25.Particles 2

Monday, December 2, 2019

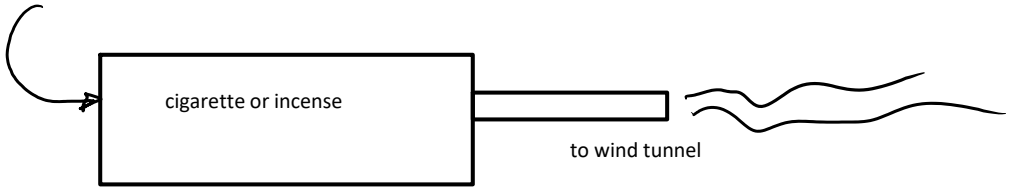
Today:

Particles - how to get/make them
Finish air, then talk about particles in water.

Aerosols in air: smoke and fog

solids liquids

Alt technique:
pressurized air



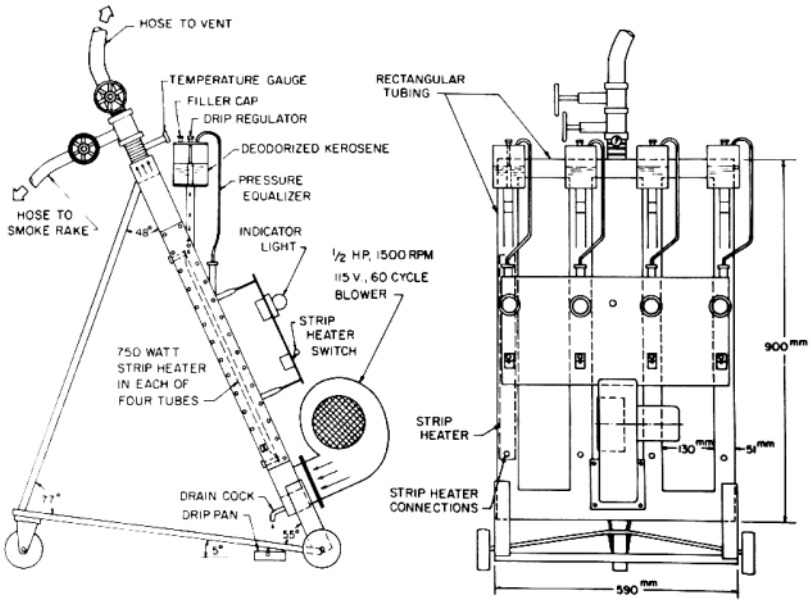
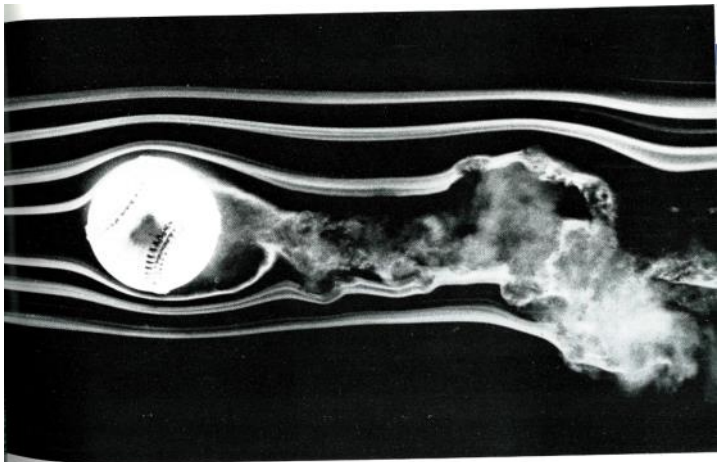
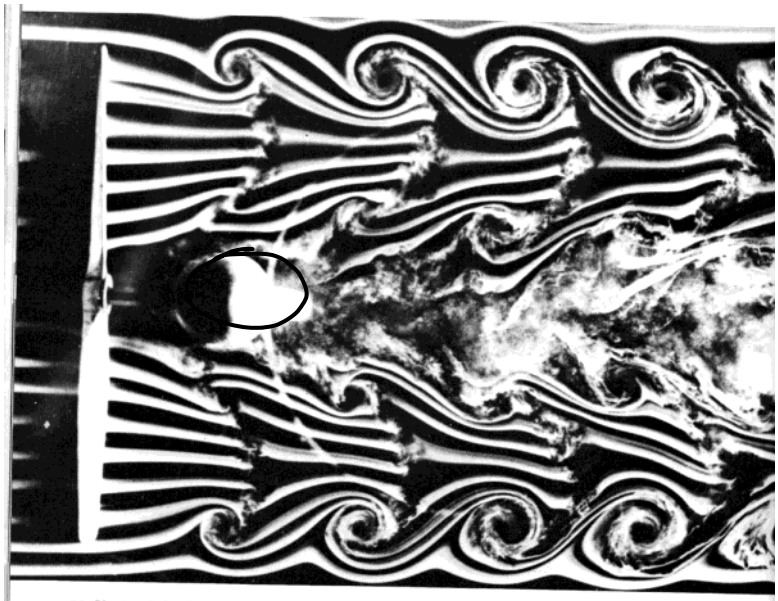


