



State of Oregon Department of Environmental Quality

OAR 340-232-0170

Attachments

SOURCE TEST PROCEDURE **ST-7**

ORGANIC COMPOUNDS

REF: Regulation 8

1. APPLICABILITY

- 1.1 This procedure is used to quantify emissions of organic compounds. It is applicable to the determination of compliance with Regulation 8.
- 1.2 The combustion technique detailed in ST-7 is not applicable when carbon dioxide constitutes over 85%, on a molar basis, of the total carbon (organic plus inorganic, as C₁), in the sample.
- 1.3 The use of a flame ionization detector (FID) for direct measurement of organic compounds may be used when carbon dioxide constitutes over 85%, on a molar basis, of the total carbon in the sample.

2. PRINCIPLE

- 2.1 **Combustion Technique:** A continuous sample of effluent is passed through a combustion tube. The combusted sample is conditioned to remove water and particulate. The continuously combusted sample is analyzed for Total Carbon (TC) using a non-dispersive infrared (NDIR) CO₂ analyzer. At the same time, a continuous sample of effluent is conditioned to remove water and particulate material. This sample which has bypassed the combustion tube is analyzed to determine the background CO₂, CO, and methane concentrations which are subtracted from the TC value to determine the non-methane organic carbon (NMOC) concentration. The background CO₂ concentration is measured using the same NDIR as that used to measure TC.
- 2.2 **FID Direct Measurement:** A continuous sample of effluent is conditioned to remove water and particulate material. The conditioned sample is analyzed for total hydrocarbons (THC) by FID. NMOC concentration is calculated by subtracting the methane concentration from the THC concentration.
- 2.3 The methane content of the sample is determined either (A) by filling an evacuated cylinder with sample for subsequent gas chromatographic analysis or (B) by directing a portion of the conditioned sample through a bed of activated carbon to remove NMOC and then into a FID.

3. RANGE AND SENSITIVITY

- 3.1 The minimum measurable concentration of carbon dioxide is 10 ppm if the appropriate NDIR cell is used.
- 3.2 The maximum concentration of organic compounds for which the combustion technique in this procedure is applicable is 5% when the appropriate NDIR cell is used.
- 3.3 The minimum sensitivity of the NDIR is 2% of full scale.
- 3.4 Use of the combustion technique requires a molar concentration ratio of oxygen to VOC of 5:1 or greater.

- 3.5 The minimum measurable concentration of THC by FID is 5 ppmv when interferences are not present.
- 3.6 The minimum sensitivity of the FID is 2% of full scale.

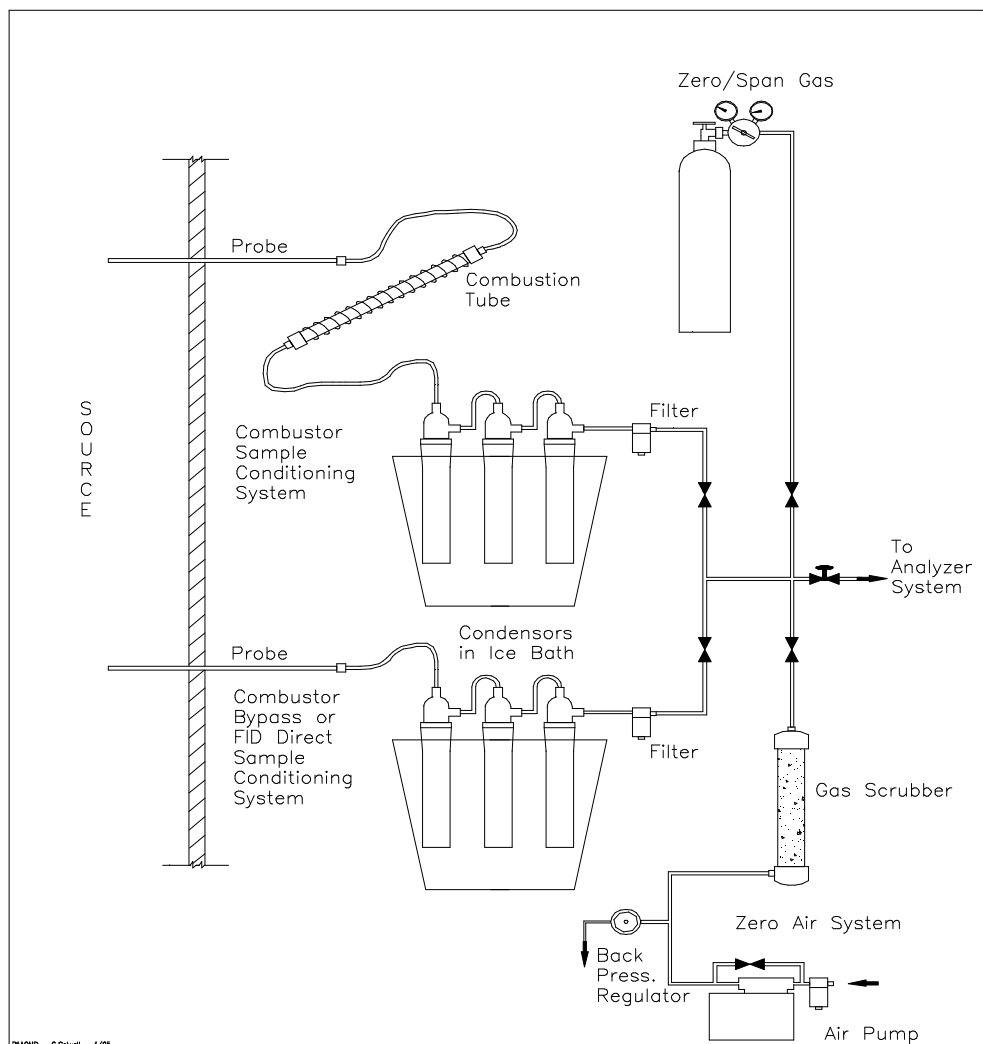
4. INTERFERENCES

- 4.1 Combustion Technique: Negative bias may occur due to reaction of highly reactive organics (e.g., aldehydes or acids) with internal surfaces or if the condensation point of the sample is above the condenser temperature. Combustion at the emission point, prior to condenser and the use of the minimum probe to combustor tubing length, greatly reduces this bias.
- 4.2 Combustion Technique: High concentrations or widely varying concentrations of methane, carbon monoxide or carbon dioxide may adversely affect the accuracy of this procedure for the measurement of the organic compounds present. Alternate methods may be used upon prior approval by the Source Test Section Manager.
- 4.3 FID Direct Measurement: Response factors vary between hydrocarbons. Propane used as a span gas minimizes this variability. The measurement of chlorinated hydrocarbons, in some instances, may require the use of an alternative span gas. Use of an alternative span gas must be approved by the Source Test Manager.
- 4.4 FID Methane Measurement: The activated charcoal scrubber adsorbs non-methane hydrocarbons from sample gas before its subsequent analysis by FID. Previous contamination or unclean activated charcoal in this scrubber can lead to the determination of erroneously high levels of methane. This problem is obviated by establishing a zero methane base-line response. Methane determination requires that the response time must be sufficient to allow for the residence time of sample gas in the carbon adsorber.

