Technical Analysis Ballast Water Treatment Using Economizer Utilizing Main Engines Exhaust Heat to Comply with International Ship Ballast Water Management at "MV. Leader Win"

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Abstract*— based on the International Ballast Water Management regulations (IBWM), waste water ballast itself has the attention of some researchers to reduce the amount of waste species present in the ballast water with a variety of methods, as of biological, physical, mechanical, and chemical. The decision-making tools such as ballast water heater, flow-through system and others where possible these tools can minimize waste species in ballast water at a certain temperature or pressure of the flow according to the calculations. This study was aimed to calculate and analysis the effectiveness of the system treatment between Option 1 (Economizer & Bundle) and Option 2 (Economizer & Heat Excharger) then it will compare. First option is using economizer and bundles to transfer a heat from a source heat of exhaust gas then medium by thermal oil circulated. The second option is using economizer and heat excharger where a same heat source , but sea water from ballast tank sirculated to heat excharger. And from economizer to heat excharger is using thermal oil as a heat medium. For all calculation and anaalysis is using softwere HTRI. First option having a duty 2.503 MegaWatts at economizer and 1.9567 MegaWatts at bundles. Over design 2.01% at Economizer and 7.1%5 at bundles. Pessure drop 63.287 kPa at thermal oil after economizer and 68.196 kPa after bundles. Treatment time to this option is 44.424 hors. Second option having a duty 3.38 MegaWatts at economizer and 3.1227 MegaWatts at heat excharger. Over design 5.85% at Economizer and 3.49%5 at heat excharger. Pessure drop 38.697 kPa at thermal oil after economizer and 28.476 kPa after heat excharger. Treatment time to second option is 42.03 hours. Option 2 (Economizer & Heat Excharger) is more optimum than option in analytical techniques. By analysis of treatment system, are expected this thesis can be applied to either the MV. Leader Win Vessel to comply with the operational needs according to standard employability.

Keywords— international ballast water management, software HTRI, economizer, heat excharger, bundle, thermal oil, temperature

I. INTRODUCTION

Ballast water is currently an important concern in addition to the dirty water issue but also suspected to be the source of the global spread of microorganisms. Ballast water like this became one of the problems of marine pollution due to waste water discharge ballast vessel on the high seas. From the problems of course already set by IMO concerning the standardization of waste disposal of ballast water in certain zones. The issuance of regulations on ballast water management are intended to reduce the spread of marine organisms that are not controlled. The standard regulates the charging and discharging ballast water, are not allowed to spend more than 10 live organisms per cubic meter, equivalent to the size of more than 50 micrometers and may not put out more than 10 living organisms per milliliter of size less than 50 micrometers. Indicator discharge microorganisms should not exceed concentrations determined namely Toxicogenic Vibrio cholerae less than 1 cfu (colony forming units) per 100 milliliters or less than 1 cfu per gram zooplankton, Escherichia coli less than 250 cfu per 100 milliliters and intestinal entericocci less than 100 cfu per 100 milliliters.

Based on the International Ballast Water Management regulations (IBWM), waste water ballast itself has the attention of some researchers to reduce the amount of waste species present in the ballast water with a variety of methods, as of biological, physical, mechanical, and chemical. The decision-making tools such as ballast water heater, flow-through system and others where possible these tools can minimize waste species in ballast water at a certain temperature or pressure of the flow according to the calculations.

From the various methods of technical treatment of ballast water, in this final project chose to use methods of ballast water heater. Where the heat is use the heat from the main engine exhaust gas vessel which will be distributed in such a way by using economizer. Using the ballast system design of the vessel "MV. Leader Win " key plan will be modified therefore, the technical treatment methods ballast water heater can be applied economically for ship owners and technical treatment can be said to be environmentally sociable.

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II. LITERATURE REVIEW

Ballast water is water used to ballast and balancer while the vessel voyage. Therefore addition and substraction to keep ship balance, ballast water exchange will be removal the microorganism or other pollutants while sailing and will contaminate destination port.

Inside of International Health Regulation, that mentioned din every harbor or air port shall available efective ways adn safety in terms of sewage and waste disposal along other things dangerous for health.

Ballast water exchange vessel get an attention from IMO (International Maritim Organization), with issue a regulation which requires ballast water in deballasting process shall be clean water condition. This regulation can fulliled with many kind ways, therefore deballasting water in clean conditio and safety at destination port.

Issued regulation about ballast water management means for decrease spread of sea microorganism uncontrolled. This following standard of ballast water management adjusted to vessel size and build year :

Standard of ballast water management based on regulation D-1 :

When ballasting or deballasting process , ship system shall capable to charging or emtying at least 95% from total of ballast thank capacity.

For ship use with pumping-through method, pumping ability shall can pumping continously during charging 3x ballast tank volume.

Standard of ballast water management based on regulation D-2 :

Ships conducting Ballast Water Management in accordance with this regulation shall discharge less than 10 viable organisms per cubic metre greater than or equal to 50 micrometres in minimum dimension and less than 10 viable organisms per millilitre less than 50 micrometres in minimum dimension and greater than or equal to 10 micrometres in minimum dimension; and discharge of the indicator microbes shall not exceed the specified concentrations described in paragraph 2.

Indicator microbes, as a human health standard, shall include:

Toxicogenic Vibrio cholerae (O1 and O139) with less than 1 colony forming unit (cfu) per 100 millilitres or less than 1 cfu per 1 gram (wet weight) zooplankton samples ;

Escherichia coli less than 250 cfu per 100 millilitres;

Intestinal Enterococci less than 100 cfu per 100 milliliters.

Balaji and Yaakob had analyzed heat availability on board an operational tanker, considering all available waste heat. The range of temperatures on shipboard diesel engines for propulsion and auxiliary purposes would be around 200-450º C, depending upon the loads.

Motor ships have greater waste heat potential in the engine exhaust gases. For harvesting this heat, a heat exchanger design was optimised using the Lagrangean methods. A combination treatment system was envisaged including the optimised heat exchanger. The envisaged system was developed based on the existing system on board an operational vessel. The working of the system was checked on two separate engine test rig arrangements. Two heat exchanger designs were developed to suit the engines and the identified heat duties. Heat exchangers suitable for the duties were commercially procured and fitted. The paper reports on the development of the heat exchanger designs for the tests and comparison with the fitted heat exchangers.

The designs of heat exchangers for experiments were developed on the basic characteristics of this optimised design. The optimised shipboard design was developed for harvesting exhaust heat from a 2-stroke engine. However, due to non-availability of marine 2-stroke diesel engines at laboratory levels, 4-stroke engines were chosen. Moreover, the control and measurement systems (Dynamometer etc.) available in workshops were well suited for 4-stroke engines only. The data for design were based on the parameters of 4-stroke engines employed for experiments. Since only temperatures and heat recovery percentages (of input energies) were significant for the experiments, the use of 4-stroke engines was justified.

The heat absorbed by the engine cooling water systems and the structure (engine parts), losses in radiation, lubricating oil and exhaust gases, as also the useful work realised on the shaft are accountable in this input energy. The heat energy absorbed by various systems will be the product of the mass flow rate and specific heat capacity and temperature rise. The heat balance and hence the heat availability for treatment was computed based on this.

Heat lost to exhaust gases were higher indicating a greater potential for waste heat recovery. The analyses based on test bed heat recovery experiments by Balaji and Yaakob had recorded a maximum recovery of 33 % from exhaust gases. Cooling water had accounted for 5.38 % and shaft power accounted for 43.86 % of the input energies.

Assuming steady state and neglecting heat losses due to radiation, the heat available in exhaust gases would be

$$Qexg = mg \cdot Cg \cdot \Delta Tg \qquad (1)$$

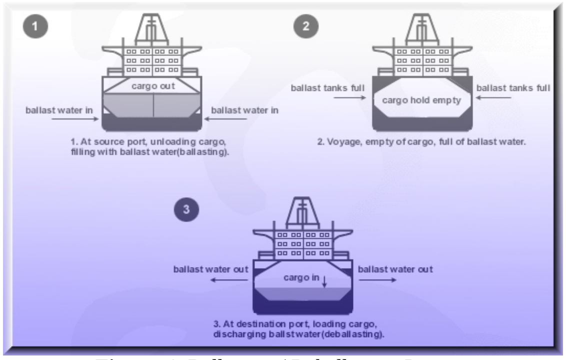

Figure. 1. Ballasting / Deballasting Process

Figure. 2. Microorganism selection by *IMO*

Figure 2 shows the kinds of microorganisms which selected by IMO. Those microorganisms should be killed by treatment system. The method is using ballst water heating. It can be die at 60°C during 30 minutes.

III. RESEARCH METHODOLOGY

In this research is used methodology. Methodology is determine of porpuse and step to do this Final Project. The function of methodology is main sketch to determine this research. This Final Project is use mix method, as following : (1) Identification and Problem Formulation (2) Looking for Data and Study Literature (3) Analysing and Intrepresentation Data (4) Draw Design (key plan & isometry) and Report.

