

## **B.4 WET SCRUBBERS FOR PM CONTROL**<sup>1,2,8,9,15,22</sup>

### **B.4.1 Background**

Wet scrubbers use a liquid to remove pollutants from an exhaust stream. Applications include foundries, lime kilns, incinerators, boilers, wood products dryers, asphalt plants, and the chemical and pulp and paper industries. In particulate matter (PM) emission control applications, PM in the exhaust stream collide with the liquid droplets, are collected in the liquid, and are removed with the scrubbing liquid. The three main mechanisms by which wet scrubbers control PM emissions are: (1) impaction of the particle into the target droplet; (2) interception of the particle by the droplet; and (3) diffusion of the particle through the gas into the droplet. Collection efficiency tends to increase with particle size (for particles with diameters greater than 0.5  $\mu\text{m}$ ) and pressure differential across the scrubber. A wet scrubber's particle collection efficiency is directly related to the amount of energy expended in contacting the gas stream with the scrubber liquid. There are several types of wet scrubber designs, including venturi, spray towers, and mechanically aided wet scrubbers. High energy scrubbers include venturi, hydrosonic, collision, or free jet scrubber designs.

Venturi scrubbers are very common for PM control; compared to most scrubber designs, they create a larger pressure differential and higher turbulence, and therefore have a high energy consumption and a low penetration of small particles. However, they have co-current flow and are therefore not as effective as spray towers in controlling gaseous emissions. Mechanically aided wet scrubbers utilize a rotor or fan to shear the liquid into droplets. Again, there is low PM penetration but a high energy cost, and frequent buildup of PM and erosion of the blades. Spray towers (countercurrent flow) are frequently used to control gaseous emissions when PM is also present. Once the PM has been captured by the droplets, the water droplets are separated from the exhaust gas by gravity, centrifugal force, and baffles. Mesh pads and mist eliminators are used in the exhaust to capture any entrained droplets

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 high dissolved solids liquid; nozzle erosion or pluggage; air inleakage; particle re-entrainment; freezing/plugging of lines; and scaling.

### **B.4.2 Indicators of Wet Scrubber (for PM) 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 (PM or gaseous), scrubber design, and exhaust gas characteristics. For PM control, the primary indicators of wet scrubber performance are pressure differential and scrubber liquid flow rate. Other parameters that can indicate wet scrubber performance include gas flow rate, scrubber liquid solids content, scrubber outlet gas temperature, and scrubber liquid makeup or blowdown rates. For systems that recycle the scrubbing liquid, scrubbing liquid solids content and makeup

or blowdown rate may be appropriate performance indicators. Scrubber outlet gas temperatures may be appropriate parameters for thermal processes. Table B-4 lists these indicators and illustrates potential monitoring options for wet scrubbers for PM control. These indicators are described below.

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. Pressure differential is particularly important for scrubber designs, such as venturi scrubbers, that operate with relatively high pressure differentials. The control efficiency of a venturi scrubber is a function of the total energy consumption within the scrubber, and total energy consumption is largely a function of the pressure differential across the scrubber.

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 or atomized, and the liquid-gas interface is maintained. Under these conditions, higher liquid flow rates are indicative of higher levels of control.

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 solids content. When the scrubber liquid is recycled, the solids content of the liquid is indicative of the likelihood of re-entrainment of PM from the scrubber liquid, of nozzle plugging, and of solids buildup elsewhere in the recirculation system. Although less reliable as an indicator of performance, the scrubber liquid conductivity can be monitored as a surrogate for monitoring the scrubber liquid solids content.

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.

Makeup/blowdown rates. To keep the solids 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 solids content of the scrubber liquid, provided the scrubber inlet PM loading does not change significantly. Under the conditions of constant inlet loading, decreases in makeup or blowdown rates generally correspond to increases in the solids content of the scrubbing liquid. This indicator is not commonly monitored, and scrubber liquid solids content is a better indicator.

Scrubber inlet gas temperature/Process exhaust temperature. For wet scrubbers that are used to control thermal processes, the inlet gas temperature (or process exhaust temperature) also is an important indicator of performance. Increases in scrubber inlet temperatures may indicate that the scrubber liquid flow rate should be increased to ensure that the process exhaust stream is being quenched properly and/or the scrubber liquid flow is adequate. Too high a temperature and too low a liquid flow rate can indicate a decrease in performance. Scrubber liquid temperature can be monitored as a surrogate for inlet gas temperature (or process exhaust gas temperature), but would not be as reliable an indicator of performance as would monitoring scrubber inlet gas temperature directly.