5. APPARATUS

- 5.1 Carbon dioxide analyzer. Use a non-dispersive infrared gas analyzer (in accordance with ST-5).
- 5.2 Carbon monoxide analyzer. Use a non-dispersive infrared gas analyzer (in accordance with ST-6).
- 5.3 Flame ionization detector.
- 5.4 Chart recorder. Record the continuous output from each analyzer.
- 5.5 Sample conditioning, zero air, and span gas system. Assemble this system as shown in Figure 7-1. Sample conditioning system shall provide a dry, particulate-free gas flow to the instrument. The zero-air system shall provide clean, dry CO₂ free air for instrument calibration. The span-gas system shall provide known concentration of the appropriate gas for use in calibrating the analyzers. Except as specified, all materials which come in contact with either the sample or span gases must be constructed of Teflon or stainless steel.

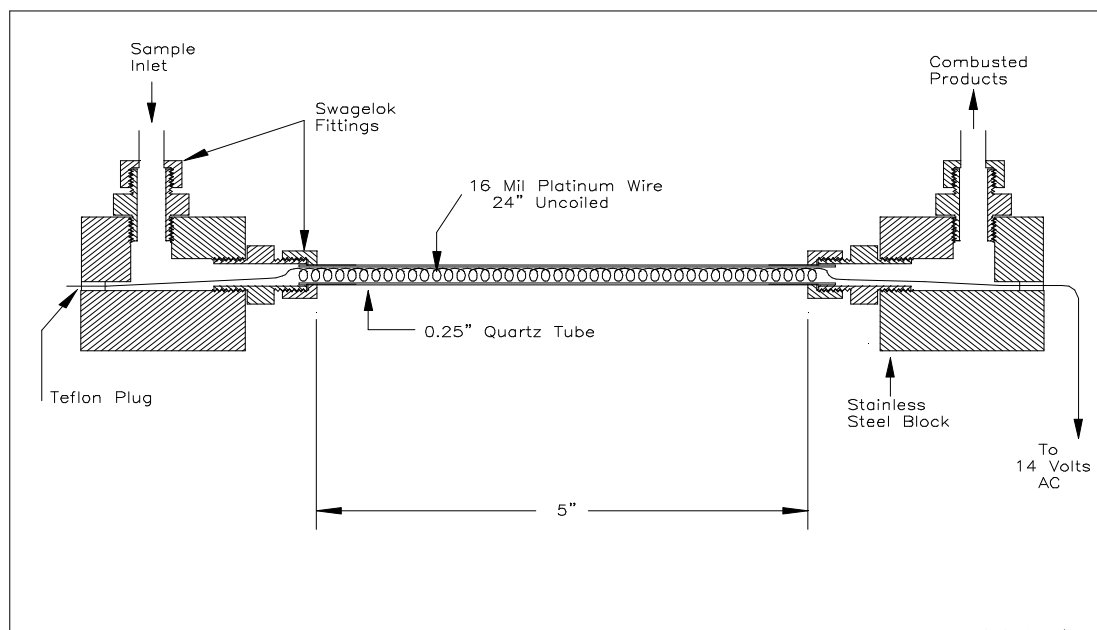
Figure 7-1
Sample Conditioning, Zero Air, Zero/Span Gas Systems



- 5.7 Sample probe. Use a tube of inert material and sufficient length to traverse the stack being tested. If the stack temperature exceeds 425C (800F), use a quartz probe. Other probes are acceptable subject to approval by the Source Test Section.
- 5.8 Condensers. Use modified Greenberg-Smith impingers with the impaction plates removed and the inlet tubes shortened to a length of 10 CM (4 inches).
- 5.9 Cooling system. Immerse the impingers in an ice bath during the test.
- 5.10 Particulate filter. Use a Balston type 95 holder with a grade B filter, or equivalent, in the sample system.
- 5.11 Pumps. Use leak-free, Teflon-lined, diaphragm pumps in the sample and zero air system. The pumps shall have a free-flow capacity of at least 28 liters/min. (1.0 CFM).

- 5.12 Gas scrubber. Use a bed of silica gel, Ascarite (or soda-lime), and charcoal to remove moisture, carbon dioxide, and hydrocarbons from the zero air system.
- 5.13 Span gas. Use a high-pressure cylinder containing a known concentration of propane in air or nitrogen. A cylinder containing a known concentration of solvent, where applicable, may also be used. This option may only be used with prior approval of the Source Test Section.
- 5.14 Combustor. Use a system to oxidize all organics in the sample including methane. Examples of acceptable combustion tubes found adequate by the BAAQMD are described in Figures 7-2 and 7-3.

Figure 7-2
Internally Heated Combustion Tube



6. PRE-TEST PROCEDURES

- 6.1 Warm-up the instruments according to manufacturers' instructions.
- 6.2 Assemble the sampling system as shown in Figure 7-4 or 7-5.
- 6.3 Leak-test the sampling system by starting the pump, plugging the probe, and assuring that the pressure to the analyzer falls to zero.
- 6.4 Introduce zero-air into the analyzers and calibrate the instruments according to manufacturers' instructions.
- 6.5 Introduce span-gas into the analyzers and calibrate the instruments according to manufacturers' instruction.
- 6.6 Conduct a preliminary concentration traverse (in accordance with ST-18) to determine if stratification of the stack gases exists. If the hydrocarbon concentration at any point differs from the average concentration by more than 10%, traverse the stack during the test; if not, sample at any single point.

