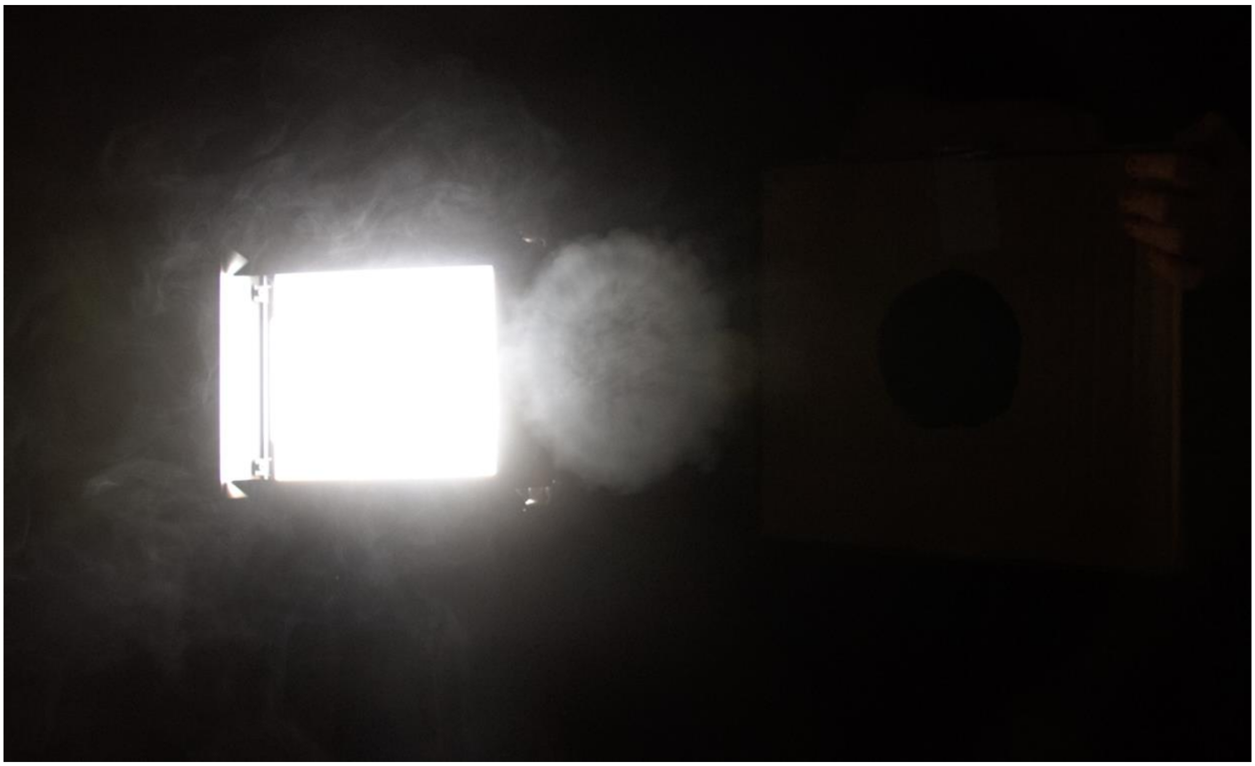
IV2 Report:

A Guide on How to Become the Lord of The Fog Ring



David Milner
MCEN5151
Oct. 10, 2022

Introduction:

For this project, I worked with Alex Kelling and Ben Carnicelli to document fog rings in a controlled flow experiment. We worked together to visualize one of the most common types of flow vortices: smoke rings. Components required for the experiment include: a theatre fog machine, a high-intensity stage-light with adjustable intensity and temperature, and a camera. Be prepared to encounter several difficulties in your attempt to document the fog rings. Notably, you will have to create an apparatus that has enough buffer to hold the fog, while still being able to emit the rings (this will be elaborated on later). Also, lighting configurations will vary significantly based on your environment, and may prove to be especially finnicky depending on your camera.

Flow Description:

For this experiment we employed a theatre fog machine, a stage light, a camera, and a simple cardboard box. The documentation method required three steps:

1. Fill the cardboard box with fog
2. Cover the box while assuring the light and camera are correctly assembled
3. Remove the cover, and hit the box to produce rings

These steps are further displayed in *Appendix A*. The cardboard box used in this experiment was about 2' x 2' x 2'. This volume was suitably large to store fog for periods up to a minute, while still producing smoke rings. We found that a period of ~1 minute of active fog from the fog machine was enough to reasonably fill the volume. After filling the box with fog, we covered the ring-shaped hole with a piece of standard printer paper while assuring the camera and light were coordinated correctly. Finally, when ready to document the flow, we removed the cover and took still images with the camera. The documentation method is further elaborated upon in *Experimental Procedure* and *Camera Settings*.

