

# Making of: Flicker

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# 1 Introduction

Fire is mesmerizing with its ever-changing shapes and pulsating lights. Fire is beautiful and dangerous. To capture that duality, we created a fire whirl. When air rotates about a fire, the fire grows in size and intensity and transforms into a spiraling flame. Mimicking an apparatus first used in 1967, this experiment captures the nature of fire whirls to be appreciated for its aesthetics and complexity.

## 2 Methods

The flame sources were made using glass ashtrays, cotton balls, metal additives, and methanol. The metal additives changed the fire color to add more variety to the flame colors. The most visible additive was copper sulfate which turned the flame green. Boric acid was also added to some of the flames to create a slightly red flame. The methanol used in this experiment was Heet Gas Line Antifreeze. To produce a vibrant, consistent colored flame, we placed the cotton balls in the ashtrays, sprinkled metal additive overtop, and poured the methanol overtop.

To induce a free-vortex around the flame, we placed a metal mesh trashcan atop a lazy susan and secured it using duct tape. The trash can was about 18 inches tall with a top diameter of about 12 inches. Initially we secured the flame sources using command strips but later switched Gorilla glue when the command strips started to melt together. While one person spun the lazy susan, the another tester would capture the fire whirl. Figure 1 below shows the layout of the experiment:

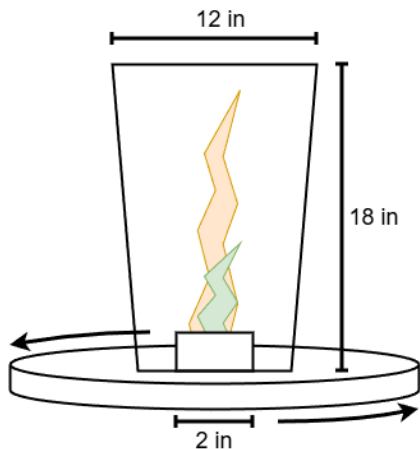


Figure 1: Schematic of the Apparatus

To safely perform this experiment, we gathered a grill lighter, non-flammable cooking lid, and an ABC fire extinguisher. With the grill lighter, we lit the flame

while keeping our hands at a safe distance from the flow. After finishing the experiment, the fire was snuffed out via the cooking lid. A damp towel would also suffice for this purpose. During the whole course of the experiment, we had an ABC fire extinguisher within reach in case the fire needed to be rapidly extinguished.

### 3 Fluid Physics

Emmons and Ying’s study in 1967 is one of the first studies on fire whirls. Their apparatus is similar to ours with a rotating mesh cylinder surrounding a flame rising along the cylinder’s center axis. Within the free vortex, increasing angular momentum decreases the turbulent mixing within the flow. Turbulent mixing drives the combustion within a fire whirl, but plume theory at the time could not easily explain the non-linear relationship between flame radius and height [1].

During testing, flame rotation had a significant impact on the flame height. Even without a way to set a constant rotation rate, it was clear that faster rotation rates increased flame height. Kuwana et al. describes the height ratio of fire whirls using the following relationship [2]:

$$\frac{H}{D_0} \approx \begin{cases} \left( \frac{\Gamma^2}{gD_0^3} \right)^{1/3} & \text{for } \frac{\Gamma^2}{gD_0^3} \rightarrow \infty \\ \left( \frac{\Gamma^2}{gD_0^3} \right) & \text{for } \frac{\Gamma^2}{gD_0^3} \rightarrow 0 \end{cases} \quad (1)$$

For our flow experiment, the circulation can be estimated using the size of the trash can and the rotation rate of the lazy susan. Taking the trashcan diameter as 12 inches and the rotation rate as 30 rpm, the circulation is about 0.46 m<sup>2</sup>/s. The pool diameter for the first flame was roughly 2 inches, so the factor  $\Gamma^2/(gD_0^3)$  is about 160. This is much larger than zero, so following eq 1 along the infinity limit, this yields a height ratio of about 5. This roughly matches the observed flame behavior as flame rotation seemed to increase the height by a factor of 2-4.

### 4 Visualization and Photography

Since flames generate light, the visualization setup focused on creating a dark environment to contrast the bright flames. After setting up the experiment, all lights were turned off to make the flame the sole light source. Behind the experiment, we set up a black backdrop to provide a neutral background. The mesh trashcan was black already, but the minimal lighting also helped to hide the lazy susan within frame. Image focus was significantly limited by the mesh wall in front of the flame. We used manual focus to blur out the mesh walls and better highlight the flame structures.

A Canon EOS 7D Mark II DSLR camera took the photo with an ISO of 1250, f/ of 5 and focal length of 56 mm. The first clip of the single fire plume

was taken with a shutter speed of 1/40 sec, while the other clips were taken at shutter speed of 1/30 sec. The camera was about two feet from the trash can, and had an approximate FOV of 2 x 1 feet. The final video has a resolution of 1920 x 1080 pixels at 30 fps.

## 5 Conclusion

*Flicker* combines the complex physics and aesthetic beauty of fire whirls into a montage of flush, form, and flame. While the framing and focus of the work leaves some room for future improvement, the mesmerizing colors and shapes evokes curiosity and calm. Even with something as long studied as fire whirls, there is active research attempting to apply the research to benefit future fire safety. These aspects of art and science are not so far apart. It is my hope that this work will inspire an artist, a scientist, or a thinker who appreciates both sides of the coin.

## References

- [1] Howard W. Emmons and Shuh-Jing Ying. The fire whirl. *Symposium (International) on Combustion*, 11(1):475–488, 1967.
- [2] Ali Tohidi, Michael J. Gollner, and Huahua Xiao. Fire whirls. *Annual Review of Fluid Mechanics*, 50(Volume 50, 2018):187–213, 2018.