | 515 | 515 |
| BC   | 65 | 75 | 85 | 110| 125| 145| 160| 190| 200| 250 | 320 | 385 | 450 | 450 | 450 |
| wt(kg) | 4 | 4  | 5  | 8  | 11 | 15 | 25 | 26 | 42 | 56  | 82  | 152 | 230 | 290 | 290 |

METRIC BUTTERFLY
VALVES

SIZES: 40mm to 750mm
JIS and DIN


<table>
<thead>
<tr>
<th>SIZE</th>
<th>6K JIS</th>
<th>Bro Disc</th>
<th>9494202-5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SS Disc</td>
<td>9494202-10</td>
<td></td>
</tr>
<tr>
<td>JIS</td>
<td>Bro Disc</td>
<td>9494202-5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SS Disc</td>
<td>9494202-10</td>
<td></td>
</tr>
<tr>
<td>PN 6 DIN</td>
<td>Bro Disc</td>
<td>9494202-5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SS Disc</td>
<td>9494202-10</td>
<td></td>
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<tr>
<td>PN 10 DIN</td>
<td>Bro Disc</td>
<td>9494202-5</td>
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<tr>
<td></td>
<td>SS Disc</td>
<td>9494202-10</td>
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<tr>
<td>PN 16 DIN</td>
<td>Bro Disc</td>
<td>9494202-5</td>
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</tr>
<tr>
<td></td>
<td>SS Disc</td>
<td>9494202-10</td>
<td></td>
</tr>
</tbody>
</table>

Options available: Ductile (Nodular) iron body; add SI to item number; Monel Disc; add MD to item number; Gear Operator; add GO to item number; Viton Seat/Liner; add VS to item number; EPDM Seat/Liner; add SP to item number.
## SPESIFIKASI UNTUK KACA WOL PIPA

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Indeks</th>
<th>Didukung Nilai</th>
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</thead>
<tbody>
<tr>
<td>Bulk density</td>
<td>kg/m³</td>
<td>64-150</td>
<td>64-150</td>
</tr>
<tr>
<td>Diameter rata-rata serat</td>
<td>m</td>
<td>&lt; 8</td>
<td>0.4-0.6</td>
</tr>
<tr>
<td>Resistivitas kelembaban</td>
<td>%</td>
<td>&gt; 98</td>
<td>&gt; 98.5</td>
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<tr>
<td>Konduktivitas termal</td>
<td>W/m</td>
<td>0.049-0.042</td>
<td>0.045-0.032</td>
</tr>
<tr>
<td>Tahan api</td>
<td></td>
<td></td>
<td>hingga standar (Grade A)</td>
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<tr>
<td>Koefisien penyerapan suara</td>
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<td></td>
<td>1.03 gama positioning produk 24 kg/m³ 2000 Hz</td>
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<tr>
<td>Max suhu kerja</td>
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<td>400</td>
<td>410</td>
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</table>
Aluminium Foil

<table>
<thead>
<tr>
<th>Property</th>
<th>Value/Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>2.7</td>
</tr>
<tr>
<td>Weight</td>
<td>At 6.35 µm foil weight 17.2 g/m²</td>
</tr>
<tr>
<td>Melting point</td>
<td>960°C</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>37.57 mV/m² (64.54% IACS)</td>
</tr>
<tr>
<td>Electrical resistivity</td>
<td>2.68 µΩcm</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>235 W/m.K</td>
</tr>
<tr>
<td>Thickness</td>
<td>Foil is defined as metal measuring 0.2mm (or 200 µm and below)</td>
</tr>
<tr>
<td>Surface finish</td>
<td>Above 40µm aluminium foil has a brightly polished surface on both sides imparted by the rolling cylinders. Below 40µm one side has a matt finish due to the process of rolling two layers of foil simultaneously. If specified by the customer, foil can be supplied below 10µm thickness with both surfaces bright. Other surface finishes such as etched, grained or embossed can be supplied to meet particular customer needs.</td>
</tr>
</tbody>
</table>

