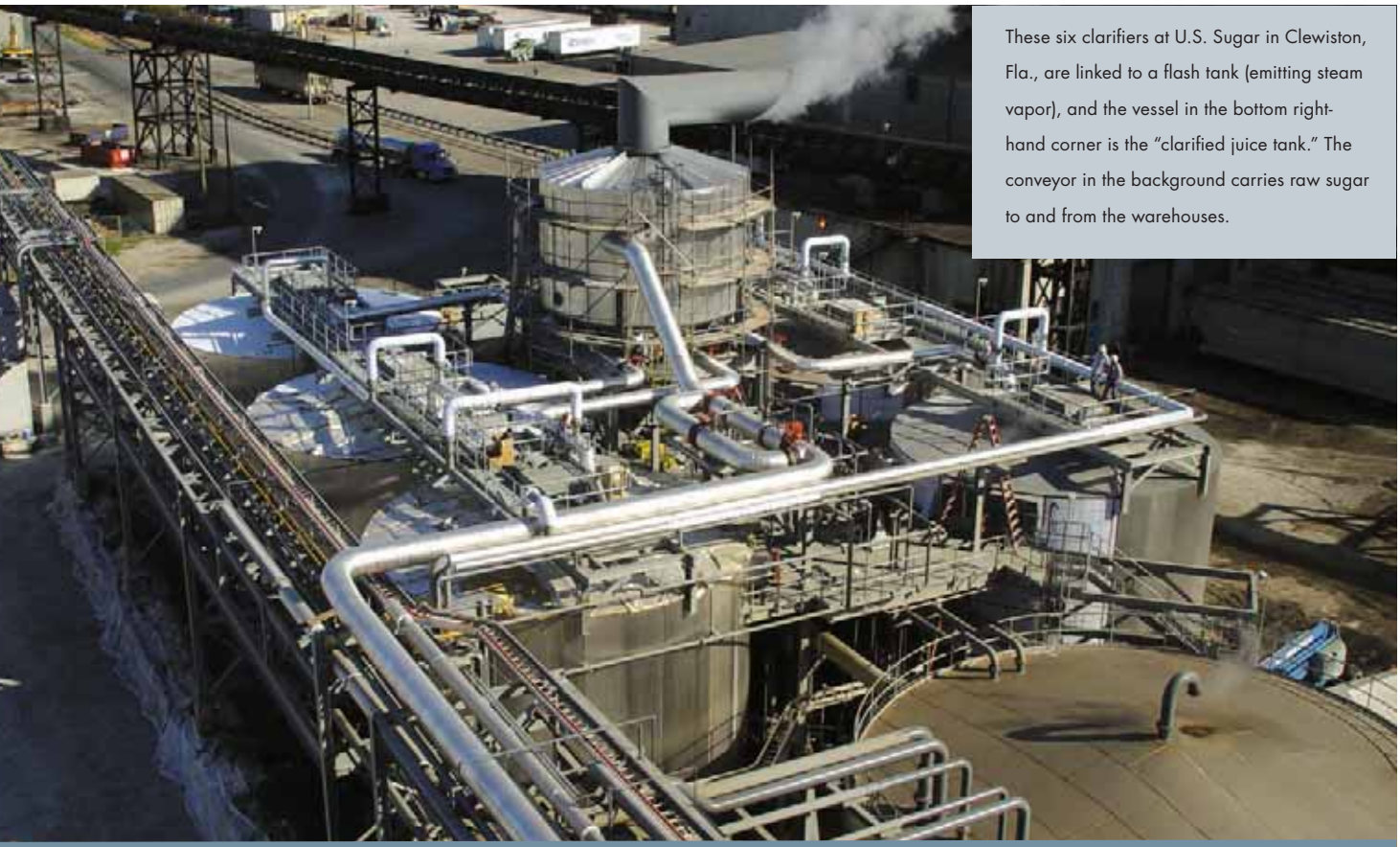

These six clarifiers at U.S. Sugar in Clewiston, Fla., are linked to a flash tank (emitting steam vapor), and the vessel in the bottom right-hand corner is the "clarified juice tank." The conveyor in the background carries raw sugar to and from the warehouses.

SUGAR & SPICE & EVERYTHING NICE

A major automation upgrade at the largest U.S. sugar processing complex means the company now is the most automated, making it more cost-effective and more competitive in the international marketplace.

