BACHELOR THESIS & COLLOQUIUM – ME 184841

ANALYSIS OF USING EXHAUST GAS FOR ABSORPTION REFRIGERATION SYSTEM IN 10 GT FISHING VESSEL

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DOUBLE DEGREE PROGRAM
DEPARTMENT OF MARINE ENGINEERING
FACULTY OF MARINE TECHNOLOGY
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
SURABAYA
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ENDORSEMENT PAGE

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Submitted to fulfill one of the requirement for obtaining a Bachelor Engineering Degree in the field of study of Marine Machinery and System (MMS)

Program Study of Double Degree Bachelor Engineering (S-1) of

Department Marine Engineering

Faculty of Marine Technology

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ANALYSIS OF USING EXHAUST GAS FOR ABSORPTION REFRIGERATION SYSTEM IN 10 GT FISHING VESSEL

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ABSTRACT

In every fishing vessel, absolutely it needs the cooling system to store and make the fishes stay fresh. Nowadays, the fossil's source is decreasing, there should be the process to use the renewable energy. In this research, will be observed the implementation of absorption refrigeration system in the 10 GT Fishing Vessel which using the exhaust gas from the diesel engine as a heat source and calculate the performance of the system due to variation of working fluids and load of diesel engine. The result is during operational engine load, C_4H_9NO – R134A with the composition 55/45 with the COP about 0.79. While, C_4H_9NO – R134A with the composition 50/50 has the biggest value of COP about 0.88 in 25% engine load.

Keywords - Absorbent, Coefficient of Performance, Engine Load, Refrigerant

ANALISIS PENGGUNAAN GAS BUANG UNTUK SISTEM PENDINGIN ABSORPSI PADA KAPAL IKAN 10 GT

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ABSTRAK

Pada setiap kapal ikan, tentunya membutuhkan sistem pendingin yang digunakan untuk mendinginkan dan membuat ikan agar tetap dalam keadaan segar. Dan juga pada saat ini, sumber energi dari fossil juga mengalami penurunan, sehingga perlu ada sebuah langkah untuk menggunakan energy yang terbarukan. Pada penelitian ini, akan dikembangkan dan diteliti mengenai pemanfaatan penggunaan sistem pendingin absorpsi pada kapal ikan berukuran 10 GT dimana akan menggunakan gas buang dari mesin sebagai sumber panas pada sitem dan kemudian akan dihitung nilai dari koefisien performa pada sistem berdasarkan pada variasi dari jenis fluida dan beban operasi pada mesin kapal. Hasil pada penelitian ini didapat bahwa pada kondisi operasional kapal, C_4H_9NO – R134A dengan komposisi 55/45, didapatkan nilai COP sebesar 0.79. Sedangkan secara keseluruhan dari seluruh beban yang ada, didapati bahwa C_4H_9NO – R134A dengan komposisi seimbang 50/50 mempunyai nilai koefisien performa paling besar dengan nilai sebesar 0.88 pada kondisi operasi 25% daya.

Kata kunci - Absorbent, Coefficient of Performance, Engine Load, Refrigerant

PREFACE

The author would express and give thanks to those who helped her during completing the Bachelor Thesis:

The God Almighty, who gives strength, healthy, mercy and blessing to completing this thesis

The author's parents who always give support and always praying for the author until the author can completing the bachelor thesis

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The author's seniors and friends who have given support during the working of the thesis

Author realizes that this thesis is further away from the perfectness, all the suggestions are highly received for the improvement and better bachelor thesis.

Surabaya, January 2019

Author

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CHAPTER I
INTRODUCTION

1.1 Backgrounds

Indonesia is known as the maritime country which consist of two-thirds of its area is water. Also, it is the second longest coastline country which has around 95,181 km – long of the coastline. Those make the Indonesia has the big potential in marine and fisheries commodities. In the first – quarter of 2017, data from The Fishery Ministry, known that Indonesia produces around 3.97 million tons of the fish. It increases 37 percent than the first – quarter of 2016. (Simanjuntak, 2017)

Indonesia ranks on the second world's most important fisheries producers. Moreover, Indonesia is located between Indian Ocean and Pacific Ocean which known as the ocean with the producing of Tuna. With the 2.7 million km^2 (which is known as the world's sixth largest EEZ). it is such a big opportunity for Indonesia to improve the production of marine sector. (California Environmental Associates, 2016) Because of these opportunity, it will be the top concern and focusing of the government to establish and control the aquaculture. One of the acts from the government is the provision of the fishing vessel. The function of the vessel is not only for fishing, but also for distribute the products.

In the public society, usually the size of the fishing vessel used is 10 GT Fishing Vessel. To cooling the fish, 10 GT Fishing vessel usually use ice. The amount of the ice is restricted with the time of cooling the fish. Because of that the vessel needs the lot of space for the ice. From the data, one ton of fish require about 1.5 until 2 tons of ice, depend on the trip of vessel.

On the other system, the vapor compression refrigeration system is used for the alternative cooling system on the ship. Vapor compression refrigeration system is the system which has the higher efficiency than the usage of ice. The vapor compression refrigeration system uses the compressor to produce the differential of pressure to transport the refrigerant. The weakness of the vapor compression refrigeration system is the usage of electricity which used as the power for compressor beside of powering vessel engine. The addition of the usage electricity will affect the requirement of the diesel generator on the ship.

The other system which does not need of electricity and does not limited by time is absorption refrigeration system. Despite does not need of the compressor the create the differential pressure, it uses the differential heat from the outsource. The outsource can be from solar energy, geothermal energy and waste heat.

As we can know that the half of energy from engine is coming out as exhaust heat in form of exhaust gas, through jacket water and cooling air. It makes the engine's efficiency is only at 35 – 40%. Because of that problem, there is energy conservation which using the waste energy recovery for the outsource of the system. This recovery is used because of the prosperity of diminish of the operation cost of the vessel.

The research suggested that absorption refrigeration system which using the waste heat is efficiently and environmental friendly (K.E Herold, 1996). The usage of the waste heat source refrigeration system for refrigerating in fishing vessel making the energy saving for the vessel.

Several research about the usage of exhaust gas from engine for heat source of absorption refrigeration system were developed. The results from the research are varied based on the used liquid and the model of the system. On this research, there will be investigated of the system which has been tested in the room and has the good result (Serly A., 2017) to be applied on fishing vessel. There will be analyze of the effect and efficiently of the system.

1.2 Problem Statements

1. What is the best working fluid to be used in absorption refrigeration system for 10 GT Fishing Vessel?
2. How is the performance of the system based on variation of the working fluid for 10 GT Fishing Vessel?
3. How is the performance of the system based on variation of the load diesel engine for 10 GT Fishing Vessel?

1.3 Scope of Problems

1. The ship is on steady – state condition.
2. The absorption process which will be used is Single – Effect Absorption Refrigeration.
3. The working fluids used are CH_3NH_2-H_2O, H_2O-NH_3, and R124-DMAC.
4. The compositions of absorbent/refrigerant are 45/55, 50/50 and 55/45.
5. Heat losses to the environment are negligible.

1.4 Objectives

This study is purposed to:

1. Analyze and calculate the performance of the absorption refrigeration system theory using variation of working fluids.
2. Analyze and calculate the performance of using exhaust gas as heat source for generator in absorption refrigeration system due to variation of load diesel engine.

1.5 Benefits

The expected benefits from this research:

1. Developing the research about absorption refrigeration system.
2. Utilizing the further method of refrigeration in 10 GT Fishing Vessel.
3. Used as reference for engineer to design the refrigeration system in 10 GT Fishing Vessel

CHAPTER II
LITERATURE STUDY

2.1 Refrigeration System

Refrigeration is defined as the process or complex system that is accumulating of the item or substance which is designed to cool or freeze the equipment below room temperature by removing heat from the substance and transfer it to the another object. Heat transfer of the system is depended on the properties of the refrigerant. Every refrigerant has different enthalpy in the given state. Based on the type of input energy used, the system is classified into two:

1) Vapor Compression System

The vapor compression system is the system which using mechanical work to transfer the refrigerant. (Yeh, 2018) This system uses electricity to produce mechanical work to cooling. This system is highly efficiencies, low cost and quick response time. (Wang, et al., 2012) In the contrary, the vapor compression system uses high – grade electricity and can causing the overload of electricity generation if it used in large – scale. (Wu, et al., 2015)

2) Heat – Driven Cooling System

This system uses low – grade of the thermal energy. This system is classified into two types, those are closed cycle system and open cycle system. The closed cycle system uses the same refrigerant for every cycle of refrigeration. The example for this system are absorption refrigeration system and adsorption refrigeration system. While, in the open cycle system, the air is directly passed over the substance which is to be cooled. The pressure of this cycle is limited with the atmospheric pressure. DEC (Desiccant Evaporative Cooling) is classified into this cycle (Rasul, et al., 2017). Absorption refrigeration system reduce or can operate without the electricity during peak utility hours, reduce the operational costs, and impact low environmental due to the use of CFC-free refrigerants. (Fallek, 1986) Absorption refrigeration system compared to the compression refrigeration system is using the environmental friendly of working fluids. (Wang, et al., 2016). Absorption refrigeration system driven by waste heat related with exhaust gas of engine is a beneficial alternative cooling to the vapor compression refrigeration system. (Mukul KUMAR, 2019)

2.2 Working Principle of Absorption Refrigeration System

The working concept of the compressor is replaced by an absorber and a generator. The compression process in this system is done by the incoming heat energy in generator. After there is the mixing process of fluids in absorber, those fluids go to the generator where it is heated. The outsource heat of this system is by using the heat from exhaust gas temperature of the diesel engine. Here, the refrigerant and absorbent are separated. Concentrated absorbent fluid is going to absorber, while the vapor refrigerant is going to the condenser. In the condenser, the vapor refrigerant with the high temperature and high pressure, is cooled down by the air and change into the liquid form with high pressure. The cooled pressurized refrigerant then goes through the expansion valve and the pressure is reduced. In the evaporator, the refrigerant will take the heat from the cooled cargo room out, so it will change into vapor again. Then the fluid is going to absorber and there is the mixing process between absorbent and refrigerant fluids. The pump is functioned to increase the mixing fluid's pressure and transport it to the generator. The cycle then continues. Below are mentioned the heat transfer rate for each equipment.

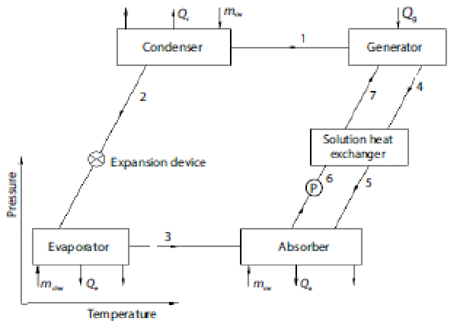

Figure 2. 1 Single Effect Absorption Cycle (Balaji K., Iniyan S., Gurubalan A., Senthilkumar R., 2018)

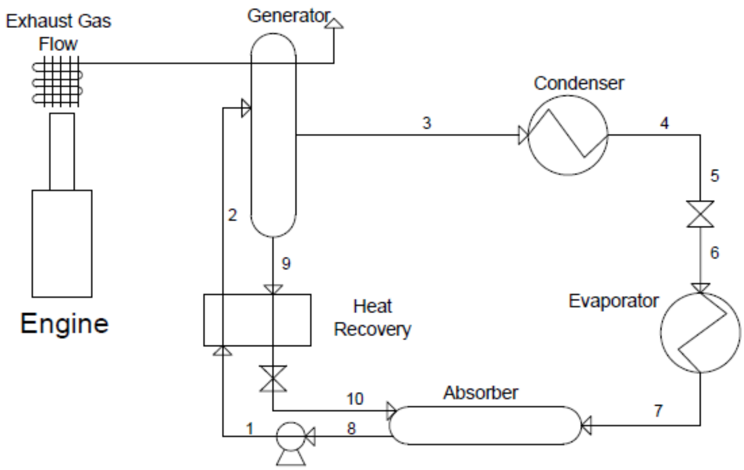

Figure 2. 2 PID Absorption Refrigeration System

1.1 Absorber

Absorber is the equipment where the absorbent and vapor refrigerant are met. The lower temperature of the absorbent will absorb the vapor refrigerant, and the fluids will mix. To cooled the fluids, there is external coolant in the absorber. In this equipment, the refrigerant which absorbed by absorbent will decreasing of the volume which makes the compression of refrigerant. So, this equipment is called as suction part of the compressor.

$$Q_{ab} = m_7 h_7 + m_{10} h_{10} - m_8 h_8 \tag{2.1}$$

1.2 Pump

Pump is used for increasing the pressure of the fluids to generator.

$$W_{pump} = \frac{m_1 h_1 (p_{gen} - p_{abs})}{m_r \eta_{pump}} \quad (2.2)$$

1.3 Generator

On this equipment, there are external sources like waste heat, solar heat and etc which heating the fluids, and make the fluids are separated.

$$Q_{gen} = m_9 h_9 + m_3 h_3 - m_2 h_2 \quad (2.3)$$

$$Q_{gen} = m_{exh} C_{exh} (T_{exh,in} - T_{exh,out}) \quad (2.4)$$

1.4 Condenser

This equipmet is used for cooling the refrigerant which has the high temperature from the generator. There is external coolant on this equipment.

$$Q_{gen} = m_3 h_3 - m_4 h_4 \quad (2.5)$$

1.5 Evaporator

In this equipment, the refrigerant will absorb the hot air from the room and take the heat and create the cooling effect to the room.

$$Q_a = m_7 h_7 - m_6 h_6 \quad (2.6)$$

1.6 Heat Recovery

$$Q_{hr} = m_1 (h_2 - h_1) \quad (2.7)$$

$$Q_{hr} = m_9 (h_{10} - h_9) \quad (2.8)$$

1.7 Heat Balance

$$Q_{evap} + Q_{gen} + W_{pump} = Q_{con} + Q_{abs} \quad (2.9)$$

In the type of fired units, is classified into two types:

a) Direct-fired absorption units
The heat source is gas or some other fuel that is burned in the unit.

b) Indirect-fired absorption units
The heat source use from other transfer fluid that brings the heat from separate source such as steam, hot water, a boiler, solar energy or waste heat.