Level Alarm

Price: Starting at $179.00 Call For Lead Time
Manufacturer: Ozimo
Manufacturer Part No: THL/TLL

Select Product Options And Calculate Price

- Configuration: [Select Configuration]
- Working Depth: [Select Working Depth]
- Power Supply: [Select Power Supply]
- Material: [Select Material]
- Quantity: 1

Add to Cart

Email this page to a friend
Control Valve

**Technical data**

**Approvals:**
- Area classification (ATEX/IEC)
  - 2200 series: Ex II 2G, Ex d IIB + H2, Ex d A21P6X
  - 2600 series: Ex II 2G, Ex d IIC, Ex d A21P6X

**Enclosure standards (IEC)**
- All enclosures: IP66/67

**Switches**
- All Models: V3 mechanical SPDT contacts
- All Models: DPDT mechanical
- All Models: V3 slotted and barrel inductive proximity sensors
- All Models: Magnum SPDT (hermetically sealed proximity type) switches
- 2200 Series: GO hermetically sealed switches, SPDT

**Enclosures**
- All Models: Aluminum
- Stainless steel

**Falcon Solenoid Valves**
- Ox: Choice of 1.1, 3.5
- Materials: Aluminum and stainless steel

---

**Sentrifugal Pump**

- **Merk:** EBARA
- **Type:** DLA 65
- **Cap.:** 300 Ltr/ Mnt
- **Head:** 10 M
- **Power:** 1.5 KW / 3 Phase / 380 V / 50 Hz
- **Price:** Rp 14.800.000,-/ Unit C/W Motor
Technical Description

The FUNKE heat exchanger type A 100 was designed in accordance with type CP and is exclusively available as a gas cooler - media routing "gas through the tubes" - in a tube side single-pass version. It is a heat exchanger with straight internal tubes, a removable tube bundle whose fixed tubeshheet is clamped up in between the shell side and tube side device flanges by means of two nut seals and bolts. The movable tubeshheet, floating due to the combination of two sealing rings and a leakage ring between the device flanges, protects against a mixing of the shell side and tube side flowing media. In the case of leakages due to a single or both sealing rings being defective the pertinent media always escape towards the outside through signal bores on the circumference of the leakage ring. All seals of this design seal against atmosphere.

The tube/tubeshheet connections are produced by appropriate tube expand rollings or tube weldings in accordance with the construction regulations, material combinations and operating media as well as the maximum permissible operating parameters (P/T). Naturally, to avoid gap corrosion, after a tube welding the internal tubes are fully expanded again.

The connection chambers are available in various different versions whose selection is effected in accordance with the required standards and in accordance with fluid engineering aspects.

Venting and draining points as well as a corresponding base construction are designed in relation to the installation position.

Material selection

In accordance with the respective regulations, construction regulations and operating media, carbon steels, stainless steels as well as nonferrous heavy metals are used. A reasonable integration of special materials, plateings and coatings is possible.

Application

This heat exchanger type A 100 is exclusively used for cooling and drying air or similar gases, with the gas flowing on the tube side and the cooling water flowing within the shell space around the internal tubes.

Any operation with gases having a low molecular weight (e.g. hydrogen) is not effective due to the type of seal used on the floating tubeshheet.

If partial condensation occurs, a cyclone separator for phase separation may be flanged directly to the outlet chamber, if required.

Acceptance

The FUNKE heat exchanger type A 100 can be supplied in accordance with all pertinent national and international certification bodies, regulations and construction regulations as e.g. pursuant to the Pressure Equipment Directive (PED), AD-2000, ASME-VIII, Div. I, U-Stamp, TEMA standard, CHINA-SOL. The integration of works standards or customer specifications is no problem either.

Boundary conditions

Due to its design and sealing type the maximum permissible operating conditions are

<table>
<thead>
<tr>
<th></th>
<th>Shell side</th>
<th>Tube side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum operating</td>
<td>41 bar</td>
<td>41 bar</td>
</tr>
<tr>
<td>overpressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum operating</td>
<td>250°C</td>
<td>250°C</td>
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<tr>
<td>temperature</td>
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* The maximum values may reduce due to regulations, works standards and construction regulations.
ECNLOSURE D
Hot & Cold Water System Existing
Cold & Hot potable water unit

Model: two hydrophore pumps, one hydrophore vessel, an activated carbon fine filter, an UV-disinfection system, one hot water calorifier, two hot water circulation pumps and a control box.

