B.5 WET SCRUBBERS FOR GASEOUS CONTROL[1,2,9,15]

B.5.1 Background

Wet scrubbers use a liquid to remove pollutants from an exhaust stream. In gaseous emission control applications, wet scrubbers remove pollutants by absorption. For this reason, wet scrubbers used for gaseous pollutant control often are referred to as absorbers. Absorption is very effective when controlling pollutant gases present in appreciable concentration, but also is feasible for gases at dilute concentrations when the gas is highly soluble in the absorbent. The driving force for absorption is related to the amount of soluble gas in the gas stream and the concentration of the solute gas in the liquid film in contact with the gas. Water is the most commonly used absorbent, but nonaqueous liquids of low vapor pressure (such as dimethylaniline or amines) may be used for gases with low water solubility, such as hydrocarbons or hydrogen sulfide (H_2S). Water used for absorption may frequently contain other chemicals to react with the gas being absorbed and reduce the concentration. When water is not used, absorbent separation and scrubbing liquid regeneration may be frequently required due to the cost of the scrubbing liquid.

Wet scrubbers rely on the creation of large surface areas of scrubbing liquid that allow intimate contact between the liquid and gas. The creation of large surface areas can be accomplished by passing the liquid over a variety of media (packing, meshing, grids, trays) or by creating a spray of droplets. There are several types of wet scrubber designs, including spray tower, tray-type, and packed-bed wet scrubbers; these are generally referred to as low-energy scrubbers.

Packed-bed scrubbers provide excellent gas-liquid contact and efficient mass transfer; they can generally be smaller in size than spray scrubbers and so are an effective option when space is limited. Plugging may occur in packed-bed scrubbers if there is a high PM loading, but the packing can be removed for cleaning. Some packed-bed scrubbers employ mobile spherical packing; the movement of the packing increases turbulence and helps keep the packing clean. Tray-type (or plate-type) scrubbers provide a film of liquid for the gas to pass through. Contact between gas and liquid is obtained by forcing the gas to pass upward through small orifices and bubbling through a liquid layer flowing across the plates. A number of plates are used in series to achieve the required absorption efficiency. Spray towers (countercurrent flow) may be used to control gaseous emissions when PM is also present.

Wet scrubbers should exhibit a relatively constant pressure differential, liquid flow, and gas flow. Common scrubber performance problems include: low gas flow rate; low liquid flow rate; condensation of aerosols in the system; poor liquid distribution; use of liquid with high pollutant concentration; use of high dissolved solids liquid (if PM is also present); nozzle erosion or pluggage (if PM is also present); bed pluggage (if PM is also present); tray/plate collapse; air inleakage; pollutant re-entrainment; freezing/pluggage of lines; and scaling.

B.5.2 Indicators of Performance

Several parameters can be used as indicators of wet scrubber performance. The most appropriate indicators to monitor depend upon a number of factors, including type of pollutant (whether PM is also present), scrubber design, and exhaust gas characteristics. For the control of gaseous pollutants (VOC and acid gases), the key indicators of wet scrubber performance generally are the same as the critical performance indicators for PM emission control with a few exceptions. Pressure differential, liquid flow rate, scrubber liquid outlet concentration are the key indicators of performance. Other, less significant indicators of gaseous pollutant control efficiency for wet scrubbers are gas flow rate, neutralizing chemical feed rate, scrubber outlet gas temperature. Parameters to monitor as alternatives to scrubber liquid outlet concentration include scrubber liquid pH, scrubber liquid specific gravity, and scrubber makeup/blowdown rates. For systems that control thermal processes, scrubber outlet gas temperature may be monitored as a surrogate for scrubber liquid flow rate. For systems that are designed to control gaseous pollutants with low PM loadings, there is no advantage to monitoring the scrubbing liquid solids content. In such cases, significant changes in the solids content of the liquid would be expected to occur only over extended periods of time due to the low level of PM. Table B-5 lists these indicators and illustrates potential monitoring options for wet scrubbers for gaseous pollutants and acid gas control.

Pressure differential. Pressure differential is one of the most critical indicators of performance for most wet scrubber designs. Pressure differential remains fairly constant and reflects normal operation of the liquid flow and gas flow through the system. For packed-bed scrubbers, plugging of the bed can result in increased pressure differential; the increase in pressure differential would likely be observed as a gradual increase over time. In such cases, an increase in pressure differential can correspond to a decrease in performance.

Liquid flow rate. Gas flow rate is often a constant based on process conditions and is the major design consideration of the scrubber; the liquid-to-gas (L/G) ratio is determined and maintained by the scrubber liquid flow rate. Scrubber liquid flow rate is a key indicator of performance provided the liquid is being properly distributed, and the liquid-gas interface is maintained. Under these conditions, higher liquid flow rates are indicative of higher levels of control. However, for packed-bed scrubbers, there is a critical flow rate above which flooding occurs.

Scrubbing liquid distribution system pressure or pump motor current can be monitored as surrogates for liquid flow rate, but would be less reliable indicators of scrubber performance than would liquid flow rate. In addition, the scrubber liquid level in the scrubber liquid reservoir may be monitored as an indication of the liquid flow rate, however this would be a less reliable indicator because the actual flow through the scrubber is not monitored. Scrubber liquid outlet temperature is another surrogate parameter for liquid flow rate; this parameter may be used for thermal processes only and is less reliable than monitoring of the liquid flow rate.

Scrubber liquid outlet concentration. The scrubber liquid outlet concentration is a critical indicator of gaseous pollutant removal efficiency. Increases in the concentration of pollutant may result in lower removal efficiency of the pollutant because of increased vapor pressure of the component in the liquid and lowering of the absorption gradient. For wet scrubbers used to control acid gas emissions, monitoring scrubber liquid pH is an adequate surrogate for scrubber liquid outlet concentration.

Gas flow rate. Exhaust gas flow rate affects the L/G ratio, which is a key design parameter for wet scrubbers. Gas flow rate is generally a constant parameter and may be monitored to ensure that the flow is within design range. An increase in exhaust gas flow rate, without a corresponding increase in liquid flow rate, results in a decrease in the L/G ratio, which generally corresponds to a decrease in scrubber control efficiency. Fan motor current can be monitored as a surrogate for exhaust gas flow rate.

Scrubber outlet gas temperature. For wet scrubbers used to control thermal processes, the scrubber exhaust gas temperature is also an indicator of performance. Increases in the outlet or exhaust temperature of the gas stream are an indication of a change in operation. Either the process exhaust temperature has increased, the gas flow rate has increased, or the liquid flow rate has decreased.

Scrubber liquid pH. Scrubber liquid pH is an indicator of acid gas removal efficiency. A drop in pH can indicate that the acid gas inlet concentration is increasing or that less acid is being neutralized. If caustic or other acid neutralizing chemicals are used, a change in pH can indicate a problem with the chemical feed system. Low pH levels typically result in increased corrosion of liquid contact surfaces in the scrubber and the recirculating system piping, and high pH levels that result from excess chemical feed can cause scaling and encrustation of piping and other recirculation system components.

Neutralizing chemical feed rate. If a neutralizing chemical is used, the chemical feed rate is an indicator of wet scrubber operation. As explained below, changes in caustic feed rate that result in changes to pH can result in increased corrosion or scaling of piping and other surfaces in contact with the scrubbing liquid.

Scrubber liquid specific gravity. Scrubber liquid specific gravity is an indicator of pollutant gas removal efficiency. Changes in the specific gravity provide an indication that the pollutant concentration is increasing (or decreasing) in the scrubber liquid.

Makeup/blowdown rates. To keep the pollutant content of recirculating liquids from becoming excessive, additional liquid must be added to the system (makeup) and recirculating liquid must be bled from the system (blowdown). Therefore, the makeup rate and/or the blowdown rate of the recycled liquid are indicative of the pollutant content of the scrubber liquid, provided the scrubber inlet loading does not change significantly. Under the conditions of constant inlet loading, decreases in makeup or blowdown rates generally correspond to increases in the pollutant content of the scrubbing liquid. This indicator is not commonly monitored, and scrubber liquid outlet concentration is a better indicator.

B.5.3 Illustrations

The following illustrations present examples of compliance assurance monitoring for wet scrubbers:

5a: Monitoring scrubber liquid pH and liquid flow rate (for SO_2 control).
5b: Monitoring pressure differential (for fluorides control).
5c: Monitoring pressure differential, scrubber liquid flow rate, and make up liquid flow rate (for VOC control).

B.5.4 Bibliography

TABLE B-5. SUMMARY OF PERFORMANCE INDICATORS FOR WET SCRUBBERS FOR GASEOUS POLLUTANT AND ACID GAS CONTROL

		Approach No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
		Illustration No.	**5a**										**5b**	**5c**		
		Example CAM Submittals	**A20**		**A4b**											**A4a**
Parameters	**Performance indication**	**Comment**	✔	✔		✔	✔	✔	✔	✔	✔	✔			✔	
Primary Indicators of Performance																
Pressure differential	An adsorber will operate at a relatively constant pressure differential. Differential pressure shows whether there is normal gas flow and normal liquid flow. A significant increase in pressure differential indicates a resistance to flow caused by plugging within the packing, higher inlet gas flow, or higher liquid flow rate.							X	X	X		X	X	X		
Scrubber liquid flow rate	Decrease in liquid flow rate results in decrease in L/G; want to assure required L/G is maintained. Can use scrubber inlet liquid supply pressure or pump motor current as surrogates for liquid flow rate.		X	X	X		X	X	X	X	X			X		X
Scrubber liquid outlet concentration	Increase in scrubber liquid concentration may indicate a decrease in the concentration gradient and removal efficiency, even with good gas-liquid contact. Can use scrubber liquid pH or specific gravity as surrogate for concentration.				X										X	X
Other Performance Indicators																
Gas flow rate	Increase in gas flow rate without increase in liquid flow rate results in lower L/G and potentially lower control efficiency. Can also measure fan current as surrogate for gas flow rate.			X			X									X
Scrubber gas outlet temperature	Increase in outlet gas temperature can indicate inadequate liquid flow. For application with thermal processes only; surrogate parameter for scrubber liquid flow rate.															

TABLE B-5. (Continued)

		Approach No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
		Illustration No.	**5a**										**5b**	**5c**		
		Example CAM Submittals	**A20**		**A4b**											**A4a**
Parameters	**Performance indication**	**Comment**	✔	✔		✔	✔	✔	✔	✔	✔	✔			✔	
Scrubber liquid outlet temperature	Increase in outlet liquid temperature can indicate inadequate liquid flow. For application with thermal processes only; surrogate parameter for scrubber liquid flow rate.					X										
Scrubber liquid pH	For acid gas control applications. Decrease in pH results in a lower driving force, i.e., a decrease in ability to absorb. This is more important for some acid gases than others because of differing absorption coefficients, e.g., it is more important for SO_2 control than HCl control. Can indicate likelihood of scaling or corrosion of piping and liquid contact surfaces.		X				X					X				
Neutralizing chemical feed rate	Changes in chemical feed rate can affect scrubber performance as well as pH, which can impact maintenance.									X						
Scrubber liquid specific gravity	Increase in specific gravity may indicate an increase in pollutant concentration, which may decrease removal efficiency.					X										
Scrubber liquid makeup and/or blowdown rate	Changes in makeup or blowdown rates can result in changes in pollutant concentration in recycled scrubber liquid, resulting in decreased removal efficiency.								X					X		
Scrubber liquid level	Changes in the liquid level in the reservoir may indicate insufficient liquid flow rate and insufficient makeup rate. Not as reliable a parameter as scrubber liquid flow rate.															

CAM ILLUSTRATION
No. 5c. WET SCRUBBER FOR VOC CONTROL

1. APPLICABILITY

1.1 Control Technology: Packed bed scrubber [050]
1.2 Pollutants
Primary: Volatile organic compounds (VOCs)
Other: Sulfur dioxide (SO_2), acid gases
1.3 Process/Emissions Unit: Polymer manufacturing, distillation units, air oxidation units, miscellaneous reactors

2. MONITORING APPROACH DESCRIPTION

2.1 Parameters to be Monitored: Pressure differential, scrubber liquid flow rate, and makeup liquid flow rate.

2.2 Rationale for Monitoring Approach
- Pressure differential: Indicative of adequate system performance.
- Scrubber liquid flow rate: Adequate liquid flow insures good gas/liquid contact and maintenance of proper pressure differential.
- Makeup liquid flow rate: If makeup flow rate is maintained, VOC concentration is likely being maintained at a consistent level to maintain scrubber control efficiency.

2.3 Monitoring Location
- Pressure differential: Measure across inlet and outlet ducts.
- Scrubber liquid flow rate: Measure at pump discharge or scrubber liquid inlet.
- Makeup liquid flow rate: Measure at inlet to reservoir or scrubber inlet.

2.4 Analytical Devices Required
- Pressure differential: Differential pressure gauges, manometers, or alternative methods/instrumentation for pressure differential.
- Scrubber liquid flow rate: liquid flow meter, pump discharge pressure gauge, or other device for liquid flow; see section 4 for information on specific types of instruments.
- Makeup liquid flow rate: liquid flow meter, pump discharge pressure gauge, or other device for liquid flow; see section 4 for information on specific types of instruments.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement: Hourly, or recorded continuously strip chart or data acquisition system.
- Reporting units:
  - Pressure differential: Inches water column (in. wc).
  - Scrubber liquid flow rate: Gallon per minute (gpm).
  - Makeup liquid flow rate: Gallon per minute (gpm).
- Recording process: Operators log data manually, or recorded automatically on strip chart or data acquisition system.

2.6 Data Requirements
- Baseline pressure differential, scrubber liquid flow rate, and makeup liquid flow rate measurements concurrent with emissions test.
- Historical plant records of pressure differential, scrubber liquid flow rate, and makeup liquid flow rate measurements.

2.7 Specific QA/QC Procedures: Calibrate, maintain, and operate instrumentation taking into account manufacturer's specifications.

2.8 References: 9, 14.

3. COMMENTS

3.1 Data Collection Frequency: For large emission units, a measurement frequency of once per hour would not be adequate; collection of four or more data points each hour is required. (See Section 3.3.1.2.)

B.6 THERMAL OXIDIZERS[1,2,16,17]

B.6.1 Background

Thermal oxidizers or thermal incinerators are combustion systems that control VOC, CO, and volatile HAP emissions by combusting them to carbon dioxide (CO_2) and water. The design of an incineration system is dependent on the pollutant concentration in the waste gas stream, type of pollutant, presence of other gases, level of oxygen, stability of processes vented to the system, and degree of control required. Important design factors include temperature (a temperature high enough to ignite the organic constituents in the waste gas stream), residence time (sufficient time for the combustion reaction to occur), and turbulence or mixing of combustion air with the waste gas. Time, temperature, degree of mixing, and sufficient oxygen concentration govern the completeness of the combustion reaction. Of these, only temperature and oxygen concentration can be significantly controlled after construction. Residence time and mixing are fixed by oxidizer design, and flow rate can be controlled only over a limited range.

The rate at which VOC compounds, volatile HAP, and CO are oxidized is greatly affected by temperature; the higher the temperature, the faster the oxidation reaction proceeds. Because inlet gas concentrations are well below the lower explosive limit (LEL) to prevent pre-ignition explosions in ducting the stream from the process to the oxidizer, the gas must be heated with auxiliary fuel above the autoignition temperature. Thermal destruction of most organics occurs at combustion temperatures between 800°F and 2000°F. Residence time is equal to the oxidizer chamber volume divided by the total actual flow rate of flue gases (waste gas flow, added air, and products of combustion). A residence time of 0.2 to 2.0 seconds, a length-to-diameter ratio of 2 to 3 for the chamber dimensions, and an average gas velocity of 10 to 50 feet per second are common. Thorough mixing is necessary to ensure that all waste and fuel come in contact with oxygen. Because complete mixing generally is not achieved, excess air/oxygen is added (above stoichiometric or theoretical amount) to ensure complete combustion.