#### B.4.3 Illustrations

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

- 4a: Monitoring pressure differential across scrubber.
- 4b: Monitoring pressure differential across scrubber and scrubber liquid flow rate.
- 4c: Monitoring pressure differential across scrubber, scrubber liquid flow rate, and scrubber liquid solids content.

#### B.4.4 Bibliography

TABLE B-4. SUMMARY OF PERFORMANCE INDICATORS FOR WET SCRUBBERS FOR PM CONTROL

Parameters	Performance indication	Approach No.	1	2	3	4	5	6	7	8	9
		Illustration No.	4a	4b							4c
		Example CAM Submittal	A17		A2				A8	A14	
		Comment	✓	✓		✓	✓	✓			
<b>Primary Indicators of Performance</b>											
Pressure differential (ΔP)	A wet scrubber will operate at a relatively constant pressure differential. Shows whether there is normal gas flow and normal liquid flow. Poor gas-liquid distribution can decrease efficiency without affecting pressure differential; plugging can result in higher pressure differential without corresponding increase in control.	X	X		X		X		X	X	
Scrubber liquid flow rate	Low liquid flow causes a decrease in pressure differential and lower collection efficiency; want to maximize L/G ratio. Can use scrubber inlet liquid supply pressure or pump motor current as surrogates for liquid flow rate.		X	X		X					X
<b>Other Performance Indicators</b>											
Gas flow rate	Increase in gas flow rate without increase in liquid flow rate results in lower L/G ratio and lower control efficiency. Can also measure fan current or inlet velocity pressure as surrogate for gas flow rate.			X		X					
Scrubber liquid solids content	High solids can cause plugging and reduced particle capture. Applicable if scrubber liquid is recycled or if water quality is an issue; can monitor conductivity or specific gravity as surrogates of solids content.										X
Scrubber outlet gas temperature	Increase in outlet gas temperature can indicate inadequate liquid flow.			X					X	X	
Scrubber inlet gas temperature	High inlet gas temperature indicates that there has been a change in operation; scrubber liquid must be increased to handle the gas stream. Applies only to scrubbers that control thermal processes; scrubber liquid temperature can be used as a surrogate for inlet gas temperature.									X	
Inlet velocity pressure	Inlet pressure provides an indication of the inlet gas flow rate.							X			

TABLE B-4. (Continued)

Parameters	Performance indication	Approach No.	1	2	3	4	5	6	7	8	9	
		Illustration No.	4a	4b								4c
		Example CAM Submittal	A17		A2					A8	A14	
		Comment	✓	✓		✓	✓	✓				
Scrubber liquid supply pressure	Pressure provides indicator of liquid flow rate (see above). Because it typically is easier to measure than measuring liquid flow rate, pressure often is used as a surrogate for flow rate.					X						
Inspections	Filter check or visible emissions inspection.						X		X			
<p>Comments:</p> <ul style="list-style-type: none"> <li>• Approach No. 1 also corresponds to 40 CFR 63, subpart XXX (Ferroalloys Production) for a venturi scrubber.</li> <li>• Approach No. 2 is required by several NSPS and 40 CFR 63, subparts X (Secondary Lead Smelting) and AA (Phosphoric Acid).</li> <li>• Approach No. 4 is required by several NSPS.</li> <li>• Approach No. 5 corresponds to 40 CFR 63, subpart LL (Primary Aluminum) for wet scrubbers.</li> <li>• Approach No. 6 corresponds to 40 CFR 63, subpart N (Chromium Electroplating) for combination packed bed and composite mesh-pad systems for chromium acid droplets; the pressure differential and inlet velocity pressure are monitored for the packet bed, and the pressure differential is monitored for the composite mesh pad.</li> </ul>												

