6.1 Compression of a Gas with Variable Specific Heats

6.1.1 Introduction

In this lab you will empirically describe the property relationship for a gas, and determine the work to compress the gas based on the property relationship.

Compression of a Gas

In the study of engineering systems it is important to identify and quantify interactions. One type of interaction commonly observed is a work interaction. A work interaction is energy transit across the boundary of a system, and is done by the system if it could produce the one and only effect of raising a weight. Let the system of interest be an expandable fluid enclosed within a cylinder and piston. In equilibrium, the volume of fluid V, has a pressure P which acts on the system boundary. The system boundary must also have an equal resistive force from the surroundings for the system to be in equilibrium. If the external force acting on the piston is decreased an infinitesimal amount, the piston will move outwards and the volume of gas will increase an amount dV. The piston will stop when the internal force of the gas is equal and opposite to the external force. The work done by the gas is PdV. If the system proceeds through a process in the preceding manner, the total work would be

$$W = \int PdV \tag{1}$$

In this model, the pressure is assumed uniform for the entire process, such that the gas proceeds through a series of internal equilibrium states. This process is referred to as a quasi-static process.

The work for a quasi-static process can be found if the relation between P and V are known. In polytropic processes, the relation is

$$PV^n = C \tag{2}$$

Where n is the polytropic exponent and C is a constant. For an adiabatic process of a perfect gas, n is equal to the specific heat ratio. For an isothermal process the exponent is equal to one.

Apparatus

The apparatus that you will be using to compress the gas is the spark-ignition, glass engine shown in Fig. 1. During this experiment the engine will not be supplied with fuel so there will not be any combustion inside the cylinder. Instead, the engine will be motored by an electric motor, listed as the dynamometer in Fig. 1. The air trapped in the cylinder during the suction stroke will be compressed by the piston, thereby increasing the gas pressure. The engine is equipped with a pressure transducer attached to the cylinder head that will be used to measure instantaneous cylinder gas pressure. The pressure transducer will sense this pressure change and will send a signal that will be displayed on the oscilloscope, Fig. 2. Knowing the calibration of the transducer and the amplification ratio, the pressure of the gas inside the cylinder can be determined at any given time. Also, knowing the piston diameter, stroke of the piston, and the engine speed the volume of the gas inside the cylinder can be estimated. Thus, knowing the pressure of the gas inside the cylinder and the corresponding volume, a plot of pressure versus volume can be made. The polytropic exponent and the work of compression can then be calculated.

Compression of a Gas Worksheet

1. List objectives of this experiment.

2. Confirm with your instructor that the set up i.e., the engine, pressure transducer, and the oscilloscope, is ready to run.

3. Turn on the oscilloscope and the charge amplifier. The amplifier requires that it warm up for at least twenty minutes.

4. Confirm that the charge amplifier sensitivity is set. The transducer sensitivity and the gain must be adjusted by the instructor.

5. Confirm that the oscilloscope is set to the correct gains.

6. Turn on the compressed air valve for cooling. The gage G4 should show at least 10 psi.

7. Make sure the needle valves V1 and V2 are in closed position (turning them clockwise till they stop) and the throttle valve TH is in line with the manifold, i.e., parallel to it.

8. Keep switch S2 in the OFF position and S3 in the GEN position (both the switches in the center position).

9. Switch S4 must be in the OFF position (this is the ignition switch).

10. Turn the rheostat R all the way to the right and switch S1 to HIGH.

11. Connect the two leads (with banana jacks) to the power supply, red to the positive, black to the negative. The pilot light P should be on.

12. Turn switch S2 to +. The piston is now ready to compress the gas.

13. Flip the switch S3 to start the compression. The piston will start to reciprocate and the oscilloscope will show two traces, as shown in Fig. 3. To increase the speed, turn the rheostat R slowly counterclockwise and adjust it until you get about 1000 rpm on the tachometer T.

14. Store the trace on the oscilloscope.

15. To stop the piston, flip the switch S3 to center position GEN and follow steps in descending order from step 13 to step 2.

16. Record the atmospheric pressure.

17. Construct a detailed 'cylinder gas pressure versus cylinder volume' plot from the experimental data by following the instructions below.

18. Using the oscilloscope trace plot the gas pressure at different points as shown in Fig. 3.

19. Identify point [2] on the plot. This is the beginning of the compression process. This point is not necessarily the atmospheric pressure.