By Janet Kreiling, Contributing Writer, The Journal

In sugar cane country, sugar is recovered from cane by extracting and purifying the juice, then crystallizing out the sucrose. That sounds fairly simple. But, of course, it's not. The actual process depends on precision control of feedstock, pressures, temperatures, conveyors, and the addition of purifying agents, sugar and water content — indeed, hundreds of variables as the cane proceeds through the raw sugar mill and the refinery.

When the United States Sugar Corporation (U.S. Sugar, www.ussugar.com) began to consolidate all its raw sugar mill and refining operations in 2005 at one site in Clewiston, Fla., this massive three-year upgrade would more than double the plant's capacity. The project was named "Breakthrough," and the name was fitting: the upgrade created the largest sugar processing facility in the world. The foremost goal, according to Matt Roberts, engineering and instrumentation manager, was automating all processes to make the complex as cost-effective as possible and thus remain competitive in the global market.

A second goal, says Bruce McManus, process manager at the company, was enabling the entire complex to be run from one central control room. "Central control allows the teams that operate various subsections of the complex to communicate easily with each other," he points out.

"In addition, bringing the entire complex under one automated control system gives us economies of scale in operations that in turn give us more options about how we run it," McManus explains. "For example, with all equipment essentially controlled as one big pool, we have more redundancy and more flexibility in its use, so if we need to switch a unit off for maintenance, we have choices about the one we use for

backup. We can also select the units we run to optimize energy efficiency."

The immediate goal for the project was to complete all of the new work in three six-month phases between 2005 and 2007 during the off-season when the October-to-April harvest didn't demand the complex be working flat out.

On-site at the beginning in 2005 was a modern sugar refinery, commissioned in 1998 and using Allen-Bradley® PLC-5® controllers (www.rockwellautomation.com/go/tjplc5) from Rockwell Automation with ControlNet — in fact, it was the largest ControlNet installation in the Southeast at the time.

Along with this refinery was the 1950s-era B sugar mill (see sidebar at right).

A second mill was to be added, called the C mill, to replace the nearby Bryant facility that was scheduled for shutting down. The new milling tandem would be built with its own cane dump, cane preparation and conveying systems — and have more than twice the capacity of the older B tandem.

The two mills would function as one operation. The refinery already was fully automated; the sugar mills and raw mill operations were not. Their automation was a large part of the Breakthrough project.

The engineering on this project started in 2003 to prepare for the upgrades. Work on the two sugar mills was carried out simultaneously, divided into the three phases by task. Thus, Phase 1, in 2005, focused on several stages of the processing including chopping and milling the can and preparing the cane waste, called bugasse, to serve as boiler fuel; automating the B mill and the boiler feed water and bagasse systems; and updating the boilers.

Phase 2, in 2006, focused on juice processing, which encompasses evapo-

This control panel at U.S. Sugar includes an Allen-Bradley ControlLogix PAC, DeviceNet cards and other I/O cards.

>> 2005: Details About the B Milling Tandem

For U.S. Sugar's Breakthrough upgrade project, construction began in 2005 to upgrade the existing B milling tandem, where sugar cane is brought from the fields by rail car. These cars must be emptied by a hydraulic system that would tip the car and dump the contents onto the conveyor. It had previously taken four operators to run the cane dump; after the automation upgrade, it took one.

The rail car needs to be precisely positioned on the dump table. This was accomplished using an Allen-Bradley PowerFlex 700 VFD with encoder feedback and an Allen-Bradley ControlLogix PAC. An Allen-Bradley PanelView™ Plus operator terminal (www.ab.com/go/tj10pp) provides local control for the single operator. This combination allows maximum torque as the entire line of up to 50 rail cars, each with up to 40 tons of cane, is pulled forward to the ready position.

A single car is then uncoupled and rapidly positioned on the dump table within a 2-in. tolerance. As the car is dumped, the winch is rapidly moved back to the beginning position ready for the next cycle. Positioning a 40-ton rail car quickly and accurately is a demanding task, and the PowerFlex drives handle the task day after day.

