CEE494 ChemE468 ME468 "Air Pollution Control Equipment Design" Winter 2007

1. Overview of Air Pollution Problem

1.2 Types of Air Pollutants

EPA Criteria air pollutants CO SO_2 NO_2 O_3 Lead Particles (PM10, PM2.5)

The 6 criteria air pollutants have National Ambient Air Quality Standards (NAAQS)

189 Hazardous Air Pollutants (defined by 1990 Clean Air Act Amendments)

There are *no* air quality standards for hazardous air pollutants, probably because there is no safe concentration level agreed upon.

1.3 Global Concerns

Depletion of ozone in stratosphere resulting from chlorine and other chemicals reacting with ozone and the chlorine in the stratosphere coming from decomposition of chlorofluorocarbons (CFCs) or Freons which are used as refrigerants.

Global Climate Change

Greenhouse gases such as CO_2 and CH_4 may contribute to climate change

Sources for Global Climate Change

CO_2 resulting from combustion of fossil fuels (coal, oil, etc), decomposition of solid waste, deforestation with combustion of plants and wood

What can be done?

Kyoto Protocol commits some industrial countries to reducing greenhouse gas emissions to 7% below their 1990 levels by 2009-2012.

The major CO_2 emission source in the US if the combustion of coal.

What were the major groups which lobbied California to adopt policies and regulations to limit and reduce the emissions of greenhouse gases in the State of California?

In other words, why is there so much interest and concern about climate warming in California?

The Calif Air Resources proposes requiring a 2-5 % reduction in greenhouse gas emissions in 2009, depending on vehicle type, increasing to about 30 % below projected 2009 levels by 2014. The cost-effective reduction measures identified by Calif Air Resource Board include discrete variable valve lift, dual cam phasing, turbocharging with engine downsizing, automated manual transmissions, and camless valve actuation. The Calif Air Resources Board expects that the regulations will add around $1000 to the cost of a new car in 2014 but that the increased up-front cost will be more than offset by decreased operating costs over the life of the vehicle.

The Calif Air Resources Board is required to adopt regulations by January 1, 2005.

Question: The combustion of coal is the major source of CO_2 emissions in the US, so why is California not requiring reductions in CO_2 from coal combustion facilities in Calif?

Answer: There were no coal fueled power plants in California.

The US Clean Air Act allows California to establish air pollutant emission standards for motor vehicles because the Calif air polllutant regulations were issued before the US motor vehicle emission standards and becuase California historically had the worst air pollution problems. This enables Calif to set motor vehicle emission standards which are more strict than the EPA Federal motor vehicle emission standards.

1.4 Legislative and Regulatory History

1955 Air Pollution Control Act Provided $ for research and technical assistance to States

1963 Clean Air Act Provided $ for research, grants, Public Health Service training grant started the air pollution program at Univ. of Washington.

1965 Motor Vehicle Control Act Federal Emission Standards protected auto industry from each State establishing its own motor vehicle emission standards (except for California)

1967 Amendments to 1963 Clean Air Act Provided $ for air quality region formation & this resulted in the 4 counties of King, Snohomish, Pierce and Kitsap forming the Puget Sound Air Pollution Control Region

1970 Amendments to 1963 Clean Air Act EPA took over air pollution control from US Public Health Service (who had already established the Ambient Air Quality Standards). Required States to develop "State Implementation Plans" or "SIPS" for attaining and maintaining the National Air Quality Standards". Established "New Source Performance Standards" or "NSPS" for stationary sources such as pulp mills & power plants

1977 Amendments to 1963 Clean Air Act
Established "Prevention of Significant Deterioration "PSD" of the air quality in regions where the air was cleaner than the National Ambient Air Quality Standards. Identified Class I (pristine areas like National Parks), Class II (most everywhere else), and Class III (industrialized areas). No regions of the US have been identified as Class III - probably because of the acknowledgment that these areas would be susceptible to the worst air pollution and the associated harmful health effects.