Operators manual & warranty

Shipment date: March 2014
Our reference: 476032
Clients reference: Yard no.: 414 - PKR
Address client: Damen Schelde Naval Shipbuilding
Glacisstraat 165
4381 SE Vlissingen
The Netherlands
Safety instructions

This manual contains basic information that must be considered at set-up and during operation and maintenance.
For this reason, the operating, maintenance and assembly personnel must read the operating instructions before assembly, commissioning and operating.
The manual must also be available to the responsible personnel/machine minder at the place of operation at all times.
Make sure the environs of the installation is clean and well illuminated.

Qualification personnel

The operating, maintenance and assembly personnel must be appropriately qualified for the work they carry out.

Risks resulting from ignoring the safety information

Ignoring the safety information may lead to hazards for the people involved as well as endangering the environment and the system.
The non-observation of the safety information shall invalidate all claims for damages incl. compensation for damages

Maintenance

Basically the system must not be pressurized and the electrical power must be switched off before carrying out any maintenance work on the system.

Spare parts

Original spare-parts shall be used for safety-related reasons.
The use of other parts shall lead to invalidation of the warranty for any consequences resulting including claims for compensation of damages.


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Hatenboer-Water b.v. reserves the right to change for improvement without notice.
INDEX

1. General description
2. Technical specification
3. Operation / maintenance
4. Installation instructions
5. Start-up
6. Fault diagnosis
7. Recommended spare parts list
8. Drawings and Parts literature
1 General description

The hydrophore unit is designed to operate as a stand-alone unit. The pumps will boost the water from the fresh water tanks to the user tap points and the hot water calorifier. The two pumps will start automatically by pressure switches, the hydrophore vessel is installed to prevent frequent switching of the pumps. The selection of the sequence of the pumps is automatically switched when both pumps are switched off. The hydrophore pumps can be switched on continuously by putting the selection switch in manual position.

Activated Carbon Water Fine Filters for the effective removal of solids and organics to improve the taste, colour and appearance of the fresh water. Housing is made of stainless steel and contains ‘quick-change’ elements with a selectivity of 5 microns.

The UV disinfection system emits Ultraviolet light in the UV-C band to the water flowing through the UV chamber and so disinfecting the water. The UV unit has a control unit which shows the status of the system; power on, lamp failure and a hour-counter showing the number of hours of use.

The heating of the calorifier is electric, the three heating centres can be switched on individually. Three heating centres of 65kW total are provided to have sufficient hot water heating capacity. Each electrical heating element has an adjustable thermostat between 65-90 degrees C and a safety cut-off if the thermostat fails; it cuts off the current at 112 degrees C. Do not switch on power until the calorifier is filled with clean water without chlorine.

Two hot water circulation pumps are installed, with the selection switch one pump can be set into operation and the other pump is standby, the sequence is manual by the selection switch.
2 Technical specification

Hydrophore pumps
Quantity : 2 pcs
Type : SK 3203LA
Make : Speck
Capacity : 5 m³/h at 6 bar.
E-motor : 3.4kW, 3x440V/60Hz
Material : bronze casing, bronze impeller

Fresh Water Hydrophore Vessel
Quantity : 1 pc
Make : Reflex
Capacity : 400 Ltr.
Max. working pressure : 10 bar
Material : Coated carbon steel
Certification : PED

Activated Carbon Water Fine Filter
Quantity : 1 pc
Type : HDCF 7-30
Capacity : 10 m³/h
Max. working pressure : 10 bar
Selectivity : 5 microns
Material : Stainless Steel 1.4521
Number of cartridges : 21pcs/each
Type of cartridges : HAC24870

