Toronto Metropolitan University

Faculty of Engineering and Architectural Science

Department of Mechanical, Industrial, and Mechatronics Engineering

Course Number	**MEC511**
Course Title	**Thermodynamics and Fluids**
Semester/Year	**Spring 2025**
Instructor	**Prof. B. Gheynani**

Lab Report No.	3

Report Title	**Steam Pressure/Temperature Relationship**

Group	Sec02-Group D
Submission Date	June 11, 2025
Due Date	Due on June 11, 2025 11:59 PM

Name	Student ID	Signature*
Hamza Malik	12545	Hamza Malik
Sean Motilall	33028	Sean Motilall
Fatema Mirza	39435	Fatema Mirza
Muzamil Mujahid	52441	Muzamil Mujahid
Saif Nasir	30476	Saifullah Nasir

(Note: remove the first 4 digits from your student ID)

**By signing above you attest that you have contributed to this submission and confirm that all work you have contributed to this submission is your own work. Any suspicion of copying or plagiarism in this work will result in an investigation of Academic Misconduct and may result in a "0" on the work, an "F" in the course, or possibly more severe penalties, as well as a Disciplinary Notice on your academic record under the Student Code of Academic Conduct, which can be found online at: http://www.ryerson.ca/senate/policies/pol60.pdf.*

Table of Contents

ii. Summary

The purpose of this experiment was to examine the relationship between the pressure and temperature of water and steam under constant volume conditions using the WL204 Marcet Boiler. By measuring both the temperature and pressure within the closed boiler system, the experiment explored how pressure and temperature interact as water transitions between liquid and vapor phases. To evaluate the accuracy of the experimental data, the recorded temperatures were compared with standard tabular (saturation) temperature values at corresponding absolute pressures. The gauge pressure readings were converted to absolute pressure, and the percent error between experimental and tabular temperatures was calculated. The percent error ranged from a minimum of 0.381% at higher pressures to a maximum of 4.937% at lower pressures, with an average percent difference of 1.875%. These small discrepancies indicate strong agreement with theoretical values and confirm the expected thermodynamic relationship between pressure and temperature in saturated steam. Therefore, the results validate the effectiveness of the experimental setup and support the established phase-change behavior of water under constant volume conditions.

1. Introduction

This experiment investigates the relationship between steam pressure and temperature of the Marcet boiler while maintaining a constant volume.

Equation 1: $$p_{abs} = p_{rel} + p_{atm}$$

This equation calculates the absolute pressure (p_{abs}), by adding the relative pressure (p_{rel}), and the atmospheric pressure (p_{atm}), which is assumed to be a constant value of 101.3 kPa.

Equation 2: $$r = \frac{p_{abs} - p_1}{p_2 - p_1}$$

The pressure ratio, r, is determined using the formula, showing the relationship between the absolute pressure (p_{abs}), and the initial pressures, p_1, and p_2.

Equation 3: $$T^* = (1 - r)T_1 + (r)T_2$$

This equation calculates the interpolated temperature (T*), in degrees Celsius. It uses two reference temperatures, T_1 and T_2, adjusted by the pressure ratio (r), to approximate temperature at intermediate pressure values.

Equation 4: $$\%\, Error = \frac{100\,(T - T^*)}{T^*}$$

This formula computes the percent error of the interpolated temperature (T*), relative to the actual recorded temperature (T), indicating the accuracy of the interpolation.

2. Apparatus

- WL 204 - Marcet boiler
    - Drain Valve
    - Heater
    - Overflow
    - Temperature sensor
    - Safety Valve
    - Filer opening
    - Boiler with insulating jacket
    - Manometer
    - Master switch
    - Heater switch
    - Temperature gauge

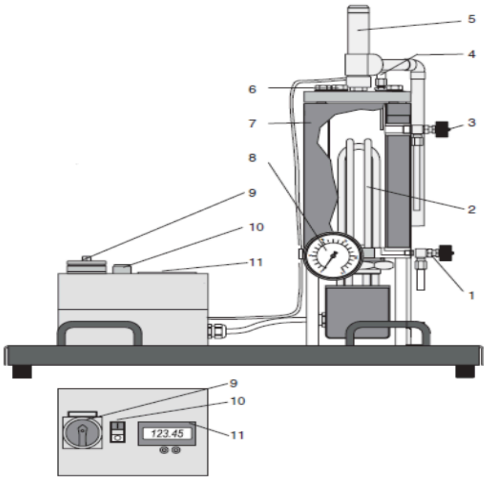

Figure 1: WL 204 general view

3. Procedure

1. The barometric pressure was measured and corrected for local conditions such as temperature and ambient pressure.
2. The unit was switched on at the master switch.
3. The heater was switched on at the master switch and the boiler began to heat up.
4. The boiler was heated up to 100°C and the water was cooked for approximately 1 minute so that the steam passed through the open valve.
5. The boiler pressure and temperature values were logged in increments of 0.5 bar. The recorded data was compared with the values from the manual.
6. After the experiment was completed, the switch at the master switch of the unit was turned off and the int was disconnected from the main power, leaving the boiler to cool down.

