Flux force condensation scrubbing

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Flux force condensation scrubbing technology is used to capture fine (submicron) particulate at extremely high efficiency. It is a preferred method when using wet scrubbing to collect and control dioxins from combustion sources. As an added benefit, through the use of condensation, the water vapor plume commonly associated with a wet scrubbing system can be effectively eliminated. The overall collection efficiency of acid gases plus particulate is greater than with "dry" systems because the acid gas removal efficiency is exceptionally high.

The flux force condensation (FFC) technique uses the condensation of water vapor onto the particulates to coat them with a water film, thus making the particles aerodynamically larger and easier to capture. This occurs in a device called a condenser/absorber or C/A. Because water vapor is condensed, the downstream equipment (fan, stack, or similar equipment) is physically smaller and often less expensive. The reduction in size occurs because the voluminous water vapor is condensed to low-volume water droplets, and the dry gas portion of the flow reduces in volume by cooling. The C/A circuit is also typically pH-controlled to simultaneously remove acid gases.

Applications in which FFC scrubbing is often used include hazardous and medical waste incinerators, boilers, calciners, kilns, and other sources that emit submicron particulate along with acidic gases. It is most often applied to sources that provide saturation temperatures higher than 145°F but can be applied to lower-temperature applications through the introduction of steam.

How it works

FFC technology mimics the particulate capture that occurs naturally in the atmosphere through the formation of raindrops. Raindrops primarily form on dust particles in the air through a process called nucleation. The atmospheric water vapor condenses around the particulate, thus coating each one and making a heavier droplet that then falls to earth. If it weren't for this process, dust would remain in the atmosphere, and air-breathing life forms would suffocate.

The nucleation and condensation effect was explored decades ago and was revealed during the Wilson Cloud Chamber experiments in the early 20th century. Vapors were observed to condense on particles, which acted as nuclei. Modern FFC systems create a controlled environment for this naturally occurring phenomenon. The gas stream is saturated with water, then the stream is cooled, thus forcing the condensation to occur in a controlled, confined space. This process is described in Figure 1.

Design engineers start the process by first saturating the hot gases with water or steam in a quencher. The gases are then placed into direct contact with cooled scrubbing liquid in the C/A, a process called subcooling. This causes artificial "rain" to form in the C/A. Through differences in temperature and concentrations, a flux occurs that pulls the dry particulates from the gas stream and encapsulates them with water. Now enlarged, the droplets are commonly removed by a venturi scrubber operating at a far lower pressure drop (and far lower gas volume) than if the gases were not cooled and condensed. In extreme applications, a wet electrostatic precipitator (WESP) is used after the venturi. Particulate outlet loadings of less than 0.005 grains per dry standard cubic foot (grs/dscf) are achievable in many applications with more than 99.9 percent removal of soluble acid gases.

