Design and Construction of Bernoulli Blower

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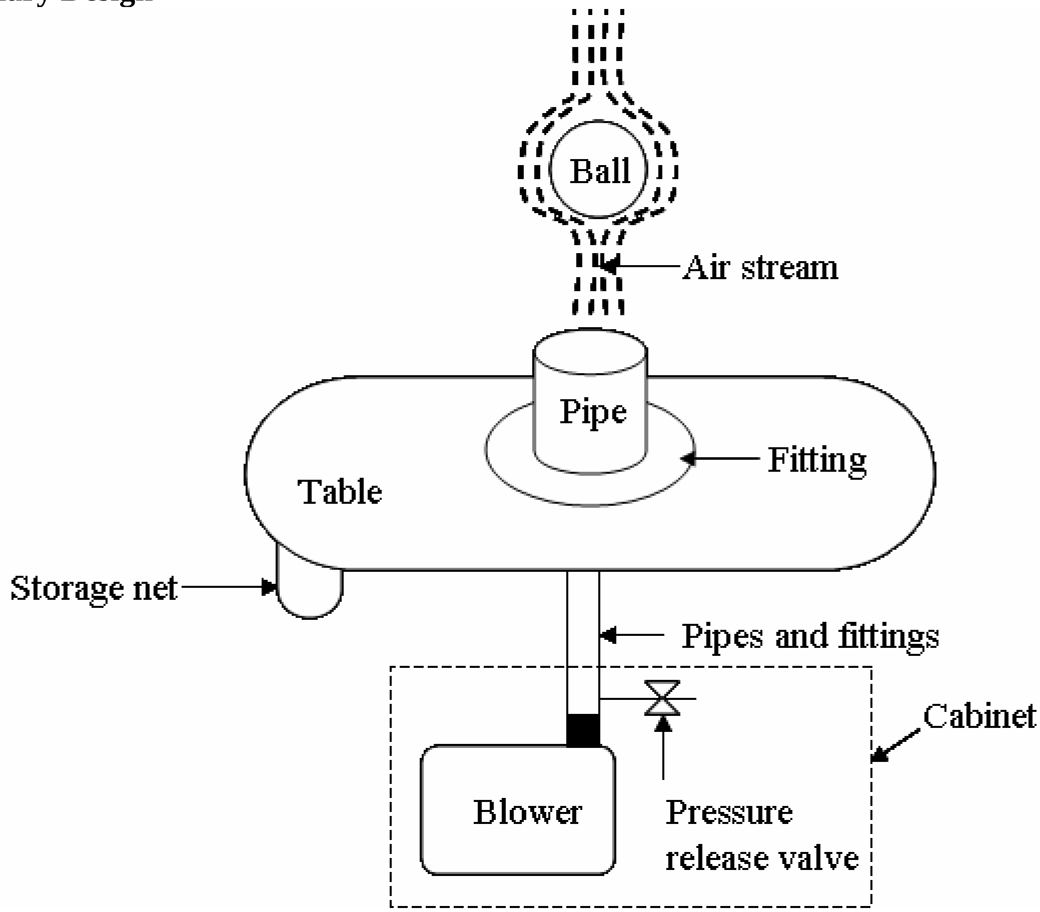
Introduction

A Bernoulli blower is an educational and interesting demonstration for a children's science museum. It comprises of a balancing ball suspended in an air stream generated by a blower. Due to the Bernoulli effects, the ball is stable to small perturbations in any direction. Therefore, when the ball is pushed down, up, or sideways, it will spring back to its equilibrium position. Hence this demonstration facilitates an implicit understanding of Bernoulli's principles while also providing entertainment.

Objective

The objective of this proposal is to illustrate the design and construction of a Bernoulli Blower by SPE Texas Tech Student Chapter. The concept behind this project is to create a fun and educational exhibit which adequately describes Bernoulli effects. The primary considerations of our design are to enhance the interactive experience, which is crucial for such an exhibit. Additionally, the design also incorporates the need for safe, noise-free, and long-term operation. The subsequent sections of this proposal outline the preliminary design, construction, and implementation of the Bernoulli blower.

Preliminary Design



Parts and Accessories

Part name	**Source**	**Specification**	**Price ($)**
Table	Ikea	Bright color and durable	15
Blower	McMaster-Carr	Single stage, High flow, Regenerative blower. Model # 9960K57	611
PVC pipes, fittings, and seals	Hardware outlets	Various in size, color, and shape	150
Pressure release valve	Stra-Val	Low pressure set for safety	150
Ball	Retail outlets	Beach balls and other light weight balls	50
Surge Protectors and power cords	Radio shack	To connect to 110 V AC source	20
Metal Plaque	Texas Tech Physical Plant	Society name and date	100
Storage nets	Retail outlets	For storing balls and pipes	10
Instruction Manual	Texas Tech Student Chapter	Provide detailed information regarding the maintenance and the operations of the Bernoulli Blower	0