3.1. Study Literature

Study Literature is a first step to do this research to looking for many references and analysis material. Those are shall accordance by confidence literature then help to do this Final Project.. Study Literature can take from sourch of references such as Book, Catalog, Journals, Papers, etc.

3.2. Data Collection

After collect of study literature, the next step is collect data. There are Main data Vessel, performance main engine data (project guide), characteris microorganism, properties of sea water, exhaust gas, and thermal oil. Thats all shall needed to calculated and inputed on HTRI software.

3.3.Calculation of Data

From Data collection before, then can make calculations . the calculation as following :

a) Calculation of Mass Flow Rate of Exhaust Gas
b) Calculation of Mass Flow Rate Thermal Oil (Option 1 (Economizer & Bundle))
c) Calculation of Mass Flow Rate Sea Water (Option 1 (Economizer & Bundle))
d) Calculation of Mass Flow Rate Thermal Oil (Option 2 (Economizer & Heat Excharger))
e) Calculation of Mass Flow Rate Sea Water (Option 2 (Economizer & Heat Excharger))
f) Calculation of Pressure Drop Ballast Water Treatment Option 1 (Economizer & Bundle)
g) Calculation of Pressure Drop Ballast Water Treatment Option 2 (Economizer & Heat Excharger)

3.4. Running HTRI Software

Running HTRI Software is needed to Find Optimum Dimention, duty, over design and temperatur of Economizer, Bundle and Heat Excharger Design. To running this software, so there are need data collection such as sea water properties, thermal oil properties, exhaust gas properties. The properties are mass flow rate, temperature, fouling resistance, pressure drop of exhaust gas, and etc.

Because in this step is to find optimum all of data above, so the scenario can be change or mass flowrate thermal oil or sea water to get effective system, that treatment time is not exceed than sailing time.

3.5. Analysis Running HRTI Software

Analyis flowrate and time treatment between Option 1 (Economizer & Bundle) & 2 from running that software shall be known the results to be analyzed as follows over design, pressure drop, duty, and temperature. Treatment time is also calculated and analyzed as a comparison between Option 1 (Economizer & Bundle) and Option 2 (Economizer & Heat Excharger). The results
Of analysis shall be write by table.

3.6. Design Key Plan and Isometry

Key plan and Isometry Ballast Treatment are included of analysis processing steps, one of which is to determine the number of fittings resistance and head losses which have been converts to pressure to determine the ability of pump to the pressure drop is calculated. Design of Ballast system had fullfil, will make as key plan and Isometry. So it will be look how the scenario at both system.

3.7. Compiling Material Requirment Plan (MRP)

In this step is compile the material of all in the ballast water treatment. Such a material, schedule of pipe, fitting (valve, SDNRV, filter), economizer, bundle, and heat excharger.

3.8. conclution and Suggestion

Conclution and Suggestion made based all aspec of this Final Project discussion.

IV. RESULTS AND DISCUSSION

4.1 Prinsipal Dimention

Principal Dimention of MV. Leader Win :

Loa	: 110	m
Lwl	: 105.06 m	
Lpp	: 102	m
B	: 18.8	m
H	: 12.7	m
T	: 7.964	m
Cb	: 0.682	
Vs	: 14	knot
Type	: General Cargo	

4.2 Data of Performance Main Engine

WÄRTSILÄ 32

Wärtsilä 32 - Project guide
1. General data and outputs

1. General data and outputs

The Wärtsilä 32 is a 4-stroke, non-reversible, turbocharged and intercooled diesel engine with direct fuel injection.

Cylinder bore	320 mm
Stroke	400 mm
Piston displacement	32.2 l/cylinder
Number of valves	2 inlet valves 2 exhaust valves
Cylinder configuration	6, 7, 8 and 9 in-line 12, 16 and 18 in V-form
V-angle	55°
Direction of rotation	Clockwise, counterclockwise on request
Speed	720, 750 rpm
Mean piston speed	9.6, 10.0 m/s

1.1 Maximum continuous output

Table 1.1 Rating table for Wärtsilä 32

Cylinder configuration	Main engines	Generating sets			
	750 rpm	720 rpm		750 rpm	
	[kW]	Engine [kW]	Generator [kVA]	Engine [kW]	Generator [kVA]
W 6L32	3000	2880	3460	3000	3600
W 7L32	3500	3360	4030	3500	4200
W 8L32	4000	3840	4610	4000	4800
W 9L32	4500	4320	5180	4500	5400
W 12V32	6000	5760	6910	6000	7200
W 16V32	8000	7680	9220	8000	9600
W 18V32	9000	8640	10370	9000	10800

WÄRTSILÄ 32

Wärtsilä 32 - Project guide
3. Technical data

3.3 Wärtsilä 8L32

Wärtsilä 8L32		AE/DE	AE/DE	CPP/FPP
Engine speed Cylinder output	RPM kW/cyl	720 480	750 500	750 500
Engine output	kW	3840	4000	4000
Mean effective pressure	MPa	2.49	2.49	2.49
Combustion air system (Note 1)				
Flow at 100% load	kg/s	6.59	6.98	6.98
Temperature at turbocharger intake, max.	°C	45	45	45
Air temperature after air cooler (TE 601)	°C	55	55	55
Exhaust gas system (Note 2)				
Flow at 100% load	kg/s	6.8	7.2	7.2
Flow at 85% load	kg/s	6.45	6.8	6.7
Flow at 75% load	kg/s	5.8	6.1	5.8
Flow at 50% load	kg/s	4.1	4.3	4.6
Temperature after turbocharger, 100% load (TE 517)	°C	390	385	385
Temperature after turbocharger, 85% load (TE 517)	°C	336	330	330
Temperature after turbocharger, 75% load (TE 517)	°C	337	330	350
Temperature after turbocharger, 50% load (TE 517)	°C	360	350	330
Backpressure, max.	kPa	3.0	3.0	3.0
Exhaust gas pipe diameter, min	mm	700	700	700
Calculated pipe diameter for 35m/s	mm	680	697	697

Figure. 3. Data of Performance Main Engine

Figure 3 is show of data from engine project guide. There is available value of output engine degree celcius, diameter pipe of exhaust gas. And etc.

4.3 Properties Necessary for Running Software HTRI

4.3.1 Ballast Tank Dimention

This ballast tank dimention/volume is used to compliance data to do this Final Project. These tanks is used to known and calculate thermal oil and sea water mass flow rates. Detail calculation of that will explained at sub-chapter 4.4. Data of ship ballast tanks volume as follows on table 1. This Final project is use the biggest volume of tank (marked) to calculate the sea water flow rates shall be known. ¼ Ballast tank volumre is used to calculate sea water flow rates at Ballast Treatment System Option 2 (Economizer & Heat Exchanger)

4.3.2 Exhaust Gas Properties

In this Final Project Ballast Water Treatment is using heating method. The source is take from heat exhaust gas main engine vessel or called heat recovery. As for exhaust gas properties needed and then input those data like density, viskocity, specific heat, pressure of exhaust gas, and etc to Software HTRI. Those properties are needed to knowing a summary of running that software. The properties table shal be known as follows on table 2.

TABLE 1.
BALLAST TANK VOLUME

Data volume ballast tank by tank :			
Total Ballast Tanks Volume	=	2114.10	m^3
Ballast Tank Volume I	=	192.75	m^3
Ballast Tank Volume II	=	192.75	m^3
Ballast Tank Volume III	=	383.68	m^3
Ballast Tank Volume IV	=	383.68	m^3
Ballast Tank Volume V	=	304.80	m^3
Ballast Tank Volume VI	=	304.80	m^3
Forepeak Tank Volume I	=	175.83	m^3
Forepeak Tank Volume II	=	175.83	m^3
1/4 V. Tanki Ballast :			
Ballast Tank Volume I	=	48.19	m^3
Ballast Tank Volume II	=	48.19	m^3
Ballast Tank Volume III	=	95.92	m^3
Ballast Tank Volume IV	=	95.92	m^3
Ballast Tank Volume V	=	76.20	m^3
Ballast Tank Volume VI	=	76.20	m^3
Forepeak Tank Volume I	=	43.96	m^3
Forepeak Tank Volume II	=	43.96	m^3

TABLE 2.
EXHAUST GAS PROPERTIES

T	ρ	h	s	C_p	μ	k
260	1.34	260	6.727	1.006	0.165	0.0231
280	1.245	280.2	6.802	1.006	0.175	0.0247
300	1.161	300.3	6.871	1.007	0.185	0.0263
350	0.995	350.7	7.026	1.009	0.208	0.0301
400	0.871	401.2	7.161	1.014	0.23	0.0336
450	0.774	452.1	7.282	1.021	0.251	0.0371
500	0.696	503.4	7.389	1.03	0.27	0.0404
600	0.58	607.5	7.579	1.051	0.306	0.0466
800	0.435	822.5	7.888	1.099	0.37	0.0577
1000	0.348	1046.8	8.138	1.141	0.424	0.0681
1200	0.29	1278	8.349	1.175	0.473	0.0783
1400	0.249	1515	8.531	1.207	0.527	0.0927

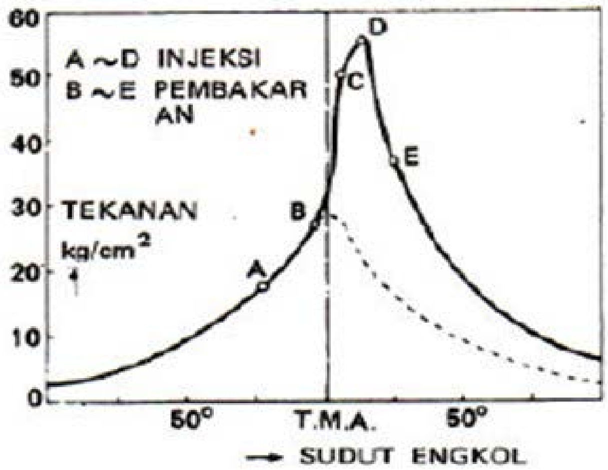

Chart. 1. Process Combustion Engine

From graphic on Chart 1 is known pressure of exhaust gas = 8.0047 kg/cm2 or 785 kPa.
That property tabel was obtaind from internet, cause unavailable on main engine project guide.

