TiO_2 FACILITY FINDS HIDDEN PLANT

Millennium Inorganic Chemicals Increased Capacity, Improved Quality, and Reduced Maintenance Costs With Loop Performance Analysis. **By Paul Berwanger**

I was brought over to Millennium from Equistar in 1998 to manage new capital projects. Market demand for titanium dioxide was expected to outpace installed capacity by 2005 due to the closure of outdated and noncompetitive lines, and Millennium wanted to know what could be done to meet this demand while maximizing shareholder value.

The traditional—and assumed—answer was to build new plants and additions. But new plants take money (a lot of money), people, and time to build, and even more time to pay back. Therefore, they don't necessarily maximize profit. To maximize profit, a company must maximize the value added for each incremental investment dollar spent. In other words, a sound business case must be made. That became my first task.

The idea was to follow the usual "build" formula where finance and manufacturing negotiate with sales to determine how much product can be moved at a range of prices. We then developed price/output/profit curves. Such curves are rarely linear, and profits don't always rise with volume.

Once we agreed on the point of maximum projected profit, my job was to give sales that level of production as cost-effectively as I could, using our existing capacity. If we then found that we were still capacity-constrained, our next step was line expansion, and finally, a new plant.

Assessing the Options

Titanium dioxide (TiO_2) is one of Millennium's top profit-makers. It's the ideal white pigment for paint-makers. Our first project was to increase Millennium's current production of TiO_2 from the Ashtabula, Ohio, plant. Then the company would introduce a new, higher-tier TiO_2 trade-named Tiona 596.

To meet the immediate needs of 4-5 metric tons/day to replace the closure of the inefficient lines, we would need a $10 million line expansion. Calculations estimated the cost of a new greenfield TiO_2 facility at about $2,000 per installed ton/year of capacity. If we decided to plan for capacity expansion of future sales projections, we would need to build a new plant. Since an optimally efficient, world-class TiO_2 plant sizes out at about 150,000 tons/year, the cost would be $300 million or so—a big, risk-filled chunk of change for any company. Covering depreciation alone would absorb $15 million per year in gross profit over 20 years.

Added to the $300 million would be the cost of servicing the debt, plus the cost of other needed infrastructure. Infrastructure work at the location chosen would add $150 per ton/year, or another $22.5 million to the investment. It obviously makes sense to build a greenfield facility at times, but we felt there had to be a better way than to just start pouring concrete.

TABLE I.

TiO_2 TALLY

Costs:	
Loop audits	$50,000
Corrective actions	$450,000
Benefits:	
Sales increase, per year	$1,000,000+
Profit improvement, per year	$750,000
Maintenance reduction, per year	$900,000
Capital cost avoidance	$12,000,000
Throughput improvement	45% for TiO_2
Throughput improvement	25% for Tiona 596

The obvious question was whether Millennium's current TiO_2 manufacturing assets were fully optimized. The Ashtabula plant, the company's largest, looked highly efficient. Year after year, our plant took honors for being the most efficient plant in our system. Could we wring out additional tons? Even if additional production could be squeezed out, how much would it be? How would the cost of releasing each additional hidden-plant ton compare to the cost of each new ton from a line extension or new plant?

So we set out to find if a larger, hidden plant lay within the Ashtabula TiO_2 facility. Two intertwined avenues were explored: process reliability and its evil twin, process variability. I define process reliability broadly here as the percent of time plant assets are available for their intended purpose at full design capacity; downtime or poor performance due to *plant problems or constraints, and which result in shutdowns or slowdowns ordered by management, are excepted and addressed.*

Start With Loop Performance

Process variability is a demon that often lurks unseen in reliability's shadow, cutting efficiency and output and damaging the plant. Variability problems can lead to failures of rotating equipment, mechanical erosion, and losses in product quality, throughput, and yield.