Normal operation of a thermal oxidizer should include a fixed outlet temperature or an outlet temperature above a minimum level. A variety of operating parameters that may be used to indicate good operation include: inlet and outlet VOC concentration, outlet combustion temperature, auxiliary fuel input, fuel pressure (magnehelic gauge), fan current (ammeter), outlet CO concentration, and outlet O_2 concentration.

B.6.2 Indicators of Thermal Oxidizer Performance

For VOC control, the primary indicators of thermal oxidizer performance are the outlet VOC concentration and outlet combustion temperature. Other indicators of thermal oxidizer performance include outlet CO concentration, exhaust gas flow rate, fan current, outlet CO_2 concentration, outlet O_2 concentration, and auxiliary fuel line pressure. For CO control, the indicators of performance are the same as for VOC control, with the exception of outlet VOC and CO_2 concentrations, which would not be monitored for a CO emission limit. Each of these indicators is described below. Table B-6A lists these indicators and illustrates potential monitoring options for thermal oxidizers for VOC control, and Table B-6B lists the indicators and monitoring options for CO control by thermal oxidation.

Outlet VOC concentration. The most direct single indicator of the performance of a thermal oxidizer is the VOC concentration at the outlet of the unit.

Outlet combustion temperature. The outlet temperature of the combustion chamber provides a good indication of thermal oxidizer performance. As temperature increases, control efficiency also increases.

Outlet CO concentration. When VOC is the primary pollutant to be controlled, the CO concentration at the outlet of a thermal oxidizer provides an indication of combustion efficiency. The presence of CO indicates incomplete combustion. An increase in CO levels indicates a decrease in combustion efficiency. When CO is the primary pollutant, outlet CO concentration is a direct indicator of performance.

Exhaust gas flow rate. Thermal oxidizer control efficiency is primarily a function of combustion chamber temperature and residence time, and residence time is a function of exhaust gas flow rate. Consequently, as flow rate increases, residence time decreases and control efficiency also decreases. For processes with fairly constant flow rates, exhaust gas flow rate is not as good an indicator of performance as is outlet combustion temperature because temperature has a much greater effect on control efficiency than small variations in flow rates.

Fan current. Changes in fan current generally correspond to changes in exhaust gas flow rate. Consequently, fan current can be a surrogate for exhaust gas flow rate. An increase in fan current would signify an increase in flow rate and a decrease in residence time.

Outlet O_2 or CO_2 concentration. Outlet O_2 or CO_2 concentration by itself does not provide an indication of thermal oxidizer performance. However, monitoring the O_2 or CO_2 level provides an indication of the excess air rate and may be used to normalize the measured VOC concentration to a standard O_2 or CO_2 level. For emission limits that specify VOC concentrations corrected to a specified percent O_2, monitoring both the VOC and O_2 concentrations would be required to determine compliance.

Inspections. Inspections of the oxidizer can ensure proper operation of the device. These inspections may include frequent visual checks of the flame and burner while in operation and annual inspections of the burner assemblies, blowers, fans, dampers, refractory lining, oxidizer shell, fuel lines, and ductwork.

B.6.3 Illustrations

The following illustrations present examples of compliance assurance monitoring for thermal oxidizers:

For CO Control:

6a: Monitoring combustion temperature and annual burner inspection.
6b: Monitoring CO concentration.

For VOC Control:

6c: Monitoring combustion temperature and annual burner inspection.
6d: Monitoring combustion temperature, annual burner inspection, and exhaust gas flow rate.
6e: Monitoring combustion temperature and CO concentration.

B.6.4 Bibliography

Review DRAFT

TABLE B-6A. SUMMARY OF PERFORMANCE INDICATORS FOR THERMAL OXIDIZERS FOR VOC CONTROL

		Approach No.	**1**	**2**	**3**	**4**	**5**
		Illustration No.	**6c**	**6d**	**6e**		
		Example CAM Submittals	**A1a**		**A1b**		
Parameters	**Performance indication**	**Comment**	✔	✔		✔	✔
Primary Indicators of Performance							
Outlet VOC concentration	Direct measure of outlet concentration. Most direct single indicator of oxidizer performance; for limits that are corrected to an O_2 content, must be combined with O_2 monitoring to determine compliance.						X
Outlet combustion temperature	Control efficiency is largely a function of temperature. Control efficiency increases with increasing outlet combustion temperature.		X	X	X	X	
Other Performance Indicators							
Outlet CO concentration	Indicator of combustion efficiency. Presence of CO indicates incomplete combustion.				X		
Exhaust gas flow rate	Determines residence time within oxidizer. Increase in flow rate generally indicates a decrease in residence time, which may affect control efficiency.			X			
Inspections	Visual check of burner and flame can indicate if burner is operating properly. Annual inspection of the burner and oxidizer can ensure proper operation.		X	X			

Comments:
- Approach No. 2 also is required by 40 CFR 60, subparts III ( ), and NNN (Wool Fiberglass).
- Approach No. 4 is specified by several NSPS and NESHAP, including 40 CFR 63, subparts G (HON), O (Commercial Ethylene Oxide Sterilization), R (Gasoline Distribution), U (Polymers and Resins I), Y (Marine Vessel), CC (Petroleum Refiners), DD (Offsite Waste and Recovery), EE (Magnetic Tape), GG (Aerospace), HH (Oil and Natural Gas), JJ (Wood Furniture), KK (Printing and Publishing), JJJ (Polymers and Resins IV), MMM (Pesticides), NNN (Wool Fiberglass), and OOO (Polymers and Resins III).
- Approach No. 5 is specified as an alternative monitoring approach by 40 CFR 63, subparts G (HON), S (Pulp and Paper), Y (Marine Vessel), DD (Offsite Waste and Recovery), EE (Magnetic Tape), DDD (T and Formal content), and MMM (Pesticides),.

[S T & residence time, outlet HAP conc alt]
[DDD T & Formal content]
[GG inlet & outlet conc]

TABLE B-6B. SUMMARY OF PERFORMANCE INDICATORS FOR THERMAL OXIDIZERS FOR CO CONTROL

		Approach No.	**1**	**2**
		Illustration No.	**6a**	**6b**
		Example CAM Submittals		
Parameters	**Performance indication**	**Comment**		
Primary Indicators of Performance				
Outlet CO concentration	Direct measure of outlet concentration. Most direct single indicator of oxidizer performance for CO.			X
Outlet combustion temperature	Control efficiency is largely a function of temperature. Control efficiency increases with increasing combustion chamber temperature.		X	
Other Performance Indicators				
Exhaust gas flow rate	Determines residence time within oxidizer. Increase in flow rate generally indicates a decrease in residence time, which may affect control efficiency.			
Inspections	Visual check of burner and flame can indicate if burner is operating properly. Annual inspection of the burner and oxidizer can ensure long-term proper operation.		X	
Comments: None.				

CAM ILLUSTRATION
No. 6c. THERMAL OXIDIZER FOR VOC CONTROL

1. APPLICABILITY

1.1 Control Technology: Thermal oxidizer [021]; also applicable to direct flame afterburners with or without heat exchangers [021, 022], boilers, or similar devices for controlling VOC emissions by combustion

1.2 Pollutants
Primary: Volatile organic compounds (VOCs)
Other: Higher molecular weight organic compounds

1.3 Process/Emissions units: Coating, spraying, printing, polymer manufacturing, distillation units, wastewater treatment units, air oxidation units, petroleum refining, miscellaneous SOCMI units

2. MONITORING APPROACH DESCRIPTION

2.1 Indicators Monitored: Combustion chamber temperature and annual burner inspection.

2.2 Rationale for Monitoring Approach
- Combustion chamber temperature: Proper temperature range is related to good performance.
- Annual burner inspection: Maintain proper burner operation and efficiency.

2.3 Monitoring Location
- Combustion chamber temperature: Outlet of combustion chamber.
- Annual burner inspection: At the burner.

2.4 Analytical Devices Required
- Combustion chamber temperature: Thermocouples, RTDs, or alternative methods/instrumentation as appropriate for specific gas stream; see section 4.2 (Temperature) for additional information on devices.
- Annual burner inspection: None.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement:
  - Combustion chamber temperature: Hourly, or recorded continuously on strip chart or data acquisition system.
  - Annual burner inspection: Annually.
- Reporting units:
  - Combustion chamber temperature: Degrees Fahrenheit or Celsius (°F, °C).
  - Annual burner inspection: None.
- Recording process:
  - Combustion chamber temperature: Operators log data manually, or recorded automatically on strip chart or data acquisition system.
  - Annual burner inspection: Operators log data manually.

2.6 Data Requirements
- Baseline combustion chamber temperature measurements concurrent with emission test.
- Historical plant records on combustion chamber temperature measurements and burner inspection.

2.7 Specific QA/QC Procedures
- Calibrate, maintain, and operate instrumentation using procedures that take into account manufacturer's specifications.

2.8 References: 1, 2, 3, 4.

3. COMMENTS

3.1 Data Collection Frequency: For large emission units, a measurement frequency of once per hour would not be adequate; collection of four or more data points each hour is required. (See Section 3.3.1.2.)

CAM ILLUSTRATION
No. 6d. THERMAL OXIDIZER FOR VOC CONTROL

1. APPLICABILITY

1.1 Control Technology: Thermal oxidizer [021]; also applicable to direct flame afterburners with or without heat exchangers [021, 022], for controlling VOC emissions by combustion

1.2 Pollutants
Primary: Volatile organic compounds (VOCs)
Other: Higher molecular weight organic compounds

1.3 Process/Emissions units: Coating, spraying, printing

2. MONITORING APPROACH DESCRIPTION

2.1 Indicators Monitored: Combustion chamber temperature, annual burner inspection, and exhaust gas flow rate.

2.2 Rationale for Monitoring Approach
- Combustion chamber temperature: Proper temperature range can be related to good performance.
- Exhaust gas flow rate: Maintaining proper flow through the entire control system is important for maintaining capture efficiency.
- Annual burner inspection: Maintain proper burner operation and efficiency.

2.3 Monitoring Location
- Combustion chamber temperature: Outlet of combustion chamber.
- Exhaust gas flow rate: Oxidizer outlet or fan instrumentation.

2.4 Analytical Devices Required
- Combustion chamber temperature: Thermocouples, RTDs, or alternative methods/instrumentation as appropriate for specific gas stream.
- Exhaust gas flow rate: Differential pressure flow device, fan motor ammeter, or other type of device that measures gas velocity or flow rate.

2.5 Data Acquisition and Measurement System Operation:
- Frequency of measurement: Hourly, or recorded continuously on strip chart or digital data acquisition system.
- Reporting units:
  - Combustion chamber temperature: Degrees Fahrenheit or Celsius (°F, °C).
  - Exhaust gas flow rate: Cubic feet per minute (ft^3/min); amps if fan motor current.
- Recording process: Operators take readings and manually log data, or recorded automatically on strip chart or digital data acquisition system.

2.6 Data Requirements
- Baseline combustion chamber temperature measurements, exhaust gas flow rate measurements, and outlet VOC concentration or destruction efficiency measurements concurrent with emission test; or
- Historical plant records on combustion chamber temperature and exhaust gas flow rates.

2.7 Specific QA/QC Procedures
- Calibrate, maintain and operate instrumentation using procedures that take into account manufacturer's specifications.

2.8 References: 1, 2, 3, 4.

3. COMMENTS

3.1 Data Collection Frequency: For large emission units, collection of four or more data points each hour is required. (See Section 3.3.1.2.)

CAM ILLUSTRATION
No. 6e. THERMAL OXIDIZER FOR VOC CONTROL

1. APPLICABILITY

1.1 Control Technology: Thermal oxidizer [021; also applicable to direct flame afterburners with or without heat exchangers [021, 022], boilers, or similar devices for controlling VOC emissions by combustion

1.2 Pollutants
Primary: Volatile organic compounds (VOCs)
Other: High molecular weight organic compounds

1.3 Process/Emissions Unit: Coating, spraying, printing, polymer manufacturing, distillation units, wastewater treatment units, air oxidation units, petroleum refining, miscellaneous SOCMI units

2. MONITORING APPROACH DESCRIPTION

2.1 Parameters to be Monitored: Combustion chamber temperature and outlet CO concentration.

2.2 Rationale for Monitoring Approach
- Combustion chamber temperature: Proper temperature range is related to good performance.
- Outlet CO concentration: CO is a product of incomplete combustion and is an indicator of combustion efficiency.

2.3 Monitoring Location
- Combustion chamber temperature: Outlet of combustion chamber.
- Outlet CO concentration: Outlet to oxidizer.

2.4 Analytical Devices Required
- Combustion chamber temperature: Thermocouples, RTDs, or alternative methods/instrumentation as appropriate for specific gas stream; see section 4.2 (Temperature) for additional information on devices.
- Outlet CO concentration: Nondispersive infrared (NDIR) analyzer calibrated to manufacturer's specifications, or other methods or instrumentation.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement: Hourly if read manually, or continuously recorded on strip chart or data acquisition system.
- Reporting units:
  – Combustion chamber temperature: Degrees Fahrenheit or Celsius (°F, °C).
  – Outlet CO concentration: parts per million by volume (ppmv), dry basis.
- Recording process: Operators log data manually, or recorded automatically on strip chart or data acquisition system.

2.6 Data Requirements
- Baseline combustion chamber temperature measurements and outlet CO concentration measurements concurrent with emission test.
- Historical plant records on combustion chamber temperature and outlet CO concentrations.

2.7 Specific QA/QC Procedures
- Calibrate, maintain and operate instrumentation using procedures that take into account manufacturer's specifications.

2.8 References: 1, 2, 3, 4, 16, 17.

3. COMMENTS

3.1 Data Collection Frequency: For large emission units, a measurement frequency of once per hour would not be adequate; collection of four or more data points each hour is required. (See Section 3.3.1.2.)

B.7 CATALYTIC OXIDIZERS[1,2,16,17]

B.7.1 Background

Catalytic oxidizers are oxidation systems (similar to thermal oxidizers) that control VOC and volatile HAP emissions. Catalytic oxidizers use a catalyst to promote the oxidation of VOCs to CO_2 and water (i.e., increase the kinetic rate).

The design of the oxidation system is dependent on the pollutant concentration in the waste gas stream, type of pollutant, presence of other gases, level of oxygen, stability of processes vented to the system, and degree of control required. Important design factors include temperature (an operating temperature high enough to oxidize the waste gas on the catalyst), residence time (sufficient residence time in the catalyst bed for the oxidation reaction to occur), turbulence or mixing of combustion air with the waste gas, VOC concentration and species, catalyst characteristics, and the presence of masking agents in the waste gas that can reduce the effectiveness of the catalyst bed. Time, temperature, degree of mixing, and sufficient O_2 govern the completeness of the combustion reaction. Of these, only the temperature and the oxygen can be significantly controlled after construction. Residence time and mixing are fixed by incinerator design, and flow rate can be controlled only over a limited range.

The rate at which VOC compounds and volatile HAP are oxidized is greatly affected by temperature; the higher the temperature, the faster the oxidation reaction proceeds. The operating temperature needed to achieve a particular VOC control efficiency depends on the species of pollutants, concentration, and the catalyst type. Each pollutant has a temperature which must be reached to initiate the catalytic oxidation reaction. The initiation temperature is also dependent on the type of catalyst. The use of the catalyst allows the combustion reaction to occur at a lower temperature than the autoignition temperature. Catalytic oxidizers generally operate between 650°F and 1000°F.