Figure 7-3
Externally Heated Combustion Tube

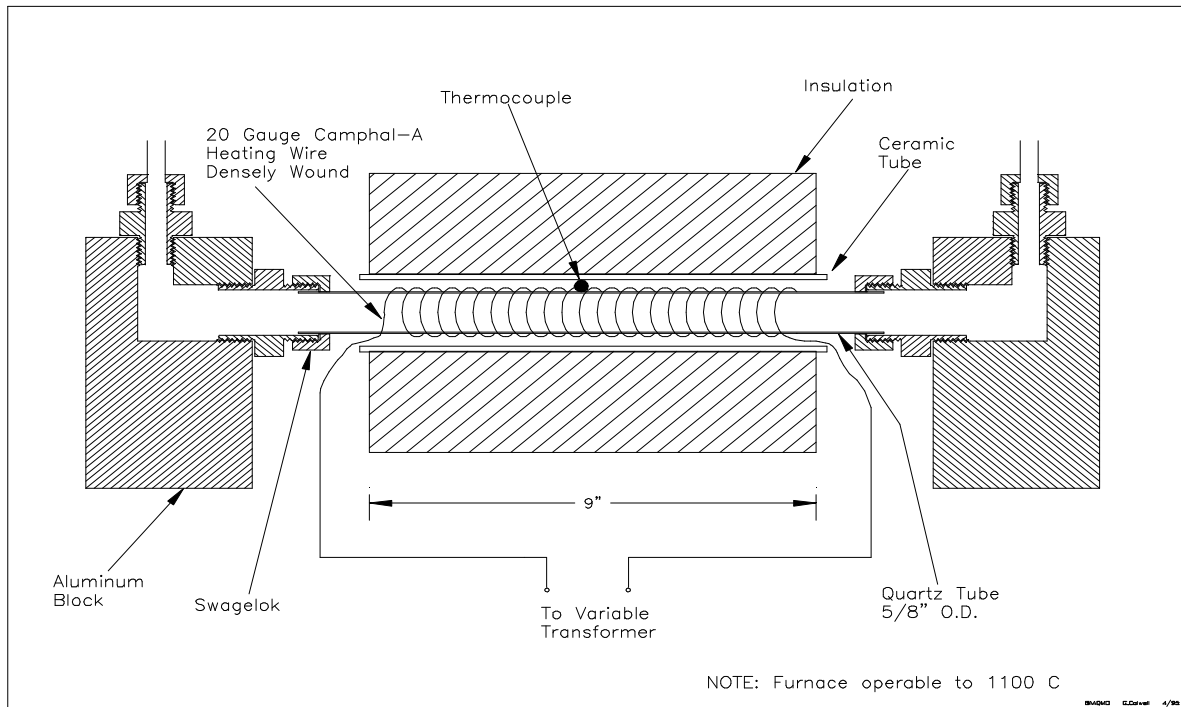


Figure 7-4
Analyzer Manifold for ST-7

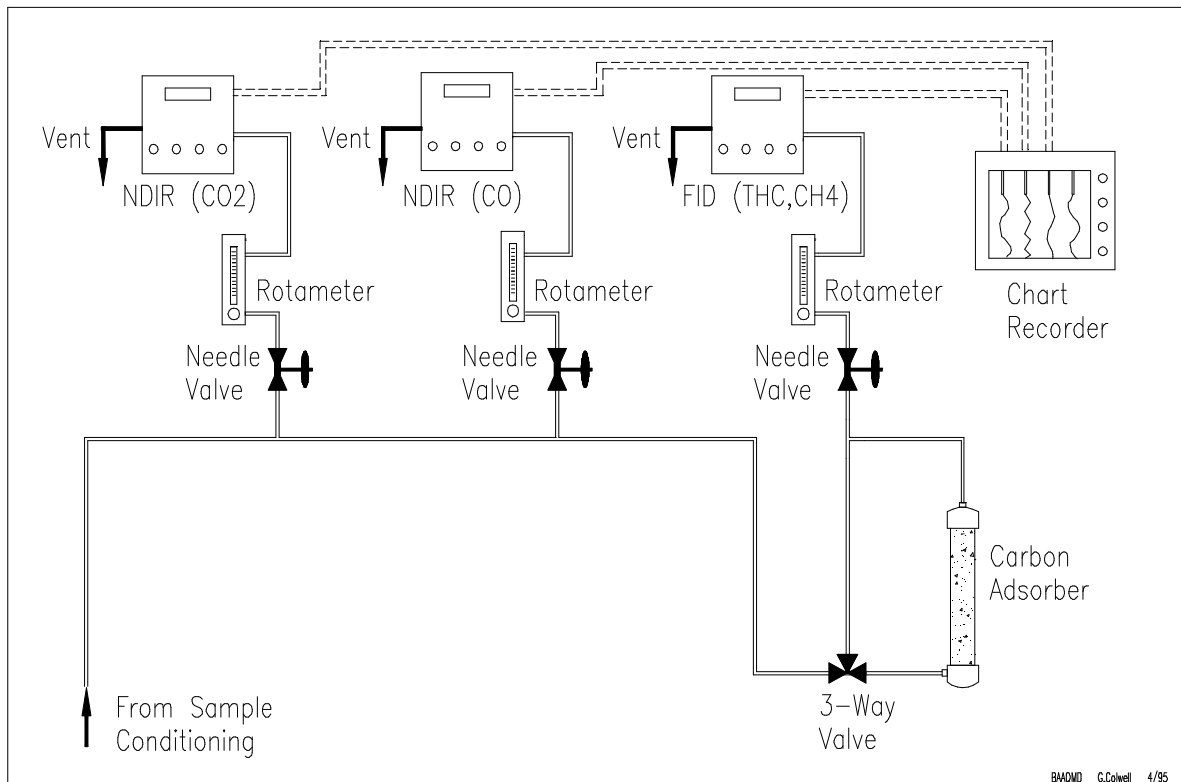
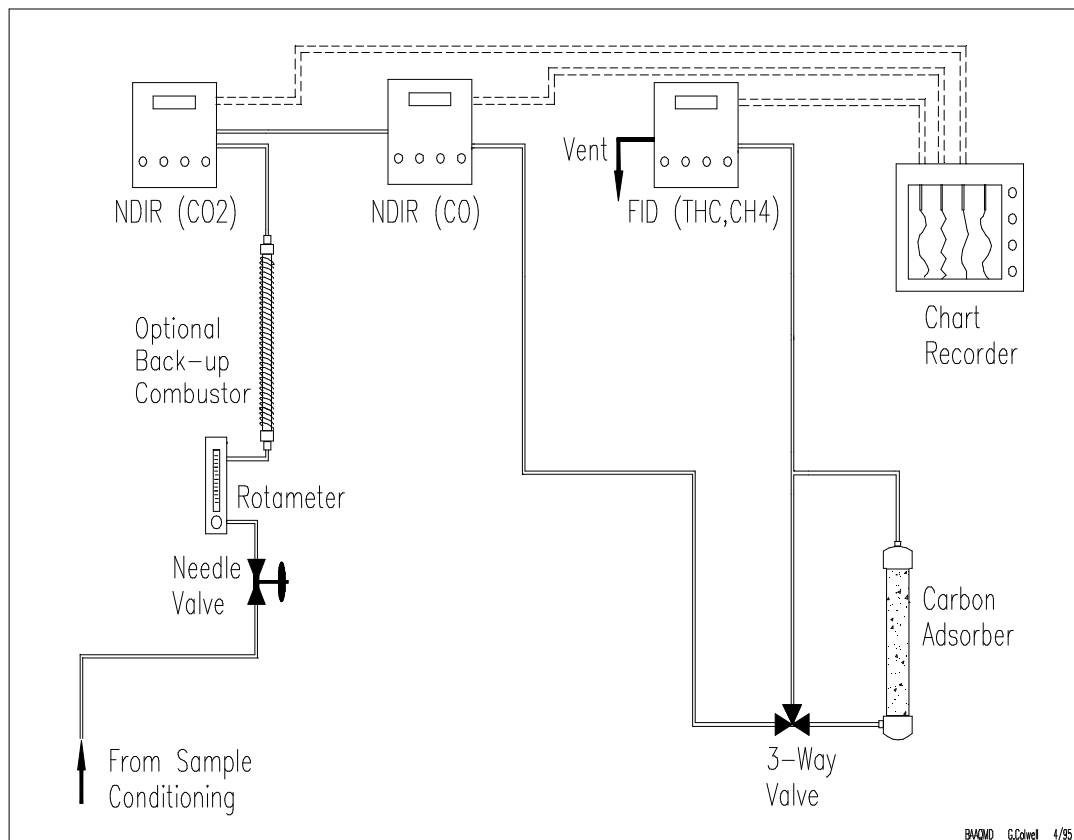


