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JUDUL: **ENERGY LOSS THROUGH THE STEAM TRAP IN A STEAM SYSTEM**

SESI PENGAJIAN: 2010/2011

Saya **MOHD HANIF BIN AB HAMID (880225-29-5099)**
(HURUF BESAR)

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ENERGY LOSS THROUGH THE STEAM TRAP IN A STEAM SYSTEM

MOHD HANIF BIN AB HAMID

Report submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Manufacturing Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2010

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature :
Name of Supervisor : LEE GIOK CHUI
Position : LECTURER
Date: : 6 DECEMBER 2010

STUDENT'S DECLARATION

I hereby declare that the work in this project is solely of my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature :
Name : MOHD HANIF BIN AB HAMID
ID Number : MA07076
Date : 6 DECEMBER 2010

Dedicated to my beloved family & friends

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ABSTRACT

This thesis is about the energy loss through the steam trap in the steam system. In industry, steam traps frequently fail but they are not noticed except when they are leaking. If steam trap fail in failed open, live steam can escape to surrounding. High amount of energy will loss from the steam system. It takes weeks or months before it being repaired or replaced. The first objective of this study is to measure the heat loss for normal thermodynamic steam trap in respond to operating pressure for different condensate load. The second objective is to measure the heat loss for failed open thermodynamic steam trap in respond to operating pressure for different condensate load. The last objective is to compare energy loss between normal and failed open steam trap. From the last objective, the actual energy loss if failed steam trap is not repaired is determined. Thermodynamic steam trap has been tested in the experiment and the operating pressure is below 1 bar. Condensate that discharges from steam trap is collected to record the reading of its temperature and weight. These data is used to determine the energy loss through the steam trap. For normal steam trap, energy loss for high condensate load is higher than low condensate load. For failed open steam trap, energy loss for high condensate load is lower than low condensate load. Finally, after comparing the result, steam system that has low condensate load has higher energy loss compare to high condensate load.

ABSTRAK

Tesis ini adalah berkenaan tenaga yang hilang melalui perangkap stim pada stim system. Di industry, perangkap stim sering mengalami kegagalan tetapi tidak dapat dikesan kecuali ia bocor. Jika perangkap stim gagal dan injapnya sentiasa terbuka, stim akan terbebas ke udara. Sejumlah tenaga akan dibazirkan. Ia mengambil masa yang lama untuk dibaiki atau diganti. Objektif pertama kajian ini ialah untuk mengukur tenaga yang dibazirkan oleh perangkap stim yang normal. Objektif yang kedua ialah untuk mengukur tenaga yang dibazirkan oleh perangkap stim yang mengalami kerosakan. Objektif yang terakhir ialah membandingkan jumlah tenaga yang dibazirkan antara perangkap stim yang normal dengan perangkap stim yang mengalami kerosakan. Daripada objektif yang terakhir, jumlah tenaga yang dibazirkan andai perangkap stim yang mengalami kerosakan tidak dibaiki dapat ditentukan. Perangkap stim jenis termodinamik digunakan dalam eksperimen ini dan tekanan stim yang digunakan adalah bawah 1 bar. Air yang terhasil akan dikeluarkan oleh perangkap stim dikumpul dan bacaan suhu dan berat diambil. Data ini digunakan untuk mendapatkan jumlah tenaga yang dibazirkan oleh perangkap stim. Untuk perangkap stim normal, tenaga yang dibazirkan apabila sistem stim yang mengandungi jumlah air yang tinggi adalah lebih tinggi daripada sistem stim yang mengandungi jumlah air yang randah. Untuk perangkap stim yang mengalami kerosakan, tenaga yang dibazirkan apabila sistem stim yang mengandungi jumlah air yang tinggi adalah lebih rendah daripada sistem stim yang mengandungi jumlah air yang randah. Akhirnya, dengan membandingkan data, sistem stim yang mengandungi jumlah air yang randah membazirkan lebih tenaga daripada sistem stim yang mengandungi jumlah air yang tinggi.

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LIST OF ABBREVIATIONS

C_p	Specific Heat
E	Energy
h	Enthalpy
M	Mass
SDPJ	Sime Darby Plantation Jabor
T	Temperature
TD	Thermodynamic
W	Weight

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Water steam is thermal fluid that is widely used in industry due to two main characteristics: which is high energetic content and easy to transport.

Water can be in three phases: solid, liquid and gas or steam. The process of changing phase from solid to steam uses energy while from steam to solid gives energy. To produce steam from water, boiler is used. Boiler will supply heat to water and it will change form to steam.

Steam has high amount of energy. Steam will conveyed through pipeline to be used to run steam turbine, or used for cooking vegetables, steam cleaning of fabric and carpets, and heating buildings. Condensate will form inside the pipe when steam gives up its enthalpy of evaporation (latent heat) due to heat loss.

Presence of condensate in the pipeline will decrease the steam energy and maybe will make damage to the equipment if water hammer happens. So, the proper removal of condensate from steam plant of all types is very important if the plant is to work efficiently and this operation is commonly performed by a steam trap.

A steam trap is a self-contained automatic valve which automatically drains the condensate from a steam-containing enclosure while remaining closed to live steam. Some traps pass live steam at controlled rate. Most traps also pass air and other non condensate gases while remaining closed to live steam.

The difference between condensate and steam is sensed in several ways. One group of steam trap reacts to a difference in temperature, another group detects the difference in density and the third relies on the difference in flow characteristics.

In industry, steam traps frequently fail but they are not noticed except when they are leaking. If steam trap fail in failed open, live steam can escape to surrounding. High amount of energy will loss from the steam system.

Many factors that affect the amount of energy loss through failed open steam trap. Different operating pressure and amount of condensate load in the pipeline will influence the amount of steam loss and energy loss.

Efforts and methods implementation needs to be considered are: study on the steam trap characteristics and how it work in real application in industry. The methodology uses is by experimental.

1.2 PROBLEM STATEMENT

A common problem of steam heating systems is steam loss through the steam trap. In normal operating, there is some energy loss through steam since the efficiency is not 100%. Steam trap has mechanical part inside. As the time passed, this mechanical part will fail due to wear and corrosion. Live steam will manage to escape if the steam trap is failed open, which mean the trap is blowing steam continuously across the valve seat and will not close. Live steam has great amount of energy and will become energy losses. The difference of energy loss for failed open steam trap and normal operating steam trap is the actual energy loss if the failed steam trap in industry is not replace by new one.

1.3 OBJECTIVE

The objectives of this research are as following:

i. measure the heat loss for normal thermodynamic steam trap in respond to operating pressure for different condensate load.
ii. measure the heat loss for failed open thermodynamic steam trap in respond to operating pressure for different condensate load.
iii. compare energy loss between normal and failed open steam trap

1.4 SCOPES

In this project, thermodynamic steam trap is the type of steam trap that will be tested in the experiment. New steam trap will be used in the first experiment. Then, in second experiment, failed open steam trap is tested. Low steam pressure is applied to the steam trap due to safety of the experiment, since high pressure steam is dangerous to operate and not suitable for experiment setup. The tested pressure is below 1 bar.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter explains about the literature review that has been done. It evaluates in detail about thermal properties of steam, the steam system, water hammering, and the need of steam trap in steam system and type of steam traps that are available in market.

2.2 THERMAL PROPERTIES OF STEAM

2.2.1 Boiling Point

The boiling point is the temperature at which water starts to boil and turn into its vapor phase. At sea level or when atmospheric pressure is at 101.4kPa, the boiling point of saturated water is 100°C. At high altitude, the atmospheric pressure will decrease and make the boiling pressure decrease. Conversely, when pressure increase, the boiling pressure will also increase. In steam system, usually boiling point is also called "saturation temperature" (S. Schmidt, 2004).

2.2.2 Saturated Steam

When the water begins to boil, steam is produced. As long as the pressure remains constant, the temperature remains at the saturation temperature, and when more heat is added, more liquid is converted to steam. This steam we called as "saturated steam" (S. Schmidt, 2004).

2.2.3 Superheated Steam

After the water is completely boiled off, the saturated steam will turn into superheated steam if more heat is added to the system continuously (S. Schmidt, 2004).

2.2.4 Enthalpy

This is the term given to the total energy, due to both pressure and temperature, of a fluid (such as water or steam) at any given time and condition. More specifically it is the sum of the internal energy and the work done by an applied pressure. The basic unit of measurement is the joule (J). Since one joule represents a very small amount of energy, it is usual to use kilojoules (kJ) (1 000 Joules). The specific enthalpy is a measure of the total energy of a unit mass, and its units are usually kJ/kg (Sarco, 2007).

2.2.5 Condensate

Condensate is the liquid produced when steam condenses on a heater surface to become water. Steam gives up its enthalpy of evaporation (latent heat) and condenses either by raising its pressure or lowering its temperature.

2.2.6 Flash Steam

The term 'flash steam' is traditionally used to describe steam issuing from condensate receiver vents and open-ended condensate discharge lines from steam traps. Flash steam occurs whenever water at high pressure (and a temperature higher than the saturation temperature of the low-pressure liquid) is allowed to drop to a lower pressure. Conversely, if the temperature of the high-pressure water is lower than the saturation temperature at the lower pressure, flash steam cannot be formed. In the case of condensate passing through a steam trap; it is usually the case that the upstream temperature is high enough to form flash steam (Sarco, 2007).

2.3 STEAM SYSTEM

Nearly half of the energy used by industry goes into the production of process steam. Why is so much of our energy resource expanded for the generation of industrial steam?

Steam has many performance advantages that make it an indispensable means of delivery energy. Steam has low toxicity, ease of transportability, high efficiency, high heat capacity and low cost compare to other alternatives. This advantages make steam is one of the most abundant, least expansive and most effective heat-transfer media available. Furthermore, water is found everywhere, and only need relatively little modification from its raw state to make it directly usable in process equipment (Tuner, 2004).

Figure 2.1 below shows the complete steam cycle operation. There are four important categories in steam system components that will lead to enhance steam system performance: steam generation, steam distribution, steam user and recovery. These four categories will follow the path of steam as it flow out from boiler as pressurized steam and returns through condensate return system.

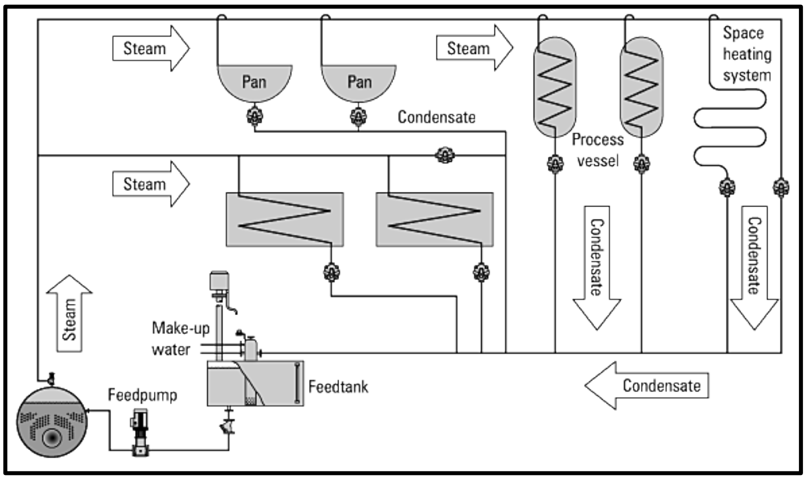

Figure 2.1: Steam system operation.