The catalyst support and bed geometry influence the size and shape of the catalyst bed and affect the pressure differential across the bed. The catalyst typically lasts 2 to 5 years. Thermal aging over the lifetime of the catalyst and the presence of PM and catalyst poisons in the inlet gas streams reduce the catalyst's ability to promote the oxidation reaction by masking and coating the catalyst, thereby preventing contact between VOC and the catalyst surface.

Thorough mixing is necessary to ensure that all waste and fuel come in contact with oxygen. Because complete mixing generally is not achieved, excess air/oxygen is added (above stoichiometric or theoretical amount) to ensure complete combustion. For catalytic oxidizers, good mixing of the waste gas and oxygen promotes uniform oxidation in the catalyst bed and avoids localized heating of bed sections.

Normal operation of a catalytic oxidizer is characterized by a fixed inlet gas temperature and a higher bed outlet temperature. A thermocouple, or other temperature monitoring device, is placed at the inlet to the catalyst bed to measure the temperature of the preheated waste gas stream. A thermocouple at the outlet to the catalyst bed can be connected to a controller that maintains the desired catalyst bed temperature by altering the rate of auxiliary fuel consumption in the oxidizer's burner. A variety of operating parameters that may be used to indicate good operation include: outlet VOC concentration, inlet temperature (prior to catalyst bed), outlet temperature (after catalyst bed), pressure differential across oxidizer sections (preheat, catalyst bed, heat exchanger), auxiliary fuel input, and outlet CO concentration. Periodic tests of samples of the catalyst also may be used to confirm performance of the catalyst.

B.7.2 Indicators of Catalytic Oxidizer Performance

The primary indicators of catalytic oxidizer performance are the outlet VOC or volatile HAP concentration, catalyst bed inlet temperature, and catalyst activity. Other indicators of catalytic oxidizer performance include outlet CO concentration, temperature rise across the catalyst bed, exhaust gas flow rate, catalyst bed outlet temperature, fan current, outlet O_2 or CO_2 concentration, and pressure differential across the catalyst bed. Each of these indicators is described below. Table B-7 lists these indicators and illustrates potential monitoring options for catalytic oxidizers that are used for VOC or volatile HAP control.

Outlet VOC concentration. The most direct single indicator of the performance of a catalytic oxidizer is the VOC or volatile HAP concentration at the outlet of the unit.

Catalyst bed inlet temperature. The temperature at the inlet to the catalyst bed is a key catalytic oxidizer operating parameter. The inlet gas stream must be heated to the minimum temperature at which catalytic oxidation will occur on the bed. Above this minimum temperature, as temperature increases, control efficiency also increases.

Catalyst activity. When the catalyst becomes contaminated or masked, the control efficiency of the unit decreases. Catalyst deactivation will result in increased VOC emissions. The catalyst should be tested periodically to determine its activity.

Outlet CO concentration. The CO concentration at the outlet of a catalytic oxidizer provides a good indication of combustion efficiency. The presence of CO indicates incomplete combustion. An increase in CO levels indicates a decrease in combustion efficiency.

Temperature rise across catalyst bed. The temperature rise across the catalyst bed provides an indication of the degree of combustion that is occurring in the unit. The greater the level of combustion, the greater the rise in temperature. Because the temperature rise is dependent on the degree of combustion occurring across the catalyst, the temperature rise is dependent upon the inlet VOC loading to the catalyst. In other words, if the VOC loading to the oxidizer is reduced, the temperature rise across the catalyst will decrease. Consequently, a decrease in temperature rise across the catalyst is not necessarily an indication of reduced performance, but may simply be an indication of reduced VOC loading to the oxidizer.

Exhaust gas flow rate. Catalytic oxidizer control efficiency is primarily a function of catalyst bed inlet temperature and space velocity (similar to residence time), and space velocity is a function of exhaust gas flow rate. Consequently, as flow rate increases, space velocity increases and control efficiency may decrease. For processes with fairly constant flow rates, exhaust gas flow rate is not as good an indicator of performance as is bed inlet temperature because temperature has a much greater effect on control efficiency than small variations in flow rates.

Catalyst bed outlet temperature. For a particular type of catalyst, there is a maximum operating temperature, above which the catalyst begins to sinter. Monitoring the bed outlet temperature can ensure that the temperature within the bed does not exceed its working limit. In addition, the bed outlet temperature is an indicator that minimum oxidation temperatures are occurring in the unit.

Fan current. Changes in fan current generally correspond to changes in exhaust gas flow rate. Consequently, fan current can be a surrogate for exhaust gas flow rate. An increase in fan current would signify an increase in flow rate and space velocity.

Outlet O_2 or CO_2 concentration. Outlet O_2 or CO_2 concentration by itself does not provide an indication of thermal oxidizer performance. However, monitoring the O_2 or CO_2 level provides an indication of the excess air rate and may be used to normalize the measured VOC concentration to a standard O_2 or CO_2 level. For emission limits that specify VOC concentrations corrected to a specified percent O_2, monitoring both the VOC and O_2 concentrations would be required to determine compliance.

Pressure differential across catalyst bed. For inlet gas streams that contain significant levels of PM, bed fouling or plugging can be a problem. An increase in pressure differential across the bed is an indicator that plugging is occurring. Pressure differential across the catalyst bed should be maintained within an optimal pressure differential range for the system. Changes in pressure differential are likely to be gradual over time.

B.7.3 Illustrations

The following illustration presents examples of compliance assurance monitoring for catalytic oxidizers:

- 7a: Monitoring catalyst bed inlet temperature and catalyst bed outlet temperature.
- 7b: Monitoring catalyst bed inlet temperature and catalyst activity check.
- 7c: Monitoring catalyst bed inlet temperature, catalyst bed outlet temperature, and outlet CO concentration.

B.7.4 Bibliography

TABLE B-7. SUMMARY OF PERFORMANCE INDICATORS FOR CATALYTIC OXIDIZERS FOR VOC CONTROL

Parameters	Performance indication		1	2	3	4	5	6	7	8
		Approach No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
		Illustration No.	**7a**						**7b**	**7c**
		Example CAM Submittals								
Parameters	**Performance indication**	**Comment**	✔	✔	✔	✔	✔	✔		
Primary Indicators of Performance										
Outlet VOC concentration	Direct measure of outlet concentration. Most direct single indicator of oxidizer performance.				X					
Catalyst bed inlet temperature	Indicator that bed inlet is of sufficient temperature to initiate oxidation. Above the minimum oxidation temperature, control efficiency increases with increasing bed inlet temperature.		X	X		X	X	X	X	X
Catalyst bed activity	Indicates contamination, masking, or deactivation of the catalyst; the control efficiency of the unit decreases as catalyst activity decreases.								X	
Other Performance Indicators										
Outlet CO concentration	Indicator of combustion efficiency. Presence of CO indicates incomplete combustion.									X
Temperature rise across bed	Indicates level of combustion occurring in unit. The greater the degree of combustion, the greater the temperature rise. NOTE: Degree of combustion and resulting temperature rise is dependent upon VOC loading to control device. As VOC loading decreases, temperature rise also will decrease, even when combustion efficiency is being maintained. Therefore, may not be an appropriate indicator for situations where VOC loading to oxidizer varies greatly.					X		X		
Exhaust gas flow rate	Determines space velocity within catalyst bed. Increase in flow rate generally indicates an increase in space velocity and may result in a decrease in control level.			X						
Catalyst bed outlet temperature	Indicates level of combustion occurring in unit. Indicator used to assure temperature does not exceed design limits of bed. If bed outlet temperature exceeds working limit, the catalyst bed can be destroyed.		X	X						X

TABLE B-7. (Continued)

		Approach No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
		Illustration No.	**7a**						**7b**	**7c**
		Example CAM Submittals								
Parameters	**Performance indication**	**Comment**	✔	✔	✔	✔	✔	✔		
Pressure differential across bed	Indicator of bed fouling or plugging. Increase in pressure differential indicates that bed is becoming fouled or plugged. Changes in pressure differential are likely to be gradual.						X			

Comments:

- Approach No. 1 is specified by several NSPS and by 40 CFR 63, subparts U (Polymers and Resins I), DD (Offsite Waste and Recovery), JJ (Wood Furniture), HH (Oil and Natural Gas), and OOO (Polymers and Resins III).
- Approach No. 2 is required by 40 CFR 60, subparts III (   ) and NNN (Wool Fiberglass).
- Approach No. 3 is specified as an alternative monitoring approach by 40 CFR 63, subpart G (HON), DD (Offsite Waste and Recovery), HH (Oil and Natural Gas), MMM (Pesticides) and OOO (Polymers and Resins III).
- Approach No. 4 is required by 40 CFR 63, subpart G (HON), CC (Petroleum Refiners), EE (Magnetic Tape) GG (Aerospace), MMM (Pesticides), and JJJ (Polymers and Resins IV).
- Approach No. 5 corresponds to 40 CFR 63, subpart JJ (Wood Furniture) for fluidized catalyst bed.

[Both KK & O use inlet T only.] Do not include/recommend these.

CAM ILLUSTRATION
No. 7a. CATALYTIC OXIDIZER FOR VOC CONTROL

1. APPLICABILITY

1.1 Control Technology: Catalytic incinerator [019]; also applicable to catalytic afterburners with or without heat exchangers [019, 020]

1.2 Pollutants
Primary: Volatile organic compounds (VOCs)
Other: High molecular weight organic compounds

1.3 Process/Emissions Unit: Coating, spraying, printing, polymer manufacturing, distillation units, wastewater treatment units, air oxidation units, petroleum refining, miscellaneous SOCMI units

2. MONITORING APPROACH DESCRIPTION

2.1 Parameters to be Monitored: Catalyst bed inlet and outlet temperatures.

2.2 Rationale for Monitoring Approach
- Catalyst bed inlet temperature: Indicates whether the gas flowing into catalyst bed is of sufficient temperature to initiate oxidation.
- Catalyst bed outlet temperature: Indication that combustion is occurring on the catalyst bed, allows for calculation of temperature differential across bed, and that temperature does not exceed design limits of the catalyst.

2.3 Monitoring Location
- Catalyst bed inlet temperature: Preheat chamber outlet or catalyst bed inlet.
- Catalyst bed outlet temperature: Catalyst bed outlet.

2.4 Analytical Devices Required: Thermocouples, RTDs, or alternative methods/ instrumentation as appropriate for specific gas stream.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement: Hourly if manually read, or recorded continuously on strip chart or data acquisition system; continuously if CEMS.
- Reporting units: Degrees Fahrenheit or Celsius (°F, °C).
- Recording process: Operators log data manually, or recorded automatically on strip chart or data acquisition system.

2.6 Data Requirements
- Baseline catalyst bed inlet and outlet temperatures concurrent with emission test; or
- Historical plant records on catalyst bed inlet and outlet temperature measurements.

2.7 Specific QA/QC Procedures
- Calibrate, maintain, and operate instrumentation using procedures that take into account manufacturer's specifications.

2.8 References: 1, 2, 3, 4, 16, 17.

3. COMMENTS

3.1 Data Collection Frequency: For large emission units, collection of four or more data points each hour is required. (See Section 3.3.1.2.)

CAM ILLUSTRATION
No. 7b. CATALYTIC OXIDIZER FOR VOC CONTROL

1. APPLICABILITY

1.1 Control Technology: Catalytic incinerator [019]; also applicable to catalytic afterburners with or without heat exchangers [019, 020]

1.2 Pollutants
Primary: Volatile organic compounds (VOCs)
Other: High molecular weight organic compounds

1.3 Process/Emissions Unit: Printing and publishing

2. MONITORING APPROACH DESCRIPTION

2.1 Parameters to be Monitored: Catalyst bed inlet temperature and catalyst activity.

2.2 Rationale for Monitoring Approach
- Catalyst bed inlet temperature: Indicates whether the gas flowing into catalyst bed is of sufficient temperature to initiate oxidation.
- Catalyst activity: Determines conversion efficiency of catalyst; indicates that catalyst is not poisoned or masked beyond operational range.

2.3 Monitoring Location
- Catalyst bed inlet temperature: Preheat chamber outlet or catalyst bed inlet.
- Catalyst activity: Sample of catalyst.

2.4 Analytical Devices Required
- Temperature: Thermocouples, RTDs, or alternative methods/ instrumentation as appropriate for specific gas stream.
- Catalyst activity: Qualified laboratory (e.g., catalyst manufacturer) for determining activity of catalyst sample.

2.5 Data Acquisition and Measurement System Operation
- Temperature:
  - Frequency of measurement: Hourly or recorded continuously on strip chart or data acquisition system.
  - Reporting units: Degrees Fahrenheit or Celsius (°F, °C).
  - Recording process: Operators log data manually, or recorded automatically on strip chart or data acquisition system.
- Catalyst activity: Annual analyses of catalyst sample.

2.6 Data Requirements
- Temperature:
  - Baseline catalyst bed inlet and outlet temperatures concurrent with emission test; or
  - Historical plant records on catalyst bed inlet and outlet temperature measurements.
- Catalyst activity: Laboratory results of conversion efficiency.

2.7 Specific QA/QC Procedures

- Calibrate, maintain, and operate instrumentation using procedures that take into account manufacturer's specifications.

2.8 References: 1, 2, 3, 4, 16, 17.

3. COMMENTS

3.1 Data Collection Frequency: For large emission units, a measurement frequency of once per hour would not be adequate; collection of four or more data points each hour is required. (See Section 3.3.1.2.)

3.2 This illustration is applicable for catalytic systems controlling process streams that exhibit a highly variable range of VOC concentration, thereby making the use of temperature differential as a routine monitoring parameter impractical.

CAM ILLUSTRATION
No. 7c. CATALYTIC OXIDIZER FOR VOC CONTROL

1. APPLICABILITY

1.1 Control Technology: Catalytic incinerator [019]; also applicable to catalytic afterburners with or without heat exchangers [019, 020]

1.2 Pollutants
Primary: Volatile organic compounds (VOCs)
Other: High molecular weight organic compounds

1.3 Process/Emissions Unit: Coating, spraying, printing, polymer manufacturing, distillation units, wastewater treatment units, air oxidation units, petroleum refining, miscellaneous SOCMI units

2. MONITORING APPROACH DESCRIPTION

2.1 Parameters to be Monitored: Catalyst bed inlet and outlet temperatures and outlet CO concentration.

2.2 Rationale for Monitoring Approach
- Catalyst bed inlet temperature: Indicates whether the gas flowing into catalyst bed is of sufficient temperature to initiate oxidation.
- Catalyst bed outlet temperature: Indication that combustion is occurring on the catalyst bed, allows for calculation of temperature differential across bed, and that temperature does not exceed design limits of the catalyst.
- Outlet CO concentration: CO is a product of incomplete combustion and is an indicator of combustion efficiency.

2.3 Monitoring Location
- Catalyst bed inlet temperature: Preheat chamber outlet or catalyst bed inlet.
- Catalyst bed outlet temperature: Catalyst bed outlet.
- Outlet CO concentration: Outlet to oxidizer.

2.4 Analytical Devices Required
  - Catalyst bed inlet temperature: Thermocouples, RTDs, or alternative methods/ instrumentation as appropriate for specific gas stream.
  - Catalyst bed outlet temperature: Thermocouples, RTDs, or alternative methods/ instrumentation as appropriate for specific gas stream.
  - Outlet CO concentration: Nondispersive infrared (NDIR) analyzer calibrated to manufacturer's specifications, or other methods or instrumentation.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement
  - Catalyst bed inlet temperature: Hourly, or recorded continuously on strip chart or data acquisition system.
  - Catalyst bed outlet temperature: Hourly, or recorded continuously on strip chart or data acquisition system.
  - Outlet CO concentration: Continuously.