Figure 7-5

Analyzer Manifold for Combustor of Less Than 100% Efficiency



BVAQMD G.Covert 4/95

- 6.7 Prepare the chart recorder according to manufacturer's instructions.
- 6.8 Set the voltage to the combustor to at least 14 volts A.C. for the combustor illustrated in Figure 7-2. Efficiency of this combustor will be a function of the platinum wire, voltage, sample flow-rate and sample composition. All voltages will be combustor specific and efficiency data may be requested by the Source Test Section.
- 6.9 Set the temperature of the combustor to $870^{\circ}\text{C} \pm 10^{\circ}\text{C}$ ($1598^{\circ}\text{F} \pm 18^{\circ}\text{F}$) for the combustor in Figure 7-3. The residence time of sample through this combustor must be greater than 2 seconds. Efficiency data may be required by the Source Test Section.

7. SAMPLING

- 7.1 Each test run shall be of 30 minute duration when testing from continuous operations. Each test run of a batch operation shall be for 90% of the batch time or thirty minutes, whichever is less.
- 7.2 At sources requiring both inlet and outlet tests on a control device (e.g., afterburners), the test times may be adjusted to aid in obtaining representative results.
- 7.3 Introduce sample gas into the analytical system at the same flow rate used to calibrate the analyzers.

- 7.4 By-pass the combustion tube (at approximately ten minute intervals), to measure the background CO₂, CO, and methane in the sample stream.
- 7.5 Verify that the CO and THC concentrations from the combustor are zero. Non-zero concentrations of these parameters must be continuously monitored during all combustion technique testing.
- 7.6 Determine the methane concentration by either passing a portion of the sample stream through an activated carbon scrubber to remove non-methane hydrocarbons and then through a flame ionization detector or by obtaining a grab sample for analysis by Lab 17.
- 7.7 Maintain ice in the cooling system throughout the test.
- 7.8 Calibrate the analyzers before and after each test run. Record each step of the process on the chart recording.
- 7.9 Conduct three consecutive test runs.

8. AUXILIARY TESTS

- 8.1 Stack gas flow rate. Use ST-17 to determine the stack gas flow rate after each test run.
- 8.2 Moisture content. Use ST-23 to determine the moisture content of the stack gases.

9. CALCULATIONS

- 9.1 Use Equations 1 and 2 to calculate Non-Methane Organic Compound concentrations from Combustion Technique data.

$$C_{TC} = (C_{TC})_{Comb} + (C_{CO})_{Comb} + (C_{THC})_{Comb} \quad (1)$$

$$C_{NMOC} = C_{TC} - C_{CO_2} - C_{CO} - C_M \quad (2)$$

- 9.2 Use Equation 3 to calculate Non-Methane Organic Compound concentrations from FID Direct Measurement data:

$$C_{NMOC} = C_{THC} - C_M \quad (3)$$

- 9.3 Mass flow rate of the non-methane organic compounds, as carbon are calculated according to equation 4.

$$M_{NMOC} = \frac{12(\text{lb C/lb-mole C}_1) \times Q_O \times C_{NMOC} \times 60 (\text{min/hr})}{386.9 (\text{SDCF/lb-mole}) \times 10^6 (\text{ppm})} \quad (4)$$

- 9.4 Mass flow rate of Volatile Organic Compounds are calculated according to equation 5:

$$M_{\text{VOC}} = \frac{X_{\text{VOC}} \times Q_o \times C_{\text{NMOC}} \times 60 \text{ (min/hr)}}{386.9 \text{ (SDCF/lb-mole)} \times 10^6 \text{ (ppm)}} \quad (5)$$

- 9.5 Molecular weight and VOC Density Calculations. If organic mass rate emissions are subject to rules requiring the determination of precursor organic compounds or volatile organic compounds, then the average molecular weight of VOC per carbon (X_{VOC}) must be determined. If it is not practicable to determine or estimate X_{VOC} , then a value of 14 lb/lb-mol shall be used. Calculations of exhaust emission rates shall be based upon the same X_{VOC} as that determined for the inlet. Use the worksheet shown in Figure 7-6 to correctly calculate or estimate the average molecular weight.

- 9.6 Mass flow rate of carbon monoxide is calculated according to equation 6:

$$M_{\text{CO}} = \frac{28 \text{ (lb CO/lb-mole)} \times Q_o \times C_{\text{CO}} \times 60 \text{ (min/hr)}}{386.9 \text{ (SDCF/lb-mole)} \times 10^6 \text{ (ppm)}} \quad (6)$$

- 9.7 The VOC Emission Factor, $(m_{\text{Ctg}})_{\text{overall}}$, from coating operations, will be calculated according to equation 7. If organic emissions are subject to equivalent control (for example: Regulation 8 Rule 11, Section 302), the Equivalent Coatings Emission Factor, $(m_{\text{EQCtg}})_{\text{overall}}$, shall be calculated using worksheet shown in Figure 7-7. Fugitive emissions shall be added to measured emission rates by calculating solvent usage rate (lb/hr), subtracting control device inlet VOC rate and adding the result to the control device outlet VOC rate.

$$(m_{\text{Ctg}})_{\text{overall}} = \frac{(M_{\text{VOC}})_{\text{overall}}}{\text{Application Rate (gal/hr)}} \quad (7)$$

- 9.8 If organic emissions are controlled by incineration, the efficiency of oxidation to carbon dioxide for the determination of exemption in Regulation 8, Rule 1, Section 110.3, shall be calculated using equations 8 or 9. Operations whose emissions are not controlled by incineration or are not subject to the exemption, shall be calculated using equations 10 or 11.