4. Results and Calculations

Table 1: Recordings of the experimental gauge pressure, absolute pressure, temperature, interpolated reference temperature from tabulated values in **Appendix A**, and percent error. Sample calculations can be found in **Appendix B** and **Appendix C**.

Gauge Pressure (P_{gauge}) [bar]	**Absolute Pressure (P_{abs}) [bar]**	**Experimental Temperature (T) [°C]**	**Reference Temperature (T*) [°C]**	**%E**
0.5	1.5	105.9	111.4	4.937
1	2	115.1	120.2	4.243
1.5	2.5	123.1	127.4	3.375
2	3	129.5	133.6	3.069
2.5	3.5	134.9	138.9	2.880
3	4	139.6	143.6	2.786
4	5	148.6	151.9	2.172
5	6	156.0	158.9	1.825
6	7	162.3	165	1.636
7	8	168.3	170.4	1.232
8	9	173.4	175.4	1.140
9	10	177.9	179.9	1.112
10	11	182.9	183.6	0.381
11	12	186.3	187.3	0.534
12	13	190.1	190.9	0.419
13	14	193.7	194.6	0.462
14	15	196.6	198.3	0.857
15	16	200.0	201.4	0.695

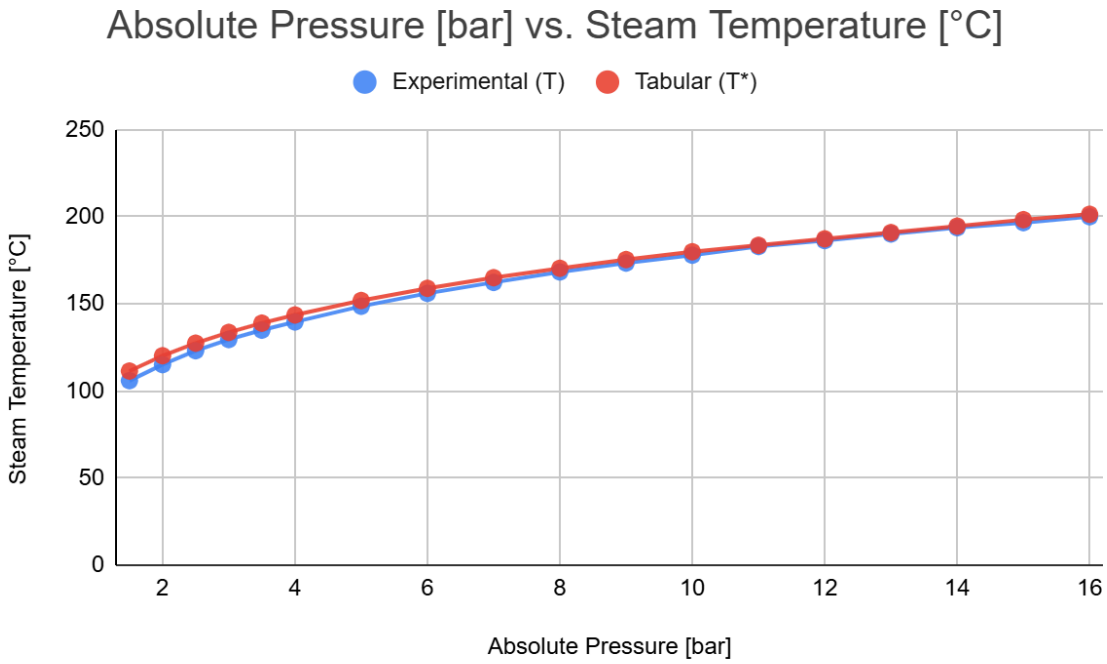

Figure 2: Absolute pressure vs. experimental and tabular steam temperature.

5. Discussion

As shown in **Figure 2**, the comparison of the experimental and tabular temperature values at incremental absolute pressure values indicates minimal difference and proves the success of this experiment. From the calculated percent errors in **Table 1**, the greatest difference was approximately 4.937% at the lowest absolute pressure, while the smallest difference was approximately 0.381% at the larger absolute pressure. With the range of percent errors, the average difference was determined to be 1.875%.

The plot in **Figure 2** and the low average percent difference illustrate minimal discrepancies between the experimental and tabular temperature values. These discrepancies can be attributed to a variety of factors during the experiment. As no experimental system can be completely insulated, the heated water in the WL 204 boiler does experience minor heat/vapour loss, which affects the pressure and temperature of the vessel. Furthermore, the data collection process also introduces sources of error, such as the timing for deaerating the boiler and reading the pressure increments from the manometer.