- Reporting units
  - Catalyst bed inlet temperature: Degrees Fahrenheit or Celsius (°F, °C).
  - Catalyst bed outlet temperature: Degrees Fahrenheit or Celsius (°F, °C).
  - Outlet CO concentration: Parts per million by volume (ppmv), dry basis.
- Recording process: Operators log data manually, or recorded automatically on strip chart or data acquisition system.

2.6 Data Requirements

- Baseline catalyst bed inlet and outlet temperatures and outlet CO concentration concurrent with emission test; or
- Historical plant records on catalyst bed inlet and outlet temperature and outlet CO concentration measurements.

2.7 Specific QA/QC Procedures

- Calibrate, maintain, and operate instrumentation using procedures that take into account manufacturer's specifications.

2.8 References: 1, 2, 3, 4, 16, 17.

3. COMMENTS

3.1 Data Collection Frequency: For large emission units, a measurement frequency of once per hour would not be adequate; collection of four or more data points each hour is required. (See Section 3.3.1.2.)

B.8 FLARES [To Be Completed]

B.9 CONDENSERS[1,2,24]

B.9.1 Background

Condensers are used to convert condensible components of a gas stream to the liquid phase, usually by reducing the temperature of the gas stream. Condenser efficiencies vary from 50 to 95 percent, and are dependent on the type of gas stream entering the condenser and on the condenser's operating parameters (e.g., coolant temperature). Gas stream properties such as the number of pollutants, chemical and physical properties of those pollutants, moisture content, particulate matter content, flow rate, and temperature all affect how well the condenser operates. Condensers can be classified as either contact condensers or surface condensers. In contact condensers, the exhaust gas comes into direct contact with the coolant. Contact condenser designs are similar to spray towers. In surface condensers, the coolant typically is circulated through a series of tubes around which the exhaust gas flows. No secondary pollutants are generated from the operation of surface condensers because the coolant flows through a closed system.

Condensation occurs when the partial pressure of the condensible pollutant in the waste gas stream is equal to its vapor pressure as a pure substance at the outlet gas temperature of the condenser. The waste gas stream is cooled by transfer of its heat to a refrigerant or coolant; the waste gas becomes saturated with one or more of its pollutants at the dew point or saturation temperature, and as the gas continues to cool, the pollutants condense. The temperature at which the gases condenses can be predicted from vapor pressure data for the pollutant and its mole fraction in the waste gas stream. The temperature required to achieve a given removal efficiency or outlet concentration depends on the inlet conditions of the waste gas stream.

The coolant used in a condenser depends upon the saturation temperature needed to condense the pollutants of interest in the gas stream. Chilled water can be used for condensation temperatures above approximately 40˚ to 45˚F, brines above 10˚ to 15˚F, and chlorofluorocarbons for condensation temperatures below −29˚F. Temperatures as low as −80˚F may be necessary to condense some streams. When such low temperatures must be achieved to reach the dew point for a particular pollutant, other components of the waste gas stream, such as water, can solidify and foul the heat transfer surfaces. In these instances a two-stage condensation system can be designed; the first stage removes moisture while the second stage is cooled to the lower temperature desired.

A condenser is designed for a maximum pressure and temperature. Normal operation of a condenser should include an outlet gas maximum temperature setpoint and a fixed inlet and outlet coolant/refrigerant temperature. The outlet gas temperature is a critical indicator of the efficiency of a condenser. Normal operation may also include a constant pressure differential across nozzles, tubes, etc. System pressures are important operating parameters that can indicate proper waste gas stream flow and coolant flow. The coolant flow rate should be checked on a regular basis to ensure that it is within design criteria. Several operating parameters may be used to indicate good operation of the condenser, including: outlet pollutant concentration of the most volatile pollutant, inlet temperature of the waste gas stream, outlet temperature of the waste gas stream, temperature of the condensate pool, inlet temperature of the coolant, and outlet temperature of the coolant.

There are several common problems or malfunctions associated with condenser operation. Excessive flow rates may increase erosion of the device and may cause entrainment of liquids and PM in the waste gas stream. Fouling or plugging may occur on the shell, tubes, pipes, valves, and monitors; symptoms of fouling or plugging may include an increase or decrease in pressure, a performance decrease, hot or cold spots, and short-circuiting of flow patterns. Routine maintenance is an important component of proper condenser operation.

B.9.2 Indicators of Condenser Performance

The primary indicators of the performance of condensers are the condenser outlet VOC concentration and condenser outlet gas temperature. Other parameters that indicate condenser performance include coolant inlet temperature, coolant outlet temperature, exhaust gas flow rate, pressure differential across condenser, coolant flow rate, pressure differential across coolant recirculation system, and condensate collection rate. Each of these indicators is described below. Table B-9 lists these indicators and illustrates potential monitoring options for condensers.

Outlet VOC concentration. The most direct indicator of condenser performance in removing specific organic compounds from the exhaust stream is the concentration of those compounds at the condenser outlet; however, measuring concentrations of specific compounds may be impractical. For most applications, the most practical and direct indicator of condenser performance is the outlet VOC concentration.

Outlet gas temperature. The temperature of the gas exiting the condenser is a key indicator of condenser performance. The temperature necessary to achieve a specific outlet concentration of a compound can be determined based upon engineering principles. Increases in outlet temperature can indicate a problem with the condenser, such as plugging, or an increase in process gas temperature as it enters the condenser. In either case, removal rates are likely to decrease as condenser outlet temperature increases.

Coolant inlet temperature. The temperature of the coolant as it enters the condenser provides a good indication the condenser is operating as designed. If the incoming process gas stream flow rate and temperature do not vary significantly, coolant inlet temperature can be a reliable indicator of condenser performance. However, if the process gas stream characteristics vary, coolant inlet temperature is not a good indicator of condenser performance. Generally, increases in coolant temperature are likely to result in decreased organic removal from the process exhaust stream.

Coolant outlet temperature. Coolant outlet temperature, together with the coolant inlet temperature and coolant flow rate, affect the degree of heat transfer from the inlet gas stream to the coolant. The heat transfer rate provides a good indicator of condenser performance.

However, by itself, this parameter would be a less reliable indicator of condenser performance than other parameters (outlet VOC concentration, condenser outlet gas temperature). The coolant outlet temperature should be monitored in conjunction with other coolant parameters; coolant outlet temperature must be compared to the coolant inlet temperature and flow rate to determine heat transfer and the rate of organic compound removal.

Exhaust gas flow rate. Exhaust gas flow rate determines the gas residence time within the condenser. Higher flow rates result in shorter residence times and less cooling of the inlet process gas stream; higher gas flow rates affect the heat transfer equation. Consequently, the level of organic removal (or the efficiency) would likely decrease with increasing exhaust gas flow rate.

Pressure differential across condenser. An increase in pressure differential (resistance to flow) across the condenser is an indication of fouling, plugging, or obstruction of the flow paths around the condenser tubes; as a result, condenser effectiveness would diminish. Fouling would decrease the heat transfer rate from exhaust gas stream to coolant. Pressure differential across the condenser should be maintained within design range. Changes in pressure differential are likely to be gradual over time.

Coolant flow rate. The coolant flow rate affects the rate of heat transfer from the incoming process exhaust gas to the coolant. Decreases in coolant flow rate are likely to result in decreases in organic removal rates. This parameter is of limited use as an indicator of condenser performance unless coolant temperatures also are measured.

Pressure differential across coolant refrigeration system. Increases in the pressure differential through the refrigeration system are an indication of plugging of the tubes and can result in a decrease in coolant flow rate. Decreases in coolant flow rate would adversely affect condenser performance.

Condensate collection rate. The rate at which condensate is collected from the condenser provides a direct measure of the rate of organics removal from the process exhaust gas stream. This parameter is a useful indicator of condenser performance only if the process gas stream characteristics (flow rate, temperature, concentrations of organic constituents) do not vary significantly, or if process input data (i.e., usage) are being used in conjunction with the condensate removal data to conduct a material balance and calculate control efficiency or emission rate.

Periodic inspection. An annual inspection of the internal surfaces of the condenser should be performed to check for fouling or corrosion of condenser surfaces.

B.9.3 Illustrations

The following illustrations present examples of compliance assurance monitoring for condensers:

9a: Monitoring outlet gas temperature.
9b: Monitoring inlet coolant temperature, outlet coolant temperature, coolant flow rate, and condensate collection rate.

B.9.4 Bibliography

TABLE B-9. SUMMARY OF PERFORMANCE INDICATORS FOR CONDENSERS

		Approach No.	**1**	**2**	**3**	**4**
		Illustration No.	**9a**	**9b**		
		Example CAM Submittals	**A3**			
Parameters	**Performance indication**	**Comment**	✔		✔	✔
Primary Indicators of Performance						
Outlet VOC concentration	Direct measure of outlet concentration. Most direct indicator of condenser performance; can be monitored continuously or periodically.					X
Outlet gas temperature	Indicates if gas is being cooled to/below dew point of target compounds; indicator of level of condensation. Too high indicates condensation to the level expected will not occur; increase in outlet temperature may indicate plugging or fouling problems.		X		X	
Other Performance Indicators						
Coolant inlet temperature	Indicates that condenser is meeting inlet design parameters. Good indicator of performance if inlet gas temperature and flow rate do not vary; increase in coolant inlet temperature indicates organic compound removal rate will be lower.			X		
Coolant outlet temperature	If coolant inlet and outlet temperature and flow rate are measured, indicates level of heat transfer from inlet gas stream. By itself, would be less reliable indicator of performance than other parameters; decrease would indicate decrease in organic compound removal rate (i.e., heat transfer to the coolant is not occurring).			X	X	
Coolant flow rate	Affects heat transfer rate. Decrease indicates decrease in condenser performance; parameter is of limited use without coolant temperature data.			X		
Condensate collection rate	Organic compound removal rate. Useful indicator of condenser performance only if process gas stream characteristics do not vary, or if used in conjunction with material balance.			X		

Review DRAFT

TABLE B-9. (Continued)

Parameters	Performance indication					
		Approach No.	**1**	**2**	**3**	**4**
		Illustration No.	**9a**	**9b**		
		Example CAM Submittals	**A3**			
		Comment	✔		✔	✔

Comments:

- Approach No. 1 corresponds to 40 CFR 60, subparts G (HON), M (Perchloroethylene Dry Cleaning, R (Gasoline Distribution), U (Polymers and Resins I), W (Polymers and Resins II), Y (Monhe Tank Vessel Loading), DD (Offsite Waste and Recovery), EE (Magnetic Tape), HH (Oil and Natural Gas), DDD ( ), III ( ), JJJ (Polymer and Resins IV), MMM (Pesticides), NNN (Wool Fiberglass), OOO (Polymers and Resins III), RRR ( ), SSS ( ), VVV ( ), and 40 CFR 63, subpart M (Perchloroethylene Dry Cleaning) requires both inlet and outlet gas temperatures for condensers on washer units.
- Approach No. 3 corresponds to 40 CFR 61, subpart FF.
- Approach No. 4 corresponds to 40 CFR 60, subpart DDD, III, NNN, and RRR; 40 CFR 61, subpart FF; and 40 CFR 63, subpart G (HON), R (Gasoline Distribution), U (Polymers and Resins I), Y (Manhe Tank Vessel Loading), DD (Offsite Waste and Recovery), HH (Oil and Natural Gas), MMM (Pesticides), OOO (Polymers and Resins III); 40 CFR 63, Subpart EE (magnetic tape) requires both inlet and outlet VOHAP concentration.

[EE - inlet & outlet VOHAP concentration.]

CAM ILLUSTRATION
No. 9a. CONDENSER FOR VOC CONTROL

1. APPLICABILITY

1.1 Control Technology: Condenser [072, 073, 074]
1.2 Pollutants
Primary: Volatile organic compounds (VOCs)
1.3 Process/Emissions Unit: Coating, polymer manufacturing, distillation units, equipment leaks, air oxidation units, miscellaneous reactors, pharmaceuticals

2. MONITORING APPROACH DESCRIPTION

2.1 Parameters to be Monitored: Outlet gas temperature.
2.2 Rationale for Monitoring Approach: Condenser outlet gas temperature affects removal efficiency; an increase in outlet gas temperature indicates decreased removal efficiency.
2.3 Monitoring Location: Outlet vent of condenser.
2.4 Analytical Devices Required: Thermocouples, RTDs, or alternative methods/instrumentation as appropriate for specific gas stream or specific equipment design; see section 4.2 (Temperature) for additional information on devices.
2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement: Hourly, or recorded continuously on strip chart or data acquisition system.
- Reporting units: Degrees Fahrenheit or Celsius (°F, °C).
- Recording process: Operators log data manually, or recorded automatically on strip chart or data acquisition system.

2.6 Data Requirements
- Baseline outlet gas temperature measurements concurrent with emissions test;
- Calculations indicating outlet gas temperature necessary to achieve compliance; or
- Historical plant records on outlet gas temperature measurements.

2.7 Specific QA/QC Procedures
- Calibrate, maintain, and operate instrumentation using procedures that take into account manufacturer's specifications.

2.8 References: 1, 2.

3. COMMENTS

3.1 Data Collection Frequency: For large emission units, a measurement frequency of once per hour would not be adequate; collection of four or more data points each hour is required. (See Section 3.3.1.2.)

CAM ILLUSTRATION
No. 9b. CONDENSER FOR VOC CONTROL

1. APPLICABILITY

1.1 Control Technology: Condenser [072, 073, 074]
1.2 Pollutants: Volatile organic compounds (VOCs)
1.3 Process/Emissions units: Coating, polymer manufacturing, distillation units, equipment leaks, air oxidation units, miscellaneous reactors, pharmaceuticals

2. MONITORING APPROACH DESCRIPTION

2.1 Indicators Monitored: Inlet and outlet coolant temperatures, coolant flow rate, and condensate collection rate.
2.2 Rationale for Monitoring Approach
- Inlet coolant temperature: Affects removal efficiency; an increase in the coolant temperature decreases removal efficiency; demonstrates that coolant is at design temperature.
- Outlet coolant temperature: Gives an indication of removal efficiency; a decrease in the outlet coolant temperature decreases removal efficiency.
- Coolant flow rate: Affects the heat transfer rate.
- Condensate collection rate: Demonstrates that VOC component is being removed by the condenser; a decrease in collection rate indicates a decrease in removal efficiency.

2.3 Monitoring Location
- Inlet coolant temperature: Front end heads.
- Outlet coolant temperature: Rear end heads.
- Coolant flow rate: Front end heads.
- Condensate collection rate: Condensate pool.

2.4 Analytical Devices Required
- Inlet coolant temperature: Thermocouples, RTDs , or alternative methods/instrumentation as appropriate for specific gas stream or specific equipment design; see section 4.2 (Temperature) for additional information on devices.
- Outlet coolant temperature: Thermocouples, RTDs , or alternative methods/instrumentation as appropriate for specific gas stream or specific equipment design; see section 4.2 (Temperature) for additional information on devices.
- Coolant flow rate: Liquid flow meter or other flow device; see section 4 for more information on specific types of instruments.
- Condensate collection rate: If measured by weight, use of a scale or other weight monitor; if measured by volume, use of a flow meter, tank level indicator, or visually observing changes in the level of the condensate pool tank.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement: Hourly, or recorded continuously on strip chart or data acquisition system.

- Reporting units:
  - Inlet coolant temperature: Degrees Fahrenheit or Celsius (°F, °C).
  - Outlet coolant temperature: Degrees Fahrenheit or Celsius (°F, °C).
  - Coolant flow rate: Gallons per minute (gpm) or pounds per hour (lb/hr).
  - Condensate collection rate: Weight or volume units (pounds, kilograms, liters, gallons, etc.).
- Recording process: Operators log data manually, or recorded automatically on strip chart or data acquisition system.

