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MCEN 5228 – Flow Visualization
Assignment #1
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Context

The image shows the interaction between a downward laminar jet and a buoyant plume from a heated surface. Smoke is used as a tracer for the laminar flow field in a hospital operating room ventilation system. The downward airflow is redirected an interaction with a buoyant plume from the top of a surgical light. This image describes a common break in the laminar flow field in an operating room by a blockage and heat source. Typical air velocities and temperatures were used to create this image, with the main difference from the typical application being that the air stream is isothermal.

Flow Apparatus

For this image, air is introduced isothermally into a full-scale chamber (20' L x 20' W x 9.5' H) from a commercial laminar air flow diffuser. The laminar air flow diffuser is a typical commercial HVAC component used in clean room and hospital applications. A 23" surgical light fixture is placed 24" below the diffuser within the flow path.

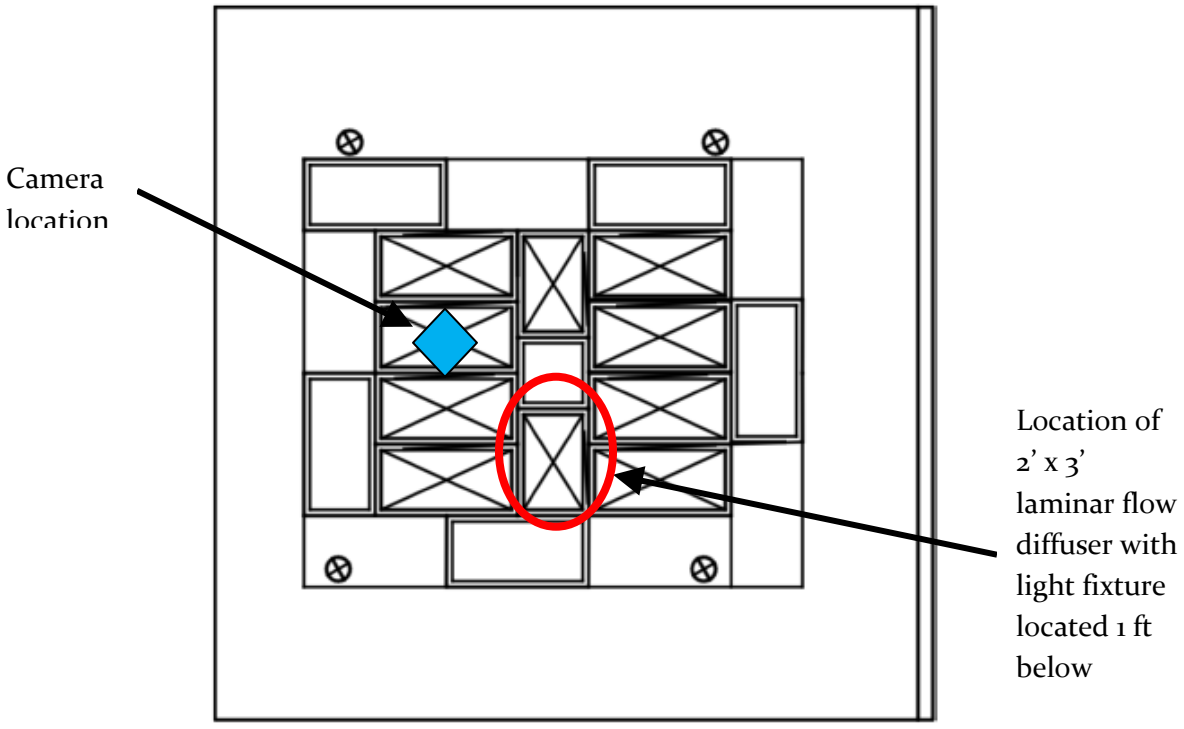

Figure 1 Test Chamber Diagram

The flow can be characterized as a laminar jet leaving a circular orifice with a diameter of 1/16 of an inch. The jet has a velocity of 34 ft/min with a temperature of 75 °F, which relates to a Reynolds number of 18. This jet interacts with a buoyant plume from the back of the light fixture. The light fixture has a temperature of approximately 121 °F and a diameter of 23 inches. The Grashof number for the natural convection from the top of the light is 0.82.

Visualization Technique

This image attempts to capture the physics of the air flow through the use of smoke as a flow tracer. The smoke was produced by vaporizing a propylene glycol mixture with an electric resistance heater. The smoke is warmer than the surrounding air from the vaporization process. It was therefore captured in a plastic bottle and released into the air flow. This allowed the smoke to gain thermal equilibrium with the ambient conditions prior to being introduced into the flow field. The plastic bottle contained an opening on both sides, allowing the ventilation air to enter the bottle and assist in pouring the smoke into the air stream. Attempts were made to limit the influence on the flow pattern by introducing the smoke from the side of the diffuser towards the center.

Photographic Technique

This photo was taken using a Canon EOS Rebel XT digital SLR camera with the stock 18 - 55 mm zoom lens. The image was shot using manual focus and a tripod from a location 3 feet from where the smoke was introduced. The camera was located at a height of 92 inches from the floor, at the approximate height of the light fixture. Two surgical light fixtures, a small flood light, and the camera's flash were used provide illumination for the photograph. The first surgical light was aimed downward and is shown in the picture. The second light is aimed at the smoke location from a distance of approximately one foot. This light fixture produces the coloring that is apparent in the smoke. Ambient lighting in the room was turned off to limit reflections from the light colored surfaces. A matte black backdrop was mounted behind the light fixture to improve the contrast with the smoke line.

Camera: Canon EOS Rebel XT
Type: Digital SLR
Resolution: 8 megapixels
ISO: 1600
Focal Length: 55 mm
Shutter Speed: 1/200 sec
Aperture: f/5.6

The image was adjusted in Adobe Photoshop Lightroom 2 in order to remove the graininess that was apparent from the use of a high ISO. The following adjustments were made to the image:

Black cut-out:	0	->	32
Brightness:	0	->	+21
Contrast:	+10	->	-50

Care was taken to not alter the structure of the main smoke line that was captured in the image. There appears to be a thin vortex behind the main smoke line that was lost in the alteration of the image. This loss was deemed to be acceptable since the primary objective in the image was to capture the effect of the thermal plume from the back of the light fixture. This is captured most effectively in the image of the main smoke line.

Describe what image reveals

The image describes several flow phenomena that are occurring. The interactions that are occurring in this image are for a hospital operating room, but the overall physics are common in most indoor environment applications. This image is of particular interest for the hospital environment, because it shows the impact of heat sources within the operating room on the downward laminar clean air system. The buoyant plumes from these heat sources impact the clean air field that surrounds the patient, and permit the introduction of turbulence and particles into the flow field. The design of ventilation systems in operating rooms tries to minimize these effects, since it increases the possibility of introducing contaminants into the surgical wound.

The upper picture shows the downward laminar flow from the diffuser jet. The air stream direction is changed abruptly by the interaction with the buoyant thermal plume from the light fixture. The ventilation system air path is then redirected upwards away from the light. Interestingly, the air path is redirected towards the break in the laminar flow field, which is in the center of the laminar flow diffuser grid. This location is used for hanging the boom for the surgical light and provides a volume with little to no velocity that allows for the migration of any buoyant plumes.