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Save Energy In Distillation

Revamping may cut consumption considerably

By John Pendergast, Louisiana State University, Dennis Jewell and David Vickery, Dow Chemical Company, and Jose Bravo, Fractionation Research, Inc.

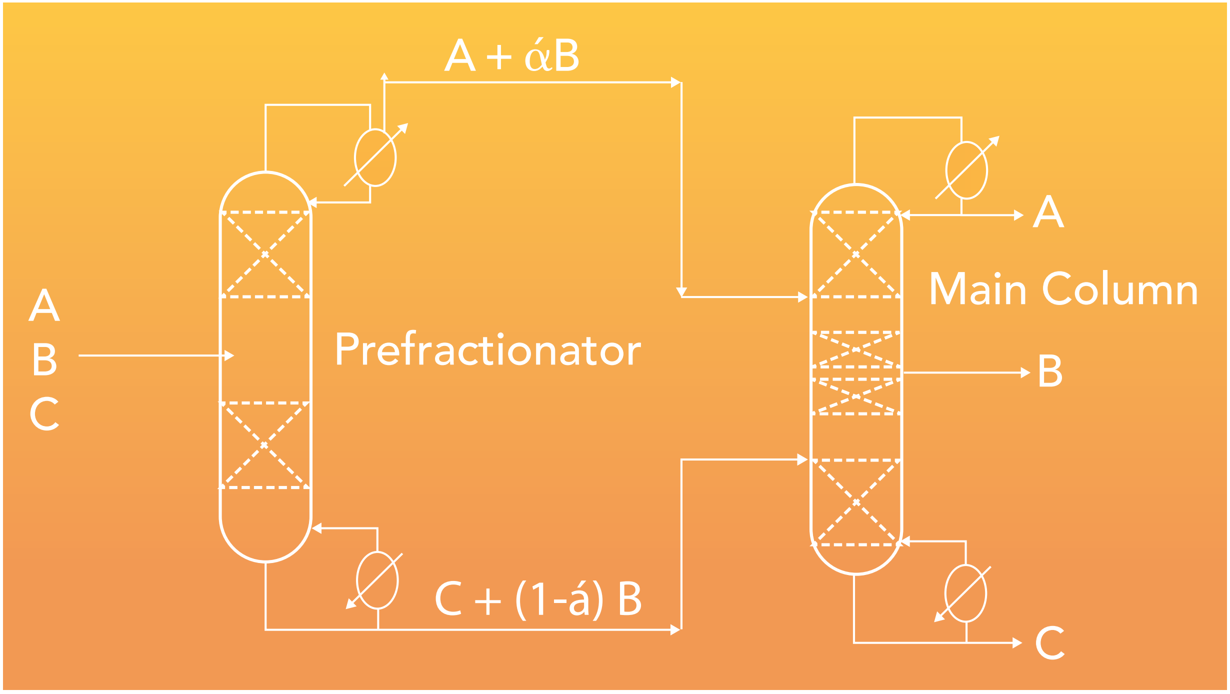
Separations operations account for roughly 50–70% of the energy used in large-scale chemicals manufacturing [1]. Distillation — which we'll use to encompass the related operations of absorption and stripping — dominates for such separations.

Distillation rules the separation landscape not because of any efficiency advantage but rather because of several other factors that favor it. For instance, distillation:

- scales well, generally to the 0.6 power;
- when performed by itself, doesn't introduce an extra mass agent (solvent, sorbent, etc.) that needs subsequent recovery, as in the case of absorption or liquid extraction;
- allows heat integration within individual units and across facilities, which can foster effective heat utilization in many separations operations; and
- provides an inter-relationship between pressure and temperature.

Moreover, the technology is well understood and robust, leading to high confidence in designs.

However, its maturity means that distillation usually isn't the focus of academic research, with several notable exceptions such as the work of Rakesh Agrawal at Purdue, Bruce Eldridge, Frank Seibert and Gary Rochelle at the University of Texas, and Ross Taylor at Clarkson. Fortunately, long-established and robust industrial consortia carry out investigations and continue to refine the practice of distillation. For instance, Fractionation Research, Inc. (FRI), www.fri.org,



PREFRACTIONATOR
Figure 1. Adding such a column typically leads to a 20–40% cut in energy consumption.

which has more than 85 corporate members, operates industrial-scale distillation columns and performs research on modern distillation devices.