Source: www.spiraxsarco.com

2.3.1 Steam Generation

Boiler is a device used for generating steam for power generation process use or heating purpose. Water that enters the boiler will be heated and temperature will increase until it reached boiling point and saturated steam will be produce. At 1atm pressure, pure water will boil at 100°C (Chattopadhyay, 2001).

If the saturated steam produced in a boiler is exposed to a surface with a higher temperature, its temperature will increase above the evaporating temperature. Superheated steam cannot be directly from water, as any additional heat simply evaporates more water and become saturated steam. The saturated steam must be passed through an additional heat exchanger. This may be a second heat exchange stage in the boiler, or a separate superheater unit. The primary heating medium may be either the hot flue gas from the boiler, or may be separately fired.

Figure 2.2 shows the process of producing steam. Water in the boiler is heated until it changes into steam. This less density steam will flow out from the boiler and again, heat is supply to the system through superheater. This process makes the saturated steam change to superheated steam. Superheated steam has higher energy than saturated steam. So, superheated steam usually used in heavy work such as generate electrical energy, or it can use the steam energy directly as seen in machines such as steam-powered trains, steam engines, and steam shovels (*Marick*, 1980).

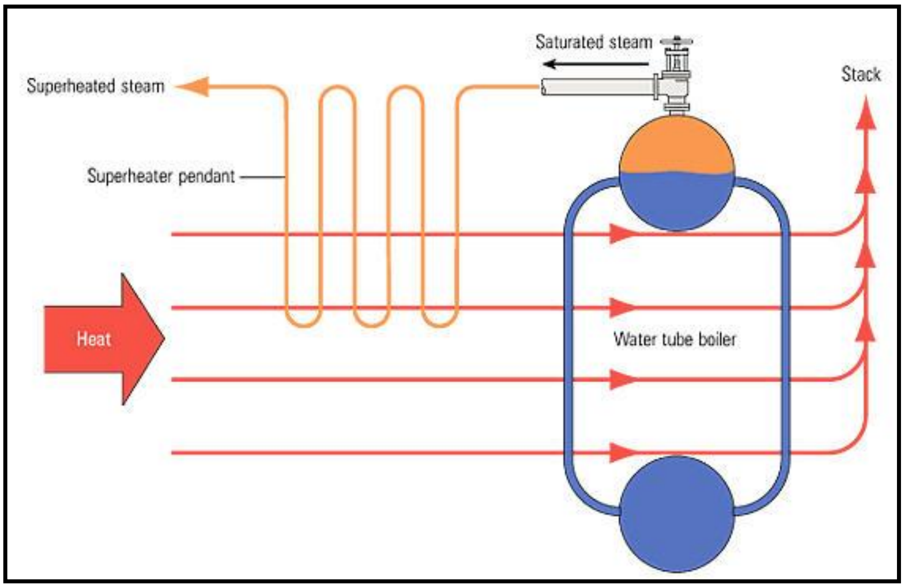

Figure 2.2: Boiler with superheater

Source: www.spiraxsarco.com

2.3.2 Steam Distribution

The steam distribution is the essential link between the steam generator and the steam user. The steam generated in the boiler must be conveyed through pipe work to the point where its heat energy is required. Initially there will be one or more main pipes, or 'steam mains', which carry steam from the boiler in the general direction of the steam using plant. Smaller branch pipes can then carry the steam to the individual pieces of equipment.

2.3.3 Steam User

There are many different steam users. Common steam user includes heat exchanger, oven for bakery and restaurants, laundry presses and plastic molding. When steam flow through these devices, it will transfer its latent heat until it condenses. In power plant, the steam user is turbine. Steam that flows in turbine will transfer its energy to mechanical work to drive rotating machinery which is electric generator. The steam that has condensate will pass steam trap into the condensate return system.

2.3.4 Recovery

The condensate return system sends the condensate back to the boiler. The boiler already has certain amount of pressure. So feed pump is used to increase the feed water pressure to above boiler pressure and bring it into the boiler to complete the cycle.

2.4 THE NEED OF STEAM TRAP

Steam is generated in the boiler and conveyed through piping system to the steam user. The steam pipe is usually well insulated to prevent heat loss to the environment. But in real life, heat loss still happen due to convection and radiation process. Steam traveling along the pipe line will make up to heat loss and will condense forming condensate in bottom of pipeline.

This condensate will exact heat from steam, thus decrease the steam temperature and more condensate will be form. If this condensate not be removed continuously, it will fill up the pipe and blocking the route of steam.

Condensate also will cause water hammer occur in the pipe work. Water hammer is the term used to describe the noise (and sometimes movement of pipe work) caused by slugs of condensate colliding at high velocity into pipe work, fittings, plant, and equipment. This can result in fracture of the steam line or fittings leading to hazardous conditions, loss of steam, and downtime. Therefore, an automatic device is required to allow condensate to drain from the pipe without allowing the steam to escape.

Such a device is known as steam traps and become an important parts of any steam system. Their basic function is to prevent the passage of steam while allowing condensate to flow. Large steam systems often include hundreds or even thousands of traps used in similar installations (Tuner, 2004).

Steam traps represent a common type of process equipment used in virtually all steam systems. Depending on their design, they may perform one or more of the following functions.

i. Keep steam from escaping. Steam that escapes through a trap reduces the overall efficiency of the steam system and wastes valuable resources. Wasted steam is expensive.
ii. Remove condensate. Condensate that forms when the latent heat of evaporation is reclaimed from steam must be removed as it accumulates or the steam system will not function properly. A backup of condensate, known as water logging or flooding, can adversely affect heat transfer, promote corrosion of carbon steel components, and cause a potentially dangerous condition known as water hammer.
iii. Remove air. Air and other no condensable gases must be removed from any steam system because they can combine with condensate to form a corrosive mixture. This mixture can be very detrimental to the long-term performance of certain metallic components, particularly those made of carbon steel. The noncondensables can also act as an insulator and impede the transfer of heat from the steam. Removal of air and any other gases that may be present is usually most critical during system start up.

(Oland, 2000)

2.5 STEAM TRAP

A steam trap quite literally 'purges' condensate, (as well as air and other incondensable gases), out of the system, allowing steam to reach its destination in as dry a state/condition as possible to perform its task efficiently and economically.

The quantity of condensate a steam trap has to deal with may vary considerably. It may have to discharge condensate at steam temperature (i.e. as soon as it forms in the steam space) or it may be required to discharge below steam temperature, giving up some of its 'sensible heat' in the process (Sarco, 2007).

There are many types of steam trap in use today. All this type of steam trap can be classified into three main categories: thermostatic, mechanical and thermodynamic.

2.5.1 Thermostatic Steam Traps

Thermostatic steam trap works by principal of temperature differential. By cooling the condensate a few degrees below saturated temperature, we can differentiate between steam and condensate. This temperature difference is used to open or close a valve. Common types of thermostatic traps include balanced pressure, liquid expansion and bimetallic (Oland, 2000).

2.5.1.1 Balanced Pressure Steam Trap (Bellows Steam Trap)

A large improvement on the liquid expansion trap is the balanced pressure trap. Its operating temperature is affected by the surrounding steam pressure. The operating element is a capsule containing a special liquid and water mixture with a boiling point below that of water.

Bellows steam trap in Figure 2.3 has a valve that expands and contracts in response to temperature of the fluid in the chamber surrounding the bellows. On start-up, condensate and air are pushed ahead of the steam directly through the trap. The thermostatic bellows element is fully contracted and the valve remains wide open until steam approaches the trap (Schmidt, 2004).

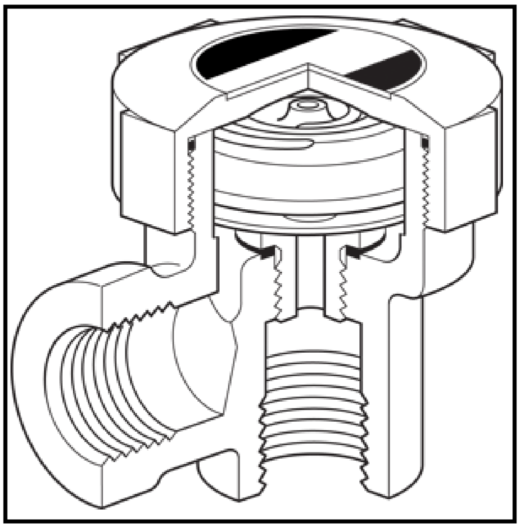

Figure 2.3: Bellows steam trap.

Source: www.spiraxsarco.com

As the temperature inside the trap increases, it quickly heats the charged bellows element, increasing vapor pressure inside. When pressure inside the element becomes balanced with the system pressure in the trap body, the spring effect of the bellows causes the element to expand, closing the valve. When temperature in the trap drops a few degrees below saturated steam temperature, imbalanced pressure contracts the bellows, opening the valve. This is a feature of all balanced pressure traps and explains why they are well suited to air venting.

2.5.1.2 Liquid Expansion Steam Trap

The liquid expansion steam trap in Figure 2.4 senses condensate temperature and opens to allow flow only when the condensate temperature is below the set point, well below saturated steam temperature. The condensate forms a liquid seal ahead of each steam trap preventing live steam losses. Also, the sensible heat in the condensate between steam temperature and the trap discharge temperature is used for heating. The adjustment allows the temperature of the trap discharge to be altered between 60°C and 100°C, which makes it ideally suited as a device to get rid of large quantities of air and cold condensate at start-up.

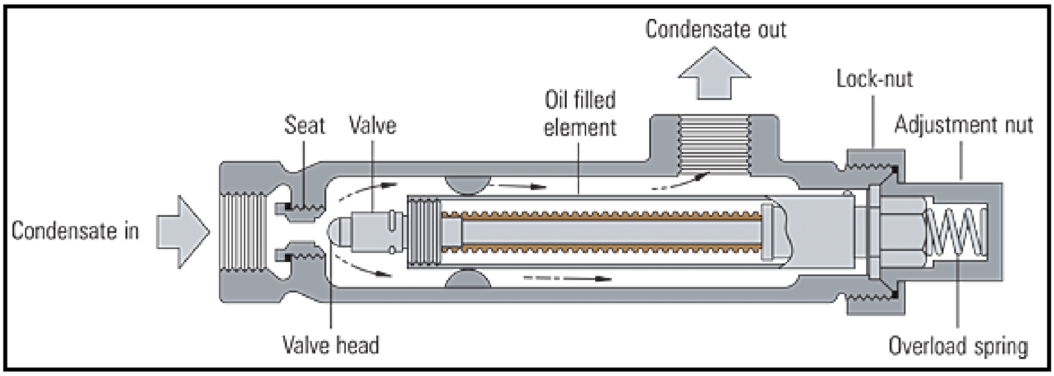

Figure 2.4: The liquid expansion steam trap

Source: www.spiraxsarco.com

2.5.1.3 Bimetallic Trap

As the name implies, bimetallic steam traps are constructed using two strips of dissimilar metals welded together into one element. In Figure 2.5, the element deflects when heated.