CAM ILLUSTRATION  
No. 4a. WET SCRUBBER FOR PM CONTROL

**1. APPLICABILITY**

- 1.1 Control Technology: Wet scrubber [001, 002, 003]; also applicable to spray towers [052], venturi scrubbers [053], impingement scrubbers [055], and wet cyclonic separator [085]
- 1.2 Pollutants  
Primary: Particulate matter (PM)  
Other:
- 1.3 Process/Emissions Unit: Combustors, mineral processing units, furnaces, kilns

**2. MONITORING APPROACH DESCRIPTION**

- 2.1 Indicators Monitored: Differential pressure.
- 2.2 Rationale for Monitoring Approach: Decrease in pressure differential indicates decrease in gas or liquid flow or poor liquid distribution; increase in pressure differential indicates clogging or increased gas flow.
- 2.3 Monitoring Location: Across inlet and outlet ducts.
- 2.4 Analytical Devices Required: Differential pressure transducer, differential pressure gauge, manometers, or alternative methods/instrumentation; see section 4.3 for information on specific types of instruments.
- 2.5 Data Acquisition and Measurement System Operation
  - Frequency of measurement: Hourly, or recorded continuously on strip chart or data acquisition system.
  - Reporting units: Inches of water column (in. w.c.).
  - Recording process: Operators log data manually, or automatically recorded on strip chart or data acquisition system.
- 2.6 Data Requirements
  - Baseline pressure differential measurements concurrent with emissions test; or
  - Historical plant records of pressure differential measurements.
- 2.7 Specific QA/QC Procedures
  - Calibrate, maintain, and operate instrumentation using procedures that take into account manufacturer's specifications.
- 2.8 References: 8, 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.)

CAM ILLUSTRATION  
No. 4b. WET SCRUBBER FOR PM CONTROL

**1. APPLICABILITY**

- 1.1 Control Technology: Wet scrubber [001, 002, 003], spray tower [052], venturi scrubber [053], impingement scrubber [055], or wet cyclonic separator [085]
- 1.2 Pollutants
  - Primary: Particulate matter (PM)
  - Other: Fluorides
- 1.3 Process/Emissions Unit: Combustors, furnaces, dryers, calciners, kilns, material handling systems

**2. MONITORING APPROACH DESCRIPTION**

- 2.1 Parameters to be Monitored: Pressure differential and scrubber liquid flow rate.
- 2.2 Rationale for Monitoring Approach
  - Pressure differential: Decrease in pressure differential indicates decrease in gas or liquid flow or poor liquid distribution; increase in pressure differential indicates clogging or increased gas flow.
  - Scrubber liquid flow rate: Monitoring scrubber liquid flow will indicate adequate liquid flow through the scrubber.
- 2.3 Monitoring Location
  - Pressure differential: Measure across inlet and outlet ducts.
  - Scrubber liquid flow rate: Measure at scrubber liquid inlet.
- 2.4 Analytical Devices Required
  - Pressure differential: Differential pressure transducer, differential pressure gauge, manometers, or alternative methods/instrumentation for pressure.
  - Scrubber liquid flow rate: Liquid flow meter or other device for liquid flow; see section 4 for more information on specific types of instruments.
- 2.5 Data Acquisition and Measurement System Operation
  - Frequency of measurement: Hourly, or recorded continuously on strip chart or data acquisition system.
  - Reporting units:
    - Pressure differential: Inches water column (in. wc).
    - Scrubber liquid flow rate: Gallons per minute (gpm) or cubic feet per minute (ft<sup>3</sup>/min).
  - Recording process: Operators log data manually, or recorded automatically on strip chart or data acquisition system.
- 2.6 Data Requirements
  - Baseline pressure differential and scrubber liquid flow rate measurements concurrent with emissions test.
  - Historical plant records of pressure differential and scrubber liquid flow rate measurements.