- 9.8.1 If the control device is an incinerator and $(M_{\text{CO}})_{\text{out}}$ is greater than $(M_{\text{CO}})_{\text{in}}$, then control efficiency will be calculated using equation 8 or 9:

$$E_{\text{device}} = \frac{(M_{\text{NMOC}})_{\text{in}} - (M_{\text{NMOC}})_{\text{out}} - (12/28) \times \{(M_{\text{CO}})_{\text{out}} - (M_{\text{CO}})_{\text{in}}\}}{(M_{\text{NMOC}})_{\text{in}}} \times 100\% \quad (8)$$

$$E_{\text{device}} = \frac{(M_{\text{VOC}})_{\text{in}} - (M_{\text{VOC}})_{\text{out}} - (X_{\text{VOC}}/28) \times \{(M_{\text{CO}})_{\text{out}} - (M_{\text{CO}})_{\text{in}}\}}{(M_{\text{VOC}})_{\text{in}}} \times 100\% \quad (9)$$

9.8.2 In all other situations, the control efficiency will be calculated using equation 10 or 11:

$$E_{\text{device}} = \frac{(M_{\text{NMOC}})_{\text{in}} - (M_{\text{NMOC}})_{\text{out}}}{(M_{\text{NMOC}})_{\text{in}}} \times 100\% \quad (10)$$

$$E_{\text{device}} = \frac{(M_{\text{VOC}})_{\text{in}} - (M_{\text{VOC}})_{\text{out}}}{(M_{\text{VOC}})_{\text{in}}} \times 100\% \quad (11)$$

9.9 Overall mass rate emissions shall include fugitive emissions according to equations 12 through 15.

9.9.1 Overall mass rate emissions of Non-Methane Organic Carbon shall include fugitive emissions as given by equations 12 and 13:

$$(M_{\text{NMOC}})_{\text{fugitive}} = (M_{\text{NMOC}})_{\text{process}} - (M_{\text{NMOC}})_{\text{in}} \quad (12)$$

$$(M_{\text{NMOC}})_{\text{overall}} = (M_{\text{NMOC}})_{\text{out}} + (M_{\text{NMOC}})_{\text{fugitive}} \quad (13)$$

9.9.2 Overall mass rate emissions of Volatile Organic Compounds shall include fugitive emissions as given by equations 14 and 15:

$$(M_{\text{VOC}})_{\text{fugitive}} = (M_{\text{VOC}})_{\text{process}} - (M_{\text{VOC}})_{\text{in}} \quad (14)$$

$$(M_{\text{VOC}})_{\text{overall}} = (M_{\text{VOC}})_{\text{out}} + (M_{\text{VOC}})_{\text{fugitive}} \quad (15)$$

9.10 Sample calculations.

Example 1: Incinerator Abating Cyclohexanone

Given:

Process data shows coating applied at a rate of 8 gallons per hour. Laboratory analysis of the coating indicates it contains 5 pounds VOC per

gallon. The VOC is pure Cyclohexanone ($C_6H_{10}O$). The Incinerator outlet flow is virtually the same as the inlet flow.

Inlet measurements to the Afterburner:

$$\begin{aligned} Q_o &= 1,000 \text{ SDCFM} \\ (C_{TC})_{comb} &= 22,400 \text{ ppm} \\ (C_{CO})_{comb} &< 10 \text{ ppm} \\ (C_{THC})_{comb} &< 5 \text{ ppm} \\ C_{CO} &= 250 \text{ ppm} \\ C_M &= 150 \text{ ppm} \\ C_{CO_2} &= 10,000 \text{ ppm} \end{aligned}$$

Outlet measurements from the Afterburner:

$$\begin{aligned} C_{THC} &= 200 \text{ ppm} \\ C_M &= 100 \text{ ppm} \\ C_{CO} &= 50 \text{ ppm} \end{aligned}$$

Calculation of Afterburner Inlet parameters:

$$\begin{aligned} C_{TC} &= (C_{TC})_{Comb} + (C_{CO})_{Comb} + (C_{THC})_{Comb} & (1) \\ &= 22400 - (<10) - (<5) \end{aligned}$$

$$C_{TC} = 22400 \text{ ppm}$$

$$\begin{aligned} C_{NMOC} &= C_{TC} - C_{CO_2} - C_{CO} - C_M & (2) \\ &= 22400 - 10000 - 250 - 150 \end{aligned}$$

$$C_{NMOC} = 12000 \text{ ppm}$$

$$\begin{aligned} M_{NMOC} &= \frac{12(\text{lb C/lb-mole } C_1) \times Q_o \times C_{NMOC} \times 60 \text{ (min/hr)}}{386.9 \text{ (SDCF/lb-mole)} \times 10^6(\text{ppm})} & (4) \\ &= (12 \times 1000 \times 12000 \times 60)/(386.9 \times 10^6) \end{aligned}$$

$$M_{NMOC} = 22.3 \text{ lbs NMOC/hr}$$

$$X_{VOC} = 16.33 \text{ lb VOC/lb-mol } C_1 \quad (\text{From Worksheet IV-22})$$

$$\begin{aligned} M_{VOC} &= \frac{X_{VOC} \times Q_o \times C_{NMOC} \times 60 \text{ (min/hr)}}{386.9 \text{ (SDCF/lb-mole)} \times 10^6(\text{ppm})} & (5) \\ &= (16.33 \times 1000 \times 12000 \times 60)/(386.9 \times 10^6) \end{aligned}$$

$$M_{\text{VOC}} = 30.39 \text{ lb VOC/hr}$$

Calculation of Afterburner Outlet parameters:

$$\begin{aligned} C_{\text{NMOC}} &= C_{\text{THC}} - C_{\text{M}} & (3) \\ &= 200 - 100 \end{aligned}$$

$$C_{\text{NMOC}} = 100 \text{ ppmv}$$

$$\begin{aligned} M_{\text{NMOC}} &= \frac{12(\text{lb C/lb-mole } C_1) \times Q_o \times C_{\text{NMOC}} \times 60 (\text{min/hr})}{386.9 (\text{SDCF/lb-mole}) \times 10^6 (\text{ppm})} & (4) \\ &= (12 \times 1000 \times 100 \times 60) / (386.9 \times 10^6) \end{aligned}$$

$$M_{\text{NMOC}} = 0.19 \text{ lb NMOC/hr}$$

$$\begin{aligned} M_{\text{VOC}} &= \frac{X_{\text{VOC}} \times Q_o \times C_{\text{NMOC}} \times 60 (\text{min/hr})}{386.9 (\text{SDCF/lb-mole}) \times 10^6 (\text{ppm})} & (5) \\ &= (16.33 \times 1000 \times 100 \times 60) / (386.9 \times 10^6) \end{aligned}$$

$$M_{\text{VOC}} = .25 \text{ lb VOC/hr}$$

Calculation of Afterburner and Process parameters:

$$\begin{aligned} E_{\text{device}} &= \frac{(M_{\text{VOC}})_{\text{in}} - (M_{\text{VOC}})_{\text{out}}}{(M_{\text{VOC}})_{\text{in}}} \times 100\% & (11) \\ &= ((30.39 - .25) / 30.39) \times 100\% \end{aligned}$$

$$E_{\text{device}} = 99.1\%$$

$$\begin{aligned} (M_{\text{NMOC}})_{\text{fugitive}} &= (M_{\text{NMOC}})_{\text{process}} - (M_{\text{NMOC}})_{\text{in}} & (12) \\ &= (12 / 16.33) \times 40 - 22.3 \end{aligned}$$

$$(M_{\text{NMOC}})_{\text{fugitive}} = 7.09 \text{ lb NMOC/hr}$$

$$\begin{aligned} (M_{\text{NMOC}})_{\text{overall}} &= (M_{\text{NMOC}})_{\text{out}} + (M_{\text{NMOC}})_{\text{fugitive}} & (13) \\ &= 0.19 + 7.09 \end{aligned}$$