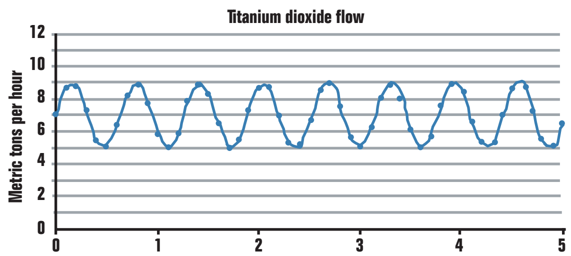
We approached our investigations systematically. First, we needed people with lots of experience in evaluating processes and their control; we didn't have the staff to properly do it ourselves. I had earlier been impressed by feedback loop auditing work performed by Emerson Process Management's EnTech team at an Equistar plant. Loop audits seemed a good place to start developing hard data.

Rather than starting the consultant with a process in the TiO_2 *chain where we suspected problems, we gave him a process where we thought we were running nearly perfectly. You might call it a challenge: "If you can find problems here, you can find problems anywhere." The process was the oxidizer, a main operating unit where titanium tetrachloride is reacted with toluene, oxygen, and nitrogen to create* TiO_2.

Figure 1 is a typical trend chart presented to the operator at that time, detailing the reactor's TiO_2 *output in metric tons per hour. Some cyclic variability can be noted, with flows ranging around 6.7 tph. The design rate was 7.0 tph. Product quality was 90% first-pass prime. We were happy as clams.*

FIGURE 1.

IGNORANCE IS BLISS



A TYPICAL OPERATOR TREND CHART OF THE REACTOR TIO_2 OUTPUT SHOWED CYCLIC VARIABILITY WITH FLOWS AVERAGING AROUND 6.7 TPH. THE DESIGN RATE WAS 7.0 TPH.

The consultant looked at the chart and immediately discounted the data presented to the operator—something that I and engineers at most companies would probably not think to do. He compared it with field data using an EnTech auditing tool connected to the final control element I/O.

WHAT'S NEXT?

The TiO_2 process is complex and requires a lot of operator input. Eventually we would like pushbutton operation when starting cold or transitioning from one product to another. The operator would just key in what product and how much, and hit Go.

The application of process automation is obviously the key. We sought a single platform that can integrate well with PLCs, laboratory information management systems (LIMS), and other analytical instruments, and also provide advanced control techniques, predictive maintenance, exhaustive data collection and processing, seamless communications with the MES and ERP levels, etc.

We investigated various DCS and PLC turnkey automation platforms to replace the Ashtabula plant's Emerson RS3 DCS. Central to this effort was a lifecycle, total-cost-of-ownership bid analysis.

Bids often are close in price and difficult to compare. One bid may be heavy on I&E, another on the mechanical aspects. Therefore, the bids had to be conditioned to make sure we were comparing apples to apples. Important was the age of the candidate platforms: Buying soon-to-be-outdated technology would be a disaster.

We also looked at the bidders' grasp of schedule and commitment, the people issues and résumés. We asked for references from former projects of a similar nature, suggestions on improving project performance beyond our ideas, and information about project and subcontractor management and staffing approaches and experience. We looked at the migration path and cutover from the existing system, ability to perform not only in the U.S. but in Timbuktu for future projects, local support worldwide after commissioning, etc.

Each bidder had to allow our evaluation team to attend, gratis, a weeklong training course on their automation software. We know that buying and using software often costs more than hardware over the long run. Some bidders balked, saying they charge $3,000 a head for training. We suggested they build it into their prices.

I've yet to see a software presentation that didn't look terrific, but we had to get an idea how much time would be spent learning, programming, updating, and modifying the software and integrating it with other equipment and systems. Our team conducted after-hours research during each course, trying to duplicate existing Millennium DCS graphics and configurations. Ease-of-use here varied widely among bidders.

The 12 people on the evaluation team unanimously chose Emerson's PlantWeb digital plant architecture. Primary reasons for the choice were ease-of-use and robust connectivity to field equipment, to other systems, and to ERP and IT networks. PlantWeb hardware and software were not the least expensive, but bid-conditioning demonstrated that they provided the greatest added value, lowest total cost of ownership, and most promising future viability.

The PlantWeb selection paves the way for us to look at connecting the process to our SAP Enterprise Resource Planning (ERP) system in the hope of optimizing the supply chain and gaining even more efficiencies. The goal of supply chain management is to relay information to the right people in a manner and speed that facilitates the decision-making process for buying raw materials and making and delivering products.