The phenomena being visualized here is a vertex flow. Unfortunately, we did not plan on calculating this, and did not make essential notes about the diameter of the vertex, or the controlled conditions that are required to calculate the character of the vertex[1].

The best way to understand the flow behavior is to calculate the Reynold's number. This dimensionless number indicates whether the flow is laminar or turbulent. Based on Tinh (2010), the Reynold's number can be calculated using the velocity of the fluid (V), the characteristic length of the flow (L), and the kinematic viscosity of the fluid (v). If the kinematic viscosity is unavailable, this variable can be replaced with the fluid density (ρ) over the dynamic viscosity (μ)[2]. These are derived below in Eq. 1.

$$Re = \frac{VL}{v} = \frac{\rho VL}{\mu} \tag{1}$$

[1] Rodi, W., & Fueyo, N. (2002). Engineering turbulence modelling and experiments 5: Proceedings of the 5th International Symposium on Engineering Turbulence modelling and experiments, Mallorca, Spain, 16-18 September 2001. Elsevier.

[2] Trinh, T. (2010). On The Critical Reynolds Number for Transition From Laminar To Turbulent Flow

For our experiment, we can make several assumptions about the density of medium, velocity, characteristic length, and dynamic viscosity. The velocity of each vertex was about 0.1 m/s, the density of the air in the room was approximately 0.7434 kg/m^3 [3], the characteristic length of the ring was about 0.02 m, and the dynamic viscosity is 1.825e-5[3].

$$Re = \frac{\rho V L}{\mu} = \frac{(0.7434)(0.1)(0.02)}{(0.00001825)} = 81.46$$

The resultant Reynold's number is 81.46 implying a laminar flow.

Experimental Procedure:

Describe the visualization technique used: Dye, smoke etc. Specify details such as exact source of materials, any relevant environmental conditions. Give dilutions if appropriate. In second part of paragraph, describe the lighting used: flash on camera, bright sunshine, flame emission, etc. Again, the minimum goal is to provide enough information for the image to be repeated.

As previously mentioned, we used a fog machine to create fog rings. The experiment was conducted in a medium-sized conference rooms, with no windows. The room was approximately 10' x 30' x 8'. In order to get the correct conditions to photograph the fog rings, we needed complete control over the lighting conditions. We were looking to have a dark background, with a bright foreground so that we could accurately illuminate the fog rings. Consequently, we shot these images with all of the lights turned off in the room, and relied solely on the theatre/stage light that we had with us.

Lighting control proved to be the largest challenge we faced in this experiment. In the photo here, the light source was pointed directly at the camera. We used a studio light, turned up to 100% light intensity. The thought process for lighting was as follows: as the fog rings eject from the box, the light shine into an area in the field of view in the foreground. This is illuminated field of view is where we activated the sensor and captured our fog rings.

Camera Settings:

I used a Canon 7D, Mark 1 for this visualization experiment. This camera is a digital single-lens reflex (DSLR) camera. This means that photos are captured through an aperture and sensor. The light emitted to the sensor is controlled by the camera's shutter speed, as well as the lens aperture. For further information concerning the camera settings, lens specs, and experimental procedure see *Table 1* below.

