# Energy balance lab report

Hasha Dar

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## Contents

# 1 Lab data

## 1.1 1 bar

- $T_0 = 25$ degrees
- $T_1 = 23$ degrees
- $P_0 = 1$ bar
- $P_1 = 0.05$ bar
- $P_2 = 1$ bar
- $V_{in} = 285 \text{ L min}^{-1}$
- $N = 1430$ N
- $F = 1.5$ kg
- $\dot{W}_{el} = 1150$ W

### 1.1.1 $T_2$ readings

| Time (min) | $T_2$ (degrees) |
|---|---|
| 0 | 95 |
| 1 | 98 |
| 2 | 101 |
| 3 | 104 |
| 4 | 106 |
| 5 | 108 |
| 6 | 110 |
| 7 | 112 |
| 8 | 114 |
| 9 | 116 |
| 10 | 118 |
| 11 | 119 |
| 12 | 121 |
| 13 | 122 |
| 14 | 124 |
| 15 | 125 |
| 16 | 127 |
| 17 | 128 |
| 18 | 130 |
| 19 | 131 |
| 20 | 131 |

Table 1: $T_2$ readings from apparatus with 1 bar compressor

## 1.2 0.6 bar

- $T_0 = 25$ degrees
- $T_1 = 24$ degrees
- $P_0 = 1$ bar
- $P_1 = 0.06$ bar
- $P_2 = 1$ bar
- $V_{in} = 310\ \mathrm{L\,min^{-1}}$
- $N = 1445$ N
- $F = 1.5$ kg
- $\dot{W}_{el} = 1000$ watt

### 1.2.1 $T_2$ readings

| Time (min) | $T_2$ (degrees) |
|---|---|
| 0 | 63 |
| 1 | 68 |
| 2 | 71 |
| 3 | 74 |
| 4 | 77 |
| 5 | 79 |
| 6 | 81 |
| 7 | 84 |
| 8 | 86 |
| 9 | 88 |
| 10 | 89 |
| 11 | 91 |
| 12 | 92 |
| 13 | 94 |
| 14 | 95 |
| 15 | 97 |
| 16 | 98 |
| 17 | 99 |
| 18 | 101 |
| 19 | 102 |
| 20 | 103 |

Table 2: $T_2$ readings from apparatus with 0.6 bar compressor

## 1.3 0.3 bar

- $T_0 = 25$ degrees
- $T_1 = 25$ degrees
- $P_0 = 1$ bar
- $P_1 = 0.08$ bar
- $P_2 = 1$ bar
- $V_{in} = 320\ \mathrm{L\,min^{-1}}$
- $N = 1459$ N
- $F = 1.5$ kg
- $\dot{W}_{el} = 850$ watt

### 1.3.1 $T_2$ readings

| Time (min) | $T_2$ (degrees) |
|---|---|
| 0 | 52 |
| 1 | 55 |
| 2 | 58 |
| 3 | 60 |
| 4 | 62 |
| 5 | 63 |
| 6 | 65 |
| 7 | 67 |
| 8 | 68 |
| 9 | 69 |
| 10 | 70 |
| 11 | 71 |
| 12 | 72 |
| 13 | 73 |
| 14 | 74 |
| 15 | 75 |
| 16 | 76 |
| 17 | 76 |
| 18 | 77 |
| 19 | 78 |
| 20 | 78 |

Table 3: $T_2$ readings from apparatus with 0.3 bar compressor

# 2 Experiment 1 calculations

All the calculations completed below were done with data from the 1 bar experiment.

## 2.1 Volumetric flow rate

The formula for the volumetric flow rate is:

$$\dot{V} = \frac{V_i n}{60 \times 10^3} \text{ m}^3\,\text{s}^{-1} \tag{1}$$

Thus, our volumetric flow rate (using equation (1)) is:

$$\dot{V} = \frac{285}{60 \times 10^3} = \frac{19}{4000} = 4.75 \times 10^{-3} \text{ m}^3\,\text{s}^{-1} \text{ (3sf)}$$

## 2.2 Mass flow rate

The specific volume through flowmeter is given by the following equation

$$v_0 = \frac{RT_0}{P_0} \text{ (m}^3\,\text{kg}^{-1}\text{) where } R = 0.287 \text{ kJ}\,\text{kg}^{-1}\,\text{K}^{-1} \tag{2}$$

The mass flow rate is given by the following equation:

$$\dot{m} = \frac{\dot{V}}{v_0} \text{ kg}\,\text{s}^{-1} \tag{3}$$

Calculating the specific volume (2) and inputting the volume flow rate calculated previously (from equation (1)) our mass flow rate is:

$$v_0 = \frac{0.287 \cdot (25 + 273.15)}{100} = 0.856 \text{ kg}\,\text{s}^{-1} \text{ (3sf)}$$

$$\dot{m} = \frac{4.75 \times 10^{-3}}{0.856} = 5.55 \times 10^{-3} \text{ kg}\,\text{s}^{-1} \text{ (3sf)}$$