2.7 Specific QA/QC Procedures

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

2.8 References: 8, 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.)



CAM ILLUSTRATION  
No. 4c. WET SCRUBBER FOR PM CONTROL

**1. APPLICABILITY**

- 1.1 Control Technology: Wet scrubber [001, 002, 003], spray tower [052], venturi scrubber [053], impingement scrubber [055], or wet cyclonic separator [085]
- 1.2 Pollutants
  - Primary: Particulate matter (PM)
  - Other: Fluorides
- 1.3 Process/Emissions Unit: Combustors, furnaces, dryers, calciners, kilns, material handling systems

**2. MONITORING APPROACH DESCRIPTION**

- 2.1 Parameters to be Monitored: Pressure differential, scrubber liquid flow rate, and scrubber liquid solids content.
- 2.2 Rationale for Monitoring Approach
  - Pressure differential: Decrease in pressure differential indicates decrease in gas or liquid flow or poor liquid distribution; increase in pressure differential indicates clogging or increased gas flow.
  - Scrubber liquid flow rate: Monitoring scrubber liquid flow will indicate adequate liquid flow through the scrubber.
  - Scrubber liquid solids content: High solids content increases likelihood of re-entrainment.
- 2.3 Monitoring Location
  - Pressure differential: Measure across inlet and outlet ducts.
  - Scrubber liquid flow rate: Measure at scrubber liquid inlet.
  - Scrubber liquid solids content: Measure at inlet water line or recycle liquid tank.
- 2.4 Analytical Devices Required
  - Pressure differential: Differential pressure transducer, differential pressure gauge, manometers, or alternative methods/instrumentation for pressure; see section 4 for more information.
  - Scrubber liquid flow rate: Liquid flow meter or other device for liquid flow; see section 4 for more information.
  - Scrubber liquid solids content: Manual sampling of liquid.
- 2.5 Data Acquisition and Measurement System Operation
  - Frequency of measurement: Hourly, or recorded continuously on strip chart or data acquisition system; scrubber liquid solids content, weekly.
  - Reporting units:
    - Pressure differential: Inches water column (in. wc).
    - Scrubber liquid flow rate: Gallons per minute (gpm) or cubic feet per minute (ft<sup>3</sup>/min).
    - Scrubber liquid solids content: Percent solids.

- 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, scrubber liquid solids content measurements concurrent with emissions test.
  - Historical plant records of pressure differential, scrubber liquid flow rate, scrubber liquid solids content measurements.
- 2.7 Specific QA/QC Procedures
- Calibrate, maintain, and operate instruments using procedures that take into account manufacturer's recommendations.
- 2.8 References: 8, 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.5 WET SCRUBBERS FOR GASEOUS CONTROL**<sup>1,2,9,15</sup>

### **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<sub>2</sub>S). 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 leakage; 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<sub>2</sub> 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

Parameters	Performance indication	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
		Comment	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓		
<b>Primary Indicators of Performance</b>																		
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		
<b>Other Performance Indicators</b>																		
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.																	

CAM TECHNICAL GUIDANCE DOCUMENT  
B.5 WET SCRUBBERS FOR VOC CONTROL

TABLE B-5. (Continued)

Parameters	Performance indication	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
		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 <sub>2</sub> 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.																



TABLE B-5. (Continued)

Parameters	Performance indication	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
		Comment	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	
Comments:		<ul style="list-style-type: none"> <li>• Approach No. 1 also corresponds to 40 CFR 63, subparts U (Polymers and Resins I), JJJ (Polymers and Resins IV), and MMM (Pesticides).</li> <li>• Approach No. 2 corresponds to 40 CFR 63, subpart Y (Marine Vessels).</li> <li>• Approach No. 4 corresponds to 40 CFR 63, subparts G (HON), U (Polymers and Resins I), JJJ (Polymers and Resins IV), OOO (Polymers and Resins III) for HAP.</li> <li>• Approach No. 5 corresponds to 40 CFR 63, subpart G (HON) for halogenated HAPs from process vents or transfer operations, S (Pulp and Paper), and OOO (Polymers and Resins III).</li> <li>• Approach No. 6 corresponds to 40 CFR 63, subpart AA (Phosphoric Acid).</li> <li>• Approach No. 7 corresponds to 40 CFR 63, subpart CCC (Steel Pickling-HCl).</li> <li>• Approach No. 8 corresponds to 40 CFR 63, subpart NNN (Wool Fiberglass).</li> <li>• Approach No. 9 corresponds to 40 CFR 63, subpart W (Polymers and Resins II).</li> <li>• Approach No. 10 corresponds to 40 CFR 63, subpart MMM (Pesticies).</li> <li>• Approach No. 13 corresponds to 40 CFR 63, subpart O (Commercial Ethylene Oxide Sterilization). It should be scrubber liquid outlet concentration OR scrubber liquid level. <b>Can move scrubber liquid level to another approach, but is bad ex. O (commercial Ed Ster) - scrubber liquid EO concentration, S (Pulp and Paper) -pH or oxid/red potential of liquid, liquid flow, gas flow.</b></li> </ul>															

