20.Particles 2

Wednesday, November 9, 2016

Today: Critique catch up
Particles
News: research independent study opportunities; see me

Minute paper at the end of class today

- Strengths of the course
- Improvements you'd like to see

Flame propagation follows Hyugen's principle, resulting in cusped flames, at least when premixed.

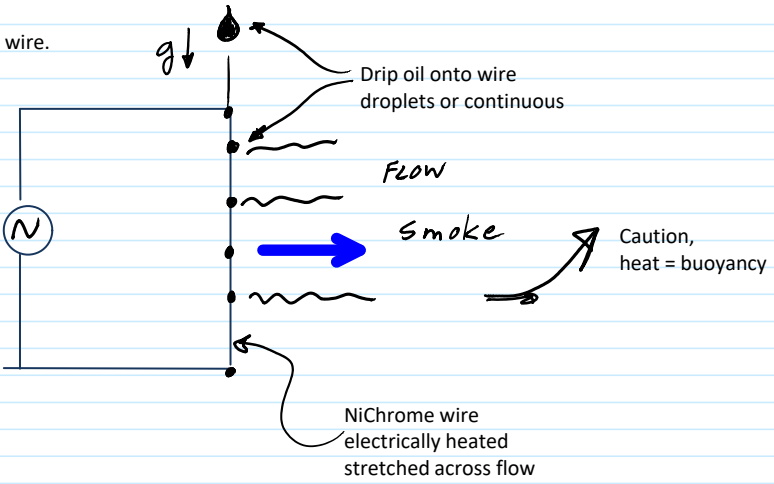
Next: How to make or get particles

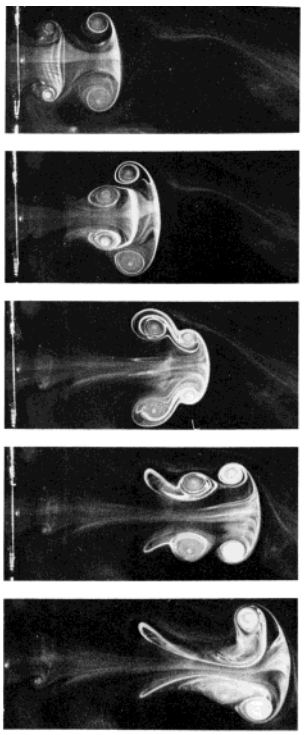
Aerosols in air: smoke and fog

solids liquids

A) Smoke = soot usually, carbon particles

Smoke wire.



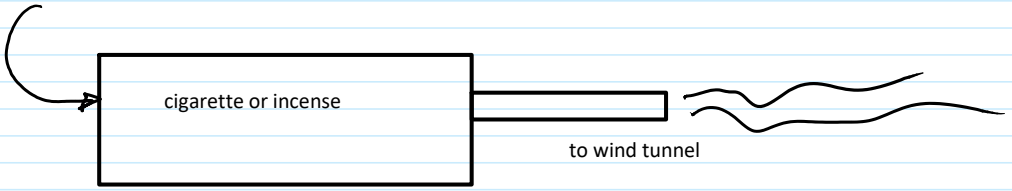


79. Leapfrogging of two vortex rings. Two successive puffs of air are ejected from an orifice of 8-cm diameter by a piston that is driven by the impacts of two pendulums. The flow is made visible by a smoke wire stretched across the orifice, at the left of the photographs. At this Reynolds number of about 1600 based on orifice diameter, the second ring travels faster in the induced field of the first, and has slipped through it in the third photograph. Then the process is repeated, the first ring slipping through the second in the last photograph. Yamada & Matsui 1978

Van Dyke, Milton. *Album of Fluid Motion*. 10th ed. Parabolic Press, Inc., 1982.

Most oils work. Veg is less toxic.
Generates 1µm particles. Penetrates into lungs, causes cancer, regardless of composition.