Fig. 2.6 Smoke generator designed at the University of Notre Dame. (From Mueller, 1983. Published by Hemisphere Publishing Corporation.)

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

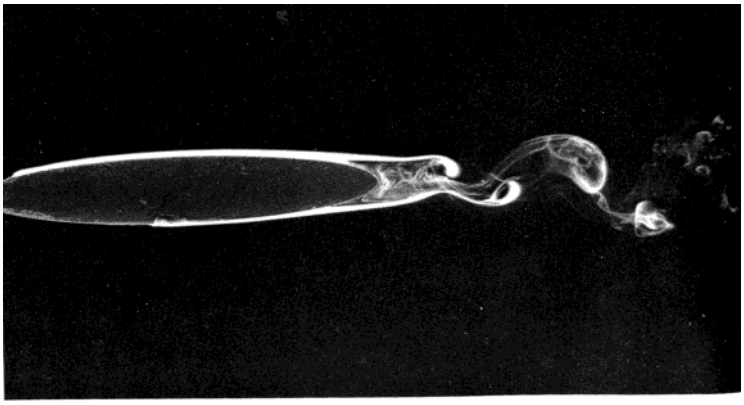


66. **Spinning baseball.** The late F. N. M. Brown devoted many years to developing and using smoke visualization in wind tunnels at the University of Notre Dame. Here the flow speed is about 77 ft/sec and the ball is rotated at 630 rpm. This unpublished photograph is similar to several in Brown 1971.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

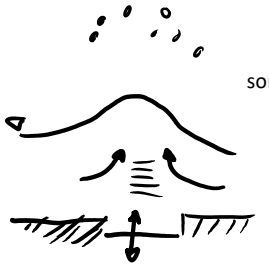


32. Laminar separation on a thin ellipse. A 6:1 elliptic cylinder is held at zero angle of attack in a wind tunnel. The Reynolds number is 4000 based on chord. Drops of titanium tetrachloride on the surface form white smoke, which shows the laminar boundary layer separating at the rear. *Bradshaw 1970*

B) Fog = aerosols of liquids

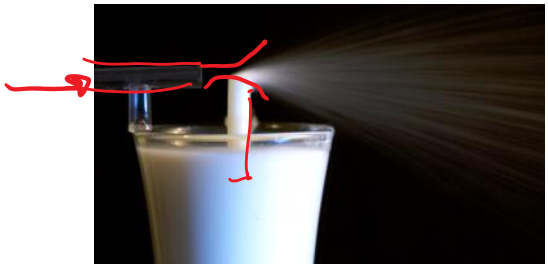
Water fog: Safe, but evaporates quickly

- 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)



