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BIOMASS FUEL PRODUCTION GETS SWEETER

Improved instrumentation and control strategies allow biofuel producers to reap the benefits of new processing techniques and advanced control strategies.

by David W. Spitzer

Flow, level, pressure and temperature instrumentation are commonly applied in the process industries, and also are used in plants that convert biomass to fuel. However, in contrast to the typical process plant, density/concentration and pH measurements are used extensively in processing biomass, and purifying its products. These physical properties are key to increasing yield, reducing processing time, and reducing energy consumption, so operators can control biomass process facilities profitably.

In North America, natural gas and hydroelectric power form the majority of thermal and electrical energy production. This is because of historically low fuel prices. In other locations, taxes and other disincentives to consumption make alternative energy sources more attractive. For example, windmills generate electricity in the Netherlands, geothermal energy provides about 50% of Iceland's energy, and ethanol made from sugarcane fuels cars in Brazil.

It makes more sense to consider alternative sources of energy as energy prices climb. North America is focusing on generating electricity from solar cells and windmills, and producing alternative fossil fuels such as liquefied and gasified coal, as well as increasing fuel production from tar sands. In addition, throughout the cornbelt, small energy producers are using corn to produce ethanol.

FIGURE 1.

TANK DENSITY/CONCENTRATION SENSOR AND TRANSMITTER

Courtesy SMAR

Differential pressure probes can determine sugar concentration.

The ethanol production cycle from biomass begins with plants that use atmospheric carbon dioxide to produce organic carbon. These plants are harvested, and converted into a useable feedstock, typically some form of sugar. The most commonly used plants are sugarcane and corn, but processes that use other crops and waste biomass are in development. Sugarcane typically is crushed before its juice is concentrated, and cooked prior to fermentation. Corn often is milled, and separated into its components to produce starch that's further processed into sugar. After fermenting the sugar into ethanol and other byproducts, the ethanol is typically purified using distillation. Both biomasses use similar sugar fermentation and ethanol purification processes. More variations between processes are expected as the processes are improved.

The concentration of sugar can affect many parts of these processes. In general, too little sugar dilutes the process and reduces throughput. Conversely, too much over-saturates the process with sugar, so the it doesn't function properly. This implies the process will operate best when its sugar concentration is between these two extremes, so sugar concentration should be controlled at its proper value within tight tolerances for the process to maintain peak or near-peak performance. So, sugar concentration is a key control parameter that should be accurately measured and tightly controlled.

Sugar is denser than water, and increasing its concentration in a sugar/water mixture causes its density to increase. The density of the mixture can be calculated when the sugar concentration is known. Conversely, the mixture's sugar content can be calculated when the density is known. Sugar concentration measurements must be located both in flowing streams and in materials in vessels.

The density of material in vessels can be determined by measuring the differential pressure between two submerged pressure taps located at known elevations. In these installations, differential pressure transmitter diaphragm seals are used in both taps to reduce the possibility of plugging. However, to eliminate these nozzles and their potential for plugging, a differential pressure probe with differential pressure sensors, originally developed for processing sugar, can be inserted vertically into the vessel (Figure 1). This approach "fixes" the distance between the sensors, and eliminates the requirement to precisely determine and control nozzle locations. Also, the height of the probe is adjustable after installation to help ensure that the sensors remain submerged, which contrasts with fixed-vessel nozzles that are difficult to alter due to errors or process changes.

Measuring Sugar Content

Sugar content in flowing pipelines can be inferred by measuring density using inline differential pressure probes, radiation, and U-tube densitometers. Inline differential pressure probes are inserted into a vertical section of pipe (Figure 2), and operate similarly to those used in vessels. Radiation densitometers infer density by measuring radiation reaching the sensor from its source after the radiation travels through the material to be measured. U-tube densitometers infer density from frequency measurements of a U-shaped tube containing the material, whereby its natural frequency changes with changing material density. This same principle allows most Coriolis mass flowmeters to measure density in addition to flow.

"Density measurements are important in my sugar production plant because they infer sugar concentration," says Clovis Massachi Muraishi, industrial engineering supervisor at Usina Açucareira Guaíra, São Paulo, Brazil. The plant has been making ethanol for over 20 years.

"Operating certain process streams at low sugar concentrations [inferred by relatively low-density measurements] can cause inefficient processing and poor crystallization. Streams operating at high sugar concentrations [inferred by relatively high density measurements] can cause inefficient processing, and create operational problems, such as crystal sugar deformation, machine and inversion problems," adds Pedro Collegari, general manager at Grupo João Lyra's Vale do Paranaíba plant, Capinopolis, Minas Gerais, Brazil.

Improved inline density measurements allow Collegari's plant to operate in the proper range of concentrations on a consistent basis, and improve product quality. Collegari uses differential pressure probes and U-tube densitometers for accurate density measurement. Radiation densitometers aren't based on physical property of density, but rather on the amount of radiation that travels through the material. This amount depends on the material density in these applications, but also is affected by the temperature of the material. This means measurement errors can occur when operating the instrument at a different temperature than that at which it was calibrated. Therefore, Collegari doesn't have radiation densitometers in his plant because their accuracy suffers over many temperatures in his applications.

FIGURE 2.

INLINE DENSITY/CONCENTRATION TRANSMITTER INSTALLATION

Courtesy SMAR

Inline differential pressure probes operate similarly to those used in vessels.

