Sample Calculations

Sample Calculations, Unit 1 Stack, Method 5B/202, Run 1

Area of Sample Location

$$A_s = \pi \times \left(\frac{d_s}{2 \times 12}\right)^2$$

$$A_s = \pi \times \left(\frac{192.0}{2 \times 12}\right)^2$$

$$A_s = 201 ft^2$$

where:

A_s	= area of sample location (ft^2)
d_s	= diameter of sample location (in)
12	= conversion factor (in/ft)
2	= conversion factor (diameter to radius)

Stack Pressure Absolute

$$P_a = P_b + \frac{P_s}{13.6}$$

$$P_a = 29.27 + \frac{-0.4}{13.6}$$

$$P_a = 29.24\ in.Hg$$

where:

P_a	= stack pressure absolute (in. Hg)
P_b	= barometric pressure (in. Hg)
P_s	= static pressure (in. H_2O)
13.6	= conversion factor (in. H_2O/in. Hg)

Volume of Dry Gas Collected Corrected to Standard Temperature and Pressure

$$V_{m(std)} = \frac{17.64(V_m)(Y_d)\left(P_b + \frac{\Delta H}{13.6}\right)}{(T_m + 460)}$$

$$V_{m(std)} = \frac{17.64(55.09)(1.0141)\left(29.27 + \frac{1.26}{13.6}\right)}{(104 + 460)}$$

$$V_{m(std)} = 51.33 scf$$

where:

$V_{m(std)}$	= volume of gas collected at standard temperature and pressure (scf)
V_m	= volume of gas sampled at meter conditions (ft^3)
Y_d	= gas meter correction factor (dimensionless)
P_b	= barometric pressure (in. Hg)
ΔH	= average sample pressure (in. H_2O)
T_m	= average gas meter temperature (^oF)
13.6	= conversion factor (in. H_2O/in. Hg)
17.64	= ratio of standard temperature over standard pressure (^oR/in. Hg)
460	= conversion (^oF to ^oR)

Volume of Water Vapor Collected Corrected to Standard Temperature and Pressure

$$V_{w(std)} = 0.04715 \times (V_{wc} + V_{wsg})$$

$$V_{w(std)} = 0.04715 \times (173.7 + 33.3)$$

$$V_{w(std)} = 9.76 scf$$

where:

$V_{w(std)}$	= volume of water vapor at standard conditions (scf)
V_{wc}	= weight of liquid collected (g)
V_{wsg}	= weight gain of silica gel (g)
0.04715	= volume occupied by one gram of water at standard temperature and pressure (ft^3/g)

Percent Moisture[2]

$$B_{ws} = 100 \times \left[\frac{V_{w(std)}}{\left(V_{m(std)} + V_{w(std)}\right)} \right]$$

$$B_{ws} = 100 \times \left[\frac{9.76}{(51.33 + 9.76)} \right]$$

$$B_{ws} = 16.0\%$$

where:

B_{ws}	= moisture content of the gas stream (%)
$V_{m(std)}$	= volume of gas collected at standard temperature and pressure (scf)
$V_{w(std)}$	= volume of water vapor at standard conditions (scf)
100	= conversion factor

Molecular Weight of Dry Gas Stream[3]

$$M_d = \left(44 \times \frac{\%CO_2}{100}\right) + \left(32 \times \frac{\%O_2}{100}\right) + \left(28 \times \frac{(\%N_2)}{100}\right)$$

$$M_d = \left(44 \times \frac{13.0}{100}\right) + \left(32 \times \frac{5.83}{100}\right) + \left(28 \times \frac{(81.1)}{100}\right)$$

$$M_d = 30.31 lb / lbmole$$

where:

M_d	= molecular weight of the dry gas stream (lb/lb-mole)
$\%CO_2$	= carbon dioxide content of the dry gas stream (%)
44	= molecular weight of carbon dioxide (lb/lb-mole)
$\%O_2$	= oxygen content of the dry gas stream (%)
32	= molecular weight of oxygen (lb/lb-mole)
$\%N_2$	= nitrogen content of the dry gas stream (%)
28	= molecular weight of nitrogen and carbon monoxide (lb/lb-mole)
100	= conversion factor

[2] The moisture saturation point is used for all calculations if it is exceeded by the actual moisture content.
[3] The remainder of the gas stream after subtracting carbon dioxide and oxygen is assumed to be nitrogen.