We quickly discovered we needed a detailed plan to implement an ERP-to-process connection, which required that we flowchart a base communications layer comprised of two pieces: the PlantWeb architecture and an existing, OSI PI-based, custom LIMS.

The PlantWeb-LIMS base layer connects a manufacturing execution system (MES) layer. This layer consists of the DeltaV system's PC-based historian, engineering, and application workstations. The application station stores such items as advanced control, batch records, process recipes, planning and scheduling tables, etc. It is also the station that connects to the ERP layer.

Information must flow bidirectionally and seamlessly among the three levels. We are working on developing periodic forecasts, material resource plans, process orders, customer inputs, and material consumption, confirmation, and finished goods reports. As yet, our supply chain does not extend to vendors.

In the future, customer orders will automatically feed into the system and could affect production in minutes. If the Ashtabula TiO_2 plant continues to run at 100% first-pass prime without grade transition losses, it's possible to optimize the grade mix by dialing in the quality.

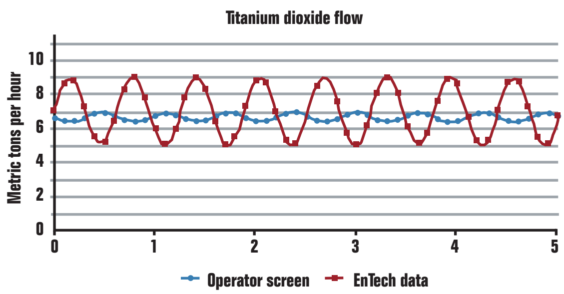
If a customer changes its requirements, we will learn of it instantly to better meet its just-in-time delivery requirements. This is slated as a service to those customers who make up the majority of our business. Supply chain optimization will allow us to be so close to those customers that they'll have no incentive to look to any other vendor.

Today, we are continuing to reveal hidden plants throughout Millennium facilities worldwide. Some 75% of our savings still come from working in the basement: efforts like correcting a scrub salt valve. The rest (25%) results from adding and replacing automation and instrumentation.

We're not seeing supply chain savings yet, but we're developing the capability. Eventually, we expect half of savings will come from the supply chain side.

FIGURE 2.

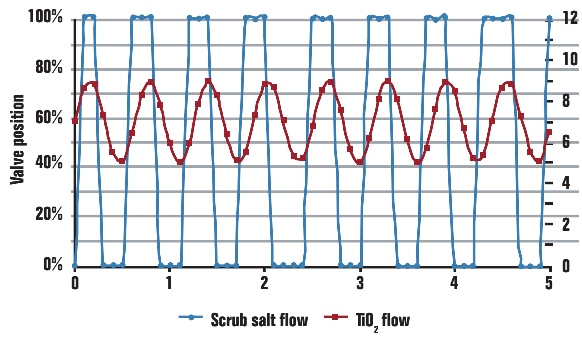
FILTER OFF



A LOOP AUDIT OF DATA FROM THE FINAL CONTROL ELEMENTS OVERLAID ON THE OPERATOR CHART (FIGURE 1) SHOWED THE SAME AVERAGE FLOWS AND PERIOD WITH THE CYCLES OUT OF PHASE BY 180 DEGREES, AND THE POTENTIAL FOR A PRODUCTION RATE OF MORE THAN 9 TPH.

FIGURE 3.

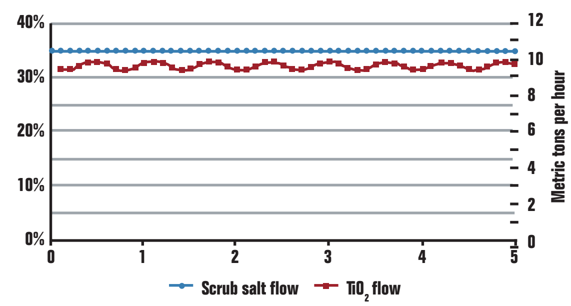
SALT VALVE EXPOSED



A FULL AUDIT SHOWED THE SCRUB SALT VALVE HAD THE SAME PERIOD AS REACTOR TIO_2 OUTPUT. WHEN THE VALVE WAS SWITCHED TO AN ARBITRARY CYCLE OF 25 SECONDS OPEN AND 23 SECONDS CLOSED, THE REACTOR OUTPUT TRACKED EXACTLY.