Progress is taking place in decreasing distillation energy consumption. Facilities now being planned certainly can benefit. However, energy reductions alone generally can't justify investment to replace an existing column.

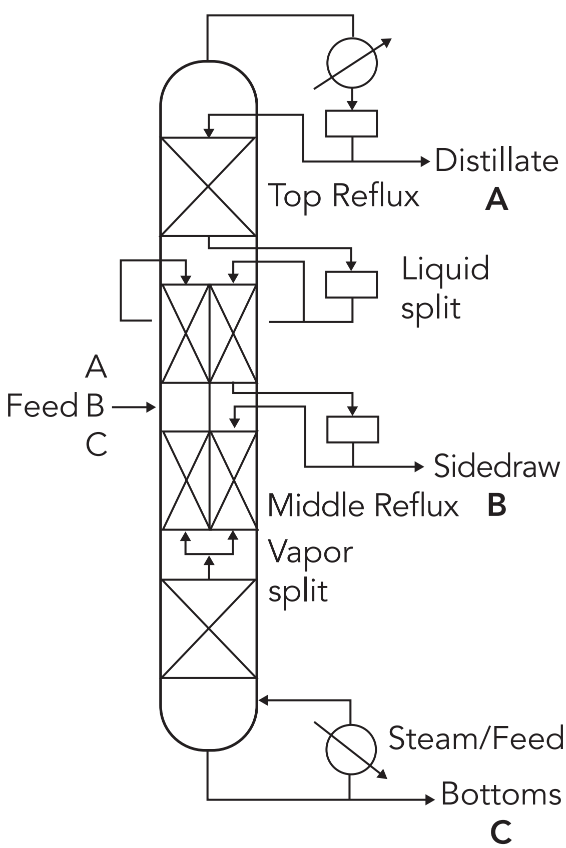
Operating companies expect distillation columns to operate for decades; a life span of 30 years isn't uncommon. So, sites over time may make modifications and upgrade instrumentation, and often keep the units in excellent physical condition.

Thus, the most-feasible approach for saving energy is via retrofitting. Here, we'll focus on some ideas for energy reduction in existing columns.

CONVERTING AN EXISTING SEQUENCE

If the infrastructure already exists to perform the separation by conventional methods, you may be able to convert the current sequence to a prefractionator or Petlyuk arrangement (Figure 1). This can save a significant amount of energy for the required separation; typically, it reduces energy consumption by 20–40%. Alternatively, you can produce more products from the facility for the same amount of energy.

Converting an existing facility from a conventional sequence to a prefractionation one certainly isn't trivial; it requires careful study, including rigorous simulation, and then a detailed evaluation of the mechanical modifications necessary. You should assess, e.g., the internal tower hardware before and after the modifications, suitability of the pre-fractionator reboiler and condenser in the new service, turndown capability in the new service, and other details.



DIVIDING WALL COLUMN
Figure 2. Existing towers with low-volume overheads or bottoms often are good candidates for conversion.

A further way to achieve or increase energy savings is by converting the sequence to sequences that employ side-rectifiers or side-strippers.

OPTING FOR A SINGLE DIVIDING WALL

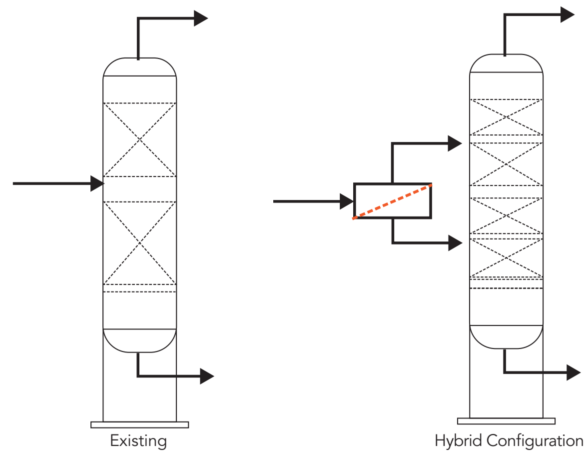
A dividing wall column (DWC) may save a substantial amount of energy. (See: "Consider Dividing Wall Columns," https://goo.gl/sUY27t [2].) Depending on whether significant changes in product mix or capacity requirements have occurred over time, it may be possible to convert a two-tower system to a single dividing wall column (Figure 2). This is more likely when the original tower configuration was developed to remove relatively small fractions of light component (A) or heavy component (C) or both.