Molecular Weight of Wet Gas Stream

$$M_s = \left(M_d \times \left(1 - \frac{B_{wsat}}{100}\right)\right) + \left(18 \times \frac{B_{wsat}}{100}\right)$$

$$M_s = \left(30.31 \times \left(1 - \frac{15.4}{100}\right)\right) + \left(18 \times \frac{15.4}{100}\right)$$

$$M_s = 28.42 lb / lbmole$$

where:

M_s	= molecular weight of the wet gas stream (lb/lb-mole)
M_d	= molecular weight of the dry gas stream (lb/lb-mole)
B_{wsat}	= moisture saturation point of the gas stream (%)
18	= molecular weight of water (lb/lb-mole)
100	= conversion factor

Velocity of Gas Stream

$$V_s = 85.49 (C_p)(\sqrt{\Delta P}) \sqrt{\frac{(T_s + 460)}{(M_s)\left(P_b + \frac{P_s}{13.6}\right)}}$$

$$V_s = 85.49 (0.84)(0.740) \sqrt{\frac{(130 + 460)}{(28.42)\left(29.27 + \frac{-0.4}{13.6}\right)}}$$

$$V_s = 44.8 ft / \sec$$

where:

V_s	= average velocity of the gas stream (ft/sec)
C_p	= pitot tube coefficient dimensionless
$\sqrt{\Delta P}$	= average square root of velocity pressures (in. H_2O)$^{1/2}$
T_s	= average stack temperature (^oF)
M_s	= molecular weight of the wet gas stream (lb/lb-mole)
P_b	= barometric pressure (in. Hg)
P_s	= static pressure of gas stream (in. H_2O)
85.49	= pitot tube constant (ft/sec)([(lb/lb-mole)(in. Hg)]/[(^{o}R)(in. H_2O)])$^{1/2}$
460	= conversion (^{o}F to ^{o}R)
13.6	= conversion factor (in. H_2O/in. Hg)

Volumetric Flow of Gas Stream - Actual Conditions

$$Q_a = 60(V_s)(A_s)$$

$$Q_a = 60(44.8)(201)$$

$$Q_a = 540{,}076 acfm$$

where:

Q_a	= volumetric flow rate of the gas stream at actual conditions (acfm)
V_s	= average velocity of the gas stream (ft/sec)
A_s	= area of duct or stack (ft^2)
60	= conversion factor (min/hr)

Volumetric Flow of Gas Stream - Standard Conditions

$$Q_{std} = \frac{17.64(Q_a)\left(P_b + \frac{P_s}{13.6}\right)}{(T_s + 460)}$$

$$Q_{std} = \frac{17.64(540{,}076)\left(29.27 + \frac{-0.4}{13.6}\right)}{(130 + 460)}$$

$$Q_{std} = 472{,}358 scfm$$

where:

Q_{std}	= volumetric flow rate of the gas stream at standard conditions (scfm)
Q_a	= volumetric flow rate of the gas stream at actual conditions (acfm)
T_s	= average stack temperature (°F)
P_b	= barometric pressure (in. Hg)
P_s	= static pressure of gas stream (in. H_2O)
13.6	= conversion factor (in. H_2O/in. Hg)
17.64	= ratio of standard temperature over standard pressure (°R/in. Hg)
460	= conversion (°F to °R)

Volumetric Flow of Gas Stream - Standard Conditions - Dry Basis

$$Q_{dstd} = Q_{std}\left(1 - \frac{B_{wsat}}{100}\right)$$

$$Q_{dstd} = 472{,}358\left(1 - \frac{15.4}{100}\right)$$

$$Q_{dstd} = 399{,}908 dscfm$$

where:

Q_{dstd}	= volumetric flow rate of the gas stream at standard conditions, on a dry basis (dscfm)
Q_{std}	= volumetric flow rate of the gas stream at standard conditions (scfm)
B_{wsat}	= moisture saturation point of the gas stream (%)
100	= conversion factor