UV Water Disinfection System
Quantity : 1 pcs
Model : BM175L2
Make : Hatenboer-Water
Capacity : 10 m³/h
Max. working pressure : 10 bar
Material UV chamber : Stainless Steel 1.4521
Power supply : 230V/60Hz, 150Watt

Hot water calorifier
Quantity : 1 pc
Make : OSO
Model : 17 RE-1000cut down
Execution : Vertical ships execution
Volume : 616 ltr.
Heating : Electric 65kW
Electrical supply : 3x440V/60Hz
Working pressure : 10 bar max.
Inner tank : Stainless steel
Outside dimensions : Ø1000 mm x 1500 mm
Net Weight : 260 kg
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<th><strong>Hot water circulation pumps</strong></th>
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<td><strong>Model</strong></td>
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<tr>
<td><strong>E-motor</strong></td>
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</table>
3 Operation

**Consult parts literature before operating the installation.**

**Pressure control**

The hydrophore vessel has two pressure switches to control the pumps. The pressure in the system will decrease when water is consumed. When the pressure has dropped to the switch-on value of pressure switch PS0500-01A (setting 6 – 7 bar) the first pump will start, when the pressure decrease more the second pump will be started by pressure switch PS0500-01B (setting 5 – 6 bar). When less water is consumed, the pressure will increase until the switch-off value of the pressure switches is reached and the pumps will be switched off. The selection of the sequence of the pumps is automatically switched when both pumps are switched off.

**Low pressure alarm**

The unit has a 4-20mA pressure transmitter PT 0500-01 to detect pipe-works burst, a failure of pumps, a blocked suction or other failures.

**Activated carbon fine filter**

As these filters are of a disposal type, regular change of the cartridge is necessary. In case of an increasing pressure drop a filter change has to be carried out. **USE ONLY CARTRIDGES SUPPLIED BY HATENBOER-WATER.** Type HAC24870; art.no. 0210- HAC24870

Read pressure indicators and compare readings with previous readings. In order to compare readings record readings. If the pressure drop is exceeding 0.8 bar over pressure drop with clean cartridges replace the filters. In any case the cartridges should be replaced every 3 months.

The procedure to fill the cartridge filters with filter elements is:

**Filling of cartridge filter**

1. Make sure that the cartridge filter housing is not pressurized and the system is drained.
2. Remove the filter housing top lid by releasing the nuts on top of the filter and remove the old filter elements.
3. Place the filter elements inside the filter housing and check if the filter elements are in a straight upright position.
4. Bring the top lid back on its place and close the filter by turning the nuts.
5. Tighten the nuts crosswise and evenly.
6. De-aerate the filter housing.
7. Flush the filter before use.
8. The procedure is finished.

When the unit is in operation:

1. Check the filter housing upon leaking.
2. Remove any trapped air by opening the air-bleed valve on the top of the filter housing.
**UV disinfection unit**

Before putting the UV-system in operation the following precautionary measures should be taken:

- The pipe work system with the UV-system must be completely filled with liquid and de-aerated.
- The flow-rate of the liquid medium must be sufficiently high to cool the system. A flow of at least 0.1 m³/hour is a typical value.
- Check whether the correct supply voltage is present on the connection contacts in the control cabinet.

Only switch the system on if the end closures are in position or if you are wearing safety glasses. If the end closures are not in position, a small quantity of UV-light can escape via the lamp holders. This can harm your eyes! Never look directly into a UV-lamp that has been switched on!

- Turn the system on using the main switch. The lamps immediately start working and reach the correct output level after 1 to 5 minutes.
- Check the display to make sure all the lamps have been switched on.
- Check the output signal of the UV sensor, see section 2.8 of the manual
- Check the setting of the ECtronic printed circuit board in accordance with section 2.8 of the manual
- The UV-output indicator on the display shows the current UV-intensity.

**Attention!** Repeatedly switching the lamps on and off considerably shortens their life span!

**Warning!** If the lamps are not fully heated up, there is no guarantee of an adequate UV-dose. The flow of liquid is however required for cooling the lamps!

- If necessary, turn the system off using the main switch.