1990 Amendments to 1963 Clean Air Act
US Congress recognized that EPA was slow in improving air quality so it established specific emission reduction requirements. The act made 7 sections called Title I through Title 7 and essentially made the State air pollutios Federally enforceable. Also large emission source must have operating permits which serves to see that the source obeys the regulations.

Federal Regulations for Air Pollutants

Ambient Air Quality Standards NAAQS Table 1.1 page 22 Cooper & Alley

Emission Standards

New Source Performance Standards for stationary sources "NSPS" Table 1.2 page 23

National Emission Standards for Hazardous Air Pollutants "NESHAPS" Table 1.3 page 34

Best Available Control Technology "BACT"

EPA RACT/BACT/LAER http://cfpub1.epa.gov/rblc/htm/bl02.cfm

RactBactLaer data base contains case-specific information on the "Best Available" air pollution technologies that have been required to reduce the emission of air pollutants from stationary sources (e.g., power plants, steel mills, chemical plants, etc.). & a regulation data base that summarizes EPA emission limits required in New Source Performance Standards (NSPS), National Emission Standards for Hazardous Air Pollutants (NESHAP), and Maximum Achievable Control Technology (MACT) standards.

Estimating Emissions from Sources

The US Public Health Service published a number of reports on air pollution and numbered the reports starting with AP-1. The report AP-42 "Compilation of Air Pollutant Emission Factors" is maintained and updated by the EPA and it provides information on uncontrolled and controlled emissions from any stationary sources. There is a similar report for mobile sources. The internet web site for this is at http://www.epa.gov/ttn/chief/

Permit to Construct

To construct a facility which may emit air pollutants, a permit is required. If the air pollution emissions are great enough, then the Federal "Prevention of Significant Deterioration" permit application must be prepared and submitted. The PSD permit includes air pollution dispersion calculations (using EPA dispersion modeling software) which show the predicted downwind air pollutant concentrations and increments. Table 1.4 page 28 shows the Federal PSD allowable increments for SO_2 and particles.

Emission Standard Units

Stationary source emission standards have units of:

lbs air pollutants/million Btu of heat input

grains particulate matter/standard cubic ft 7000 grains = 1.0 lb

lbs/standard cubic ft

75 ppm NOx corrected to 15 % O_2 dry volume basis (ppmvd) combustion turbine

Motor Vehicles

3.4 grams CO/mile for Light Duty vehicles

0.10 grams particulate matter/brakehorsepower-hour for heavy duty diesel vehicles

Air Pollutant Emission Source Standard Conditions

Stationary Sources Temp = 68°F Pressure = 1 atm or 29.92"Hg Dry

The oxygen concentration in combustion exhaust gases

coal fired boilers 7% oxygen on a dry basis

combustion turbines 15% oxygen on a dry basis

F-Factors for Relating Air Pollutant Concentrations to lb pollutants/million Btu Heat Input

The use of the F factor in relating the air pollutant emission concentrations from stationary combustion sources was promulgated by the US in the Oct 6, 1975 *Federal Register*. The F factor is used to reduce the amount of measured data and complexity needed to calculate the air pollutant emissions in the units of lbs air pollutant/million Btu heat input.

The air pollutant concentration in the stack gases C_s can be in units of grains/standard cubic ft for particles or parts per million by gaseous volume (dry basis).

The air pollutant mass emission rate = pmr_s and is in units of lbs/hr, tons/day, tons/year, etc.

The air pollutant emission rate E is related to the gas volumetric flow rate Qs (ft^3/hr), Cs, and the heat input rate Q_H (Btu/hr) by:

$$E := \frac{(Cs)\cdot(Qs)}{QH}$$

To obtain C_s, Q_s, and Q_H, one needs to measure (air pollutant source testing):

1) Pollutant concentration Cs
   a) mass of air pollutant sampled during source test
   Ref. Mth 5 Particles, Mth 6 SO_2, Mth 7 NOx
   b) dry standard volume of stack gas sampled