## 2.3 Energy added to air by compressor

The equation to calculate the energy added to air by compressor is:

$$\dot{H}_c = \dot{m} c_P (T_2 - T_1) \text{ (W) where } c_P \text{ is } 1005 \text{ kJ}\,\text{kg}\,\text{K}^{-1} \tag{4}$$

Inputting the variables into equation (4), we get:

$$\dot{H}_c = 5.55 \times 10^{-3} \times 1005 \times (131 - 23) = 602.296 \text{ W (3dp)}$$

### 2.4 Power out of motor

The equation for the power out of the motor is:

$$\dot{W}_m = \frac{19.62NFL\pi}{60} \text{ W} \tag{5}$$

Thus, our motor power is:

$$\dot{W}_m = \frac{19.62 \times 1430 \times 1.5 \times 0.2 \times \pi}{60} = 440.712 \text{ W (3dp)}$$

### 2.5 Heat losses in the compressor

The equation for the heat emitted from the compressor is:

$$\dot{Q}_c = \dot{W}_m - \dot{H}_c \tag{6}$$

Thus, our motor heat losses are:

$$\dot{Q}_c = 440.712 - 602.296 = -161.685 \text{ W (3dp)}$$

## 3 Experiment 1 discussion

### 3.1 Plot graph of outlet temperature against time

Importing the data into MATLAB, I plotted the data on a graph.

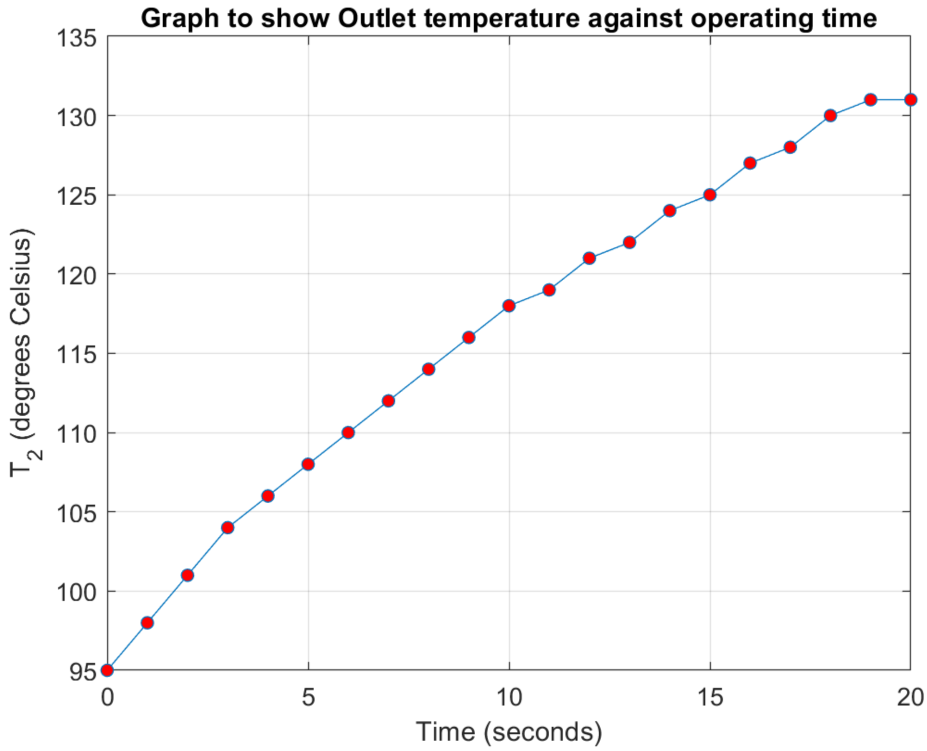


Figure 1: Plot of $T_2$ against the operating time of the apparatus

#### 3.1.1 Why does the graph have this shape?

# 4 Experiment 2 calculations

## 4.1 Specific volume of air at atmosphere and the inlet and outlet of compressor

We can calculate the specific volumes at atmosphere, before and after the compressor using equation (??), which is shown below.

$$v_0 = \frac{RT_0}{P_0}\ (\mathrm{m^3\,kg^{-1}})\ \text{where}\ R = 0.287\ \mathrm{kJ\,kg^{-1}\,K^{-1}} \qquad (??)$$