$$(M_{\text{NMOC}})_{\text{overall}} = 7.28 \text{ lb NMOC/hr}$$

$$\begin{aligned} (M_{\text{VOC}})_{\text{fugitive}} &= (M_{\text{VOC}})_{\text{process}} - (M_{\text{VOC}})_{\text{in}} & (14) \\ &= 40 - 30.39 \end{aligned}$$

$$(M_{\text{VOC}})_{\text{fugitive}} = 9.61 \text{ lb VOC/hr}$$

$$\begin{aligned} (M_{\text{VOC}})_{\text{overall}} &= (M_{\text{VOC}})_{\text{out}} + (M_{\text{VOC}})_{\text{fugitive}} \\ &= .25 + 9.61 \end{aligned} \quad (15)$$

$$(M_{\text{VOC}})_{\text{overall}} = 9.86 \text{ lb VOC/hr}$$

$$\begin{aligned} (m_{\text{Ctg}})_{\text{overall}} &= \frac{(M_{\text{VOC}})_{\text{overall}}}{\text{Application Rate (gal/hr)}} \\ &= \frac{9.86}{8.0} \\ &= 1.23 \text{ lb VOC/gallon coating applied} \end{aligned} \quad (7)$$

Example 2:

Given:

A source subject to Regulation 8, Rule 2, uses incineration to control non-methane organic carbon emissions. The process operates 20 hours per day.

Inlet Measurements to the Afterburner:

$$\begin{aligned} Q_o &= 100 \text{ SDCFM} \\ C_{\text{TC}} &= 10300 \text{ ppmv} \\ C_{\text{CO}_2} &= 500 \text{ ppmv} \\ C_{\text{CO}} &= 800 \text{ ppmv} \\ C_{\text{M}} &< 5 \text{ ppmv} \end{aligned}$$

Outlet Measurements from the Afterburner:

$$\begin{aligned} Q_o &= 500 \text{ SDCFM} \\ C_{\text{THC}} &= 500 \text{ ppmv} \\ C_{\text{CO}} &= 400 \text{ ppmv} \\ C_{\text{M}} &= 100 \text{ ppmv} \end{aligned}$$

Calculation of Afterburner Inlet parameters:

$$\begin{aligned} C_{\text{NMOC}} &= C_{\text{TC}} - C_{\text{CO}_2} - C_{\text{CO}} - C_{\text{M}} \\ &= 10300 - 500 - 800 - (<5) \end{aligned} \quad (2)$$

$$C_{\text{NMOC}} = 9000 \text{ ppmv}$$

$$M_{\text{NMOC}} = \frac{12(\text{lb C/lb-mole } C_1) \times Q_o \times C_{\text{NMOC}} \times 60 \text{ (min/hr)}}{386.9 \text{ (SDCF/lb-mole)} \times 10^6 \text{ (ppm)}} \quad (4)$$

$$= (12 \times 100 \times 9000 \times 60) / 386.9 \times 10^6$$

$$M_{\text{NMOC}} = 1.675 \text{ lb NMOC/hr}$$

$$M_{\text{CO}} = \frac{28(\text{lb CO/lb-mole}) \times Q_o \times C_{\text{CO}} \times 60 \text{ (min/hr)}}{386.9 \text{ (SDCF/lb-mole)} \times 10^6 \text{ (ppm)}} \quad (6)$$

$$= (28 \times 100 \times 800 \times 60) / (386.9 \times 10^6)$$

$$M_{\text{CO}} = 0.347 \text{ lb CO/hr}$$

Calculation of Afterburner Outlet parameters:

$$C_{\text{NMOC}} = C_{\text{THC}} - C_{\text{M}} \quad (3)$$

$$= 500 - 100$$

$$C_{\text{NMOC}} = 400 \text{ ppmv}$$

$$M_{\text{NMOC}} = \frac{12(\text{lb C/lb-mole } C_1) \times Q_o \times C_{\text{NMOC}} \times 60 \text{ (min/hr)}}{386.9 \text{ (SDCF/lb-mole)} \times 10^6 \text{ (ppm)}} \quad (4)$$

$$= (12 \times 500 \times 400 \times 60) / 386.9 \times 10^6$$

$$M_{\text{NMOC}} = 0.372 \text{ lb NMOC/hr}$$

$$M_{\text{CO}} = \frac{28(\text{lb CO/lb-mole}) \times Q_o \times C_{\text{CO}} \times 60 \text{ (min/hr)}}{386.9 \text{ (SDCF/lb-mole)} \times 10^6 \text{ (ppm)}} \quad (6)$$

$$= (28 \times 500 \times 400 \times 60) / (386.9 \times 10^6)$$

$$M_{\text{CO}} = 0.868 \text{ lb CO/hr}$$

Calculation of Afterburner Efficiency:

$$E_{\text{device}} = \frac{(M_{\text{NMOC}})_{\text{in}} - (M_{\text{NMOC}})_{\text{out}} - (12/28) \times \{(M_{\text{CO}})_{\text{out}} - (M_{\text{CO}})_{\text{in}}\}}{(M_{\text{NMOC}})_{\text{in}}} \times 100\% \quad (8)$$

$$= \frac{(1.675 - 0.372 - (12/28) \times \{(0.868 - 0.347)\}}{1.675} \times 100\%$$

$$E_{\text{device}} = 64.5 \%$$

$$\text{Emission Rate (lb/day)} = \text{Emission Rate (lb/hr)} \times \text{Operating Time (hr/day)}$$

$$= 0.372 \text{ lb NMOC / hr} \times 20 \text{ hr / day}$$

$$= 7.44 \text{ lb NMOC/day}$$

Example 3: Paint spray booth abated by a Charcoal Adsorber

Given:

Solvent fumes to the adsorber are primarily from methyl ethyl ketone (MEK). Material and Safety Data Sheets (MSDS) indicate that other solvents are also present, but plant operating data show their contribution is unknown and less than 10 % of the total. The coating is 5.2 lb VOC/gal and 3.0 lb solids/gal. Regulations do not allow the use of a coating with a solvent content in excess of 3.5 lb VOC/gal unless emissions are controlled to an extent equivalent to that of a compliant coating. There is no water in the coating. No dilution of gas occurs through the adsorber bed.

Estimate:

$$X_{\text{VOC}} = 18 \text{ lb/lb-mol} \quad (\text{ref. sect 9.5 and Fig. 7-6})$$

Process Measurements:

Paint is drawn out of a one foot diameter drum at a rate of 3.0 inches per hour. 100 pieces per hour at 400 in² per piece are coated with paint. Quality assurance data indicate that there are 0.20 grams of solids per 4 in².