Manual cleaning system

Manual cleaning can take place while the system is operating. The required cleaning frequency depends on the medium and the UV-intensity given on the display (only where a UV-sensor is fitted).

- Remove the locking pin.

**Warning!** By removing the locking pin the handle of the wipe unit can be pressed forcefully to the outside by the pressure in the chamber!

- Pull the wiper system completely out with the handle or handgrip and then push it back in again. If necessary, repeat this action several times.
- Replace the locking pin.

**Hot water Calorifier**

The three heating centres can be switched on individual by the switches on the control panel. Each electrical heating element has an adjustable thermostat between 65-90 degrees C and is factory adjusted.

**Attention!** Do not switch on power until the calorifier is filled with clean water without chlorine.
**Hot water circulation**

In position 1 of the selection switch circulation pump PU0600-01A is continues in operation, in position 2 pump PU0600-01B is continues in operation.

The selection of the pump in operation is manual by the selection switch.
It is advised to switch over ones a week to prevent standstill problems.
4 Installation instructions

1. Before starting any work, make sure that the HATENBOER-WATER hot and cold water unit is horizontally placed on a smooth floor. After filling the unit and vessels with water, the heavy weight of the complete machine prevents further adjustments.

2. Pipe connections must be made to and from the unit for feed water and discharge fresh water, warm water discharge and warm water circulation inlet.

3. The pipe-work must be properly supported and without stress before being connected to the unit. Refer to the Process & Instrumentation Diagram and lay-out drawing for more details. Refer to the Electrical scheme for details. The electrical scheme provides technical information on the control box. In case of an electrical failure refer to the suppliers literature and the electrical schemes.

4. The following connections have to be made by the user on the:

   **MAKE SURE THAT POWER IS SHUT OFF DURING THIS PROCEDURE.**

   a. Power supply (440V AC, 60 Hz, P= 73kW) to "main power switch" of the control panel .
   b. Common alarm
   c. Pump failure alarm

**Attention!** Do not switch on power until the calorifier is filled with clean water without chlorine.

Refer to the electrical drawings for the used coding of terminal connections.

After all connections are made, the thermal relays of the pumps have to be adjusted on the nominal current, which can be found on the nameplate of the pumps.
5 Start-up

The following procedure must be followed to start the Hydrophore unit:

Turn the pump selector switches to the "0" position.

Partly open the isolation valve's and air vent the pumps, as described in the manual of the pumps.

Completely open the isolating valves of the pumps.

Check if valves BV 0500-02, GV 0221-01 and GV0221-02 are closed.

Turn the main switch to position "1". The control voltage light will turn on.

Turn the pump control switch of pump A to "1 - automatic".

Make sure pump 1 starts and rotates in the direction indicated on the pump
Exchange two phases on the terminals if the pump rotates in the opposite direction.

Repeat this for the pump B.

The pressure switches are pre-adjusted and the unit will operate automatically, the pumps will be switch off. If the pressure settings have to be re-adjusted see suppliers literature.

The pressure switches are pre-adjusted and the unit will operate automatically, the pumps will be switch off. If the pressure settings have to be re-adjusted see parts literature of the switch.

Make sure the filter elements are placed in the filter housing.

Slowly open the valves GV 0221-01 and air vent the filter housing.

Slowly open the valves GV 0221-03 and GV 0430-01.
The UV chamber must be completely filled with water (no air is entrapped).
Switch on the UV disinfection units with the Main switch on the UV connection box.
Slowly open the valve GV 0430-03.

Fill up the boiler by opening the cold water inlet valve BV 0600-05. The hot water valve must remain open to let the air escape. The boiler is completely filled up when water flows out of the hot water valve.
Fill the ship hot water system and let the air flow out.
The electric heating can be switched on when the boiler and the system is completely filled with clean water without chlorine.

Put a circulation pump in operation by turning the selection switch in position 1 or 2.

Check the system upon leaking.

Shut-down

If the unit is shut-down for more then eight hours the power for the UV – steriliser must be switched off.
Note: Frequent on/off switching of the UV unit will shorten the UV lamp lifetime.
If the unit is switched off for a longer period the power for the calorifier heating elements must be switched off.