The cane is transported by a system of conveyors through a motor-driven knife assembly and a steam turbine driven shredder to prepare it for further processing. Conveyor speed control is critical for maintaining a steady flow of cane under varying conditions. PowerFlex 700 VFDs control the conveyors under the control of the primary milling tandem ControlLogix PAC. The 1,500-hp steam turbine has its own ControlLogix processor to control start-up and shutdown sequences, and to monitor all critical parameters during operation.

The prepared cane is then fed to a five-stage milling tandem where the sugar juice is extracted by pressure and grinding. The cane residue, called bagasse, is then sent to the boilers via several hundred feet of conveyors, and the juice is pumped to the juice-processing facility.

The mill kept producing sugar during the construction.

ration, juice clarification and sugar cleaning operations.

Phase 3, in 2007, focused on the crystallization part of the raw mill, along with upgrading the operations that produce molasses.

Automation Across Both Sugar Mill and Refinery

Given that automation had to be totally integrated into the sugar mill's operations, the planning for process control and instrumentation began at the beginning of the overall Breakthrough project. O'Dell Automation, of Conyers, Ga., working with Mark Handlan, Account Manager with authorized Rockwell Automation distributor McNaughton-McKay, of Atlanta, had developed the instrumentation and controls for the refinery in the late 1990s, so they were brought in again when U.S. Sugar rebuilt and expanded the sugar mill. Actually, you could say the planning began with the refinery, as the control choices made for the refinery influenced the subsequent sugar mill automation.

One driver for choosing Allen-Bradley Programmable Automation Controllers (PACs) in the 1990s, says Roberts, was that "we, like many companies, depend on OEMs to integrate systems, especially smaller 'plug-and-play' assemblies of equipment that are likely to be mounted on skids. Most OEMs we deal with use Allen-Bradley PACs, so if we chose the same products for the refinery, we would only have to learn to use one control system. And in the 10 years since we built the refinery, we've had great success with them. None of the PACs have failed. They're bulletproof."

U.S. Sugar's new C Tandem mill replaced the nearby Bryant facility that was shut down. The new milling tandem was built with its own cane dump, cane preparation and conveying systems, with more than twice the capacity of the older B tandem.

The refinery used PLC-5s with ControlNet and Allen-Bradley CENTERLINE® 2100 Motor Control Centers (MCCs,www.rockwellautomation.com/go/tjmcc). Terry O'Dell, CEO of O'Dell Automation, believed strongly that centralized operations would depend heavily on uniformity of control systems across both the refinery and mill. Uniformity

also would make running the huge complex simpler. When the refinery was built, O'Dell worked with products from several different manufacturers.

Although the Rockwell Automation equipment already at the refinery had performed with no problems, the Breakthrough project engineering team rigorously evaluated offerings from various automation companies. The team concluded that Rockwell Automation solutions were still the top choice for the upgrades.

"When we built the refinery, U.S. Sugar looked at MCCs and PACs from a number of other manufacturers, but we agreed to go with Allen-Bradley," O'Dell says. "There are none better, especially now, given the Rockwell Automation software suite with RSLogix™ 5000 [www.rockwellautomation.com/go/tjrsl], RSLinx®, FactoryTalk® View SE and the other components. All of the software and everything we configured had a uniform handshake."

> The raw sugar mill employs more than 1,550 automated valves — more than 1,000 transmitters and 450 motors, including more than 100 VFDs.

McNaughton-McKay developed a plan to ensure product continuity so the user interfaces, electrical panel design, nameplates and other attributes of the control systems would remain constant even though products were being ordered over three years and even if different personnel with different ideas did the ordering. That was especially important because the project was being built through a design-build process in which construction would begin on some parts of the job in each phase before the designs for other parts were final. With this fluidity, continuity became especially important.

Valves Galore, and Other Devices Too

Many types and numbers of controls are needed throughout the complex. For the first step, a conveyor carries the sugar cane under rotating knives and

ControlLogix PACs manage all of the MCCs deployed throughout the sugar mill. DeviceNet connects the MCC starters to the PACs. For each MCC, just one DeviceNet cable replaces hundreds of control wires, making installation and maintenance much easier.

>> 2006: Automation for the Control Room, Evaporators

As part of the Breakthrough project at U.S. Sugar, a new evaporator complex was constructed for Mill B in 2006. It's the largest of its kind in the world, with new juice clarifiers and a complete storage and distribution system for the chemical clean-in-place system.