Alt technique:
pressurized air



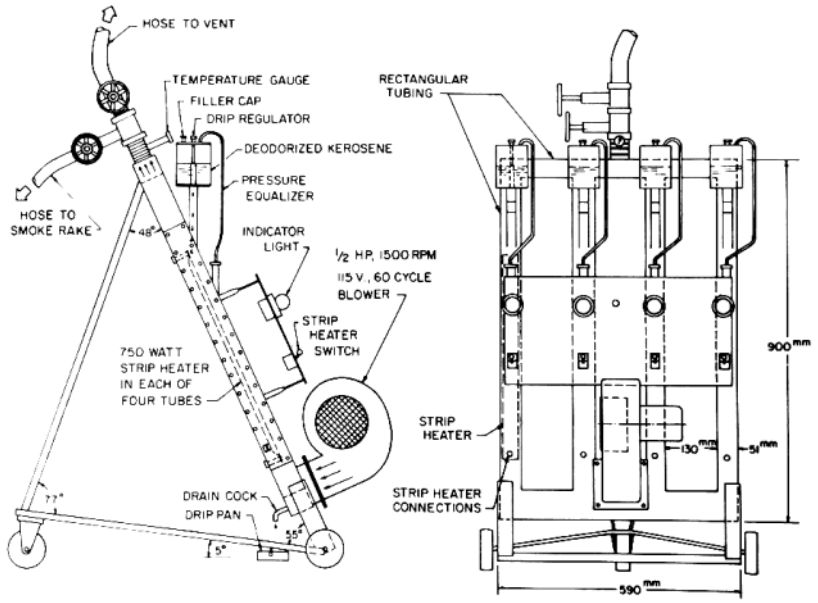
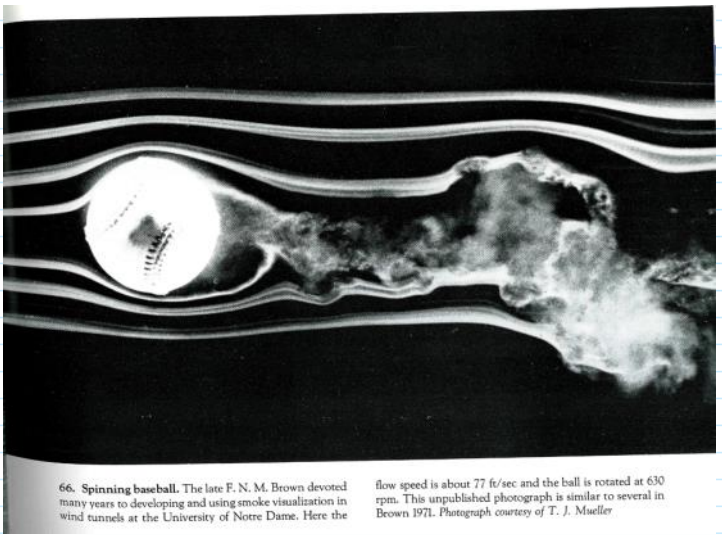
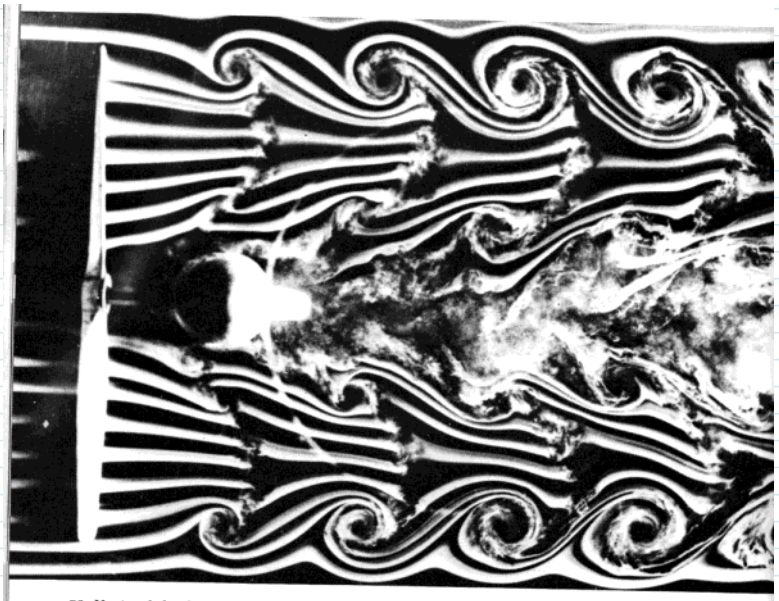


Fig. 2.6 Smoke generator designed at the University of Notre Dame. (From Mueller, 1983. Published by Hemisphere Publishing Corporation.)

Merzkirch, Wolgang. *Flow Visualization, Second Edition*. 2nd ed. Academic Press, 1987.