4.3.3 Thermal Oil Properties

Thermal oil is used as heating medium ballast water, where thermal oil circulated in Economizer to Heat Exchanger or Bundle. Thermal oil receives heat from main engine flue gas heat then circulated to units which have been mentioned. For thermal oil properties is already available in Software HTRI. In this Final Project is use Therminol LT for type of thermal oil. At menu data input on that software can be selected types of thermal oil as follows on Figure 4.

In addition to the software is already available properties like density, viscocity, spesific heat, and etc as folows on figure 5.

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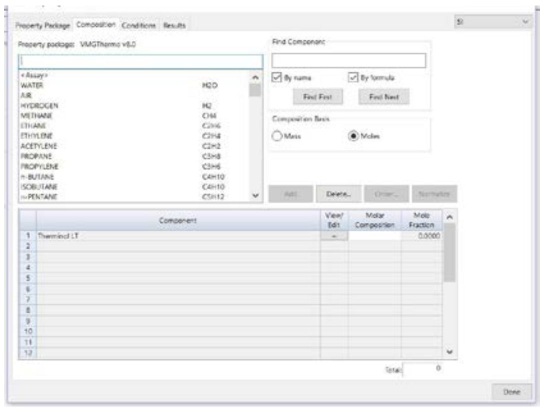

Figure. 4. Example types of Thermal Oil in Software HTRI

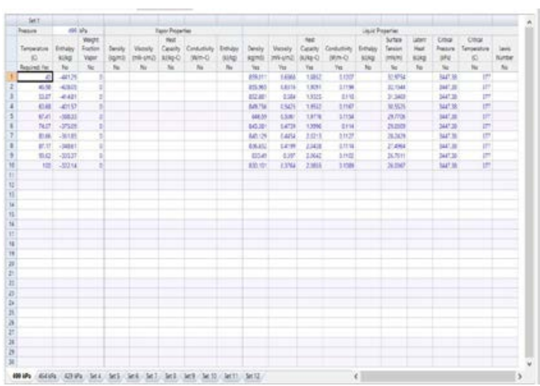

Figure. 5. Properties of Therminol LT in Software HTRI

4.3.4 Sea Water Properties

Sea water on ballast thank will be in treatment base on ballast water management standards. Sea water receiving heat from thermal oil inside of bundle or heat excharger. The software is not already available properties like density, viscocity, spesific heat, and etc. So, sea water properties are use reference from internet as follows on Figure 6.

At menu data input on that software can be inputted sea water properties as follows on Figure 7.

mathematical models are expressed below:

4.4 Data Calculation

4.4.1 Mass Flow Rate of Exhaust Gas

The recommended flow velocity in the pipe is 35…40 m/s at full engine output. If there are many resistance factors in the piping, or the pipe is very long, then the flow velocity needs to be lower. The exhaust gas mass flow given in chapter Technical data can be translated to velocity using the formula:

$$v = \frac{4\,x\,m}{1.3\,x\left(\frac{273}{273+t}\right)x\,\pi\,x\,D^2}$$

$$40 = \frac{4\,x\,m}{1.3\,x\left(\frac{273}{273+330}\right)x\,3.14\,x\,0.72}$$

40 = 4m / 1.54621

$$m = \frac{40 \times 1.54621}{4}$$

m = 15.462 kg/s

Where :

v = Gas velocity, 40 [m/s]
m = Exhaust gas mass flow [kg/s]
t = Exhaust gas temperature, 330 [°C] at85%
D = Exhaust gas pipe diameter, 0.7 [m]

Properties of Seawater

		State 1			State 2	
Temperature	ϑ_1	20	°C	ϑ_2	30	°C
Salinity	x_1	10	g/kg	x_2	45	g/kg
Density	ρ	1006	kg/m³	ρ	1029	kg/m³
Specific heat capacity	cp	4131	J/(kg·K)	cp	3947	J/(kg·K)
Thermal conductivity	λ	0.603	W/(m·K)	λ	0.6135	W/(m·K)
Dynamic viscosity	η	1.021	mPa·s	η	0.8759	mPa·s
Kinematic viscosity	ν	0.001015	m²/s	ν	0.000851	m²/s
Prandtl number	Pr	6.995	-	Pr	5.635	-
Thermal diffusivity	a	1.451E-7	m²/s	a	1.511E-7	m²/s
Coeff. of thermal expansion	β	0.000698	1/K	β	0006682	1/K

Validity: 0 °C ≤ ϑ ≤ 180 °C
0 g/kg ≤ x ≤ 150 g/kg

Figure. 6. Properties of Sea Water

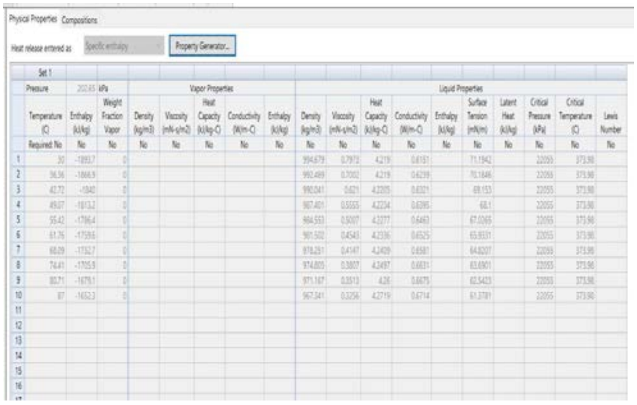

Figure. 7. Input Properties of Sea Water in Software HTRI

4.4.1 Mass Flow Rate Thermal Oil (Option 1 (Economizer & Bundle))

1) Massflowrate of thermal oil :

ṁ = Q x ρ / 3600 ⟶ Q = get from spesification pump (this flow rate is most optimum number)

= 178 x 830.05 / 3600

= 41 kg/s

This number of mass flow rate will inputted into the softwere HTRI.

4.4.2 Mass Flow Rate Sea Water (Option 1 (Economizer & Bundle))

For Option 1 (Economizer & Bundle), sea water receiving heat from bundle.

Velocity of sea water :

v = Q/A ⟶ Q = V/t

$= \frac{47.96}{0.7425}$ = $\frac{383.68}{8}$

= 64.59 m/hr = 47.96 m^3/hr

= 0.01 8 m/s

where :
V = Volume (m3
t = Time (certained) (hr)

Massflowrate of sea water :

ṁ = Q x ρ / 3600
= 47.96 x 1121 /3600
= 13.66 kg/s

A = p x l
= 1.5 x 0.495
= 0.7425 m^2

where :
p = long of bundle (m)
l = wide of bundle (m)

This number of mass flow rate will inputted into the softwere HTRI.

Particle of sea water on ballast tank are quiet, but while thermal oil circulate on tube of bundle and it will make convection heat transfer . This make sea water particle moving on each other. Velocity of sea water on the biggest tank is 0.018 m/s with time heating 8 hours. Detail time calculate for all tank will be explained at sub-chapter 4.6.

4.4.3 Mass Flow Rate Thermal Oil (Option 2 (Economizer & Heat Exchanger))

2) Massflowrate of thermal oil :

ṁ = Q x ρ / 3600 ⟶ Q = get from spesification pump (this flow rate is most optimum number)
= 240 x 830.05 / 3600
= 55.34 kg/s

This number of mass flow rate will inputted into the softwere HTRI.

4.4.4 Mass Flow Rate Sea Water (Option 2 (Economizer & Heat Excharger))

For Option 2 (Economizer & Heat Excharger), sea water is circulated from ballast tank then pass into heat exchanger then entered into other ballast tank (modification tank) and then it shall circulated back into the first tank.

1) Massflowrate of sea water :

ṁ = Q x ρ / 3600 ⟶ Q= get from spesification pump (this flow rate is most optimum number)
= 70 x 1025 / 3600
= 21.80 kg/s

This number of mass flow rate will inputted into the softwere HTRI.