2.6 Data Requirements
- Baseline coolant temperature measurements, coolant flow rate, and condensate collection measurements concurrent with emission test;
- Calculations indicating outlet gas temperature necessary to achieve compliance, baseline outlet gas temperature measurements concurrent with coolant temperature measurements, coolant flow rate, and condensate collection rate; or
- Historical plant records on coolant temperature, coolant flow rate, and condensate collection rate measurements.

2.7 Specific QA/QC Procedures
- Annual process review to determine process or materials changes that could affect the initial determination of condensation parameters.
- Calibrate, maintain, and operate instrumentation using procedures that take into account manufacturer's specifications.

2.8 References: 1, 2.

3. COMMENTS

3.1 Data Collection Frequency: For large emission units, a measurement frequency of once per hour would not be adequate; collection of four or more data points each hour is required. (See Section 3.3.1.2.)

3.2 Use of these control device parameters are appropriate for process systems where the process vent gas stream characteristics (flow rate, temperature, VOC concentration) are consistent over time.

B.11 CARBON ADSORBERS[1,2,24]

B.11.1 Background

Carbon adsorbers control VOC emissions in exhaust gas streams. Adsorbers are used for both air pollution control and solvent or product recovery. There are three basic types of adsorption systems, which can be categorized by the manner in which the adsorbent bed is maintained or handled during the adsorption and regeneration cycles. These three types of systems are: (1) fixed or stationary bed, (2) moving bed or rotary concentrator, and (3) fluidized bed. The stationary bed design is the most common. Units typically have two identical beds, one adsorbing while the other is desorbing, but may also consist of multiple identical beds depending on the volumetric flow and concentration of the stream to be controlled. In a typical stationary bed system, the vapor is collected from various point sources, transported through a particulate filter and into one of two carbon adsorption beds. As the carbon adsorber operates, three zones form within the bed: the saturated zone, mass transfer zone, and fresh zone. In the saturated zone, which is located at the entrance to the bed, the carbon has already adsorbed its working capacity of VOC; no additional mass transfer can occur in this zone. The mass transfer zone is where VOC is removed from the gas stream. The carbon in this zone is at various degrees of saturation, but is still capable of adsorbing VOC. The fresh zone is the region of the bed that has not encountered VOC-laden air since the last regeneration. This zone has a full working capacity available for adsorption of additional VOC.

As the carbon bed operates, the mass transfer zone moves through the bed in the direction of flow toward the bed outlet. Breakthrough occurs when the mass transfer zone first reaches the bed outlet. At this point, a sharp increase in the outlet VOC concentration occurs. The available adsorption time (the time before breakthrough occurs) depends on the amount of carbon in the bed, the working capacity of the bed, and the VOC concentration and mass flow rate of the gas stream. Once the breakthrough point is reached, the carbon bed must be regenerated. When this occurs, the flow of VOC-laden air is redirected to the second bed, while the first bed undergoes a regeneration cycle.

Most carbon adsorption beds are regenerated using steam. Regeneration removes the adsorbed VOC vapor from the carbon and restores the carbon's ability to adsorb VOC for the next cycle. The steam desorbs the VOC from the carbon bed and carries the VOC through a condenser, then through a decanter and/or distillation column for separation of the VOC from the steam condensate. An ambient air stream is often passed through the bed to dry the bed and reduce the bed temperature following the steam desorption. The regenerated carbon bed is then ready to be put back online before the second bed reaches breakthrough.

Carbon bed systems may also be regenerated by vacuum. Regeneration is accomplished with a combination of high vacuum and purge air stripping.

A moving bed or rotary concentrator adsorber consists of a rotating cylindrical shell within which is a second cylindrical shell containing the carbon bed. The carbon bed is partitioned into several pie-shaped sections that are parallel to the axis of the shell. The VOC-laden gas enters the unit, flows through a section of the bed, then exits the unit. As the unit operates, one section of the bed is online, while the section that has just come offline undergoes regeneration. During each rotation of the unit, each bed section undergoes an adsorption cycle and a regeneration cycle. Regeneration of a rotary concentrator unit is often conducted with hot gas rather than steam or vacuum. Two advantages of rotary adsorbers are lower pressure differentials and shorter bed lengths. The main disadvantage of rotary bed adsorbers is that, unlike stationary bed units, rotary bed units contain moving parts and seals that contact moving parts.

In a fluidized bed adsorber, the VOC-laden gas flows up through the carbon at high velocity. The granular carbon, which is fluidized by the upward flowing gas, migrates to the bottom of the bed, where it continuously exits the bed and is transported to a separate regeneration chamber, then fed back into the top of the bed. The countercurrent movement of the incoming gas and carbon increases the effectiveness of the carbon. The main disadvantage to a fluidized bed adsorber is that some carbon is suspended in the outlet gas stream and is lost.

Adequate auxiliary equipment is needed to collect, transport, and filter vapor-laden air streams to a carbon adsorber. The ducts and piping must be sized properly for the air flows required to optimize adsorber efficiency. A fan forces the gas stream into and out of the unit; designing and sizing this equipment is critical. The placement of a particulate matter (PM) filter varies, depending on the adsorber configuration and the inlet gas stream characteristics. Placed before the inlet air stream (in stationary or rotary bed units), the PM filter will reduce possible contamination of the adsorbent and fouling of the bed. In a fluidized-bed adsorber, the PM filter is placed at the outlet to reduce emissions of suspended carbon. Additional auxiliary equipment is also required for recovery of the contaminant from the regeneration cycle. Generally, a condenser and separator installed in series are used to recover VOC from the regeneration stream in traditional fixed bed units with stream regeneration. For rotary concentrators or moving bed units, other devices such as thermal oxidizers or catalytic oxidizers may be used to handle the regeneration stream.

Inlet gas stream characteristics are important to the design and operation of adsorption systems. Characteristics that may be important include: specific compounds present in the gas stream and their concentration, flow rate, temperature, and relative humidity.

Bed fouling and channeling gradually reduce the carbon’s adsorption capacity. Carbon particles erode with time, the capillaries become plugged with contaminants, and the carbon may become masked. This erosion and contamination results in the carbon granules losing their ability to adsorb and retain VOC molecules; consequently, control efficiency decreases over time. A routine maintenance program should provide for scheduled inspections of all equipment components as well as all necessary monitoring of operating parameters to ensure continued proper operation of the control equipment. Four major categories of system components that require routine maintenance include: air handling, adsorbing, regeneration, and recovery.

Routine maintenance also may include yearly sampling and testing of the carbon to evaluate its working capacity.

B.11.2 Indicators of Carbon Adsorber Performance

The primary indicators of the performance of carbon adsorbers are the adsorber outlet VOC concentration, regeneration cycle timing, total regeneration stream (steam or nitrogen) flow or the vacuum achieved during regeneration, and carbon bed activity sampling. Other indicators of adsorber performance include bed operating temperature, inlet gas temperature, gas flow rate, inlet VOC concentration, pressure differential, inlet gas moisture content, and leak check monitoring. Each of these indicators is described in the following paragraphs. Table B-11 lists these indicators and illustrates potential monitoring options for carbon adsorbers.

Outlet VOC concentration. The most direct indicator of performance of a carbon adsorber in removing VOC from the exhaust stream is the VOC concentration at the bed outlet.

Regeneration cycle timing or Bed replacement interval. The timing of the regeneration cycle is critical to the continued performance of a carbon adsorber. Specifically, the frequency and length of regeneration cycles are key operating parameters that affect the adsorption capacity of the bed. If regeneration cycles do not occur before or immediately after breakthrough, periods of high VOC emissions are likely. In addition, the length of regeneration cycles must be adequate to allow complete or near complete desorption of the bed. Otherwise, breakthrough will occur sooner once the bed is back online.

If the carbon bed is not regenerated onsite (e.g., if a carbon drum is used and sent back to the manufacturer for regeneration), the replacement interval is an important parameter. The amount of time the unit is online and adsorbing VOC will indicate when it is time to replace the unit, based on the rated capacity of the unit and a mass balance calculation.

Total regeneration stream flow. This parameter is important for carbon beds regenerated using steam or nitrogen. The total regeneration stream flow, which is a measure of the total mass of the regenerating fluid (e.g., steam, nitrogen) used over the course of a complete regeneration cycle, determines the extent to which the bed is desorbed during regeneration. If the total regeneration stream flow decreases, the bed may not be fully regenerated when it is put back online (depending on the VOC loading during the adsorption cycle), and the bed may reach breakthrough sooner than expected.

Vacuum profile during regeneration cycle. The vacuum profile during regeneration is an important variable in the performance of the unit. Sufficient vacuum must be achieved at a long enough interval to assure desorption of VOC from the carbon bed. If the carbon bed is saturated, the time to achieve certain vacuum levels will be longer. This parameter is important only for carbon beds that employ vacuum regeneration.

Carbon bed activity sampling. When the carbon in the bed becomes contaminated or masked or erodes over time, the carbon loses its adsorptive ability and the control efficiency of the unit decreases. The carbon should be tested periodically to determine its activity.

Bed operating temperature and Bed regeneration temperature. The adsorptive capacity of the bed decreases with increasing bed temperature. Therefore, bed operating temperature can provide an indication of the need to adjust the regeneration cycle frequency. The bed temperature also can indicate problems in the unit (e.g., VOC combustion in the bed). For steam regeneration, measuring the maximum temperature achieved during the regeneration cycle can indicate that a temperature sufficient to regenerate the bed was reached (e.g., a temperature at or above the boiling point of the least volatile component). Similarly, measuring the minimum temperature achieved before the regenerated bed is placed back into adsorption service indicates that the bed has cooled sufficiently to operate within the prescribed range of bed operating temperature.

Inlet gas temperature. The bed operating temperature is a better indicator of adsorber performance than inlet gas temperature because inlet temperature measurements do not account for chemical reactions occurring within the bed that generate additional heat. However, if monitoring bed temperature is impractical, monitoring the inlet gas temperature is an option.

Gas flow rate. An increase in gas flow rate results in a decrease in the time period before the carbon bed reaches breakthrough. By monitoring the gas flow rate, regeneration cycle timing can be adjusted as needed. The pressure in the carbon adsorber inlet duct can be used as an indicator of flow and can be used to trigger bypass if excess pressure builds up in the inlet line.

Inlet VOC concentration. The inlet VOC concentration can be monitored to ensure that the adsorption system is operating within design limits. If inlet VOC concentrations increase, it may be necessary to change the timing of the regeneration cycles. If an applicable rule requires the control device to achieve a certain control efficiency, monitoring the inlet and outlet VOC concentration provides the most accurate measurement of compliance.

Pressure differential. An increase in pressure differential across the adsorber is an indication of bed fouling or plugging. A decrease in pressure differential across the bed may indicate channeling (the vapor is not flowing through all areas of the bed).

Inlet gas moisture content. At moderate to low inlet VOC concentrations (less than 1,000 ppm), moisture competes with adsorbate (VOC) for adsorption sites on the carbon. As a result, the adsorptive capacity of the bed is reduced and adjustments should be made to the regeneration cycle timing.

Leak check. Vapor leaks in the vapor collection or recovery system mean VOC emissions are not being controlled. Periodic checks while the unit is online ensure that there are no leaks and all captured VOC emissions are routed to the carbon adsorber. A leak is defined as greater than or equal to 10,000 ppmv, as methane.

B.11.3 Illustrations

The following illustrations present examples of compliance assurance monitoring for carbon adsorbers:

11a: Regeneration cycle frequency, total regeneration stream flow, maximum bed temperature during regeneration cycle, minimum bed temperature at end of cooling cycle, and carbon bed activity.
11b: Monitoring bed replacement interval.
11c: [Add CAM example.]

B.11.4 Bibliography

TABLE B-11. SUMMARY OF PERFORMANCE INDICATORS FOR CARBON ADSORBERS

	Approach No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	Illustration No.		**11a**		**11b**					
	Example CAM Submittals	**A18**					**A5**	**A24**		
Parameter	**Performance indication** / **Comment**		✔		✔	✔	✔		✔	
Primary Indicators of Performance										
Outlet VOC concentration	Direct measure of outlet concentration. Most direct indicator of adsorber performance; can be monitored continuously or periodically.	X					X		X	
Regeneration cycle timing	Key factor in determining adsorptive capacity of bed. If regeneration cycles are too infrequent, VOC emissions may be excessive; if regeneration times are too short, the adsorption capacity of the bed is reduced.		X							X
Bed replacement interval	For non-regenerative units, frequency of carbon replacement is important.				X					
Total regeneration stream flow	Indicates extent to which bed is desorbed (regenerated). Decreases in regeneration stream flow result in a shorter time period to reach breakthrough.		X	X						
Vacuum profile during regeneration cycle	Indicates extent to which bed is desorbed (regenerated). If the maximum vacuum is not achieved during the regeneration cycle, the bed may not be fully regenerated and may reach breakthrough more quickly during the next adsorption cycle.							X		X
Carbon bed activity sampling	Indicates contamination or masking of the carbon and its adsorptive ability; the control efficiency of the unit decreases as carbon activity decreases.		X					X		

TABLE B-11. (Continued)

Parameter	Performance indication	1	2	3	4	5	6	7	8	9
	Approach No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	Illustration No.		**11a**		**11b**					
	Example CAM Submittals	**A18**					**A5**	**A24**		
Parameter	**Performance indication** / **Comment**		✔		✔	✔	✔		✔	
Other Performance Indicators										
Bed operating temperature	Affects adsorptive capacity of bed. Indicates problems such as fire in the bed. Adsorptive capacity decreases with increasing temperature.									
Bed regeneration temperatures	Measuring maximum temperature during regeneration cycle assures temperature required for regeneration was reached; measuring minimum temperature to which bed is cooled after regeneration before adsorption cycle begins assures bed is at proper operating temperature; applies to steam regeneration only.		X	X		X				
Inlet gas temperature	Indirect indicator of bed operating temperature. See comments for *Bed operating temperature*. Not as useful as bed operating temperature but can be used as an alternative.					X				
Inlet VOC concentration	Indicator that system is operating within design limits. Increases in VOC concentrations may require adjustments to regeneration cycle timing.						X			
Leak check of unit	Identifies vapor leaks in the system and reduces VOC emissions from leaks; a leak is defined as greater than or equal to 10,000 ppmv, as methane.	X						X		

TABLE B-11. (Continued)

		Approach No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
		Illustration No.		**11a**		**11b**					
		Example CAM Submittals	**A18**					**A5**	**A24**		
Parameter	**Performance indication**	**Comment**		✔		✔	✔	✔		✔	

Comments:

- Approach 2: 40 CFR, Subpart MMM (Pesticides)
- Approach 3: 40 CFR 60, Subparts III, NNN, RRR; 40 CFR 63, Subparts G (HON), U (Polymers and Resins I), Y (Monhe Tank Vessel Loading), DD (Offsite Waste and Recovery), HH (Oil and Natural Gas), JJ (???), KK (???), JJJ (Polymer and Resins IV), and OOO (Polymers and Resins III).
- Approach 4: 40 CFR 60, Subpart FF; 40 CFR 63, Subparts G (HON), DD (Offsite Waste and Recovery), EE (Magnetic Tape), GG, HH (Oil and Natural Gas), and MMM (Pesticides).
- Approach 5: 40 CFR 61, Subpart E (Mercury).
- Approach 6: 40 CFR 63, Subparts EE (Magnetic Tape), GG.
- Approach 7: 40 CFR 63, Subpart Y (Regeneration Time and Vacuum D).
- Approach 8: 40 CFR 60, Subparts BBB, DDD, III, NNN (Wool Fiberglass), QQQ, RRR, SSS, and VVV; 40 CFR 61, Subparts L, BB, FF; 40 CFR 63, Subparts G (HON), M (Perchloroethylene Dry Cleaning), R (Gasoline Distribution), T, U (Polymers and Resins I), W (Polymers and Resins II), Y (Mohe Tank Vessel Loading), DD (Offsite Waste and Recovery), EE (Magnetic Tape), GG, HH (Oil and Natural Gas), JJ, KK, III, MMM (Pesticides), OOO (Polymers and Resins III).
- Approach 9: 40 CFR 63, Subpart Y.