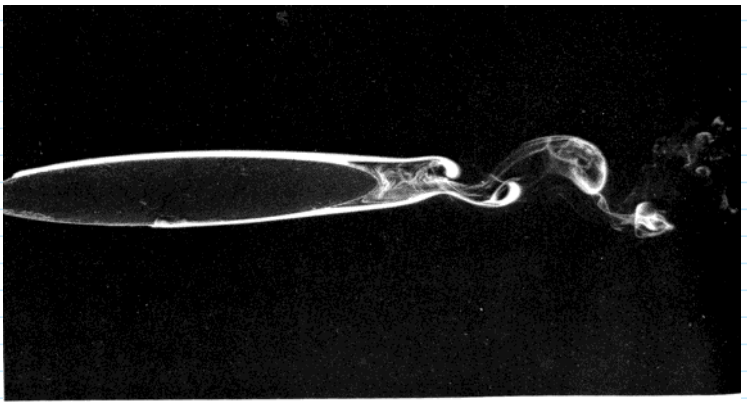


66. **Spinning baseball.** The late F. N. M. Brown devoted many years to developing and using smoke visualization in wind tunnels at the University of Notre Dame. Here the flow speed is about 77 ft/sec and the ball is rotated at 630 rpm. This unpublished photograph is similar to several in Brown 1971. *Photograph courtesy of T. J. Mueller*



75. Vortices behind a rotating propeller. A striking pattern of helical tip and root vortices is revealed by smoke in the Notre Dame wind tunnel. The stream flows at 48 ft/s while the propeller rotates at 4080 rpm. *Brown 1971, courtesy of T. J. Mueller*

Chemically generated particles:
TiO_2 Titanium dioxide particles from
titanium tetrachloride + water vapor = dense TiO2 smoke + HCl
HCl + water vapor = hydrochloric acid vapor
Spectacular smoke, but toxic, and hard on equipment, corrosive

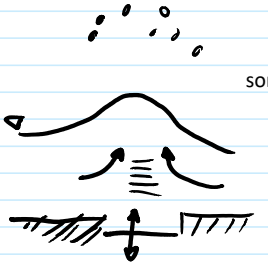


32. Laminar separation on a thin ellipse. A 6:1 elliptic cylinder is held at zero angle of attack in a wind tunnel. The Reynolds number is 4000 based on chord. Drops of titanium tetrachloride on the surface form white smoke, which shows the laminar boundary layer separating at the rear. *Bradshaw 1970*

B) Fog = aerosols of liquids

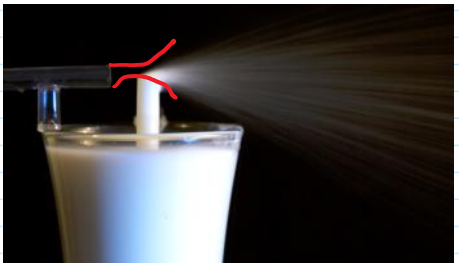
Water fog: Safe, but evaporates quickly

- ultrasonic humidifier http://www.youtube.com/watch?v=rN-OcMSwS2I&feature=youtube_gdata_player
- http://www.youtube.com/watch?v=rkrLl7tJOIg&feature=youtube_gdata_player with acoustic streaming
- medical nebulizer
- dry ice (solid CO2)



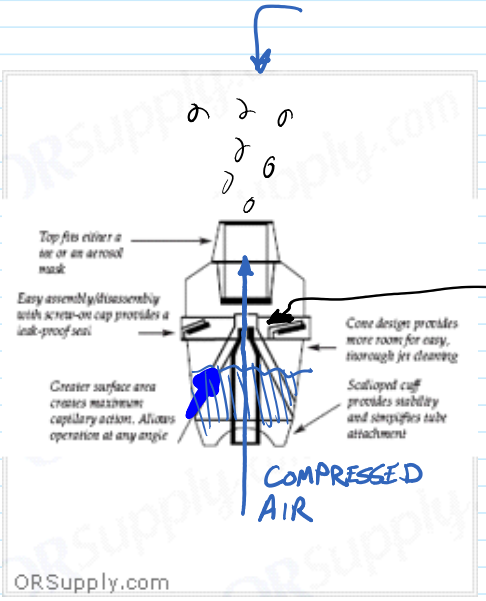
sonication

transducer = diaphragm
vibrates @ n MHz



Matt Blessinger
Get Wet 2009

Bernoulli atomizer
Jet nebulizer
Small Volume Nebulizer (SMN)