Inlet Measurements:

$$\begin{aligned} Q_o &= 1000 \text{ SDCFM} \\ C_{\text{TC}} &= 2350 \text{ ppm} \\ C_{\text{CO}} &< 10 \text{ ppm} \\ C_{\text{CO}_2} &= 350 \text{ ppm} \\ C_{\text{M}} &< 5 \text{ ppm} \end{aligned}$$

Outlet Measurements:

$$\begin{aligned} C_{\text{THC}} &= 40 \text{ ppm} \\ C_{\text{M}} &< 5 \text{ ppm} \end{aligned}$$

Calculation of process parameters:

One way to calculate the volume of paint used is:
 Paint Used = 3/12 ft/hr x π (1 ft²)/4 x 7.48 gal/ft³
 Paint Used = 1.469 gph

An alternative way to calculate paint usage would be:

$$\begin{aligned} \text{Paint Used} &= (0.2 \text{ g solids}/4 \text{ in}^2) \times (\text{lb}/453.6 \text{ g}) \times (100 \text{ pieces/hr}) \times (400 \\ &\text{in}^2/\text{piece}) \times (\text{gal}/3 \text{ lb solids}) \\ \text{Paint Used} &= 1.469 \text{ gph} \end{aligned}$$

$$\begin{aligned} (M_{\text{VOC}})_{\text{process}} &= 1.469 \text{ gph} \times 5.2 \text{ lb VOC/gal} \\ (M_{\text{VOC}})_{\text{process}} &= 7.638 \text{ lb VOC/hr} \end{aligned}$$

Calculation of Adsorber Inlet parameters:

$$C_{\text{NMOC}} = 2000 \text{ ppmv}$$

$$\begin{aligned} M_{\text{VOC}} &= \frac{X_{\text{VOC}} \times Q_o \times C_{\text{NMOC}} \times 60 \text{ (min/hr)}}{386.9 \text{ (SDCF/lb-mole)} \times 10^6 \text{ (ppm)}} \quad (5) \\ &= (18 \times 1000 \times 2000 \times 60) / (386.9 \times 10^6) \end{aligned}$$

$$M_{\text{VOC}} = 5.582 \text{ lb VOC/hr}$$

Calculation of Adsorber Outlet parameters:

$$C_{\text{NMOC}} = C_{\text{THC}} - C_{\text{M}} \quad (3)$$

$$C_{\text{NMOC}} = 40 \text{ ppmv}$$

$$\begin{aligned} M_{\text{VOC}} &= \frac{X_{\text{VOC}} \times Q_o \times C_{\text{NMOC}} \times 60 \text{ (min/hr)}}{386.9 \text{ (SDCF/lb-mole)} \times 10^6 \text{ (ppm)}} \quad (5) \\ &= (18 \times 1000 \times 40 \times 60) / (386.9 \times 10^6) \end{aligned}$$

$$M_{\text{VOC}} = .112 \text{ lb VOC/hr}$$

$$\begin{aligned} (M_{\text{VOC}})_{\text{fugitive}} &= (M_{\text{VOC}})_{\text{process}} - (M_{\text{VOC}})_{\text{in}} \quad (16) \\ &= 7.638 - 5.582 \end{aligned}$$

$$(M_{\text{VOC}})_{\text{fugitive}} = 1.056$$

Calculation of Adsorber Bed parameters:

$$\begin{aligned} E_{\text{device}} &= \frac{(M_{\text{VOC}})_{\text{in}} - (M_{\text{VOC}})_{\text{out}}}{(M_{\text{VOC}})_{\text{in}}} \times 100\% \quad (11) \\ &= (5.582 - 0.112) / 5.582 \times 100\% \end{aligned}$$

$$E_{\text{device}} = 98.0\%$$

Calculation of Emissions per gallon equivalent coating: (ref. Fig. 7-7)

Line A	= 0	There is no water in this coating
Line B	= 0	There are no exempt volatiles in this coating
Line C		Leave blank. This is not listed on the MSDS cited in this example
Line D	= 0	No water
Line E	= 0	No exempt volatiles
Line F	= 0.671	5.2 lb VOC per 8.2 lb Coating
Line G	= 7.36	There is no PNRS, therefore assign it this default value
Line H	= 6.885	MEK has a known density
Line I	= 8.2	Specified operating condition
Line J	= 5.2	$F/(1/I - D/8.34 - E/G)$
Line K	= 1.168	Exhaust of .112 plus fugitive of 1.056 From source test data and calculations
Line L	= 3.5	Specified in this example. Actual value will depend on which regulation applies
Line M	= 0.245	$1 - J/H$
Line N	= 1.469	Calculated above
Line P	= 1.469	$(1 - A - B) \times N$
Line Q	= 0.492	$1 - L/H$
Line R	= 0.359	$P \times M$
Line S	= 0.731	R/Q
Line T	= 1.60	K/S

$$(m_{EQCtg})_{overall} = 1.60 \text{ lb VOC/gal Equivalent Coating}$$

Example 4 Petroleum Dry Cleaner

Given:

Petroleum Dry Cleaner washes two 10 lb loads per hour. The solvent used has an average molecular weight per carbon of 14. Gases are vented to a solvent recovery dryer.

Outlet Measurements:

$$\begin{aligned} Q_o &= 1000 \text{ SDCFM} \\ C_{THC} &= 100 \text{ ppm} \\ C_M &< 5 \text{ ppm} \end{aligned}$$

Calculation of Recovery Dryer Exhaust:

$$\begin{aligned} M_{VOC} &= \frac{X_{VOC} \times Q_o \times C_{NMOC} \times 60 \text{ (min/hr)}}{386.9 \text{ (SDCF/lb-mole)} \times 10^6 \text{ (ppm)}} & (5) \\ &= (14 \times 1000 \times 100 \times 60)/(386.9 \times 10^6) \end{aligned}$$

$$M_{\text{VOC}} = 0.217 \text{ lb VOC/hr}$$

$$\begin{aligned} M_{\text{VOC}} / 100 \text{ kg clothes} &= M_{\text{VOC}} / (2 \text{ load/hr} \times 10 \text{ lb/load}) \times (5/5) \times (\text{Kg/lb} / \text{Kg/lb}) \\ &= 5 \times M_{\text{VOC}} (\text{Kg/lb})(\text{hr}) / 100 \text{ Kg Clothes} \end{aligned}$$

$$M_{\text{VOC}} / 100 \text{ kg clothes} = 1.085 \text{ kg VOC}/100 \text{ kg clothes}$$

10. Reporting

10.1 Results shall be reported as shown in Figure 7-8.

11. Nomenclature

C_{CO}	[=] Concentration of Carbon Monoxide, ppmv
C_{CO_2}	[=] Concentration of Carbon Dioxide, ppmv
C_{M}	[=] Concentration of Methane, ppmv
C_{NMOC}	[=] Concentration of Non-Methane Organic Carbon, ppmv
C_{TC}	[=] Concentration of Total Carbon, ppmv
C_{THC}	[=] Concentration of Total Hydrocarbons, ppmv
E_{device}	[=] Efficiency with which NMOC or VOC emissions are abated by the Control Device on a mass basis, %
M_{CO}	[=] Mass flow rate of CO, lbs/hr
M_{NMOC}	[=] Mass flow rate of NMOC, lbs/hr
M_{VOC}	[=] Mass flow rate of VOC, lbs/hr
Q_o	[=] Volumetric Flowrate, SDCFM
X_{VOC}	[=] Molecular weight of VOC per Carbon, lb VOC/lb-mol C_1
$(C_{\text{CO}})_{\text{comb}}$	[=] Apparent CO concentration measured at combustor. Non-zero only when combustor is less than 100% efficient, ppmv
$(C_{\text{TC}})_{\text{comb}}$	[=] Apparent CO_2 (Total Carbon) measured at combustor. $(C_{\text{TC}})_{\text{comb}}$ is less than C_{TC} only when combustor is less than 100% efficient, ppmv
$(C_{\text{THC}})_{\text{comb}}$	[=] Apparent THC measured at combustor. Non-zero only when combustor is less than 100% efficient, ppmv

