LABTRONIC

User's Manual

HEAT TRANSFER

CHANGE OF STATE OF GASES

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1. Introduction

The LT-TO101 unit is designed to verify the state equation for ideal gases and to demonstrate Boyle's law and Gay-Lussac law. It illustrates the relationship between volume and pressure changes in an enclosed gas, as described by Boyle's law (experiment 1), and the relationship between pressure and temperature changes, as explained by Gay-Lussac's law (experiment 2).

In both experiments, air is used as the experimental gas, where it can be compressed or expanded inside a transparent acrylic vessel.

In one vessel, hydraulic oil acts like a piston, increasing or decreasing the volume of the enclosed gas. The experiment is conducted slowly enough to ensure isothermal conditions.

In the other chamber, air at a fixed volume is heated to test the state equation, allowing the corresponding pressure changes to be measured.

The unit includes a 7-segment display for visualizing processes and measurements, and it connects to LabTronic software for data analysis. This unit is ideal for lecturer demonstrations as well as student laboratory experiments, but it is intended exclusively for educational purposes.

2. Safety

WARNING: Reaching into the open control cabinet can cause electric shocks.

- Always disconnect the unit from the power supply before opening.
- Only qualified electricians should perform any work on the system.
- Keep the control cabinet dry at all times.

WARNING: Risk of burns from hot surfaces.

- Avoid leaving the heater on for extended periods to prevent exceeding the temperature limit.

WARNING: Risk of explosion due to overpressure.

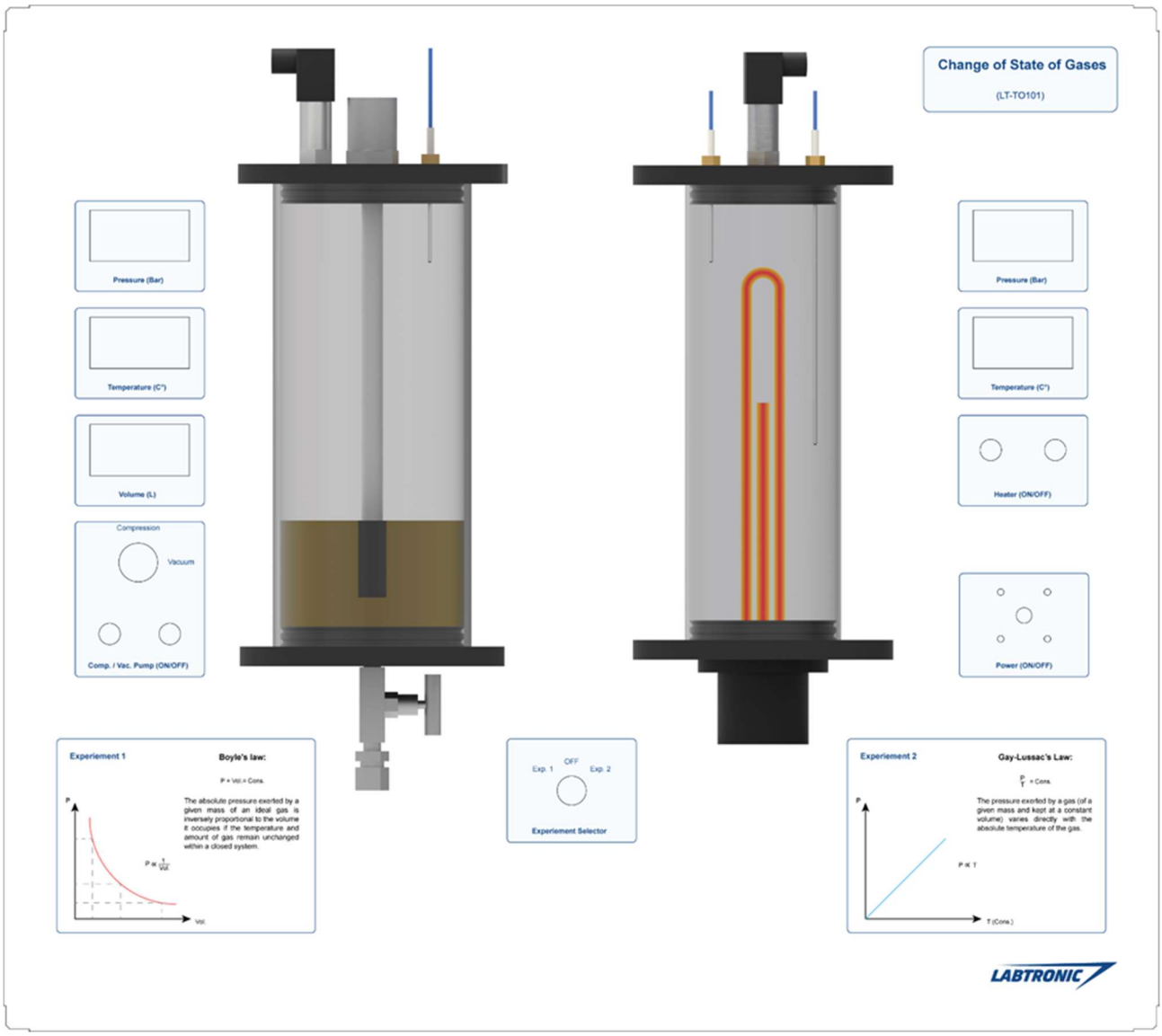
- Do not compress the air in the pressure cylinder beyond 2.5 bars.