According to the number of stages of absorption, the system is classified into three type. Those are:

1) Single - Effect Absorption Refrigeration
The system only cooled once the refrigerant from the evaporator.
2) Double - Effect Absorption Refrigeration
In this type, there are a main cycle and auxiliary cycle. The chilled water is cooled down twice by the refrigerant from a double tray in the evaporator and the vaporized refrigerant is absorbed into concentrated solution which is coming from the 2nd generator.
3) Triple - Effect Absorption Refrigeration
This system consists of three generators, there are a high temperature generator, a medium temperature generator and a low temperature generator.

2.3 Calculation of Fish Hold Cooling Load

For calculating the total cooling load on 10 GT Fishing Vessel, there are several aspects to be calculate, those are:

Wall Gain Load

When the inside room is cooler than the outside, the heat will be move from the outside to the inside because of the properties of the heat which always move to the cooler (less heated) area.

The heat through element can be calculated by:

$$Q_w = A \times U \times (t_o - t_i) \quad (2.10)$$

Q_w	=	Total heat transfer of element [W]
A	=	Area of element [cm^2]
U	=	coefficient of heat transfer [W/cm^oC]
t_o	=	Outside temperature [^oC]
t_i	=	Inside temperature [^oC]

$$U = \frac{1}{R} \quad (2.11)$$

$$R = \frac{x}{k} \quad (2.12)$$

Air Change Load

When the door of the cargo room is opened, there is the flow of the air which come into the room. This load should be calculated because of the activity loading and unloading the fish.

Product Load

The temperature of the fish which are loaded to the cargo room have the original temperature from the outside condition. In the cargo room, it will be cooled and the fish will release the heat. After the fishes stored in the cargo room, the temperature of should be maintained in the required temperature.

The formula of heat needed for the system to cooling the fish until reach the required temperature (Johnston, et al., 1994):

$$Q_c = \frac{m \times c \times \Delta t}{t} \quad (2.13)$$

Q_c = The heat needed for cooling the fish until required temperature [kcal/hour]

m = Mass of fishes [kg]

c = The caloric value [kcal/kg°C]

Δt = The differences temperature of fish [°C]

t = time needed to cooling [hour]

And when the fish reach the required temperature for storage, its temperature should be maintained until the fish discharged. The formula of this process:

$$Q_m = \frac{m \times L}{t_b} \quad (2.14)$$

Q_m = The heat needed to maintain the temperature [kcal/hour]

m = Mass of fishes [kg]

L = The latent heat of the fish [kcal/kg]

t_b = time until the ship berthing [hour]

Then, the number of product load is by calculate the total of the heat needed for cooling and the heat needed for maintain the temperature.

$$Q_p = Q_c + Q_m \quad (2.15)$$

Q_p = The heat of product load

Q_c = The heat needed for cooling the fish until required temperature

Q_m = The heat needed to maintain the temperature

2.4 Calculation of Exhaust Gas Based on Power Engine

Finding the temperature of exhaust gas of the engine could be calculated by formula from the analysis of thermodynamic during the combustion process. In every step of the process, there should be calculation which directing to final temperature. To using this calculation, the cycle should be assumed as the ideal cycle.

1.1 Charging Process

Charging or intake process is the process when the air and mixture comes into the combustion chamber. It happens because of the pressure inside chamber lower than outside of the chamber. (Petrovsky, 1979)

$$P_a = (0.85 - 0.92)P_0 \tag{2.16}$$

P_a	=	Final pressure on intake process [atm abs]
P_o	=	Atmosphere pressure (assume as initial pressure) [atm abs]

$$T_a = \frac{T_o + \Delta T_W + \gamma_r T_r}{1 + \gamma_r} \tag{2.17}$$

T_a	=	Temperature during intake process [^oC]
T_o	=	Initial Temperature (using atmosphere temperature) [^oC]
ΔT_W	=	Heat increasing because of the friction between cylinder wall and piston
γ_r	=	Coefficient of residual gas
T_r	=	Temperature of residual gas

$$\gamma_r(x) = a_{\gamma_r} x + b_{\gamma_r} \tag{2.18}$$

Coefficient of residual gas for every engine load can be determined by the formula above. X is the number of the ratio for engine load, while the coefficient number of a and b is -0.3 and 0.35. (Vornicu, et al., 2017)

$$\eta_{ch} = \frac{\varepsilon}{\varepsilon - 1} \times \frac{Pa}{Po} \times \frac{1}{\frac{Ta}{To}(1 + \gamma_r)} \tag{2.19}$$

η_{ch}	=	The charge efficiency
ε	=	Compression ratio

1.2 Compression Process

The process when the air – fuel mixture is compressed inside the chamber.

$$P_c = P_a \times \varepsilon^{n1} \tag{2.20}$$

P_c	=	Final pressure at compression process [atm abs]
P_a	=	Initial pressure at compression process [atm abs]
n1	=	Polytrophic coefficient

$$A + BT_a\left(\varepsilon^{k_1-1} + 1\right) = \frac{1.985}{k_1 - 1} \tag{2.21}$$

A,B	=	Coefficient found experimentally by N.M Glagolev for each particular gas
k_1	≈	n_1

$$T_c = T_a \times \varepsilon^{n1-1} \tag{2.22}$$

T_c	=	Final temperature at compression process [^{o}C]
T_a	=	Initial temperature at compression process [^{o}C]

1.3 Combustion Process

$$L'_o = \frac{1}{0.21}\left(\frac{c}{12} + \frac{h}{4} - \frac{o}{32}\right) \tag{2.23}$$

c	=	Carbon composition (86%)
h	=	Hydrogen composition (13%)
o	=	Oxygen composition (1%)
L'_o	=	The theoretical air required for the combustion of the fuel

$$L' = L'_o \times \alpha \tag{2.24}$$

L'	=	The actual amount of air
α	=	The excess air coefficient (1.3-1.7)

The total quantity of combustion products:

$$M_g = M_{CO2} + M_{H2O} + M_{N2} + M_{O2} \tag{2.25}$$

The chemical coefficient of molar change

$$\mu_o = \frac{M_g}{L'} \tag{2.26}$$

The coefficient of molar change taking into account the residual gasses

$$\mu = \frac{\mu_o + \gamma_r}{1 + \gamma_r} \tag{2.27}$$

The mean molar heat capacity of gasses at a constant volume

$$(mc_v)_g = A_g + B_g T_z \tag{2.28}$$

The mean molar isobaric heat capacity of gasses at constant pressure

$$(mc_p)_g = (mc_v)_g + 1.985 \tag{2.29}$$

The mean molar isochoric heat capacity of air at constant volume and temperature Tc

$$(mc_v)_a = A_a + B_a T_c \tag{2.30}$$

$$\frac{\xi_z Q_t}{\alpha L_o'(1 + \gamma_r)} + [(mc_v)_a + 1.985\lambda]T_c = \mu(mc_p)_g T_z \tag{2.31}$$

ξ_z	=	The heat utilization coefficient
Q_t	=	The lower heat value of the fuel
α	=	The heat utilization coefficient
γ_r	=	Coefficient of exhaust gas
mc_v	=	Mean molar isochoric heat capacity of the gases found for the given temperature
μ	=	Coefficient of molar change
L_o'	=	The theoretical quantity of the air required for the complete combustion

1.4 Exhaust Process

The mean exponent of polytrophic expansion, taken after a number of successive calculation.

$$A_g + B_g T_z \left(1 + \frac{1}{\delta^{n_2 - 1}}\right) = \frac{1.985}{k_1 - 1} \tag{2.32}$$

$$T_b = \frac{T_z}{\delta^{n_2 - 1}} \tag{2.33}$$

T_b	=	The temperature at the end of the expansion [^{o}C]
T_z	=	The temperature at combustion process [^{o}C]
δ	=	The degree of the subsequent expansion
n_2	=	The polytrophic expansion coefficient

2.5 The COP (Coefficient of Performance) of The System

The COP (Coefficient of Performance) is defined as the ratio of cooling effect produced the heat input to produce the cooling. The coefficient of performance is used for analyzing the refrigerator that used to create the refrigeration effect, a heat pump which heating effect is used for rejected heat and a heat recovery system which the refrigerating and heating effect are used in the same time. (Wang, 2001)

$$COP_{ref} = \frac{Q_{ref}}{W_{in}} \tag{2.34}$$

Q_{ref}	=	Refrigeration effect [Watt]
W_{in}	=	Work input [Watt]

Consideration of the first and second law of thermodynamics, the formula of ideal COP will be:

$$COP_{Ideal} = \frac{T_c}{T_h}\frac{(T_h - T_m)}{(T_m - T_c)} \tag{2.35}$$

T_c	=	temperatures of the cold source [^{o}C]
T_h	=	temperatures of driving heat source [^{o}C]
T_m	=	intermediate temperatures level where heat is rejected [^{o}C]

The COP of the absorption refrigeration system is the ratio between the cooling duty and energy needed. The formula is :

$$COP_{ARS} = \frac{Qcoolingload}{Qgenerator + Wpump} \tag{2.36}$$

2.6 The Previous Research

Due to the advantages of the absorption refrigeration system, there are several researches which researched the technical aspect of the system especially its application on the ship by using waste heat related to exhaust gas of the engine.

(Cao, et al., 2015) mentioned that applying the waste heat powered absorption cycle cooling system in the cruise ship can save the total energy by 8.23%. (C., 2014) research about the usage of the absorption refrigeration system in naval ship and found that use the absorption refrigeration system can reduce the fuel consumption and CO_2 emission. (Palomba, et al., 2016) also analyze the absorption refrigeration system in fishing vessel. It resulted that this system has the exploitation potential of waste heat recovery for refrigeration on board. (Xingguo, et al., 2017) mentioned that the stability of exhaust heat driven refrigeration systems in fishing vessels would be influenced not only by the vibration, but also the continuity and quantity of the heat of exhaust gas from the engines, which depended on the engine load. (Satriananda, 2017) analyzed the absorption chiller system in PKR Ship with the optimum operation in 50% load of diesel engine with COP 0.74.

2.7 Characteristics of The Working Fluids

1. Ammonia (NH_3)

   Ammonia is the colorless gas, highly soluble in water and a cost-effective solution for refrigeration. It has several advantages, those are most safety refrigerant for the environment which has ODP rating of zero and GWP rating of zero, cheaper than CFCs and HCFCs, for the system costs less than CFCs resulting of lower operation costs. But it also has disadvantages, those are this fluid is corrosive with copper, so the system should be avoided to use the copper, will be danger in high concentration so the system needs the scheduled preventive maintenance.
2. Methylamine (CH_3NH_2)

   The studied found that its thermodynamic properties suitable for applied in absorption refrigeration system. (Gao, et al., 2003). The other studied also found that the COP monomethylamine-water has better COP than ammonia-water.
3. Dimethylacetamide

   Dimethylacetamide is the colorless liquid and slight of scent like ammonia. It has the same density with water. Classified as inflammable liquid, so it makes it more safety than the others. This compound is produced specially for industrial work.

CHAPTER III
METHODOLOGY

3.1 Methodology Flowchart

The following chart describe the process working of Bachelor Thesis

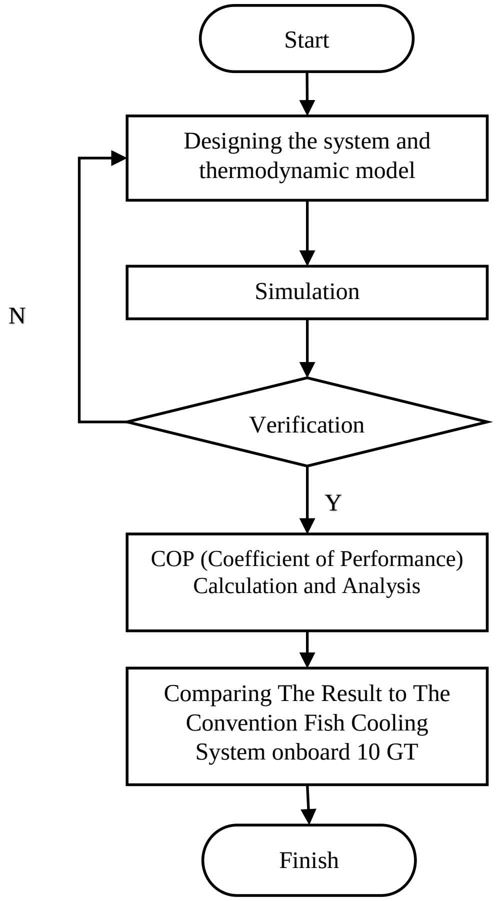

Figure 3. 1 Main Flowchart

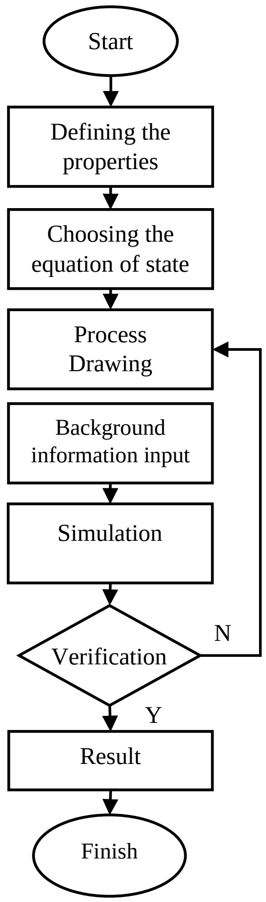

Figure 3. 2 Simulation Flowchart

3.2 Designing The System and Thermodynamic Model

To input the simulation into the program, it exactly need the design of system and the proper thermodynamic model to be input.