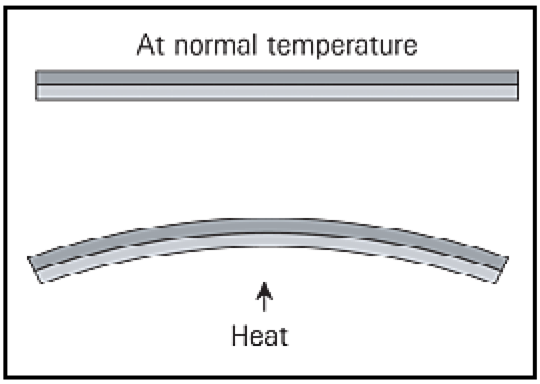

Figure 2.5: Bimetallic element.

Source: www.spiraxsarco.com

As shown in Figure 2.6 below, air and condensate pass freely through the valve until the temperature of the bimetallic strip approaches the steam temperature. After steam heats the bimetallic strip and causes it to close the valve, the trap remains shut until the temperature of the condensate cools sufficiently to allow the bimetallic strip to return to its original shape and thereby open the valve. Bimetallic traps can fail in either the open or closed position (Oland, 2000).

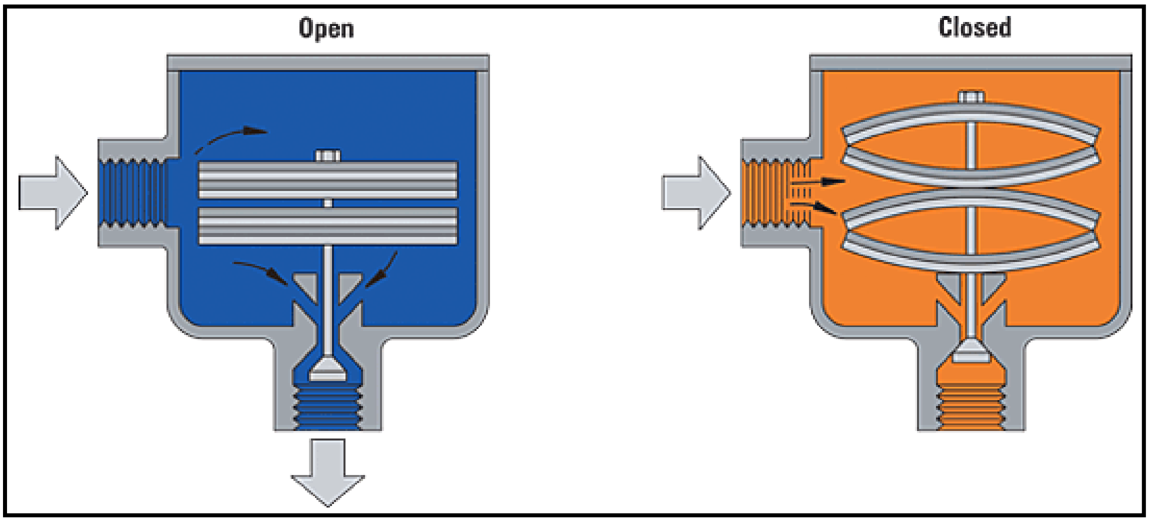

Figure 2.6: Bimetallic steam trap.

Source: www.spiraxsarco.com

2.5.2 Mechanical Steam Traps

Mechanical steam traps work upon the principle that condensate is dense and we can use density to our advantage to differentiate between steam and condensate trap (Schmidt, 2004). Common types of mechanical steam trap are ball float steam trap, inverted bucket steam trap and float and thermostatic steam trap.

2.5.2.1 Ball Float Steam Trap

A ball float trap (Figure 2.7) has a spherical ball that will open and close the outlet opening in the trap body. When no condensate is present, the ball covers the outlet opening, thereby keeping air and steam from escaping. As condensate accumulates inside the trap, the ball floats and uncovers the outlet opening. This movement allows the condensate to flow continuously from the trap. Ball float traps cannot vent air on start up. It has continuous discharge (Oland, 2000).

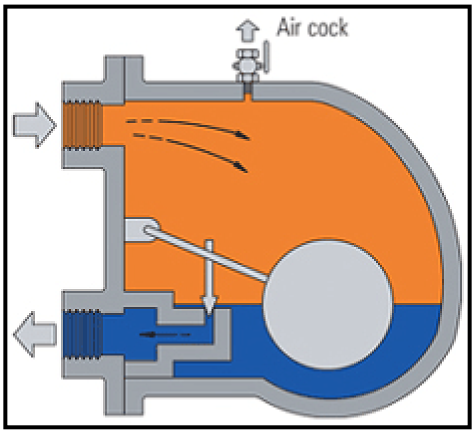

Figure 2.7: Ball float steam trap

Source: www.spiraxsarco.com

2.5.2.2 Inverted Bucket Steam Trap

The mechanism consists of an inverted bucket which is attached by a lever to a valve. An essential part of the trap is the small air vent hole in the top of the bucket. Figure 2.8 shows the method of operation. In (i) the bucket hangs down, pulling the valve off its seat. Condensate flows under the bottom of the bucket filling the body and flowing away through the outlet. In (ii) the arrival of steam causes the bucket to become buoyant, it then rises and shuts the outlet. In (iii) the trap remains shut until the steam in the bucket has condensed or bubbled through the vent hole to the top of the trap body. It will then sink, pulling the main valve off its seat. Accumulated condensate is released and the cycle is repeated (Sarco, 2007).

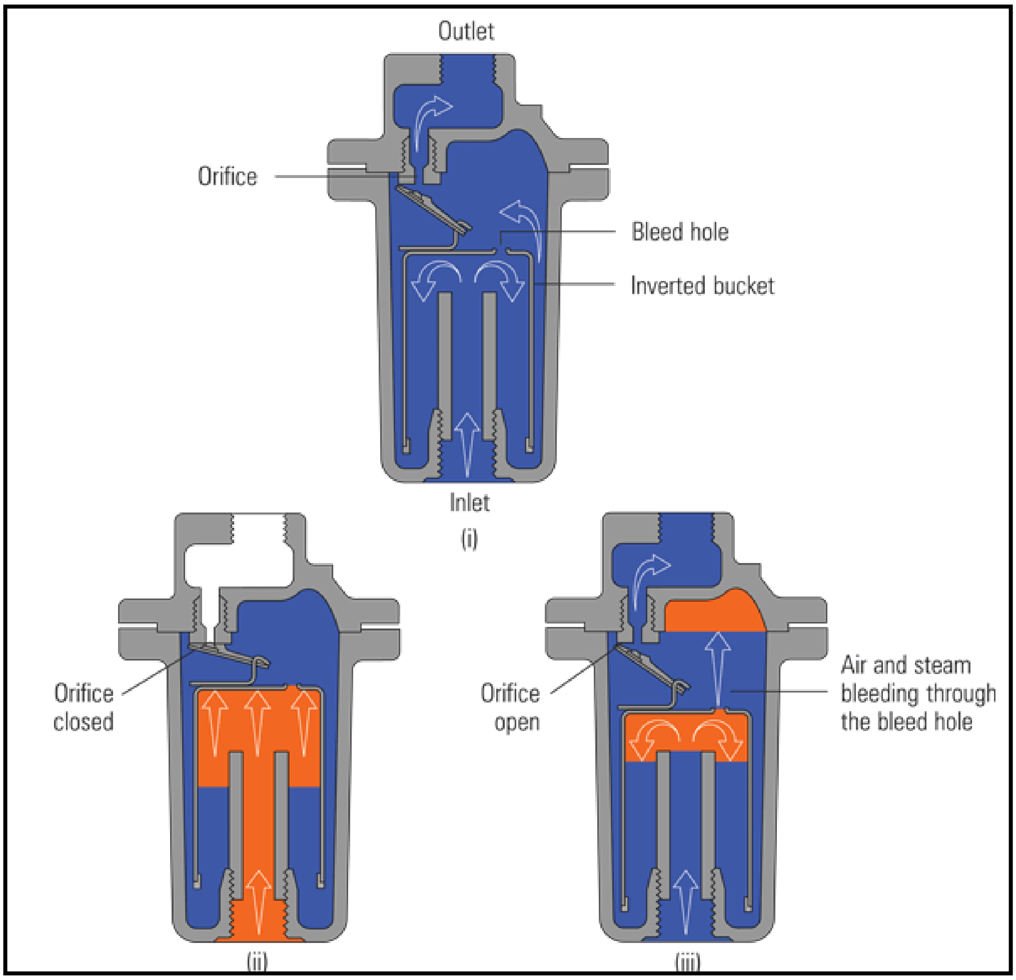

Figure 2.8: Operation of an inverted bucket steam trap

Source: www.spiraxsarco.com

2.5.2.3 Float and Thermostatic Steam Trap

Float and thermostatic steam traps (Figure 2.9) are similar to float traps except it consist of a thermostatic element that allows air to be discharged at start up. Thermostatic elements used in these traps are the same as those used in thermostatic traps. A small thermostatically actuated valve in the top of the trap will distinguish between air and steam (Oland, 2000).

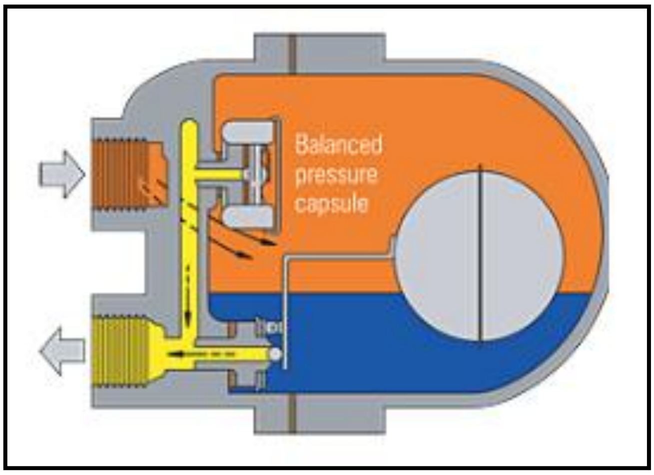

Figure 2.9: Float and thermostatic steam trap

Source: www.spiraxsarco.com

2.5.3 Thermodynamic Steam Trap

Thermodynamic traps use the difference in either kinetic energy or velocity between condensate and live steam to operate a valve (Oland, 2000). This type of trap is very simple in construction and can be made quite compact and resistant to damage from water hammer (Schmidt, 2004).

2.5.3.1 Disk Steam Trap

When condensate air enters the disk steam trap (Figure 2.10) from left, it pushes up the disk and flows out through the passage on the right. When steam enters the trap, it passes around the edge of the disk and creates a downward pressure on the top of the trap. When this pressure is great enough, the disk drops and trap closes. The trap will open when the steam above the disk cools and giving lower pressure against the top of the disk (Doty, 2007).

