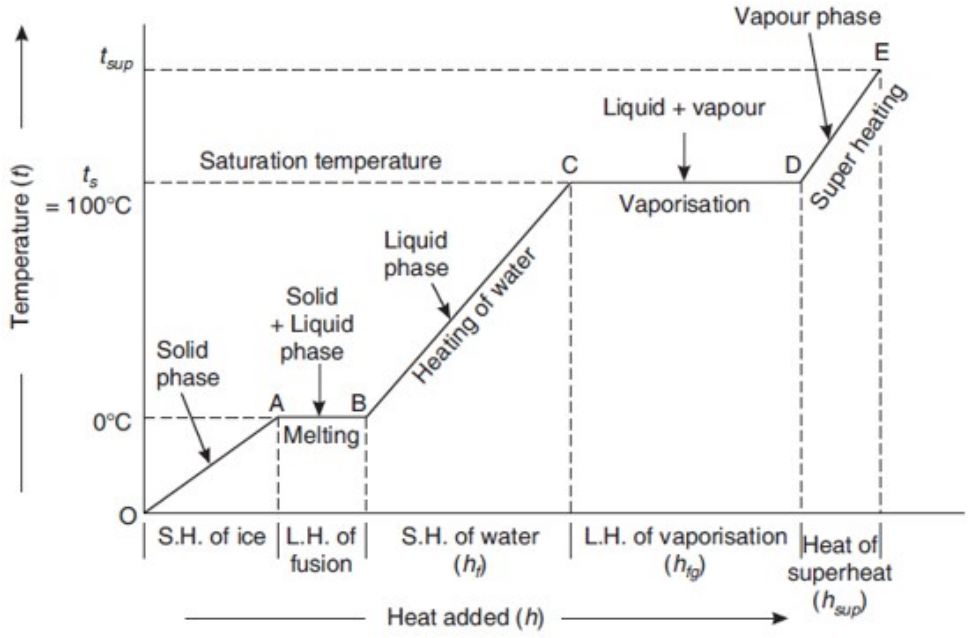
Experiment name: Marcet Boiler
Experiment No.: 4
Aim of experiment:

- To determine the relationship between the pressure and the temperature of saturated steam in equilibrium.
- To demonstrate the vapor pressure curve P-T curve.

1. Introduction

Thermodynamics study about the interchange of heat and work between a system and the surroundings which occurs when the system undergoes a process. Thermodynamic also concerned about the changes in the properties of fluid. Most thermodynamics substances such as gases and vapors are often referred as P-V-T substances.

An ideal gas obeys the equation of state that relates the pressure, specific volume or density, and absolute temperature with mass of molecule and the gas constant, R.
When energy is added within water, the increasing of activities among the molecules caused the increase in the number of molecule escape from the surface until an equilibrium state is reached. The state of equilibrium depends on the pressure between the water surface and steam. The lower the pressure, the easier the molecules leaving the water surface and thus less energy is required to achieve the state of equilibrium (boiling point).
"When heat energy is transferred to water, its enthalpy and its physical state changes. As heating takes place, the temperature of the water rises and generally its density increases".



The temperature where equilibrium occurs at a given pressure level is called **saturated temperature**. The pressure where equilibrium occurs at a given temperature is called **saturated pressure.**

The Marcet Boiler was used for this experiment. When the pressure increases, the temperature also increases. Therefore, the relationship of pressure and temperature is directly proportional. The derived formulae and the data were used to calculate the slope. The dT/dP measured was compared with the data in the steam table. Theoretically, the values measured should be almost the same with the predicted values. However, at certain points, the values are not the same. This may because of the errors made in the experiment

2. Experiment Methods and Materials

The apparatus used was a unit of Marcet Boiler and water. The unit of Marcet Boiler consists of a stainless-steel pressure vessel fitted with high pressure immersion electrical heater, control panel, a safety relief valve, water inlet port & valve, Bourdon tube pressure gauge, temperature and pressure measuring devices.

