Laboratory Report - Pool Boiling Experiment

Name	ID Number	Email
Yu Qinrong	999021223	yu24315@gtiit.edu.cn
Yuan Ce	999021231	yuan24280@gtiit.edu.cn
Yun Zhuorui	999021264	yun24239@gtiit.edu.cn
Zeng Hanting	999021298	zeng24556@gtiit.edu.cn
Zhang Yaqin	999021306	zhang24747@gtiit.edu.cn

1 Abstract

This laboratory experiment investigated the pool boiling phenomenon using a standard experimental apparatus. The setup consisted of a transparent liquid pool filled with refrigerant SES36, an electrically heated rod, temperature sensors, and a data acquisition system. By incrementally increasing the electrical power supplied to the heater (from 10 W to 300 W) and recording the corresponding steady-state temperatures of both the heater surface and the bulk liquid, the relationship between heat input and temperature difference (ΔT) was studied. Also, we observed the gas and the liquid phases were changing as the power was increasing. The resulting data was plotted to generate a boiling curve. Analysis of the curve identified distinct heat transfer regimes: natural convection at lower power levels and nucleate boiling at higher power levels. The overall trends observed in the experimental data were consistent with established pool boiling theory, although some deviations from reference data were noted, particularly at very high heat fluxes.

2 Experimental Equipment Introduction

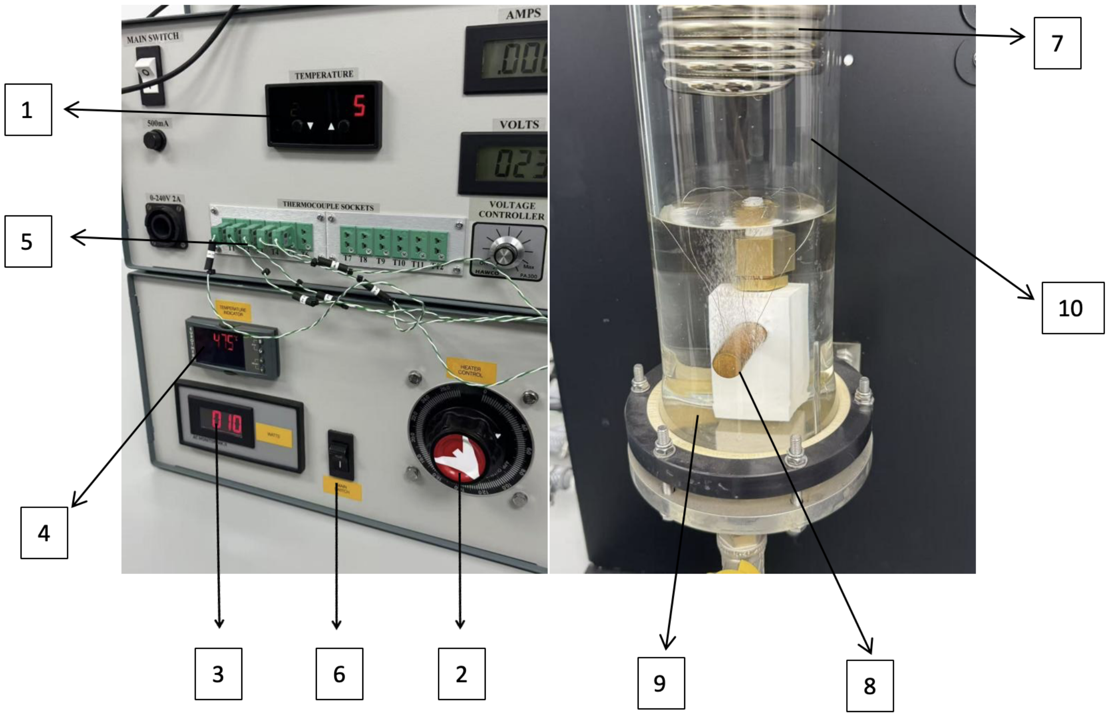


Figure 1: system setup

1: Liquid Temperature Sensor
2: Power Controller
3: Power Meter
4: Heater Surface Temperature Sensor
5: Thermocouple
6: Switch
7: Condenser
8: Heat Rod
9: Refrigerant SES36
10: Liquid Pool