You must assess mechanical details such as tower hydraulics, feed locations and auxiliary equipment rating as well as other details to determine the feasibility of such a conversion. As with all complex column configurations, it's essential to remember that the *levels* of energy consumption are an important consideration for the evaluation of the benefits of new separation configurations. While the single DWC will consume less energy from a First Law perspective, it may be disadvantaged from a Second Law perspective. So, you must analyze the system individually, taking into account the utilities and economics for the particular operation or entity.

POWERFUL LOW-COST "TRICKS"

Small changes that require minimal capital investment sometimes can produce great benefits. You should consider such "tricks" when searching for improved energy or capacity performance from an existing facility. Some examples include:

- *Feed location.* Always look into this. A feed in less-than-optimum position in the distillation column negatively affects energy use and, thus, capacity. Feed location might have been appropriate initially but, as time has passed and feed or product specifications have changed, may require repositioning. A small change in feed location can save on large reboiler duties.
- *Use of side-draws.* A precursor of the concepts of prefractionation and the DWC is the thoughtful use of side-draws in a given multicomponent distillation train. A classic example is that where top and bottom products are needed at high purity and the middle boiler is present in small amounts in the feed. If you look into the composition profiles of existing columns such as these, you'll see that the concentration of the middle boiler presents a steady-state "bulge" that reduces at the ends. Using a side-draw within that bulge allows retrieving the middle boiler at high concentration in a small stream, drastically reducing the heat duty of the column.
- *Treating pressure as a variable.* Engineers generally think of the operating pressure of a distillation column (i.e., the average between top and bottom) as a given. However, you can effectively use changes in pressure to alter performance. Because relative volatilities vary with pressure, it sometimes proves useful to lower column average operating pressure to require less heat duty. A very common example of this is the well-known trend in refineries to use low-pressure-drop packing in crude and vacuum towers instead of trays to reduce pressure drop and improve fractionation.
- *Feed condition.* Adding or removing heat from the feed can change the requirements of a reboiler or a condenser. This may not alter the overall heat balance but might allow for easier heat recovery schemes with feed exchangers that may help with the loads on reboilers and condensers.



MEMBRANE/DISTILLATION HYBRID
Figure 3. Using a membrane as a prefractionator frequently can provide substantial energy savings.

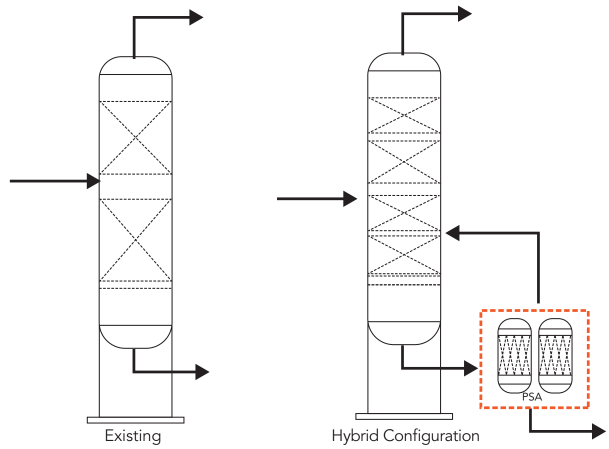
Properly assessing the viability of these modifications requires a well-validated model of the distillation column that can provide reliable pressure, composition and temperature profiles.

HYBRID OPERATIONS

Progress in both membrane and adsorption materials has enhanced the prospects of hybrid separation, by which we mean the use of either membranes or an adsorber in tandem with distillation. The combination of these unit operations potentially can reduce the separation energy of some energy-intensive separations while still meeting the financial hurdles required of any improvement project.

While myriad combinations of other operations with distillation are possible, these two have a strong synergy with distillation that can lead to improved energy efficiency or capacity.

