International Sooting Flame Workshop
Baseline Radiation Model

The baseline radiation model is a gray, optically thin (emission only) model that has been adopted by the International Workshop on Measurement and Computation of Turbulent Nonpremixed Flames (TNF Workshop), augmented to include soot radiation. The TNF radiation model accounts for emission from four gas-phase species: CO_2, H_2O, CH_4 and CO. The temperature variation of the Planck-mean absorption coefficient for each species is expressed as a polynomial, where the polynomial coefficients have been fit to match the RADCAL radiation property database over the temperature range 300 K to 2500 K. Technical details and acknowledgements can be found on the TNF website and the references that are cited there: see www.sandia.gov/TNF/radiation.html. The soot radiation model can be found in Guo, Liu & Smallwood, *Combust. Theory Modell*. **8**:475-489 (2004), for example. That was based on the model in Smooke *et al*., *Combust. Flame* **117**:117-139 (1999), which in turn was derived from the model in Grosshandler, *NIST Technical Note 1402* (1993).

A summary of the basic model quantities, their dimensions and the relationships among them follows.

Physical constants

p_{atm} Atmospheric pressure: p_{atm} = 101325. Pa

σ Stefan-Boltzmann constant: $\sigma = 5.67051 \cdot 10^{-8}$ W/(m^{2}K^4)

Model constants

Polynomials and coefficients giving the temperature dependence of individual gas species partial-pressure Planck-mean absorption coefficients are given on the TNF website

C_{soot} Soot radiation model constant: $C_{soot} = 3.334 \cdot 10^{-4}$ W/(m^{3}K^5)

Physical variables

T Temperature (K)

T_∞ Background temperature (K) - see TNF website for a note on the use of T_∞

p Mixture pressure (atm)

χ_α Mole fraction of gas species α

p_α Partial pressure of gas species α (atm)

$\kappa_{p\alpha}$ Partial-pressure Planck-mean absorption coefficient for gas species α (1/(m-atm))

κ_α Planck-mean absorption coefficient for gas species α (1/m)

Q_α Volumetric radiative emissive power for gas species α (W/m^3)

f_v Soot volume fraction

κ_{soot} Effective Planck-mean absorption coefficient for soot (1/(m))

Q_{soot} Volumetric radiative emissive power for soot (W/m^3)

Q_{tot} Total volumetric radiative emissive power (W/m^3)

Relationships/equations

$p_\alpha = p \cdot \chi_\alpha$

$\kappa_{p\alpha} = \kappa_{p\alpha}(T)$ from the polynomials given on the TNF website

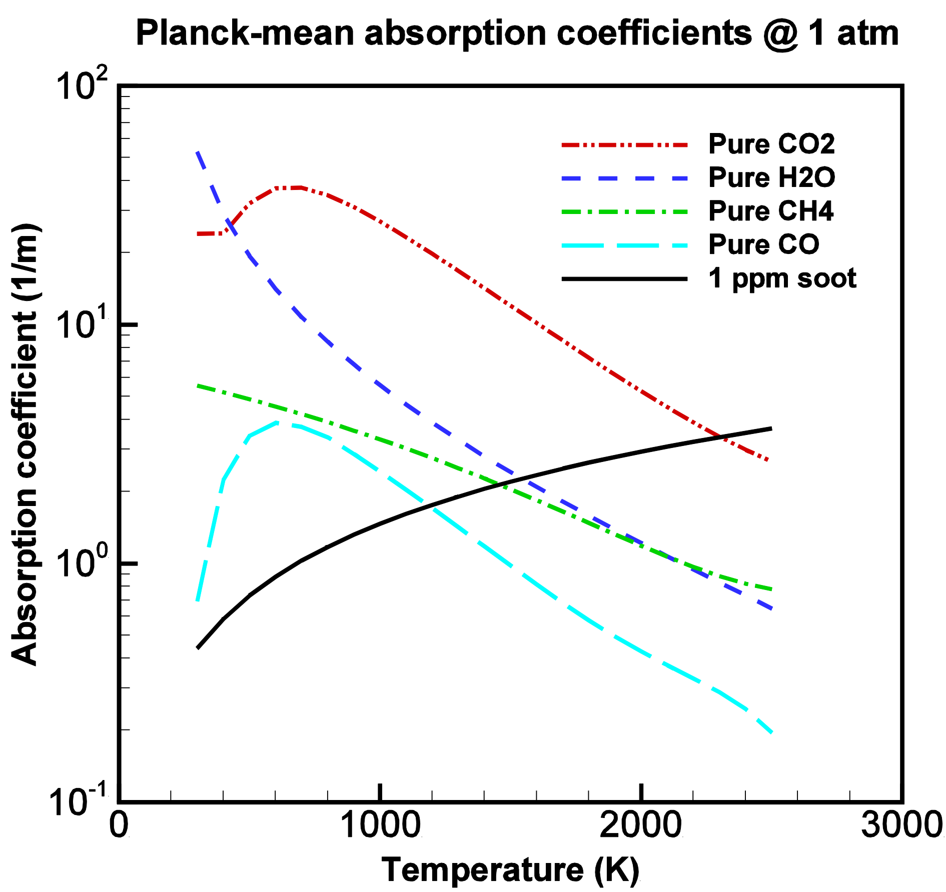
$\kappa_\alpha = p_\alpha \cdot \kappa_{p\alpha}$

$Q_\alpha = 4\sigma \kappa_\alpha \cdot (T^4 - T_\infty^4)$

$Q_{soot} = C_{soot} \cdot f_v \cdot T^5$

$$\kappa_{soot} = Q_{soot}/(4\sigma T^4) = C_{soot} \cdot f_v \cdot T/(4\sigma)$$
$$Q_{tot} = \Sigma_\alpha(Q_\alpha) + Q_{soot} = \Sigma_\alpha(\kappa_\alpha) \cdot 4\sigma(T^4 - T_\infty^4) + \kappa_{soot} \cdot 4\sigma \cdot T^4$$

For a species partial pressure of one atmosphere (p_α = 1 atm), the numerical value of $\kappa_{p\alpha}(T)$ is equal to that of $\kappa_\alpha(T)$. For soot, the effective Planck-mean absorption coefficient $\kappa_{soot}(T)$ is proportional to the soot volume fraction and to the temperature. The figure below shows the species Planck-mean absorption coefficients $\kappa_\alpha(T)$ for pure CO_2, H_2O, CH_4 and CO as functions of temperature (300 K $\le T \le$ 2500 K) for p = 1 atm. These are identical to the corresponding curves for $\kappa_{p\alpha}(T)$ that are provided in the figure on the TNF website. Also shown is $\kappa_{soot}(T)$ over the same temperature range for a soot volume fraction of 1 ppm ($f_v = 10^{-6}$).



Contact information
Dan Haworth
Department of Mechanical & Nuclear Engineering
The Pennsylvania State University
232 Research East Building
University Park, PA 16802 USA
dch12@psu.edu