6. Conclusion

The purpose of this experiment was to investigate the pressure-temperature relationship for steam undergoing a constant volume process. Using a WL 204 steam boiler, the steam temperature at incremental pressure values was collected. Converting the gauge pressure values to absolute pressure, the experimental pressure-temperature relationship was achieved. To quantify the accuracy of this relationship, the experimental temperature values were compared to tabular values from **Appendix A**. As shown by **Table 1** and **Figure 2**, the experimental and tabular temperature values were closely aligned, with an average difference of approximately 1.875%. Despite the minor discrepancies, the experiment successfully explored the pressure-temperature relationship of steam contained within a constant volume.

7. References

[1] M. J. Moran, H. N. Shapiro, D. D. Boettner, and M. B. Bailey, Fundamentals of Engineering Thermodynamics, 9th ed. Hoboken, N.J.: Wiley, 2018.

8. Appendix

TABLE A-3 Properties of Saturated Water (Liquid–Vapor): Pressure Table

Pressure Conversions: 1 bar = 0.1 MPa = 10^2 kPa		Specific Volume m^3/kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy kJ/kg · K		
Press. bar	Temp. °C	Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Sat. Liquid u_f	Sat. Vapor u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Sat. Vapor s_g	Press. bar
0.04	28.96	1.0040	34.800	121.45	2415.2	121.46	2432.9	2554.4	0.4226	8.4746	0.04
0.06	36.16	1.0064	23.739	151.53	2425.0	151.53	2415.9	2567.4	0.5210	8.3304	0.06
0.08	41.51	1.0084	18.103	173.87	2432.2	173.88	2403.1	2577.0	0.5926	8.2287	0.08
0.10	45.81	1.0102	14.674	191.82	2437.9	191.83	2392.8	2584.7	0.6493	8.1502	0.10
0.20	60.06	1.0172	7.649	251.38	2456.7	251.40	2358.3	2609.7	0.8320	7.9085	0.20
0.30	69.10	1.0223	5.229	289.20	2468.4	289.23	2336.1	2625.3	0.9439	7.7686	0.30
0.40	75.87	1.0265	3.993	317.53	2477.0	317.58	2319.2	2636.8	1.0259	7.6700	0.40
0.50	81.33	1.0300	3.240	340.44	2483.9	340.49	2305.4	2645.9	1.0910	7.5939	0.50
0.60	85.94	1.0331	2.732	359.79	2489.6	359.86	2293.6	2653.5	1.1453	7.5320	0.60
0.70	89.95	1.0360	2.365	376.63	2494.5	376.70	2283.3	2660.0	1.1919	7.4797	0.70
0.80	93.50	1.0380	2.087	391.58	2498.8	391.66	2274.1	2665.8	1.2329	7.4346	0.80
0.90	96.71	1.0410	1.869	405.06	2502.6	405.15	2265.7	2670.9	1.2695	7.3949	0.90
1.00	99.63	1.0432	1.694	417.36	2506.1	417.46	2258.0	2675.5	1.3026	7.3594	1.00
1.50	111.4	1.0528	1.159	466.94	2519.7	467.11	2226.5	2693.6	1.4336	7.2233	1.50
2.00	120.2	1.0605	0.8857	504.49	2529.5	504.70	2201.9	2706.7	1.5301	7.1271	2.00
2.50	127.4	1.0672	0.7187	535.10	2537.2	535.37	2181.5	2716.9	1.6072	7.0527	2.50
3.00	133.6	1.0732	0.6058	561.15	2543.6	561.47	2163.8	2725.3	1.6718	6.9919	3.00
3.50	138.9	1.0786	0.5243	583.95	2546.9	584.33	2148.1	2732.4	1.7275	6.9405	3.50
4.00	143.6	1.0836	0.4625	604.31	2553.6	604.74	2133.8	2738.6	1.7766	6.8959	4.00
4.50	147.9	1.0882	0.4140	622.25	2557.6	623.25	2120.7	2743.9	1.8207	6.8565	4.50
5.00	151.9	1.0926	0.3749	639.68	2561.2	640.23	2108.5	2748.7	1.8607	6.8212	5.00
6.00	158.9	1.1006	0.3157	669.90	2567.4	670.56	2086.3	2756.8	1.9312	6.7600	6.00
7.00	165.0	1.1080	0.2729	696.44	2572.5	697.22	2066.3	2763.5	1.9922	6.7080	7.00
8.00	170.4	1.1148	0.2404	720.22	2576.8	721.11	2048.0	2769.1	2.0462	6.6628	8.00
9.00	175.4	1.1212	0.2150	741.83	2580.5	742.83	2031.1	2773.9	2.0946	6.6226	9.00
10.0	179.9	1.1273	0.1944	761.68	2583.6	762.81	2015.3	2778.1	2.1387	6.5863	10.0
15.0	198.3	1.1539	0.1318	843.16	2594.5	844.84	1947.3	2792.2	2.3150	6.4448	15.0
20.0	212.4	1.1767	0.09963	906.44	2600.3	908.79	1890.7	2799.5	2.4474	6.3409	20.0
25.0	224.0	1.1973	0.07998	959.11	2603.1	962.11	1841.0	2803.1	2.5547	6.2575	25.0
30.0	233.9	1.2165	0.06668	1004.8	2604.1	1008.4	1795.7	2804.2	2.6457	6.1869	30.0
35.0	242.6	1.2347	0.05707	1045.4	2603.7	1049.8	1753.7	2803.4	2.7253	6.1253	35.0
40.0	250.4	1.2522	0.04978	1082.3	2602.3	1087.3	1714.1	2801.4	2.7964	6.0701	40.0
45.0	257.5	1.2692	0.04406	1116.2	2600.1	1121.9	1676.4	2798.3	2.8610	6.0199	45.0
50.0	264.0	1.2859	0.03944	1147.8	2597.1	1154.2	1640.1	2794.3	2.9202	5.9734	50.0
60.0	275.6	1.3187	0.03244	1205.4	2589.7	1213.4	1571.0	2784.3	3.0267	5.8892	60.0
70.0	285.9	1.3513	0.02737	1257.6	2580.5	1267.0	1505.1	2772.1	3.1211	5.8133	70.0
80.0	295.1	1.3842	0.02352	1305.6	2569.8	1316.6	1441.3	2758.0	3.2068	5.7432	80.0
90.0	303.4	1.4178	0.02048	1350.5	2557.8	1363.3	1378.9	2742.1	3.2858	5.6772	90.0
100.	311.1	1.4524	0.01803	1393.0	2544.4	1407.6	1317.1	2724.7	3.3596	5.6141	100.
110.	318.2	1.4886	0.01599	1433.7	2529.8	1450.1	1255.5	2705.6	3.4295	5.5527	110.