Function:

- **Liquid Temperature Sensor**: Measures bulk liquid temperature (T_{liquid}).
- **Power Controller**: Adjusts electrical input to the heater.
- **Power Meter**: Displays real-time heating power (W).
- **Heater Surface Temperature Sensor**: Measures heat rod surface temperature (T_{heater}).
- **Thermocouple**: Based on the Seebeck effect, measured both the heater surface and bulk liquid temperatures to construct the boiling curve.
- **Switch**: Controls system status.
- **Condenser**: Removes excess heat, condenses vapor and recycle the Refrigerant SES36.

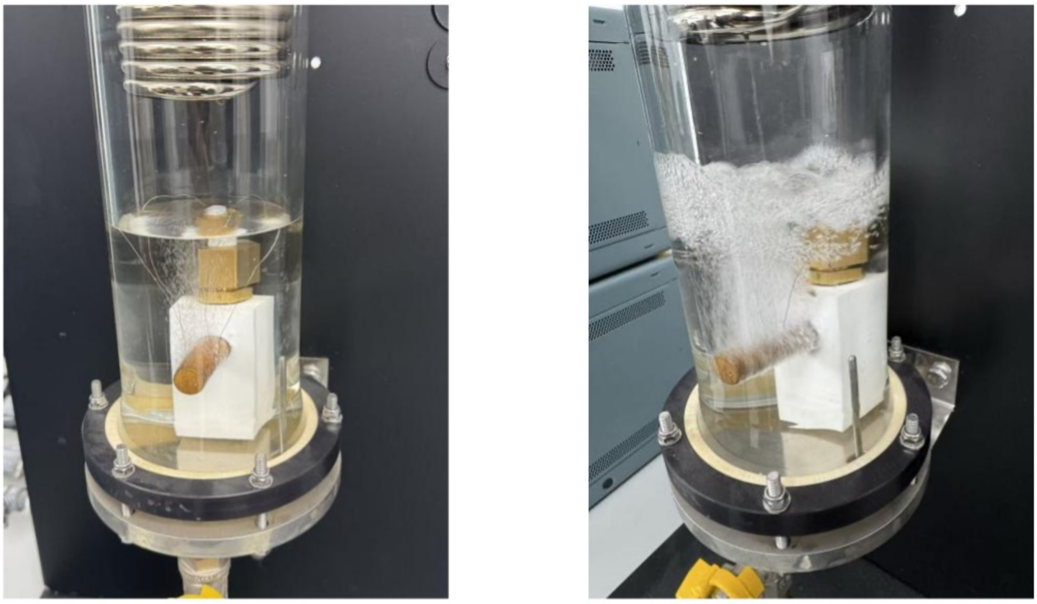
- **Heating Rod**: Main heating element.
- **Refrigerant SES36**: Working fluid.
- **Liquid Pool**:Insulated,transparent vessel

3 Experimental Procedure and Raw Data

The apparatus was pre-assembled and filled with refrigerant SES36 to the appropriate level.Set the initial heater power to 0 W by using the controller.