3.3 Simulation

In this research, the simulation will be done by using system simulator. As seen on figure 3.2, there are several step of the simulation. Those are choosing the fluids that will be used, the thermodynamic model of the system, create the system model and input the background system. The simulation will use the designing system on figure 2.2 and there will be two types of the varying data. Those are data of composition of absorbent and refrigerant fluids and the data of the loads of engine.

3.4 Verification of The System

Verification of the system is need to be done to ensure the system is applied with the applied terms.

3.5 COP (Coefficient of Performance) Analysis

On this step, the COP of the simulation will be calculated.

3.6 Comparing The Result to The Convention Fish Cooling System onboard

The result obtained from the simulation will be compared to the conventional cooling onboard.

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CHAPTER IV
DISCUSSION AND RESULTS

In this chapter will be explained the calculation of the cooling load and the analysis of using absorption refrigeration system for cooling the cargo hold with the varieties of working fluids.

4.1 Information Data Used

For this thesis, the size of the fishing vessel that will be used is 10 GT Fishing Vessel with the temperature of the cargo hold is 0 ^{o}C. The general data of the ship is mentioned below

Specification: Multi-Purpose Line Hauler 10 GT Fishing Vessel

Construction material: Fiberglass Reinforced Plastic (FRP)

Length Overall: 13.50 meter

Beam: 2.80 meter

Height: 1.45 meter

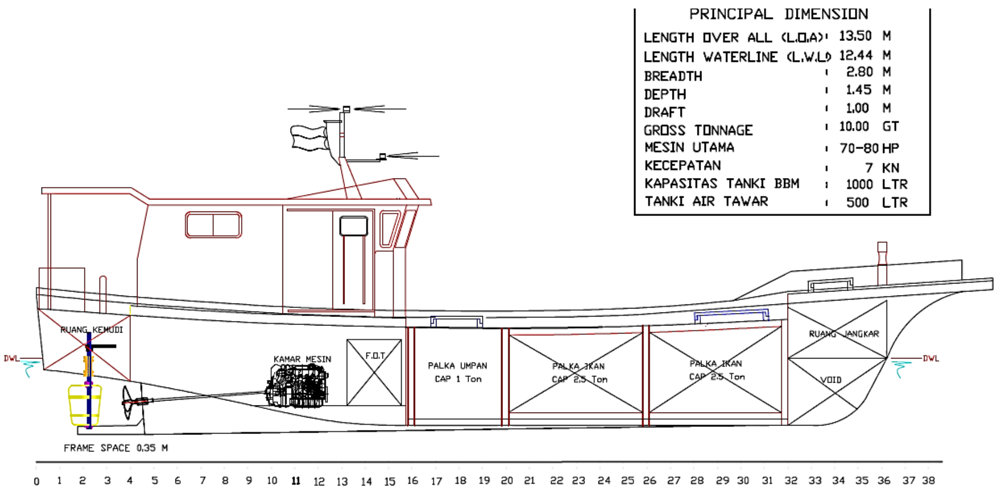
Draft: 1.00 meter

Speed: 7 knot

Engine: Volvo Penta 75 HP

Fish hold: 7.5 m^3 capacity equipped with 5 cm and 10 cm (side to engine room) Polyurethane foam and water tight insulation.

Dimension of hold cover: 60 x 60 cm



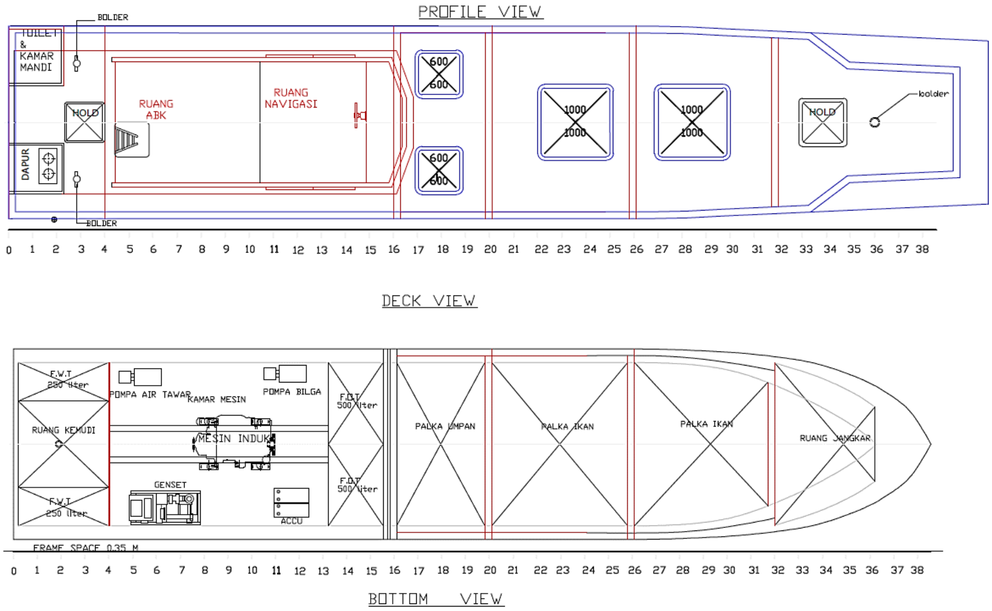


Figure 4. 1 General Arrangement of 10 GT Fishing Vessel

4.2 Exhaust Gas Temperature

Based on equation 2.7 – 2.24 with the power engine 75 HP, we could find the exhaust gas temperature with varying load which is mentioned on the table 4.1.

Tabel 4. 1 Processed Data of Exhaust Gas of Volvo Penta 75 HP

Load Engine	Texh (K)	Texh (°C)
25%	451.26	178.26
50%	463.86	190.86
75%	477.71	204.71
100%	491.14	218.14

4.3 Cooling Load

Using equation 2.1 – 2.6, we find the fish cooling load calculation on this vessel. Known that the outside temperature 33°C (chosen from the highest point). The temperature on engine room 45 °C and temperature of the other room (next to cargo hold) is 27°C.

<u>Wall gain load</u>

- Bottom Floor

Water data:

$$\mathrm{Re} = \mathrm{L} \times \mathrm{V} \times \frac{\rho}{v} \quad (4.37)$$

Re	=	Reynolds number
L	=	Length of the ship [m]
V	=	Speed of the ship [m/s]
ρ	=	Density [kg/m^3]
v	=	Viscosity [kg/m.s]

$\mathrm{Re} = \mathrm{L} \times \mathrm{V} \times \frac{\rho}{v}$

$\mathrm{Re} = 13.5 \times 4.115 \times \frac{0.823}{0.0000022}$

$\mathrm{Re} = 20784513$ (turbulent)

$$\mathrm{Nu} = 0.023 \times \mathrm{Re}^{0.8} \times \mathrm{Pr}^{n} = \mathrm{h} \times \mathrm{L} \times \mathrm{k} \quad (4.38)$$

Nu	=	Nusselt number
Pr	=	Prandtl number
n	=	Constanta
h	=	Convection coefficient
k	=	Thermal conductivities

$\mathrm{Nu} = 0.023 \times \mathrm{Re}^{0.8} \times \mathrm{Pr}^{n}$

$\mathrm{Nu} = 0.023 \times 20784513^{0.8} \times 5.412^{0.4}$

$\mathrm{Nu} = 32304.5$

$\mathrm{h} = 1482.18$

$$\mathrm{Rs} = \frac{1}{\mathrm{h}} \quad (4.39)$$

$\mathrm{Rs} = \frac{1}{\mathrm{h}}$

$\mathrm{Rs} = 0.00067$

Below mentioned in table 4.2, the isolation type with the number of coefficient of heat transfer.

Tabel 4. 2 Table of Heat Transfer Coefficient for Each Material

Isolation type	k (W/cm ºC)
Space with water	0.0006747
Fiberglass	0.0003065
polyurethane foam	0.000231
Inside space air	0.1067236
Frame	0.003065
Stiffner	0.003065
Grider	0.003065

$\text{Total length of the frame} = 280 \times 50$

$\text{Total length of the frame} = 1400 \text{ cm}$

$\text{Length of the stiffner} = 28 \times 30$

$\text{Length of the stiffner} = 840 \text{ cm}$

$\text{Length of the grider} = 28 \times 20$

$\text{Length of the grider} = 560 \text{ cm}$

Condition note:

Q1: The heat flow direct from the wall to the hold
Q2: The heat flow through the frame
Q3: The heat flow through the stiffner
Q4: The heat flow through the grider

$\text{A2 (frame)} = 7000\ cm^2$ (width of the frame is 5 cm)

$\text{A3 (stiffner)} = 4200\ cm^2$ (width of the stiffmer is 5 cm)

$\text{A4 (grider)} = 2800\ cm^2$ (width of the grider is 5 cm)

Below are shown table of the heat of the wall for each condition.

Tabel 4. 3 Table of The Heat of Each Flow on Bottom Floor

Isolation type	k (W/cm °C)	x (cm)	Q1 (R)	Q2	Q3	Q4
Space with water	0.0006747		0.000667	0.000667	0.000667	0.000667
Fiberglass	0.0003065	10	32626.42741	32626.427	32626.427	32626.43
polyurethane foam	0.000231	5	21645.02165	21645.022	21645.022	21645.02
Inside space air			0.106723586	0.1067236	0.1067236	0.106724
Frame	0.003065	5	-	1631.3214	-	-
Stiffner	0.003065	5	-	-	1631.3214	-
Grider	0.003065	5	-	-	-	1631.321
Total R =			54271.55644	55902.878	55902.878	55902.88

	U=1/R	A	A bottom	A/Abottom	A/AxU
Q1	0.0000184	50400	50400	1	0.0000184
Q2	0.0000179	7000	50400	0.1388889	0.0000025
Q3	0.0000179	4200	50400	0.0833333	0.0000015
Q4	0.0000179	2800	50400	0.0555556	0.0000010
Total (Ubtm) =					0.0000234

$Q_{btm} = A \times U \times (t_o - t_i)$

$Q_{btm} = 50400 \times 0.0000234 \times (33-0)$

$Q_{btm} = 38.9102$ W

$Q_{btm} = 33.46278$ kcal/h

- Top Floor

Total length of the deck beam (transversal) = 1400 cm

Total length of the deck beam (longitudinal) = 360 cm

Q1: The heat flow direct from the wall to the hold
Q2: The heat flow through the deck beam (transversal)
Q3: The heat flow through the deck beam (longitudinal)

A2 (transversal) = 7000 cm^2 (width of the beam is 5 cm)

A3 (longitudinal) = 1800 cm^2 (width of the beam is 5 cm)

Tabel 4. 4 Table of The Heat Coefficient of Top Floor

Isolation type	k (W/cmoC)	x (cm)	Q1	Q2	Q3
Flowing air	299.37		299.37	299.37	299.37
Fiberglass	0.0003065	10	32626.42741	32626.427	32626.42741
polyurethane foam	0.000231	5	21645.02165	21645.022	21645.02165
Inside space air			0.106723586	0.1067236	0.106723586
Deck beam	0.003065	5		1631.3214	1631.32137
Total R =			54570.92577	56202.247	56202.24715

	U=1/R	A	A top	A/Atop	A/AxU
Q1	0.00001832	46800	50400	0.9285714	0.00001702
Q2	0.00001779	7000	50400	0.1388889	0.00000247
Q3	0.00001779	1800	50400	0.0357143	0.00000064
Total (Utop) =					0.00002012

Q_{top}= A × U × (t_o- t_i)

Q_{top}= 50400 × 0.00002012 × (33-0)

Q_{top}= 33.4678 W

Q_{top}= 28.7823 kcal/h

- Side (above LWL)

Total length of the frame = 1400 cm

Total length of the beam = 1800 cm

Q1: The heat flow direct from the wall to the hold
Q2: The heat flow through the frame
Q3: The heat flow through the beam

A1 = 8100 cm^2

A2 (frame) $= 7000\ cm^2$

A3 (beam) $= 9000\ cm^2$

Tabel 4. 5 Table of The Heat Coefficient of Side (Above LWL)

Isolation type	k (W/cmoC)	x (cm)	Q1	Q2	Q3
Flowing air	299.37		299.37	299.37	299.37
Fiberglass	0.0003065	10	32626.42741	32626.427	32626.42741
polyurethane foam	0.000231	5	21645.02165	21645.022	21645.02165
Inside space air			0.106723586	0.1067236	0.106723586
Frame	0.003065	5		1631.3214	
Beam	0.003065	5			1631.32137
Total R =			54570.92577	56202.247	56202.24715

	U=1/R	A	A aLWL	A/AaLWL	A/AxU
Q1	0.00002	1800	8100	0.22222	0.00000
Q2	0.00002	7000	8100	0.86420	0.00002
Q3	0.00002	9000	8100	1.11111	0.00002
Total (UaLWL) =					0.00004

Q_{alwl}= A × U × (t_o- t_i)

Q_{alwl}= 8100× 0.000039× (33-0)

Q_{alwl}= 20.966 W

Q_{alwl}= 18.03 kcal/h

- Side (below LWL)

Total length of the frame $= 1400$ cm

Total length of the beam $= 1800$ cm

A1 $= 18000\ cm^2$

A2 (frame) $= 7000\ cm^2$

A3 (beam) $= 9000\ cm^2$

Tabel 4. 6 Table of The Heat Coefficient of Side (Below LWL)

Isolation type	k (W/cmoC)	x (cm)	Q1	Q2	Q3
Flowing water			0.000674683	0.0006747	0.000674683
Fiberglass	0.0003065	10	32626.42741	32626.427	32626.42741
polyurethane foam	0.000231	5	32626.42741	32626.427	32626.42741
Inside space air			0.106723586	0.1067236	0.106723586
Frame	0.003065	5		1631.3214	
Beam	0.003065	5			1631.32137
Total R =			65252.96221	66884.284	66884.28358