Construction

1. The blower used in this set up is a regenerative blower which ensures noise-free operation. Furthermore, in order to maintain lower decibel levels, we suggest that the blower should be positioned on the floor beneath the table instead of mounting on the table (based on the discussions with Paul Orselli, Paul Orselli workshop). The typical capacity of this blower is 92 CFM, which is suggested to be adequate for this demonstration. In addition, for a first approximation, the generated air flow by the blower is able to suspend a 16 g ball with a diameter of 20 cm. Detailed calculation is shown in the appendix.
2. PVC pipes and fittings will be used to connect the outlet of the blower to the table and to ensure a uniform air flow to the outlet.
3. In order to facilitate safe operation of the Bernoulli blower, the bottom part of this exhibit which comprises of the blower and the connection pipes will be enclosed in a cabinet, which also ensures adequate air ventilation to the blower. Also, a pressure release valve will be connected to the pipe line in case the pipes are blocked accidentally.
4. Various sizes and shapes of PVC pipes will be used on the top of the table to create desired flow rates.
5. Different colorful balls will be used to demonstrate the Bernoulli effects. The color of the balls will be in contrast to that of the pipes to enhance the interactive experience. The weight and the diameter of the ball will be determined by the air stream velocity, which in turn will be determined by the diameter of the PVC pipes (see appendix for detail).
6. Storage net will be set underneath of the table to store the free pipes and balls.
7. After assembly, the operability of the Bernoulli Blower will be tested and improvisation will be performed as necessary. A detailed instruction manual will be provided.

Cost Estimates

Cost	**$**
Materials	1106
Tools	80
Freight (parts and the final Bernoulli blower)	200
Miscellaneous	100
Total	**1486**

Implementation Time Line

Activities	**Timeframe (week)**
Material Procurement	2
Finalize design	1
Construction	3
Testing and improvisation	2
Shipping	1
Total	**9**

Involvement of Texas Tech SPE Student Chapter

The Texas Tech Student Chapter of SPE currently has 30 enthusiastic student members with a strong background in engineering and science. Most of our members have prior experience in creating and presenting demonstrations either for course work or for laboratories. We will also be assisted in our endeavor by our experienced faculty members. In addition, Texas Tech has several infrastructural facilities such as workshops and physical plants, which will be valuable for completing this project. Finally, the Texas Tech Student Chapter will greatly appreciate the opportunity to contribute towards the community activities of SPE.

Acknowledgement

The members of the Texas Tech Student Chapter would like to express their gratitude to Paul Orselli of the Paul Orselli workshop for his valuable suggestions and input.

Appendix: Specification of the Ball and the Blower

The Bernoulli ball is balanced by its own weight and the drag exerted on it by the air stream:

$$Mg = F_D$$

where M is the mass of the ball, g is the acceleration of gravity, and F_D is the drag. According to the fluid mechanics [1], the drag on a spherical shaped object can be calculated using the relation,

$$F_D = \frac{1}{2} C_D A_p \rho u_0^{\ 2}$$

where C_D is the drag coefficient, A_p is the projected area of the ball, ρ is the density of the fluid, and V_0 is the velocity of the approaching stream. From mass balance, u_0 can be obtained from the capacity of the blower, and the corresponding C_D can be found in the Chemical Engineers' handbook [2]. Therefore, the specification of the ball can be estimated from these calculations.

For example, assuming D = 0.2 m (diameter of the ball), then,

$$u_0 = \frac{Capacity}{A_p} = \frac{Capacity}{\frac{\pi}{4} D^2} = \frac{92 (feet)^3 / \min}{\frac{\pi}{4} (0.2m)^2} = 3.91 m/s$$

The Reynolds number for the ball in the air flow is

$$N_{\mathrm{Re}} = \frac{D \rho u_0}{\mu} = \frac{0.2m \times 1.29 kg/m^3 \times 3.91 m/s}{1.86 \times 10^{-5} N \cdot s/m^2} = 54240$$

Corresponding to the Reynolds number, C_D = 0.53 (from reference 2)

$$F_D = \frac{1}{2} C_D A_p \rho u_0^{\ 2} = \frac{1}{2} \times 0.53 \times \frac{\pi}{4} \times (0.2m)^2 \times 1.29 kg/m^3 \times (3.91 m/s)^2 = 0.16N$$

$$M = \frac{F_D}{g} = \frac{0.16N}{9.81 m/s^2} = 16.3g$$

Therefore, a very light ball such as a beach ball or a party ball will be required and considered.

Reference

1. W. L. McCabe, J. C. Smith, and P. Harriott, *Unite Operations of Chemical Engineering*, 5th ed., McGraw-Hill, New York, 1993, P143.
2. J. H. Perry (ed.), *Chemical Engineers' Handbook*, 6th ed., McGraw-Hill, New York, 1984, P5.