Sea water on ballast thank will be circulated to Heat Excharger. After passing on Heat exharger, where heat from thermal oil transferred to sea water on tubes of heat excharger. Detail time calculate for all tank will be explained at sub-chapter 4.6.

4.4.5 Calculation Pressure Drop Ballast Water Treatment Option 1 (Economizer & Bundle)

A. Calculation Pressure Drop Thermal Oil

Total head losses (Hl) = hs + hv + hp + hf1 + hl1 + hf2 + hl2
= 0 + 0 + 0 + 0.68 + 1.208 + 5.628 + 1.264 + 0.530 + 0.531
= 9.84 m

Pressure from suc. and disc. Pump = 96.51 kPa
Pessure drop at Bundle A = 34.014 kPa
Pessure drop at Bundle B = 34.181 kPa
Pessure drop at Economizer = 63.287 kPa

Total pressure = pressure drop pump + prssure drop Bundle A + prssure drop Bundle B + prssure drop economizer
= 96.51 + 34.014 + 34.181 + 63.287
= 227.99 kPa

TABLE 3.
SPESIFICATION OF BALAST TREATMENT (THERMAL OIL0 PUMP OPTION 1 (ECONOMIZER & BUNDLE)

Merk	=	**Sili Pump RY 125 - 100 - 200**	
Capacity	=	178	m^3/hr
Head	=	40	m
Temperature	=	350	°C
Speeds	=	3500	rpm
Frequent	=	60	Hz

4.4.6 Calculation Pressure Drop Ballast Water Treatment Option 2 (Economizer & Heat Excharger)

B. Calculation Pressure Drop Thermal Oil

Total head losses (Hl) = hs + hv + hp + hf1 + hl1 + hf2 + hl2
= 0 + 0 + 0 + 0.90 + 0.873 + 0.45 + 0.146 + 0.27 + 10140
= 3.74 m

Pressure drop suc. and disc. Pump = 36.65 kPa
Pessure drop at H.E = 28.476 kPa
Pessure drop at Economizer = 38.697 kPa

Total pressure = pressure pump + prssure H.E + pressure eco.
= 36.65 + 28.476 + 38.697
= 103.82 kPa

Spesification of pump will be show at Table 4.

4.4.7 Calculation Pressure Drop Thermal Oil

Total head losses (Hl) = hs + hv + hp + hf1 + hl1 + hf2 + hl2
= 7.25 + 0 + 0 + 12.76 + 0.495 + 6.531 + 0.307 + 0.408 + 0.317
= 28.07 m

Pressure from suc. and disc. Pump = 275.19 kPa
Pessure drop at H.E = 4.747 kPa

Total pressure = pressure pump + prssure H.E
= 275.19 + 4.747
= 279.94 kPa

Spesification of sea water pump will be show at Table 5.

TABLE 4.
SPESIFICATION OF BALAST TREATMENT (THERMAL OIL) PUMP OPTION 2 (ECONOMIZER & HEAT EXCHARGER)

Merk	=	**Sili Pump RY 125 - 100 - 200**	
Capacity	=	240	m^3/hr
Head	=	70	m
Temperature	=	350	°C
Speeds	=	3500	rpm
Frequent	=	60	Hz

TABLE 5.
SPESIFICATION OF BALAST TREATMENT (SEA WATER) PUMP OPTION 2 (ECONOMIZER & HEAT EXCHARGER)

Merk	=	**Sili Pump 100CLH -8.5**	
Capacity	=	70	m^3/hr
Head	=	45	m
Temperature	=	80	°C
Speeds	=	2900	rpm
Frequent	=	50	Hz

4.5 Analysis of Running Software HTRI Summary

4.5.1 Analysis Ballast Treatment Option 1 (Economizer & Bundle)

From running that software shall be known the results to be analyzed as follows over design, pressure drop, duty, and temperature. Treatment time is also calculated and analyzed as a comparison between Option 1 (Economizer & Bundle) and Option 2 (Economizer & Heat Excharger).

Result of Running Software HTRI For Economizer will be show on Table 6, and from that can be obtained as follows on Table 7.

With that results, so Economizer needs ballast water treatment systems already optimum for option.

Result of Running Software HTRI For Bundle will be show on Table 8, and from that can be obtained as follows on Table 9.

Treatment time shall be calculate as following :

$Q = \dot{m} \times cp \times \Delta T \longrightarrow \dot{m} = \Delta m/\Delta t$
$\dot{m} = \Delta m/\Delta t$ $\quad m = \rho \times V$
$t = m/\dot{m}$
$m = 1025 \times 383.675$
$= 393267/13.66$
$m = 393267$ kg
$t = 8$ hr

Total treatment time all ballast water tanks will be show on Table 10.

TABLE 6.
RESULT OF RUNNING SOFTWARE HTRI FOR ECONOMIZER 1

Output Summary P
Released to the following HTRI Member Company:
PT Heat Transfer Solutions Indonesia
Joko Paritono

Xace 7.3 Beta 12/6/2016 16:57 SN: 08983-36984811 **SI U**

Rating-Horizontal economizer countercurrent to crossflow

No.							
1	See Data Check Messages Report for Warning Messages.						
2	See Runtime Message Report for Warning Messages.						
3	**Process Conditions**		**Outside**		**Tubeside**		
4	Fluid name		Gas Buang		Thermal Oil		
5	Fluid condition			Sens. Gas		Sens. Liq	
6	Total flow rate	(kg/s)		15.462			
7	Weight fraction vapor, In/Out		1.0000	1.0000	0.0000	0.0	
8	Temperature, In/Out	(Deg C)	330.00	169.63	70.00	100	
9	Skin temperature, Min/Max	(Deg C)	115.47	206.59	96.42	159	
10	Pressure, Inlet/Outlet	(kPa)	785.00	781.66	499.00	435	
11	Pressure drop, Total/Allow	(kPa) (kPa)	3.337	10.000	63.287	70.	
12	Midpoint velocity	(m/s)		15.36		2	
13	- In/Out	(m/s)			2.67	2	
14	Heat transfer safety factor	(--)		1.0000		1.0	
15	Fouling	(m2-K/W)		0.001761		0.000	
16			**Exchanger Performance**				
17	Outside film coef	(W/m2-K)	57.88	Actual U	(W/m2-K)	31.	
18	Tubeside film coef	(W/m2-K)	3084.7	Required U	(W/m2-K)	30.	
19	Clean coef	(W/m2-K)	38.716	Area	(m2)	528	
20	Hot regime		Sens. Gas	Overdesign	(%)	2	

No.							
16				**Exchanger Performance**			
17	Outside film coef	(W/m2-K)		57.88	Actual U	(W/m2-K)	31.
18	Tubeside film coef	(W/m2-K)		3084.7	Required U	(W/m2-K)	30.
19	Clean coef	(W/m2-K)		38.716	Area	(m2)	528
20	Hot regime			Sens. Gas	Overdesign	(%)	2
21	Cold regime			Sens. Liquid	**Tube Geometry**		
22	EMTD	(Deg C)		155.5	Tube type		High-fin
23	Duty	(MegaWatts)		2.503	Tube OD	(mm)	25.
24	**Unit Geometry**				Tube ID	(mm)	22.
25	Bays in parallel per unit			1	Length	(m)	1.
26	Bundles parallel per bay			1	Area ratio(out/in)	(--)	26.
27	Extended area	(m2)		528.53	Layout		Stagge
28	Bare area	(m2)		27.386	Trans pitch	(mm)	60.
29	Bundle width	(m)		1.377	Long pitch	(mm)	52.
30	**Nozzle**		**Inlet**	**Outlet**	Number of passes	(--)	
31	Number	(--)	1	1	Number of rows	(--)	
32	Diameter	(mm)	193.68	193.68	Tubecount	(--)	
33	Velocity	(m/s)	1.65	1.68	Tubecount Odd/Even	(--)	22 /
34	R-V-SQ	(kg/m-s2)	2291.2	2333.4	Material		Cop
35	Pressure drop	(kPa)	1.260	0.817	**Fin Geometry**		
36	**Fan Geometry**				Type		Circ
37	No/bay	(--)		0	Fins/length	(fin/meter)	43
38	Fan ring type				Fin root	(mm)	25.
39	Diameter	(m)		0.000	Height	(mm)	15.
40	Ratio, Fan/bundle face area	(--)		0.0000	Base thickness	(mm)	0.
41	Driver power	(kW)		0.00	Over fin	(mm)	57.
42	Tip clearance	(mm)		0.000	Efficiency	(%)	8
43	Efficiency	(%)		0.0000	Area ratio (fin/bare)	(--)	23.
44	**Airside Velocities**		**Actual**	**Standard**	Material		Cop
45	Face	(m/s)	8.15		**Thermal Resistance, %**		
46	Maximum	(m/s)	21.04		Air		53
47	Flow	(100 m3/min)	8.756		Tube		26
48	Velocity pressure	(Pa)	0.00		Fouling		19
49	Bundle pressure drop	(Pa)	3337.2		Metal		0
50	Bundle flow fraction	(--)	1.000		Bond		0
51	Bundle	100.00	**Airside Pressure Drop, %**		Louvers		0
52	Ground clearance	0.00	Fan guard	0.00	Hail screen		0
53	Fan ring	0.00	Fan area blockage	0.00	Steam coil		0