- Before starting the experiment, a quick inspection was performed to ensure the unit is in proper operating condition. The unit of Marcet Boiler was later connected to the nearest power supply. Valve at the feed port and the level sight tube were opened.
- After that, the boiler was filled with distilled water through the feed port and the water level was made sure to be at about half of the boiler's height. Then, the valves at the level sight tube were closed and the power supply is turned on.
- The temperature controller was set at 120 °C which is slightly above the expected boiling point of the water at 10.0 bar(abs).
- The valve at feed port was opened and the heater was turned on. The valve at the level sight tube is made sure to be closed before turning on the heater as the sight tube is not designed to withstand high pressure and temperature. The rise of steam temperature was observed as the water boils.
- The steam from the valve was allowed to come out for 30 seconds before the valve was closed. This step is important to remove air from the boiler as the accuracy of the experimental results will be significantly affected if air is present.
- The steam temperature, gauge pressure at 1.00 bar (abs) and time taken for the steam to reach 1.00 bar (abs) were recorded. This step was repeated by increase the interval of pressure with 0.5 bar (abs) until the steam pressure reaches 10.0 bar (abs).
- After that, the heater was allowed to cool down to room temperature. All the results were recorded and tabulated under the table below. Graph of temperature against absolute pressure was plotted. Calculation of the slope of the graph was made. Graph of $\left(\frac{dT}{dP}\right)_{sat.}$ **versus** $\boldsymbol{P}$ and $\frac{T v_{fg}}{h_{fg}}$ **versus** $\boldsymbol{P}$ was also plotted.

3. Theory/Calculation:

Marcet Boiler is used to investigate the relationship between the pressure and temperature of saturated steam in equilibrium with water at all temperature levels between the atmospheric pressure and 10 bars. The measured value of the slope of the graph (dT/dP) obtained from the experiment results can be compared to the theoretical value determined through calculation from the steam table.

Clausius-Clapeyron states:

$$\left(\frac{dT}{dP}\right)_{sat.} = \frac{T\ v_{fg}}{h_{fg}}$$

$$\left(\frac{dT}{dP}\right)_{sat.} = \frac{T\ (v_g - v_f)}{(h_g - h_f)}$$

In which,

v_f = specific volume of saturated liquid

v_g = specific volume of saturated vapor

h_f = enthalpy of saturated liquid

h_g = enthalpy of saturated vapor

h_{fg} = latent heat of vaporization

T = Temperature in K

Experimental calculation:

Change gauge pressure (psi) to absolute pressure (psi) = p gage + 14.7 (atm pressure in psi)

Then convert to kPa and bar (1 psi =6.89476 kPa) (1 bar = 100 kPa)

Find dP = pressure at each point – pressure at the former point (P_2-P_1), (P_3-P_2), (P_4-P_3), etc.

Find dT = temperature at each point – pressure at the former point (T_2-T_1), (T_3-T_2), (T_4-T_3), etc.

Error = $\left[\left(\frac{dT}{dP} - \frac{Tvg}{hfg}\right) / \left(\frac{dT}{dP}\right)\right] * 100$

$\frac{dT}{dP} = - - - - -$

Use steam table for the saturated steam (table 1 or 2) at each temperature find

T °C	v_f	v_g	h_{fg}

4. Experimental Results

Pressure, P (psi)		Absolute Pressure		Temperature		v_{fg} $(v_g - v_f)$	Measure Slope, dT/dP (K/kPa)	Calculated Slope, $Tvfg/hfg$	Error %
Gauge	Absolute	kPa	Bar	^{0}C	K				
2.5									
5									
7.5									
10									
12.5									
15									

5. Graph:

- Plot P versus dT/dP and Tvg/hfg on a same graph.
- Plot P versus T (K) and P (abs, bar) on a same graph.

6. Discussion

Answer these questions:

• Complete Table attached.
• Compare and discuss the graph plotted from experiment data to that of the calculated data.
• Discuss the variation of the error with pressure.
• Discuss any discrepancy and sources of error of the experiment.
• Why is it necessary to ensure no air trapped within the device at the beginning of the experiment?
• Discuss the liquid and vapor behavior observed through the experiment and list some examples of its industrial applications.