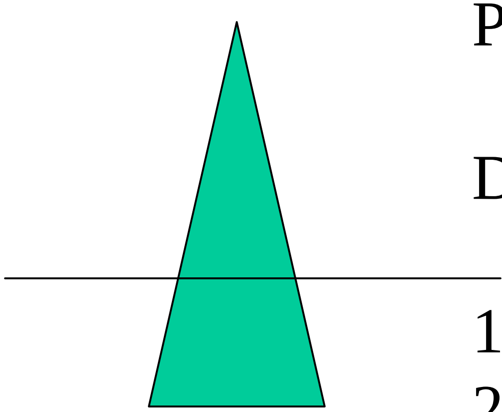
PATTERNATION?

What is Patternation of nozzles

<u>Definition</u>



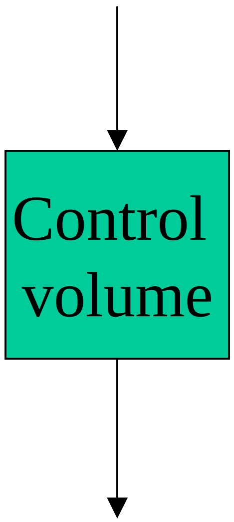
Planar cross-section of spray

Differences in angular and radial profiles of:

1) Mass flux of liquid
2) Velocity of liquid
3) Drop sizes
4) Surface area per unit volume

Four potential parameters: Which is important?

Fuel sprays



If any of the four parameters in the spray are not the same at all locations (non-uniform pattern)? What happens?

Consider the spray to be divided into many small control volumes (unit volume). We are trying to find out which of these four parameters would be important for a combustion application For a combusting spray, the amount of fuel evaporating within the control volume controls the total amount of fuel consumed within the volume and the total amount of heat released within the volume. Within a spray if there are non-uniformities, combustion will be non-uniform and cause instability and uneven component wear.

Which of the four measures (mass flux, velocity, drop size, drop surface) is it important to maintain uniform within the spray?

Parametric space

All parameters are interconnected. For example, a mass flux change can be due to change in velocity, drop size, or number of drops.

Monte Carlo simulation carried out

Drop size varied from 1 micron to 100 micron
Velocity varied from 1 m/s to 10 m/s
Number of drops changed from 1E5 to 1E7

Formula Used*

For static drop $$\dot{m} = \frac{4\pi k_g r_s}{C_{pg}} \ln(B+1)$$

For dynamic drop $$\dot{m}_{dynamic} = \frac{N_u}{2} \dot{m}_{static}$$

$$B = \frac{C_{pg}(T_\alpha - T_b)}{h_{fg}}$$

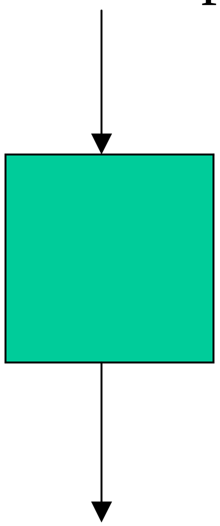
$$C_{pg} = C_{pF}(\overline{T}) \quad \text{and} \quad k_g = 0.4 k_F(\overline{T}) + 0.6 k_\infty(\overline{T}); \quad \overline{T} = (T_b + T_\infty)/2$$

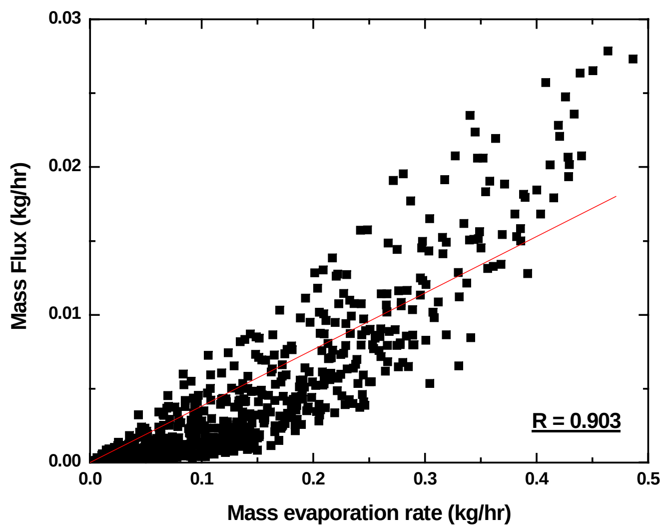
$$N_u = 2 + \frac{0.555 \, Re^{1/2} \, Pr^{1/3}}{\left[1 + 1.232/(Re\,Pr)^{4/3}\right]^{1/2}}$$

*An Introduction to Combustion: Concepts and Applications," Stephen R. Turns, Mc. Graw Hill, 2000

For Mass Flux Patternator

Mass flux varied by changing drop sizes, number of drops, and velocity randomly. The mass evaporation rate in the control volume was calculated.





