

# Probability of Pressure Invariance on the Faces of an Enclosed Rectangular Container

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**Abstract:** *The Pressure of the air that is contained within an enclosed container is considered to be constant across all the phases. The Hypothesis that is being proposed is that since the pressure on the walls of an enclosed cylinder is directly proportional to the number of colliding particles with the surface, there can be instances where the number of colliding particles on a given surface can be significantly higher than the number of colliding with other surfaces. A Python Simulation environment has been developed which constantly monitors the number of air molecules colliding with the faces of the container. The simulation logs the same data into a CSV file. The Simulation has been created taking into account the Kinetic Diameter to accurately represent the real-world scenario. The simulation log files suggest that there are instances where the number of collisions is more than a single face.*

**Keywords:** Simulation, Python, PyGame, Kinetic Gas Theory, Pressure, Kinetic Diameter

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## 1. Introduction

Regardless of size or shape, a pressure vessel is defined as any closed vessel that can hold a pressured fluid under internal or external pressure. The cylindrical vessels to which we refer in this book are computed according to the cylinders with thin walls. Selecting the proper type of container for the function for which it is intended is the first stage in container design. The purpose of the container, the location, the type of fluid that must be stored, the temperature and operating pressure, and their capacity to hold the volume required by the process are the elements that influence the choice of type. According to their intended use, temperature, pressure, materials, and geometry, pressure vessels can be categorized. The pressure vessel can be separated into storage containers and process vessels depending on how it will be used. According to the service, the first classes are referred to as storage tanks because they are solely used for holding liquids under pressure. There are many different applications for process pressure vessels, including heat exchangers, reactors, fractionating towers, distillation towers, etc. Pressure vessels can be either cylindrical or spherical depending on their shape. The former can be either horizontal or vertical, and it occasionally has coils to raise or drop the fluid's temperature. Large volumes should be stored in spherical pressure vessels, which are frequently employed as storage tanks. This would be the most inexpensive way to store pressurized fluids because the spherical shape is the "natural" shape that bodies take when they are under internal pressure. However, compared to cylindrical containers, the cost of manufacturing such containers is significantly higher. So Making pressure vessels with a rectangular design is more economical. But the issue with a rectangular pressure vessel is the localized stress at the sharp bends because of the shape. This increase the safety concerns related to pressure vessel usage.

BSI PD6493 is one of the current guidelines in fabrication codes that aim to lessen the likelihood of failures in welded pressure vessels subjected to cyclic pressure or vibrations. Nevertheless, there have been a number of spills and pipe ruptures recently. These failures frequently involve crack initiation in the weld metal and heat-

impacted zones of the welds, which are all due to inadequate reinforcing design and subpar welding technique execution. In one instance, inadequate welding was caused by an attempt to boost safety by increasing thickness, which also raised cyclic loads because the vessel was too heavy. Thankfully, severe structural failures are uncommon. However, when a structure such as a pressure vessel, a storage tank, or a pipeline fails, the consequence which can include human injury, financial loss, and environmental harm can be severe. There are failure modes like buckling, overload, and rapid fracture that happen right away after installation. Other failure modes, such as fatigue, corrosion, creep, stress corrosion cracking, and hydrogen embrittlement, only manifest themselves after a certain amount of time in service. There are a variety of strategies that can be used to avoid failure. By making sure that the design, construction, maintenance, and inspection of the pipeline or pressure vessel are carried out in accordance with a recognized Code or Standard, the majority of failures and nearly all installation failures can be avoided. This could include specifications for post-weld heat treatment, welder and welding method qualification, and proof testing. The main strategy is to make sure the material is tough enough, to design the structure to reduce high stress, to stress-relieve thick parts, to build and check the final product using certified welders and methods, to reduce the likelihood of flaws, and then to proof test. The traditional approach of proving the absence of faults that could cause a catastrophic collapse in service for pressure vessels and pipelines is known as proof testing. Water is pumped into the vessel at a pressure above the maximum service stress; if the component survives, the service conditions will be secure. However, failures of big components during proof testing can be exceedingly expensive, and this method will not account for any crack expansion that takes place during the component's lifetime. Failures that occur in the course of use may be brought on by unanticipated or unaccounted-for cycle stresses or environmental factors that result in fatigue or corrosion-related issues. These problems are frequently addressed during the design phase. However, an Engineering Critical Assessment can occasionally be used to analyze cracking that has already happened while in use (ECA).