NOTICE: Risk of hydraulic oil leakage.

- Ensure the air discharge valve at the top of the pressure cylinder is closed before compressing the air.
- Use the needle valve to control the oil flow (to slow down, speed up, or stop the flow).

NOTICE: Do not leave the unit unattended during operation.

3. Unit Description



The LT-TO101 allows two experiments to be conducted in separate vessels. The experiment is selected using a switch (i.e. experiment selector): Experiment 1 or Experiment 2. In the first vessel, hydraulic oil is pumped into a pressure cylinder via a compressor, compressing or expanding the air inside. Measurements for temperature, pressure, and compressed volume are shown on 7-segment displays. A 5/2-way valve switch allows switching between air compression and expansion, and a push-button (Compressor) activates the compressor.

In the second vessel, a fixed volume of air is heated, and the resulting pressure and temperature changes are observed. A push-button (Heater) activates a constant-power heater, which controls the temperature. The temperature is displayed on a 7-segment screen. The pressure inside both cylinders is also indicated on these displays, and the entire unit can be switched on or off via a main switch. A USB port on the right side connects the device to a PC for data recording.

Inside the control cabinet, a reservoir tank holds approximately 5 to 5.5 liters of hydraulic oil, which connects to the 5/2-way valve and compressor. A discharge valve and sealing screw are also included here for proper operation. The unit features a capacitive Level Sensor that detects the oil level by measuring changes in capacitance between oil and air, since the dielectric constants of oil and air differ greatly.

The 5/2-way valve controls whether the system compresses or vacuums air, while the needle valve regulates oil flow speed and prevents overflow or loss.

This experimental trainer device is delivered together with a Labtronic Software Program for recording measurement data on a PC via USB cable. This software provides several advantages:

- Real-time analysis and recording of the measured values of pressure, volume and temperature
- A user-friendly interface that clearly displays relationships, aiding in the understanding of the processes.
- Data tables and graphs can be printed or exported to Excel for further analysis.

4. Theory

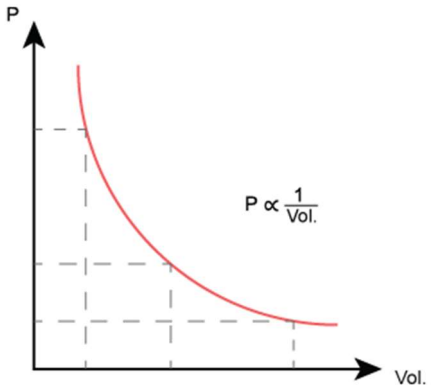
Experiment 1

When an ideal gas is compressed under fixed temperature, reducing its volume, its pressure increases. Similarly, when the volume is expanded, the pressure decreases. Boyle's law states that for a fixed amount of gas at constant temperature:

$$P \times V = const. \quad (T = const.)$$

The product of pressure and volume is constant, and the two parameters are inversely proportional to each other. The constant (P×V) represents the gas's internal energy.