Designing and programming the control strategy was a daunting task. The five-stage evaporator has more than 850 automated valves in its four parallel trains, three of which are online and one is being cleaned at any given time.

"The tight integration between RSLogix 5000, RSLinx, RSNetWorx™ and FactoryTalk View SE allowed us to do all the configuration and programming ahead of construction," notes Terry O'Dell, CEO of O'Dell Automation. "As each instrument was connected in the field, we were ready to commission it from the PAC and HMI."

Also in 2006, construction and commissioning of the central control room was completed. More than 20 FactoryTalk View SE client station allow the plant operators complete control over all aspects of the operation from one location. It also allows the programmers complete access to everything from one location.

"There are over 20 PAC processors, 450 motor starters and a dozen PanelView operator terminals out there, and we can program and configure every one of them from a central location," O'Dell explains.

Raw juice is first heated and then pumped to the clarifier where the pH is adjusted and flocculent is added maximize the mud removal. The clarified juice is then pumped to the evaporator and reduced to syrup. Control of the final sugar concentration, measured in brix, is critical because high-brix syrup could crystallize, and low-brix will reduce efficiency downstream. The entire evaporator is controlled by one Allen-Bradley ControlLogix L63 processor.

shredding devices that reduce it to small pieces to optimize juice extraction.

This first stage requires controls that ensure uniform conveyor belt speed despite the load and sufficient chopping of the cane.

Next, the chopped cane goes under steam-turbine-driven rollers that together can produce 11,200 hp — more motors and drive controls — to squeeze out the juice and ready the remaining material, called bagasse, to fuel the plant's boilers.

Subsequent operations, including clarification, evaporation and crystallization, similarly depend on precise controls. Some are large in scope: During evaporation, clarified juice is pumped through five successive evaporation vessels, reaching a higher sugar content in each one. The evaporation process, the largest in the world, employs 862 valves.

Crystallization, another large-scope process, employs some 250 motors that move refined juice and seeding crystals into huge vacuum pans.

Others are smaller in scope: As the juice is being pumped into the pans, the density of its sugar content, or brix, is measured by a refractometer with the option built into the control to use the amperage reading from the circulator motor if needed — the resistance gives another measure of brix.

After crystals reach the desired sizes, the slurry of crystals and the mother liquor goes to centrifuges that spin at 1,800 rpm. Obviously vibration controls are important, along with precision motor drives.

All told, the raw sugar mill employs over 1,550 automated valves — more than 1,000 transmitters and 450 motors, including more than 100 variable-frequency drives (VFD).

These devices and others are linked to five Allen-Bradley ControlLogix® L63 processors communicating via ControlNet among themselves and

with racks containing more than 6,340 I/O connections.

The plant also employs about 100 Allen-Bradley PowerFlex® 700 drives, about 350 E3 Plus electronic overload relays, and MCC starters connected to the PACs through DeviceNet. In addition, the mill uses Rockwell Software® RSLogix 5000, RSLinx (www.rockwellautomation.com/go/tjrslinx), FactoryTalk View SE, FactoryTalk Historian and FactoryTalk AssetCentre from Rockwell Automation.

The PACs control big swaths of activity. In the evaporation area, one PAC controls all 862 valves. The clarification area, with more than 200 valves, is run by another.

In the centrifuge area, where crystals are separated from the mother liquor, three centrifuges, called Series A, are controlled by Allen-Bradley PACs. The B and C series centrifuges, along with other biling house equipment, are run by a ControlLogix L63.

The mill crystallizes syrup going into the A centrifuges using 14 evaporator batch pans (see sidebar at right) controlled by a separate ControlLogix L63 PAC. Syrup for the B and C centrifuges is crystallized by continuous vacuum pans using their own L63 processor.

"We chose separate PAC processors for these stages to give us more flexibility in maintenance and settled on the L63 for interchangeability," O'Dell says. "Actually, one L63 could run this entire part of the process, but because

>> 2007: Boiling House Control for Chrystallization

As busy as 2006 was for the Breakthrough project at U.S. Sugar, 2007 proved to be even more of a challenge. The boiling house, where crystallization occurs, had to be almost completely revamped while continuing to run during summer operations.