Distillation plus membranes. Membranes are well suited for pre-fractionation; so, they may offer an attractive option for low energy separation upstream of the distillation tower. Figure 3 provides a simplified representation of the concept. (The graphic shows a tower with packing but the concept applies equally well to trays.) The permeate and retentate from the membranes then can go to the optimum location in the tower, lowering the energy consumed by a substantial fraction. As pointed out by Sholl and Lively [3], the use of membranes to pre-fractionate light olefin from paraffin might reduce the energy requirements by a factor of 2 to 3. As always, the key challenge to any large-scale separation with membranes is the surface area required. Membrane separations scale directly, while, as noted earlier, distillation scales to the 0.6 power, which drives large-scale separations to distillation. Applying membranes in tandem with distillation doesn't change the scale factor but does eliminate the need for the membrane to provide pure product; this enables selecting the membrane area that gives the optimum level of performance within economic constraints.



DISTILLATION/ADSORPTION HYBRID
Figure 4. An adsorber can enable reintroducing a light component at an optimum location in a column, lowering energy consumption.

Distillation plus adsorption. Such a system holds promise for lowering the energy consumption for separating zeotropic mixtures.

Indeed, this hybrid operation already is widely used for breaking the azeotrope between ethanol and water — it may well be the preferred method of operating assets producing anhydrous ethanol. As shown in the simplified schematic in Figure 4, the light components are allowed to "slip" to the bottom of the tower, from which they go to the adsorber where light components are captured and returned to the tower at the optimum location.

While the figure illustrates pressure swing adsorption (PSA), there's no fundamental reason why a hybrid process couldn't use temperature swing adsorption (TSA). The ability to rapidly regenerate beds with pressure swings, thus reducing the amount and size of the adsorbent beds needed, generally drives selection of PSA over TSA.

RETHINK YOUR CONFIGURATION

As we've pointed out, retrofitting existing columns with sequences such as Petlyuk processes, DWC, side strippers and side rectifiers and other complex arrangements may conserve distillation energy. In addition, progress in both membranes and adsorption materials has opened up opportunities for applying hybrid unit operations that may well fit into existing infrastructure and produce acceptable economic returns on energy reduction opportunities.

Modern simulation tools and optimization methods enable investigating all the potential alternatives for distillation separation sequences and selecting the best sequences. They play a key role in the design of new facilities but also can help in revamping existing columns where energy savings alone won't justify a replacement unit. Perform such evaluations for those revamping options that seem appropriate for your plant; you may identify opportunities for substantial reductions in energy consumption.

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REFERENCES

Adler, S., Beaver, E., Bryan, P., Robinson, S. and Watson, J., "Vision 2020: 2000 Separations Roadmap," Ctr. for Waste Reduction Technologies, Amer. Inst. of Chem. Eng's, New York City (2000).

Pendergast, J., Vickery, D., Au-Yeung, P. and Anderson, J., "Consider Dividing Wall Columns," *Chemical Processing* (Dec. 2008), www.chemicalprocessing.com/articles/2008/245/

Scholl, D. and Lively, R., "Seven chemical separations to change the world," *Nature*, 532, p. 435 (April 28, 2016).

EMISs Evolve to See the Bigger Picture

Adding process considerations improves energy savings and production performance.

By Carlos Ruiz and Tim Shire, KBC Advanced Technologies

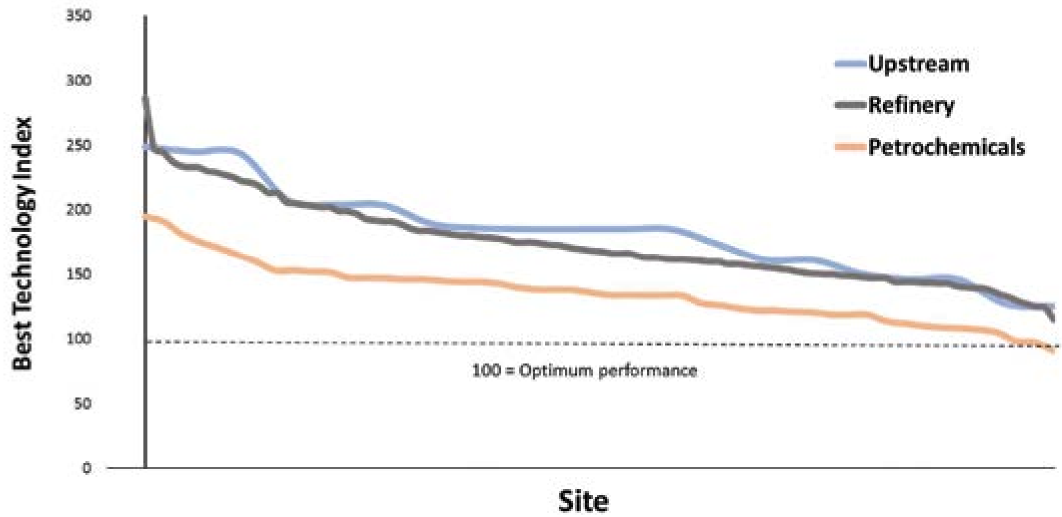
Poorly designed and overly simplistic energy performance indicators (EnPIs) often drive energy savings at the expense of product yield or quality. However, a well-designed energy management information system (EMIS) can minimize energy cost without impacting production and, in some cases, can even enhance process performance.

