

Using Venturi Scrubber Technology for Syngas Cleaning

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As part of our nation's program to reduce dependence on fossil fuels, various gasification technologies are being applied. These processes take renewable organic material and, through the application of heat and pressure, convert the materials into syngas for further use. Arguably, in nearly all of these processes, the most critical design aspect is the reliable and efficient removal of contaminant, particulate, gases, and unnecessary water vapor from the syngas stream. Complicating the gas cleaning equipment design is the detrimental formation of tars and scale, coupled with the need to operate at higher temperatures and pressures than those normally encountered with common "atmospheric" gas cleaning applications. The design philosophy and unique features of some recent successful gas cleaning systems as applied to gasification are described.

In an effort to reduce our dependence on foreign oil and to preserve valuable domestic fossil fuel reserves, many firms are looking at gasification technology as a method to convert replaceable organics into end products.

Firms currently are converting cellulosic type "wastes" and wood material — infected wood, discarded building materials, grasses, pulp mill liquors, straw, and other materials — into syngas. The syngas then can be converted to fuel gas or be further processed into materials, such as plastics, that formerly had been produced from petroleum. Often, the syngas can be used to provide the motive heat for electrical generation.

Some gasification systems are designed to produce liquid fuels, such as jet or diesel. The cooler/condenser on this recent gas cleaning system installation is the insulated cylindrical vessel shown in the foreground, along with its associated piping. The equipment has been installed with simplified service access in mind.

The gasification process typically involves preparation of the "fuel," or feedstock material, by drying and/or size reduction, followed by the application of heat, often in the form of steam — along with pressure — in a gasifier. The gasifier also may be a plasma type, wherein the feedstock is dissociated using electrical energy.

In the gasifier, feedstock is converted to syngas without the application of oxygen. The carbon in the feedstock, along with hydrogen that may be present — or be contributed by steam if it's used — is converted to primarily methane gas, the main component of the syngas. Unlike combustion, which would convert the carbon to carbon monoxide (CO) or carbon dioxide (CO_2) with a release of heat, the gasifier makes the conversion to methane and thus reduces the formation of CO_2. Reduced CO_2 formation can be an advantage since it's a gaseous component of global warming.

Removing the Particulate

The gasifier gases, however, are not clean. Particulate can be entrained from the gasifier. Water vapor and/or residual steam can be present. Removing the water improves the quality of the syngas but does require larger and more expensive equipment. Tars and other condensable organics, which can adversely affect operation of the gasification gas cleaning system, can be driven off. In addition, the produced gas often is catalytically converted in subsequent steps. Therefore, very high efficiency gas cleaning is required. In some of the process designs, a portion of the syngas actually is cleaned so well that it can be used as a fuel to provide heat for the gasifier itself. The gasifier in that case is started on fossil fuel — natural gas, for instance — until the syngas is being produced. Then a portion of the syngas is cleaned and is sent to the combustion portion of the gasifier. After that, the cycle is self-sustaining.

To date, wet technology has been applied to gasification systems with success. Some pioneering gasification projects have been sponsored by the Department of Energy, with private sector support, in order to develop the technology. One equipment manufacturer designed and supplied critical gas cleaning components at both the Weyerhaeuser (New Bern, NC) and Georgia Pacific (Big Island, VA) black liquor gasification projects. Much was learned from those installations.

For example, the inlet area of the venturi scrubber, if used, must be designed to provide efficient operation even though tars and scale may accumulate. Once the gases are cooled, any downstream surface has the potential to become a site upon which tars can be deposited. Therefore, the mechanical design must allow for constant cleaning of those surfaces, as well as for simplified access during routine maintenance.