CAM ILLUSTRATION
No. 11a. CARBON ADSORBER FOR VOC CONTROL

1. APPLICABILITY

1.1 Control Technology: Carbon adsorption system [048]
1.2 Pollutants
Primary: Volatile organic compounds (VOCs)
Other: Higher molecular weight organic compounds
1.3 Process/Emissions units: Coating, spraying, printing, polymer manufacturing, distillation units, wastewater treatment units, dry cleaning, degreasing, pharmaceuticals, equipment leaks

2. MONITORING APPROACH DESCRIPTION

2.1 Indicators Monitored: Regeneration cycle timing, total regeneration stream flow, bed regeneration temperature, bed temperature to which bed is cooled after regeneration, and carbon activity.
2.2 Rationale for Monitoring Approach
- Regeneration cycle timing: The timing of the regeneration cycle is critical to the continued performance of the carbon adsorber. The minimum regeneration frequency (i.e., operating time since last regeneration) is established and monitored.
- Total regeneration stream flow: The total regeneration stream flow determines the extent to which the bed is desorbed during regeneration. If the total regeneration stream flow decreases, the bed may not be fully regenerated when it is put back online.
- Bed regeneration temperature: Measuring the temperature achieved during the regeneration cycle indicates that a temperature sufficient to regenerate the bed was reached.
- Bed temperature after regeneration: The adsorptive capacity of the carbon bed decreases with increasing bed temperature. Monitoring the bed temperature after regeneration assures the proper operating temperature is achieved before returning the bed to the absorption cycle.
- Carbon activity: Periodic checks of the bed for poisoning assure that bed activity still meets specifications.

2.3 Monitoring Location
- Regeneration cycle timing: Each bed.
- Total regeneration stream flow: Carbon bed inlet during each regeneration cycle.
- Bed regeneration temperature: Each carbon bed.
- Bed temperature after regeneration: Each carbon bed.
- Carbon activity: Sample of bed material.

2.4 Analytical Devices Required
- Regeneration cycle timing: Clock.
- Total regeneration stream flow: Mass flow meter.

- Bed regeneration temperature: Thermocouple, RTD, or other temperature sensing device; see section 4.2 for additional information on devices.
- Bed temperature after regeneration: Thermocouple, RTD, or other temperature sensing device; see section 4.2 for additional information on devices.
- Carbon activity: Analytical laboratory to evaluate per manufacturer's instructions.

2.5 Data Acquisition and Measurement System Operation

- Frequency of measurement:
  - Regeneration cycle timing: Each cycle.
  - Total regeneration stream flow: Hourly, or continuously during each regeneration cycle on strip chart or data acquisition system.
  - Bed regeneration temperature: Hourly, or continuously during each regeneration cycle on strip chart or data acquisition system.
  - Bed temperature after regeneration: Hourly, or continuously during cooling cycle, on strip chart or data acquisition system.
  - Carbon activity: Annually.
- Reporting units:
  - Regeneration cycle timing: Minutes or hours.
  - Total regeneration stream flow: Pounds or other unit of mass.
  - Bed regeneration temperature: Degrees Fahrenheit or degrees Celsius.
  - Bed temperature after regeneration: Degrees Fahrenheit or degrees Celsius.
  - Carbon activity: Activity level per manufacturer's specifications.
- Recording process: Operators log data manually, or recorded automatically on strip chart or data acquisition system.

2.6 Data Requirements

- Baseline regeneration cycle timing, total regeneration stream flow, bed regeneration temperature, and bed temperature after regeneration measurements concurrent with emission test data, and manufacturer's (supplier's) specifications for carbon activity.
- Historical plant records on regeneration cycle timing, total regeneration stream flow, bed regeneration temperature, bed temperature after regeneration measurements, and carbon activity levels.

2.7 Specific QA/QC Procedures: Calibrate, maintain, and operate instrumentation using procedures that take into account manufacturer's specifications.

2.8 References: 11, 19.

3. COMMENTS

None.

CAM ILLUSTRATION
No. 11b. CARBON ADSORBER FOR VOC CONTROL

1. APPLICABILITY

1.1 Control Technology: Non-regenerative carbon adsorption system [048]
1.2 Pollutants
Primary: Volatile organic compounds (VOCs)
Other: Higher molecular weight organic compounds
1.3 Process/Emissions units: Coating, spraying, printing, polymer manufacturing, distillation units, wastewater treatment units, dry cleaning, degreasing, pharmaceuticals, equipment leaks

2. MONITORING APPROACH DESCRIPTION

2.1 Indicators Monitored: Bed replacement interval.
2.2 Rationale for Monitoring Approach
- Bed replacement interval: The carbon replacement interval ensures that periods of high VOC emissions do not occur. The replacement interval can be determined based on design and engineering calculations (e.g., mass balance).

2.3 Monitoring Location
- Bed replacement interval: Each carbon bed.

2.4 Analytical Devices Required
- Bed replacement interval: Timers or alternative methods/instrumentation that conform to performance specifications acceptable to the Administrator.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement:
  – Bed replacement interval: Each cycle.
- Reporting units:
  – Bed replacement interval: Hours, days, months, or other unit of time, as appropriate.
- Recording process:
  – Bed replacement interval: Operators log replacement interval data manually.

2.6 Data Requirements
- Design and mass balance calculations on which the replacement interval is based; or
- Historical plant records on bed replacement interval with periodic VOC measurements establishing that interval is adequate.

2.7 Specific QA/QC Procedures: NA.
2.8 References: 11, 19.

3. COMMENTS

3.1 The time interval may be based upon design calculations under worst case conditions. Alternatively, the VOC concentration level in the exhaust vent stream from the adsorption system may be periodically monitored (e.g., daily or at an interval no greater than 20 percent of the time required to consume the total carbon working capacity under worst case conditions) to assure breakthrough has not occurred.

CAM ILLUSTRATION
No. 11c. CARBON ADSORBER FOR VOC CONTROL [Add CAM example]

B.19 CAPTURE SYSTEMS[33]

B.19.1 Background

Capture efficiency is defined as the percentage of emissions captured and vented to a control device. Various capture systems may be used to capture emissions and direct them to a control device. These systems include enclosures and local exhaust ventilation measures.

There are basically two types of enclosures: (1) total enclosures, referred to as permanent total enclosures (PTEs), and (2) nontotal, or partial, enclosures. A PTE is an enclosure that completely surrounds a source such that all volatile organic compound (VOC) emissions are contained and directed to a control device. The EPA has established a set of criteria that must be met for an enclosure to qualify as a PTE; these criteria are contained in Reference Method 204--Criteria For And Verification of a Permanent or Temporary Total Enclosure (40 CFR 51, Appendix M). If the criteria set forth in this method are met, the capture efficiency may be assumed to be 100 percent and need not be measured. An enclosure that does not meet the minimum criteria for a PTE is not a total enclosure; it is a partial enclosure (PE) and capture efficiency is determined by measurement. Table B-19 summarizes the PTE criteria.

TABLE B-19. PERMANENT TOTAL ENCLOSURE CRITERIA

1.	Any natural draft opening (NDO) shall be at least four equivalent opening diameters from each VOC emitting point.
2.	The total area of all NDOs shall not exceed 5 percent of the surface area of the enclosure's four walls, floor, and ceiling.
3.	The average face velocity (FV) of air through all NDOs shall be at least 3,600 m/hr (200 ft/min). The direction of flow through all NDOs shall be into the enclosure.
4.	All access doors and windows whose areas are not included in the calculation in item No. 2 shall be closed during routine operation of the process.
5.	All VOC emissions must be captured and contained for discharge through a control device.

The second type of control measure used to capture emissions and vent them to a control device is the application of local exhaust ventilation. Local exhaust ventilation systems typically consist of a hood, or hoods, that capture the contaminant at the point of generation and a duct system and exhaust fan that moves the VOC-laden air to the control device.

For both types of capture systems discussed (enclosures and local exhaust ventilation systems), maintaining the integrity of the capture device (i.e., enclosure, hood) and the airflow (ventilation) through the system are the critical operating/maintenance parameters with respect to maintaining capture system performance. The indicators of performance for capture systems relate to these two parameters and, for purposes of this discussion, monitoring approaches can be divided into two subcategories:

1. Indicators of capture by the enclosure or hood (e.g., enclosure differential pressure, NDO velocity, hood face velocity); and

2. Indicators of system air flow (e.g., fan rpm, duct pressure differential) measured downstream of the capture device combined with a system integrity inspection.

The first monitoring approach is applicable to all types of capture systems. The second approach is applicable to simpler capture systems including either (a) a simply configured PTE or partial enclosure or (b) a simple exhaust ventilation system, such as a system consisting of a single hood (as opposed to multiple hoods), noncomplicated ductwork (e.g., without recirculation and multiple dampers), and a fan.

The first approach, measuring indicators of performance at the capture device, provides more reliable data related to capture efficiency than measuring air flow downstream of the capture device. For this reason, the second approach may provide a lower level of confidence than the first approach, which uses a more direct indicator of performance; the level of confidence will depend upon system design and frequency of inspection. While not essential to provide an acceptable level of confidence for the first monitoring approach, periodic inspection of the enclosure or hood and the exhaust system may be added to further increase the level of confidence. On the other hand, periodic inspections are necessary for the second monitoring approach to provide an acceptable level of confidence. The frequency and rigor of the inspection is a factor that affects the level of confidence; continuous data are not provided for this parameter. As with other CAM monitoring, the specific situation needs to be considered during selection of a monitoring approach and the factors discussed in Chapter 3 of the CAM technical guidance document should be considered (e.g., potential to emit, margin of safety, and cost).

In many cases, for both enclosures and other exhaust ventilation systems, single parameter monitoring may not be sufficient to ensure that capture efficiency is maintained. A combination of several parameters may be necessary to provide reasonable assurance of compliance with the capture efficiency requirements.

Common problems and malfunctions with capture systems include (1) an out-of-balance ventilation system due to the excessive opening and closing of doors and windows in an enclosure, (2) degradation in fan performance, (3) changes in PTE configuration due to process changes such as introducing a new VOC source within the enclosure (e.g., coating vessels or cleanup solvent drums that can be moved during the facility's day-to-day operations), and not maintaining the acceptable distance between VOC sources and NDOs; and (4) problems with the ductwork such as particulate matter accumulation in duct work, holes in the duct work, damaged hoods or enclosures, and disconnected pick up points.

B.19.2 Indicators of Capture System Performance

B.19.2.1 Enclosures. For enclosures, the primary indicators of performance include:

1. Face velocity (FV) through all NDOs or through selected representative NDOs (measurement of face velocity at each NDO);

2. Differential pressure across the enclosure; and

3. Average FV through all NDOs (measured using total volumetric air flow divided by NDO surface area) and daily inspection of NDOs.

For PTEs, FV through all NDOs and pressure differential across the enclosure are essentially equivalent measurements, and either can be used to demonstrate performance of the PTE. Note that Reference Method 204 [paragraph 8.3] indicates that a pressure differential of 0.013 mm Hg (0.0007 in. H_2O) corresponds to an average FV of 3,600 m/hr (200 ft/min). In some situations, the measurement of one parameter may be simpler than that of the other.

As stated earlier, periodic inspections of the enclosure can be used in conjunction with continuous or periodic measurement of the indicators identified above to further increase the level of confidence. The items incorporated into the inspection will vary depending on whether the enclosure is a PTE or a PE. For PTEs, the inspection should include all items required to demonstrate that the PTE criteria as established in EPA Reference Method 204 (summarized in Table 14-1) are maintained although the frequency of inspection for individual items might vary. For PEs, the inspection should require demonstration that the configuration of the enclosure remains identical to the configuration during the most recent test conducted to measure capture efficiency and is in good physical condition. Inspections for both types of enclosures also should demonstrate that the capture exhaust system is maintained in good working condition (ductwork is clear with no holes, damper operation is correct, fan is in good condition).

As discussed earlier, another indicator of performance for simply configured enclosures is measurement of the capture system air flow (or indicators of air flow, such as fan amperage, fan rpm, or static pressure) downstream of the enclosure. This monitoring approach must be combined with periodic inspections to provide an acceptable level of confidence for the approach. The type of inspection conducted will vary depending on whether the enclosure is a PTE or a PE. Also, inspections under this monitoring approach may need to be more frequent to provide a higher level of confidence.

B.19.2.3 Exhaust Ventilation Systems. For exhaust ventilation systems, the primary indicators of performance include:

1. Face velocity at the hood;

2. Exhaust flow rate in the duct near the hood; and

3. Hood static pressure.

Periodic inspections of the capture system (hood and exhaust system) could be used in conjunction with either continuous or periodic measurement of the indicators identified above to further increase the level of confidence.

Another indicator of performance for simple exhaust ventilation systems is measurement of the capture system air flow (or indicators of air flow such as fan amperage, fan rpm, or static pressure) downstream of the capture device (hood) combined with periodic capture system inspections. The frequency of inspections under this approach must be sufficient to provide an acceptable level of confidence.

B.19.3 Illustrations

The following illustrations present examples of compliance assurance monitoring for capture systems:

- 19a: PTE capture system for VOC: Pressure differential across the enclosure and periodic inspection of PTE capture system.
- 19b: PTE capture system for VOC: Average FV through all NDOs (net exhaust flow divided by NDO surface area) and periodic inspection of PTE capture system (including quarterly inspection of NDOs).
- 19c: PTE capture system for VOC: Average FV through selected NDOs (direct measure of FV) and periodic inspection of PTE capture system.
- 19d: PE capture system for VOC: Pressure differential across the enclosure and periodic inspection of capture system.
- 19e: Local exhaust ventilation system for capture of VOC: FV at the hood and periodic inspection of capture system.
- 19f: Local exhaust ventilation system for capture of VOC: Fan parameters and periodic inspection of capture system.

B.19.4 Bibliography

CAM ILLUSTRATION
No. 19a. PTE CAPTURE SYSTEM FOR VOC

1. APPLICABILITY

1.1 Capture Method: Permanent total enclosure (100 percent capture)
1.2 Pollutants: Volatile organic compounds (VOCs)
1.3 Process/Emissions Units: Coating operations, printing operations

2. MONITORING APPROACH DESCRIPTION

2.1 Indicators Monitored: Pressure differential across the enclosure and semi-annual inspection of PTE capture system.
2.2 Rationale for Monitoring Approach: Changes in pressure differential indicate changes in capture system performance. Semi-annual inspection and necessary maintenance will be used to ensure PTE criteria are maintained and exhaust system is in good working condition.
2.3 Monitoring Location (see Figure 1 for monitoring locations)
- Pressure differential: Pressure measured at points inside and outside the enclosure.
- Inspection: At all portions of PTE and exhaust system.

2.4 Analytical Devices Required
- Pressure differential: Pressure transducers, differential pressure gauges, manometers, other methods and/or alternative instrumentation as appropriate.
- Inspection: None.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement:
  - Pressure differential: Recorded continuously at 1-minute intervals using data acquisition system.
  - Inspections: Conducted semi-annually.
- Reporting units:
  - Pressure differential: Inches of water column (in. w.c.).
  - Inspection: Checklist used to verify PTE configuration and maintenance status and exhaust system conditions.
- Recording process:
  - Pressure differential: Recorded automatically on data acquisition system.
  - Inspection: Results manually logged.