This law, however, only holds if the gas amount and temperature remain unchanged. Since compression generates heat, the experiment must be performed sufficiently slowly to maintain constant temperature (isothermal conditions) and avoid erroneous results.



Strictly, Boyle's law only applies for ideal gases. Deviations from Boyle's law indicate the behavior of "real" gases, or in the case of large deviations, the term "vapour" is used. Under normal conditions, gases like air, hydrogen, and noble gases act as ideal gases, while others like chlorine and carbon dioxide behave as real gases, and gases like propane and butane act as vapors.

Experment 2

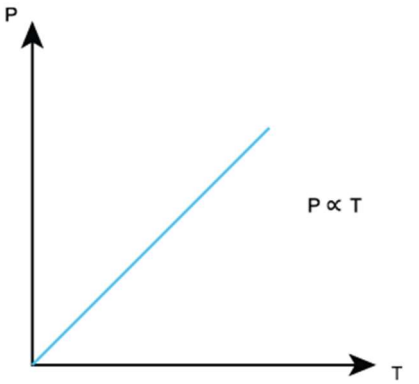
This law describes the relationship between pressure and temperature for a fixed volume of gas:

$$P/T = const. \quad (V = const.)$$

The combination of both laws leads to the general gas equation:

$$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{2} = const.$$

For a fixed amount of gas, the expression (p x V) / T always remains constant.



5. Experiments

Experiment 1

A. ISOTHERMAL COMPRESSION

In this experiment, Boyle's law is validated by compressing approximately 4 litters of gas to about 2 litters at constant temperature while measuring the change in pressure. Turn on the unit at the main switch.

1. Turn on the main switch of the unit.
2. Connect the USB cable to the PC and launch Labtronic software.
3. Set the experiment switch to Experiment 1.
4. Open the air discharge valve on top of the left cylinder.
5. Ensure the oil level in the tank is low.
6. Close the needle valve once compression is complete.
7. Close the air discharge valve on top of the left cylinder.
8. Set the 5/2-way valve switch to compression mode.
9. Activate the compressor and allow it to run until the required pressure is reached, then it will shut off automatically.
10. Open the needle valve and adjust the filling speed (a slow flow is recommended for more accurate results).
11. Start data recording via the Start button on the software.
12. Monitor the reduction in air volume and the corresponding increase in pressure, stopping around 2 to 2.5 bars.
13. Close the needle valve to halt the oil flow.
14. Stop recording the data using the Stop button on the software.
15. Slowly open the air valve until the tank returns to ambient pressure.

As shown on the 7-segment displays, the pressure increases proportionally as the volume decreases.

NOTICE: Risk of oil escaping from the top of the experiment tank.

- Ensure the air discharge valve is in the correct position.
- Always close the needle valve in the right timing to prevent overflow.

B. ISOTHERMAL EXPANSION

Alternatively, in this experiment, a fixed volume of air is expanded, and the change in pressure is recorded.

1. Turn on the unit at the main switch.
2. Connect the USB cable to the PC and open Labtronic software.
3. Set the experiment switch to Experiment 1.
4. Open the air discharge valve on top of the left cylinder.
5. Ensure the oil level in the tank is in a high level.

6. Close the needle valve till the vacuum process get finished.
7. Close the air discharge valve on top of the left cylinder.
8. Set the 5/2-way valve switch to vacuum mode.
9. Activate the compressor and let it run until the desired pressure is reached, and it automatically shuts off.
10. Slowly open the needle valve and set the flow speed. (The flow should be slow for more accurate results).
11. Start recording the data using the Start button on the software.
12. Monitor the increase in air volume and the corresponding decrease in pressure, aiming for around 0.5 to 0.3 bars.
13. Close the needle valve to stop the oil suction.
14. Stop recording the data using the Stop button on the software.
15. Open the air valve on the top on the tank slowly until ambient pressure is reached in the tank.