TABLE 7.
POINT OF ECONOMIZER 1 CALCULATION

No.	Properties	Calculation	Max. Value
1.	Over Design	2.01 (%)	10 (%)
2.	Pressure drop exhaust gas	3.337 (kPa)	10 (kPa)
3.	Pressure drop thermal oil	63.287 (kPa)	70 (kPa)
4.	Duty	2.503 (MegaWatts)	
5.	Temperature exhaust gas	169.63 (°C)	330 (°C)
6.	Temperature thermal oil	70 (°C)	100 (°C)

TABLE 8.
RESULT OF RUNNING SOFTWARE HTRI FOR BUNDLE

Output Summary Page 1
Released to the following HTRI Member Company:
PT Heat Transfer Solutions Indonesia
Joko Paritono

Xist 7.3 Beta 12/6/2016 16:58 SN: 08983-36984811 **SI Units**

: Summary Unit
Rating - Vertical With No Baffles

No.							
1	**No Data Check Messages.**						
2	**No Runtime Messages.**						
3	**Process Conditions**		**Cold Shellside**		**Hot Tubeside**		
4	Fluid name			sea water		hot oil	
5	Flow rate	(kg/s)		13.66		41.000	
6	Inlet/Outlet Y	(Wt. frac vap.)	0.0000	0.0000	0.0000	0.0000	
7	Inlet/Outlet T	(Deg C)	30.00	70.00	100.00	76.61	
8	Inlet P/Avg	(kPa)	202.65		435.00	400.90	
9	dP/Allow.	(kPa)	0.028		68.196	70.000	
10	Fouling	(m2-K/W)		0.000352		0.000176	
11			**Exchanger Performance**				
12	Shell h	(W/m2-K)	1682.1	Actual U	(W/m2-K)	607.86	
13	Tube h	(W/m2-K)	2637.0	Required U	(W/m2-K)	567.32	
14	Hot regime	(--)	Sens. Liquid	Duty	(MegaWatts)	1.9567	
15	Cold regime	(--)	Sens. Liquid	Eff. area	(m2)	92.455	
16	EMTD	(Deg C)	37.3	Overdesign	(%)	7.15	
17	**Shell Geometry**			**Baffle Geometry**			
18	TEMA type	(--)	BXU	Baffle type		Support	
19	Shell ID	(mm)	475.95	Baffle cut	(Pct Dia.)		
20	Series	(--)	2	Baffle orientation	(--)		
21	Parallel	(--)	2	Central spacing	(mm)	735.71	
22	Orientation	(deg)	90.00	Crosspasses	(--)	1	
17	**Shell Geometry**			**Baffle Geometry**			
18	TEMA type	(--)	BXU	Baffle type		Support	
19	Shell ID	(mm)	475.95	Baffle cut	(Pct Dia.)		
20	Series	(--)	2	Baffle orientation	(--)		
21	Parallel	(--)	2	Central spacing	(mm)	735.71	
22	Orientation	(deg)	90.00	Crosspasses	(--)	1	
23	**Tube Geometry**			**Nozzles**			
24	Tube type	(--)	Plain	Shell inlet	(mm)	254.51	
25	Tube OD	(mm)	19.050	Shell outlet	(mm)	254.51	
26	Length	(m)	1.500	Inlet height	(mm)	34.897	
27	Pitch ratio	(--)	1.2500	Outlet height	(mm)	34.897	
28	Layout	(deg)	30	Tube inlet	(mm)	97.180	
29	Tubecount	(--)	240	Tube outlet	(mm)	97.180	
30	Tube Pass	(--)	4				
31	**Thermal Resistance, %**		**Velocities, m/s**			**Flow Fractions**	
32	Shell	36.15		**Min**	**Max**	A	0.000
33	Tube	27.89	Tubeside	2.08	2.11	B	0.568
34	Fouling	34.35	Crossflow	3.39e-2	3.67e-2	C	0.265
35	Metal	1.62	Window	--	--	E	0.000
36						F	0.167

TABLE 9.
POINT OF BUNDLE CALCULATION

No.	Properties	Calculation	Max. Value
1.	Over Design	7.15 (%)	10 (%)
2.	Pressure drop sea water	0.028 (kPa)	(kPa)
3.	Pressure drop thermal oil	68.196 (kPa)	70 (kPa)
4.	Duty	1.9567 (MegaWatts)	
5.	Temperature sea water	30 (°C)	70 (°C)
6.	Temperature thermal oil	76.61 (°C)	100 (°C)

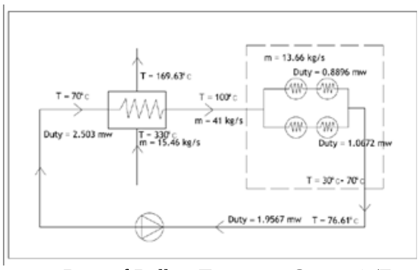

Figure. 8. Flow Diagram Duty of Ballast Treatment Option 1 (Economizer & Bundle)

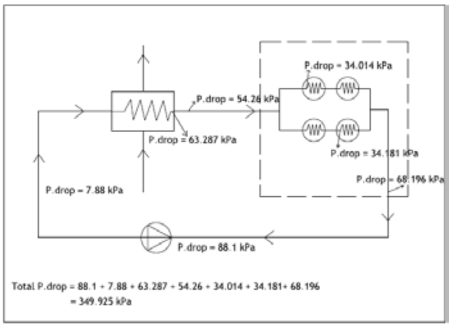

Figure. 9. Flow Diagram Pressure Drop of Ballast Treatment Option 1 (Economizer & Bundle)

TABLE 10.
TOTAL TREATMENT TIME FOR BALLAST WATER OPTION 1 (ECONOMIZER & BUNDLE)

Volume ballast tank (m^3)	Mass of sea water (kg)	ṁ sea water (kg/s)	Time circulate of sea water (sc.)	Time circulate of sea water (hr)
192.749	197568	13.66	14468.232	4.02
192.749	197568	13.66	14468.232	4.02
383.675	393267	13.66	28799.625	8.00
383.675	393267	13.66	28799.625	8.00
304.795	312415	13.66	22878.691	6.36
304.795	312415	13.66	22878.691	6.36
175.832	180228	13.66	13198.399	3.67
175.832	197108	13.66	14434.541	4.01
			Total time circulate sea water =	44.424

4.5.2 Analysis Ballast Treatment Option 2 (Economizer & Heat Exchanger)

From running that software shall be known the results to be analyzed as follows over design, pressure drop, duty, and temperature. Treatment time is also calculated and analyzed as a comparison between Option 1 (Economizer & Bundle) and Option 2 (Economizer & Heat Exchanger).

Result of Running Software HTRI For Economizer will be show on Table 11, and from that can be obtained as follows on Table 12.

With that results, so Economizer needs ballast water treatment systems already optimum for option.

Result of Running Software HTRI For Heat Exchanger will be show on Table 13, and from that can be obtained as follows on Table 14.

Treatment time shall be calculate as following :

$$Q = \dot{m} \times cp \times \Delta T \longrightarrow \dot{m} = \Delta m/\Delta t$$
$$\dot{m} = \Delta m/\Delta t \qquad m = \rho \times V$$
$$t = m/\dot{m} \qquad m = 1025 \times 251.871$$
$$= 258167.37/21.80 \qquad m = 258167.37 \text{ kg}$$
$$t = 3.29 \text{ hr}$$

Because the system uses he empty tank as an addition (modivication tank), the calculated time is a time of ballast water flow to the heat excharger and time back to the initial tank. Total treatment time all ballast water tanks will be show on Table 15.