Area of Nozzle

$$A_n = \pi \times \left(\frac{d_n}{2 \times 12}\right)^2$$

$$A_n = \pi \times \left(\frac{0.230}{2 \times 12}\right)^2$$

$$A_n = 0.000289 ft^2$$

where:

A_n	= area of nozzle (ft^2)
d_n	= diameter of nozzle (in)
12	= conversion factor (in/ft)
2	= conversion factor (diameter to radius)

Percent Isokinetic

$$I = \frac{0.0945(T_s + 460)(V_{m(std)})}{\left(P_b + \frac{P_s}{13.6}\right)(v_s)(A_n)(\Theta)\left(1 - \frac{B_{wsat}}{100}\right)}$$

$$I = \frac{0.0945(130 + 460)(51.33)}{\left(29.27 + \frac{-0.4}{13.6}\right)(44.8)(2.89 \times 10^{-4})(90)\left(1 - \frac{15.4}{100}\right)}$$

$$I = 99.4\%$$

where:

I	= percent isokinetic (%)
T_s	= average stack temperature (^oF)
$V_{m(std)}$	= volume of gas collected at standard temperature and pressure (scf)
P_b	= barometric pressure (in. Hg)
P_s	= static pressure of gas stream (in. H_2O)
V_s	= average velocity of the gas stream (ft/sec)
A_n	= cross sectional area of nozzle (ft^2)
Θ	= sample time (min)
B_{wsat}	= moisture saturation point of the gas stream (%)
0.0945	= constant (^0R/in. Hg)
460	= conversion (^oF to ^oR)
13.6	= conversion factor (in. H_2O/in Hg)
100	= conversion factor

Acetone Wash Blank-Particulate

$$W_a = \frac{(m_{ab})(v_{aw})}{v_{awb}}$$

$$W_a = \frac{(0.0000)(80)}{200}$$

$$W_a = 0.0000g$$

where:

W_a	= particulate mass in acetone wash, blank corrected (g)
m_{ab}	= mass collected, acetone wash blank (g)
v_{aw}	= volume of acetone wash (ml)
v_{awb}	= volume of acetone wash blank (ml)

Mass in Front Half, Acetone Blank Corrected

$$m_f = m_{fil} + (m_a - W_a)$$

$$m_f = 0.0244 + (0.0122 - 0.0000)$$

$$m_f = 0.0366g$$

where:

m_f	= mass in front half filter, and acetone wash, blank corrected (g)
m_{fil}	= mass in front half filter (g)
m_a	= mass in acetone wash (g)
W_a	= particulate mass in acetone wash blank (g)

Total Particulate Catch

$$M_n = m_f + m_b$$

$$M_n = 0.0366 + 0.0132$$

$$M_n = 0.0498g$$

where:

M_n	= total mass catch (g)
m_f	= mass in front half filter, and acetone wash, blank corrected (g)
m_b	= mass in back half organic fraction, and inorganic fraction, blank corrected (g)

Total Particulate Concentration, grains/dscf

$$C_{gr/dscf} = \frac{(M_n)(15.43)}{V_{m,std}}$$

$$C_{gr/dscf} = \frac{(0.0498)(15.43)}{51.33}$$

$$C_{gr/dscf} = 0.0150 grains/dscf$$

where:

$C_{gr/dscf}$ = particulate concentration (grains/dscf)
M_n = total particulate catch (g)
$V_{m(std)}$ = volume of gas collected at standard conditions (scf)
15.43 = conversion factor (grains/g)

Calculated F_d Factor, dscf/mmBtu

$$F_d = K((K_{hd} \times H) + (K_c \times C) + (K_s \times S) + (K_n \times N) - (K_o \times O_2))/GCV_w$$

$$F_d = 10^6((3.64 \times 5.14) + (1.53 \times 73.54) + (0.57 \times 3.60) + (0.14 \times 1.46) - (0.46 \times 5.03))/13,092$$

$$F_d = 10,019$$

where:

F_d = calculated fuel factor (dscf/mmBtu)
K = conversion factor (Btu/million Btu)
K_{hd} = constant (scf/lb)
H = weight percent hydrogen in coal (%)
K_c = constant (scf/lb)
C = weight percent carbon in coal (%)
K_s = constant (scf/lb)
S = weight percent sulfur in coal (%)
K_n = constant (scf/lb)
N = weight percent nitrogen in coal (%)
K_o = constant (scf/lb)
O_2 = weight percent oxygen in coal (%)
GCV = gross calorific value of fuel, dry (Btu/lb)

Total Particulate Emission Rate, lb/mmBtu [4]

$$E_{PM} = \frac{(M_n)(F_d)(20.9)}{(V_{m(std)})(453.6)(20.9 - O_2)}$$

$$E_{PM} = \frac{(0.0498)(10{,}019)(20.9)}{(51.33)(453.6)(20.9 - 5.83)}$$

$$E_{PM} = 0.0297 lb / mmBtu$$

where:

E_{PM}	= toal particulate matter emission rate, (lb/mmBtu)
M_n	= total particulate catch (g)
F_d	=fuel factor (dcsf/mmBtu)
20.9	= oxygen content of ambient air (%)
$V_{m(std)}$	= volume of gas collected at standard temperature and pressure (scf)
453.6	= conversion factor (g/lb)
$\%O_2$	= oxygen content of the dry gas stream (%)

Total Particulate Emission Rate, lb/hr

$$E_{lb/hr} = \frac{(M_n)(Q_{dstd})(60)}{(V_{m,std})(453.6)}$$

$$E_{lb/hr} = \frac{(0.0498)(399{,}908)(60)}{(51.33)(453.6)}$$

$$E_{lb/hr} = 51.3 lb / hr$$

where:

$E_{lb/hr}$	= particulate emission rate (lb/hr)
M_n	= total particulate catch (g)
$V_{m(std)}$	= volume of gas collected at standard conditions (scf)
Q_{dstd}	= volumetric flow rate of the dry gas stream at standard conditions (dscfm)
60	= conversion factor (min/hr)
453.6	= conversion factor (g/lb)

[4] All particulate emission rates are calculated in a similar manner.

Sample Calculations, Method 26, Run 1

Concentration of Hydrogen Chloride in Flue Gas (lb/dscf)[5]

$$C_{HCL} = \frac{(M_{HCl})}{(V_{m(std)})(10^3)(453.59)}$$

$$C_{HCl} = \frac{(3.51)}{(87.84)(10^3)(453.59)}$$

$$C_{HCl} = 8.81 \times 10^{-8}\, lb/dscf$$

where:

C_{HCl}	= concentration of hydrogen chloride in flue gas (lb/dscf)
M_{HCl}	= mass of hydrogen chloride collected in sample (mg)
$V_{m(std)}$	= volume of gas collected at standard temperature and pressure (scf)
10^3	= conversion factor (mg/g)
453.59	= conversion factor (g/lb)

Concentration of Hydrogen Chloride in Flue Gas (ppmdv)[6]

$$C_{ppmv} = \frac{(M_{HCl})(385.3)(10^6)}{(MW_{HCl})(V_{m(std)})(10^3)(453.59)}$$

$$C_{ppmv} = \frac{(3.51)(385.3)(10^6)}{(36.458)(87.84)(10^3)(453.59)}$$

$$C_{ppmv} = 0.931\, ppmdv$$

where:

C_{ppmv}	= concentration of hydrogen chloride in flue gas (ppmv)
M_{HCl}	= mass of hydrogen chloride collected in sample (mg)
385.3	= volume occupied by one pound gas at standard conditions (dscf/lbmole)
10^6	= conversion factor (fraction to ppm)
MW_{HCl}	= molecular weight of hydrogen chloride (lb/lb-mole)
$V_{m(std)}$	= volume of gas collected at standard temperature and pressure (scf)
10^3	= conversion factor (mg/g)
453.59	= conversion factor (g/lb)

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[5] The concentration of HF is calculated in a similar manner.

[6] The concentration of HF is calculated in a similar manner using the appropriate molecular weight.