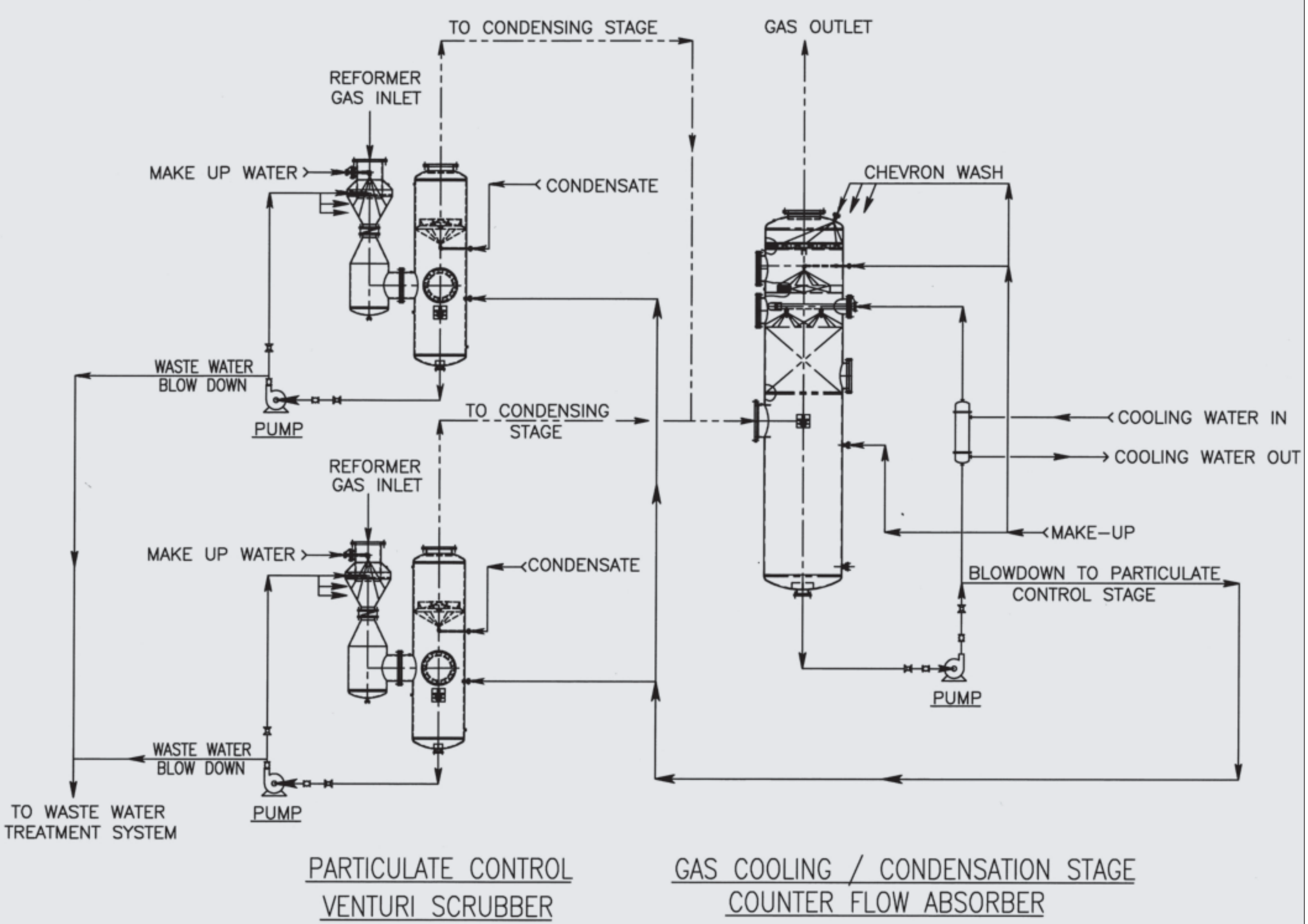
Usually, dry cyclone collectors are used to control the particulate that is entrained from the gasifier. To shorten ductwork runs, the cyclones often are placed close to the gasifier. Upflow and downflow gasifiers exhibit different particle size distributions and loadings. Typically, downflow gasifiers do not exhibit as high a particulate loading as an upflow design. The dry cyclones are, therefore, sized for the particular gasifier type. These cyclones often run at very high temperatures and in contrast to cyclones applied to common material handling applications at higher pressures. The pressures, however, often are below those required for ASME Code. As a result, the cyclone vessel often is designed more for temperature resistance than for pressure. The gas densities are usually unique to the gasifier type. The gas mixture tends to decrease the gas density — since low molecular weight hydrogen and carbon monoxide often are present — but increase given the higher gas pressure. The cyclone collector needs to be carefully designed for the specific location in which it is applied in the system. If the feedstock to the gasifier includes abrasives such as silicates, abrasion resistant linings commonly are used.

The general gas cleaning steps are shown in Diagram 1 (next page):

The system, in this case shows two venturi scrubber particulate control stages (left of center), in parallel, followed by a cooling stage to remove excess moisture. Since the gas volume is hottest and at the largest volume at this point, multiple venturi scrubbers often can be used in parallel to reduce costs. The higher temperatures experienced can also favor the use of smaller ducts and flanges, which facilitate service access since the service reach is shortened. In addition, the movable portions of multiple smaller venturi scrubbers are lighter and more easily actuated.

The venturi scrubber is typically an adjustable throat design with automatic pressure drop control that regulates the pressure drop required for particulate re-

Diagram 1
General Gas Cleaning Steps



moval. A specially modified valve can function as the venturi throat. Since the syngas does not exhibit a specific heat, density, or molecular weight common to atmospheric type systems, the venturi has to be designed for the specific gas properties and conditions. It is not uncommon to require the venturi scrubber to operate with low molecular weight and high specific heat gas mixtures that are very high in hydrogen and CO. When the hot gasifier gases meet the water in the venturi, some tars can condense. The venturi is carefully designed to reduce the adverse effects of the tars — such as plugging — and provide simplified service access for cleaning. The saturated gases leave the venturi scrubber droplet separator and proceed to a direct contact cooler so that the gas moisture content can be reduced.

In the cooler (condenser), the water vapor is condensed to liquid water, thus reducing the gas volume and the water vapor content of the mixture. As an accompanying event, tars also are condensed so the design of the cooler is critical. Current practice is to design the cooler to be as tolerant of tars as possible, but research is ongoing about methods to control tars and remove them, or even re-gasify them, so that the on-line availability of the system is enhanced. The cooler typically uses oversize packing, such as large dumped type packing, that favors drip-type mass transfer rather than film-type mass transfer, as would occur if structured packing were used. **APC**

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