TABLE 11.
RESULT OF RUNNING SOFTWARE HTRI FOR ECONOMIZER 2

Output Summary Page 1
Released to the following HTRI Member Company:
PT Heat Transfer Solutions Indonesia
Joko Paritono

Xace 7.3 Beta 12/6/2016 15:48 SN: 08983-36984811 **SI Units**

Rating-Horizontal economizer countercurrent to crossflow

1 See Data Check Messages Report for Warning Messages.
2 See Runtime Message Report for Warning Messages.

No.	Process Conditions	Unit	Outside		Tubeside	
4	Fluid name		Gas Buang		Thermal Oil	
5	Fluid condition			Sens. Gas		Sens. Liquid
6	Total flow rate	(kg/s)		15.462		55.340
7	Weight fraction vapor, In/Out		1.0000	1.0000	0.0000	0.0000
8	Temperature, In/Out	(Deg C)	330.00	113.53	70.00	100.00
9	Skin temperature, Min/Max	(Deg C)	87.30	198.02	81.25	161.03
10	Pressure, Inlet/Outlet	(kPa)	785.00	783.13	499.00	460.30
11	Pressure drop, Total/Allow	(kPa) (kPa)	1.874	10.000	38.697	50.000
12	Midpoint velocity	(m/s)		7.36		1.90
13	- In/Out	(m/s)			1.89	1.93
14	Heat transfer safety factor	(--)		1.0000		1.0000
15	Fouling	(m2-K/W)		0.001761		0.000176

No.	Item	Unit			Item	Unit	
16	**Exchanger Performance**						
17	Outside film coef	(W/m2-K)		39.17	Actual U	(W/m2-K)	23.102
18	Tubeside film coef	(W/m2-K)		2309.4	Required U	(W/m2-K)	21.825
19	Clean coef	(W/m2-K)		27.082	Area	(m2)	1388.0
20	Hot regime			Sens. Gas	Overdesign	(%)	5.85
21	Cold regime			Sens. Liquid	**Tube Geometry**		
22	EMTD	(Deg C)		111.6	Tube type		High-finned
23	Duty	(MegaWatts)		3.38	Tube OD	(mm)	25.400
24	**Unit Geometry**				Tube ID	(mm)	22.910
25	Bays in parallel per unit			1	Length	(m)	1.700
26	Bundles parallel per bay			1	Area ratio(out/in)	(--)	26.117
27	Extended area	(m2)		1388.0	Layout		Staggered
28	Bare area	(m2)		68.370	Trans pitch	(mm)	60.500
29	Bundle width	(m)		1.740	Long pitch	(mm)	52.393
30	**Nozzle**		**Inlet**	**Outlet**	Number of passes	(--)	6
31	Number	(--)	1	1	Number of rows	(--)	18
32	Diameter	(mm)	193.68	193.68	Tubecount	(--)	504
33	Velocity	(m/s)	2.22	2.26	Tubecount Odd/Even	(--)	28 / 28
34	R-V-SQ	(kg/m-s2)	4174.1	4251.0	Material		Copper
35	Pressure drop	(kPa)	2.296	1.488	**Fin Geometry**		
36	**Fan Geometry**				Type		Circular
37	No/bay	(--)		0	Fins/length	(fin/meter)	433.0
38	Fan ring type				Fin root	(mm)	25.400
39	Diameter	(m)		0.000	Height	(mm)	15.875
40	Ratio, Fan/bundle face area	(--)		0.0000	Base thickness	(mm)	0.400
41	Driver power	(kW)		0.00	Over fin	(mm)	57.150
42	Tip clearance	(mm)		0.000	Efficiency	(%)	90.4
43	Efficiency	(%)		0.0000	Area ratio (fin/bare)	(--)	23.557
44	**Airside Velocities**		**Actual**	**Standard**	Material		Copper
45	Face	(m/s)	4.93		**Thermal Resistance, %**		
46	Maximum	(m/s)	12.02		Air		58.99
47	Flow	(100 m3/min)	8.756		Tube		26.13
48	Velocity pressure	(Pa)	0.00		Fouling		14.69
49	Bundle pressure drop	(Pa)	1873.7		Metal		0.19
50	Bundle flow fraction	(--)	1.000		Bond		0.00

No.			Airside Pressure Drop, %			
51	Bundle	100.00			Louvers	0.00
52	Ground clearance	0.00	Fan guard	0.00	Hail screen	0.00
53	Fan ring	0.00	Fan area blockage	0.00	Steam coil	0.00

TABLE 12.
POINT OF ECONOMIZER 2 CALCULATION

No.	Properties	Calculation	Max. Value
1.	Over Design	5.85 (%)	10 (%)
2.	Pressure drop exhaust gas	1.874 (kPa)	10 (kPa)
3.	Pressure drop thermal oil	38.697 (kPa)	50 (kPa)
4.	Duty	3.38 (MegaWatts)	
5.	Temperature exhaust gas	113.53 (°C)	330 (°C)
6.	Temperature thermal oil	70 (°C)	100 (°C)

TABLE 13.
RESULT OF RUNNING SOFTWARE HTRI FOR HEAT EXCHARGER

Output Summary Page 1
Released to the following HTRI Member Company:
PT Heat Transfer Solutions Indonesia
Joko Paritono

Xist 7.3 Beta 12/6/2016 15:50 SN: 08983-36984811 **SI Units**

Rating - Horizontal Multipass Flow TEMA BEM Shell With Single-Segmental Baffles

1	See Data Check Messages Report for Informative Messages.							
2	See Runtime Message Report for Warning Messages.							
3	**Process Conditions**		**Hot Shellside**			**Cold Tubeside**		
4	Fluid name			hot oil				sea water
5	Flow rate	(kg/s)		55.340				21.800
6	Inlet/Outlet Y	(Wt. frac vap.)	0.0000	0.0000			0.0000	0.0000
7	Inlet/Outlet T	(Deg C)	100.00	72.37			30.00	70
8	Inlet P/Avg	(kPa)	429.65	415.41			490.00	487.63
9	dP/Allow.	(kPa)	28.476	40.000			4.747	49.000
10	Fouling	(m2-K/W)		0.000176				0.000352
11			**Exchanger Performance**					
12	Shell h	(W/m2-K)	1767.0		Actual U	(W/m2-K)		611.45
13	Tube h	(W/m2-K)	2741.2		Required U	(W/m2-K)		590.85
14	Hot regime	(--)	Sens. Liquid		Duty	(MegaWatts)		3.1227
15	Cold regime	(--)	Sens. Liquid		Eff. area	(m2)		174.74
16	EMTD	(Deg C)	30.2		Overdesign	(%)		3.49
17	**Shell Geometry**				**Baffle Geometry**			
18	TEMA type	(--)	BEM		Baffle type			Single-Seg.
19	Shell ID	(mm)	863.60		Baffle cut	(Pct Dia.)		16.93
20	Series	(--)	1		Baffle orientation	(--)		Perpend.
21	Parallel	(--)	1		Central spacing	(mm)		224.31
22	Orientation	(deg)	0.00		Crosspasses	(--)		11
23	**Tube Geometry**				**Nozzles**			
24	Tube type	(--)	Plain		Shell inlet	(mm)		193.68
25	Tube OD	(mm)	19.050		Shell outlet	(mm)		193.68
26	Length	(m)	3.048		Inlet height	(mm)		74.857
27	Pitch ratio	(--)	1.2500		Outlet height	(mm)		74.857
28	Layout	(deg)	30		Tube inlet	(mm)		146.33
29	Tubecount	(--)	992		Tube outlet	(mm)		146.33
30	Tube Pass	(--)	4					

31	**Thermal Resistance, %**		**Velocities, m/s**			**Flow Fractions**	
32	Shell	34.60		**Min**	**Max**	A	0.498
33	Tube	26.98	Tubeside	0.40	0.44	B	0.268
34	Fouling	36.80	Crossflow	0.55	0.62	C	0.022
35	Metal	1.62	Window	0.49	0.77	E	0.163
36						F	0.049

TABLE 14.
POINT OF HEAT EXCHARGER CALCULATION

No.	Properties	Calculation	Max. Value
1.	Over Design	3.49 (%)	10 (%)
2.	Pressure drop sea water	4.747 (kPa)	49 (kPa)
3.	Pressure drop thermal oil	28.476 (kPa)	40 (kPa)
4.	Duty	3.1227 (MegaWatts)	
5.	Temperature sea water	30 (°C)	70 (°C)
6.	Temperature thermal oil	72.37 (°C)	100 (°C)

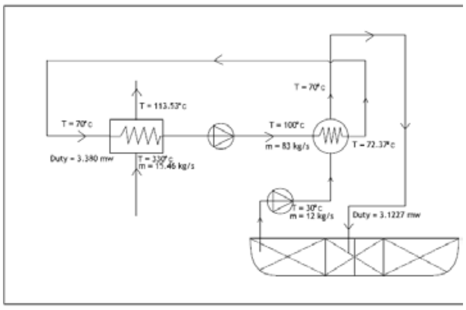

Figure. 10. Flow Diagram Duty of Ballast Treatment Option 2 (Economizer & Heat Exchager)

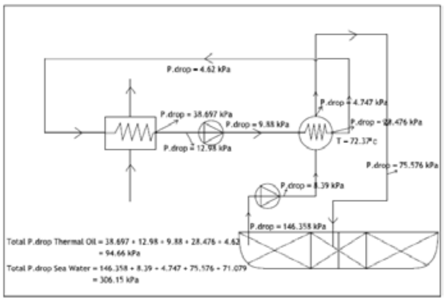

Figure. 11. Flow Diagram Pressure Drop of Ballast Treatment Option 2 (Economizer & Heat Exchager)

TABLE 15.
TOTAL TREATMENT TIME FOR BALLAST WATER OPTION 2 (ECONOMIZER & HEAT EXCHARGER)

Volume ballast tank	massa sea water	ṁ sea water (kg/s)	time to circulate (hr.)	time to circulate (hr)	total time to circulate (hr)
111.629	114419.73	21.80	1.46	2.92	1.46
111.629	114419.73	21.80	1.46	2.92	
251.871	258167.37	21.80	3.29	6.58	3.29
251.871	258167.37	21.80	3.29	6.58	
190.655	195421.38	21.80	2.49	4.98	2.49
190.655	195421.38	21.80	2.49	4.98	
89.330	91563.25	21.80	1.17	2.33	1.17
89.330	91563.25	21.80	1.17	2.33	
Total circulating time of sea water (hr) =					42.03

4.6 Design Key Plan and Isometry Ballast Treatment

Key plan and Isometry Ballast Treatment are included of analysis processing steps, one of which is to determine the number of fittings resistance and head losses which have been converts to pressure to determine the ability of pump to the pressure drop is calculated. Design of Ballast system had fullfil, will make as key plan and Isometry. So it will be look how the scenario at both system. For those drawings shall be attach on Figure 12 to 15.