FIGURE 4.

CONTROL CORRECTED



WITH CONTINUOUS INSTEAD OF ON-OFF SALT CONTROL, AVERAGE OUTPUT RISES FROM 6.7 TO 9 TPH. SALT CONSUMPTION HAS BEEN REDUCED 34% FROM AN AVERAGE OF 53% TO AN AVERAGE OF 35% OF MAXIMUM PUMP CAPACITY.

Surprise. Instead of 6.7 tph with a variability of ±2%, they found 6.7 tph with a variability of ±20%. How can that be, we asked? The consultant overlaid his chart on the chart presented to the operator (Figure 2). Both showed the same flows and period, but the cycles were out of phase by 180º, which didn't make sense. He had seen this behavior before, however, and proposed the reason: Most probably, a process problem arose years ago. Because the output remained high, rather than solving the problem someone decided to filter the output signal. What the operator saw was a time-weighted average that understated the true design output, which should have been more than 9 tph.

Variability Thief Apprehended

This discovery really piqued our interest. We wanted to know what prompted the filtering in the first place, so we asked the consultant to perform an audit of every loop in the reactor system. He shortly found the culprit to be a scrub salt additive controlled by an on/off valve, a place we had never looked since it looked so good at the operator station.

The hot TiO_2 is quenched within the pipes of a flue-pond after leaving the reactor. Rapid cooling is necessary to control particle size, and particle size equates to quality. To prevent the oxide from agglomerating in the piping, scrub salt is added just before quenching.

Though the resolution in Figure 2 is too low to show it, reactor output cycled on an exact 38-second period. The full audit indicated that the chart for the scrub salt valve had the same 38-second period in a cycle of 20 seconds open and 18 seconds closed (Figure 3). To determine if the valve was the cause, it was switched to an arbitrary 48-second cycle of 25 seconds open and 23 seconds closed. Voila! Reactor output cycling tracked exactly.

We asked Emerson to fix the problem and properly tune the reactor with a Lambda tuning algorithm. The result: TiO_2 output advanced to 9.7 tph, a 3.0 tph boost. Smoothing the output permitted the process to be run much closer to its theoretical design limits. Salt valve correction alone effectively increased plant size by 45%—a "hidden plant" we didn't know we had.

We are also saving salt. The existing on/off scrub salt addition amounted to an average flow of 53% of maximum pump capacity. Salt addition has now been made continuous (Figure 4) through a regulating valve and has been reduced to 35% of maximum pump capacity, for a 34% reduction in salt consumption. The reduction reflects the benefit of more even mixing of TiO_2 and salt.

The former, highly cyclic product output also resulted in an average of five, two-hour flue-pond downtime episodes per month totaling $75,000 in maintenance charges. These failures, which were the highest-cost repetitive maintenance items in the plant, have essentially been eliminated.

More Infected Loops Cured

We learned even more in a subsequent loop audit of the entire plant. Filtered operator data was found to exist throughout the plant. It took a full year to evaluate and remove unwanted filtering from infected loops and retune all loops in the plant. Although the additional improvements couldn't match the results of the initial audit, they did add to the size of the hidden plant savings.

Production capacity was not the only benefit; product quality improved as well. TiO_2 first-pass prime has been raised from 90% to 99.96%. (The figure would have been 100% for the past 15 months except for two substandard pallets.) Because all production is effectively prime today, grade mix can be optimized without transition losses.

Millennium recently converted the reactor to produce the Tiona 596 product, one extremely important to the company's future. Making the new product required a 20% reduction in throughput through the oxidizer. Prior to the loop auditing work, we had anticipated an investment of about $12 million to maintain capacity at the 6.7 tph level. Today, because the audit revealed a hidden plant, we're producing Tiona 596 in amounts substantially above that volume with no additional capacity investment.

A summary of the Ashtabula TiO_2 plant costs and benefits to date is shown in Table I. The success of loop audits in Ashtabula has led Millennium to take the process worldwide, spending about a half-million dollars with the consultant so far. Few of those audits have paid back as handsomely as Ashtabula, but every one has paid back well and work is continuing.

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