	U=1/R	A	AbLWL	A/AbLWL	A/AxU
Q1	0.0000153	18000	18000	1	0.0000153
Q2	0.0000150	7000	18000	0.3888889	0.0000058
Q3	0.0000150	9000	18000	0.5	0.0000075
Total (UbLWL) =					0.0000286

Q_{blwl}= A × U × (t_o- t_i)

Q_{blwl}=18000 × 0.0000286× (33-0)

Q_{blwl}= 16.997 W

Q_{blwl}= 14.617 kcal/h

- Engine Bulkhead

Total length of the beam (vertical) = 840 cm

Total length of the beam (horizontal) = 540 cm

A1 = 40600 cm^2

A2 (vertical) = 4200 cm^2

A3 (horizontal) = 2700 cm^2

Tabel 4. 7 Table of The Heat Coefficient of Engine Bulkhead

Isolation type	k (W/cmoC)	x (cm)	Q1	Q2	Q3
Flowing air	1206.16		1206.16	1206.16	1206.16
Fiberglass	0.00115	10	8695.652174	8695.6522	8695.652174
polyurethane foam	0.000231	10	43290.04329	43290.043	43290.04329
Inside space air			1.206.16	1.206.17	1.206.18
Beam	0.00115	5		0.00575	0.00575
Total R =			53191.85546	53191.861	53191.86121

	U=1/R	A	Aeb	A/Aeb	A/AxU
Q1	0.00001880	33700	40600	0.8300493	0.00001560
Q2	0.00001880	4200	40600	0.1034483	0.00000194
Q3	0.00001880	2700	40600	0.0665025	0.00000125
Total (Ueb) =					0.00001880

Q_{ebl}= A × U × (t_o- t_i)

Q_{ebl}= 40600 × 0.00001880× (45-0)

Q_{ebl}= 34.347W

Q_{ebl}= 29.538 kcal/h

- Fore Bulkhead

Total length of the beam (vertical) = 840 cm

Total length of the beam (horizontal) = 540 cm

A1 = 40600 cm^2

A2 (vertical) = 4200 cm^2

A3 (horizontal) = 2700 cm^2

Tabel 4. 8 Table of The Heat Coefficient of Fore Bulkhead

Isolation type	k (W/cmoC)	x (cm)	Q1	Q2	Q3
Flowing water	1206.16		1206.16	1206.16	1206.16
Fiberglass	0.0003065	10	32626.42741	32626.427	32626.42741
polyurethane foam	0.000231	5	21645.02165	21645.022	21645.02165
Inside space air			1.206.16	1.206.17	1.206.18
Beam	0.00115	5		0.00575	0.00575
Total R =			55477.60905	55477.615	55477.6148

	U=1/R	A	Aeb	A/Afb	A/AxU
Q1	0.0000180	33700	40600	0.8300493	0.0000150
Q2	0.0000180	4200	40600	0.1034483	0.0000019
Q3	0.0000180	2700	40600	0.0665025	0.0000012
Total (Ufb) =					0.0000180

$Q_{fbl} = A \times U \times (t_o - t_i)$

$Q_{fbl} = 40600 \times 0.00001843 \times (27-0)$

$Q_{fbl} = 20.1984$ W

$Q_{fbl} = 17.3706$ kcal/h

<u>Product load</u>

- Cooling load until the fish reach the required temperature

m = 2500 kg
c = 0.8 kcal/kg°C
T_1 = 33 °C
T_2 = 0 °C
ΔT = $T_2 - T_1$
ΔT = 33 °C
t = 10 hour

$$Q_c = \frac{m \times c \times \Delta T}{t}$$

$$Q_c = \frac{2500 \times 0.88 \times 33}{10}$$
$$Q_c = 7260 \text{ kcal/hour}$$

Total Cooling Load

Total cooling load is the total number of the load for each parameter.

Tabel 4. 9 Table of Total Load

Load	kcal/h
Cooling load at bottom	33.46
Cooling load at top	28.78
Cooling load at side above lwl	18.03
Cooling load at side below lwl	14.62
Cooling load at fore bulkhead	17.37
Cooling load at engine bulkhead	29.54
Product load	7260
Total	7401.8

4.4 System Simulation

The figure of the simulation below (Figure 4.1) is the simulation based on the system that will be used on the ship (Figure 2.2). The system consists of 7 steps of unit process, those are solution pump, solution heat exchanger, generator, condenser, expansion valve, evaporator and absorber. Then, it is simulated in the simulator. In this simulation, will be used three-pairs of different working fluids. Those are NH_3-H_2O, CH_3NH_2 - H_2O and C_4H_9NO - H_2O.

Firstly, the simulation started by setting the working fluids that will be used. After that, the process of choosing the thermodynamic model for this system. For NH_3-H_2O and CH_3NH_2 - H_2O, the thermodynamic model used is Peng-Robinson Model. While, for C_4H_9NO – R134A, the model is GP model.

Then, the process of modeling using the equipment in the simulator. It started on the stream number 1. Here, it set the initial condition of the process. The input data are the composition of the working fluids (absorbent and refrigerant) which is varied by 50:50, 55:45 and 45:55, the vapor/phase fraction of the fluids by setting to number 0 which it means the fluids in condition of saturated liquid, the low pressure and mass flow of the fluids.

The next step is input the pump model (P-100). Pump is used for increasing the pressure of the fluids to make it has the same pressure with the condition in generator. The data inputted is the output pressure from the pump.

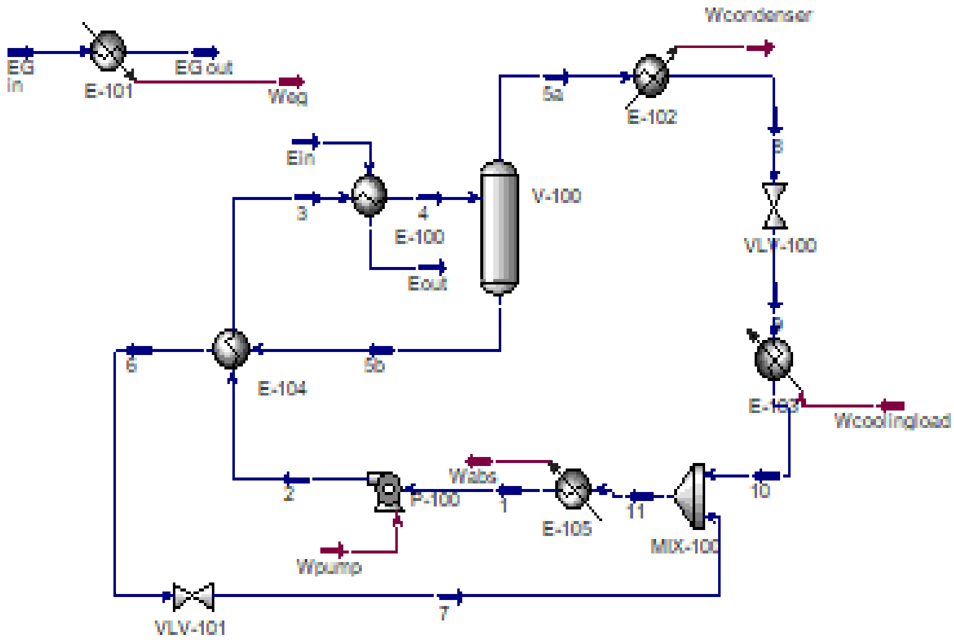


Figure 4. 2 Simulation Model of Absorption Refrigeration System

And then, the installing of the solution heat exchanger (E-104). The solution heat exchanger is used for utilize the high temperature of the outflow of the generator to heat the solution fluids up. Because of this equipment, it will increase the efficiency of energy.

After that, the generator modelling is installed. This modelling consists of heat exchanger (E-100) and separator equipment (V-100) in the simulator. The heat exchanger is used for heating the fluids with the energy from the exhaust gas flow, while separator is used for separating the two different phase of fluids. The vapor phase will flow to the condenser (E-102) and changing the form into liquid phase, whereas the absorbent will flow to the solution heat exchanger.

After the absorbent passing the solution heat exchanger, the pressure of the fluid will be decreased by passing the expansion valve (VLV-101) then going to the absorber while after passing the condenser, the vapor phase fluid will be decreased of pressure then going to the evaporator (E-103).

In the evaporator, the refrigerant will take the heat from the cargo hold which makes the room cooler and increasing the temperature the refrigerant and make this fluid into vapor phase then flows to the absorber (MIX 100 and E-105). In the absorber, the refrigerant and the absorbent are mixed and the cycle is repeated.

The calculation of COP is got from the cooling load capacity divided by the energy of exhaust gas and pump. Based on the results from the calculation of COP (Coefficient of Performance) shown that the working fluid which has the best COP is C_4H_9NO – R134A with 25% of engine load and the ratio of the composition 50/50 (absorbent/refrigerant). It shown that it gets COP about 0.8804. While the working fluid which has the lowest COP is NH_3-H_2O with 100% engine load. It gets the COP about 0.1.

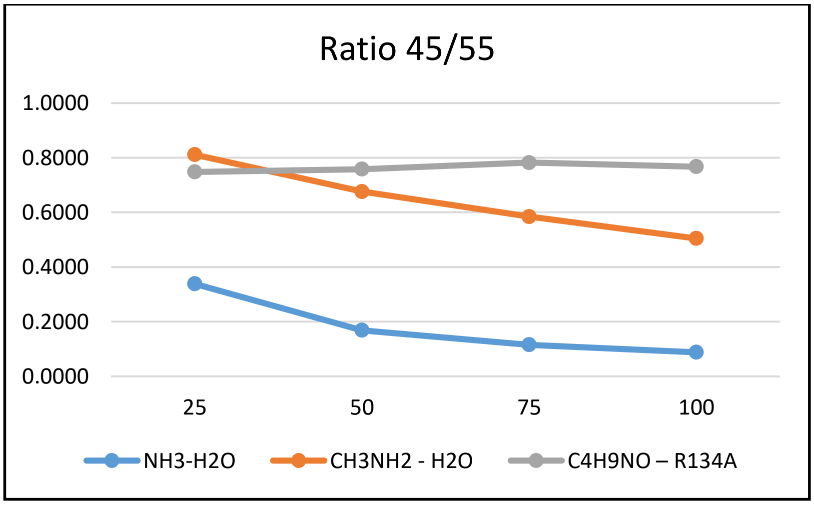
But if the load is during operational load (between 75-100% load), the working fluid which has the best COP is C_4H_9NO – R134A of the composition of 55/45 with the value about 0.79.

Tabel 4. 10 The result of COP from EG Absorption Refrigeration System

Load	Working Fluid	Ratio	COP
25%	NH_3-H_2O	45/55	0.3388
		50/50	0.3702
		55/45	0.3573
	CH_3NH_2 - H_2O	45/55	0.8114
		50/50	0.8160
		55/45	0.8189
	C_4H_9NO – R134A	45/55	0.7483
		50/50	0.8804
		55/45	0.8338
50%	NH_3-H_2O	45/55	0.1686
		50/50	0.1716
		55/45	0.1713
	CH_3NH_2 - H_2O	45/55	0.6765
		50/50	0.6766
		55/45	0.6869
	C_4H_9NO – R134A	45/55	0.7583
		50/50	0.7702
		55/45	0.8339
75%	NH_3-H_2O	45/55	0.1156

		50/50	0.1156
		55/45	0.1169
	CH_3NH_2 - H_2O	45/55	0.5843
		50/50	0.5844
		55/45	0.5960
	C_4H_9NO – R134A	45/55	0.7824
		50/50	0.7428
		55/45	0.7993
100%	NH_3-H_2O	45/55	0.0878
		50/50	0.0878
		55/45	0.0894
	CH_3NH_2 - H_2O	45/55	0.5047
		50/50	0.5288
		55/45	0.5164
	C_4H_9NO – R134A	45/55	0.7675
		50/50	0.6827
		55/45	0.7675

This absorption refrigeration system using exhaust gas as a heat source has the number of COP varied depend on the type and composition of the working fluid and the load of the engine during the operation. Below shown the graphics 4.1 which shown the effect of engine load and ratio of the composition.