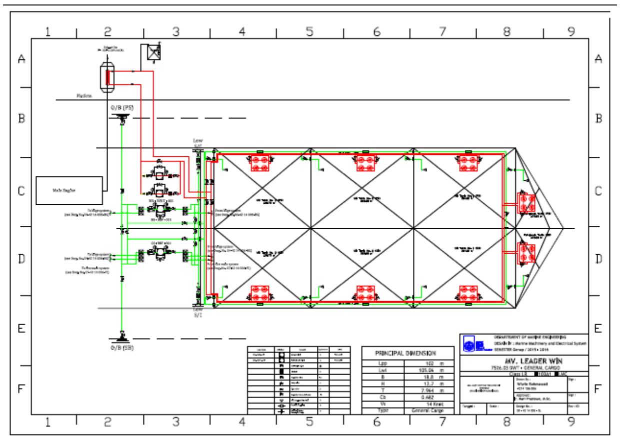

Figure. 12. Key Plan Ballast Water Treatment Option 1 (Economizer & Bundle)

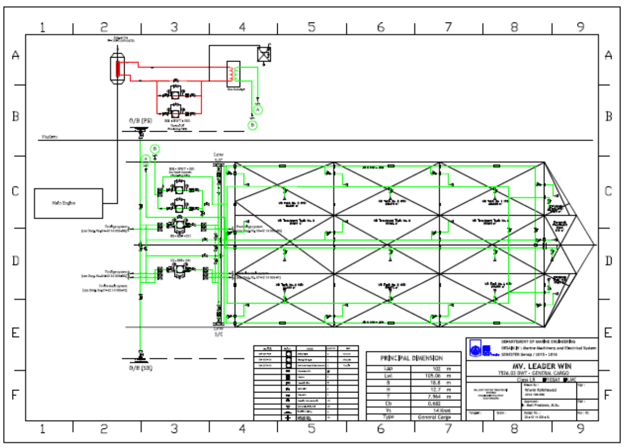

Figure. 13. Key Plan Ballast Water Treatment Option 2 (Economizer & Heat Exchanger)

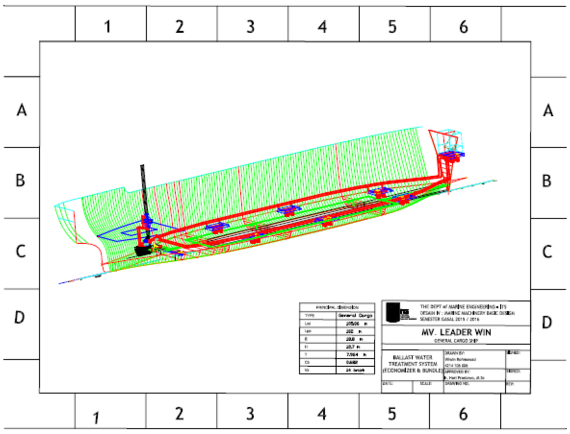

Figure. 14. Isometry Ballast Water Treatment Option 1 (Economizer & Bundle)

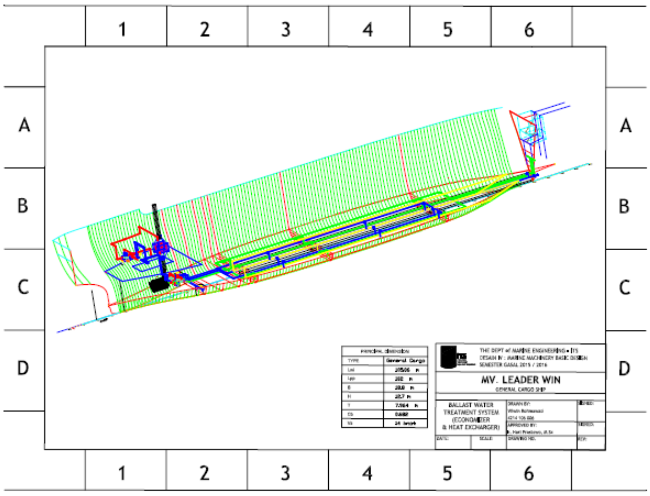

Figure. 15. Isometry Ballast Water Treatment Option 2 (Economizer & Heat Excharger)

4.7 Compiling Material Requirment Plan (MRP)

TABLE 16.
MRP OF BALLAST WATER TREATMENT OPTION 1 (ECONOMIZER & BUNDLE)

NO.	WORK BREAK DOWN			SPECIFICATION	VOLUME	
A.	MATERIAL AND EQUIPMENT					
1.	PIPING, VALVE, PUMP & FITTINGS.					
	R	100	BALLAST PIPING (INCL. MACH. PIPING)			
	R	101	Ballast pipe	Carbon steel galvanized, JIS G 3452, Sch 40	1	fullset
	R	102	Thermal oil pipe	Copper/nickel 90/10 Sch 80	1	fullset
	R	103	Exhaust pipe	700 mm, stainless steel, JIS	1	fullset
	R	104	Elbow pipe (ballast)	Carbon steel galvanized, JIS, Sch 40	1	fullset
	R	105	Elbow pipe (thermal oil)	Copper nickel elbow 90/10, Sch 8	1	fullset
	R	106	Bell mounted pipe end	5/8" - chrome	1	fullset
	R	107	Insulation	0.3 mm, Under Roof, aluminium or galvanized	1	fullset
	R	108	Flesxible Coupling			
	R	109	Bulkhead Fitting Watertight Flange			
	R	200	SCHEDULE OF VALVES			
	R	201	Ballast	gate valve (2 sets), globe (SNDRV) (6 sets) and safety valve (2 sets), cast iron, bronze	1	fullset
	R	202	Ballast treatment (thermal oil valve)	gate valve (2 sets), globe (SNDRV) (6 sets) and safety valve (2 sets), cast iron, bronze	1	fullset
		203	Ballast and thermal oil system	Strainer (14 sets)	1	fullset
	R	300	PUMP			
	R	301	Ballast pump	Electric motor driven, centrifugal type, 180 m^3/h	2	sets
	R	302	Thermal oil pump (ballast treatment)	Electric motor driven, centrifugal type, 178 m^3/h	2	sets
	R	303	ballast operation (valve remote control syst.)	● Valve remote control system : hydraulic type, total 8 set of control ● Manual buterfly valve (Total 11 sets)	1	shipset
	R	304	thermal oil operation (valve remote control syst.)	● Valve remote control system : hydraulic type, total 16 set of control ● Manual butterfly valve (Total 7 sets)	1	shipset
			SUB TOTAL PIPING, VALVE AND FITTING			

2.	MACHINERY PART					
	M	100	ECONMIZER (THERMAL OIL PLANT) & ACCESSORIES			
	M	101	Tube material	Copper/nickel 90/10 Sch 80		
	M	102	Fin material	Copper/nickel 90/10 Sch 80		
			Nozzle	Copper/nickel 90/10 Sch 80		
	OTHER MACHINERY AND OUTFIT IN ENGINE ROOM					
	M	200	PUMPS :			
	M	201	Ballast pump	180 m3/h x 28m head, 22 kW x 2	2	units
		202		Motor driven, vertical, centrifugal		
	M	203	Thermal oil pump	178 m3/h x 9.84 m head, 26.6 kW x 2900 rpm, Motor driven, horizontal, centrifugal	2	units
	M	204	Foundation for pumps	Hot rolled carbon steel plate, thck	2	units
	M	205	Fitting for pump		4	units
	M	300	bundles (excharger) :			
	M	302	Tube	Copper/nickel 90/10 Sch 80	1	set
	M	303	Nozzle	Copper/nickel 90/10 Sch 80	1	set
	M	304	Fitting for bundle		1	fullset
	M	400	TANK TABLES			
	M	401	Ballast Water Tank I	carbon steel plate, JIS	192.749	m^3
	M	402	Ballast Water Tank II	carbon steel plate, JIS	192.749	m^3
	M	403	Ballast Water Tank III	carbon steel plate, JIS	383.675	m^3
	M	404	Ballast Water Tank IV	carbon steel plate, JIS	383.675	m^3
	M	405	Ballast Water Tank V	carbon steel plate, JIS	304.795	m^3
	M	406	Ballast Water Tank VI	carbon steel plate, JIS	304.795	m^3
	M	407	Forepeak Ballast Tank I	carbon steel plate, JIS	175.832	m^3
	M	408	Forepeak Ballast Tank II	carbon steel plate, JIS	175.832	m^3
	M	409	Thermal oil expantion tank	carbon steel plate, JIS, with sight glass	1	m^3
		410	Fittings		1	fullset
			SUB TOTAL OTHER MACHINERY AND OUTFIT IN ENGINE ROOM			