CAM ILLUSTRATION  
No. 5a. WET SCRUBBER FOR SO<sub>2</sub> CONTROL

**1. APPLICABILITY**

- 1.1 Control Technology: Wet scrubber [001, 002, 003]; also applicable to gas scrubbers (general) [013], gas column absorber (packed or tray type) [050, 051]
- 1.2 Pollutants
  - Primary: Sulfur dioxide (SO<sub>2</sub>)
  - Other: Acid gases
- 1.3 Process/Emissions Unit: Combustors

**2. MONITORING APPROACH DESCRIPTION**

- 2.1 Indicators Monitored: Scrubber liquid flow rate and scrubber liquid pH.
- 2.2 Rationale for Monitoring Approach
  - Scrubber liquid flow rate: Indicates adequate liquid flow through the scrubber.
  - Scrubber liquid pH: pH level is indicative of removal efficiency from exhaust stream.
- 2.3 Monitoring Location
  - Scrubber liquid flow rate: Measure at pump discharge or at scrubber liquid inlet.
  - Scrubber liquid pH: Measure at scrubber liquid effluent.
- 2.4 Analytical Devices Required
  - Scrubber liquid flow rate: Liquid flow meter or other device for liquid flow; see section 4.4 for information on specific types of instruments.
  - Scrubber liquid pH: pH meter.
- 2.5 Data Acquisition and Measurement System Operation
  - Frequency of measurement: Hourly, or recorded continuously on strip chart or data acquisition system.
  - Reporting units:
    - Scrubber liquid flow rate: Gallons per minute (gal/min) or cubic feet per minute (ft<sup>3</sup>/min).
    - Scrubber liquid pH: pH units.
  - Recording process: Operators log data manually, or recorded automatically on strip chart or data acquisition system.
- 2.6 Data Requirements
  - Baseline scrubber liquid flow rate and scrubber liquid pH concurrent with emissions test.
  - Historical plant records of scrubber liquid flow rate and scrubber liquid pH measurements.
- 2.7 Specific QA/QC Procedures
  - Calibrate, maintain, and operate instrumentation using procedures that take 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.)

CAM ILLUSTRATION  
No. 5b. WET SCRUBBER FOR FLUORIDES CONTROL

**1. APPLICABILITY**

- 1.1 Control Technology: Wet scrubber [001, 002, 003]; also applicable to gas scrubbers (general) [013], gas absorber column (packed or tray type) [050, 051]
- 1.2 Pollutants  
Primary: Fluorides  
Other:
- 1.3 Process/Emissions Unit: Primary aluminum processing units, phosphate fertilizer manufacturing

**2. MONITORING APPROACH DESCRIPTION**

- 2.1 Indicators Monitored: Pressure differential.
- 2.2 Rationale for Monitoring Approach: Increase in pressure differential indicates plugging or increased gas flow; decrease in pressure differential indicates decrease in gas or liquid flow or poor liquid distribution.
- 2.3 Monitoring Location: Measure across inlet and outlet ducts.
- 2.4 Analytical Devices Required: Differential pressure transducer, differential pressure gauge, manometers, or alternative methods/instrumentation; see section 4.3 for information on specific types of instruments.
- 2.5 Data Acquisition and Measurement System Operation
  - Frequency of measurement: Hourly, or recorded continuously on strip chart or data acquisition system.
  - Reporting units: Inches of water column (in. w.c.).
  - Recording process: Operators log data manually, or recorded automatically on strip chart or data acquisition system.
- 2.6 Data Requirements
  - Baseline pressure differential measurements concurrent with emissions test; or
  - Historical plant records of pressure differential measurements.
- 2.7 Specific QA/QC Procedures
  - Calibrate, maintain, and operate instrumentation taking into account manufacturer's specifications.
- 2.8 References:

**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 For systems using once-through scrubber liquid, monitoring of pressure differential is sufficient. However, use of recycled water or scrubber liquid would require pH monitoring and caustic addition.

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<sub>2</sub>), 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.)