Experiment 1

Marcet boiler

Objectives:

1- To investigate the relationship between the pressure and the temperature for a saturated steam in a constant volume tank.

2- To verify the Clausius – Claperon Equation.

THEORY

Marcet Boiler (Model:HE169) has been developed for investigating the relationship between the pressure and temperature of saturated steam, in equilibrium with water, at all pressures between atmospheric and 10 bar (abs) (150lb/in^2).

Thermodynamics is a branch of physics, which deals with the energy, and work of a system. Thermodynamics deals only with the large-scale response of a system that we can observe and measure in experiments.

When the energy increases within water, the increasing of activities among the molecules enables the increase in the number of molecule escape from the surface until the equilibrium state is reached. The state of equilibrium depends on the pressure between the water surface and steam. At lower pressure, the molecules become easier leaving the water surface while less energy required in achieving the state of equilibrium (boiling point). The temperature where the equilibrium occurs at a given pressure level is called saturated temperature.

The measured value of the slope of the graph $\left(\frac{dT}{dP}\right)_{sat}$ obtained from the practical results can be compared with corresponding values calculated from the data in steam tables.

Clausius-Clapeyron states:-

$$\left(\frac{dT}{dP}\right)_{SAT} = \frac{T\Delta v}{\Delta h}$$

$$\left(\frac{dT}{dP}\right)_{SAT} = \frac{Tv_{fg}}{h_{fg}}$$

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

When the phase transition of a substance is between a gas phase and a condensed phase (liquid or solid), and occurs at temperature much lower than the critical temperature of that substance, the specific volume of the gas phase ,v_g greatly exceeds that of the condensed phase v_c.

$$\Delta v = v_g\left(1 - \frac{v_c}{v_g}\right) \approx v_g$$

Therefore, one may approximate at low temperature, Δ_v is like the equation above. Therefore,

$$\left(\frac{dT}{dP}\right)_{SAT} = \frac{T(v_g - v_f)}{h_g - h_f} = \frac{Tv_g}{h_{fg}}$$

As $v_g \gg v_f$

In which.

$v_f = specific\ volume\ of\ saturated\ liquid$
$v_g = specific\ volume\ of\ saturated\ vapour$
$h_f = enthalpy\ of\ saturated\ liquid$
$h_g = enthalpy\ of\ saturated\ vapour$
$h_{fg} = latent\ heat\ of\ vaporization$

APPARATUS & MATERIAL

Material :-

1. Distilled water

Apparatus :-

SOLTEQ® Marcet Boiler (Model:HE169)

The unit is made of stainless steel pressure vessel fitted with high pressure immersion electrical heater. The unit also comes together with a safety relief valve, temperature and pressure measuring devices. Water feed port is installed to allow water charging. It is also installed with temperature and pressure transducers so that students are able to read the respective values in the digital indicators easily. The water heater is protected from the burnout by setting the maximum operating temperature with temperature controller