Traditional energy monitoring applications mainly focus on improving energy-side key performance indicators for fired boilers and heaters efficiencies, energy intensity, utilities' marginal cost, etc. These monitoring applications rely on inputs from various process measurement instruments, with temperature leading the way, to verify performance.

However, covering an expanded range of production parameters — including energy supply, demand and recovery, product quality and process yields — requires integration of the process with energy simulation, monitoring and optimization tools. This article shows how to overcome traditional barriers to energy saving by using rigorous process simulations to monitor performance and determine optimum operating targets for improving both energy and process performance.

THE ENERGY OPPORTUNITY

Energy is the largest controllable operating cost at most process plants. A typical refinery or petrochemical plant may spend $200–300 million/y on energy — so cutting just 3% in energy cost can save $6–$9



BEST TECHNOLOGY BENCHMARKING
Figure 1. Most sites, even relatively efficient ones, don't perform close to the optimum performance benchmark.

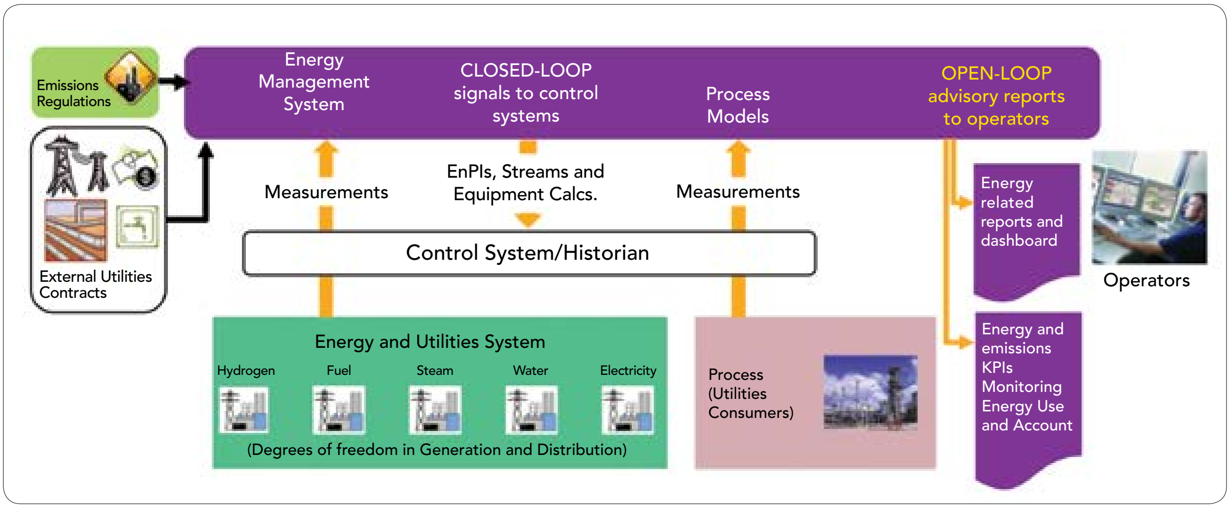
million/y. Such energy savings always result in direct bottom-line benefits, unlike adding capacity or changing product mix, which depend on anticipated market conditions.

Energy production and distribution systems often constrain processes. For example, a process compressor can be limited by its turbine drive's capacity and efficiency, so steam and condenser operating conditions or degradation of the turbine can mean the drive reaches its limit before the compressor does. In another example, the amount of heat a process furnace is able to deliver can restrict unit throughput. Energy-related bottlenecks often curb throughput of high-margin processes by 2–3%.

One challenge is understanding the amount of potential energy improvement. Plants typically compare themselves against their peers. However, this comparison only is meaningful if the leaders are highly efficient.