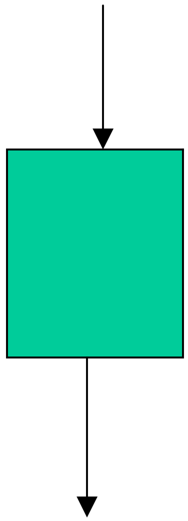
Positive correlation
Higher mass flux in general higher evaporation

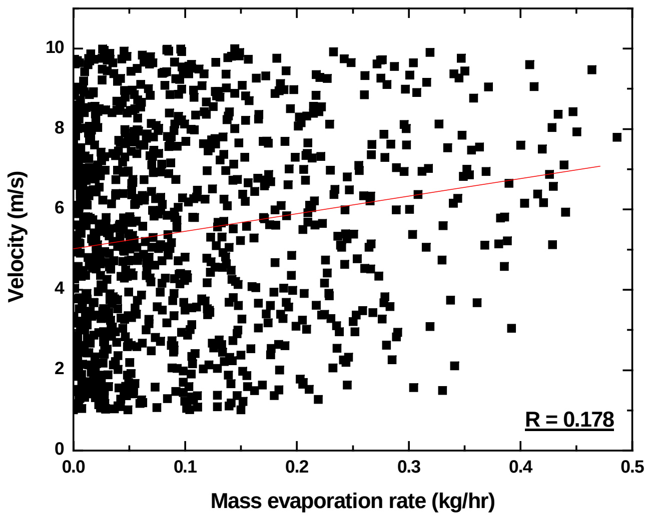
Reasonable dependence since R = 0.903

Mass flux is important parameter that describes the amount of fuel evaporated in control volume.

For Velocity Patternator

Velocity was changed randomly along with the drop size and the number of drops. Mass evaporation rates were calculated for each velocity.





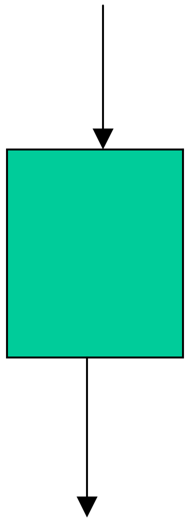
Weak dependence since
R = - 0.239

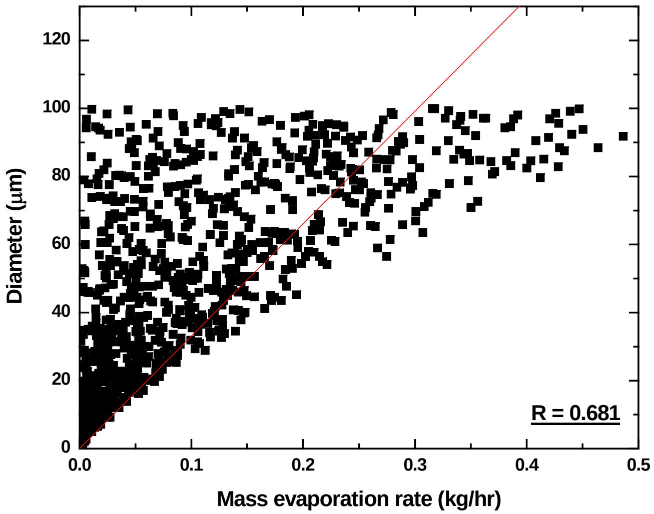
Evaporation rate does not depend on velocity

Velocity does not describe amount of fuel evaporated in control volume, non-uniformity may not be important!

For Dropsize Patternator

Drop sizes varied randomly along with velocity and the number of drops. The mass evaporation rate within the control volume was calculated for each diameter.





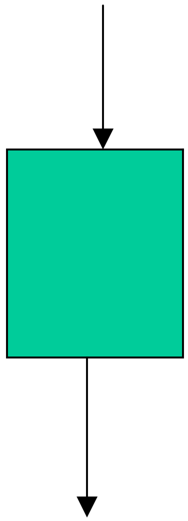
Positive correlation
Higher drop size in general higher evaporation

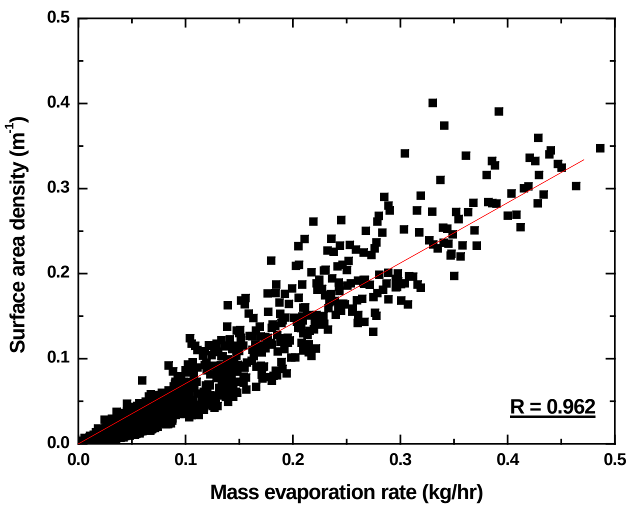
Moderate dependence since R = 0.681

Drop diameter does not describe amount of fuel evaporated in control volume, non-uniformity may not be important!

<u>For SETscan Patternator</u>

Surface area density was changed by changing the drop size, velocity, and number of drops. The mass evaporation rate within the control volume was calculated for each case.





Positive correlation
Higher surface area density in general higher evaporation

Highest correlation amongst all parameters at R = 0.96

Surface area density is probably the best parameter to use in the patternation of fuel nozzles. It is better than mass flux or dropsizes, even when comparing two different nozzles.

Concluding Remarks

If you want to compare two different fuel nozzles or compare the uniformity of the pattern provided by these nozzles, the surface area density provides the best indicator of the combustion efficiency or the uniformity of combustion.