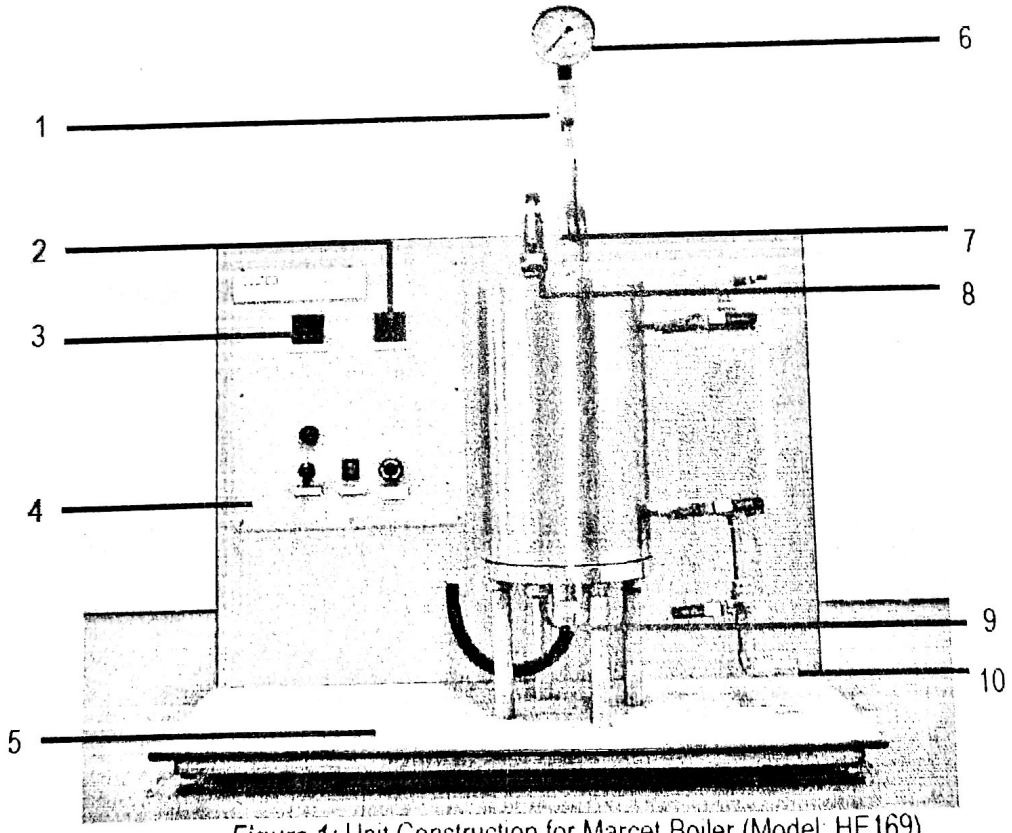


Figure 1: Unit Construction for Marcet Boiler (Model: HE169)

1. Pressure Transducer	6. Bourdon Tube Pressure Gauge
2. Pressure Indicator	7. Temperature Sensor
3. Temperature Controller/Indicator	8. Pressure Relief Valve
4. Control Panel	9. Heater
5. Bench	10. Water Inlet Port & Valve

PROCEDURES

A- General Start-up Procedures

1. A quick inspection was performed to ensure that the unit is in proper operating condition.

2. The unit to the nearest power supply connected.

3. The water in the boiler is checked whether it was filled or not. Skip step 4 and 5 skipped if the boiler already filled.

4. The valves at the feed port and the level sight tube (V1, V2 & V3) were opened.

5. The boiler with distilled water through the feed port was filled and the water level is at about the half of the boiler"s height was make sure. Then, the valves (V1) & valves (V2) at the level sight tube was closed.

6. The power supply switch was turn on.

7. The experiment now is ready to carry on.

B- General Shut-down Procedures

1. The heater was switched off and the boiler temperature was left drop until room temperature was reached.

NOTE :

Do not open the valve at the water inlet port as it is highly pressurized at high temperature.

2. The main switch and the main power supply was switched off when it has dropped to room temperature.

3. The water for next used was retained.

4. The upper part of the level sight tube, V3 was opened to drain the water and then the vales (V1) and valves (V2) was opened to drain off the water.

C- Experimental Procedures

1. The general start-up procedures were performed.

2. Initially, the boiler was filed with water; the valves at the level side tube (V2 & V3) were opened to check the water level. The Distilled water was pouring in additional if necessary. Then the valves closed.

3. The temperature controller was set to 185.0 °C which is slightly above the expected boiling point of the water at 10.0 bar (abs).

4. The vent valves (V3) was opened and the heater was turn on.

Important :

Always make sure that the valves at the level sight tube are closed before turning on the heater as the sight tube is not designed to withstand high pressure and temperature.

5. The steam temperature rise observed as the water boils.

6. The steam was allowed to come out from the valves (V3) for about 30 seconds, and then 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 when air is present.

7. The steam temperature and pressure was recorded when the boiler is heated until the steam pressure reaches 10.0 bar (abs). (The intervals of pressure data for 0.1 initially were made, followed by 0.2 and 0.5 for the following data).

Warning!

Never open the valve when the boiler is heated as pressurized steam can cause severe injury.

