Case history

Closed-steam-loop drying system clears up stack exhaust, cuts fuel costs

To beat EPA air emissions limits and cut energy and maintenance costs, an ethanol producer replaces an aging, inefficient rotary drum dryer with a closed-steam-loop drying system for processing spent-grain by-product.

Each year, the Pekin, Ill., plant of MGP Ingredients of Illinois (MGPI) turns out more than 70,000,000 gallons of ethanol, an increasingly popular clean-burning alternative to oil-based fuels. Annually, the plant uses 70,000 tons of wheat-processing residue combined with about 670,000 tons of ground corn to produce the ethanol and other alcohol products. But producing ethanol leaves behind large quantities of a by-product called *whole stillage,* a soup of grain solids and solubles. To recover some value from the whole stillage, the plant further processes it to produce feed additives for cattle, hogs, and chickens.

Processing ethanol by-product

To produce the feed additives, the whole stillage must be dried. The first step is spinning the stillage in a centrifuge to increase its solids content to 33 to 35 percent. The liquid and dissolved solids spun out during centrifuging forms a *thin stillage* that's reduced by an evaporator system to a syrup with about 38 to 40 percent solids. Next, the centrifuge solids and the syrup are recombined and mixed

The new closed-steam-loop drying system consumes its own pollutants, producing clear exhaust (at left) that contrasts sharply with the haze exhausted by the old system. The new rotary drum dryer, with the large steam exhaust duct exiting from it, is at the lower right.

with enough recycled final dry product to achieve a blend with 65 percent solids. This blend is fed to a drying system, which yields a final dry product called *distiller's dried grain with solubles (DDGS),* which the plant sells for use as animal feed additives.

Excess emissions, high fuel consumption, and frequent repairs plague drying system

In the past, the drying system included two direct-heat rotary drum dryers, installed in the early 1990s, which discharged a total of around 225,000 tons of DDGS per year. Hot flue gas from a natural-gas-fired furnace supplied the heat for each dryer, and each dryer required a relatively large amount of natural gas — 70 million BTUs — to evaporate moisture at 50,000 lb/h. Exhaust gas from the dryers passed through primary and secondary wet scrubbers that removed entrained particles, and about 40 percent of the hot cleaned gas was recycled back through the furnace. But the wet scrubbers didn't remove hazardous air pollutants — volatile organic compounds (VOCs), nitrogen oxides (NO_x), and carbon monoxide (CO) — from the remaining 60 percent of the gas vented through the plant's exhaust stack. Although the plant could solve this problem by adding an end-of-pipe regenerative thermal oxidizer (RTO) to the stack to burn up and remove these pollutants, doing so would add another layer of maintenance and fuel cost to the already aging and inefficient system.

The system's centerpiece is a direct-heat rotary drum dryer that uses superheated steam as the drying medium.

This dosing bin with twin-screw discharge meters the grain solids into a screw conveyor for transfer to a paddle mixer at the dryer's outlet.

That wasn't the only problem. "Right from the start, those dryers had lots of plugging problems," says plant project manager Joe Werth. These problems were traced to inadequate airflow caused by the drying system's undersized ductwork and a high pressure drop across one of the wet scrubbers. The system constriction and the resulting low airflow produced unnecessarily high temperatures in the dryers, scorching the product and increasing emissions. The dryers were also frequently down for repairs. The trunnion-and-chain drive system for rotating the dryer drums often failed. Cracks in the dryers' refractory lining caused the dryers to overheat. Corrosion and cracking caused the dryers' internal structures to break. The dryers needed constant lubrication and alignment adjustments. "Maintenance on both dryers was costing around $100,000 per year," Werth says. "Of course, along with maintenance costs came excessive downtime and production loss."

The hunt for cleaner, more efficient drying

In early 2001, the combination of tougher EPA emissions limits posted for mid-2002 and ever-rising fuel costs led the producer to seek a new drying system to replace the inefficient rotary drum dryers. At first, the hunt resulted in a lot of dead ends. "The dryers we investigated looked quite similar to what we had. They required about the same amount of fuel and would still need an end-of-pipe RTO to comply with EPA air emissions requirements," says Werth.