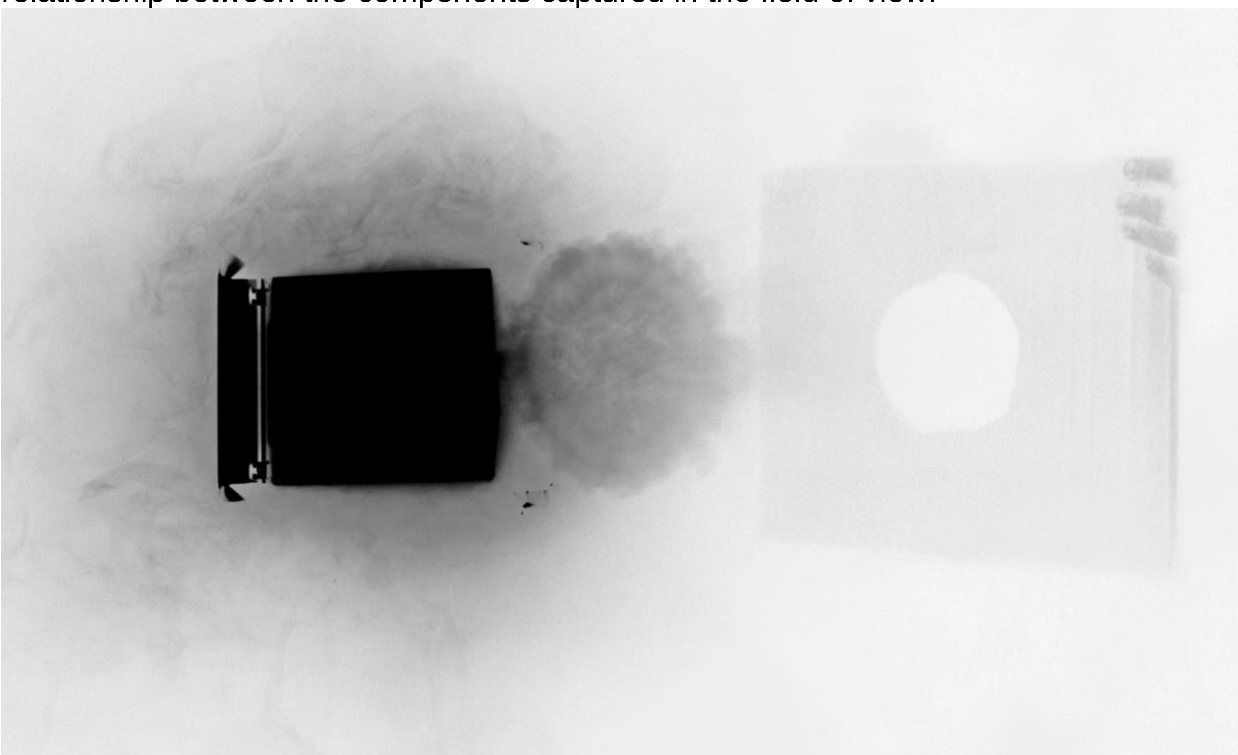
Spec	**Description**

[3] Engineers Edge, L. L. C. (n.d.). Air density and specific weight table, equations and calculator. Engineers Edge - Engineering, Design and Manufacturing Solutions. https://www.engineersedge.com/calculators/air-density.htm

Camera Type	Canon EOS 7D Mk. 1
Field of View	4' x 6'
Distance from Object to Lens	24"
Focal Length	24mm
Aperture	f/5.6
ISO	3200
Shutter Speed	1/500

Table 1: Camera settings and lens specs

I shot this photo in RAW photo format, with an initial and final resolution of 3888 x 2592 pixels. I opted against cropping the photo because of it's composition and the relationship between the components captured in the field of view.



I chose to use Adobe Photoshop as my post-processing tool. As mentioned above I opted against cropping this image. However, I did investigate different iterations of color revision. I found that inverting the image created a striking contrast that was not evident in the pre-processed version of the image. After inverting the image, I nudged the down up a further 10% in order to draw out the shadows of the image.

Conclusions:

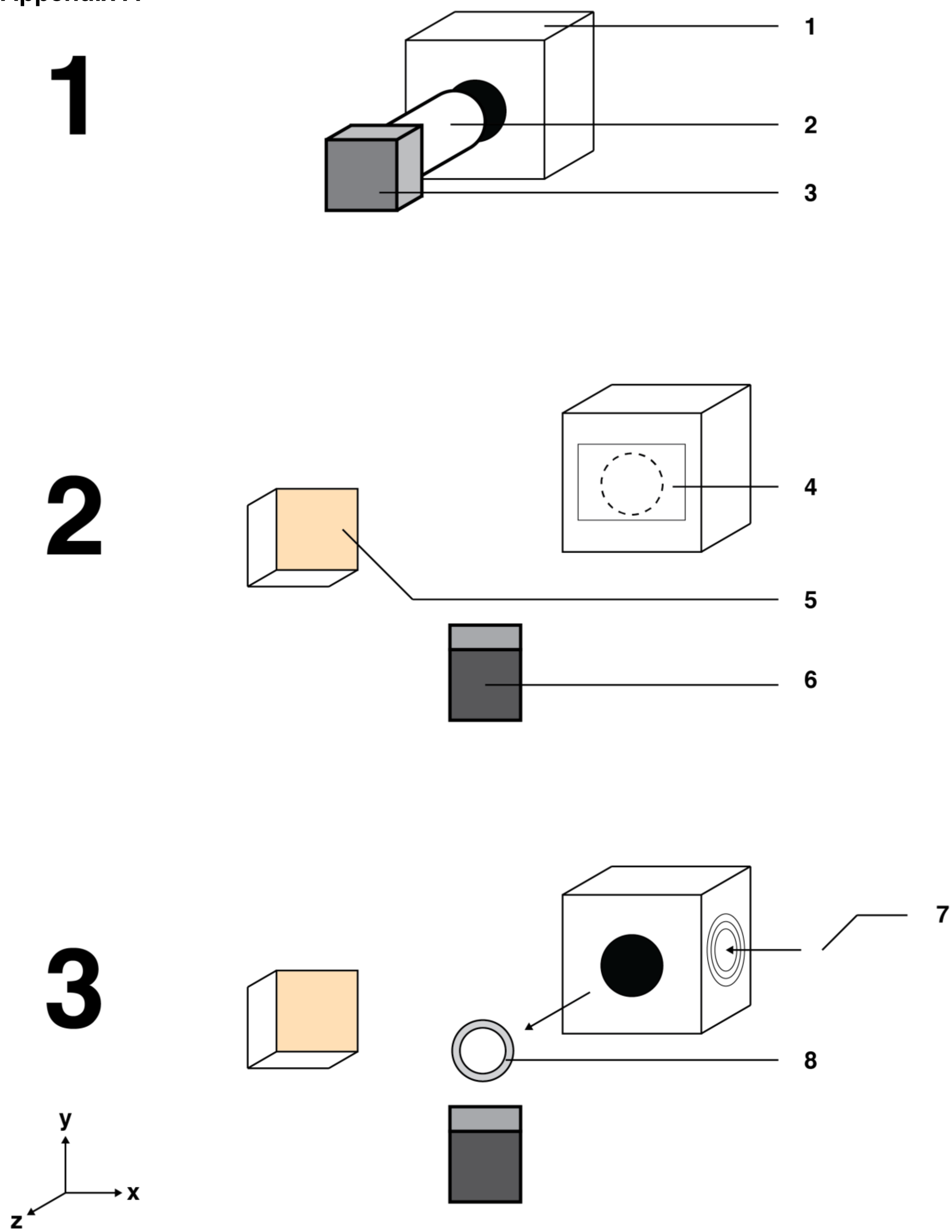
Ultimately, I believe achieves two principal goals:

1. Based on the framing, it creates a relationship between the three focal elements required for the method
2. This relationship requires viewers to consider the sequence of events, and recreate the flow phenomena

I really enjoy the effect of the inversion on illuminating the method of visualizing this flow. The inverted version introduces aspects of the image that you may not otherwise pay attention too, such as the shear intensity of the light source and the hand on the box. The inversion has some unideal consequences as well. Namely, the fog surrounding the light proves somewhat confusing to the overall narrative, and could potentially mislead viewers as to what is actually occurring in the photo.

Overall, I feel the flow effect is documented quite clearly. The smoke ring is sharp, and the other components of the methods require to capture such phenomena are present. Accompanied by this report, the photo comprehensively visualizes the flow AND can be used as a teaching tool for recreation. The photo easily fulfills the intent of the project, as well as the ethos of the course. Naturally, there are areas that could be improved if conducted again, and unclears aspects of the experiment. Firstly, I think it would have behooved us to spend more time on the experiment setup, and less time trying to create the perfect ring-producing apparatus. The hardest part of the project was not producing rings, it was documenting the rings we were eventually able to produce quite clearly. This leads me to my primary question: Is there a recognized angle and/or lighting condition at which it is most appropriate to photograph smoke/fog flow? As I mentioned, the hardest part of this experiment was the documentation aspect, not the flow aspect.

Appendix A



Component Ref.	Description
1	Box to hold fog
2	Apparatus to connect fog machine exit to hole in box
3	Fog machine
4	Paper to cover box
5	Light source
6	Camera
7	Force applied to the side of the cardboard box
8	Fog ring