This experiment yields similar results to the compression test, where pressure is inversely proportional to volume. The product of P×V remains nearly constant, despite the variation in the values of ~ 5% for the values in each experiment independently.

Note that: the product of pressure and volume is a constant number, and it is a constant for a particular temperature and amount of gas.

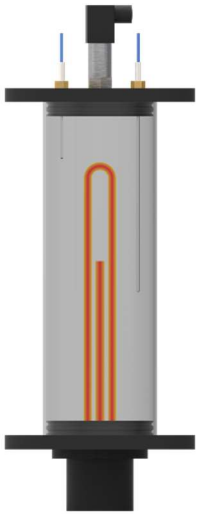
Experiment 1: Isothermal Compression / Expansion (Boyle's Law)

NO.	**Time**	**Temperature**		**Volume**	**Pressure**		**P × V**
	t [s]	T [°C]	$T[K]$	V $[L]$	P $[bar]$	P $[kPa]$	$P \times T$ $[bar \times L]$
1							
2							
3							
4							
5							
...							

Experiment 2

A. ISOCHORIC HEATING

To verify the Gay-Lussac law, in this experiment a fixed constant volume of air is heated, and the resulting pressure is recorded.



1- Turn on the unit at the main switch.
2- Connect the USB cable to the PC and open Labtronic software.
3- Set the experiment switch to Experiment 2.
4- Open the air discharge valve on top of the left cylinder.
5- Ensure that the Temperature sensor is at ambient temperature.
6- Close the air discharge valve on top of the left cylinder.
7- Turn on the heater and allow it to run until the average temperature reaches the maximum value, or manually stop it when it exceeds 60°C.
8- Start recording the data using the Start button on the software.
9- Observe the increase in temperature and the corresponding rise in pressure.
10- Stop recording the data using the Stop button on the software after reaching a significant hot temperature.
11- Slowly ppen the air valve on the top on the tank until ambient pressure is reached in the tank.

As expected, the pressure increases in direct proportion to the temperature in the cylinder. The quotient P / T remains almost constant. Despite the variation in the values of ~ 5%, this statement is still correct.

B. ISOCHORIC COOLING

As an alternative, the air is cooled while the pressure change is recorded.

1- Turn off the heater.
2- Open air discharge valve on top of the heating tank and set the vessel to ambient pressure
3- Close the air discharge valve again.
4- Start recording the data using the Start button on the software.
5- Monitor the decrease in temperature and the corresponding drop in pressure.
6- Stop recording the data using the Stop button on the software when reaching a significant cooling temperature.
7- Open the air valve on the top on the tank slowly until ambient pressure is reached in the tank.

Experiment 2: Isochoric Heating / Cooling (Gay-Lussac's Law)

NO.	**Time**	**Temperature**		**Volume**	**Pressure**		**P/T**
	t [s]	T [°C]	$T[K]$	V [L]	P [bar]	P [kPa]	P/T [kPa/K]
1							

2							
3							
4							
5							
...							

Finally, set the experiment switch to the neutral position and turn off the main switch of the trainer.

6. Appendix: Technical Specifications

Overall Specifications

Length [cm]	80
Width [cm]	60
Height [cm]	90
Weight [Kg]	50

Supply

Voltage [V]	230
Frequency [Hz]	50

Tank 1

Volume Capacity [L]	5
Pressure Range [bar] (abs.)	0.3 – 3
Working Fluid	Air and Hydraulic oil

Diaphragm Compressor

Power Output [W]	500
Pressure at Inlet [Mbar] (Abs.)	213
Pressure at Outlet [bar] (Abs.)	4

Heater

Power [W]	100
Maximum Temperature [^{o}C]	80

Heating Tank

Volume Capacity [L]	3
Pressure Range [bar] (Abs.)	0.7- 2
Working Fluid	Air