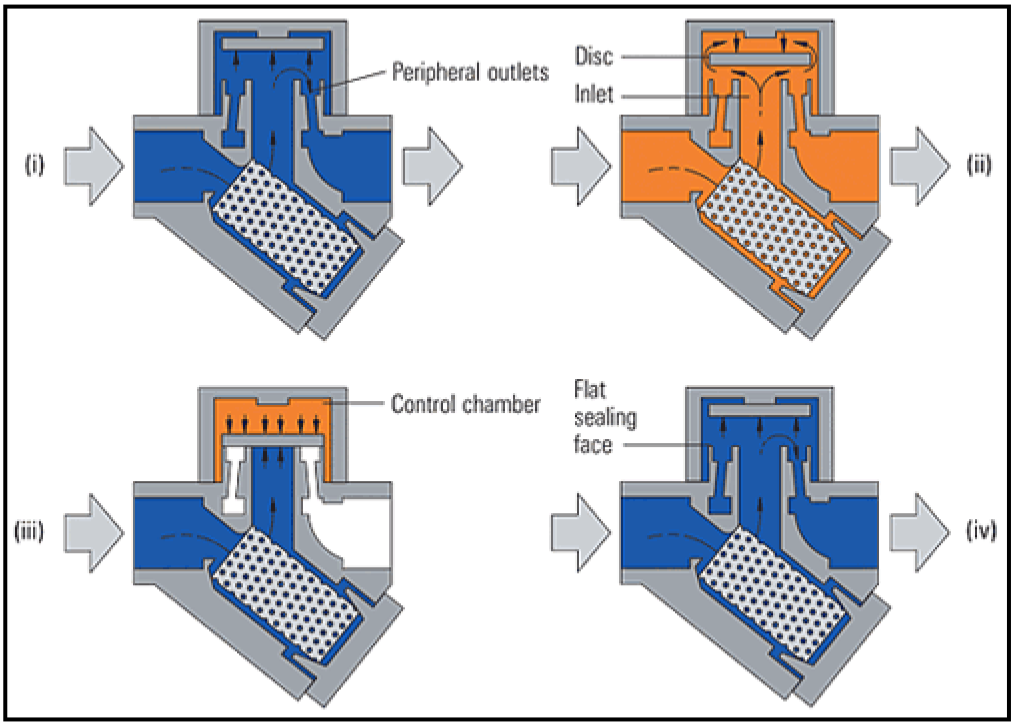

Figure 2.10: Disk steam trap

Source: www.spiraxsarco.com

2.6 STEAM TRAP FAILURE

Steam trap failure is divided into 2 types:

i. Failed open which is trap is blowing steam continuously across valve seat and will not close

ii. Failed closed which is trap is fully closed and will not open.

2.7 CHOSEN OF THERMODYNAMIC STEAM TRAP

After have a site visit to Sime Darby Plantation Jabor (SDPJ), the most population of steam trap is thermodynamic steam trap. Most oil and gas industries in Malaysia using thermodynamic steam trap too. Usually, thermodynamic steam trap fails open, due to wear and fluctuates rapidly, allowing steam to flow out.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discusses about the methodology of the experiment and how the experiment will be setting up. The experiment is used to determine the energy loss through steam trap and analyzing the result. Thermodynamic (TD) type steam traps is to be tested by using different steam pressure and different amount of condensate load in the pipeline.

3.2 FLOW CHART METHODOLOGY

To achieve the objectives of the project, a methodology were construct base on the scope of product as a guiding principle to formulate this project successfully. The important of this project is to measure the live steam that manages to escape through TD steam trap. The terminology of works and planning of this project are show in the flow chart below. This is very important to make sure that the experiment is in the right direction. Figure 3.1 shows the flowchart of this project.

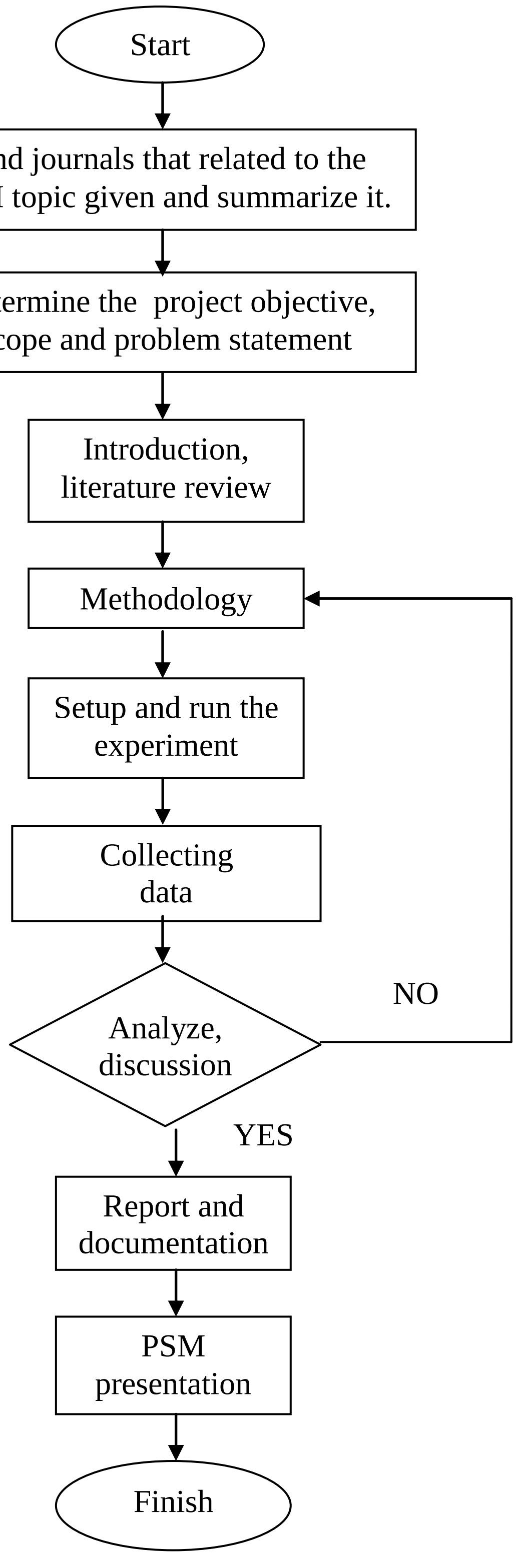

Figure 3.1: Flow chart

3.3 LITERATURE STUDY

First and for most, literature studies on various sources such as journal, reference books, printed or online conference article are done to help in developing better understanding of this thesis. Main focus would be on energy loss through steam trap in normal operation and when it fails.

3.4 SELECTION OF OPERATING PRESSURE

The operating pressure that is suitable to apply is limited to heat exchanger that is used in this experiment. Car radiator is used as the heat exchanger. The maximum pressure that allow by this heat exchanger is 0.9 bar. So this experiment will be conducted below the maximum allowed pressure.

3.5 STEAM TRAP SELECTION

In this experiment, disk thermodynamic steam trap is chosen to be tested because it has been the mostly used in industry. It becomes popular because it is an extremely robust steam trap with a simple mode of operation. It can operate across their entire working range without any internal adjustment needed. The most important is the disk is the only moving part, so maintenance can easily be carried out without removing the trap from line.

In order to perform this test, TL disk thermodynamic steam trap is used. The specification and picture of this steam trap in the Table 3.1 and Figure 3.2:

Table 3.1: Specification of steam trap

Model	**TL Disk Steam Trap (BS06)**
Connection	Screwed
Size (in)	3/4
Maximum operating pressure (bar)	16
Minimum operating pressure (bar)	0.3
Maximum operating temperature(℃)	220

Figure 3.2: Thermodynamics steam trap, model TL Disk Steam Trap (BS06)

3.6 STEAM TRAP TEST RIG

All the material must been setup such as in Figure 3.3. Steam will go through the condenser or heat exchanger. Some of steam will be condensed. The amount of condensed steam will be controlled by adjusting the speed of fan that attach to the heat exchanger. ‘A’ is control valve, installed between condenser and pressure gauge. This valve is used to control the operating pressure of steam trap. Steam trap will discharged condensate to insulated vessel through a lagged pipe. This lagged pipe work is used to prevent heat loss to surroundings.

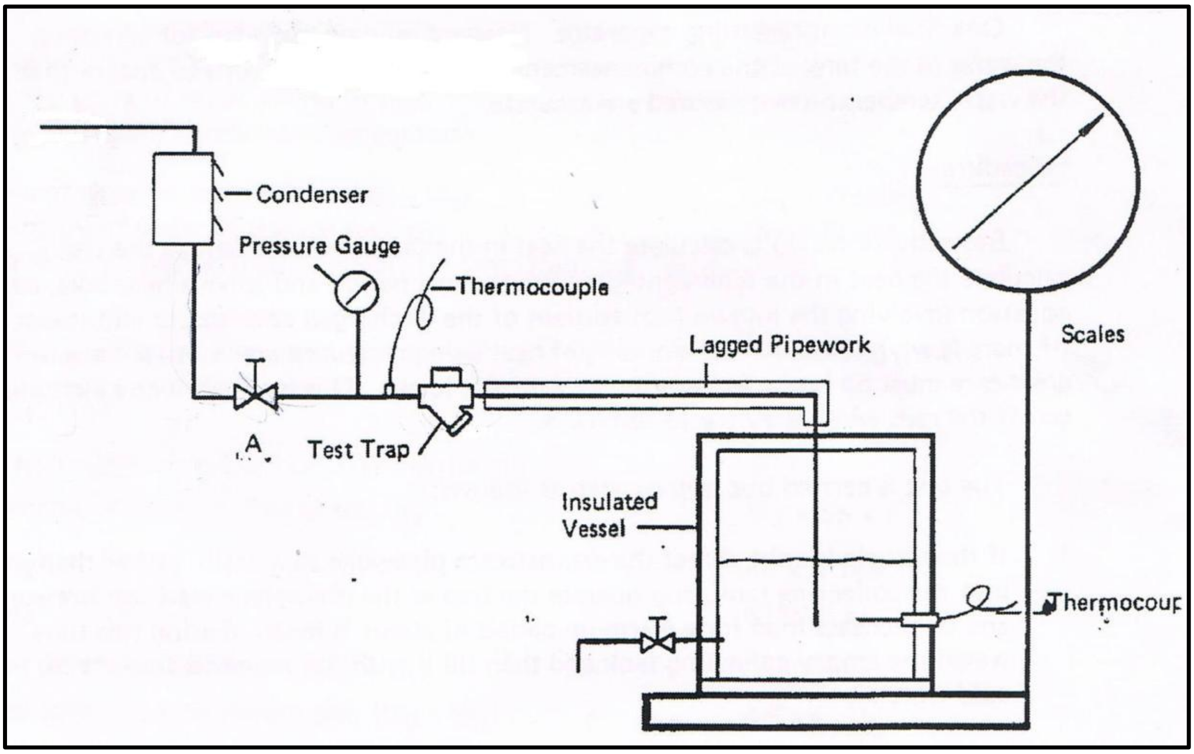

Figure 3.3: Test rig

3.7 TEST RIG PREPARATION

The steam trap should be supplied with a steady condensate load at constant pressure (variation in pressure or condensate temperature are sources of error in heat balance calculations). Steam is supply from a unit boiler which gives a steady load of steam, as shown on Figure 3.4. The steam supply to the test rig is controlled by gate valve, as shown in Figure 3.5.

Figure 3.4: Boiler to generate steam

Figure 3.5: Gate valve to control steam pressure

Steam is then flow through a heat exchanger to be cooled and became mixture (steam and condensate). In this experiment, car radiator is used together with fan as the heat exchanger, as shown in Figure 3.6 in the next page.

Figure 3.6: Heat exchanger

Speed of fan (Figure 3.7) can be controlled to manipulate the load of condensate formed. By increasing the fan speed, we can increase the percentage of condensate formed.

Figure 3.7: Fan

After come out from heat exchanger, the load will be supply to steam trap as shown in Figure 3.8 below. A new well performed steam trap will be used. A pressure gauge is installed between steam trap and heat exchanger.