2) Stack gas volumetric flow rate
   a) stack gas velocity profile (EPA Ref Mth 2)
   b) stack gas temperature, pressure,
   c) stack gas water vapor composition (EPA Ref Mth 4)\
   d) stack gas composition & molecular weight
   (CO_2, O_2, CO, N_2 via EPA Ref Mth 3)

3) Heat Input Rate Q_H
   a) Fuel Input Rate
   b) Fuel Heat Content (proximate fuel analysis)

The heat input rate QH is not easily measured and hence the EPA allows the use of the F factor. There are 4 types of F factors, F_d (based on dry stack gas volume emitted per 10^6 Btu heat input), F_w (based on wet stack gas volume emitted per 10^6 Btu heat input), Fc (based on theoretical CO_2 volume generated by fuel combustion), and Fo (based on oxygen concentration in the stack gas)

$$E \cdot \frac{lbairpollutant}{10^6 \cdot heatinput} := \left(Cs \cdot \frac{lbairpoll}{dscf}\right) \cdot \left(Fd \cdot \frac{dscf}{10^6 \cdot heatinput}\right) \cdot \left(\frac{20.9 \cdot \%}{20.9 \cdot \% - O2 \cdot \%}\right)$$

The O2% is the oxygen dry concentration in the stack gases.

Fuel	F_d (dscf / 10^6 Btu)	F_w (wscf / 10^6Btu)	F_c (scf CO_2 / 10^6 Btu)
Coal, Anthracite	10,140	10,580	1,980
Coal, Bituminous	9,820	10,680	1,810
Coal, Lignite	9,990	12,000	1,920
Oil	9,220	10,360	1,430
Natural Gas	8,740	10,650	1,040
Propane	8,740	10,240	1,200
Wood	9,280		1,840
Wood bark	9,640		1,860
Wood bark	9,640		1,860

Example Problem Calculation of Particulate Emissions from Lignite Fueled Boiler

Given: Lignite Coal Fd = 9,990 dscf/10^6 Btu heat input
Particulate mass concentration = 0.010 grains/dscf
Gas Analysis: CO_2 = 12.0%, O_2= 9.0% N_2 = 79.0%

$$grain := \frac{lb}{7000}$$

Find: a) Particle Mass Concentration Corrected to 7% Oxygen
b) Particulate mass emission rate E in lb/10^6 Btu at 7% oxygen

Conversion of Air Pollutant Concentration Data to 7% Oxygen Basis

Pollutant concentrations specified in U.S. air pollution regulations for fossil fuel combustion sources (boilers) are often expressed on a 7% oxygen basis. These formats are used to account for dilution air that often enters through fans, cracks in ductwork expansion joints, and air pollution control equipment. The 7% oxygen format for the concentration limit ensures that the regulations are fair for all emission sources, regardless of the extent of ambient air dilution of the stack gas stream prior to the air pollutant continuous emission monitor or the emission source test location. The standard equation for the correction of concentration to a specific oxygen level is shown below:

$$Conc7O2 := ConcMeasuredO2 \cdot \left(\frac{20.9\% - 7.0\%}{20.9\% - MeasuredO2\%}\right)$$

$$ConcatMeasuredO2 := 0.010 \cdot \frac{grain}{ft^3}$$

$$MeasuredO2 := 9.0\%$$

$$Conc7PercentO2 = \blacksquare \frac{grain}{ft^3}$$

$$Conc7PercentO2 := \left(0.010 \cdot \frac{grain}{ft^3}\right) \cdot \left(\frac{20.9 - 7.0}{20.9 - 9.0}\right)$$

a) Particle Mass Concentration Corrected to 7% O_2 = 0.011681 grain/ft³

$$E := \left(0.011681 \cdot \frac{grain}{ft^3}\right) \cdot \left(9990 \cdot \frac{ft^3}{10^6 \cdot BTU}\right) \cdot \left(\frac{20.9}{20.9 - 7.0}\right)$$

$$E = 0.025066 \frac{lb}{10^6 \cdot BTU}$$

b) The particle mass emission rate = 0.025066 lb/million Btu heat input @ 7.0% oxygen