Then an engineer at another MGPI ethanol plant, in Atchison, Kans., came across a closed-steam-loop drying system in a European municipal sludge-drying installation. The engineer alerted Werth about this ecoDry drying system, developed by Swiss Combi (also known as W. Kunz dryTec A.G.), Dintikon, Switzerland, and available in the US through Dedert Corp., a developer of evaporation and drying systems located in Olympia Fields, Ill. The drying system's appeal was its closed-loop operation, which not only eliminates any need for wet scrubbers to post-treat the dryer's exhaust gas but allows drying energy to be recycled back to the system and related equipment.

Intrigued, Werth met with the supplier's representatives to discuss the drying system's potential for solving the plant's dryer problems. After deciding that the drying system held promise for their application, Werth and MGPI vice president and corporate director of engineering Randy Schrick traveled to Europe to visit two sites where the new system was in use. One, a plant that processed corn and wheat starch, had a drying and evaporator setup similar to that at the Pekin ethanol plant.

"After seeing the clear stack discharge and waste-heat evaporator configuration there, we knew our plant had to become the drying system's first US installation," says Werth. In June 2001, they signed the purchase agreement for the new drying system, which would replace one of their existing dryers.

Drying system consumes its own pollutants, recycles waste heat

Later that year, the plant removed one of the existing dryers and began installing the new drying system in its place. The system consists of several pieces of equipment connected by ducting in a closed-loop configuration. The system's centerpiece is a direct-heat rotary drum dryer that uses superheated steam as the drying medium. Other equipment includes a gravimetric dosing bin, a single-shaft high-speed paddle mixer, a gas-to-gas heat exchanger fired by a natural gas furnace, two cyclones, a cooler, and a series of tightly sealed mechanical conveyors. This system, which is linked to the ethanol plant's existing centrifuge and evaporator system, has an automatic control system interfaced to the existing plantwide control system.

In operation, wet feed (the grain solids) from the existing centrifuge discharges into the dosing bin, which is mounted on load cells and has a twin-screw discharge to a screw conveyor. The bin monitors the centrifuge output and automatically controls the wet feed flow through the screw conveyor several feet to the mixer, where the feed is blended with syrup from the evaporator system. This feed mixture continuously discharges from the mixer and flows into the adjacent rotary drum dryer. Meanwhile, steam previously generated in the rotary drum dryer flows to the cyclones, which separate entrained particles from the steam so the steam can be recirculated through the closed-loop ductwork back to the heat exchanger. Flue gas from the furnace passes through the heat exchanger, where it heats the steam to 800°F. The superheated steam is then routed back to the rotary drum dryer.

These cyclones remove entrained particles from the steam exhausted by the rotary drum dryer, dropping the particles into the tightly sealed mechanical conveyor (below cyclones) for transfer with the finished DDGS to a cooler.

The steam passes through the dryer, directly contacting the wet feed mixture to heat it and evaporate moisture, while a downstream fan (located after the cyclones) draws the steam toward the dryer discharge. The dryer's cylindrical housing rotates on four independently driven, variable-speed trunnion rollers at a speed that can be easily adjusted to control the product's moisture content and throughput rate. The drum rotation and mechanical assistance inside the drum, combined with the steam flow, move the product and steam toward the dryer discharge.

Most of the product — now DGGS — is discharged through a rotary valve to a tightly sealed mechanical conveyor, but the fines and steam pass on to the cyclones, which separate the entrained particles. These particles are dropped back into the mechanical conveyor, which transfers all of the still-hot DDGS to a cooler that circulates outside air in a counter-current pattern to reduce the product's temperature. As the cooled DDGS discharges from the cooler, the unit's heated exhaust air is routed back to the furnace air intake as additional combustion air. In a process called *internal thermal oxidation,* the furnace incinerates pollutants entrained in the cooler's exhaust air. The discharged DDGS flows to a hammermill, which reduces the product before it's transferred to storage.

After the steam exits the cyclone, about 25 percent of it is bled off to drive the plant's evaporator system. The remaining steam is routed to the furnace-fired heat exchanger so it can be superheated again and recycled through the dryer. The drying system's automatic control system controls the amount of steam that's bled off to the evaporator system in response to pressure conditions inside the dryer. The steam routed to the evaporator system enters it at 250°F (about 201°F wet bulb temperature) and emerges at a wet bulb temperature of 172°F. This steam is also recirculated to the furnace, which incinerates air pollutants entrained in the steam.