Hydrogen Chloride Emission Rate, lb/mmBtu[7]

$$E_{HCl} = \frac{(C_{HCl})(F_d)(20.9)}{(20.9 - O_2)}$$

$$E_{HCl} = \frac{(8.81 \times 10^{-8})(10{,}019)(20.9)}{(20.9 - 5.83)}$$

$$E_{HCl} = 0.00122 lb / mmBtu$$

where:

E_{HCl}	= hydrogen chloride emission rate, (lb/mmBtu)
C_{HCl}	= hydrogen chloride concentration, (lb/dscf)
F_d	=fuel factor (dcsf/mmBtu)
20.9	= oxygen content of ambient air (%)
$\%O_2$	= oxygen content of the dry gas stream (%)

Hydrogen Chloride Emission Rate[8]

$$E_{HCl} = C_{HCl} \times Q_{dstd} \times 60$$

$$E_{HCl} = 8.81 \times 10^{-8} \times 372{,}370 \times 60$$

$$E_{HCl} = 1.97 lb / hr$$

where:

E_{HCl}	= hydrogen chloride emission rate, (lb/hr)
C_{ppmdv}	= hydrogen chloride concentration, dry basis, (ppmdv)
Q_{dstd}	= volumetric flow rate of the dry gas stream at standard conditions (dscfm)
MW	= molecular weight of hydrogen chloride (lb/lbmole)
60	= conversion factor (min/hr)
385.3	= volume occupied by one pound gas at standard conditions (dscf/lbmole)
10^6	= conversion factor (fraction to ppm)

[7] The emission rate of CO is calculated in a similar manner.
[8] The CO emission rate was calculated in a similar manner.

Sample Calculations, Method 29, Run 1

Concentration of Lead in Flue Gas, ug/dscm[9]

$$C_{ug/dscm} = \frac{(M_C)}{(V_{m(std)})}(35.31)$$

$$C_{ug/dscm} = \frac{(7.15)}{(68.06)}(35.31)$$

$$C_{ug/dscm} = 3.71 ug/dscm$$

where:

$C_{ug/dscm}$	= concentration of lead in flue gas (ug/dscm)
M_C	= mass of lead in sample (ug)
$V_{m(std)}$	= volume of gas collected at standard temperature and pressure(scf)
35.31	= conversion factor (ft^3/m^3)

Emission Rate of Lead in Flue Gas, lb/mmBtu[10]

$$E = \frac{(C_{ug/dscm})(F_d)(20.9)}{(35.315)(20.9 - \%O_2)(453.6)(10^6)}$$

$$E = \frac{(3.71)(10{,}019)(20.9)}{(35.315)(20.9 - 10.0)(453.6)(10^6)}$$

$$E = 4.45 \times 10^{-6} lb/mmBtu$$

where:

E	= lead emission rate (lb/mmBtu)
$C_{ug/dscm}$	= lead concentration (ug/dscm)
F_d	=fuel factor (dcsf/mmBtu)
35.315	=conversion factor (ft^3/m^3)
20.9	= oxygen content of ambient air (%)
$\%O_2$	= oxygen content of the dry gas stream (%)
453.6	= conversion factor (g/lb)
10^6	= conversion factor (ug/g)

[9] The concentrations of all MHs and mercury are calculated in a similar manner.
[10] The emission rates of all MHs and mercury are calculated in a similar manner.

Lead Emission Rate, lb/hr[11]

$$E_{lb/hr} = \frac{(C_{ug/dscm})(Q_{dstd})(60)}{(35.31)(10^6)(453.6)}$$

$$E_{lb/hr} = \frac{(3.71)(403{,}055)(60)}{(35.31)(10^3)(10^3)(453.6)}$$

$$E_{lb/hr} = 0.00560 lb/hr$$

where:

$E_{lb/hr}$	= lead emission rate (lb/hr)
$C_{ug/dscm}$	= lead concentration (ug/dscm)
Q_{dstd}	= volumetric flow rate of dry gas stream at standard conditions (dscfm)
10^3	= conversion factor (ug/mg)
10^3	= conversion factor (mg/g)
35.31	= conversion factor (ft^3/m^3)
60.0	= conversion factor (min/hr)
453.59	= conversion factor (g/lb)

[11] The emission rates of all MHs and mercury are calculated in a similar manner.