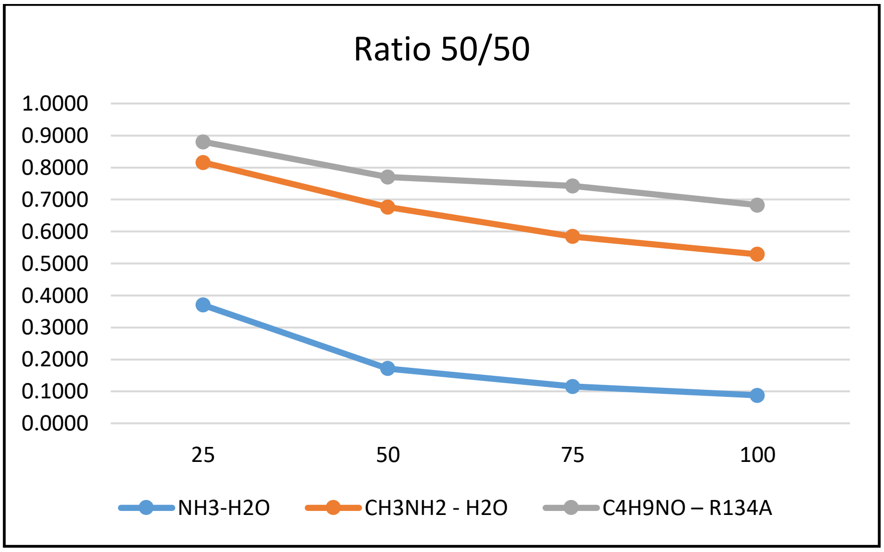


Graphic 4. 1 The comparison between load of engine with the value of COP in ratio 45/55 (absorbent/refrigerant)

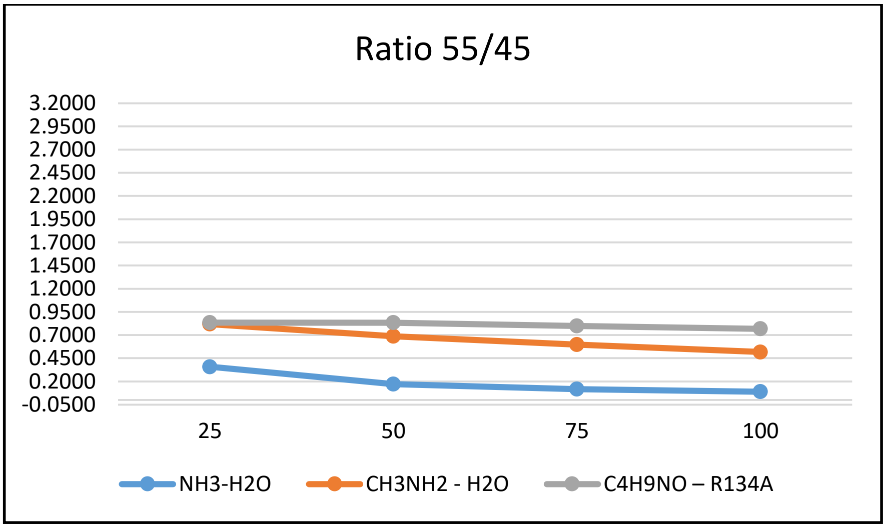
On the ratio 45/55, the working fluids is tending to decreasing if there is increasing of the engine load. It is caused by the temperature which is increasing. It means that the COP of the working fluids is inversely proportional with the temperature of the heat source.

Not only in the ratio of composition 45/55, in the 50/50, the graphic 4.2 shown that from each working fluid is tending decreasing. But in this composition, the number of COP is tending to bigger than the previous composition. One of the reason that the balanced composition between refrigerant and absorbent create the higher number of COP.

And from the graphic 4.3, prove that when the engine has 100% load, for each of the pair of working fluid get the value of COP lower than the other load. It is caused by the higher output of the exhaust gas temperature of the engine. The increasing temperature of the engine, it will make the decreasing of the performance of the system. It reinforces the previous statement. Also, the number of COP of this composition is tending higher than the composition of 45/55. The value of COP of C_4H_9NO – R134A on the operational load with 55/45 composition of working fluids has tending bigger COP than with the balanced composition (50/50).



Graphic 4. 2 The comparison between load of engine with the value of COP in ratio 50/50 (absorbent/refrigerant)



Graphic 4. 3 The comparison between load of engine with the value of COP in ratio 55/45 (absorbent/refrigerant)

For all the experiment, the working fluids which has the better COP is C_4H_9NO – R134A. But, when the load of engine reach 75-100% load which is during operational load, its COP is lower than the COP of C_4H_9NO – R134A on the lower load of engine. The reason of the lowering number of COP on the higher load is caused by the energy of exhaust gas in generator. On the same number of cooling load of the cargo hold. in the lower load, the difference temperature is bigger than in the higher load. Increasing of the load of engine is decreasing the difference of the temperature. The difference of the temperature influences the amount of energy of the exhaust gas. But, in the contrary, the mass flow rate of the engine is increasing as the increasing of the load. Because of that, when there is increasing of the load of engine, the energy will be increased and the number of COP will be decreasing when the number of cooling load is same.

On the other side, the composition of 55/45 has the value of COP higher than the composition of 45/55. This result approves the result of the research by Serly A. and Novita (Serly A., 2017)That is happened because of the reduce of the composition of refrigerant which makes the fluids easier to getting hot, and make the less usage of energy which affect the value of COP.

4.5 Analysis from The Result to be Applied on Ship

From the result above, we see that the best COP got from the system is when the load is in 25% load. But in the reality, we might not use the engine in 25% load. So, we need to see the performance between 75-100% load.

We see that the value of COP on the higher load is decreasing. It is also caused by the fixed number of the cooling load although the energy given is bigger than the low load. From that statement, to overcome the reducing of COP in the higher load, we could see that to get the higher value COP on the higher load, we could increase the number of cooling load. With the same energy of exhaust gas, simulate to get the value of COP as the COP of 25% load which is the highest COP on the system, the number of cooling load will be get (see on Table 4.11).

The recommendation working fluids to be used is C_4H_9NO – R134A because from the overall condition those working fluids has the better performance. Then, although the composition which has the bigger COP is 50/50, but if we look into the average value of the COP, the composition which will be recommended is the composition 55/45 (absorbent/refrigerant) because the important thing to be seen is the average performance where the overall performance in 55/45 is better than the balanced composition.

Tabel 4. 11 The Changing Load for increasing COP

Load	Cooling Load [kcal/h]
75 %	7722
100 %	9237

With the increasing of the cooling load to increasing the value of COP, it shown that energy of 75% load could receive the cooling load until 7722 kcal/h and of 100% load could do the cooling load until 9237 kcal/h.

4.6 Comparison with The Conventional Cooling System on The Vessel

The comparison of the cooling system is defined from the several aspects such as size, weight and the performance of the usage of the system. The choosen system to be applied is the system which has the biggest COP on the highest load. It is chosen because we should consider the usage of the system which usually used in 85% load and also for overcome the condition when the engine used in 100% load. For compare the weight of the system, we should know the minimum weight of ice needed for cooling the fish.

- From the calculation given from FAO, the ice requirement for cooling the fish is

$$\mathrm{Mi} = \frac{\mathrm{Mf} \times \mathrm{Cpf} \times (\mathrm{Ts} - \mathrm{Tc})}{\mathrm{Li}} \tag{4.40}$$

Mi = Mass of ice needed [kg]
Mf = Mass of fish [kg]
Cpf = Specific heat of fish [kcal/kg ^{o}C]

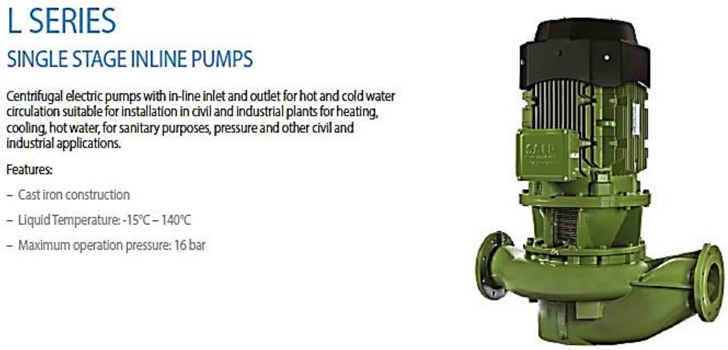
Ts	=	Initial temperature of fish [^{o}C]
Tc	=	Final temperature of fish [^{o}C]
Li	=	Latent heat of fusion of ice [kcal/kg]

$$\mathrm{Mi} = \frac{2500 \times 0.8 \times (33-0)}{80}$$

$$\mathrm{Mi} = 825 \text{ kg}$$

- After knowing the weight of needed ice, we looked for the equipment description and specification of the system. The equipment is based on the designing system on Figure 2.2. Below are mentioned the minimum specification of the equipment based on simulation:

1. Pump
   Pump should be having the capability to pump the fluids to increase the pressure of the fluid. The number of working pressure is 2 bar.



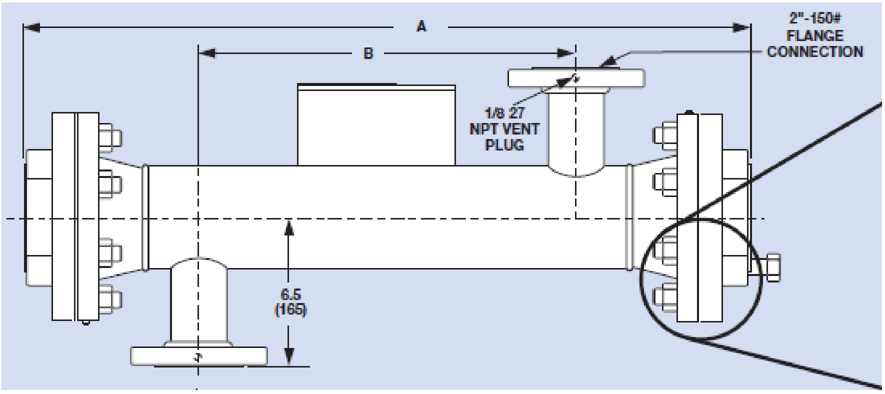
2. Solution Heat Exchanger
   The sizing data of the solution heat exchanger is get from the sizing data of the simulator that will be used as the recommendation size to be applied. The description is

Number of Shell Passes	2
Tubes Pass per Shell	12
Shell diameter [mm]	739.05
Number of holes on the tubes per shell	160
Tube Layout Angles	Triangular (30 degrees)
Shell Baffle Type	Single
Shell Baffle Orientation	Horizontal
Baffle Spacing [mm]	800
OD Tube [mm]	20
ID Tuber [mm]	16

Tube Thickness [mm]	2
Tube Length [m]	6

The estimation weight of the equipment is get from the similar equipment on the catalogue on the market.

NOMINAL LENGTH (ft)	A OVERALL LENGTH		B NOZZLE TO NOZZLE LENGTH	APPROXIMATE WEIGHT	
	UNLINED	LINED		EMPTY	WATER FILLED
18	249.1 in (6237 mm)	249.5 in (6336 mm)	223.4 in (5674 mm)	1194 lb (541 kg)	1895 lb (859 kg)



3. Absorber

As simulation, the absorber consists of the mixer and cooler equipment. The equipment's description is

Mixing Equipment

Connection Type	Horizontal
Diameter [m]	0.3048
Total Length [m]	0.9144
L/D Ratio	3
Demister to top [m]	0
Liq. Surge Height [m]	0
LLSD [m]	0.3048

4. Generator

For simulate the generator, consists of two equipment. Those are heat exchanger and separator. The description for separator is

Orientation	Vertical
Geometry	Flat Cylinder
Volume [m^3]	0.1223
Diameter [m]	0.3048

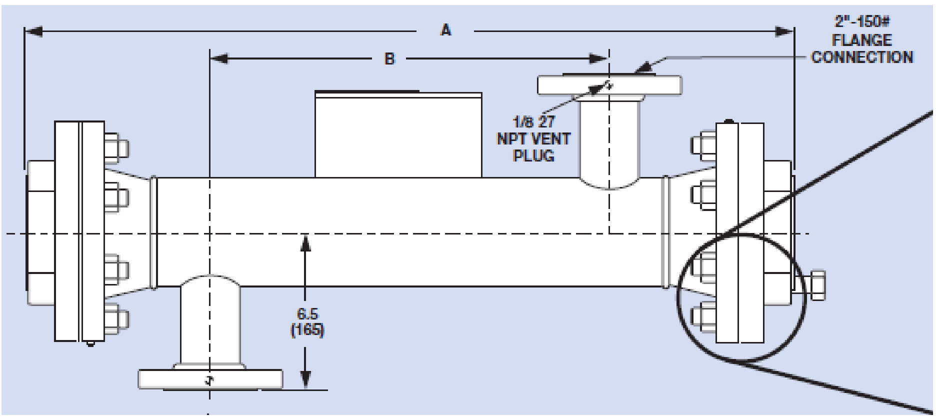
Height [m]	1.676

And the description of heat exchanger for heating the fluids by exhaust gas is

Tube Passes per Shell	12
Shell diameter [mm]	578.19
Number of holes on the tubes sheet per shell	96
Tube Layout Angles	Triangular (30 degrees)
Shell Baffle Type	Single
Shell Baffle Orientation	Horizontal
Baffle Spacing [mm]	800
OD Tube [mm]	20
ID Tuber [mm]	16
Tube Thickness [mm]	2
Tube Length [m]	6

The estimation weight of the equipment is referring from the weight of the similar equipment on the market. The weight of the similar equipment can be seen on the description below.

NOMINAL LENGTH (ft)	A OVERALL LENGTH		B NOZZLE TO NOZZLE LENGTH	APPROXIMATE WEIGHT	
	UNLINED	LINED		EMPTY	WATER FILLED
18	249.1 in (6237 mm)	249.5 in (6336 mm)	223.4 in (5674 mm)	1194 lb (541 kg)	1895 lb (859 kg)

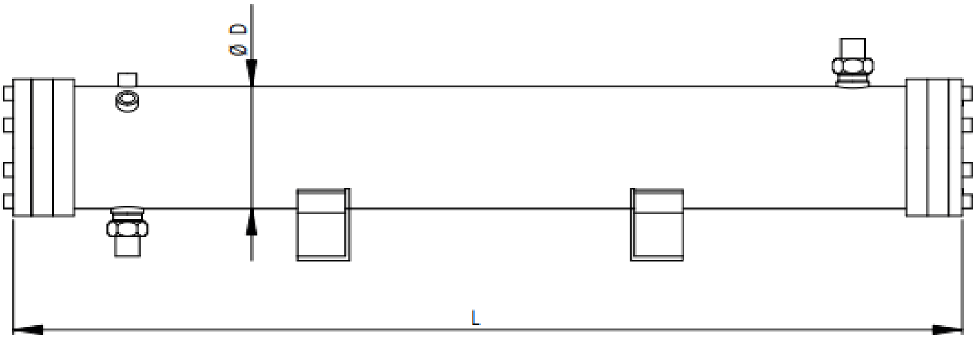


5. Condenser

For the condenser, the condensing capacity for the system based on simulation is 2928 Btu/hour.

Capacity	3 kBtu/hour
Shell diameter [mm]	6.840

Total Length [m]	0.0579



6. Evaporator
   For evaporator, the evaporating capacity data is based on the maximum cooling capacity of 100% load on the highest reached COP is 9237 kcal / hour.