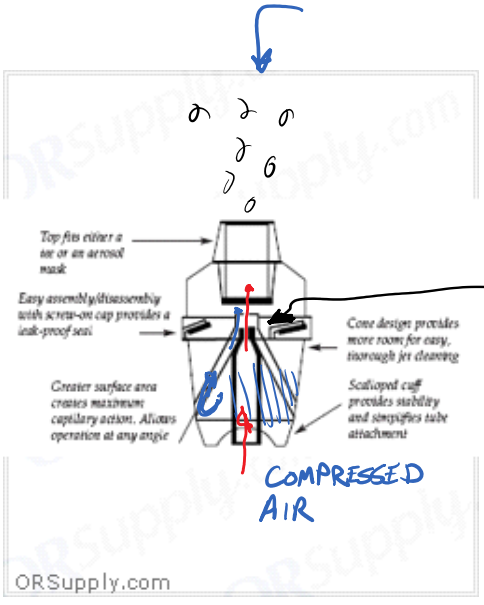
sonication

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

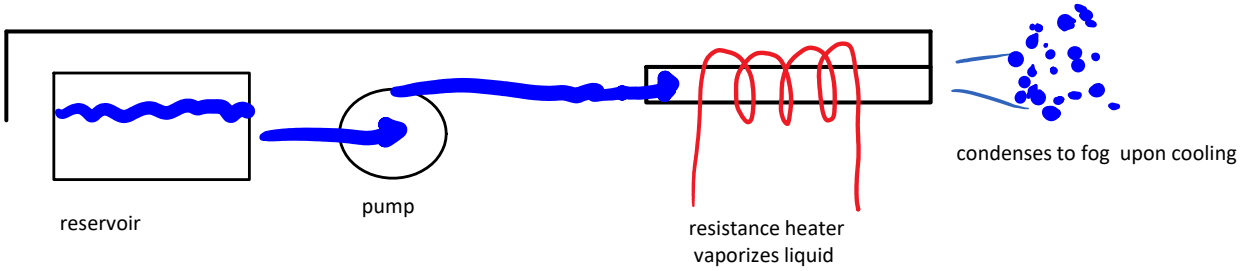
Submerge in hot water: much water fog created.

Fog production drops for water temperature < 50 F

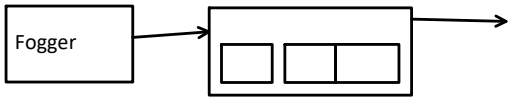
60 Pounds of Dry Ice and a Swimming Pool, 2007. http://www.youtube.com/watch?v=uhXA9ON6igk&feature=youtube_gdata_player

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

Fog machine. Physics are the same as e-cigarettes, vape



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 hr s, $30.

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

$10 ?

Juul

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 Smoke s 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 Ethyle ne Glycol by Man." *Clinical Toxicology* 7, no. 5 (January 1974): 463–76. doi:10.3109/15563657408988020.

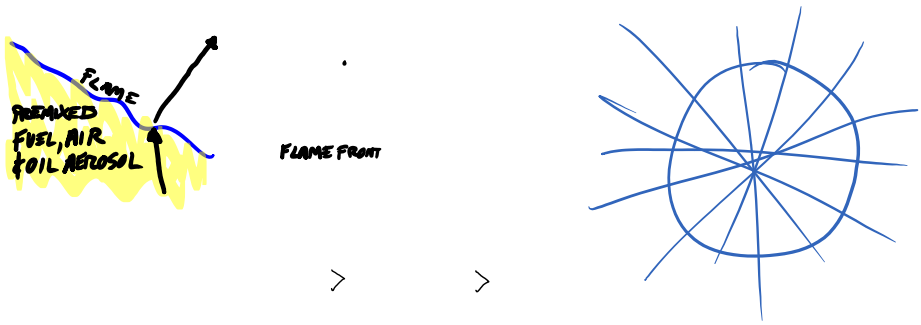
Yoshida, T., Y. Kousaka, and K. Okuyama. "A New Technique of Particle Size of Aerosols and Fine Powders Using an Ultramicrosc ope." *Industrial and Engineering Chemistry, Fundamentals*, Ind. Eng. Chem. Fundam. (USA), 14, no. 1 (February 1975): 47–51.

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.

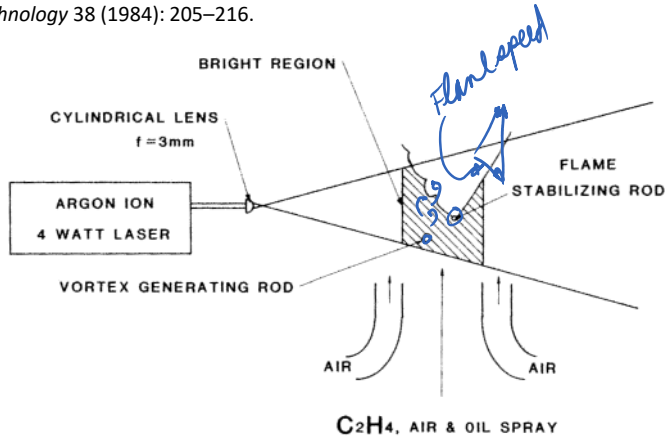


FIGURE 1 Experimental apparatus. The bright region is a cloud of oil droplets illuminated by the laser.