The entire complex is powered by these boilers. They produce steam at 600 pounds per square inch (psig) and 750°F. The steam-powered turbogenerators produce 45 MW of power, of which 40 power the complex and five are exported to Florida Power and Light.

Each of the five boilers is equipped with two PACs, one to control combustion and the other for burner management. Safety comes first and foremost.

The crystallization process is simple in theory but complex in practice. The clarified syrup is fed to a series of batch pans where it's mixed with molasses and crystallized. The recipe and sequencing are critical to proper crystal growth and quality. The resultant sugar and molasses slurry is fed to large batch centrifugals, controlled by Allen-Bradley SLC™ 500 processors (www.rockwellautomation.com/go/tjslc500) that separate the sugar and molasses.

The raw sugar is sent to the refinery, and the molasses moves on to a set of continuous vacuum pans where it's crystallized again to form B sugar.

The B sugar is separated in another set of continuous centrifuges, and the B molasses is sent to a second set of continuous vacuum pans to produce C sugar and final molasses. The B and C sugars are remelted and returned to the A batch pans as a high-purity syrup. The final molasses is sent to the molasses plant to be used as an animal feed supplement.

Four lines of evaporators (the large silver vessels) are part of the "Evaporator Cube." The largest of its kind in the world, its 825 automated valves are programmed with Rockwell Software RSLogix 5000, RSLinx, RSNetWorx and FactoryTalk View SE.

different parts of the plant need to be down for maintenance at different times or during off-season, we went with multiple PACs for convenience."

MCCs and DeviceNet Efficiencies

The same PACs also manage all of the MCCs deployed throughout the sugar mill, and MCCs control varying numbers of motors. The PACs and their MCCs are linked through DeviceNet network. As McNaughton-McKay's Handlan explains, each DeviceNet link replaces multiple separate wires between the PACs and the MCCs and between the MCCs and the motors. For each MCC, just one DeviceNet cable replaces hundreds of control wires, making installation and maintenance much easier.

The DeviceNet connection also can convey information such as horsepower, voltage, amperage, and torque as well as the status of the starters, overload relays, ground fault protectors and other devices. "If one starter fails," Handlan explains, "it's easy to grab any of several unused ones and download the device parameters into it through DeviceNet."

Central Control Room

The whole plant can be viewed and controlled from the central control room, through FactoryTalk View SE human-machine interface (HMI) software. For convenience, several satellite control rooms also are located elsewhere on the site. The HMIs and PACs communicate via the plant's Ethernet network.

Since the refinery was automated first, it has its own control room, but the central control room receives all its data and, in fact, can control the refinery too.

With all controls in one place, Roberts notes, any operator can run any part of the plant or all of it. The complex even could be run remotely over the Web if there were a reason to do so. More to the point, if a problem requires engineering attention, plant engineers can troubleshoot it from home — this is important because Clewiston is in the middle of the Everglades and staff members may live an hour away.

The First Harvest

Given the stringent time constraints of each phase — and the need to

meet three deadlines, rather than just one, by which everything affected had to be completely finished and back in operation — completion of the project was not without its nerve-wracking moments.

Roberts enlarges the construction picture, calling the deadlines "very tight, very tight." At times, three shifts worked around the clock and various trades were "stacked" — mechanical and electrical craftspeople working simultaneously, for example. But, he says, "The instrumentation and controls were right on time."

Bob Lofgren, CEO and engineer for Valley Engineering Inc., which had a large part of the mechanical design and was charged with commissioning of the plant, said it best. "This is the first project I've ever been involved with in which controls were ahead of everyone else."

The fully completed new sugar mill just finished its first harvest season in April 2008. Throughput is as targeted, as is staffing. The central control concept has proven itself in operation.

In one way, O'Dell says, the success of the complicated instrumentation and control system is evident simply because the plant functions, period.

"The mass balance of the plant of steam, electrical power, condensate and juice processing all has to be maintained within a constant specification to insure throughput," O'Dell says. " If one of these goes out of spec, the whole plant will grind to a halt."

Project Breakthrough's deadlines were absolute. The sugar processing season starts each year on Mother Nature's timetable, and the equipment and controls had to be ready. Each year of the project, the Rockwell Automation control systems were ready to go when the crop started. The cohesive Rockwell Automation solutions maximized the productivity of the engineering team. □

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