Figure 3.8: Position of steam trap and pressure gauge

Downstream of the trap the condensate is connected into a collecting tank which already filled with water. Note however that the downstream pipe and the tank, including its bottom and top are heavily lagged. In this case, radiator rubber hose is used since it is a good insulator and can minimize heat loss to surrounding, as shown in Figure 3.9 below.

Figure 3.9: Rubber hose connected to steam

The condensate is discharged well below the water level in a collecting tank. It is to make sure the water in the tank can well absorb the condensate that is discharged from steam trap. The temperature of the water in the collecting tank is checked with a thermometer or thermocouple and the tank rests on weighing scale. Figure 3.10 below showed the setup of tank and weighing scale. Figure 3.11 showed a thermometer that will be used to measure the initial and final temperature of water inside the tank.

Figure 3.10: Setup of tank and weighing scale

Figure 3.11: Thermometer

3.8 STEAM TRAP PREPAIRATION

After normal steam trap is being tested, the disk inside steam trap needs to be grind to make it perform as open-failed steam trap. Firstly, open two covers that covered up the disc, as shown in Figure 3.12. The disk is the smallest part of the steam trap. Grind around the disk to make the effect of wear and tear to disk. Then, put back dick at its original place, and screwed back the cover. Finally, this steam trap is used back in experiment as open-failed steam trap. Do trial first to make sure that the steam trap is open-failed. It is opened fail when it discharges continuously, including live steam. If not happen, grind again the edge of the disc.

Figure 3.12: Steam trap components

3.9 SAMPLE CALCULATION

The method of calculating the energy loss from steam trap during the test period is best explained by way of an example as follows:

Test pressure : 0.4 bar

Duration of test : 10 $minutes$

Mass of empty collecting tank, W_t	=	$0.62kg$
Mass of tank + water at start of test, W_s	=	$5.7kg$
Temperature of water at start of test, T_1	=	$32°C$
Mass of tank + water at end of test, W_f	=	$5.9kg$
Temperature of water at end of test, T_2	=	$40.5°C$
Mean upstream condensate temperature	=	$110°C$
Mass of water at start of test, $(W_s - W_t)$	=	$W_1 = 5.7kg - 0.62kg$
	=	$5.08kg$
Enthalpy of water at start of test, h_1	=	$W_1 \times C_p \times T_1$

Where C_p = Specific heat of water

Hence,

Enthalpy of water at start of test, h_1	=	$5.08kg \times 4.18 \frac{kJ}{kg.K} \times 32°C$
	=	$679.5008kJ$
Mass of water at end of test, $(W_f - W_t) = W_2$	=	$5.9kg - 0.62kg = 5.28kg$
Enthalpy of water at end of test, h_2	=	$W_2 \times C_p \times T_2$
	=	$5.28kg \times 4.18 \frac{kJ}{kg.K} \times 40.5°C$
	=	$893.8512kJ$
Heat gain of water in tank, $(h_2 - h_1)$	=	$893.8512kJ - 679.5008kJ$
	=	$214.3504kJ$

Mass added to tank during test, $(W_2 - W_1)$	=	$0.2kg$

The total enthalpy of the fluid added to the tank = Enthalpy of the saturated condensate (h_f) +Enthalpy of any live steam discharge $(h_f + h_{fg})$

This total also equals the heat gain calculated above, hence

$h_2 - h_1$ = Mass of condensate (M_c) x h_f + Mass of steam (M_s) x $(h_f + h_{fg})$

Now, M_c = Total mass discharge M – Steam discharge M_s
So the equation may be rewritten

$$h_2 - h_1 = (M - M_s)h_f + M_s(h_f + h_{fg})$$

This simplifies to: $M_s = \frac{(h_2 - h_1) - Mh_f}{h_{fg}}$

Where h_f, h_{fg} and h_g, are found from steam tables at $110°C$

Hence, $M_s = \frac{214.3504kJ - (0.2kg \times 461.42kJ/kg)}{2229.7kJ/kg} = 0.055kg$

Steam loss per hour = $\frac{M_s}{10minute} \times \frac{60minute}{1hour} = 0.328kg/h$

Energy loss per hour = Steam loss per hour $\times h_g$ = $0.0328kg \times 2691.1\frac{kJ}{kg} = 883.956kJ$

3.10 SUMMARY

Overall, this experiment is about carrying out energy loss through steam trap using different set of parameters. Condensate from steam trap is collected and is analyzed to get the energy loss. The effect of operating pressure and condensate load to energy loss will be study based on data from the experiment.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter shows the results and discussion on the experiment conducted. The results are expressed in tables and graphs to provide the reader with a clearer view. The experimental results will then be analyzed and compared. Recommendation will be given for future improvements.

4.2 RESULT

There are two major results in this section. The first one is the analysis of energy loss for normal steam trap in respond to operating pressure for different condensate load and the second one is analysis of energy loss for failed open steam trap in respond to operating pressure for different condensate load.

4.2.1 Analysis of Energy Loss for Normal Steam in Respond to Operating Pressure for Different Condensate Load

Table 4.1: Data for low condensate load at 0.4 bar

Data No.	Start		End	
	T_1 (°C)	W_1(kg)	T_2 (°C)	W_2 (kg)
1	31.5	6.1	60.0	6.8
2	31.5	5.8	61.5	6.5
3	31.0	5.9	59.5	6.8
4	32.0	6.0	62.0	7.0
5	31.5	6.2	61.0	7.3

Table 4.1 shows data for low condensate load at 0.4 bar. There are five data, which represent five times running of the experiment to get more accurate data. All this data need to be calculated to get the energy loss per hour. The sample of calculation is as shown below:

Test pressure : 0.4 bar

Duration of test : 10 $minutes$

Mass of empty collecting tank, W_t = $0.62kg$

Mass of tank + water at start of test, W_s = $5.7kg$

Temperature of water at start of test, T_1 = $32°C$

Mass of tank + water at end of test, W_f = $5.9kg$

Temperature of water at end of test, T_2 = $40.5°C$

Mean upstream condensate temperature = $110°C$

Mass of water at start of test, $(W_s - W_t)$ = $W_1 = 5.7kg - 0.62kg$

$= 5.08kg$

Enthalpy of water at start of test, h_1 = $W_1 \times C_p \times T_1$

Where C_p = Specific heat of water

Hence,

Enthalpy of water at start of test, h_1 = $5.08kg \times 4.18\frac{kJ}{kg.K} \times 32°C$

= $679.5008kJ$

Mass of water at end of test, $(W_f - W_t) = W_2$ = $5.9kg - 0.62kg = 5.28kg$

Enthalpy of water at end of test, h_2 = $W_2 \times C_p \times T_2$

= $5.28kg \times 4.18\frac{kJ}{kg.K} \times 40.5°C$

= $893.8512kJ$

Heat gain of water in tank, $(h_2 - h_1)$ = $893.8512kJ - 679.5008kJ$

= $214.3504kJ$

Mass added to tank during test, $(W_2 - W_1)$ = $0.2kg$

The total enthalpy of the fluid added to the tank = Enthalpy of the saturated condensate (h_f) +Enthalpy of any live steam discharge $(h_f + h_{fg})$

This total also equals the heat gain calculated above, hence

$h_2 - h_1$ = Mass of condensate (M_c) x h_f + Mass of steam (M_s) x $(h_f + h_{fg})$

Now, M_c = Total mass discharge M – Steam discharge M_s

So the equation may be rewritten

$$h_2 - h_1 = (M - M_s)h_f + M_s(h_f + h_{fg})$$

Which simplifies to $M_s = \frac{(h_2 - h_1) - Mh_f}{h_{fg}}$

Where h_f, h_{fg} and h_g, are found from steam tables at $110°C$

Hence, $M_s = \frac{214.3504kJ - (0.2kg \times 461.42kJ/kg)}{2229.7kJ/kg} = 0.055kg$

Steam loss per hour = $\frac{M_s}{10minute} \times \frac{60minute}{1hour} = 0.328kg/h$

Energy loss per hour = Steam loss per hour $\times h_g$ = $0.0328kg \times 2691.1\frac{kJ}{kg} = 883.956kJ$

Table 4.2: Result for low condensate load at 0.4 bar

Data No.	Steam Escape (kg)	Steam Loss per Hour (kg/h)	Energy Loss per Hour (kJ/h)
1	0.055	0.328	883.956
2	0.056	0.335	901.796
3	0.051	0.308	827.653
4	0.054	0.326	878.469
5	0.052	0.309	832.497
		Average	864.876

By performing some calculation like the previous data, we get the result in Table 4.2. The average energy loss for low condensate load at 0.4 bar is 864.876 kJ/h.

Table 4.3: Data for low condensate load at 0.6 bar

Data No.	Start		End	
	T_1 (°C)	W_1(kg)	T_2 (°C)	W_2 (kg)
1	32.0	5.2	42.0	5.4
2	32.5	6.0	42.5	6.2
3	31.0	5.6	43.0	5.9
4	32.5	5.7	43.5	5.9
5	32.0	6.1	43.0	6.4

Table 4.4: Result for low condensate load at 0.6 bar

Data No.	Steam Escape (kg)	Steam Loss per Hour (kg/h)	Energy Loss per Hour (kJ/h)
1	0.059	0.352	950.145
2	0.074	0.444	1197.536
3	0.072	0.430	1161.337
4	0.078	0.470	1267.171
5	0.073	0.436	1177.226
		Average	1150.690

Table 4.3 shows data for low condensate load at 0.6 bar. There are five data, which represent five times running of the experiment to get more accurate data. By performing some calculation like the previous data, we get the result in Table 4.4. The average energy loss for low condensate load at 0.6 bar is 1150.690 kJ/h.

Table 4.5: Data for low condensate load at 0.8 bar

Data No.	**Start**		**End**	
	T_1 **(°C)**	W_1**(kg)**	T_2 **(°C)**	W_2 **(kg)**
1	32.0	5.2	45.0	5.5
2	33.0	4.9	46.0	5.2
3	32.5	5.5	44.0	5.7
4	32.0	5.4	44.5	5.6
5	32.0	5.0	45.0	5.3

Table 4.6: Result for low condensate load at 0.8 bar

Data No.	**Steam Escape (kg)**	**Steam Loss per Hour (kg/h)**	**Energy Loss per Hour (kJ/h)**
1	0.070	0.420	1136.647
2	0.063	0.379	1025.698
3	0.077	0.465	1257.854
4	0.085	0.507	1372.808
5	0.065	0.390	1056.517
		Average	1169.910

Table 4.5 shows data for low condensate load at 0.8 bar. There are five data, which represent five times running of the experiment to get more accurate data. By performing some calculation like the previous data, we get the result in Table 4.6. The average energy loss for low condensate load at 0.8 bar is 1169.910 kJ/h.