TABLE 17.
MRP OF BALLAST WATER TREATMENT OPTION 2 (ECONOMIZER & HEAT EXCHARGER)

NO.	WORK BREAK DOWN			SPECIFICATION	VOLUME	
A.	MATERIAL AND EQUIPMENT					
1.	PIPING, VALVE, PUMP & FITTINGS.					
	R	100	BALLAST PIPING (INCL. MACH. PIPING)			
	R	101	Ballast pipe	Carbon steel galvanized, JIS G 3452, Sch 40	1	fullset
	R	102	Thermal oil pipe	Copper/nickel 90/10 Sch 80	1	fullset
	R	103	Exhaust pipe	700 mm, stainless steel, JIS	1	fullset
	R	104	Elbow pipe (ballast)	Carbon steel galvanized, JIS, Sch 40	1	fullset
	R	105	Elbow pipe (thermal oil)	Copper nickel elbow 90/10, Sch 8	1	fullset
	R	106	Bell mounted pipe end	5/8" - chrome	1	fullset
	R	107	Insulation	0.3 mm, Under Roof, aluminium or galvanized	1	fullset
	R	108	Flesxible Coupling			
	R	109	Bulkhead Fitting Watertight Flange			
	R	200	SCHEDULE OF VALVES			
	R	201	Ballast	gate valve (2 sets), globe (SNDRV) (6 sets) and safety valve (2 sets), cast iron, bronze	1	fullset
	R	202	Ballast treatment (thermal oil valve)	gate valve (2 sets), globe (SNDRV) (6 sets) and safety valve (2 sets), cast iron, bronze	1	fullset
		203	Ballast and thermal oil system	Strainer (14 sets)	1	fullset
	R	300	PUMP			
	R	301	Ballast pump	Electric motor driven, centrifugal type, 180 m^3/h	2	sets
	R	302	Thermal oil pump (ballast treatment)	Electric motor driven, centrifugal type, 178 m^3/h	2	sets
	R	303	ballast operation (valve remote control syst.)	● Valve remote control system : hydraulic type, total 8 set of control ● Manual buterfly valve (Total 11 sets)	1	shipset
	R	304	thermal oil operation (valve remote control syst.)	● Valve remote control system : hydraulic type, total 12 set of control ● Manual butterfly valve (Total 4 sets)	1	shipset
			SUB TOTAL PIPING, VALVE AND FITTING			
2.	MACHINERY PART					
	M	100	ECONMIZER (THERMAL OIL PLANT) & ACCESSORIES			
	M	101	Tube material	Copper/nickel 90/10 Sch 80		
	M	102	Fin material	Copper/nickel 90/10 Sch 80		
			Nozzle	Copper/nickel 90/10 Sch 80		
	OTHER MACHINERY AND OUTFIT IN ENGINE ROOM					
	M	200	PUMPS :			
	M	201	Ballast pump	180 m3/h x 28m head, 22 kW x 2	2	units
		202		Motor driven, vertical, centrifugal		
	M	203	Thermal oil pump	240 m3/h x 9.84 m head, 26.6 kW x 2900 rpm, Motor driven, horizontal, centrifugal	2	units
	M	204	Foundation for pumps	Hot rolled carbon steel plate, thck	2	units
	M	205	Fitting for pump		4	units
	M	300	Heat excharger			
		301	Shell	Copper/nickel 90/10 Sch 80	1	set
	M	302	Tube	Copper/nickel 90/10 Sch 80	1	set
	M	303	Nozzle	Copper/nickel 90/10 Sch 80	1	set
	M	304	Fitting for bundle		1	fullset
	M	400	TANK TABLES			
	M	401	Ballast Water Tank I	carbon steel plate, JIS	192.749	m^3
	M	402	Ballast Water Tank II	carbon steel plate, JIS	192.749	m^3
	M	403	Ballast Water Tank III	carbon steel plate, JIS	383.675	m^3
	M	404	Ballast Water Tank IV	carbon steel plate, JIS	383.675	m^3
	M	405	Ballast Water Tank V	carbon steel plate, JIS	304.795	m^3
	M	406	Ballast Water Tank VI	carbon steel plate, JIS	304.795	m^3
	M	407	Forepeak Ballast Tank I	carbon steel plate, JIS	175.832	m^3
	M	408	Forepeak Ballast Tank II	carbon steel plate, JIS	175.832	m^3
	M	409	Thermal oil expantion tank	carbon steel plate, JIS, with sight glass	1	m^3
		410	Fittings		1	fullset
			SUB TOTAL OTHER MACHINERY AND OUTFIT IN ENGINE ROOM			

2.	MACHINERY PART					
	M	100	ECONMIZER (THERMAL OIL PLANT) & ACCESSORIES			
	M	101	Tube material	Copper/nickel 90/10 Sch 80		
	M	102	Fin material	Copper/nickel 90/10 Sch 80		
			Nozzle	Copper/nickel 90/10 Sch 80		
	OTHER MACHINERY AND OUTFIT IN ENGINE ROOM					
	M	200	PUMPS :			
	M	201	Ballast pump	180 m3/h x 28m head, 22 kW x 2	2	units
		202		Motor driven, vertical, centrifugal		
	M	203	Thermal oil pump	240 m3/h x 9.84 m head, 26.6 kW x 2900 rpm, Motor driven, horizontal, centrifugal	2	units
	M	204	Foundation for pumps	Hot rolled carbon steel plate, thck	2	units
	M	205	Fitting for pump		4	units
	M	300	Heat excharger			
		301	Shell	Copper/nickel 90/10 Sch 80	1	set
	M	302	Tube	Copper/nickel 90/10 Sch 80	1	set
	M	303	Nozzle	Copper/nickel 90/10 Sch 80	1	set
	M	304	Fitting for bundle		1	fullset
	M	400	TANK TABLES			
	M	401	Ballast Water Tank I	carbon steel plate, JIS	192.749	m^3
	M	402	Ballast Water Tank II	carbon steel plate, JIS	192.749	m^3
	M	403	Ballast Water Tank III	carbon steel plate, JIS	383.675	m^3
	M	404	Ballast Water Tank IV	carbon steel plate, JIS	383.675	m^3
	M	405	Ballast Water Tank V	carbon steel plate, JIS	304.795	m^3
	M	406	Ballast Water Tank VI	carbon steel plate, JIS	304.795	m^3
	M	407	Forepeak Ballast Tank I	carbon steel plate, JIS	175.832	m^3
	M	408	Forepeak Ballast Tank II	carbon steel plate, JIS	175.832	m^3
	M	409	Thermal oil expantion tank	carbon steel plate, JIS, with sight glass	1	m^3
		410	Fittings		1	fullset
			SUB TOTAL OTHER MACHINERY AND OUTFIT IN ENGINE ROOM			

4.8 Conclution

From analysis, design and calculation of system had been done, so, it can take some of conclutions in this thesis as following :

1. The heat recovey by main engine of MV. Leader Win vessel is acceptable to being one of method Ballast Water treatment accordance by International Ballast water Management. This proven with calculation and analysis how the heat of exhaust gas transfered to ballast tank bay software HTRI. In this thesis, author was compare ballast tratment using option 1 system and option 2 system. There system will be explained at point 2.

2. For calculate heat necessary, this thesis is using softwere HTRI. The temperature for kill the microorganism had determined 70°C. The scenario of option 1 system is using economizer and bundle. Those heat from economizer to bundle is curry by thermal oil as medium heat transfer. And then a scenario of option 2 system is using economizer and heat exchanger. In option 2, thermal oil is circulated from economizer to heat exchanger. And sea water is circulated from ballast tank to heat exchanger too. The results are First option having a duty 2.503 MegaWatts at economizer and 1.9567 MegaWatts at bundles. Over design 2.01% at Economizer and 7.1%5 at bundles. Pessure drop 63.287 kPa at thermal oil after economizer and 68.196 kPa after bundles. Treatment time to this option is 44.424 hors. Second option having a duty 3.38 MegaWatts at economizer and 3.1227 MegaWatts at heat exchanger. Over design 5.85% at Economizer and 3.49%5 at heat exchanger. Pessure drop 38.697 kPa at thermal oil after economizer and 28.476 kPa after heat exchanger. Treatment time to second option is 42.03 hours. Option 2 is more optimum than option in analytical techniques. By analysis of treatment system, are expected this thesis can be applied to either the MV. Leader Win Vessel to comply with the operational needs according to standard employability.
3. Modification for key plan of both traetment system (option 1 & 2) have done.
4. The preparation of Material Requirment Plan (MRP) have done. This to do to know what a material and how many all of material needed and selcted.

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