2.6 Supporting Data Requirements
- Pressure differential measurements taken during PTE verification test (not required if relying on minimum “equivalent” pressure differential of 0.013 mmHg [0.0007 in. w.c.]).
- Diagram of PTE and exhaust system at time of initial PTE verification.

3. COMMENTS

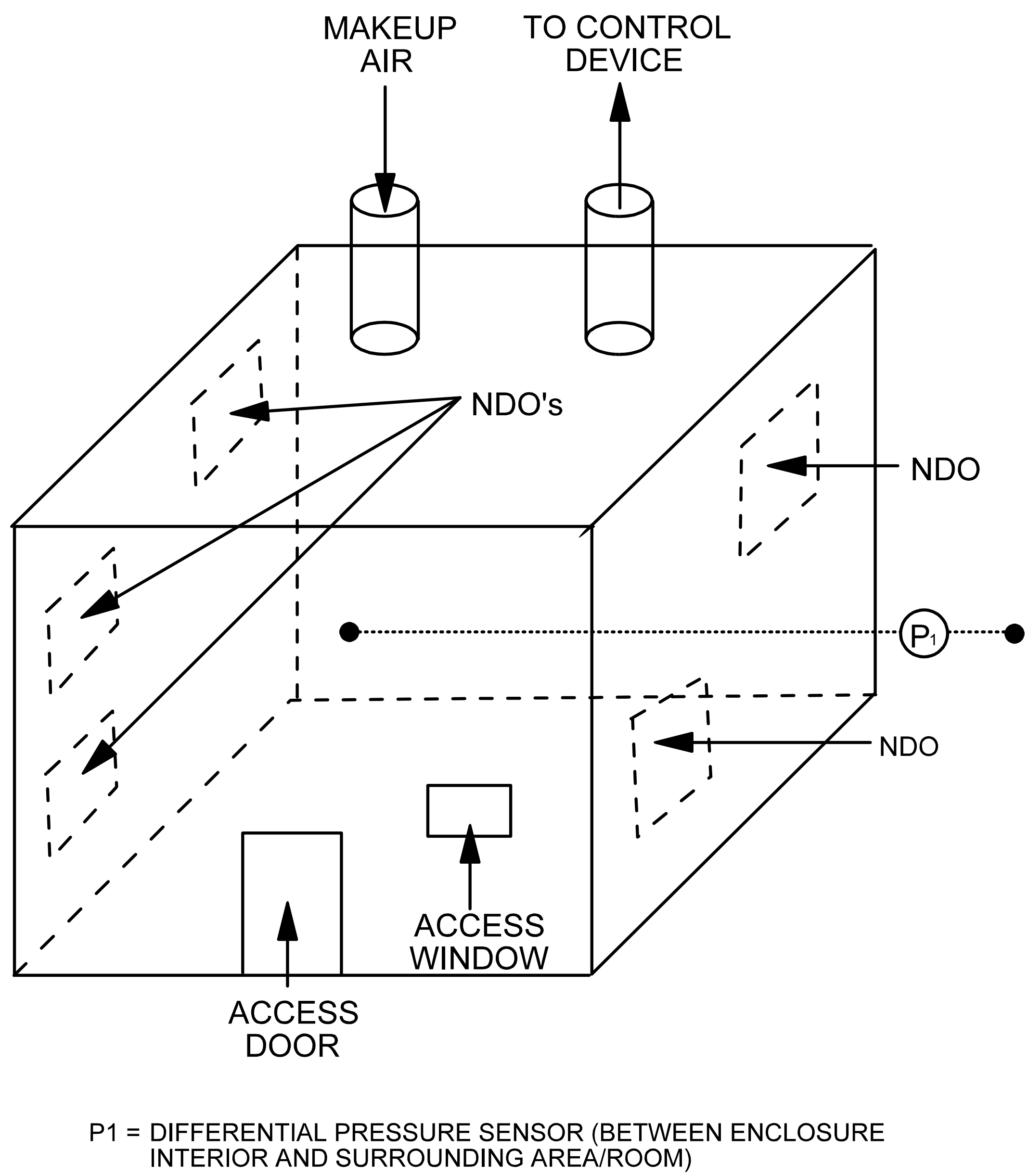

Figure B-19A. PTE: Monitoring location for differential pressure across enclosure (Illustration 19a).

CAM ILLUSTRATION
No. 19b. PTE CAPTURE SYSTEM FOR VOC

1. APPLICABILITY

1.1 Capture Method: Permanent total enclosure (100 percent capture)
1.2 Pollutants: Volatile organic compounds (VOCs)
1.3 Process/Emissions Units: Coating operations, printing operations

2. MONITORING APPROACH DESCRIPTION

2.1 Indicators Monitored: Average FV through all NDOs determined by measuring exhaust gas flow rate to control device and flow rate of forced makeup air, if any. Quarterly inspection of NDOs, and semi-annual inspection of PTE.

2.2 Rationale for Monitoring Approach: Changes in FV indicate changes in capture system performance. Quarterly NDO inspections ensure NDOs are maintained as during initial PTE verification. Semi-annual inspection and necessary maintenance will be used to ensure PTE criteria are maintained and exhaust system is in good working condition.

2.3 Monitoring Location (see Figure 2 for monitoring locations)
- Average FV: Exhaust gas duct to control device; forced makeup air duct. Net exhaust flow (total exhaust minus forced makeup air, if any) is divided by the total NDO area to determine the average FV.
- Inspections: All portions of PTE and exhaust system.

2.4 Analytical Devices Required
- FV: Flow monitors.
- Inspections: None.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement:
  - FV: Recorded continuously at 1-minute intervals on data acquisition system.
  - Inspections: Conducted quarterly on NDOs and semi-annually on PTE capture system.
- Reporting units:
  - FV: Feet per minute (ft/min).
  - Inspections: Checklist used to verify NDO and PTE configuration and maintenance status, and exhaust system conditions.
- Recording process:
  - FV: Recorded automatically on data acquisition system.
  - Inspections: Results manually logged.

2.6 Supporting Data Requirements
- Diagram of PTE and exhaust system at time of initial PTE verification.

3. COMMENTS

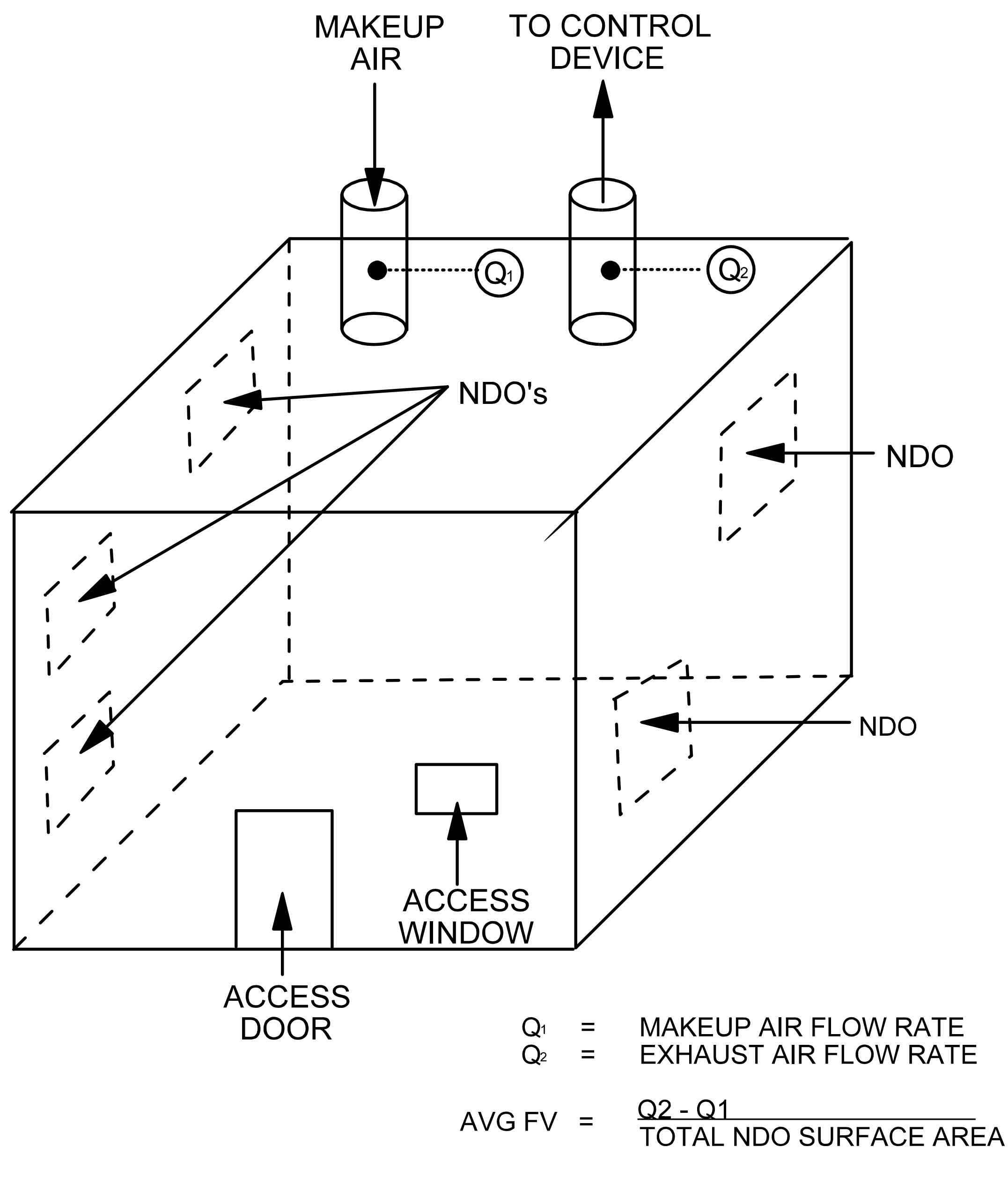

Figure B-19B. PTE: Monitoring location for average face velocity through all NDOs (Illustration 19b).

CAM ILLUSTRATION
No. 19c. PTE CAPTURE SYSTEM FOR VOC

1. APPLICABILITY

1.1 Capture Method: Permanent total enclosure (100 percent capture)
1.2 Pollutants: Volatile organic compounds (VOCs)
1.3 Process/Emissions Units: Coating operations, printing operations

2. MONITORING APPROACH DESCRIPTION

2.1 Indicators Monitored: FV at selected NDOs and semi-annual inspection of PTE capture system.

2.2 Rationale for Monitoring Approach: Changes in FV at NDOs indicate changes in capture system performance. Semi-annual inspection and necessary maintenance will be used to ensure PTE criteria are maintained and exhaust system is in good working condition.

2.3 Monitoring Location (see Figure 3 for monitoring locations)
- FV: Direct measurement at selected NDOs.
- Inspection: At all portions of PTE and exhaust system.

2.4 Analytical Devices Required
- FV: Flow velocity monitors.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement:
  - FV: Recorded continuously at 1-minute intervals on data acquisition system.
  - Inspections: Conducted semi-annually.
- Reporting units:
  - FV: Feet per minute (ft/min).
  - Inspection: Checklist used to verify PTE configuration and maintenance status and exhaust system conditions.
- Recording process:
  - FV: Recorded automatically on data acquisition system.
  - Inspections: Results manually logged.

2.6 Supporting Data Requirements
- Diagram of PTE and exhaust system at time of initial PTE verification.

3. COMMENTS

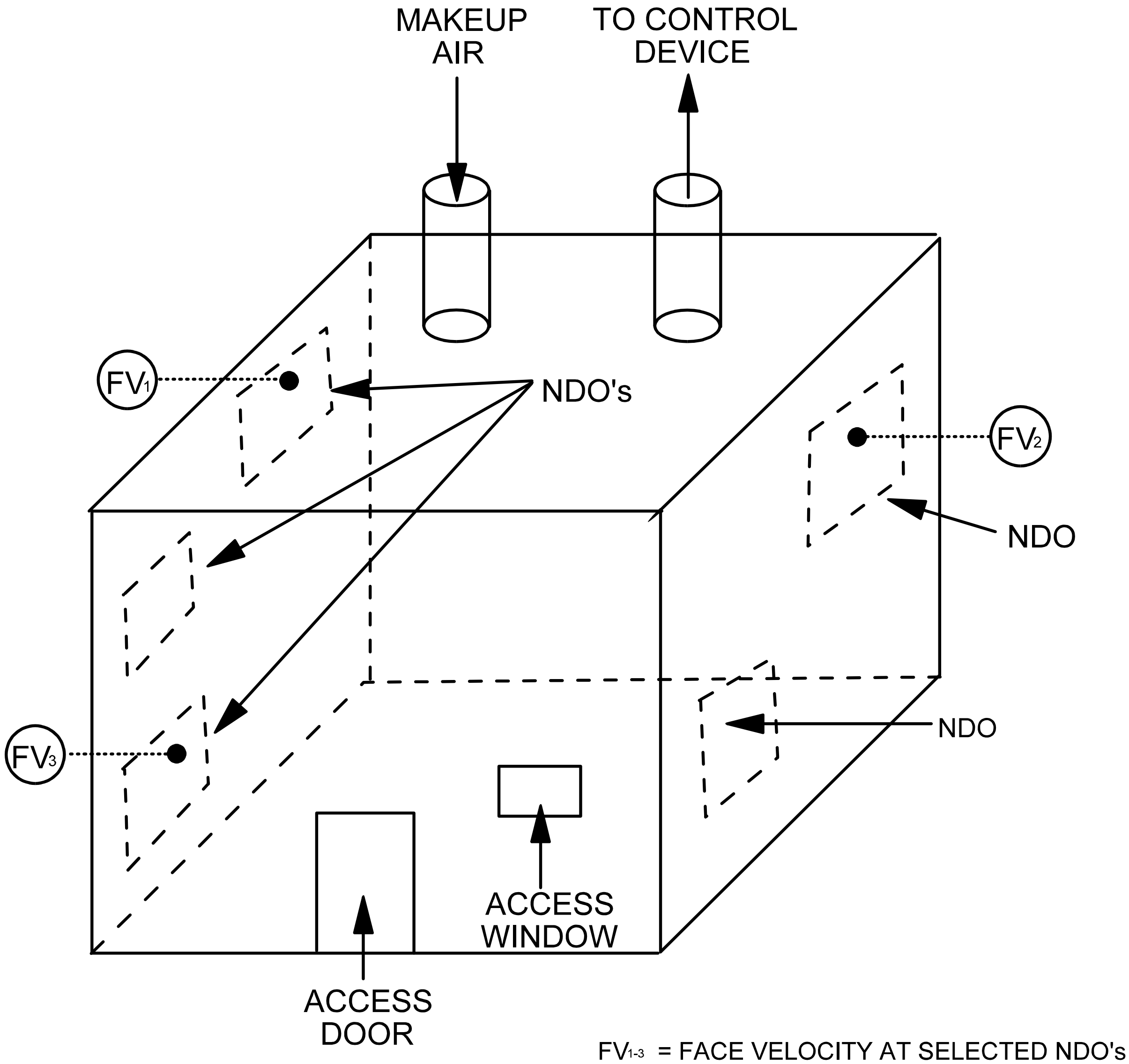

Figure B-19C. PTE: Monitoring location for face velocity at selected NDOs (Illustration 19c).

CAM ILLUSTRATION
No. 19d. PARTIAL ENCLOSURE CAPTURE SYSTEM FOR VOC

1. APPLICABILITY

1.1 Capture Method: Partial enclosure (less than 100 percent capture)
1.4 Pollutants: Volatile organic compounds (VOCs)
1.5 Process/Emissions Units: Coating operations, printing operations

2. MONITORING APPROACH DESCRIPTION

2.1 Indicators Monitored: Pressure differential across the enclosure and semi-annual inspection of capture system.
2.2 Rationale for Monitoring Approach: Changes in pressure differential indicate changes in capture system performance. Semi-annual inspections and necessary maintenance will be used to maintain capture system integrity.
2.3 Monitoring Location (see Figure 4 for monitoring locations)
- Pressure differential: Pressure measured at points inside and outside the enclosure (e.g., curing oven).
- Inspection: At all portions of capture system.