Table 4.7: Energy loss for low condensate load at different pressure

Pressure (bar)	**Energy Loss (kJ/h)**
0.4	864.876
0.6	1150.690
0.8	1169.910

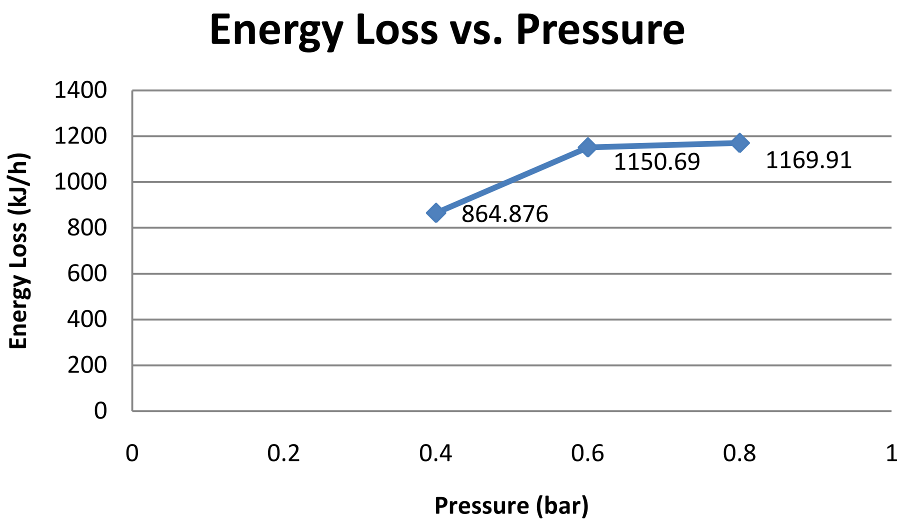

Figure 4.1: Graph of energy loss vs. pressure, for low condensate load

The Tables 4.7 and Figure 4.1 above shows graph for energy loss of 3 different operating pressure, which are 0.4 bar, 0.6 bar and 0.8 bar. Low condensate load is supply to the normal steam trap. The average value for operating pressure 0.4 bar is 864.876 kJ/h, 0.6 bar is 1150.690kJ/h and 0.8 bar is 1169.910 kJ/h. According to graph roughly, the energy loss increases as the operating pressure increases, which are from 864.876 kJ/h to 1169.910 kJ/h. In other words, it means that the energy loss is higher at higher operating pressure.

Table 4.8: Data for high condensate load at 0.4 bar

Data No.	Start		End	
	T_1 (°C)	W_1(kg)	T_2 (°C)	W_2 (kg)
1	32.0	6.1	49.5	7.1
2	31.5	5.5	52.0	6.6
3	31.0	5.9	49.5	6.9
4	32.0	6.3	50.5	7.4
5	31.0	5.6	49.5	6.5

Table 4.9: Result for high condensate load at 0.4 bar

Data No.	Steam Escape (kg)	Steam Loss per Hour (kg/h)	Energy Loss per Hour (kJ/h)
1	0.066	0.394	1059.822
2	0.067	0.403	1084.077
3	0.069	0.414	1113.704
4	0.073	0.441	1186.692
5	0.070	0.420	1130.012
		Average	1114.860

Table 4.8 shows data for high condensate load at 0.4 bar. There are five data, which represent five times running of the experiment to get more accurate data. By performing some calculation like the previous data, we get the result in Table 4.9. The average energy loss for high condensate load at 0.4 bar is 1114.860 kJ/h.

Table 4.10: Data for high condensate load at 0.6 bar

Data No.	Start		End	
	T_1 (°C)	W_1(kg)	T_2 (°C)	W_2 (kg)
1	30.0	5.7	57.0	7.2
2	30.5	5.3	58.5	6.8
3	31.0	5.9	58.0	7.5
4	32.0	5.8	58.0	7.3
5	32.0	5.8	55.5	7.1

Table 4.11: Result for high condensate load at 0.6 bar

Data No.	Steam Escape (kg)	Steam Loss per Hour (kg/h)	Energy Loss per Hour (kJ/h)
1	0.093	0.560	1511.267
2	0.086	0.516	1393.071
3	0.096	0.573	1546.538
4	0.091	0.549	1481.337
5	0.083	0.496	1337.499
		Average	1453.940

Table 4.10 shows data for high condensate load at 0.6 bar. There are five data, which represent five times running of the experiment to get more accurate data. By performing some calculation like the previous data, we get the result in Table 4.11. The average energy loss for high condensate load at 0.6 bar is 1453.940 kJ/h.

Table 4.12: Data for high condensate load at 0.8 bar

Data No.	Start		End	
	T_1 (°C)	W_1(kg)	T_2 (°C)	W_2 (kg)
1	30.0	6.8	65.0	9.6
2	32.0	5.9	66.5	8.3
3	32.0	6.2	64.5	8.4
4	31.5	6.0	64.0	8.1
5	31.0	5.5	66.0	7.6

Table 4.13: Result for high condensate load at 0.8 bar

Data No.	Steam Escape (kg)	Steam Loss per Hour (kg/h)	Energy Loss per Hour (kJ/h)
1	0.115	0.693	1874.397
2	0.100	0.598	1617.723
3	0.110	0.662	1790.179
4	0.107	0.639	1730.168
5	0.107	0.641	1734.792
		Average	1749.450

Table 4.12 shows data for high condensate load at 0.8 bar. There are five data, which represent five times running of the experiment to get more accurate data. By performing some calculation like the previous data, we get the result in Table 4.13. The average energy loss for high condensate load at 0.8 bar is 1749.450 kJ/h.

Table 4.14: Energy loss for high condensate load at different pressure

Pressure (bar)	Energy Loss (kJ/h)
0.4	1114.860
0.6	1453.940
0.8	1749.450

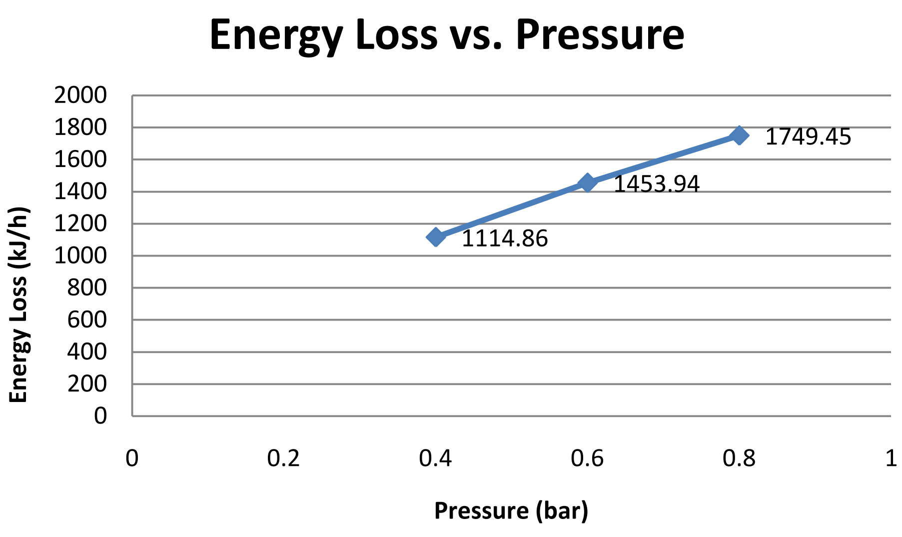

Figure 4.2: Graph of energy loss vs. pressure, for high condensate load

The Table 4.14 and Figure 4.2 above shows graph for energy loss of 3 different operating pressure, which are 0.4 bar, 0.6 bar and 0.8 bar. High condensate load is supply to the normal steam trap. The average value for operating pressure 0.4 bar is 1114.860 kJ/h, 0.6 bar is 1453.940 kJ/h and 0.8 bar is 1749.450 kJ/h. According to graph roughly, the energy loss increases as the operating pressure increases, which is from 1114.860 kJ/h to 1749.450 kJ/h. In other words, it means that the energy loss is higher at higher operating pressure.

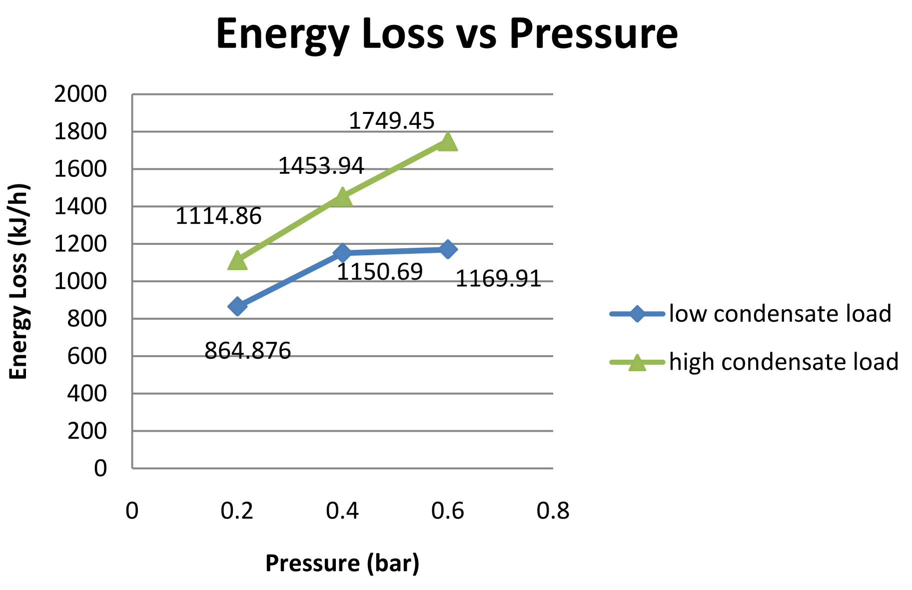

Figure 4.3: Graph of energy loss vs. operating pressure, for different condensate load

Figure 4.3 shows a graph of energy loss value of different condensate load under different operating pressure for normal steam trap. For low condensate load, the energy loss for operating pressure 0.4 bar, 0.6 bar and 0.8 bar are 864.876 kJ/h, 1150.690 kJ/h and 1169.91 kJ/h respectively. For high condensate load, the energy loss for operating pressure 0.4 bar, 0.6 bar and 0.8 bar are 1114.860 kJ/h, 1453.940 kJ/h and 1749.450 kJ/h respectively. As can see, the energy loss is increasing as the operating pressure increasing. And in comparison of the two condensate load, the energy loss for high condensate load produced higher value of energy loss.

4.2.2 Analysis of Energy Loss for Open-Failed Steam in Respond to Operating Pressure for Different Condensate Load

Table 4.15: Data for low condensate load at 0.4 bar

Data No.	Start		End	
	T_1 (°C)	W_1(kg)	T_2 (°C)	W_2 (kg)
1	31.5	6.1	60.0	6.8
2	31.5	5.8	61.5	6.5
3	31.0	5.9	59.5	6.8
4	32.0	6.0	62.0	7.0
5	31.5	6.2	61.0	7.3

Table 4.16: Result for low condensate load at 0.4 bar

Data No.	Steam Escape (kg)	Steam Loss per Hour (kg/h)	Energy Loss per Hour (kJ/h)
1	0.227	1.360	3659.894
2	0.227	1.363	3668.067
3	0.196	1.177	3168.689
4	0.212	1.271	3420.875
5	0.207	1.240	3338.276
		Average	3451.160

Table 4.15 shows data for low condensate load at 0.4 bar. There are five data, which represent five times running of the experiment to get more accurate data. By performing some calculation like the previous data, we get the result in Table 4.16. The average energy loss for low condensate load at 0.4 bar is 3451.160 kJ/h.

