This program performs a series of calculations related to gas dynamics in a blowdown process. A blowdown process is a depressurization event where gas is allowed to escape from a pressurized volume.

The program calculates mass, mass flow rate, density, pressure, and temperature of the gas over time. Let's break down these calculations step by step:

Step 1: User Input
The user inputs the initial tank pressure, Pi, outlet pressure

Step 2: Calculate Gas Properties

For the input gas chosen, the program retrieves four intrinsic properties— specific heat ratio, *k*, gas constant, *R*, and critical pressure ratio, P_{crit} , using a lookup table.

Step 3: Calculate Initial Conditions

The initial gas mass in the container is calculated using the ideal gas law:

$$m = \frac{R \times T_i}{p_i \times V}$$

where p_i is the initial tank pressure, V is the volume, and T_i is the initial temperature of the gas.

The initial density is calculated as:

$$\rho = m/V$$

If $p_o/p_i \le P_{crit}$, the flow is choked and the following formula is used to calculate mass flow rate

$$mdot = C_d A\, p_i \sqrt{\frac{k}{TR}\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Where CdA is the effective flow area of the Valve, orifice, or leak.

If $p_o/p_i > P_{crit}$, the flow is unchoked and the following formula is used to calculate mass flow rate

$$mdot = C_d A \rho \left(\frac{p_o}{p_i}\right)^{1/k} \sqrt{2RT \frac{k}{k-1} \left[1 - \left(\frac{p_o}{p_i}\right)^{\frac{k-1}{k}}\right]}$$

The initial time, t, is set to 0s and the time step, Δt is defined

Step 4: Calculate Quantities over Time

1. Update time, incremented by time step

2. Mass Update: New mass is calculated by subtracting the product of the last mass flow rate, m_i and time step from the previous mass, m_i-1.

$$m_{i+1} = m_i - mdot \cdot \Delta t$$

3. Density Update: New density is calculated using the updated mass and constant volume.

4. Pressure and Temperature Updates: Pressure and temperature are calculated for two blowdown cases - Isothermal and adiabatic.

   The difference between isothermal and adiabatic blowdown processes lies in how temperature and heat transfer are managed during the depressurization of a gas.

   In an isothermal process, the temperature of the gas remains constant throughout the blowdown event. This constant temperature is maintained by the transfer of heat between the gas and its surroundings. As the gas expands and does work on the surroundings, heat is absorbed from the surroundings to maintain the gas temperature. Isothermal processes are idealized and hard to achieve in practice since they require perfect heat exchange with the environment.

   For an isothermal process, pressure is updated based on the ideal gas law with constant temperature as follows:

$$p_1 = \rho_1 R T_0$$

   An adiabatic process is one in which no heat is exchanged with the surroundings during the blowdown. There is no heat transfer between the gas and its environment. All the changes in the gas's internal energy are due to work done by or on the gas.

   For an adiabatic process, pressure and temperature changes are calculated based on the changes in density and the properties of the gas (specific heat ratio k and gas constant R) as follows:

$$p_1 = p_0\left(\frac{\rho_1}{\rho_0}\right)^k$$

$$T_1 = T_0\left(\frac{p_1}{p_0}\right)^{\frac{k-1}{k}}$$

5. Pressure Ratio Update: The rsevior pressure is divided by the pressure at the current time time.

6. Mass Flow Rate Update: New mass flow rate is calculated using the updated pressure and density. The new pressure ratio determines which flow rate formula is used.

7. This process is iteratively repeated until the tank pressure equals the reservoir pressure. At each time step, the calculated values for mass, density, pressure, temperature, and mass flow rate are stored to their respective lists for plotting.

Example Applications:

1. Crack size for fracture analysis
2. Cold gas thruster
3. Valve force balance
4.

Backup

The pressure ratio, p_o/p_i, is calculated as the outlet pressure divided by initial tank pressure set by the user. The critical pressure ratio calculated as:

$$P_{crit} = \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$