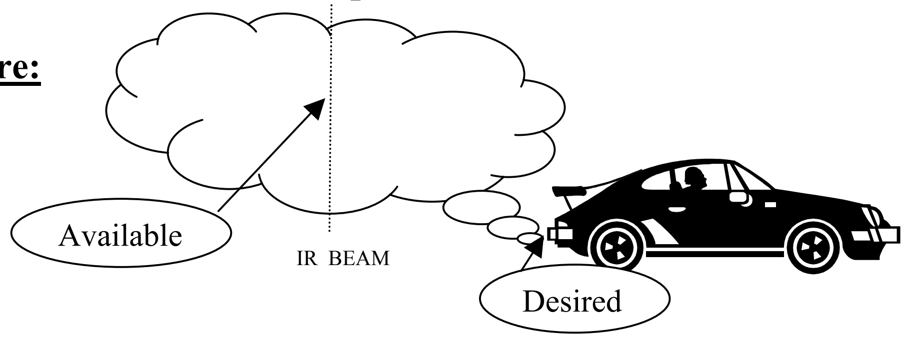
RSD Calculations: A Brief Description

A. <u>Procedure:</u>



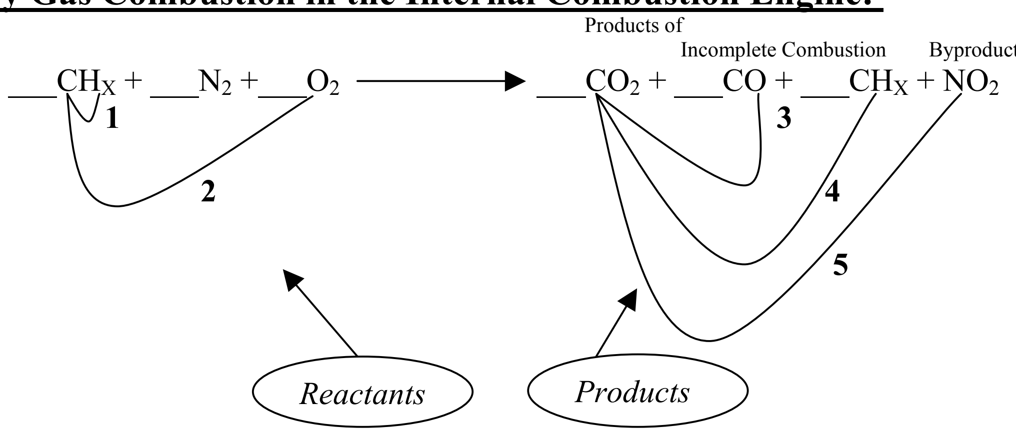
We are interested in determining the <u>tailpipe</u> concentrations of CO, HC, CO_2, and NO_X. However, we can only measure pollutant concentrations in the plume behind the passing motor vehicle. Because this plume is being diluted and dispersed, rather than attempt to measure the <u>dynamic</u> *absolute* concentrations in the diluted plume, we measure the <u>stable</u> *relative* concentrations of the pollutants and derive the tailpipe concentrations using our knowledge of combustion chemistry. *Dr. Donald Stedman's (the recognized inventor of remote sensing) paper explains scientifically why we can assume the ratios of CO/CO_2, CH_X/CO_2, and NO_X/CO_2 do not change as the plume disperses.*[i]

B. <u>Complete Combustion:</u>

$$\_\_\_\_CH_X + \_\_\_O_2 \longrightarrow \_\_\_CO_2 + \_\_\_H_2O$$

Complete and "perfect" combustion (oxidation) of fuel produces only carbon dioxide (CO_2) and water. In the internal combustion engine, some fuel (CH_X) is left unburned and some is only partially oxidized to CO. NO_X is produced at elevated engine temperatures when N_2, 79% of ambient air, is oxidized by O_2. The challenge in remote sensing is to determine the tailpipe concentrations knowing only the ratios of the exhaust pollutants behind the vehicle. We are able to do this by applying our knowledge of the stoichiometry (the mass balance in chemical reactions) of "dry" gas combustion.