7. Reducing Valve
   Reducing valve which is used for decreasing the pressure of the fluids as an initial fluids need to decrease the pressure about two bar.

PRESSURE REDUCING VALVE

An accurate and reliable directly-acting pressure reducing valve used to maintain a preset downstream pressure regardless of flow rate and upstream pressure fluctuations. Suitable for domestic, commercial and industrial applications involving potable water, oil or air.

Technical specification:
- Range: dn50 – dn150
- Adjustable downstream pressure: 1 1/2 – 6 bar, 5 – 12 bar or 12 – 24 bar
- Maximum upstream pressure: 40 bar
- Minimum dynamic differential pressure: 1 bar
- Flanged: EN1092 table 9 (PN16)
- Face to face: EN558 series 1
- Maximum temperature: 70°C
- Hydrostatic pressure tests: Seat – 1.1 x PN Body – 1.5 x PN
- Coating: WRAS listed fusion bonded epoxy

Features:
- Patented self cleaning piston
- Proven engineered balance design
- Robust ductile construction
- Stainless steel internal components
- Wras listed materials
- Tapped upstream and downstream bosses

Options:
- Inline strainer
- Isolation valve

VALVE TYPE	WEIGHT kg	CODE
DN50 SPRING 1 1/2 – 6 BAR	12	AQ/PRV50/6
DN65 SPRING 1 1/2 – 6 BAR	19	AQ/PRV65/6
DN80 SPRING 1 1/2 – 6 BAR	24	AQ/PRV80/6
DN100 SPRING 1 1/2 – 6 BAR	34	AQ/PRV100/6
DN125 SPRING 1 1/2 – 6 BAR	56	AQ/PRV125/6
DN150 SPRING 1 1/2 – 6 BAR	74	AQ/PRV150/6

From the specification data of equipment, table 4.11 summarized the weight and size of the equipment.

Tabel 4. 12 Summarized Size and Weight of The Equipment

No	Equipment	Size	Weight
1	Pump	-	8.3 kg
2	Solution Heat Exchanger	6 x 0.02 x 0.02 m	+/- 859 kg
3	Absorber	0.9 x 0.3 m	-
4	Generator	(6 x 0.02 x 0.02) + (1.676 x 0.3048) m	+/- 859 kg
5	Condenser	57.9 x 6.84 mm	
6	Evaporator		
7	Reducing Valve	-	12 kg

From the table above, if we compare the result of summation of the weight of the equipment, known that the weight is weightier than the weight of the calculation of the needed ice. The size of the equipment also need big space if installed on the ship.

On the other side, the usage of absorption refrigeration system has better performance than usage of ice. Absorption refrigeration system can be used for along the voyage. While, the time of usage of ice is depend on the amount of the ice. Not only about that, absorption refrigeration system can save energy from the exhaust gas.

Because of that good performance and the weakness is only on the size and weight, there should be other analysis to make the improving design that has suitable size of the equipment for this system to be applied on the ship.

4.7 Solution Heat Exchanger

Heat exchanger is an equipment in the system which transfer the heat from one fluid to the other fluid without mixing or contacting the both fluid. Heat exchanger can be used for increasing the COP system than without the heat exchanger. The type of heat exchanger used in this system is shell and tube type heat exchanger. It is used because of the usage of the higher temperature of the fluid and this type usually used for fluid preheating.

Also because of this type part can be easily disassemble, it will make easy for the crew for cleaning and repairing the heat exchanger.

CHAPTER V
CONCLUSION AND SUGGESTION

5.1. Conclusion

Based on the analysis of the system, the conclusion is:

The best working fluids to be used on absorption refrigeration system in fishing vessel on the operational load is C_4H_9NO – R134A with the value of COP about 0.79. While, from all the condition of the load of engine C_4H_9NO – R134A reaches the COP about 0.88 on the 25% engine load. And, the working fluid which reaches the lowest COP is NH_3-H_2O with the value about 0.1 on the 100% engine load.

And the composition between absorbent and refrigerant which has the higher value of COP is the balance composition which means the ratio is 50/50. Lower of the composition of refrigerant, increasing the value of COP.

5.2. Suggestion

There should be further analysis for improving the design of the equipment that can be fitted on the ship. And there should be a designing system which can control the calorific and the flow rate of generator so the system could get the higher COP for each load of engine in the same load of cooling.

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APPENDIX

1) NH_3-H_2O
a) 25% Load

Tabel A. 1 Working fluid with composition (NH_3-H_2O/45%:55%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.11	1.00	0.00
Temperature [C]	16.17	16.19	35.00	46.71	46.71	46.71
Pressure [kPa]	200.00	400.00	400.00	400.00	400.00	400.00
Molar Flow [kgmole/h]	1.14	1.14	1.14	1.14	0.13	1.01
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	2.15	17.85
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.00	0.02
Heat Flow [kJ/h]	-217575.21	-217568.58	-215859.65	-211741.11	-6012.29	-205728.81
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.06	1.00	0.71
Temperature [C]	25.62	25.41	-1.22	-18.21	2369.94	95.23
Pressure [kPa]	400.00	200.00	400.00	200.00	200.00	200.00
Molar Flow [kgmole/h]	1.01	1.01	0.13	0.13	0.13	1.14
Mass Flow [kg/h]	17.85	17.85	2.15	2.15	2.15	20.00
Liquid Volume Flow [m3/h]	0.02	0.02	0.00	0.00	0.00	0.03
Heat Flow [kJ/h]	-207437.74	-207437.74	-9085.58	-9085.58	21883.52	-185554.22

Tabel A. 2 Working fluid with composition (NH_3-H_2O/50%:50%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.13	1.00	0.00
Temperature [C]	21.56	21.58	35.00	47.19	47.19	47.19
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	1.14	1.14	1.14	1.14	0.15	1.00
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	2.48	17.52
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.00	0.02
Heat Flow [kJ/h]	-205200.03	-205193.19	-203968.55	-199442.52	-6842.70	-192599.82
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.05	1.00	0.73
Temperature [C]	31.88	30.96	4.72	-8.66	2252.17	103.82
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	1.00	1.00	0.15	0.15	0.15	1.14
Mass Flow [kg/h]	17.52	17.52	2.48	2.48	2.48	20.00
Liquid Volume Flow [m3/h]	0.02	0.02	0.00	0.00	0.00	0.03
Heat Flow [kJ/h]	-193824.46	-193824.46	-10296.41	-10296.41	20672.69	-173151.77

Tabel A. 3 Working fluid with composition (NH_3-H_2O/55%:45%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.14	1.00	0.00

Temperature [C]	16.12	16.15	30.00	39.98	39.98	39.98
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	1.14	1.14	1.14	1.14	0.16	0.99
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	2.67	17.33
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.00	0.02
Heat Flow [kJ/h]	-193677.91	-193670.9	-192406.91	-187880.88	-7278.52	-180602.36
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.05	1.00	0.75
Temperature [C]	24.01	24.01	4.60	-8.77	2187.81	99.91
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.99	0.99	0.16	0.16	0.16	1.14
Mass Flow [kg/h]	17.33	17.33	2.67	2.67	2.67	20.00
Liquid Volume Flow [m3/h]	0.02	0.02	0.00	0.00	0.00	0.03
Heat Flow [kJ/h]	-181866.39	-181866.39	-10930.41	-10930.41	20038.69	-161827.71

b) 50% Load

Tabel A. 4 Working fluid with composition (NH_3-H_2O/45%:55%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.23	1.00	0.00
Temperature [C]	16.17	16.19	35.00	63.10	63.10	63.10
Pressure [kPa]	200.00	400.00	400.00	400.00	400.00	400.00
Molar Flow [kgmole/h]	1.14	1.14	1.14	1.14	0.27	0.87

Mass Flow [kg/h]	20.00	20.00	20.00	20.00	4.53	15.47
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.02
Heat Flow [kJ/h]	-217575.21	-217568.58	-215859.65	-206789.16	-13718.15	-193071.01
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.06	1.00	0.73
Temperature [C]	38.68	38.73	-0.54	-17.58	1614.08	96.27
Pressure [kPa]	400.00	200.00	400.00	200.00	200.00	200.00
Molar Flow [kgmole/h]	0.87	0.87	0.27	0.27	0.27	1.14
Mass Flow [kg/h]	15.47	15.47	4.53	4.53	4.53	20.00
Liquid Volume Flow [m3/h]	0.02	0.02	0.01	0.01	0.01	0.03
Heat Flow [kJ/h]	-194779.94	-194779.94	-20545.18	-20545.18	10423.92	-184356.02

Tabel A. 5 Working fluid with composition (NH_3-H_2O/50%:50%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.25	1.00	0.00
Temperature [C]	21.56	21.58	35.00	61.30	61.30	61.30
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	1.14	1.14	1.14	1.14	0.28	0.86
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	4.81	15.19
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.02
Heat Flow [kJ/h]	-205200.03	-205193.19	-203968.55	-194909.84	-13899.43	-181010.41

Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.05	1.00	0.75
Temperature [C]	43.61	43.65	5.16	-8.25	1544.05	104.88
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.86	0.86	0.28	0.28	0.28	1.14
Mass Flow [kg/h]	15.19	15.19	4.81	4.81	4.81	20.00
Liquid Volume Flow [m3/h]	0.02	0.02	0.01	0.01	0.01	0.03
Heat Flow [kJ/h]	-182235.05	-182235.05	-20862.06	-20862.06	10107.04	-172128.01

Tabel A. 6 Working fluid with composition (NH_3-H_2O/55%:45%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.28	1.00	0.00
Temperature [C]	16.12	16.15	30.00	54.95	54.95	54.95
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	1.14	1.14	1.14	1.14	0.32	0.82
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	5.50	14.50
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.02
Heat Flow [kJ/h]	-193677.91	-193670.95	-192406.91	-182647.38	-15484.61	-167162.77
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.05	1.00	0.77
Temperature [C]	35.82	35.87	4.92	-8.47	1367.50	101.21
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00

Molar Flow [kgmole/h]	0.82	0.82	0.32	0.32	0.32	1.14
Mass Flow [kg/h]	14.50	14.50	5.50	5.50	5.50	20.00
Liquid Volume Flow [m3/h]	0.02	0.02	0.01	0.01	0.01	0.03
Heat Flow [kJ/h]	-168426.80	-168426.80	-23296.80	-23296.80	7672.30	-160754.51

c) 75% Load

Tabel A. 7 Working fluid with composition (NH_3-H_2O/45%:55%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.32	1.00	0.00
Temperature [C]	16.17	16.19	35.00	77.60	77.60	77.60
Pressure [kPa]	200.00	400.00	400.00	400.00	400.00	400.00
Molar Flow [kgmole/h]	1.14	1.14	1.14	1.14	0.36	0.77
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	6.23	13.77
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.02
Heat Flow [kJ/h]	-217575.21	-217568.58	-215859.65	-202831.83	-21672.42	-181159.41
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.06	1.00	0.75
Temperature [C]	50.10	50.14	0.80	-16.32	1186.44	96.89
Pressure [kPa]	400.00	200.00	400.00	200.00	200.00	200.00
Molar Flow [kgmole/h]	0.77	0.77	0.36	0.36	0.36	1.14
Mass Flow [kg/h]	13.77	13.77	6.23	6.23	6.23	20.00
Liquid Volume Flow [m3/h]	0.02	0.02	0.01	0.01	0.01	0.03

Heat Flow [kJ/h]	-182868.34	-182868.34	-31706.18	-31706.18	-737.08	-183605.42

Tabel A. 8 Working fluid with composition (NH_3-H_2O/50%:50%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.35	1.00	0.00
Temperature [C]	21.56	21.58	35.00	78.26	78.26	78.26
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	1.14	1.14	1.14	1.14	0.40	0.74
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	6.87	13.13
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.02
Heat Flow [kJ/h]	-205200.03	-205193.19	-203968.55	-190322.00	-22533.82	-167788.18
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.05	1.00	0.77
Temperature [C]	57.74	57.78	6.34	-7.13	1073.16	105.75
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.74	0.74	0.40	0.40	0.40	1.14
Mass Flow [kg/h]	13.13	13.13	6.87	6.87	6.87	20.00
Liquid Volume Flow [m3/h]	0.02	0.02	0.01	0.01	0.01	0.03
Heat Flow [kJ/h]	-169012.82	-169012.82	-33187.68	-33187.68	-2218.58	-171231.40

Tabel A. 9 Working fluid with composition (NH_3-H_2O/55%:45%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.37	1.00	0.00
Temperature [C]	16.12	16.15	30.00	69.29	69.29	69.29
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	1.14	1.14	1.14	1.14	0.43	0.72
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	7.32	12.68
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.01
Heat Flow [kJ/h]	-193677.91	-193670.95	-192406.91	-178760.36	-22228.53	-156531.83
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.05	1.00	0.79
Temperature [C]	47.37	47.41	5.59	-7.84	1001.77	102.09
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.72	0.72	0.43	0.43	0.43	1.14
Mass Flow [kg/h]	12.68	12.68	7.32	7.32	7.32	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.03
Heat Flow [kJ/h]	-157795.87	-157795.87	-33147.61	-33147.61	-2178.51	-159974.38

d) 100% Load

Tabel A. 10 Working fluid with composition (NH_3-H_2O/45%:55%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.39	1.00	0.00
Temperature [C]	27.75	27.78	35.00	95.82	95.82	95.82
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	1.14	1.14	1.14	1.14	0.44	0.70
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	7.57	12.43
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.01
Heat Flow [kJ/h]	-216522.32	-216515.60	-215857.71	-198994.07	-31239.03	-167755.04
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.01	0.00	0.05	1.00	0.78
Temperature [C]	84.19	79.20	9.27	-4.28	934.73	109.76
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.70	0.70	0.44	0.44	0.44	1.14
Mass Flow [kg/h]	12.43	12.43	7.57	7.57	7.57	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.03
Heat Flow [kJ/h]	-168412.93	-168412.93	-44228.36	-44228.36	-13259.26	-181672.19