An alternative approach is to compare energy use against a thermodynamically and economically achievable minimum. Our company has developed an energy metric called the Best Technology (BT) index. The target BT index is calculated based on an optimized process configuration including reactor conditions, number of distillation column trays, etc., as well as pinch analysis for heat recovery and R-curve analysis for utility delivery. This enables the specification of all equipment for maximum efficiency.

Pinch analysis is a methodology for reducing energy consumption of processes by calculating thermodynamically feasible energy targets. R-curve analysis determines



IMPROVED EMIS
Figure 2. Data from the control system and historian enable experts to make recommendations for saving energy and improving process yield.

the hypothetical ideal utility system and fuel utilization for power and steam generation.

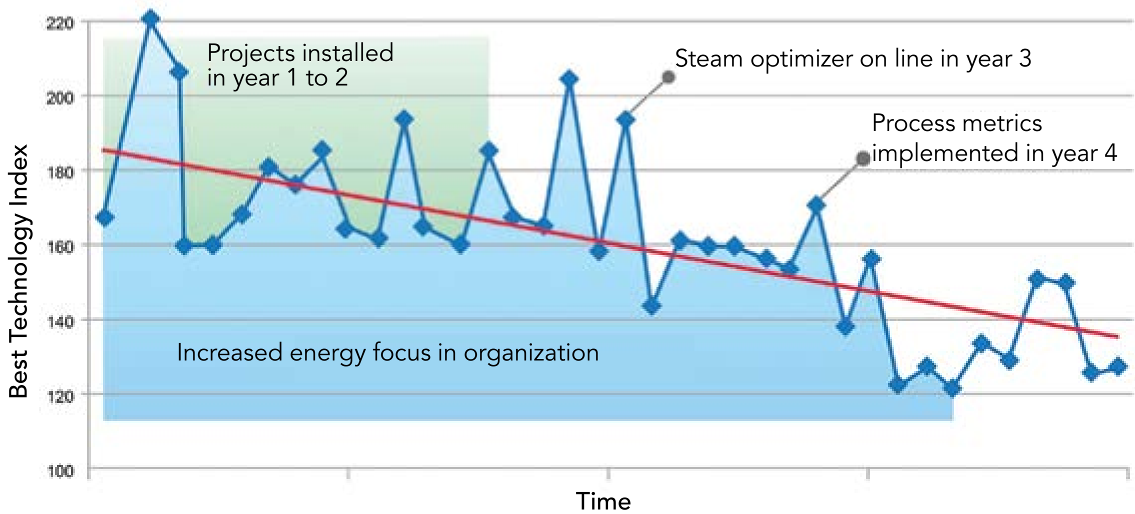
Repeating these optimization calculations for a range of feedstocks, operating severities and product yields determines a relationship between optimum energy use and process performance. The optimum target energy benchmark is defined as 100.

The actual BT index is calculated as the ratio of actual energy use divided by the target, in %. For example, if the plant is using twice as much energy as the benchmark, then its BT index is 200%. This index basically compares current energy use against that of the best available technology in the market.

Even relatively efficient plants typically use significantly more energy than the BT benchmark. Figure 1 shows a trend of the BT index for several hundred sites arranged in descending order along the x axis. In the refining and upstream industries, even the best performers (right-hand end of the scale) have a BT index well above 100%. There have been many instances of top performers saving 10–15% of energy, worth $20–30 million/y. Similar percentage reductions for CO_2 emissions also are achievable.

EMIS ISSUES

Most EMIS software packages focus only on the energy supply side (for example, the efficiency of production of steam and power for use in the process), so their EnPIs don't reflect the impact of feedstock effects or process yield. For instance, if energy consumption increases, they can't indicate whether this stems from inefficiency, lower quality feedstock or the demands of higher



ENERGY CONSUMPTION DECREASE
Figure 3. This European refinery project resulted in an about 20% overall energy savings.

quality products. These software packages may monitor equipment performance but often miss the chance to switch an item of equipment off when its output isn't needed to support production.

EMIS software can become out of date and may get misused, and plant personnel may fail to exploit its full value. Consequently, sites don't always act upon advice and recommendations provided by the EMIS because it's seen as irrelevant.

An EMIS frequently doesn't address the interaction of energy and production yield. Many plants highly integrate their energy systems with production processes, so changes in one area impact other areas significantly.