Figure 1

General flux force condensation system components

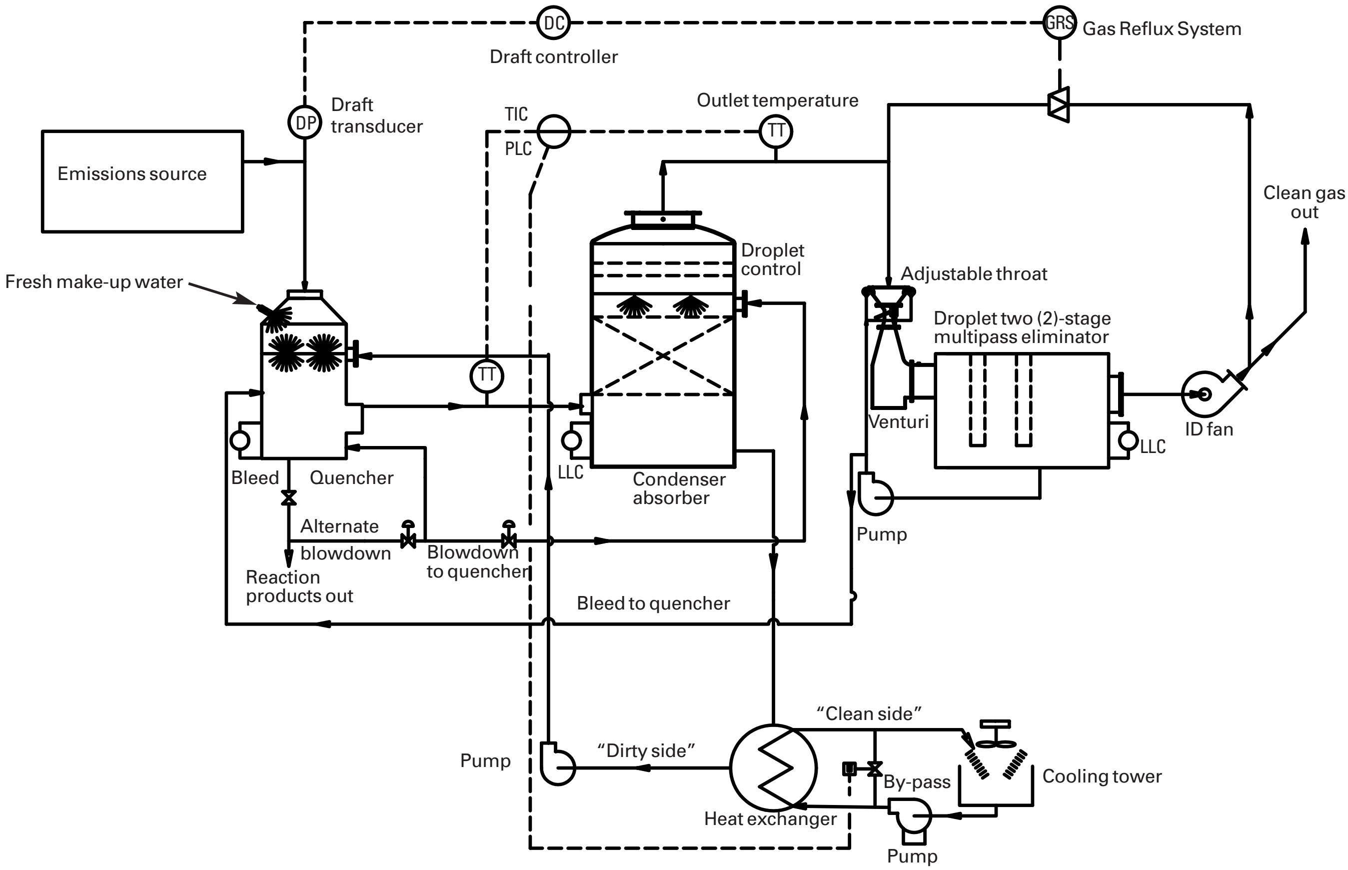

Figure 2 is a photograph of a recent FFC project. The vessel in the foreground is the condenser/absorber. and the venturi scrubber and separator is located to the lower left of the photo. The stack is in the background.

Figure 2

System installed on a hazardous waste incinerator

FFC scrubbing installation

On many installations, an adjustable-throat venturi scrubber operating in the 35–45 inches water column (w.c.) range is used for particulate collection. Because the gas volume has been reduced (usually by about 50 percent versus a system without condensing), the size of the venturi scrubber and separator is reduced, thus reducing the system's cost as well. This is important because the internal components of the venturi are often made from expensive, corrosion-resistant alloys.

Figure 3 shows the gas inlet duct with expansion joint from the C/A (top center), the adjustable-throat venturi (center), and the cross-flow droplet eliminator (lower left). The liquid injection headers are located at the wetted entrance to the venturi. The adjustable throat mechanism can be seen to the left of the ven-

Figure 3

View of condenser/absorber (C/A) outlet to venturi inlet and separator

turi throat. A cross-flow multistage (2-to-3-stage) droplet eliminator is used to remove the entrained droplets and condensed droplets from the venturi scrubber. You can see the top door for access to the primary chevron droplet-eliminator stage.

The cleaned gases are drawn from the droplet eliminator to an induced draft fan wherein the heat of compression heats the gas stream and reduces the relative humidity. A clean, nearly invisible plume results.

The following is a description of common characteristics of a modern FFC system. Common materials include the following:

- Quencher—Refractory lined steel or corrosion-resistant alloy (e.g., C-276, AL6XN)
- C/A—Fiberglass-reinforced plastic (FRP) or lined steel, thermoplastic media
- Venturi—FRP
- Venturi separator—FRP with thermoplastic chevrons
- Fan—Rubber-lined steel with alloy wheel, all alloy, all FRP
- Stack—FRP

Capacity size range

Saturated gas temperatures of 145°F and greater at all gas volume ranges. The reason for the higher saturated gas temperatures is that only a certain amount of the water vapor condenses, using the particulate as condensation nuclei, while the remainder autocondenses and doesn't participate. If the saturation temperature is too low on certain applications, the saturation temperature can be raised by steam injection before the C/A.

Control methods for FFC scrubbing systems

Although an FFC scrubbing system sounds like a complicated technology to control, it can be efficiently operated as long as some important parameters are maintained. These parameters are temperature, pressure drop, pH, and blowdown.

