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MCEN 4151, Flow Visualization

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Team Second Image: The Glory Rose

Figure 1: Glory Rose

Introduction:

The purpose of this image is to further work with the assigned team in order to create astounding flow visualization. This beautiful image was captured by placing a frozen rose on a fire pit, in order to show that it does not catch on fire or even appear to be burnt for a long time. The rose was frozen using liquid Nitrogen and the fire was made in the back yard of the photographer on a proper fire pit, following all fire safety regulations.

Flow Description:

The main properties shown in this image are two types of convection heat transfer. The first heat transfer occurs when the rose is submerged in liquid nitrogen in order for the rose to freeze; the second type of convection is involved when the frozen rose is surrounded by the hot air and flames. Liquid nitrogen is a cryogenic fluid, able to quickly freeze common objects. It has a boiling temperature of approximately 77 K (-196 °C) at atmospheric pressure (because the image was taken in Boulder, CO, this boiling temperature is slightly lower). The rose is first submerged in the liquid nitrogen, and both objects eventually come to an equilibrium temperature, where film boiling is no longer present and the rose is extremely cold and brittle, to the extent that placing the rose down can fracture the rose petals just from the force of its own weight. The new temperature of the rose allows it to withstand the flames inside the fire for a long time without burning, which is what the image is capturing. Figure 2 shows the heat transfer situations for freezing and burning of the rose. The calculation for the Reynolds number is shown below with estimates for the diameter of the rose and airspeed of the flames. As expected, the calculated Reynolds number indicates turbulent flow, with makes the calculation of exact heat transfer more complicated.

$$Re_D = \frac{\rho u_{air} D}{\mu} = \frac{1000\,\frac{kg}{m^3} * 5\frac{m}{s} * .05m}{1.78 \times 10^{-5}\,\frac{kg}{m * s}} = 1.40 \times 10^{7} \longrightarrow Turbulent\ Flow$$

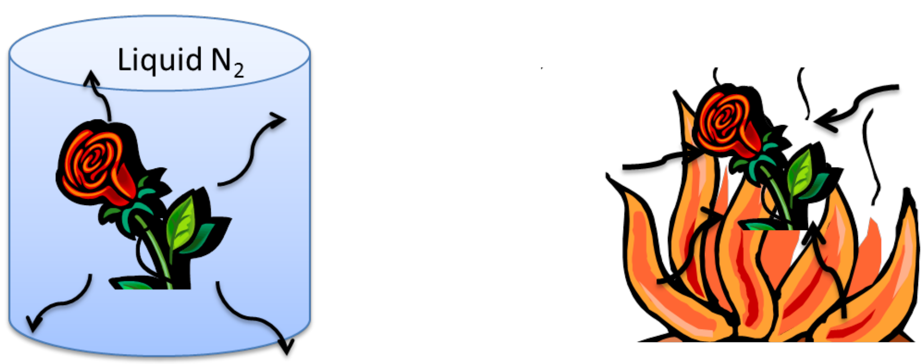

Figure 2: (a) Heat transfer from rose to cold nitrogen (b) Heat transfer from fire to the rose

The estimated time that the rose survived in the flames without any indication of burning or catching fire was about 80 seconds. Assuming the rose is an isothermal sphere with Bi<<1, and neglecting radiation effects, the equation for calculating the average convection coefficient is shown below. Unfortunately, the heat capacity of the rose was not empirically found and cannot be estimated with certainty, so a sample calculation will be shown:

$$\bar{h} = \frac{\rho c D}{6t} * \ln\left(\frac{T_{\infty} - T_i}{T_{\infty} - T}\right)$$

Where $T_{\infty}$is the temperature of the hot air, c is the heat capacity of the rose, t is the time it takes for T to reach T_{∞}, and T_i is the initial temperature. This equation was obtained from Moran and Shapiro's "Introduction to Thermal Systems Engineering," Chapter 17 (Heat transfer by Convection).

Flow Visualization Technique:

The image was captured in the back yard of the photographer: the only lighting used was that of very dim, natural sunset lighting, as well as the light coming from the fire itself. An inexpensive backdrop was placed about 10 ft. away from the fire pit, but was large enough to provide a good background. The fire pit is made of a dug-out hole and has a ring of bricks that protect the environment from the flames (the bricks provide additional background in the image). A fire extinguisher was in hand, the experiment was performed with a team member in case of an emergency. The rose was chosen in order to show a beautiful, fragile object being able to resist fire. The color of the rose was chosen to provide optimum color combination with the flames as well as the bricks.

Photographic Technique:

The image was taken with an Olympus camera, series E-500. Manual mode was used with settings F5.6, shutter speed 1/10s, ISO 200, and zoom @45mm. The maximum possible zoom was chosen in order to provide the best detail for the petals. Manual focus was also used due to the fact that the flames make it difficult for the automatic focus feature to focus properly on the rose. The ISO, shutter speed and F-stop were chosen in combination for having provided the most aesthetically pleasing image. The original image was taken as an ORF (Olympus Raw File) and processed through Olympus Viewer 2. The color contrast curve was adjusted to an S-shaped curve, as learned through the Flow Visualization class during the basic picture editing lecture. Additionally, the blue and red tones in the image were brought out to enhance the contrast, and the sharpness was slightly increased to accentuate the veins in the rose petals, showing that the rose is clearly not burning.

Conclusions:

This image is not only aesthetically pleasing; it makes a statement of cold meets hot, and truly seems to invoke a thousand words about it. One thing that can be improved with this image is the very bright area of flames on the bottom left of the image, since it can be distracting to the eye when looking at the rest of the picture. The science behind the image is very interesting since intuitively, this image cannot be easily recreated in nature. The setup to this image is a very good learning experience for people who are interested in doing experiments with liquid nitrogen; as well as with people who want to properly perform an experiment with a fire pit.

NOTE: All fire safety regulations from the flow visualization website were complied with.