C. <u>Dry Gas Combustion in the Internal Combustion Engine:</u>



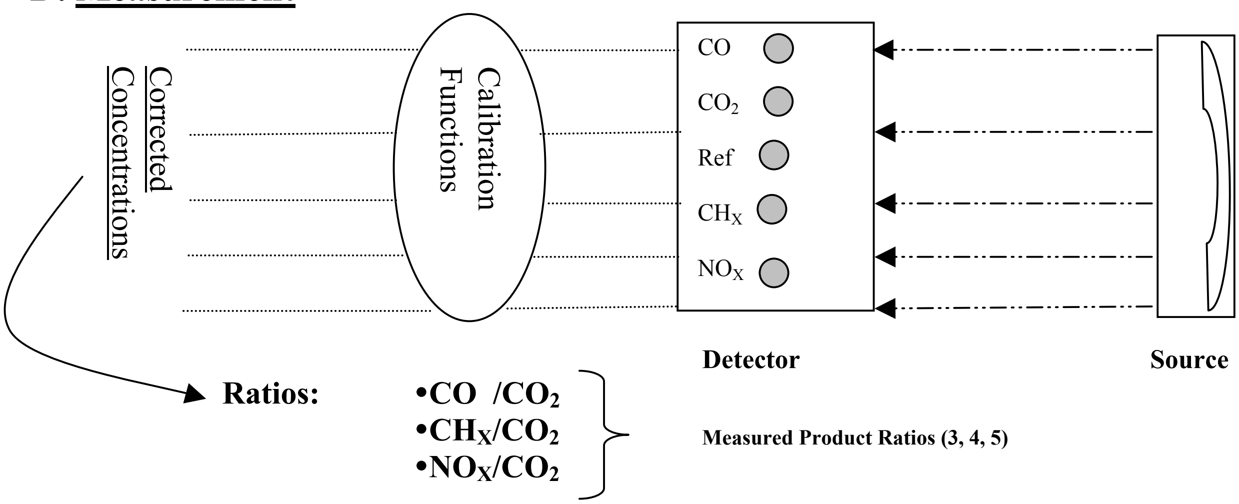
Relevant Ratios

<u>Assumed:</u>	1, 2
<u>Measured:</u>	3, 4, 5

On the reactants side of the chemical equation we can assume the required ratios (1, 2). We assume a hydrogen to carbon ratio (x) for typical refined gasoline. We also assume an air to fuel ratio for stoichiometric (just enough air to burn all the fuel) internal combustion. Again Stedman's paper in Chemical Accounts addresses the validity of these assumptions.

The remote sensing device (RSD) measures the required ratios on the product side.

D. Measurement



The RSD is an assembly of infrared light detectors each focused on the characteristic absorption frequency of a pollutant of interest. Absorption of light at a pollutant's characteristic frequency produces a voltage deflection in our RSD. A calibration equation mathematically relates a detector's voltage signals to corresponding pollutant levels. Detector calibration equations are derived experimentally in the laboratory. To RSD personnel this is the process of coefficient generation. Once the absorption signals are calibration compensated, ratios of the pollutant levels in the diluted exhaust plume are calculated. These ratios provide the necessary information on the reactant side of the "dry" gas combustion equation (3, 4, 5). A pictorial description of the RSD and the 3 systems that comprise the RSD is available on our website (www.rsd-remotesensing.com).

E. Calculating Concentrations

Now that the relative levels of all the products and reactants are known, the fuel-based concentrations of particular combustion products in the exhaust plume can be calculated using dry gas combustion mathematics. Detailed mathematics are described on the University of Denver webpage (http://www.feat.biochem.du.edu/). Select "What is a FEAT," and click on standard combustion equation.

Note, that we are not able to determine mass through this process, only concentrations, but the fuel-based concentrations are far more useful than mass for detecting malfunctions that can cause high emissions. The value of measuring pollutant ratios is that they are strong indicators of engine combustion efficiency. An inefficiently combusting engine is quite likely a gross emitting vehicle in need of mechanical repair. In Missouri, remote sensing devices are used to identify very clean vehicles conveniently and unobtrusively so they can be exempted from their next schedule station based test. In doing so for 30+ % of the fleet, the Gateway Clean Air Program is able to focus on the vehicles that can benefit from the more comprehensive emissions inspections provided at the Gateway Clean Air inspection stations. In Texas, we use RSDs to identify high emitters so they can be inspected and repaired well in advance of their next scheduled test.

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[i] Bishop, B.A., Stedman, D.H. Measuring the Emissions of Passing Cars. Accounts of Chemical Research, Volume 29, Number 10, Pages 489-495, March 6, 1996. Dr. Stedman can be reached at 303-871-2580.