Complicating the problem are changes in staffing, particularly the loss of veteran staff and the push to adopt leaner operations, making it more difficult for work processes and practices to catch up with technology.

Nevertheless, many companies still use a traditional EMIS approach. This produces energy cost savings but can miss some opportunities by not considering the combined effects of energy use and process performance.

AN IMPROVED APPROACH

Adding process considerations can solve EMIS problems. For instance, simplified EnPIs drove the wrong behavior in a fluidized catalytic cracker (FCC) at a refinery. In this FCC, an opportunity existed to lower cooling water temperature by resolving an issue on the cooling towers. This colder cooling water would improve condenser vacuum and increase the efficiency of a condensing turbine, providing benefits in one of two ways:

1. reducing steam demand and saving energy; or
2. debottlenecking the compressor being driven by the condenser.

Conventional EMIS calculations for Option 1 show a small savings of steam, amounting to $80,000/y, by improving the standard EnPI metrics of total energy use and specific energy consumption.

For Option 2, the EnPIs of total energy use and specific energy consumption increase, driven mainly by higher coke burn. However, when corrected for the improved process performance, the BT index decreases. Profitability is dramatically better, with more than $10 million/y increased value. The BT index is aligned with the yield drivers and, therefore, won't penalize profit optimization.

In this example, a single simulation platform with an integrated process and energy model performed the optimization to generate operating targets, considering both energy and yield. The resulting targets were embedded in the EMIS optimizer software.

Such an EMIS integrates energy production and supply with process modeling and optimization (Figure 2).

In closed-loop mode, the EMIS sends recommendations directly to the control system to adjust the energy system or process. It also produces energy-related reports and actionable recommendations for operators, a form of open-loop control.

SUCCESS STORIES

Updating a standard open-loop EMIS to one with closed-loop optimization capabilities can produce dramatic improvements. For example, Air Liquide achieved impressive results at its Bayport, Texas, site. That facility produces oxygen, nitrogen and hydrogen, and supplies customers along the Texas and Louisiana Gulf Coast via an extensive pipeline network. It is Air Liquide's largest industrial gas complex in the world.

After using an open-loop EMIS, including its optimization capabilities, for several years, the plant decided to implement a closed-loop EMIS to cover the steam system, cogeneration and boilers — plus the extraction/condensing turbines. The new EMIS allowed Bayport to operate in an optimum manner throughout the day, despite price variations in electricity supply every 15 minutes.

Closing the loop was like having the plant's best engineer on duty 24/7/365 acting as an energy watchdog. It produced the lowest energy cost within process constraints against a moving target created by the need to meet customer product requirements and changing energy prices. In addition, the implementation of each closed-loop variable incorporated reliability assurance [1].

A European refinery also achieved substantial benefits. KBC worked with the plant to implement a phased approach to energy improvements. The first phase involved a profit improvement program focused on opportunities to increase yield and reduce energy. By using specialized software to analyze energy consumption and make changes via the control system, the plant cut energy consumption by 2.7% across the site (Figure 3).

At the same time, KBC and the plant jointly participated in a strategic review to identify specific energy efficiency improvement projects. Implementing these projects over a two-year period reduced energy use by 11.9%. Then, addition of steam optimizer software enabled the plant to drive energy consumption down another 4%. Finally, the team developed energy metrics to monitor performance of the entire plant, saving an additional 1% in energy costs. Overall, the four-year program reduced energy costs at the refinery by 20%.

As these examples show, an on-site EMIS with optimization modeling software certainly can help cut energy costs. However, local staffing problems (i.e., fewer and less-experienced personnel) common at many facilities can undermine its value. No one at the plant may understand what the software is trying to tell plant personnel.

These types of situations can be addressed using the power of the cloud to allow collaboration beyond traditional boundaries of time and location. Data and recommendations of the local EMIS are fed to the cloud, enabling experts at the EMIS vendor to guide process plant personnel in taking appropriate action.

For example, KBC's Visual MESA energy management system and its Petro-Sim modeling software, along with the control system's process historian, can all feed data to the cloud. Then, KBC's Co-Pilot service allows our experts to access and analyze the data, to make recommendations and reports — providing the plant with the expertise and insight needed to improve operations.

UPDATE YOUR EMIS

Today, plants face a compelling need to reduce energy costs and improve yields without extensive and expensive equipment modifications — while ensuring energy enhancements don't adversely affect process performance, and ideally improve it.