Table 4.17: Data for low condensate load at 0.6 bar

Data No.	**Start**		**End**	
	T_1 **(°C)**	W_1**(kg)**	T_2 **(°C)**	W_2 **(kg)**
1	31.0	6.0	75.0	6.9
2	30.5	5.6	76.5	6.5
3	31.5	5.7	76.0	6.8
4	31.0	5.4	77.0	6.3
5	31.0	5.7	76.5	6.7

Table 4.18: Result for low condensate load at 0.6 bar

Data No.	**Steam Escape (kg)**	**Steam Loss per Hour (kg/h)**	**Energy Loss per Hour (kJ/h)**
1	0.384	2.267	6117.945
2	0.378	2.196	5925.836
3	0.345	2.067	5578.867
4	0.349	2.097	5658.594
5	0.363	2.175	5869.785
		Average	5830.205

Table 4.17 shows data for low condensate load at 0.6 bar. There are five data, which represent five times running of the experiment to get more accurate data. By performing some calculation like the previous data, we get the result in Table 4.18. The average energy loss for low condensate load at 0.6 bar is 5830.205 kJ/h.

Table 4.19: Data for low condensate load at 0.8 bar

Data No.	**Start**		**End**	
	T_1 **(°C)**	W_1**(kg)**	T_2 **(°C)**	W_2 **(kg)**
1	30.0	5.2	92.0	6.0
2	30.0	5.1	90.0	6.2
3	31.0	5.5	88.5	6.4
4	31.0	5.3	90.5	6.4
5	32.0	5.9	88.0	6.7

Table 4.20: Result for low condensate load at 0.8 bar

Data No.	Steam Escape (kg)	Steam Loss per Hour (kg/h)	Energy Loss per Hour (kJ/h)
1	0.496	2.974	8050.951
2	0.446	2.679	7251.871
3	0.478	2.867	7762.291
4	0.466	2.795	7566.649
5	0.512	3.071	8313.626
		Average	7789.078

Table 4.19 shows data for low condensate load at 0.8 bar. There are five data, which represent five times running of the experiment to get more accurate data. By performing some calculation like the previous data, we get the result in Table 4.20. The average energy loss for low condensate load at 0.8 bar is 7789.078 kJ/h.

Table 4.21: Energy loss for low condensate load

Pressure (bar)	Energy Loss (kJ/h)
0.4	3451.160
0.6	5830.205
0.8	7789.078

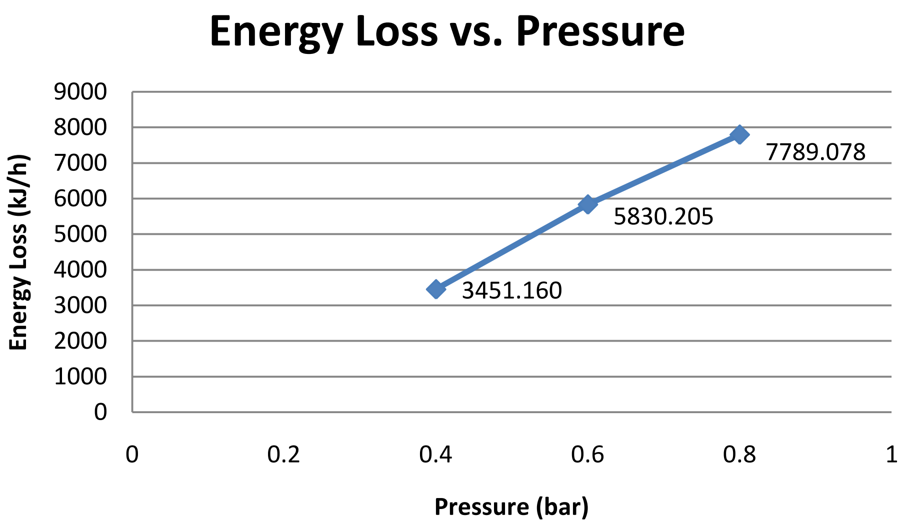

Figure 4.4: Graph of energy loss vs. pressure, for low condensate load

The Tables 4.21 and Figure 4.4 above show data for energy loss of 3 different operating pressure, which are 0.4 bar, 0.6 bar and 0.8 bar. Low condensate load is supply to the open-failed steam trap. The average value for operating pressure 0.4 bar is 3451.160 kJ/h, 0.6 bar is 5830.205 kJ/h and 0.8 bar is 7789.078 kJ/h. According to graph roughly, the energy loss increases as the operating pressure increases, which is from 3451.160 kJ/h to 7789.078 kJ/h. In other words, it means that the energy loss is higher at higher operating pressure.

Table 4.22: Data for high condensate load at 0.4 bar

Data No.	Start		End	
	T_1 (°C)	W_1(kg)	T_2 (°C)	W_2 (kg)
1	31.5	6.3	59.0	7.6
2	31.0	5.6	57.5	6.3
3	31.0	5.7	60.5	6.9
4	32.5	6.0	59.5	7.2
5	31.5	6.2	59.5	7.6

Table 4.23: Result for high condensate load at 0.4 bar

Data No.	Steam Escape (kg)	Steam Loss per Hour (kg/h)	Energy Loss per Hour (kJ/h)
1	0.168	1.006	2706.129
2	0.180	1.081	2908.474
3	0.169	1.012	2724.137
4	0.158	0.947	2548.572
5	0.159	0.956	2572.863
		Average	2692.035

Table 4.22 shows data for high condensate load at 0.4 bar. There are five data, which represent five times running of the experiment to get more accurate data. By performing some calculation like the previous data, we get the result in Table 4.23. The average energy loss for high condensate load at 0.4 bar is 2692.035 kJ/h.

Table 4.24: Data for high condensate load at 0.6 bar

Data No.	Start		End	
	T_1 (°C)	W_1(kg)	T_2 (°C)	W_2 (kg)
1	31.0	5.8	67.5	7.0
2	30.5	5.4	69.0	6.4
3	31.5	5.8	70.5	7.1
4	32.0	5.9	67.0	7.0
5	32.0	5.6	69.5	6.7

Table 4.25: Result for high condensate load at 0.6 bar

Data No.	Steam Escape (kg)	Steam Loss per Hour (kg/h)	Energy Loss per Hour (kJ/h)
1	0.248	1.489	4017.100
2	0.260	1.557	4201.891
3	0.271	1.625	4385.276
4	0.248	1.488	4016.342
5	0.257	1.541	4159.889
		Average	4156.100

Table 4.24 shows data for high condensate load at 0.6 bar. There are five data, which represent five times running of the experiment to get more accurate data. By performing some calculation like the previous data, we get the result in Table 4.25. The average energy loss for high condensate load at 0.6 bar is 4156.100 kJ/h.

Table 4.26: Data for high condensate load at 0.8 bar

Data No.	Start		End	
	T_1 (°C)	W_1(kg)	T_2 (°C)	W_2 (kg)
1	30.0	5.8	87.5	8.5
2	30.5	5.0	89.0	7.3
3	31.0	5.1	88.5	7.5
4	32.0	5.4	87.0	8.0
5	32.0	5.7	89.0	8.8

Table 4.27: Result for high condensate load at 0.8 bar

Data No.	Steam Escape (kg)	Steam Loss per Hour (kg/h)	Energy Loss per Hour (kJ/h)
1	0.396	2.377	6433.450
2	0.349	2.092	5663.970
3	0.343	2.058	5572.007
4	0.334	2.001	5417.678
5	0.364	2.185	5913.913
		Average	5800.204

Table 4.26 shows data for high condensate load at 0.8 bar. There are five data, which represent five times running of the experiment to get more accurate data. By performing some calculation like the previous data, we get the result in Table 4.27. The average energy loss for high condensate load at 0.8 bar is 5800.204 kJ/h.

Table 4.28: Energy loss for high condensate load at different operating pressure

Pressure (bar)	Energy Loss (kJ/h)
0.4	2692.035
0.6	4156.100
0.8	5800.204

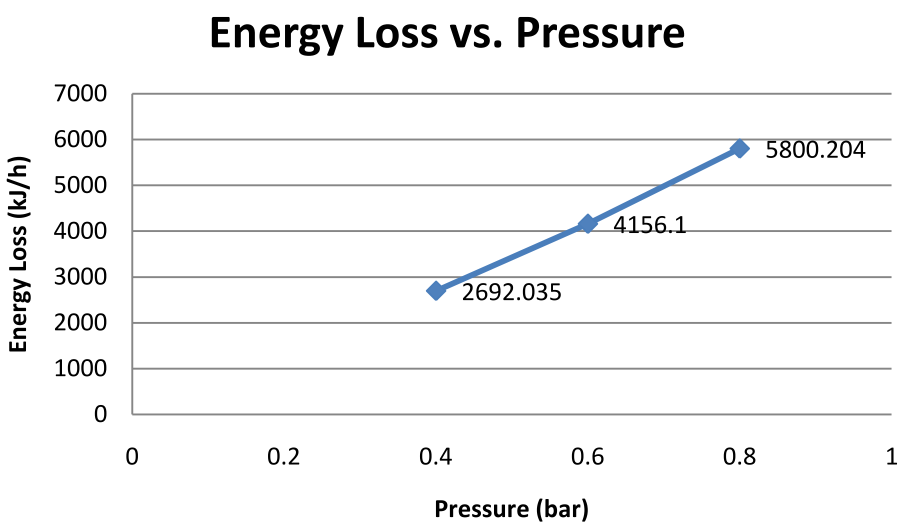

Figure 4.5: Graph of energy loss vs. pressure, for high condensate load

The Tables 4.28 and Figure 4.5 show data for energy loss of 3 different operating pressure, which are 0.4 bar, 0.6 bar and 0.8 bar. High condensate load is supply to the open-failed steam trap. The average value for operating pressure 0.4 bar is 2692.035 kJ/h, 0.6 bar is 4156.100 kJ/h and 0.8 bar is 5800.204 kJ/h. According to graph roughly, the energy loss increases as the operating pressure increases, which is from 2692.035 kJ/h to 5800.204 kJ/h. In other words, it means that the energy loss is higher at higher operating pressure.

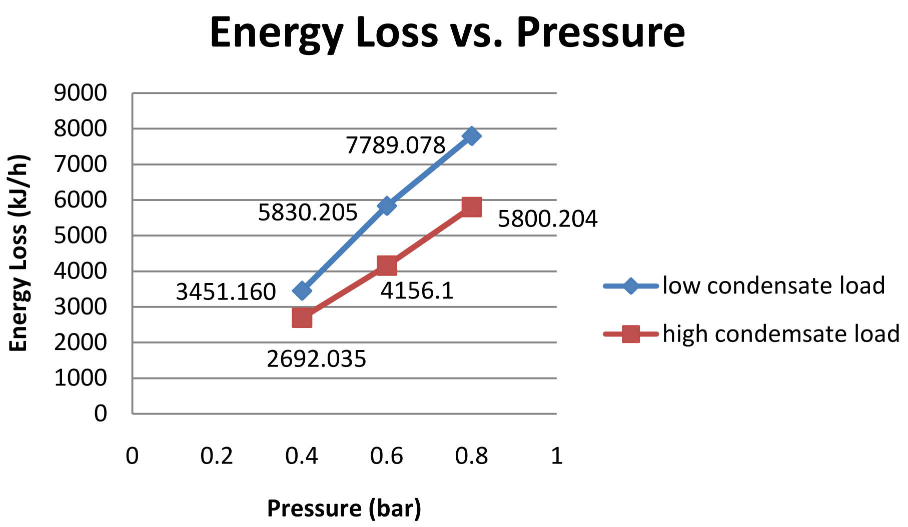

Figure 4.6: Graph of energy loss vs. operating pressure, for different condensate load

Figure 4.6 above is the graph of energy loss value of different condensate load under different operating pressure for open-failed steam trap. For low condensate load, the energy loss for operating pressure 0.4 bar, 0.6 bar and 0.8 bar are 3451.160 kJ/h, 5830.205 kJ/h and 7789.078 kJ/h respectively. For high condensate load, the energy loss for operating pressure 0.4 bar, 0.6 bar and 0.8 bar are 2692.035 kJ/h, 4156.100 kJ/h and 5800.204 kJ/h respectively. As can see, the energy loss is increasing as the operating pressure increasing. And in comparison of the two condensate load, the energy loss for low condensate load produced higher value of energy loss.