v_f = (table value)/1000

TABLE A-3 Properties of Saturated Water (Liquid–Vapor): Pressure Table (*Continued*)

Pressure Conversions: 1 bar = 0.1 MPa = 10^2 kPa		Specific Volume m^3/kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy kJ/kg · K		
Press. bar	Temp. °C	Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Sat. Liquid u_f	Sat. Vapor u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Sat. Vapor s_g	Press. bar
120.	324.8	1.5267	0.01426	1473.0	2513.7	1491.3	1193.6	2684.9	3.4962	5.4924	120.
130.	330.9	1.5671	0.01278	1511.1	2496.1	1531.5	1130.7	2662.2	3.5606	5.4323	130.
140.	336.8	1.6107	0.01149	1548.6	2476.8	1571.1	1066.5	2637.6	3.6232	5.3717	140.
150.	342.2	1.6581	0.01034	1585.6	2455.5	1610.5	1000.0	2610.5	3.6848	5.3098	150.
160.	347.4	1.7107	0.009306	1622.7	2431.7	1650.1	930.6	2580.6	3.7461	5.2455	160.
170.	352.4	1.7702	0.008364	1660.2	2405.0	1690.3	856.9	2547.2	3.8079	5.1777	170.
180.	357.1	1.8397	0.007489	1698.9	2374.3	1732.0	777.1	2509.1	3.8715	5.1044	180.
190.	361.5	1.9243	0.006657	1739.9	2338.1	1776.5	688.0	2464.5	3.9388	5.0228	190.
200.	365.8	2.036	0.005834	1785.6	2293.0	1826.3	583.4	2409.7	4.0139	4.9269	200.
220.9	374.1	3.155	0.003155	2029.6	2029.6	2099.3	0	2099.3	4.4298	4.4298	220.9

v_f = (table value)/1000

Appendix A: Properties of saturated water with respect to absolute pressure [1].

$$r = \frac{p_{abs} - p_1}{p_2 - p_1} = \frac{11-10}{15-10} = 0.20$$

$$T^* = (1 - r)T_1 + r \cdot T_2 = (1 - 0.20)(179.9) + (0.20)(198.3) = 183.6\ °C$$

Appendix B: Sample linear interpolation calculations to find reference temperature (T*) [°C] based on absolute pressure (P_{abs}) [bar]

$$E\% = 100 \times \frac{(T - T^*)}{T^*} = 100 \times \frac{(182.9 - 183.6)}{183.6} = 0.38\%$$

Appendix C: Sample percent error calculation