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

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. 6a. THERMAL OXIDIZER FOR CO 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 CO emissions by combustion

1.2 Pollutants
Primary: Carbon monoxide (CO)
Other: Volatile organic compounds (VOCs)

1.3 Process/Emissions units: Fluid catalytic cracking unit (FCCU) catalyst regenerators; petroleum refining

2. MONITORING APPROACH DESCRIPTION

2.1 Parameters to be Monitored: Combustion chamber temperature and annual burner inspection.

2.2 Rationale for Monitoring Approach
- Combustion chamber temperature: Low temperature indicates potential for insufficient destruction of CO.
- 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.
- Manufacturer's data and recommended operating ranges.

2.7 Specific QA/QC Procedures: Calibrate, maintain, and operate thermocouples 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. 6b. THERMAL OXIDIZER FOR CO 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 CO emissions by combustion

1.2 Pollutants
Primary: Carbon monoxide (CO)
Other: Volatile organic compounds (VOCs)

1.3 Process/Emissions units: Fluid catalytic cracking unit (FCCU) catalyst regenerators; petroleum refining

2. MONITORING APPROACH DESCRIPTION

2.1 Indicators Monitored: Outlet CO concentration.

2.2 Rationale for Monitoring Approach: Provides direct indicator of CO emissions.

2.3 Monitoring Location: Combustion chamber outlet.

2.4 Analytical Devices Required: Nondispersive infrared (NDIR) analyzer or other methods or instrumentation.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement: Hourly, if read manually; continuously, if CEMS.
- Reporting units: Parts per million by volume (ppm_v), dry basis.
- Recording process: Operators log data manually, or recorded automatically on strip chart or data acquisition system.

2.6 Data Requirements
- Baseline outlet CO concentration measurements concurrent with emissions test.
- Historical plant records outlet CO concentration measurements.

2.7 Specific QA/QC Procedures: Calibrate, maintain, and operate CEMS 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.)

3.2 Concentration measurements: Outlet CO concentration in terms of ppm can be used as an indicator of control device performance even if the emission standard is a mass emissions standard (i.e., lb/hr); additional information (e.g., flow) to calculate/report emission in units of the standard is not required for CAM; however, such a measurement may be a monitoring requirement of the applicable requirement.

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.)