Standard Constant-Mass Doped Flames

The Standard Constant-Mass Doped Flames are a series of fuel-doped methane/air coflow flames that we have used to generate soot concentration data for real diesel and jet fuels, their surrogates, and the individual components of the surrogates. While doped flames are usually defined in terms of MOLE, the reactant compositions for these flames are defined in terms of MASS since the molecular weights of the real fuels are not known precisely.

Available Data: Currently we have two-dimensional distributions of soot volume fraction and soot temperature measured by color-ratio pyrometry. These were measured using color-ratio pyrometry as discussed in the following publications

D.D. Das, W.J. Cannella, C.S. McEnally, C.J. Mueller, L.D. Pfefferle, Two-dimensional soot volume fraction measurements in flames doped with large hydrocarbons, Proceedings of the Combustion Institute, http://dx.doi.org/10.1016/j.proci.2016.06.047

D.D. Das, W.J. Cannella, T. Kwan, C.S. McEnally, C.J. Mueller, J. Zimmerman, L.D. Pfefferle, title TBD, journal TDB, in preparation.

Thermal Boundary Condition: The fuel tube of the burner is heated to 145 C to prevent condensation of the dopants. This heating undoubtedly affects the thermal boundary condition at the burner surface; we are currently in the process of measuring this condition.

Flame Conditions: The reactants are air and the fuel mixture (methane, nitrogen, dopant). The governing conditions that determine the reactant flowrates are

Y_d = dopant mass fraction in fuel = 0.005

Y_m = methane mass fraction in fuel = 0.583

$\dot{m}_{fuel}$ = total mass flux of the fuel mixture = 0.321 g/min

Q_{air} = volumetric flowrate of air = 50 L/min

Flowrates and Mole Fractions: Given that the flames are defined by mass, the mass fluxes and mass fractions of all reactants are identical by definition in all flames. The volumetric flowrates of air, methane, and nitrogen are also identical by definition in all flames, but the volumetric flowrates of the dopants vary depending on their average molecular weight. In particular,

Q_d (cm^3/min) = 38.533 / MW_d (g/mole)

Strictly speaking, the mole fractions of methane and nitrogen vary among the flames, but these differences are negligible (± 0.000094 for methane and ± 0.000038 for nitrogen). However, the mole fractions of the dopants vary considerably and can be calculated from

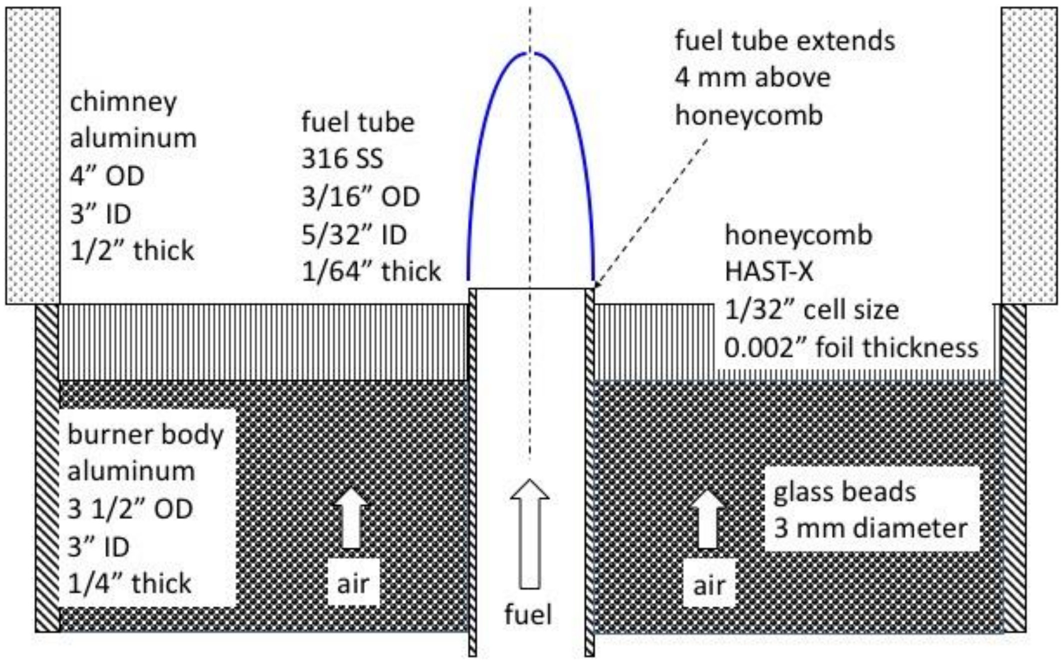
$$X_d = Q_d / (Q_m + Q_i + Q_d)$$

The table below lists nominal flowrates and mole fractions for selected flames.

Dopant	MW_d (g/mole)	Q_m	Q_i (cm3/min)	Q_d	X_m (-)	X_i (-)	X_d (ppm)
undoped	n/a	282	112	0	0.715	0.285	0
benzene	78.1	282	112	0.493	0.715	0.285	1250
n-hexane	86.2	282	112	0.447	0.715	0.285	1134
toluene	92.1	282	112	0.418	0.715	0.285	1060
n-hexadecane	226.4	282	112	0.170	0.715	0.285	431
n-eicosane	282.5	282	112	0.136	0.715	0.285	346
V0B diesel surrogate	186.5	282	112	0.207	0.715	0.285	524
POSF 4658 jet fuel	??	282	112	??	0.715	0.285	??
CFA diesel	??	282	112	??	0.715	0.285	??

MW_d = average molecular weight of the dopant
Q_m = volumetric flowrate of methane at 25 C and 1 atm
Q_i = volumetric flowrate of the inert (nitrogen) at 25 C and 1 atm
Q_d = volumetric flowrate of the dopant at 25 C and 1 atm
X_m = mole fraction of methane in the fuel mixture
X_i = mole fraction of the inert (nitrogen) in the fuel mixture
X_d = mole fraction of dopant in the fuel mixture

Burner: The measurements were performed in a Yale Coflow Burner, which has the dimensions shown in the figure below.


chimney
aluminum
4” OD
3” ID
1/2” thick
fuel tube
316 SS
3/16” OD
5/32” ID
1/64” thick
fuel tube extends
4 mm above
honeycomb
honeycomb
HAST-X
1/32” cell size
0.002” foil thickness
burner body
aluminum
3 1/2” OD
3” ID
1/4” thick
air
fuel
air
glass beads
3 mm diameter