Tabel A. 11 Working fluid with composition (NH_3-H_2O/50%:50%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.45	1.00	0.00
Temperature [C]	21.56	21.58	35.00	93.93	93.93	93.93
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	1.14	1.14	1.14	1.14	0.51	0.63
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	8.79	11.21
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.01
Heat Flow [kJ/h]	-205200.03	-205193.19	-203968.55	-185722.59	-35206.61	-150515.98
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.05	1.00	0.78
Temperature [C]	69.83	69.87	8.81	-4.73	765.91	106.09
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.63	0.63	0.51	0.51	0.51	1.14
Mass Flow [kg/h]	11.21	11.21	8.79	8.79	8.79	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.03
Heat Flow [kJ/h]	-151740.63	-151740.63	-50099.31	-50099.31	-19130.21	-170870.83

Tabel A. 12 Working fluid with composition (NH_3-H_2O/55%:45%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.01	0.48	1.00	0.00

Temperature [C]	16.12	16.15	32.00	87.79	87.79	87.79
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	1.14	1.14	1.14	1.14	0.55	0.59
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	9.46	10.54
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.01
Heat Flow [kJ/h]	-193677.91	-193670.95	-191973.04	-173727.09	-34681.76	-139045.33
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.05	1.00	0.79
Temperature [C]	52.19	52.23	7.60	-5.91	699.03	102.19
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.59	0.59	0.55	0.55	0.55	1.14
Mass Flow [kg/h]	10.54	10.54	9.46	9.46	9.46	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.03
Heat Flow [kJ/h]	-140743.24	-140743.24	-50109.10	-50109.10	-19140.00	-159883.24

2. DMAC – R134A

a) 25% load

Tabel A. 13 Working fluid with composition (C_4H_9NO – R134A/45%:55%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.56	1.00	0.00
Temperature [C]	6.15	6.30	28.04	124.19	124.19	124.19
Pressure [kPa]	200.00	400.00	400.00	400.00	400.00	400.00

Molar Flow [kgmole/h]	0.21	0.21	0.21	0.21	0.12	0.09
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	11.90	8.10
Liquid Volume Flow [m3/h]	0.02	0.02	0.02	0.02	0.01	0.01
Heat Flow [kJ/h]	-133294.86	-133290.26	-132576.66	-127371.76	-99163.37	-28208.40
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.13	1.00	1.00
Temperature [C]	83.59	83.59	11.06	-8.00	1579.60	758.55
Pressure [kPa]	400.00	200.00	400.00	200.00	200.00	200.00
Molar Flow [kgmole/h]	0.09	0.09	0.12	0.12	0.12	0.21
Mass Flow [kg/h]	8.10	8.10	11.90	11.90	11.90	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.02
Heat Flow [kJ/h]	-28921.99	-28921.99	-103030.69	-103030.69	-72061.59	-100983.59

Tabel A. 14 Working fluid with composition (C_4H_9NO – R134A/50%:50%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.33	1.00	0.00
Temperature [C]	21.59	21.73	39.38	65.84	65.84	65.84
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	0.21	0.21	0.21	0.21	0.07	0.14
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	7.07	12.93
Liquid Volume Flow [m3/h]	0.02	0.02	0.02	0.02	0.01	0.01
Heat Flow [kJ/h]	-127200.76	-127196.00	-126587.10	-124486.72	-61648.58	-62838.14

Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.10	1.00	1.00
Temperature [C]	41.76	41.76	15.89	0.82	2694.54	723.52
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.14	0.14	0.07	0.07	0.07	0.21
Mass Flow [kg/h]	12.93	12.93	7.07	7.07	7.07	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.02
Heat Flow [kJ/h]	-63447.04	-63447.04	-63329.42	-63329.42	-32360.32	-95807.36

Tabel A. 15 Working fluid with composition (C_4H_9NO – R134A/55%:45%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.37	1.00	0.00
Temperature [C]	25.08	25.22	43.33	93.84	93.84	93.84
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	0.21	0.21	0.21	0.21	0.08	0.13
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	7.97	12.03
Liquid Volume Flow [m3/h]	0.02	0.02	0.02	0.02	0.01	0.01
Heat Flow [kJ/h]	-121400.58	-121395.7	-120755.83	-117673.39	-68788.24	-48885.14
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.11	1.00	1.00
Temperature [C]	69.42	69.42	16.27	1.20	2382.18	713.74

Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.13	0.13	0.08	0.08	0.08	0.21
Mass Flow [kg/h]	12.03	12.03	7.97	7.97	7.97	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.02
Heat Flow [kJ/h]	-49525.03	-49525.03	-70922.61	-70922.61	-39953.52	-89478.54

b) 50% load

Tabel A. 16 Working fluid with composition (C_4H_9NO – R134A/45%:55%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.55	1.00	0.00
Temperature [C]	18.51	18.65	82.18	179.30	179.30	179.30
Pressure [kPa]	300.00	500.00	1522.00	1522.00	1522.00	1522.00
Molar Flow [kgmole/h]	0.21	0.21	0.21	0.21	0.12	0.09
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	11.69	8.31
Liquid Volume Flow [m3/h]	0.02	0.02	0.02	0.02	0.01	0.01
Heat Flow [kJ/h]	-132894.22	-132889.54	-130549.57	-125588.59	-95615.85	-29972.75
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.06	1.00	1.00
Temperature [C]	50.32	50.32	59.49	53.90	1626.51	766.45
Pressure [kPa]	1521.00	1321.00	1522.00	1322.00	1322.00	1321.00
Molar Flow [kgmole/h]	0.09	0.09	0.12	0.12	0.12	0.21
Mass Flow [kg/h]	8.31	8.31	11.69	11.69	11.69	20.00

Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.02
Heat Flow [kJ/h]	-32312.72	-32312.72	-99301.50	-99301.50	-68332.40	-100645.12

Tabel A. 17 Working fluid with composition (C_4H_9NO – R134A/50%:50%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.49	1.00	0.00
Temperature [C]	21.59	21.73	39.38	124.55	124.55	124.55
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	0.21	0.21	0.21	0.21	0.10	0.11
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	10.43	9.57
Liquid Volume Flow [m3/h]	0.02	0.02	0.02	0.02	0.01	0.01
Heat Flow [kJ/h]	-127200.76	-127196.00	-126587.10	-121973.90	-87647.04	-34326.86
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.11	1.00	1.00
Temperature [C]	94.61	94.61	17.51	2.44	1809.11	745.26
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.11	0.11	0.10	0.10	0.10	0.21
Mass Flow [kg/h]	9.57	9.57	10.43	10.43	10.43	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.02
Heat Flow [kJ/h]	-34935.76	-34935.76	-90887.49	-90887.49	-59918.40	-94854.15

Tabel A. 18 Working fluid with composition (C_4H_9NO – R134A/55%:45%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.37	1.00	0.00
Temperature [C]	25.08	25.22	43.33	93.76	93.76	93.76
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	0.21	0.21	0.21	0.21	0.08	0.13
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	7.96	12.04
Liquid Volume Flow [m3/h]	0.02	0.02	0.02	0.02	0.01	0.01
Heat Flow [kJ/h]	-121400.58	-121395.72	-120755.83	-117676.91	-68754.81	-48922.10
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.11	1.00	1.00
Temperature [C]	69.34	69.34	16.27	1.20	2383.45	713.70
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.13	0.13	0.08	0.08	0.08	0.21
Mass Flow [kg/h]	12.04	12.04	7.96	7.96	7.96	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.02
Heat Flow [kJ/h]	-49561.98	-49561.98	-70887.30	-70887.30	-39918.21	-89480.19

c) 75% load

Tabel A. 19 Working fluid with composition (C_4H_9NO – R134A/45%:55%)

Name	1	2	3	4	5a	5b

Vapour Fraction	0.00	0.00	0.00	0.52	1.00	0.00
Temperature [C]	18.51	18.65	28.04	164.91	164.91	164.91
Pressure [kPa]	300.00	500.00	400.00	1522.00	1522.00	1522.00
Molar Flow [kgmole/h]	0.21	0.21	0.21	0.21	0.11	0.10
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	11.05	8.95
Liquid Volume Flow [m3/h]	0.02	0.02	0.02	0.02	0.01	0.01
Heat Flow [kJ/h]	-132894.22	-132889.54	-132576.66	-126247.55	-92191.08	-34056.47
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.06	1.00	1.00
Temperature [C]	41.98	41.98	58.23	52.60	1748.65	762.18
Pressure [kPa]	1521.00	1321.00	1522.00	1322.00	1322.00	1321.00
Molar Flow [kgmole/h]	0.10	0.10	0.11	0.11	0.11	0.21
Mass Flow [kg/h]	8.95	8.95	11.05	11.05	11.05	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.02
Heat Flow [kJ/h]	-36396.44	-36396.44	-95400.81	-95400.81	-64431.72	-100828.16

Tabel A. 20 Working fluid with composition (C_4H_9NO – R134A/50%:50%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.52	1.00	0.00
Temperature [C]	21.59	21.73	39.38	140.49	140.49	140.49
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	0.21	0.21	0.21	0.21	0.11	0.10

Mass Flow [kg/h]	20.00	20.00	20.00	20.00	11.09	8.91
Liquid Volume Flow [m3/h]	0.02	0.02	0.02	0.02	0.01	0.01
Heat Flow [kJ/h]	-127200.76	-127196.00	-126587.10	-121230.00	-90770.75	-30459.25
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.11	1.00	1.00
Temperature [C]	110.06	110.06	18.83	3.76	1659.01	750.04
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.10	0.10	0.11	0.11	0.11	0.21
Mass Flow [kg/h]	8.91	8.91	11.09	11.09	11.09	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.02
Heat Flow [kJ/h]	-31068.15	-31068.15	-94544.17	-94544.17	-63575.07	-94643.22

Tabel A. 21 Working fluid with composition (C_4H_9NO – R134A/55%:45%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.41	1.00	0.00
Temperature [C]	25.08	25.22	43.33	113.64	113.64	113.64
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	0.21	0.21	0.21	0.21	0.09	0.13
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	8.85	11.15
Liquid Volume Flow [m3/h]	0.02	0.02	0.02	0.02	0.01	0.01
Heat Flow [kJ/h]	-121400.58	-121395.72	-120755.83	-116872.30	-75322.26	-41550.03

Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.11	1.00	1.00
Temperature [C]	86.39	86.39	16.92	1.85	2130.18	721.17
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.13	0.13	0.09	0.09	0.09	0.21
Mass Flow [kg/h]	11.15	11.15	8.85	8.85	8.85	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.02
Heat Flow [kJ/h]	-42189.92	-42189.92	-77922.91	-77922.91	-46953.81	-89143.73

d) 100% load

Tabel A. 22 Working fluid with composition (C_4H_9NO – R134A/45%:55%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.54	1.00	0.00
Temperature [C]	18.51	18.65	82.18	173.48	173.48	173.48
Pressure [kPa]	300.00	500.00	1522.00	1522.00	1522.00	1522.00
Molar Flow [kgmole/h]	0.21	0.21	0.21	0.21	0.11	0.10
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	11.42	8.58
Liquid Volume Flow [m3/h]	0.02	0.02	0.02	0.02	0.01	0.01
Heat Flow [kJ/h]	-132894.22	-132889.54	-130549.57	-125860.83	-94287.69	-31573.14
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.06	1.00	1.00
Temperature [C]	47.17	47.17	58.93	53.32	1676.15	764.82

Pressure [kPa]	1521.00	1321.00	1522.00	1322.00	1322.00	1321.00
Molar Flow [kgmole/h]	0.10	0.10	0.11	0.11	0.11	0.21
Mass Flow [kg/h]	8.58	8.58	11.42	11.42	11.42	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.02
Heat Flow [kJ/h]	-33913.11	-33913.11	-97770.94	-97770.94	-66801.84	-100714.95

Tabel A. 23 Working fluid with composition (C_4H_9NO – R134A/50%:50%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.63	1.00	0.00
Temperature [C]	21.59	21.73	39.38	170.81	170.81	170.81
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	0.21	0.21	0.21	0.21	0.13	0.08
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	13.13	6.87
Liquid Volume Flow [m3/h]	0.02	0.02	0.02	0.02	0.01	0.01
Heat Flow [kJ/h]	-127200.76	-127196.00	-126587.10	-119392.67	-97568.46	-21824.22
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.11	1.00	1.00
Temperature [C]	133.53	133.54	23.93	9.02	1288.55	752.19
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.08	0.08	0.13	0.13	0.13	0.21
Mass Flow [kg/h]	6.87	6.87	13.13	13.13	13.13	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.02

Heat Flow [kJ/h]	-22433.12	-22433.12	-103084.39	-103084.39	-72115.30	-94548.41

Tabel A. 24 Working fluid with composition (C_4H_9NO – R134A/55%:45%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.44	1.00	0.00
Temperature [C]	25.08	25.22	43.33	131.81	131.81	131.81
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	0.21	0.21	0.21	0.21	0.09	0.12
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	9.56	10.44
Liquid Volume Flow [m3/h]	0.02	0.02	0.02	0.02	0.01	0.01
Heat Flow [kJ/h]	-121400.58	-121395.72	-120755.83	-116067.10	-79451.33	-36615.771
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.11	1.00	1.00
Temperature [C]	104.05	104.06	18.03	2.96	1935.67	728.17
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.12	0.12	0.09	0.09	0.09	0.21
Mass Flow [kg/h]	10.44	10.44	9.56	9.56	9.56	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.02
Heat Flow [kJ/h]	-37255.65	-37255.65	-82540.93	-82540.93	-51571.83	-88827.49