Temperature

The amount of water vapor condensed is a critical element of the design. Although the C/A provides both the condensation function and an absorption function, condensation is its most important role. The outlet temperature from the C/A is a key operating parameter. Since the gases have already passed through a quencher and the packed bed of the C/A, they can be assumed to be fully saturated. Thus, by monitoring the outlet temperature of the C/A and maintaining that temperature sufficiently low, one can control its condensation performance.

Control involves monitoring the C/A outlet temperature using a thermocouple or resistance temperature detector (RTD) in the C/A outlet duct and using that signal to modulate the cooling water flow rate to the bypass (see Figure 1, lower right) in the clean side of the plate and frame heat exchanger. Experience has shown that reducing the gas temperature to 100°–110°F provides adequate and economical condensation without diminished returns. A control valve as shown is often used to modulate the clean water side bypass flow rate.

Pressure drop

The primary particulate removal is accomplished in the venturi scrubber. Its removal efficiency is a function of its pressure drop. Many permits require that this pressure drop be maintained above a certain minimum—the minimum drop typically verified by a stack test. If the venturi is equipped with an adjustable throat, some technicians include a positioner on this throat and modulate the throat position based upon the signal from a differential pressure drop sensor that measures the pressure drop across the venturi throat. This pressure drop is often data-logged as part of the permit requirements. On other systems, particularly those that are very draft-sensitive—such as a hazardous waste incinerator—as gas reflux system can be used to recycle cleaned gases back to the scrubber inlet. The flow is modulated by an opposed blade damper and control logic circuit based on a draft signal from the source. To prevent "hunting," the venturi throat is left in a fixed position. These systems can control the draft to within 0.01 inch w.c.

If the system fan is controlled by a variable-frequency drive (VFD), it is usually used only for general ventilation control and left at a speed away from any vibration-causing harmonics. Sometimes a draft sensor on the source (such as an oxidizer, kiln, or calciner) controls the VFD based on process draft requirements, and the venturi is modulated separately. To prevent "hunting," the output to the throat positioner is dampened significantly, adjusting only every few minutes rather than continually.

pH

The C/A also serves as an acid gas absorber. Therefore, the pH of its recirculation loop or sump post-reaction pH is controlled. This is performed in a conventional manner using a pH probe and controller.

Blowdown

To prevent the buildup of suspended and dissolved solids that could cause mechanical problems and reduce removal efficiency, a blowdown must be maintained. It is common to use a conductivity or density controller to adjust the blowdown from the venturi and C/A recycle circuits.

Most FFC systems "bleed forward" from the venturi stage to the quencher, and then out to local water treatment or sewer. If a WESP is used, a bleed from the flush water circuit is often sent to the venturi circuit, from which point it is bled either to the quencher and then out to a sewer or water treatment facility. On rare occasions wherein the particulate is valuable, the captured particulate is returned to a recovery system or to the process from which the particulate was emitted.

This flow arrangement bleeds the reaction products and recovered particulate at the highest concentration (lowest volume) and highest temperature. The latter reduces the thermal load on the C/A and thus improves the thermal efficiency. Various bleed schemes can be used, depending on the amount of particulate to be captured and its corrosive or erosive properties.

Magmeters are typically used to monitor the blowdown from stage to stage. Either manual or proportional control valves are used to meter the liquid flows.

The quencher blowdown line often is monitored using a magmeter and is controlled proportionately based on the process conditions to which the FFC system is attached. If the system is "base loaded" or producing a fairly constant emission rate, the blowdown can be a fixed amount. If the process varies, a conductivity, refractive index, or density meter can be used to adjust the blowdown. Volumetric control is the simplest and most reliable, however. The volumetric set-points are usually established by grab sampling during commissioning to define the blowdown liquid parameters as required by the process. Process parameters (such as the beginning of a batch and feed weigh feeder settings) are then used as surrogates to set the blowdown rates.

Condensation scrubbing can be effectively applied to applications that emit both acid gases and submicron particulate and have or can be caused to have a saturation temperature of 145°F or higher. Few air pollution control systems can match the overall pollutant collection efficiency—dry or wet—of this proven technique. **APC**

Ken Schifftner, *sales manager of Bionomic Industries, has more than 40 years of experience in air pollution control. A 1970 graduate of Newark College of Engineering (now New Jersey Institute of Technology), he is an inventor and author of numerous technical papers including two books,* Wet Scrubbers *and the* Air Pollution Control Equipment Selection Guide. *Ken can be reached at 201-529-1094, ext. 113; kschifftner@bionomicind.com. The Bionomic Industries website is www.bionomicind.com.*