SMOKE MEASUREMENT

Environmental Systems Products
Gary Full
Standard Smoke Meter
(light beam passes through entire smoke column)

Defining Relationship

\[ T_{gl} := e^{-K_{gl} \cdot N_{smk\_total}} \]

- \( T_{gl} \): Green light transmittance (1-opacity) measurement.
- \( K_{gl} \): Apparent cross-sectional size per particle at green light wavelength.
- \( N_{smk\_total} \): Total number of smoke particles per unit cross-section.
Remote Sensing Smoke Measurement
(light beam passes through a portion of smoke column)

Defining Relationship

\[ T_{uv} := e^{-K_{uv} \cdot N_{smk\_frac}} \]

- **UV transmittance (1-opacity) measurement**
- **Apparent cross-sectional size per particle at UV wavelength.**
- **The number of smoke particles per unit cross-sectional area; a fraction of total.**
Remote Sensing Foundation

• Since the sensing beam does not necessarily pass through the entire exhaust column, “total” exhaust measurements are not possible.

• On the other hand, for a small time period (time prior to significant diffusion or stratification effects), the exhaust can be treated as a uniform mixture at any instant in time. This means the ratio measurement of one exhaust component to another exhaust component is accurate.

• Remote sensing measurements are ratios!
Other Gas Relationships
(simplified approximations)

Defining Relationships

\[ T_{CO} := e^{-K_{CO} \cdot N_{CO\_frac}} \]
\[ T_{CO2} := e^{-K_{CO2} \cdot N_{CO2\_frac}} \]
\[ T_{HC} := e^{-K_{HC} \cdot N_{HC\_frac}} \]

\[ N_{CO\_frac} := \frac{-\ln(T_{CO})}{K_{CO}} \]
\[ N_{CO2\_frac} := \frac{-\ln(T_{CO2})}{K_{CO2}} \]
\[ N_{HC\_frac} := \frac{-\ln(T_{HC})}{K_{HC}} \]
Our Smoke Number
(a value proportional to number of exhaust smoke particles per unit fuel)

\[
SF := \frac{-100 \cdot \ln(T_{uv})}{N_{CO2\_frac} + N_{CO\_frac} + N_{HC\_frac}}
\]

where

- \(N_{CO2\_frac}\) is amount of plume CO2 in %-cm
- \(N_{CO\_frac}\) is amount of plume CO in %-cm
- \(N_{HC\_frac}\) is amount of plume HC in %-cm
SF Summary

• Numerator is result of opacity-based measurement across an unknown portion of the exhaust column. Measurement is made at UV wavelengths (~232nm) which is the ~wavelength for peak mass density of diesel particulate.

• Denominator is the sum of measured carbon-based gases across the same unknown portion of the exhaust column. Carbon-based components can only come from the fuel.

• The ratio is an accurate representation of smoke per unit fuel at the instant (0.5-second) that the data is acquired.

• Smoke can be represented as particle density or as mass density per unit fuel through proper engineering units.