2.4 Analytical Devices Required
- Pressure differential: Pressure transducers, differential pressure gauges, manometers, other methods and/or alternative instrumentation as appropriate.
- Inspection: None.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement:
  – Pressure differential: Recorded continuously at 1-minute intervals on data acquisition system.
  – Inspection: Conducted semi-annually.
- Reporting units:
  – Pressure differential: Inches of water column (in. w.c.).
  – Inspection: Checklist used to verify condition of capture system.
- Recording process:
  – Pressure differential: Recorded automatically on data acquisition system.
  – Inspection: Results manually logged.

2.6 Supporting Data Requirements
- Pressure differential measurements taken during test to measure capture efficiency, or design information if capture efficiency test not required by applicable regulation.
- Diagram of enclosure and exhaust system at time of test to measure capture efficiency.

3. COMMENTS

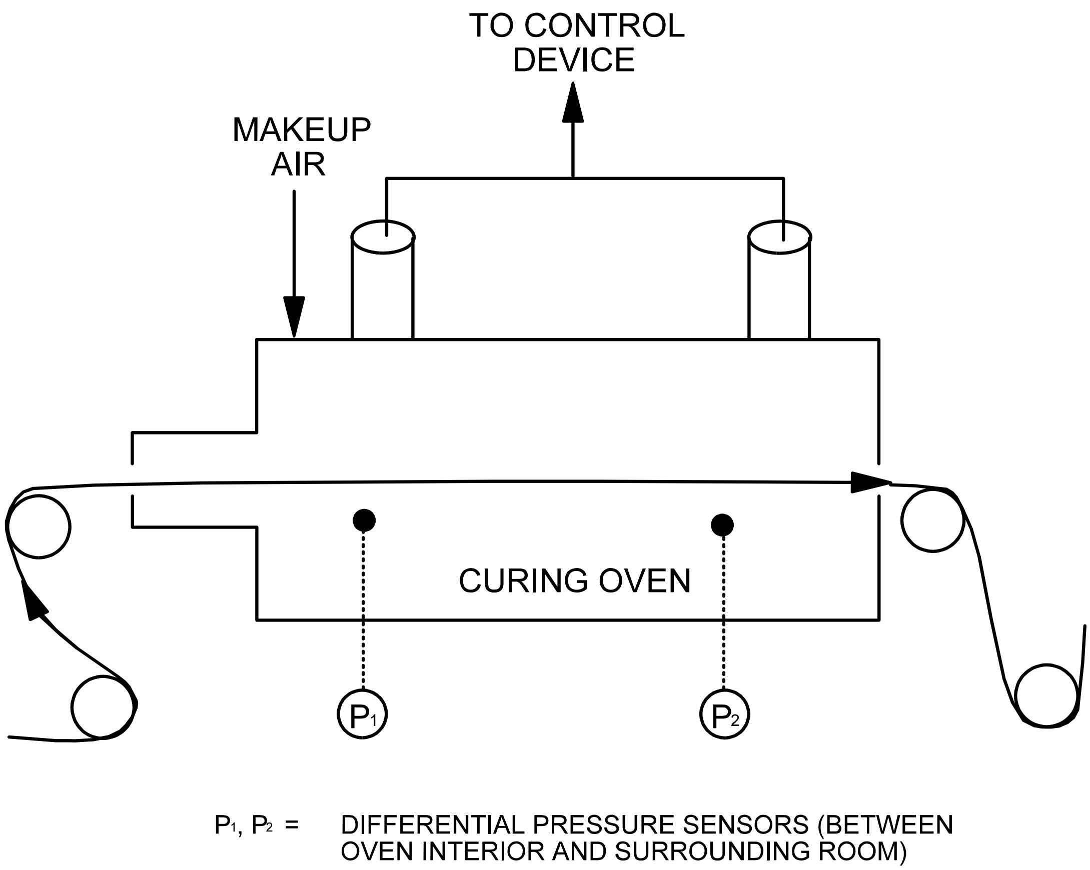

Figure B-19D. Partial enclosure: Example monitoring locations for pressure differential across enclosure (Illustration 19d).

CAM ILLUSTRATION
No. 19e. LOCAL EXHAUST VENTILATION SYSTEM FOR CAPTURE OF VOC

1. APPLICABILITY

1.3 Capture Method: Local exhaust ventilation system
1.4 Pollutants: Volatile organic compounds (VOCs)
1.5 Process/Emissions Units: Coating operations

2. MONITORING APPROACH DESCRIPTION

2.1 Indicators Monitored: Velocity at the hood and semi-annual inspection of capture system.
2.2 Rationale for Monitoring Approach: A change in velocity at the hood indicates changes in capture system performance. Semi-annual inspections and necessary maintenance will be used to maintain the capture system in good working condition.
2.3 Monitoring Location (see Figure 5 for monitoring locations)
- Velocity: At hood or in duct near hood.
- Inspection: At all portions of capture system.

2.4 Analytical Devices Required
- Velocity: Velocity meter.
- Inspection: None.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement:
  - Velocity: Recorded continuously at 1-minute intervals on data acquisition system.
  - Inspection: Conducted semi-annually.
- Reporting units:
  - Velocity: Feet per minute (ft/min).
  - Inspection: Checklist used to verify condition of capture system.
- Recording process:
  - Velocity: Recorded automatically on data acquisition system.
  - Inspection: Results manually logged.

2.6 Supporting Data Requirements
- Velocity measurements taken during test to measure capture efficiency or design velocity information if capture efficiency test not required by applicable regulation.

3. COMMENTS

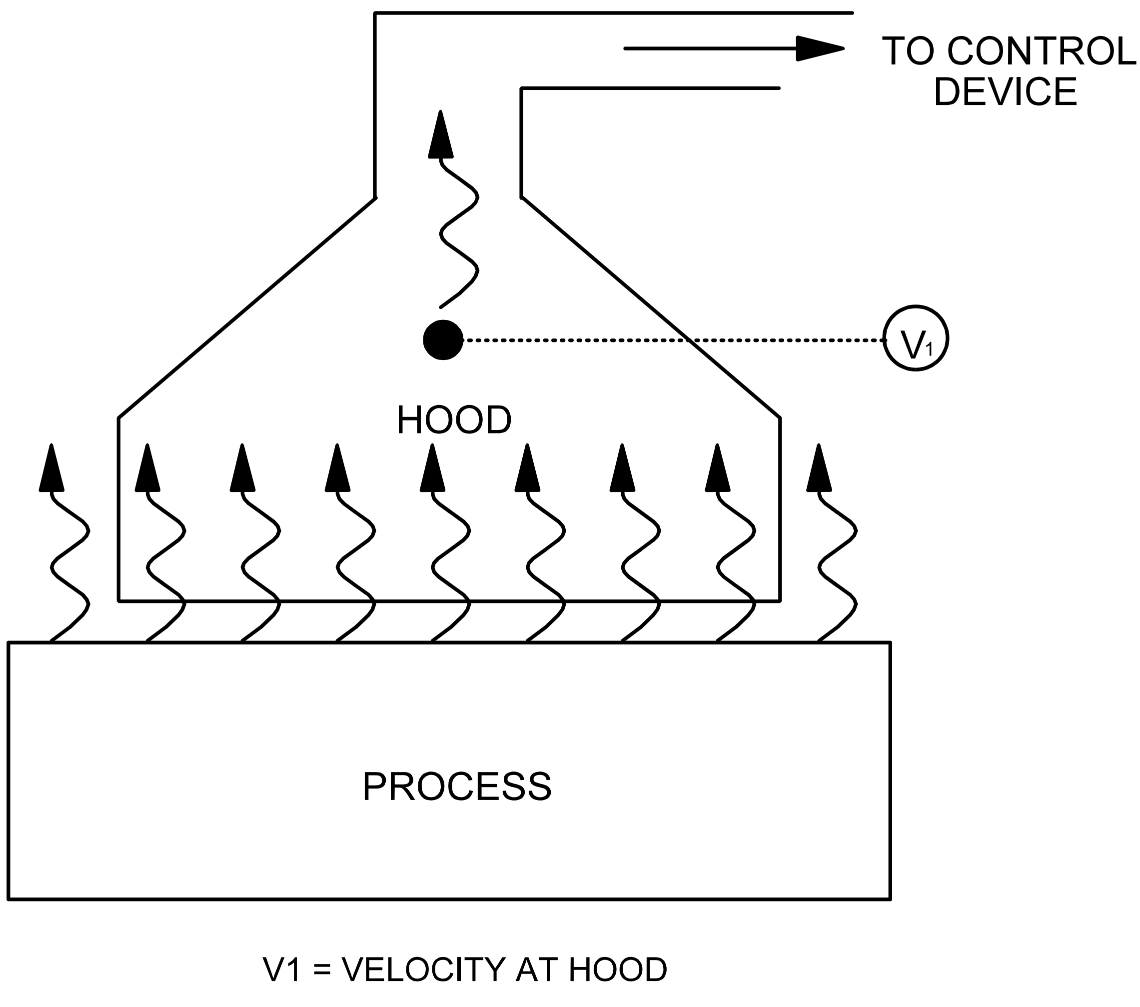

Figure B-19E. Local exhaust ventilation system: Monitoring location for velocity at the hood (Illustration 19e).

CAM ILLUSTRATION
No. 19f. LOCAL EXHAUST VENTILATION SYSTEM FOR CAPTURE OF VOC OR FUGITIVE PM

1. APPLICABILITY

1.1 Capture Method: Local exhaust ventilation system
1.2 Pollutants: Volatile organic compounds (VOCs), fugitive particulate matter (PM)
1.3 Process/Emissions Units: Coating operations, material handling

2. MONITORING APPROACH DESCRIPTION

2.1 Indicators Monitored
- Ventilation system fan parameters such as speed, current, static pressure, damper position, or a combination these parameters depending upon fan type and system design; and
- Inspection of capture hood and duct integrity.

2.2 Rationale for Monitoring Approach: A change in ventilation flow through the system will impact capture system efficiency; a decrease in flow will decrease the capture efficiency. Also, for any given ventilation rate through the system, the integrity of the capture hood and ducting must be maintained in order to maintain the capture efficiency. Fan performance is monitored as an indicator that a minimum ventilation rate is maintained. Periodic inspection is used to monitor the capture system condition and indicate the need for corrective action (maintenance).

2.3 Monitoring Location (see Figure 6 for monitoring locations)
- Fan operation: Fan housing and ductwork.
- Inspection: All portions of capture system.

2.4 Analytical Devices Required
- Fan parameters: (Will depend on parameters monitored)
  – Fan speed: revolutions per minute (rpm) meter.
  – Fan current: Ammeter.
  – Fan static pressure: Differential pressure gauge.
  – Damper position: Position indicator.
- Inspection: None.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement:
  – Fan parameters: Once per day or once per shift, or continuously at 15-minute intervals on data acquisition system; less frequent measurements (e.g., once per shift or day) may be considered for smaller systems.
  – Inspection: Daily.
- Reporting units:
  – Fan parameters: Speed (rpm), current (amperage), pressure (inches of water).
  – Inspection: Checklist used to verify condition of capture system.

- Recording process:
  - Fan parameters: Operators log data manually (for smaller systems), or recorded automatically on strip chart or data acquisition system.
  - Inspection: Operators log results manually.

2.6 Supporting Data Requirements

- Fan parameters measured during initial demonstration test of capture system (e.g., initial capture system efficiency test, face velocity measurements) or parameters established by design (e.g, flow needed to achieve minimum hood face velocity); and
- Fan curve from manufacturer or vendor.

3. COMMENTS

This approach relies on the basic concept that a minimum capture system performance level will be achieved when the system ventilation rate is maintained at a minimum level and the capture system integrity is maintained. Consequently, this approach is most applicable to systems which are rather simple in design, e.g., a system consisting of a single hood or enclosure connected to a fan with a limited amount of ductwork and dampers. As the complexity of the capture system increases (e.g, a single fan ventilating multiple hoods or enclosures with a complicated dampering system and recycle air), the level of confidence of this approach decreases. For more complex capture systems, an approach that incorporates a performance indicator involving a more direct measure at the point of capture is recommended.

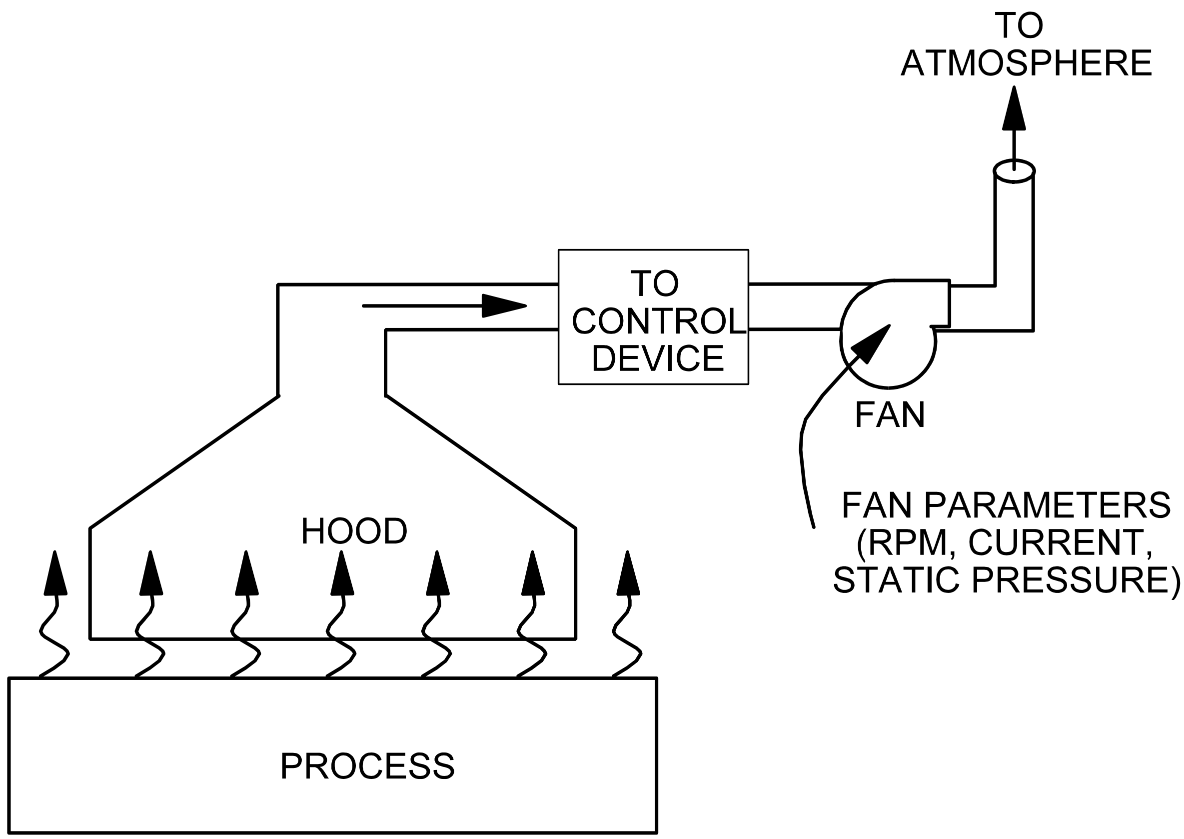

Figure B-19F. Local exhaust ventilation system: Monitoring locations for fan parameter (Illustration 19f).