20. Identify on the plot, where the gas is at atmospheric pressure.

21. Calculate the absolute pressure of the gas at point [2] and enter into the table below.

22. Divide the distance from point [2] to [3] into five equal time increments.

23. Identify points [1], [4], [5], [6], and [7] on the plot.

24. Complete the table below.

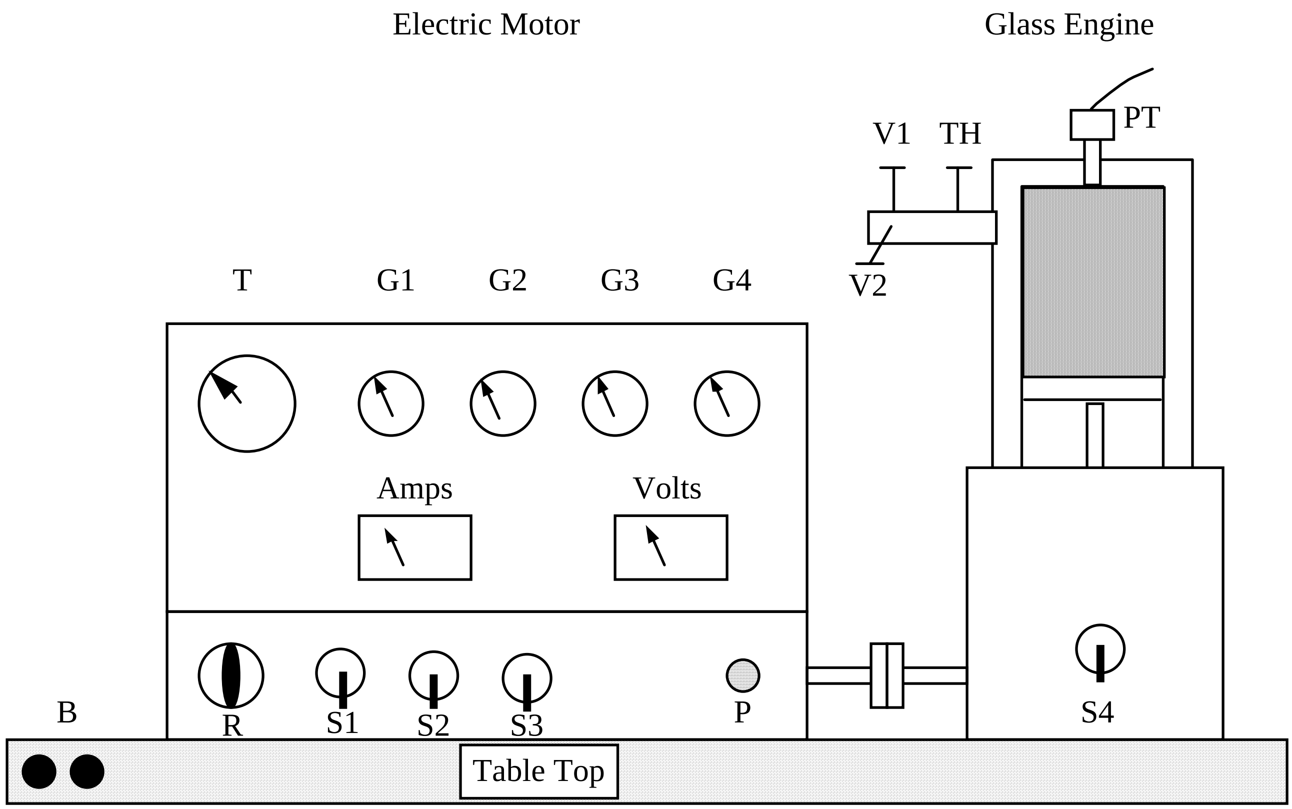
Point	Voltage [V]	Gage Pressure [psig]	Absolute Pressure [psia]	Volume [cc]
1				
2				95.16
3				27.19
4				89.57
5				74.02
6				53.04
7				33.68

25. Plot 'log P' versus 'log V'. Run a linear regression on the data to determine the polytropic exponent *n*.

26. Calculate the work required to compress the gas using Eq. 1.

    Calculations:

Discussion of Results and Conclusions



T:	Tachometer	G1:	Torque gage
G2:	manifold pressure gage	R:	rheostat
G3:	Cylinder pressure	V1:	fuel valve
G4:	Cooling air pressure gage	V2:	fuel valve
Amps: DC ammeter		TH:	throttle
Volts: DC volts	S1:		switch
S2:	switch	S3:	switch
S4:	switch	P:	pilot light
B:	Banana Jacks	PT:	pressure transducer

Figure 1: Electric Motor and Glass Engine Apparatus.