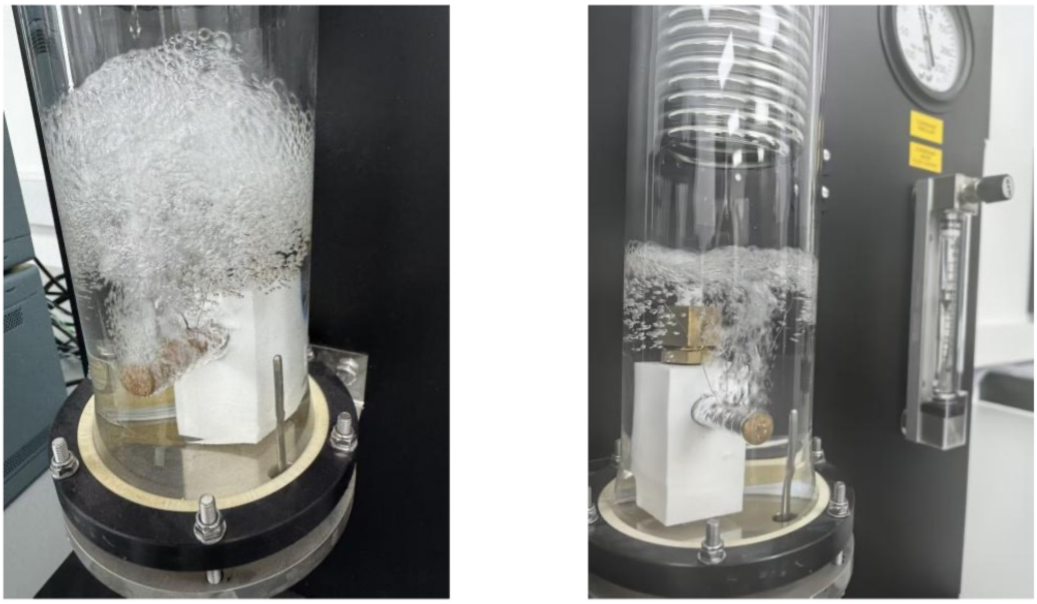
Increasing the power by rotate the controller by 5W/10W at once and record the value of the power meter, Liquid Temperature sensor and the Heater Surface Temperature Sensor until they became stable.

Repeated upper procedure until the power reach 300W and find that the heat rod was overheating for the reason that it went to film boiling, the rod was surrounded by the vapor so that the heat could not be released in time, the rod temperature ascending very fast and the whole system stop working in order to protect the devices.All recorded data was compiled into a table for analysis.



(a) (b)

Figure 2: Representing Pool Boiling Regimes: (a) Natural Convection, (b) Nucleate Boiling (Low Heat Flux)



(c) (d)

Figure 2: Representing Pool Boiling Regimes (continued): (c) Nucleate Boiling (High Heat Flux), (d) Film Boiling

Raw Data Table

Table 1: Experimental Pool Boiling Data

Power (W)	$T_{\textbf{heater}}$ ($^{\circ}C$)	$T_{\textbf{liquid}}$ ($^{\circ}C$)	$T_h - T_l$ ($^{\circ}C$)
10	47.5	40.5	7.0
20	49.7	42.0	7.7
30	51.3	43.1	8.2
40	52.5	44.3	8.2
45	53.2	45.2	8.0
50	53.9	46.2	7.7
55	54.4	46.9	7.5
60	54.7	47.1	7.6
65	55.0	47.3	7.7
70	55.2	47.5	7.7
75	55.4	47.7	7.7
80	55.6	47.8	7.8
85	55.7	47.9	7.8
90	55.9	48.0	7.9
95	56.0	48.0	8.0
100	56.1	48.2	7.9
105	56.2	48.2	8.0
110	56.3	48.4	7.9
115	56.4	48.4	8.0
120	56.5	48.5	8.0
130	56.8	48.6	8.2
140	57.1	48.9	8.2

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Table 1: Experimental Pool Boiling Data (Continued)