Thus, at atmosphere our specific volume of air is:

$$v_0 = \frac{0.287 \times (25 + 273.15)}{100} = 0.856 \text{ m}^3\,\text{kg}^{-1} \text{ (3sf)}$$

The temperature is constant before the compressor and $T_2$ approaches a constant value after some time, hence we can use a formula for specific volume where T is constant:

$$v_1 = v_0 \times \left(\frac{P_0}{P_0 - P_1}\right) \text{ m}^3\,\text{kg}^{-1} \tag{7}$$

Using equation (**??**), the specific volume before the compressor is:

$$v_1 = 0.856 \times \left(\frac{100}{100-5}\right) = \frac{428}{475} = 0.901 \text{ m}^3\,\text{kg}^{-1} \text{ (3sf) (1 bar)}$$

$$v_1 = 0.856 \times \left(\frac{100}{100-6}\right) = \frac{214}{235} = 0.911 \text{ m}^3\,\text{kg}^{-1} \text{ (3sf) (0.6 bar)}$$

$$v_1 = 0.856 \times \left(\frac{100}{100-8}\right) = \frac{107}{115} = 0.930 \text{ m}^3\,\text{kg}^{-1} \text{ (3sf) (0.3 bar)}$$

Using equation (**??**), the specific volume after the compressor is:

$$v_2 = 0.856 \times \left(\frac{100}{100+100}\right) = \frac{107}{115} = 0.428 \text{ m}^3\,\text{kg}^{-1} \text{ (3sf) (1, 0.6, 0.3 bar)}$$

## 4.2 Volumetric flow rate of air

Using equation (**??**) we can calculate the volumetric flow rate of air.

$$\dot{V} = \frac{V_i n}{60 \times 10^3} \text{ m}^3\,\text{s}^{-1} \tag{??}$$

$$\dot{V} = \frac{285}{60 \times 10^3} = \frac{19}{4000} = 4.75 \times 10^{-3} \text{ m}^3\,\text{s}^{-1} \text{ (3sf) (1 bar)}$$

$$\dot{V} = \frac{310}{60 \times 10^3} = \frac{31}{6000} = 5.17 \times 10^{-3} \text{ m}^3\,\text{s}^{-1} \text{ (3sf) (0.6 bar)}$$

$$\dot{V} = \frac{320}{60 \times 10^3} = \frac{2}{375} = 5.33 \times 10^{-3} \text{ m}^3\,\text{s}^{-1} \text{ (3sf) (0.3 bar)}$$

## 4.3 Mass flow rate of air

The mass flow rate of air can be calculated using equation (??)

$$\dot{m} = \frac{\dot{V}}{v_0}\ \mathrm{kg\,s^{-1}} \tag{??}$$

Calculating the specific volume and inputting the volume flow rate calculated previously (from equation (1)) our mass flow rate is:

$$v_0 = \frac{0.287 \cdot (25 + 273.15)}{100} = 0.856\ \mathrm{kg\,s^{-1}}\ \text{(3sf)}$$

$$\dot{m} = \frac{4.75 \times 10^{-3}}{0.856} = 5.55 \times 10^{-3}\ \mathrm{kg\,s^{-1}}\ \text{(3sf) (1 bar)}$$

$$\dot{m} = \frac{5.17 \times 10^{-3}}{0.856} = 6.04 \times 10^{-3}\ \mathrm{kg\,s^{-1}}\ \text{(3sf) (0.6 bar)}$$

$$\dot{m} = \frac{5.33 \times 10^{-3}}{0.856} = 6.23 \times 10^{-3}\ \mathrm{kg\,s^{-1}}\ \text{(3sf) (0.3 bar)}$$

## 4.4 Theoretical mass flow rate of air

The compressors swept volume is $V_{comp} = 2.67 \times 10^{-4}$, hence we can calculate the theoretical mass flow rate using equation (??)

$$\dot{m} = \frac{\dot{V}_{comp} \times N}{60 \times v_0}\ \mathrm{kg\,s^{-1}} \tag{??}$$

$$\dot{m} = \frac{2.67 \times 10^{-4} \times 1430}{60 \times 0.856} = 7.43 \times 10^{-3}\ \mathrm{kg\,s^{-1}}\ \text{(3sf) (1 bar)}$$

$$\dot{m} = \frac{2.67 \times 10^{-4} \times 1445}{60 \times 0.856} = 7.51 \times 10^{-3}\ \mathrm{kg\,s^{-1}}\ \text{(3sf) (0.6 bar)}$$

$$\dot{m} = \frac{2.67 \times 10^{-4} \times 1459}{60 \times 0.856} = 7.58 \times 10^{-3}\ \mathrm{kg\,s^{-1}}\ \text{(3sf) (0.3 bar)}$$

# List of Figures