If the total unit is not operated for more than two weeks it’s advised to empty the total system, to remove the filter elements and to preserve the hydrophore pumps.

Before using a system that has been switched off for a longer period, it is advised to disinfect the system with chlorine. To disinfect the drinking water system most yards prescribe a shock chlorine concentration (a approved product such as Hadex®, can be used) High chlorine concentration can damage the heating elements. Be sure the system is rinsed effectively before starting up the calorifier. Free chlorine concentration < 2 ppm

Note: The chlorine content can be check with a chlorine test kit

During the chlorination process, the calorifier must be cold and with the power supply switched off. Place new filter elements in the filter housings before putting the system in operation according the start-up procedure.
6 Fault diagnosis

ALWAYS disconnect power supply before opening the electric control box.

Low pressure alarm
The unit has a pressure transmitter PT0500-01 to signal pipe-works burst, a failure of pumps, a blocked suction, a closed valve or other failures.

Failure hydrophore pump
In case of a thermal shut-off the pump is stopped and an alarm is given through a red lamp on the front of the switchboard and through the general alarm-output.
The other hydrophore pump is switched on.

This alarm is caused by an overload of the pump, dry running of the pump, one phase absent, low air pressure in the hydrophore tank or wrong power supply.

A manual restart can be achieved by pressing the reset button on the thermal-block inside the switchboard, after the cause has been solved.

Failure UV unit
In case of this alarm the UV disinfection is switched off and an alarm is given through a red lamp on the front of the switchboard and through the general alarm-output.

When the “Lamp failure” LED illuminates;
Clean the quartz sleeves if the UV-intensity is too low.
Replace defective lamps (check the lamp indicators on the display), or Replace all lamps because of their age. See the instructions in the UV-system manual.
Check the composition of the liquid and the water temperature.

Calorifier
No heating or inefficient heating.

Check the electrical power supply, the overload protection switch and the safety thermostat of the heating elements.
The reset button of the safety thermostat must be pressed to reset the safety cut off switch.

Circulation pumps
In case of a thermal shut-off the pump is stopped and an alarm is given through a red lamp on the front of the switchboard and through the general alarm-output.
The other circulation pump can be switched on with the selection switch.

This alarm is caused by an overload of the pump, dry running of the pump, one phase absent or wrong power supply.

A manual restart can be achieved by pressing the reset button on the thermal-block inside the switchboard, after the cause has been solved.
7 Recommended spare parts list
8 Drawings and Parts literature

A. Process & Instrumentation Diagram and Parts list no. 476032

B. Lay out drawing no. 476032

C. Electrical diagrams no. 476032

D. Hydrophore pumps : Speck SK 3203LA

E. Hydrophore vessel : Reflex DT5 0400/10

F. Pressure switch : Danfoss CS

G. UV-disinfection unit : BM175/L2

H. Hot water calorifier : OSO 17 RE-616/65kW

I. Circulation pumps : Wilo Stratos Z30/1-12

J. Filter housing : HDCF 7-30

K. Activated carbon fine filter : HAC24870

L. Pressure transmitter : Trafag NAT 0-10
# Spare parts & Consumables Recommendation List

<table>
<thead>
<tr>
<th>Description of Part</th>
<th>Model</th>
<th>Spare part description</th>
<th>Article nr.</th>
<th>Make</th>
<th>Qty for 2 year</th>
<th>Price/pcs</th>
<th>Price total</th>
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<td>Mechanical seal pos. (947) 24.13 right SK-</td>
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*Prices are in Euro excl VAT
*Delivery is free address Netherlands
*Packing & labeling according to makers standard
*Validity until ...2014*
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Weights:
Transport: approx. 1120 kg
Operational: approx. 2120 kg

Center Of Gravity (COG) operational (transport)

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Weights:
Operational: approx. 2120 kg
Transport: approx. 1120 kg

Connections support detail
(Some parts are left out of the view)
All UNP140 except *
Hatenboer-Water BV

PORTABLE WATER SYSTEM
COLD & HOT WATER YNIT

CUSTOMER: 
DAMEN SCHELDE NAVAL - SHIPBUILDING
YARD NR. 414 - PKR

PROJECT INFORMATION:

PROJECT ENGINEER: 
PROJECT NUMBER : 476032-2
CABINET NUMBER : 13010358

CONCEPT 02-07-2013
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* WHEN YOU NEED A (SUPPLY) CURRENT ON ACTIVE SURVEYORS/SENSORS THE SURVEYOR/SENSOR DETERMINES TERMINAL-CODING (X4).