$(m_{\text{Ctg}})_{\text{overall}}$	[=] Mass flow rate of VOC, including fugitives, exhausted from a coating operation relative to the quantity of coating applied, lb/gal
$(m_{\text{EQCtg}})_{\text{overall}}$	[=] Mass flow rate of VOC, including fugitives, exhausted from a coating operation relative the quantity of equivalent coating used had a compliant coating been used in place of the actual coating, lb/gal
$(M_{\text{CO}})_{\text{in}}$	[=] Mass flow rate of CO at the inlet of a given abatement device, lb/hr
$(M_{\text{CO}})_{\text{out}}$	[=] Mass flow rate of CO at the outlet of a given abatement device, lb/hr
$(M_{\text{NMOC}})_{\text{fugitives}}$	[=] Mass flow rate of NMOC attributed to fugitive emissions from a given process, lb NMOC/hr
$(M_{\text{NMOC}})_{\text{in}}$	[=] Mass flow rate of NMOC at the inlet of a given abatement device, lb NMOC/hr
$(M_{\text{NMOC}})_{\text{out}}$	[=] Mass flow rate of NMOC at the outlet of a given abatement device, lb NMOC/hr
$(M_{\text{NMOC}})_{\text{overall}}$	[=] Mass flow rate of NMOC attributed to fugitive and exhausted emissions from abatement devices associated with a given process, lb NMOC/hr
$(M_{\text{NMOC}})_{\text{process}}$	[=] The calculated usage rate of NMOC based on process data, lb NMOC/hr
$(M_{\text{VOC}})_{\text{fugitives}}$	[=] Mass flow rate of organics as VOC attributed to fugitive emissions, lb VOC/hr
$(M_{\text{VOC}})_{\text{in}}$	[=] Mass flow rate of organics as VOC at the inlet of a given abatement device, lb VOC/hr
$(M_{\text{VOC}})_{\text{out}}$	[=] Mass flow rate of organics as VOC at the exhaust of a given abatement device, lb VOC/hr
$(M_{\text{VOC}})_{\text{overall}}$	[=] Mass flow rate of organics as VOC attributed to fugitive and exhausted emissions from abatement devices associated with a given process, lb VOC/hr
$(M_{\text{VOC}})_{\text{process}}$	[=] The calculated usage rate of organic compounds based on process data, lb VOC/hr

Figure 7-6: Molecular Weight and VOC Density Calculation Worksheet

	a	b	c	d	e	f	g	h
	Weight of Solvent	Weight fraction of each Component	Molecular Weight of each Component	Number of Carbons Per Component	Molecular Weight Per Carbon	Molecular Weight Fraction for each Component	VOC Density (lb/gal)	VOC Density Per Component
	*	a / a_{total}	**	**	c / d	$b \times e$	**	$b \times g$
A								
B								
C								
D								
E								
etc.								
Total		1.000						

Average Molecular Weight per Carbon (from total sum f) _____

Average Solvent Density (from total sum h) _____

- * From Laboratory Analysis or Coating Data Sheet
 ** From Reference Material

Figure 7-7 Equivalent Coatings Worksheet

- A) Volume fraction H₂O*, gal H₂O/gal CTG _____
- B) Volume fraction PNRS*, gal PNRS/gal CTG _____
- C) Volume fraction VOC*, gal VOC/gal NECTG _____
- D) Weight fraction H₂O*, lb H₂O/lb CTG _____
- E) Weight fraction PNRS*, lb PNRS/lb CTG _____
- F) Weight fraction VOC*, lb VOC/lb CTG _____
- G) Density of PNRS*, lb PNRS/gal PNRS
If unknown use 7.36 _____
- H) Assumed solvent density, lb VOC/gal VOC
If unknown use 7.36 _____
- I) Coating density*, lb CTG/gal CTG _____
- J) Lb VOC/gal NECTG $J = \frac{H \times C}{1 - A - B}$ _____
or
 $J = \frac{F}{\frac{1}{I} - \frac{D}{8.34} - \frac{E}{G}}$ _____
- K) Emission rate **, lb VOC/hr, includes fugitives _____
- L) Regulation limit, lb VOC/gal EQCTG _____
- M) Gal solids/gal NECTG $M = 1 - J/H$ _____
- N) Application Rate **, gal CTG/hr _____
- P) Gal NECTG/hr $P = N (1 - A - B)$ _____
- Q) Gal solids/gal EQCTG $Q = 1 - L/H$ _____
- R) Gal solids/hr $R = P \times M$ _____
- S) Gal EQCTG/hr $S = R/Q$ _____
- T) Lb VOC emitted/gal EQCTG, (m_{EQCTG})_{overall} $T = K/S$ _____

CTG - Coating as applied

PNRS - photochemically non-reactive solvent

NECTG - non-exempt coating (excludes water and PNRS)

EQCTG - equivalent coating

* From coating data

** From source test data

Figure 7-8

Report No.: _____ Test Date: _____	BAY AREA AIR QUALITY MANAGEMENT DISTRICT Summary of Source Test Results	Test Times: Run A: _____ Run B: _____ Run C: _____
Source Information		Test Representatives
Firm Name and Address	Firm Representative and Title	
	Phone No. ()	
Permit Conditions:	Source:	Operating Parameters
	Plant No. Permit No. Operates Hr/Day & Day/Yr.	
Applicable Regulations:		

Source Test Results and Comments:

METHOD: TEST

RUN A	RUN B	RUN C	AVERAGE
<u>IN*</u> <u>OUT*</u>	<u>IN</u> <u>OUT</u>	<u>IN</u> <u>OUT</u>	<u>IN</u> <u>OUT</u>

- Run Time,minutes
- Sample point temperature, F
- ST-17 Stack Volume Flowrate,SDCFM
- ST-14 O₂, percent
- ST-5 CO₂, percent
- ST-6 CO, PPM
- ST-23 H₂O, percent
- ST-7 Non-methane organic carbon, as C₁
 - a) PPM
 - b) lb/hr
- ST-7 Volatile Organic Compounds, as C₁
 - a) PPM
 - b) lb/hr
- ST-7 Abatement Efficiency, %

* Control device inlet
 ** Control device outlet

Test Team Leader	Date	Reviewed by	Date	Approved By	Date
------------------	------	-------------	------	-------------	------