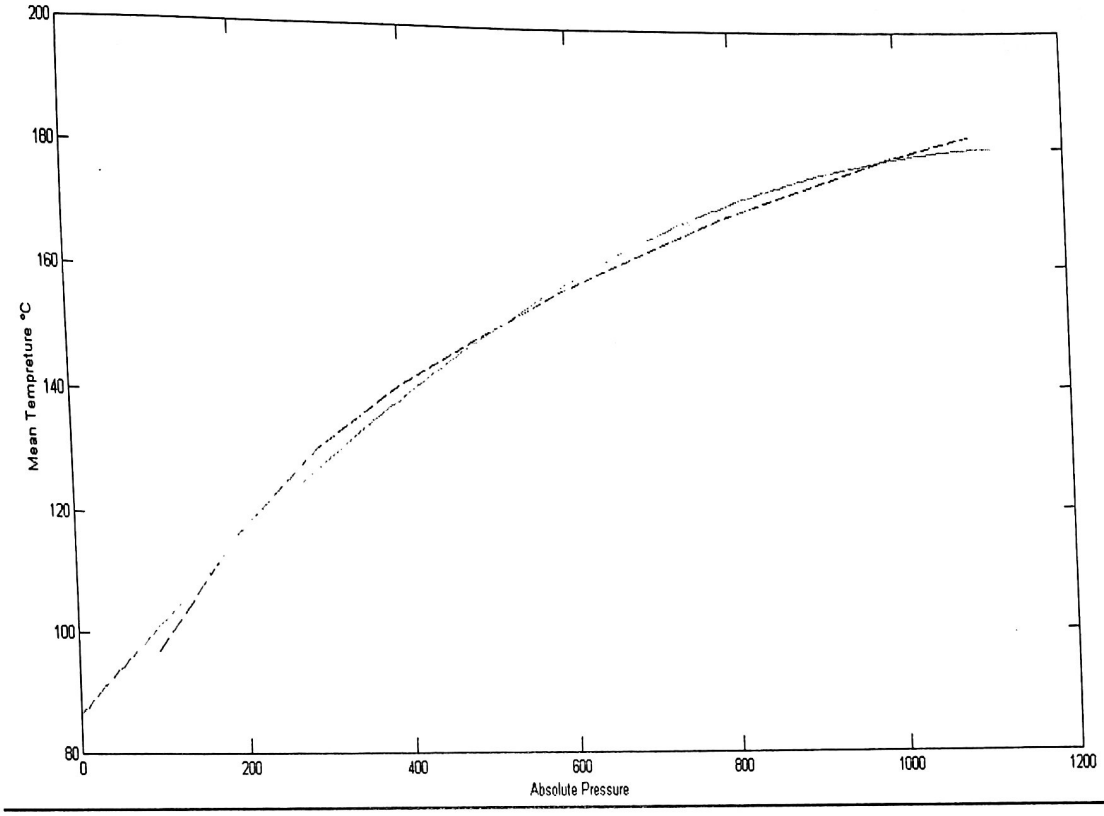
8. Then, the heater was turn off and the steam temperature and pressure began to drop. The steam temperature was recorded when the boiler was cooled until the steam pressure reached the atmospheric pressure.

9. The boiler was allowed cooled down to room temperature.

10. The steam temperatures were recorded at different pressure readings when the boiler is heated and cooled.

RESULTS

Pressure (bar)		Steam Temperature °C			Measured Slope, $\left(\frac{dT}{dP}\right)$	Calculated Slope, $\left(\frac{Tv_{fg}}{h_{fg}}\right)$	Error
Gauge	Absolute	Increasing	Decreasing	Mean			
0	0.9	95	97.5				
1	1.9	115.2	117.7				
2	2.9	129.5	132				
3	3.9	140	142.5				
4	4.9	148.6	150.3				
5	5.9	156.3	157.5				
6	6.9	161.9	163.9				
7	7.9	168.1	169.5				
8	8.9	172.5	174.7				
9	9.9	177.1	179.6				
10	10.9	182.2	182.2				


200
180
160
140
120
100
80
Mean Tempreture °C
0
200
400
600
800
1000
1200
Absolute Pressure