* WHEN YOU NEED A (SUPPLY) CURRENT ON CORRECTION EQUIPMENT THE SUPPLY VOLTAGE DETERMINES TERMINAL-CODING (X4).
SUPPLY
3x440VAC PE
60Hz
Inom: ... A

HEATER 1
Type:...
P=30kW
I\text{nom}=39.5A

HEATER 2
Type:...
P=20kW
I\text{nom}=26A

HEATER 3
Type:...
P=15kW
I\text{nom}=20A
PORTABLE WATER SYSTEM
COLD & HOT WATER UNIT

Hatenboer-Water BV
Postbus 6013
3002 AA Rotterdam

MAIN VOLTAGE

Control Voltage
230VAC
24VAC

Supply
UV-Steriliser
230V

Type: BM175c L1
P = 0.18kW
I = 1.6A

CabinetFan 1
CabinetFan 2

12S9

12F6
4A-K

12T6
440-230V
630VA

12F6.1
4A-K

12F9
2A-K

12M9

12F16
4A-K

12T16
440-24V
250VA

12F16.1
6A-K

12A6

11.18/L1
11.18/L2
11.18/L3
Hatenboer-Water BV
Postbus 6013
3002 AA Rotterdam

PORTABLE WATER SYSTEM
COLD & HOT WATER UNIT

CONTROL VOLTAGE

- 13.18/C 24VAC
- 14S3 10F9 14H5
- 14S9 10F9 14H8
- 14Q4 14K6 14Q10
- LC1D32B7 MY4N 24VAC
- 17.8 10.13 17.8 10.13 17.8 10.13 17.8 10.13
- 10.9 10.9 10.9 10.9 10.9 10.9
- 14H11 14K12 14H14 14K15
- LC1D32B7 MY4N 24VAC MY4N 24VAC
- 17.13 17.13 17.13

FAILURE UV-UNIT

HEATER 2

OPERATIONAL

FAILURE

HEATER 3

OPERATIONAL

FAILURE
## PORTABLE WATER SYSTEM
### COLD & HOT WATER UNIT

**Table 1: Terminal Connections**

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**Diagram 1: PE-Terminal = EarthRail**

---

Hatenboer-Water BV  
Postbus 6013  
3002 AA Rotterdam
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### PORTABLE WATER SYSTEM

#### COLD & HOT WATER YNIT

**X3**

**PE-TERMINAL = EARTHRAIL**

---

**Hatenboer-Water BV**

**PORTABLE WATER SYSTEM**

**COLD & HOT WATER YNIT**

---

**Page:** 19 of 26

**Date:** 02.07.2013

**Rev.:** JPS

**Issue:** JPS
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**Cable**
- **W4-001**: 2x
- **W4-002**: 2x

**Terminal**

**Page/Path**

**Designation**
- 17.2: PRESSURE TRANSMITTER 0-10BAR
- 17.3: SIGNAL PRESSURE TRANSMITTER 0-10BAR
- 17.4: = 17PT2 = 17PT2

**Date**
- 02.05.2013
- 02.07.2013

**Rev.**
- 01

**Drawn:**
- 02

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**PE-TERMINAL = EARTHRAIL**
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Hatenboer-Water BV
Postbus 6013
3002 AA Rotterdam

PORTABLE WATER SYSTEM
COLD & HOT WATER YNIT

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<td>LED FRONTM. 18-30V RED CAGE</td>
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<td>AUXILIARY RELAY 24VAC 4CH LED+TEST</td>
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