We will be focusing our research work on Kinetic Molecular Theory. The assumption that matter is made up of microscopic particles that are always in motion forms the foundation of the kinetic-molecular theory, which explains the states of matter. The observable characteristics and behaviors of solids, liquids, and gases are explained by this theory. However, as gases are the subject of kinetic-molecular theory, we will start our in-depth examination with them. The theory specifically pertains to the ideal gas model of a gas. An ideal gas is a hypothetical gas whose behavior exactly matches all of the kinetic-molecular theory's presumptions. Although they are not perfect in actuality, gases come extremely close to being perfect in most real-world situations. The kinetic molecular theory relies on 5 basic assumptions.

1. When compared to their size, the tiny, spherical particles that make up gases are spaced far away from one another.
2. Gas particles are constantly moving quickly and randomly.
3. Elastic collisions occur when gas particles collide with one another and with the container walls.
4. Between gas particles, there are no forces of attraction or repulsion.
5. The temperature of the gas affects the average kinetic energy of gas particles.

The above definition and assumptions allow us to model the closed container system as just a cuboidal box in which there is an air mixture. We can simulate the environment to predict the amount of collision occurring on a certain wall at any given point in time. We assume that the air mixture is made up of mainly 4 components oxygen, nitrogen, carbon dioxide, and water vapor. We created a simulation model where we monitor the number of molecules colliding with any wall of the cuboidal enclosure at any given point in time. Thus allowing us to comment on the pressure on that particular wall.

The remainder of the paper is drafted as such. Section 2 summarizes the contemporary literature research domain. Section 3 is the methodology adopted for solving the problem under consideration which is followed by section 4 which is the results and discussion. Finally section 5 of the paper concludes the research and briefly describes the future scope of the research work.