Power (W)	$T_{\textbf{heater}}$ $(^{\circ}C)$	$T_{\textbf{liquid}}$ $(^{\circ}C)$	$T_h - T_l$ $(^{\circ}C)$
150	57.4	49.1	8.3
160	57.7	49.2	8.5
170	58.1	49.4	8.7
180	58.4	49.6	8.8
190	58.7	49.8	8.9
200	59.1	49.9	9.2
210	59.4	50.1	9.3
220	59.9	50.2	9.7
230	61.2	50.5	10.7
240	61.6	50.6	11.0
250	62.6	50.7	11.9
260	63.1	50.9	12.2
270	64.2	51.1	13.1
280	65.9	51.2	14.7
290	67.1	51.4	15.7
300	69.3	51.6	17.7

4 Pool Boiling Curve and Comments

The experimental pool boiling curve (Figure 3) illustrates the relationship between the power input and the temperature difference ($\Delta T = T_{heater} - T_{liquid}$)

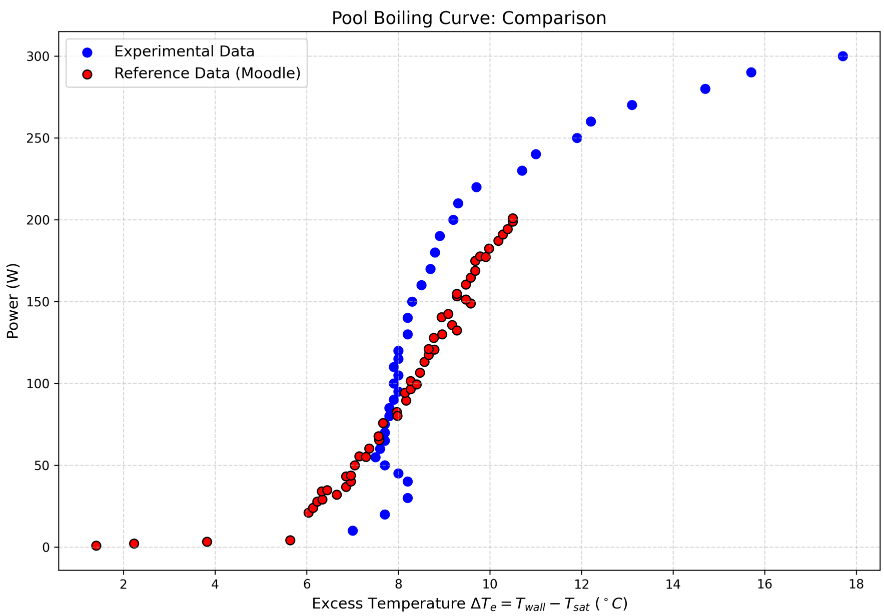

Figure 3: Boiling Curve

4.1 Trends

As observed in the plot, the heating power increases from 10 W to 300 W, while the temperature difference only increases from approximately 7.6°C to 17.9°C. The slope of the curve is relatively steep, indicating a high heat transfer coefficient. This trend is consistent with the characteristics of the Nucleate Boiling Regime. In this regime, the formation and detachment of bubbles from the heater surface significantly enhance the heat transfer rate compared to natural convection, allowing for a large increase in heat flux with a relatively small increase in surface superheat."

4.2 Comparison with Reference Data

Comparing the experimental data with the reference dataset, our measured curve lies slightly to the left of the reference curve. This indicates a higher heat transfer efficiency in our setup.

4.3 Comparison with Expectation

The observed trend is consistent with the standard pool boiling curve. The data points clearly fall within the nucleate boiling region."

5 Conclusion

This experiment successfully demonstrated the primary characteristics of a pool boiling system. The collected data allowed for the identification of the natural convection heat transfer regime and captured a clear indication of the Critical Heat Flux (CHF) condition. The significant temperature spike at 300 W serves as a practical demonstration of the dangerous temperature excursion that can occur upon CHF exceedance in heating elements. While the overall data trend supports fundamental boiling theory, the observed deviations from expected reference curves highlight the sensitivity of boiling phenomena to experimental conditions. To improve accuracy, future work could involve using a heater with a known surface finish, implementing more precise temperature control for the bulk fluid, and taking data points with smaller power increments near the anticipated CHF