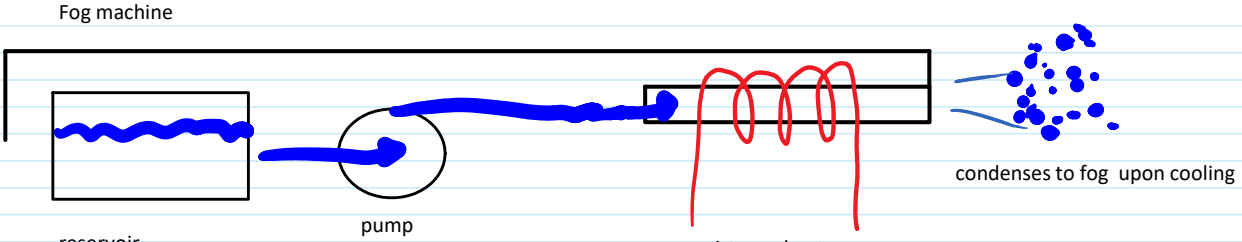
Inexpensive: $3
Makes 1 μm to 100μm droplets
Larger droplets impact on surfaces, can't exit device.

Liquid is delivered to jet exit by capillary action

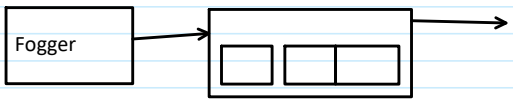
Dry Ice Vapor: Dry ice = solid CO2
Sublimates (solid to gas) at 1 atm, -78 C (-109 F)
http://www.dryiceinfo.com/fog.htm
Submerge in hot water: much water fog created.
Fog production drops for water temperature < 50 F
60 Pounds of Dry Ice and a Swimming Pool, 2007. http://www.youtube.com/watch?v=uhXA9ON6igk&feature=youtube_gdata_player

Stage fog = Water + glycerin or propylene glycol. Additive slows evaporation

Fog machine



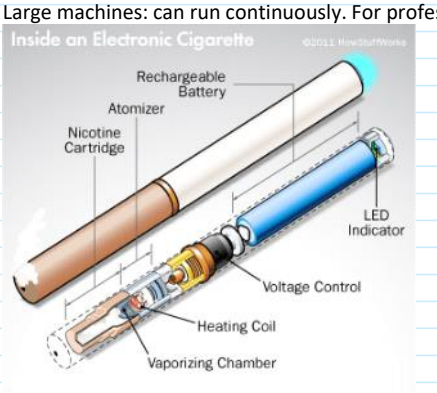
Small machines: heater too small to run continuously. Buy at Target, 1 month before Halloween for $35.



For fog-on-the-ground: chillers
Approximately 1 micron diameter droplets.
Yoshida, T., Y. Kousaka, and K. Okuyama. "A New Technique of Particle Size of Aerosols and Fine Powders Using an

Ultramicroscope." *Industrial and Engineering Chemistry, Fundamentals*, Ind. Eng. Chem. Fundam. (USA), 14, no. 1 (February 1975): 47–51.

Large machines: can run continuously. For professional stage and theaters. $1000. Mfg: Roscoe, Le Maitre. 1 gallon lasts 4 hrs, $30.



E-cigarettes also use propylene glycol fluid. Same physics as fog machines.

$10 ?

http://science.howstuffworks.com/innovation/everyday-innovations/electronic-cigarette1.htm

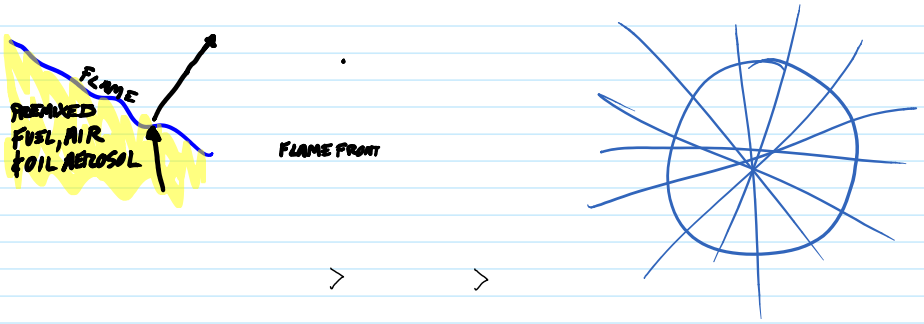
Health effects of stage fog are minimal, except to asthmatics and opera singers.