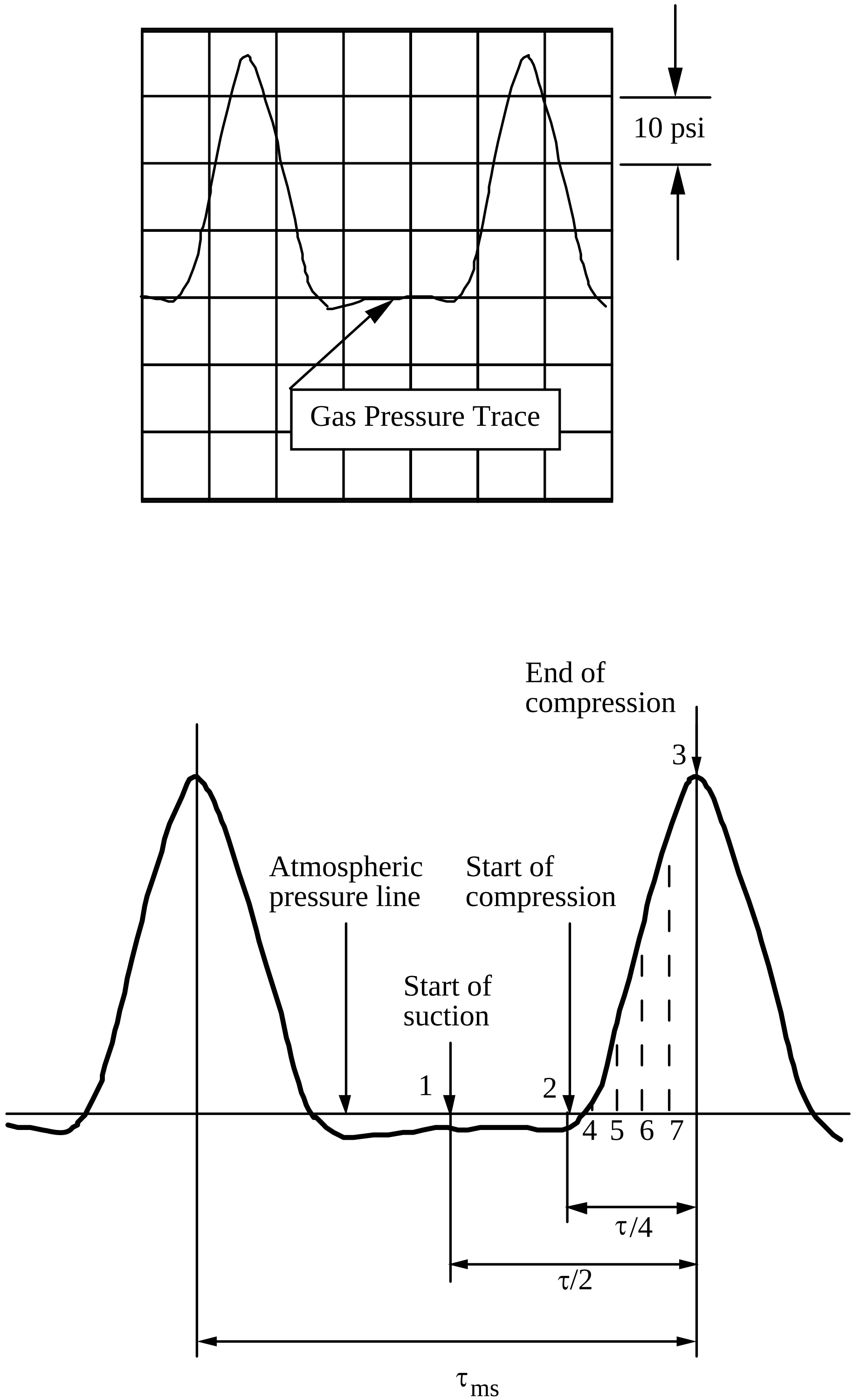


Figure 3: Oscilloscope Gas Pressure Trace for Compression Process.