3. Methylamine-water

a.) 25% load

Tabel A. 25 Working fluid with composition (CH_3NH_2 - H_2O /45%:55%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.14	1.00	0.00
Temperature [C]	44.73	44.81	55.00	70.26	70.26	70.26
Pressure [kPa]	300.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	0.84	0.84	0.84	0.84	0.12	0.72
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	3.63	16.37
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.02
Heat Flow [kJ/h]	-147200.80	-147193.77	-146406.30	-142644.74	-3496.96	-139147.79
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.02	0.70	0.72	1.00	1.00
Temperature [C]	58.22	52.76	40.00	25.01	2465.29	186.26
Pressure [kPa]	500.00	300.00	500.00	300.00	300.00	300.00
Molar Flow [kgmole/h]	0.72	0.72	0.11	0.12	0.12	0.84
Mass Flow [kg/h]	16.37	16.37	3.25	3.63	3.63	20.00
Liquid Volume Flow [m3/h]	0.02	0.02	0.00	0.01	0.01	0.03
Heat Flow [kJ/h]	-139935.25	-139935.25	-4047.90	-4637.79	26331.31	-113603.95

Tabel A. 26 Working fluid with composition (CH_3NH_2 - H_2O /50%:50%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.16	1.00	0.00

Temperature [C]	28.77	28.85	50.00	57.86	57.86	57.86
Pressure [kPa]	200.00	400.00	400.00	400.00	400.00	400.00
Molar Flow [kgmole/h]	0.82	0.82	0.82	0.82	0.13	0.68
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	4.02	15.98
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.02
Heat Flow [kJ/h]	-134741.88	-134734.85	-133140.00	-129654.34	-3552.39	-126101.95
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.93	0.96	1.00	1.00
Temperature [C]	32.02	32.04	40.00	26.27	2272.80	206.64
Pressure [kPa]	400.00	200.00	400.00	200.00	200.00	200.00
Molar Flow [kgmole/h]	0.68	0.68	0.13	0.13	0.13	0.82
Mass Flow [kg/h]	15.98	15.98	4.02	4.02	4.02	20.00
Liquid Volume Flow [m3/h]	0.02	0.02	0.01	0.01	0.01	0.03
Heat Flow [kJ/h]	-127696.81	-127696.81	-3943.15	-3943.15	27025.95	-100670.86

Tabel A. 27 Working fluid with composition (CH_3NH_2 - H_2O /55%:45%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.15	1.00	0.00
Temperature [C]	47.86	47.99	60.00	73.78	73.78	73.78
Pressure [kPa]	400.00	700.00	700.00	700.00	700.00	700.00
Molar Flow [kgmole/h]	0.79	0.79	0.79	0.79	0.12	0.67
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	3.66	16.34

Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.02
Heat Flow [kJ/h]	-120354.65	-120343.6	-119422.20	-115833.03	-3154.23	-112678.81
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.03	0.00	0.05	1.00	1.00
Temperature [C]	59.57	53.69	40.00	29.94	2295.49	218.46
Pressure [kPa]	700.00	400.00	700.00	400.00	400.00	400.00
Molar Flow [kgmole/h]	0.67	0.67	0.12	0.12	0.12	0.79
Mass Flow [kg/h]	16.34	16.34	3.66	3.66	3.66	20.00
Liquid Volume Flow [m3/h]	0.02	0.02	0.01	0.01	0.01	0.03
Heat Flow [kJ/h]	-113600.17	-113600.17	-6114.04	-6114.04	24855.06	-88745.11

b.) 50% load

Tabel A. 28 Working fluid with composition (CH_3NH_2 - H_2O /45%:55%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.29	1.00	0.00
Temperature [C]	31.86	31.97	60.00	82.95	82.95	82.95
Pressure [kPa]	200.00	500.00	500.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	0.84	0.84	0.84	0.84	0.24	0.60
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	7.26	12.74
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.02
Heat Flow [kJ/h]	-148179.21	-148168.85	-146015.38	-138966.79	-9021.69	-129945.10

Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.35	0.44	1.00	1.00
Temperature [C]	41.13	41.17	40.00	13.81	1254.79	161.07
Pressure [kPa]	500.00	200.00	500.00	200.00	200.00	200.00
Molar Flow [kgmole/h]	0.60	0.60	0.24	0.24	0.24	0.84
Mass Flow [kg/h]	12.74	12.74	7.26	7.26	7.26	20.00
Liquid Volume Flow [m3/h]	0.02	0.02	0.01	0.01	0.01	0.03
Heat Flow [kJ/h]	-132098.57	-132098.57	-13484.74	-13484.74	17484.36	-114614.21

Tabel A. 29 Working fluid with composition (CH_3NH_2 - H_2O /50%:50%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.31	1.00	0.00
Temperature [C]	28.77	28.85	45.00	68.96	68.96	68.96
Pressure [kPa]	200.00	400.00	400.00	400.00	400.00	400.00
Molar Flow [kgmole/h]	0.82	0.82	0.82	0.82	0.25	0.56
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	7.69	12.31
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.01
Heat Flow [kJ/h]	-134741.88	-134734.85	-133521.74	-126127.36	-8144.30	-117983.06
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.84	0.88	1.00	1.00
Temperature [C]	44.27	44.30	40.00	23.45	1290.05	270.15
Pressure [kPa]	400.00	200.00	400.00	200.00	200.00	200.00

Molar Flow [kgmole/h]	0.56	0.56	0.25	0.25	0.25	0.82
Mass Flow [kg/h]	12.31	12.31	7.69	7.69	7.69	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.03
Heat Flow [kJ/h]	-119196.17	-119196.17	-9681.04	-9681.04	21288.05	-97908.11

Tabel A. 30 Working fluid with composition (CH_3NH_2 - H_2O /55%:45%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.33	1.00	0.00
Temperature [C]	47.86	47.99	60.00	84.82	84.82	84.82
Pressure [kPa]	400.00	700.00	700.00	700.00	700.00	700.00
Molar Flow [kgmole/h]	0.79	0.79	0.79	0.79	0.26	0.53
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	7.89	12.11
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.02
Heat Flow [kJ/h]	-120354.65	-120343.57	-119422.20	-112027.82	-8167.92	-103859.90
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.01	0.00	0.04	1.00	1.00
Temperature [C]	66.17	63.37	40.00	30.76	1100.54	218.86
Pressure [kPa]	700.00	400.00	700.00	400.00	400.00	400.00
Molar Flow [kgmole/h]	0.53	0.53	0.26	0.26	0.26	0.79
Mass Flow [kg/h]	12.11	12.11	7.89	7.89	7.89	20.00
Liquid Volume Flow [m3/h]	0.02	0.02	0.01	0.01	0.01	0.03
Heat Flow [kJ/h]	-104781.27	-104781.27	-14915.77	-14915.77	16053.33	-88727.94

c.) 75% load

Tabel A. 31 Working fluid with composition (CH_3NH_2 - H_2O /45%:55%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.38	1.00	0.00
Temperature [C]	54.62	54.73	60.00	106.01	106.01	106.01
Pressure [kPa]	400.00	700.00	700.00	700.00	700.00	700.00
Molar Flow [kgmole/h]	0.84	0.84	0.84	0.84	0.31	0.52
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	9.18	10.82
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.01	0.01
Heat Flow [kJ/h]	-146436.42	-146425.73	-146013.98	-135531.56	-15681.42	-119850.14
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.04	0.00	0.03	1.00	1.00
Temperature [C]	97.18	87.20	40.00	33.82	936.94	176.07
Pressure [kPa]	700.00	400.00	700.00	400.00	400.00	400.00
Molar Flow [kgmole/h]	0.52	0.52	0.31	0.31	0.31	0.84
Mass Flow [kg/h]	10.82	10.82	9.18	9.18	9.18	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.01	0.01	0.01	0.03
Heat Flow [kJ/h]	-120261.88	-120261.88	-24757.70	-24757.70	6211.40	-114050.48

Tabel A. 32 Working fluid with composition (CH_3NH_2 - H_2O /50%:50%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.45	1.00	0.00
Temperature [C]	28.77	28.85	50.00	85.47	85.47	85.47
Pressure [kPa]	200.00	400.00	400.00	400.00	400.00	400.00
Molar Flow [kgmole/h]	0.82	0.82	0.82	0.82	0.37	0.45
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	10.86	9.14
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.02	0.01
Heat Flow [kJ/h]	-134741.88	-134734.85	-133140.00	-122137.36	-16966.03	-105171.33
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.61	0.67	1.00	1.00
Temperature [C]	42.81	42.84	40.00	21.31	926.58	274.05
Pressure [kPa]	400.00	200.00	400.00	200.00	200.00	200.00
Molar Flow [kgmole/h]	0.45	0.45	0.37	0.37	0.37	0.82
Mass Flow [kg/h]	9.14	9.14	10.86	10.86	10.86	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.02	0.02	0.02	0.03
Heat Flow [kJ/h]	-106766.18	-106766.18	-21935.82	-21935.82	9033.28	-97732.91

Tabel A. 33 Working fluid with composition (CH_3NH_2 - H_2O /55%:45%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.47	1.00	0.00

Temperature [C]	47.86	47.99	60.00	99.17	99.17	99.17
Pressure [kPa]	400.00	700.00	700.00	700.00	700.00	700.00
Molar Flow [kgmole/h]	0.79	0.79	0.79	0.79	0.37	0.42
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	11.06	8.94
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.02	0.01
Heat Flow [kJ/h]	-120354.65	-120343.57	-119422.20	-108419.56	-15769.26	-92650.30
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.03	1.00	1.00
Temperature [C]	74.58	74.62	40.00	32.55	781.04	218.81
Pressure [kPa]	700.00	400.00	700.00	400.00	400.00	400.00
Molar Flow [kgmole/h]	0.42	0.42	0.37	0.37	0.37	0.79
Mass Flow [kg/h]	8.94	8.94	11.06	11.06	11.06	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.02	0.02	0.02	0.03
Heat Flow [kJ/h]	-93571.67	-93571.67	-26127.56	-26127.56	4841.53	-88730.13

d.) 100% load

Tabel A. 34 Working fluid with composition (CH_3NH_2 - H_2O /45%:55%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.50	1.00	0.00
Temperature [C]	54.62	54.73	60.00	119.73	119.73	119.73
Pressure [kPa]	400.00	700.00	700.00	700.00	700.00	700.00

Molar Flow [kgmole/h]	0.84	0.84	0.84	0.84	0.42	0.42
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	11.76	8.24
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.02	0.01
Heat Flow [kJ/h]	-146436.42	-146425.73	-146013.98	-131522.94	-30021.76	-101501.18
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.03	0.00	0.01	1.00	1.00
Temperature [C]	108.40	100.32	40.00	37.63	694.55	171.38
Pressure [kPa]	700.00	400.00	700.00	400.00	400.00	400.00
Molar Flow [kgmole/h]	0.42	0.42	0.42	0.42	0.42	0.84
Mass Flow [kg/h]	8.24	8.24	11.76	11.76	11.76	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.02	0.02	0.02	0.03
Heat Flow [kJ/h]	-101912.92	-101912.92	-43302.02	-43302.02	-12332.92	-114245.84

Tabel A. 35 Working fluid with composition (CH_3NH_2 - H_2O /50%:50%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.64	1.00	0.00
Temperature [C]	28.77	28.85	50.00	124.64	124.64	124.64
Pressure [kPa]	200.00	400.00	700.00	700.00	700.00	700.00
Molar Flow [kgmole/h]	0.61	0.61	0.61	0.61	0.39	0.22
Mass Flow [kg/h]	15.00	15.00	15.00	15.00	10.75	4.25
Liquid Volume Flow [m3/h]	0.02	0.02	0.02	0.02	0.02	0.00
Heat Flow [kJ/h]	-101056.41	-101051.14	-99853.57	-86058.19	-32002.59	-54055.60

Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.00	1.00	1.00
Temperature [C]	58.31	58.34	40.00	40.01	758.25	391.86
Pressure [kPa]	700.00	500.00	700.00	500.00	500.00	500.00
Molar Flow [kgmole/h]	0.22	0.22	0.39	0.39	0.39	0.61
Mass Flow [kg/h]	4.25	4.25	10.75	10.75	10.75	15.00
Liquid Volume Flow [m3/h]	0.00	0.00	0.02	0.02	0.02	0.02
Heat Flow [kJ/h]	-55253.16	-55253.16	-44851.23	-44851.23	-13882.13	-69135.30

Tabel A. 36 Working fluid with composition (CH_3NH_2 - H_2O /55%:45%)

Name	1	2	3	4	5a	5b
Vapour Fraction	0.00	0.00	0.00	0.61	1.00	0.00
Temperature [C]	47.86	47.99	60.00	114.77	114.77	114.77
Pressure [kPa]	400.00	700.00	700.00	700.00	700.00	700.00
Molar Flow [kgmole/h]	0.79	0.79	0.79	0.79	0.48	0.31
Mass Flow [kg/h]	20.00	20.00	20.00	20.00	13.78	6.22
Liquid Volume Flow [m3/h]	0.03	0.03	0.03	0.03	0.02	0.01
Heat Flow [kJ/h]	-120354.65	-120343.57	-119422.20	-104236.19	-30259.36	-73976.827
Name	6	7	8	9	10	11
Vapour Fraction	0.00	0.00	0.00	0.02	1.00	1.00
Temperature [C]	80.06	80.10	40.00	36.02	583.00	213.54

Pressure [kPa]	700.00	400.00	700.00	400.00	400.00	400.00
Molar Flow [kgmole/h]	0.31	0.31	0.48	0.48	0.48	0.79
Mass Flow [kg/h]	6.22	6.22	13.78	13.78	13.78	20.00
Liquid Volume Flow [m3/h]	0.01	0.01	0.02	0.02	0.02	0.03
Heat Flow [kJ/h]	-74898.19	-74898.19	-45027.38	-45027.38	-14058.28	-88956.47

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