Varughese, Sunil, Kay Teschke, Michael Brauer, Yat Chow, Chris van Netten, and Susan M. Kennedy. "Effects of Theatrical Smokes and Fogs on Respiratory Health in the Entertainment Industry." *American Journal of Industrial Medicine* 47, no. 5 (2005): 411–18. doi:10.1002/ajim.20151.
Wills, J. H., F. Coulston, E. S. Harris, E. W. McChesney, J. C. Russell, and D. M. Serrone. "Inhalation of Aerosolized Ethylene Glycol by Man." *Clinical Toxicology* 7, no. 5 (January 1974): 463–76. doi:10.3109/15563657408988020.
Yoshida, T., Y. Kousaka, and K. Okuyama. "A New Technique of Particle Size of Aerosols and Fine Powders Using an Ultramicroscope." *Industrial and Engineering Chemistry, Fundamentals*, Ind. Eng. Chem. Fundam. (USA), 14, no. 1 (February 1975): 47–51.

C) Oil aerosols

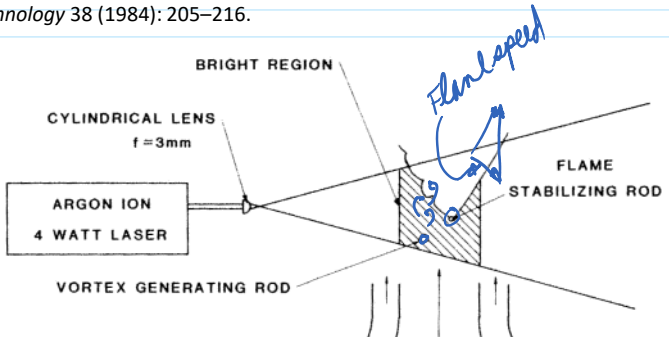
Won't evaporate unless burned. Oil has low vapor pressure.
Use medical or Bernoulli atomizer/nebulizer

Can be used to mark flame fronts. Illuminate fog with a laser sheet = "laser tomography" in 1980s.



Danger! Oil aerosol will coat lungs = pneumonia = death
"Guidance-for-Aerosol-Applications-of-Silicone-Based-Materials.pdf." Accessed November 11, 2015. http://sehsc.americanchemistry.com/Research-Science-Health-and-Safety/Guidance-for-Aerosol-Applications-of-Silicone-Based-Materials.pdf.
Discusses oil aerosol effects in general.

JEAN R. HERTZBERG, MEHDI NAMAZIAN, and LAWRENCE TALBOT. "A Laser Tomographic Study of a Laminar Flame In a Karman Vortex Street." *Combustion Science and Technology* 38 (1984): 205–216.



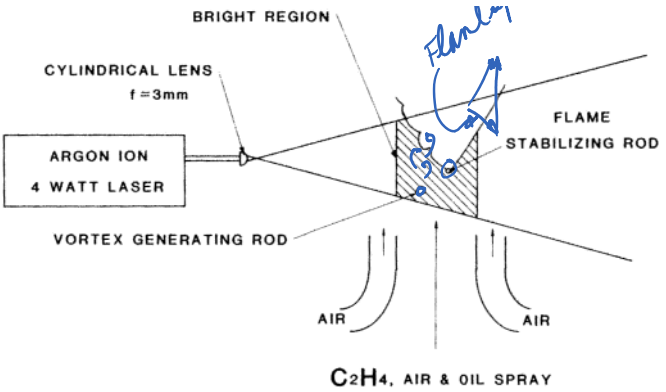


FIGURE 1 Experimental apparatus. The bright region is a cloud of oil droplets illuminated by the laser.

FIGURE 4 Example of tomography. Free jet, 1.2 m/s, issuing into stagnant room air.

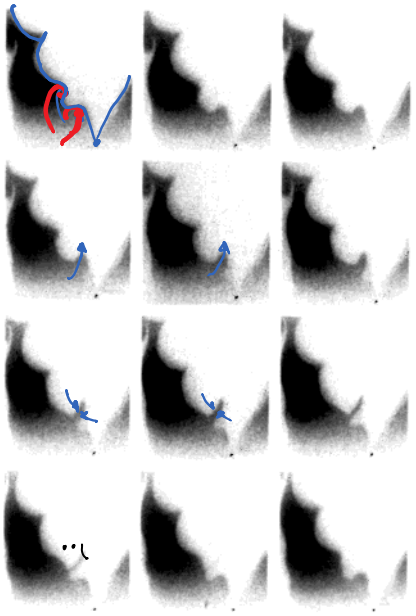


FIGURE 6 Example of tomography with combustion; from high-speed 16 mm film. The flame appears as the boundary of the dark V-shaped region. One complete cycle of interaction with vortex street is shown.