4.2.3 Comparing Energy Loss for Normal Steam Trap and Failed Open Steam Trap

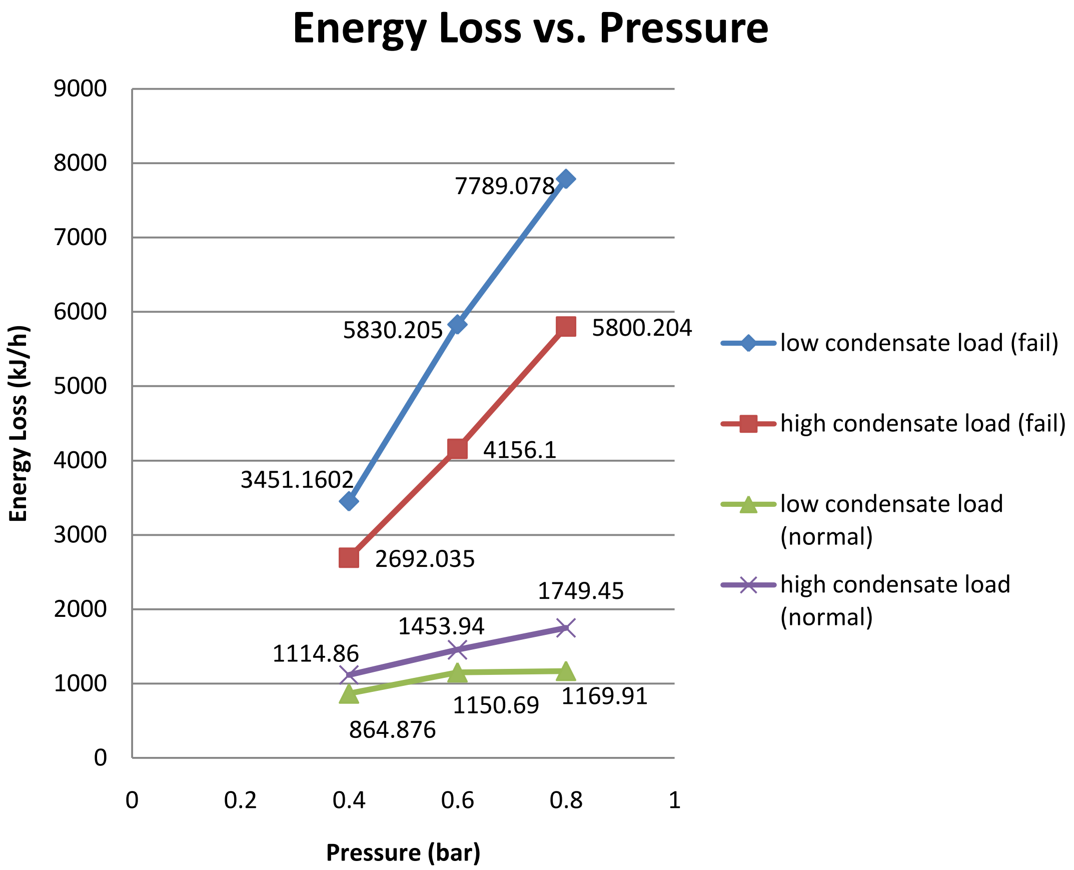

Figure 4.7: Graph of energy loss vs. operating pressure, for different condensate load at normal and open-failed steam trap

Figure 4.7 above is graph of energy loss versus operating pressure, for different condensate load for both normal and open-failed steam trap. As we can see, there is a huge different between energy loss for normal steam trap and energy loss for open-failed steam trap. The open-failed steam trap has very high energy loss because the live steam which has huge amount of enthalpy manages to escape through fail-opened steam trap. The actual value of energy loss if the failed steam trap is not replace with new one is the difference between two points of energy loss at normal and open-failed steam trap. So, the actual energy loss is shown by an example below.

For low condensate:

$$Actual\ Energy\ Loss = Energy\ Loss\ (fail) - Energy\ Loss\ \ (normal)$$

$$= 3451.1602\frac{kJ}{h} - 864.676\frac{kJ}{h}$$

$$= 2586.284\frac{kJ}{h}$$

Table 4.29: Actual Energy Loss

Pressure (bar)	Actual Energy Loss (kJ/h)	
	Low Condensate Load	**High Condensate Load**
0.4	2586.284	1577.175
0.6	4679.515	2702.160
0.8	6619.168	4050.754

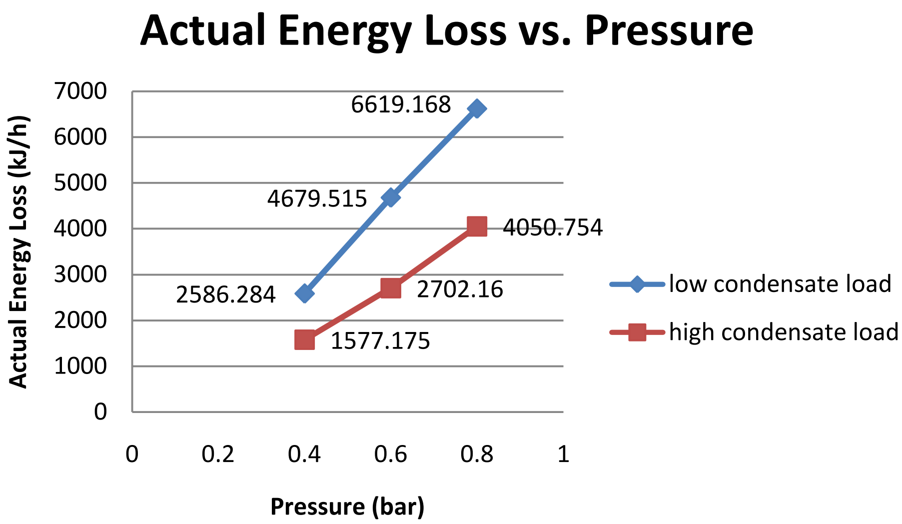

Figure 4.8: Graph of actual energy loss vs. operating pressure

From Graph 4.8 above, low condensate load achieve higher energy loss for each point respectively compare to high condensate load. For low condensate load, the actual energy loss for operating pressure 0.4 bar, 0.6 bar and 0.8 bar are 2586.284 kJ/h, 4679.515 kJ/h and 6619.168 kJ/h respectively. For high condensate load, the actual energy loss for operating pressure 0.4 bar, 0.6 bar and 0.8 bar are 1577.175 kJ/h, 2702.160 kJ/h and 4050.754 kJ/h respectively. These occur because low condensate load has higher amount of live steam per volume, compare to high condensate load. Live steam carry high amount of energy. So, the energy loss is also high. The highest point of energy loss is at low condensate load, 0.8 bar pressure while the lowest point is at high condensate load, 0.4 bar pressure.

4.3 DISCUSSION

From the experiment conducted, we can conclude that the higher operating pressure is, the higher the value of energy loss. This means that higher operating pressure produces more energy loss. Operating pressure is one of the parameters that control the energy loss. At low pressure, steam contains low amount of enthalpy. Steam that manages to escape has low amount of enthalpy. So, energy loss is lower at this point. On the other hand, as the operating pressure increases, the amounts of enthalpy that occupy in steam also increase. So, energy loss will also be increase.

For the actual energy loss, low condensate load allow more energy loss compare to high condensate load. This situation take place because of low condensate load has higher amount of live steam per volume, compare to high condensate load. Live steam carry high amount of energy. So, the energy loss is also high.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

This chapter is the summary of what this whole research is about. It concludes all the outcomes, observation of results and analysis, and discussion throughout the experiment. Recommendations may also be given on improving future work and studies.

5.2 CONCLUSION

From the results, it can be concluded that for normal steam trap, high condensate load in the steam system caused higher energy loss compare to low condensate load. This happen because when more condensate appeared in the steam line, steam trap need to discharge frequently. Increasing the condensate discharge will increase the amount of steam loss through steam trap.

For failed open steam trap, high condensate load in the steam system caused lower energy loss compare to low condensate load. This happen because failed open steam trap will discharge condensate and also steam all the time. High condensate load in steam line has lower energy compare to low condensate since it has lower amount of steam. Condensate carried less energy than steam.

At low condensate load, if the steam trap failed and the company do not replace it immediately, they will loss approximately 2586.284 kJ/h to 6619.168 kJ/h at pressure between 0.4 bar to 0.8 bar. At high condensate load, if the steam trap failed and the company do not replace it immediately, they will loss approximately 1577.175 kJ/h to 4050.754 kJ/h at pressure between 0.4 bar to 0.8 bar. These huge amount of wasted energy will be increased day by day if no instantaneous action taken. Hence, the profit of the company will decrease.

5.3 RECOMMENDATION

For every studies and researches that has been done, there is always room for further improvements. So is this research. There are some suggestion and method that can be taken into account when running this research in the future.

Firstly, researchers may select more operating pressure and amount of condensate load when carry out the experiment. More level of parameter can help to eliminate errors and leads to accuracy. In this research, only 3 operating pressure and 3 amount of condensate load are used, and the energy loss did increases when operating pressure and amount of condensate load increases.

Secondly, it is suggested that future researchers use other type of steam trap. Be it mechanical, thermostatic or thermodynamic steam trap. By testing these types, we can compare the data that we get from each type of steam trap and do a comparison on energy loss.

Lastly, the collecting tank is suggested to be well insulated. This is to prevent the heat loss to surrounding. As the steam trap discharged the condensate, the water in the tank must able to absorb all the heat. This process is taking time to be equilibrium. So, by using well insulated tank, we can reduce the heat loss to surrounding and leads to an accuracy.

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APPENDIX A1
STEAM TRAP CONNECTION

Figure 3.13: Steam Trap Connection

Figure 3.14: Steam Trap Connection

APPENDIX A2
EXPERIMENT SETUP

Figure 3.15: Setup of Radiator, Pressure Gauge and Steam Trap

Figure 3.16: Condensate Collector

APPENDIX B

GANTT CHART FOR FYP 1

No.	Activities/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Project Title															
2	Objectives And Scopes															
3	Introduction															
4	Literature Review															
5	Define Objective and Scope															
6	Methodology															
7	Submit proposal and draft of report															
8	Presentation of Proposal															

GANTT CHART FOR FYP 2

No.	Activities/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Literature Study																
2	Analysis Project																
3	Collect The Data																
4	Analysis of Data and Results																
5	Interprets Data																
6	Conclusion																
7	Final Presentation																
8	Preparing and Submit Report																