The Relationship Between The Height of Vortices and The Amount of Airflow Allowed In The System

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Abstract:

Tornadoes are caused by a rotation in the air, with hot air trapped underneath cold air. This lab studies the effectiveness of these vortices as a function of how easily cold air can travel to warm air. It was orchestrated by creating a system where cold air rushed into a bed of hot air in a rotational fashion. After completing the experiment, it was found that the primary factor that affects the height of the vortex is how much rotation in the atmosphere is occurring in the system.

Introduction:

According to Harold Brooks, "More than 18,000 people died from tornadoes between 1875 and 2000" [1]. Gaining a better understanding of tornado genesis ultimately allows for a greater ability to be prepared when they occur, and also possibly prevent them from happening in the first place. Essentially, tornadoes are caused by an interaction of cold air and hot air [2]. The hot air, which is less dense, attempts to rush out above the cold air, displacing it in the process [2]. This phenomenon, combined with any slight rotation in the air creates the deadly vortex known as the tornado [2]. Such vortices can be formed over different surfaces, which create various types of twisters. Dust devils, water spouts, and tornadoes are all caused by imbalances of high and low pressure. They simply differ due to the setting in which they occur.

With fire tornadoes, the setting involves combustible material within the system. This material also interacts with the hot air in the system, causing fire within the vortex of the system. California's latest firenado had claimed six lives and destroyed thousands of structures, as reported by Cal Fire [3]. Understanding tornado genesis is integral to the prevention of a tornado's formation as well as minimizing its damage to the public. This lab specifically studies fire tornadoes so that the vortex is clearly visible, and so that the system can have an interaction between high and low pressure. It was hypothesized that a fire tornado would be formed as soon as cold air is able to interact with the hot air in the system. This vortex would most likely decrease in power in an inverse linear relationship with how easily cold air may flow inside and equilibrate with the hot air.

Objective:

The objective of this lab is to understand the relationship between the effectiveness of a vortex as it relates to the amount of air flow allowed in the system. The effectiveness of the tornado would be shown through its height, and the amount of airflow allowed will be described as how easily high-pressure areas can travel to low-pressure areas.

Materials:

- Glass cylinder vase (8.8 cm diameter and 17.78 cm height) [4]
- DREMEL Variable speed rotary tool w/ diamond cut off wheel
- Tabletop
- 91% Isopropyl alcohol [4]
- Lighter
- Candleholder [4]
- Ruler

Procedure:

1. Draw two lines on either side of the glass cylinder from the base to the top of the cylinder. These lines should be diametrically opposed to one another. Also, mark one line that follows the circumference of the cylinder slightly above its base.

2. Using the rotary tool, cut the glass cylinder along the previously drawn lines. This should be done while running water on the surface of the glass to ensure that the glass does not break, and that the rotary tool is not damaged. After this, there should be symmetrical glass semi cylinders.
3. Put the candleholder on the tabletop and pour isopropyl alcohol inside the candleholder so that it is only half-full. This is for the safety of the lab practitioner.
4. Using a lighter, light the isopropyl alcohol inside the candleholder on fire. This fire will be the medium through which the vortex will be observed.
5. Put both pieces of glass so that they are standing on either side of the flame. The semi-cylinders should be facing one another so that the flame is encased in the bottom of a glass cylinder. Make sure there are no gaps in between the two pieces of glass. Observe any possible changes to the fire.
6. Offset both pieces of glass so that there is a 0.5 cm gap in between both sides of the glass cylinder. This is to allow cold air from the surrounding atmosphere into the system. Observe any changes to the flame and record its height.
7. Repeatedly increase the gap in between the cylinders by 0.5 cm. Each time, record the height of the flame at a new increment. This will measure the effectiveness of the vortex as a function of how easily air flow can occur through the system.

Figure 1

The vortex should form once the pieces of glass allow air

Results:

When the fire was fully encased by the glass cylinder, there were no changes that occurred. However, the fire began to increase in height and rotate in a circular motion as soon as the pieces of glass were offset. The height of the fire was relatively unchanged during the first few increments of offsetting the glass.

As the gap was increased even more however, the rotation within the fire began to become less pronounced and the height of the flame began to decrease. At approximately 2.5 cm, the fire began to die out completely.

Gap between semi-cylinders	Height of fire
0.0 cm	8 cm
0.5 cm	15.0 cm
1.0 cm	15.0 cm
1.5 cm	14.5 cm
2.0 cm	9 cm
2.5 cm	0.0 cm

Analysis:

As hypothesized, a vortex was formed as soon as the surrounding cold air was allowed to interact with the hot air within the cylinder. This is most likely because the cold air has higher pressure than the hot air, therefore being pre-disposed to rush inside the cylinder in order to reduce the pressure imbalance. Since the system is cylindrical, the cold air was forced to move inside in a circular motion. What should also be noted is that the hot air within the system has lower pressure, so it traveled upwards in the atmosphere. This upwards motion combined with the rotation in the air caused by the cold air resulted in the desired vortex. It seems as though the vortex wasn't affected by the differences in the first few increments because no matter how easily the cold air rushed inside the system, the fuel sufficiently fed the fire and created the pressure imbalance necessary to form the vortex. However, the vortex lost its effectiveness when the gap between the cylinders was increased to 2 cm. At this increment, it's likely that the system was distorted to the point where the cold air no longer rushed inside the system in a circular fashion. Because of this, the vortex could not be sustained. It can be assumed that the flame completely died out at the gap of 2.5 centimeters because the atmosphere where this experiment took place was relatively cold. As time went on, the fire could not be sustained in such a cold environment, especially when the opening within the cylinder is so large.

Reference List

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