## 2. Literature Review

Vilde Braten et al.[1] researched the small-size effect on open and closed systems for ideal gas. The difference in the properties of the open and closed system is because of the reduction in the free area. A simple model has been used to study the property of the gas in an enclosed system giving meaningful insights. The chemical property of the gas also changes due to the variation in the density of the gas present in a certain volume of air. M. Rovere et al.[2] did a comparative study on the nearest-neighbor lattice gas model and the two-dimensional off-lattice Lennard-Jones system. A simulation of both models was conducted to determine whether the temperature and density estimates were correct. J. Błachut[3] has reviewed the buckling of pressure vessel components. Experimental Methods in Buckling of Thin-Walled Structures have been conducted. Under the broad heading of "buckling," practical elements of load-bearing capability are covered. In addition to bifurcation and snap-through/collapse, plastic loads and burst pressures are also taken into account. The review focuses on the axial compression and/or external pressure-induced bowing out of conical shells, cylinders, and their single and combination static stability. Shyam R. Gupta and Chetan P. Vora[4] the determination of the stress concentration factor in pressure vessels at openings, the stress analysis of various end connections, and the minimization of stress with the aid of an optimized nozzle location and angle on the shell and head are all covered in this study. The study of stress concentration in pressure vessels is gaining more attention, according to the literature. Analysis of the stress concentration at pressure vessel openings and methods to mitigate its effects are the driving forces behind this research. The ASME pressure vessel code governs pressure vessel design. The thickness and tension of fundamental components are specified by the code; it is up to the designer to choose the proper analytical assay. Durga Prasanth And Sachidananda. H. K.[5] the project's primary goal was to build a pressure vessel in accordance with ASME standards and perform thermal analysis on the pressure vessel made up of various types of materials by adjusting the shell thickness of the vessel for various ambient temperatures. Finding the ideal thickness for which the pressure vessel is safe for use in the industry requires comparing the results. The worst-case scenario also takes into account the possibility of a crack on the pressure vessel's exterior surface. Fracture mechanics is used to examining the various crack geometries in various types of materials. determining the pressure vessel's level of useability safety. Sanjay Kumar et al.[6] The storage of gases, liquids, and solid waste that is subject to both internal and exterior pressures that are different from atmospheric pressure is done in pressure vessels. The design and analysis of a rectangular pressure vessel utilizing ANSYS software are presented in the current study. The rectangular pressure vessel's finite element study was carried out by altering its length from 1000 mm to 10000 mm while maintaining constant its width, height, and thickness. Stiffeners are utilized to give the pressure vessel's wall strength and lessen the bulging effect. The stiffener count has been adjusted from 2 to 6 in step 2 in order to comprehend the impact of stiffeners on the bulging of rectangular pressure vessels. Mohamad A. et al.[7] The structural analysis and assessment of an unusual rectangular pressure vessel are the topics of this work. Equipment for drilling and collecting samples from radioactive waste kept in high-capacity waste storage tanks on the Hanford Site was to be housed in the vessel. A cover plate that could be removed from the vessel had to be constructed. The vessel has to be qualified in accordance with Section VIII of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (hereinafter referred to as the Code) because of its size and working pressure (ASME 1989). The Code was compared to the stress analysis results. A stay plate was added to the design to stiffen the vessel's long side in order to meet Code standards.

## 3. Proposed Methodology

Very few research papers have been published related to the Kinetic Molecular theory. There is no simulation available where the idea of pressure variance has been proposed although there might be a possibility of this occurring. We created a python program to simulate the volume of the enclosed cuboidal cylinder. The PyGame module was used to create the simulation. The below table shows the parameters that were used in the simulation.

**Table 1. Kinetic Diameter and Composition of air mixture**

Molecule	Kinetic Diameter (picoMeter)	Composition (%)
Oxygen (O <sub>2</sub> )	346	21
Nitrogen (N <sub>2</sub> )	364	78
Water Vapour (H <sub>2</sub> O)	265	0.5
Carbon Dioxide (CO <sub>2</sub> )	330	0.5

The simulation was done on the air mixture. The composition of the molecules was taken to be the same as that of the standard air mixture. The code made sure that the number of molecules that were spawned was of the same composition as that of the standard air mixture. The Diameter of the molecules was considered to be the kinetic diameter. The likelihood that a molecule in gas may collide with another molecule is expressed by the measurement of kinetic diameter, which is applied to atoms and molecules. It provides information on the target molecule's size. The atomic diameter which, depending on the definition used, is typically much smaller than defined in terms of the size of the atom's electron shell is not the same as the kinetic diameter. Instead, the sphere of influence's size is what can cause a scattering event. Once started the simulation would continuously run until stopped manually by the user. The simulation would keep count of the number of particles colliding with each wall. The data was recorded and logged into a CSV file at an interval of 5 min. The Python simulation used the random module to spawn the molecules randomly. The simulation, while spawning the molecules would make sure that the molecules would not spawn into each other. By setting the seed of the python random module we could recreate the simulation ensuring that the results would end up the same. The Ideal scenario would be to simulate the entire environment in a 3D simulation. But instead, we decide to use a 2D environment for ease. The results that were collected in the 2D simulation can be assumed to be the same as the results that would have been captured when the simulation was done in 3D as the number of faces would increase but apart from the number of faces there would be no parameters that would be variable.