At the same time, vapor in the thin-stillage evaporator system is recycled to recover its heat. The evaporator system consists of two evaporator units, called the *first effect* (where initial evaporation occurs) and *second effect* (where final evaporation occurs). The syrup produced from the thin stillage is boiled in each effect to give off a vapor. The vapor released from the first effect flows to the second effect, where the vapor serves as the heat source driving the final evaporation stage. To achieve this, the plant replaced the existing first effect with a new unit, supplied by Dedert Corp., that could be driven by steam exhausted by the new rotary drum dryer.

Exhaust haze clears, fuel costs drop, and uptime jumps

The new drying system was up and running by spring 2002. Right away, the MGPI plant staff could see tremendous improvements in emissions levels and processing efficiency.

"Our new drying system performed comfortably within the new EPA limits for our local area right from the start," says Werth. "The system continually impresses us with the clear air above the stack. It's a striking contrast to the haze our old system produced."

The new drying system's fuel costs have also dropped. The system provides a 55,000-lb/h evaporation rate driven by less than 62 million BTUs of natural gas. "That's an evaporation rate of no more than 1,125 BTU per pound of evaporated water, compared with the 1,400-BTU rate in our old system, giving us a fuel savings of about 20 percent," Werth says.

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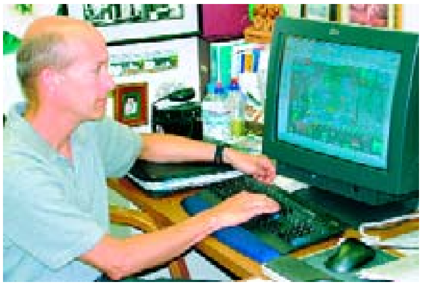
Total fuel savings are even greater considering that the plant would have had to install an end-of-pipe RTO on the old system to meet current US and Illinois EPA limits for dryer emissions. That RTO would have required additional fuel, while the new drying system provides internal thermal oxidation of pollutants without requiring any extra fuel. In fact, the new system's burned pollutants help lower fuel requirements by adding their energy to the dryer heat.



Plant project manager Joe Werth monitors the drying system's operation from his office PC, which is linked to the drying system's automatic control system.

The benefits don't end there. Monthly records for 2004 show an average system uptime of 95.7 percent, contrasting with about 80 percent for the old system. "The drying system's reliability has been outstanding," says Werth.

The drying system's automatic control system has improved reliability too. The system provides automatic start and shutdown sequencing and, once the drying system is operating at capacity, regulates itself with very little operation intervention. An important benefit is the control system's easy interface with the existing plantwide control system.

The drying control system provides extensive high-temperature and fire protection, as well, taking readings from thermal sensors located at critical points throughout the drying system. The control system can call operator attention to high temperature readings or begin automatic shutdown while adding water at strategic points to cool the drying system. "No system is absolutely failsafe, but this system has the most extensive and effective protection I've seen on this type of dryer," Werth says.

Although not part of the main drying system, the new thin-stillage evaporator unit installed in the plant's evaporation system has made its own contribution to improving process efficiency. "The new first effect has performed extremely well, giving us an 80 percent increase in evaporation rate," Werth says. The unit's continuous washdown system, a feature designed particularly for closed-steam-loop drying applications, keeps the gas-side tubes' exterior surfaces clear of particle buildup.

The plant staff is extremely pleased with the new drying system. "With more than three years of operation now proving the system's effectiveness, we've installed a second system to bring the same improvements to our sister plant in Atchison. And we've recently received an EPA construction permit for a third system to replace the other old dryer still running here," says Werth. **PBE**

Note: Find more information on related topics in articles listed under "Drying" and "Air pollution control" in *Powder and Bulk Engineering*'s comprehensive article index at www.powderbulk.com and in the December 2005 issue.

Anhydro / Dedert Corp.,
Olympia Fields, IL
708-747-7000
www.dedert.com