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

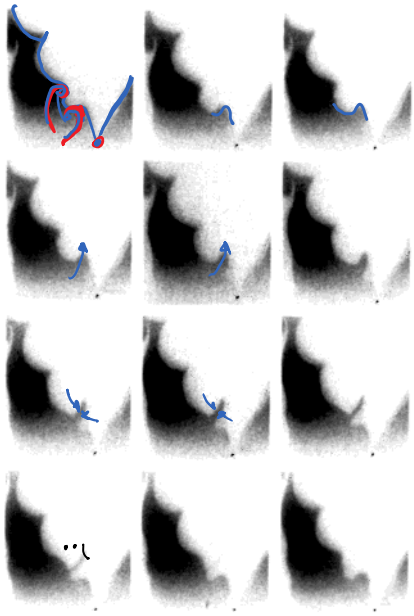


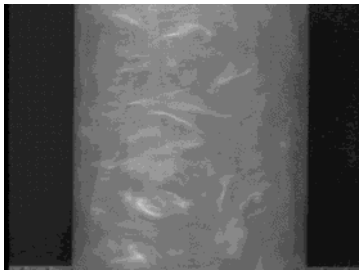
FIGURE 6 Example of tomography with combustion; from high-speed 16 mm film. The flame appears as the boundary of the dark V-shaped region. One complete cycle of interaction with vortex street is shown.

Particles for Water

Rheoscopic fluids:

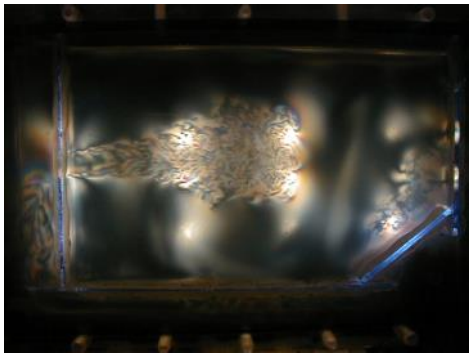
Pearl Ex (art pigment, TiO_2 coated mica).

'Pearl Swirl' $5/gallon from Steve Spangler Science
Shiny opaque or translucent particles, crystal flakes, ~10 μm size, aligns with shear gradient.
Used in soaps, shampoos
https://www.youtube.com/watch?v=vrTM9O6owII
Probably the same as:
Stearic acid crystals extracted from shaving cream,
Borrero-Echeverry, Daniel, Christopher J. Crowley, and Tyler P. Riddick. "Rheoscopic Fluids in a Post-Kalliroscope World." *Physics of Fluids* 30, no. 8 (August 1, 2018): 087103. https://doi.org/10.1063/1.5045053.



Check out the Taylor Couette Instability demo in the ITLL Lobby. Tall blue column. Nope, it's gone.

'Blackstock' fluid, now 'KaleidoFlow Rheoscopic Fluid'



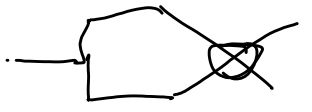
http://buphy.bu.edu/~duffy/thermo/4B20_77.html
Streaming birefringence, seen when viewed between polarizing filters
Has 2 indices of refraction
Suspension of microscale mica flakes.

http://www.laminarsciences.com/

For individual particle images (PIV)

Neutral buoyancy
- Corn starch (diluted)
- Glass or polystyrene microspheres
- Latex bubbles
- Rust (filtered)
- Alumina
- Wax beads (Pine Sol)

Mica powder for makeup
polishing powder
ultrasound to break up clumps



Laser

Pine pollen (floats on surface)
Lycopodium powder (also used as flash powder)
http://vimeo.com/89491724 Cymatics
Susie Sie

Lycopodium powder (also used as flash powder)
http://vimeo.com/89491724 Cymatics
Susie Sie

break up clumps

Laser
Doppler
Velocimetry
Point meas of velocity