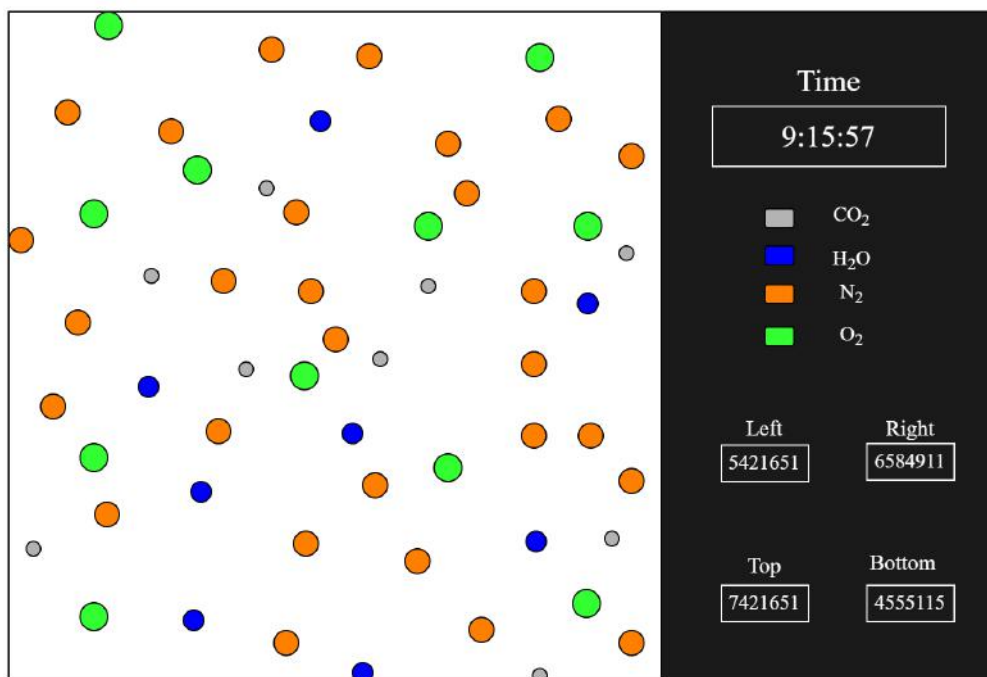


Fig 1. Screenshot of the Python Simulation

#### 4. Test Results

**Table 1. Number of molecules colliding with the wall at different intervals of time**

	Top	Bottom	Left	Right
1	1547854	1545484	1451589	1456114
2	3451546	3154879	3784915	3974214
3	4875421	4879121	4963432	4875461
4	6415151	6484151	6984115	6978411
5	7456516	7516511	7451615	7894851
6	9451510	8451111	8451187	8794521
7	17546112	11455131	12484512	17516151
8	34485152	24516186	38741514	27556114
9	47814516	42454841	58456120	41265154
10	64815141	54515164	78451121	67845122

The above table shows the number of particles that have collided with any wall at a given instant of time. The values were read from the CSV file that was created when the simulation was running. So 10 evenly spaced time instances were considered for sampling and the data.

#### 5. Conclusion

The data suggest that there are instances where the total collisions on a particular face can be significantly more than the collisions on the other faces. And as per the Kinetic molecular theory, the total pressure is directly proportional to the number of molecules colliding with a surface. So it can be concluded that there is the possibility that the pressure on a single face of a rectangular cylinder will be more than the pressure on the other face. Although the probability of this happening is very low.

##### 5.1. Future Scope

The simulation that has been conducted provides an in-depth view of the pressure variations inside an enclosed rectangular volume. We can add the gas equations to the simulation thus enabling the simulation to also consider the effects of temperature variations on the overall pressure that is built up. Designers can also use the data that is generated by the model to consider additional safety considerations if required in any design. These additional pressure variations can also be added to the traditional pressure vessel design software so that the software can compensate for the edge cases that might exist in the system. These simulations can be added to the school curriculum to help the children understand the concept of molecules and pressure inside a closed cylinder. Also, the temperature dependence of the gas can be simulated by incorporating simple changes.

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