Biomass from the Beginning

In their early days, instrumentation manufacturers often initially focused on one niche or industry before expanding into others. Examples of this include Bailey Controls (boilers), Fischer & Porter (rotameters), Foxboro (recorder/controller), Honeywell (furnace regulation), and Taylor (weather measurement).

On the other hand, "SMAR has focused on the biomass processing industry since it was founded in 1974," says Cesar Cassiolato, marketing director at SMAR, Sertãozinho, Brazil. "This was primarily due to its location in a town surrounded by fields of sugarcane and refineries. Using sugarcane to produce fuel has been steadily increasing since the 1970s, in part due to government policies that promoted the production of fuel-grade ethanol from locally grown biomass to displace imported gasoline. Increased production of ethanol fuel from sugarcane has helped Brazil become self-sufficient with regard to imported oil (on a net basis)."

Usina's Muraishi says that his plant has "various types of measurements including flow, level, pressure, temperature, concentration, pH and conductivity. In particular, differential pressure density instruments measure sugar concentration and the alcohol concentration of intermediate and output alcohol streams from the distillation and dehydration columns. These measurements have significantly increased the productivity of the plant."

Collegari concurs and adds that in the past, "New processes simply were not implemented because of the inability to control the process. Improved instrumentation and control strategies now allow the plant to reap the benefits of new processing techniques and the implementation of more advanced control strategies. Overall, improved online measurements and better control have increased plant production by at least 25% in the past five years."

Cassiolato adds, "Over the years, SMAR has developed instruments for biomass processing, including a transmitter that hydrostatically measures the density of liquids in a range of ±0.5 to ±5.0 by inserting a temperature-compensated probe with two pressure sensors into a tank. Also, close proximity to these plants has generated considerable process knowledge that has resulted in automation projects that improved product quality and production efficiency in more than 90% of sugar and alcohol plants in Brazil, and made SMAR a leader in this market. As a result, instrumentation and automation has been crucial to making the area surrounding Sertãozinho reputedly the most productive sugar growing/producing/refining region in the world."

Greg Loest, director of engineering at ICM, Colwich, Kan., says, "We've noted that additional levels of automation, such as better instrumentation, programming logic and/or valves, have made our plants easier to operate and more consistent, while improving their overall energy efficiency," ICM has designed approximately 75% of the ethanol plants in the USA.

Cassiolato adds that performance benchmarks improved in Brazil between 1977 and 2005. Fermentation yield went from 75%-80% to 90%-92%; distillation yield from approximately 95% to over 99%; fermentation time was cut from 18 hours-22 hours to 6 hours-10 hours; and sugar extraction

FIGURE 3.

BRAZILIAN ETHANOL PLANT

Increased production of ethanol fuel from sugarcane has helped Brazil become self-sufficient with regard to imported oil.

from sugarcane increased from approximately 88% to 98%.

Working at a sugar plant that has been making alcohol for fuel for over 25 years, Marcos Antonio Barreto, production manager at Usina Mandu, São Paulo, Brazil, says, "Hydrostatic density measurements are also used to infer the interface level in decanters to control the withdrawal of the heavy phase. Proper interface location is important to achieve good decantation and removal of impurities."

Proper elimination of impurities is the key to efficient plant operation. Measurement and control of pH is important to enhance the separation of impurities. "Our process has various acid additions. Neutralization of the process streams after these additions is important for efficient decanter operation because poor pH control increases the amount of impurities fed to the downstream processes. These tend to upset the operation, cause product losses and degrade plant efficiency," says Barreto.

His plant uses one pH probe and transmitter. Cleaning the probe typically takes less than five minutes and is performed with the pH controller in manual. In contrast, Collegari's plant typically installs two pH measurement systems because the probes periodically get dirty and require maintenance.

Reliable density/concentration, pH and other measurements have put plant operation under better control with supervisory operating stations in each section to which plant managers have remote access. "Due to process changes and expansions, it is difficult to determine the yield improvement solely due to improved automation, but I wouldn't be surprised if it exceeded 10% on a total plant basis," says Barreto.

"The final ethanol fuel purity is important, especially with regard to its water content," says Charlie Voss, production manager at Quad-County Corn Processors, Galva, Iowa. "We currently take manual samples to the laboratory where test results are available in about 15 minutes. Engineers are investigating the installation of online infrared analyzers to provide continuous water content measurements that can reduce the time required to identify and correct water content issues and improve final ethanol fuel quality."

Loest says, "Density measurement instruments and NIR moisture analyzers are used extensively and located strategically throughout our ethanol plants. For example, density and NIR moisture measurements of the dryer and liquid products are extremely critical to reduce energy consumption and improve product quality. Moisture measurements are also important during fermentation and in the molecular sieve processes."

The production of ethanol from sugarcane, corn and other biomass have much in common, especially in the fermentation and purification operations. Research continues to improve the processes associated with biomass energy production to improve process efficiency. Nonetheless, the importance of appropriate instrumentation and control strategies is crucial to achieving and maintaining world-class plant performance and specialized measurement systems such as those that measure density/concentration and pH.

BETTER BENCHMARKS IN BRAZIL

From 1977 to 2005, better technology and improving production techniques have raised the bar at Brazilian ethanol plants.

- **Fermentation yield has improved from 75%-80% to 90%-92%.**
- **Distillation yield has improved from 95% to over 99%.**
- **Fermentation time has been reduced from 18 hours-22 hours to 6 hours-10 hours.**
- **Sugar extraction from sugar cane has increased from 88% to 95%-99%.**

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