Improvements needed in EMIS software to address these issues include:

- process simulation to monitor performance and determine optimum operating targets by considering both energy and process performance;

- updated EnPIs with well-defined targets to track energy performance in a consistent way while minimizing feedstock and yield effects;
- site-wide energy management and optimization of utilities to deliver results and recommendations to the right people at the right time; and
- cloud-based support from the EMIS vendor to provide performance management and expert troubleshooting to resolve complex issues in real time.

Initial results of such an integrated approach show benefits can be substantial. Achieving 3–10% cuts in energy consumption or carbon emissions often is possible without capital investment in new equipment. Where energy systems are constraining process performance, sites have realized 1–3% increases in throughput or yield, with the synergy between process and energy optimization leading to benefits far greater than considering either in isolation.

REFERENCE

1. Reid M. and Reitmeier, T., "Closing the Loop With Visual MESA. The Transition of Air Liquide's Real-Time Utility Optimizer to Closed Loop at the Bayport, Texas Facility," Industrial Energy Technology Conference, New Orleans (May 2011).

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Consider Liquid Ring Technology for Dry Chlorine Compression

Liquid ring compressors offer lower cost and other advantages for chlorine processing applications

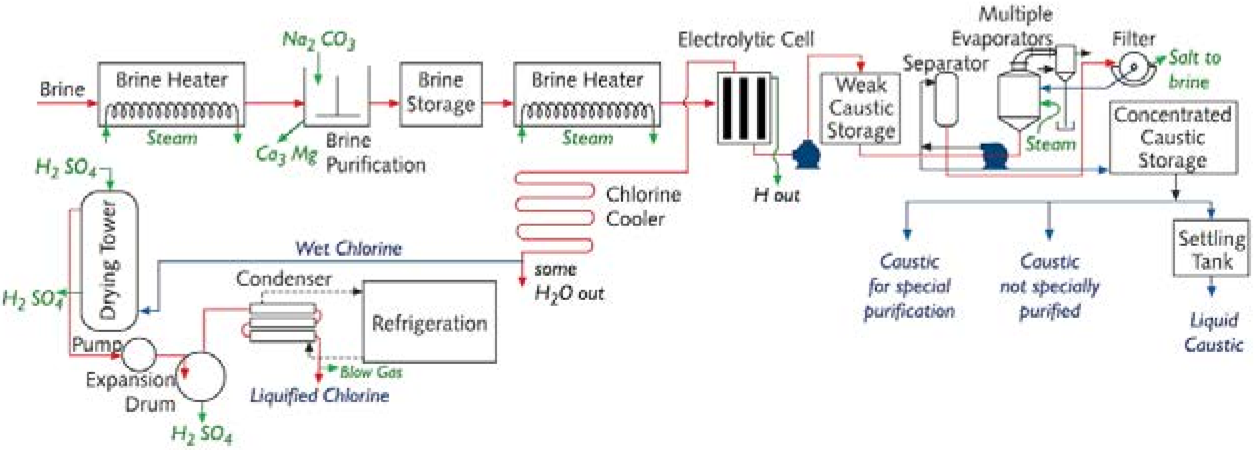
By Alessandro Pertusati, Gardner Denver Nash / Garo

Alongside fluorine and bromine, chlorine is considered an integral component in the chemical industry. As a basic inorganic chemical, chlorine and chlor-alkali products have seen a rising demand in a number of end-use industries, including the production of PVC, organic, inorganic and agro chemicals. Additionally, chlor-alkali products have been widely used for water treatment, paper bleaching, and as a key component in household and industrial cleaning products.

According to Grand View Research Inc., this spike in demand for chlorine products will have a significant impact on the global chlorine compressor market, which is expected to grow to $83.7 million USD by 2025.

As a toxic, lethal, and extremely corrosive substance, chlorine production processes require equipment that complies with a number of international environmental and safety standards, and provides a high degree of reliability. Additionally, most chlorine production processes operate at atmospheric pressure, and require that chlorine gas is compressed and liquified for transport and storage purposes.

Boasting a lower capital expenditure, when compared to centrifugal compressors, liquid ring compressors (LRC) have proved a popular alternative for plants where the maximum reachable capacity doesn't exceed approximately 5–6 units running in parallel. With worldwide investments focusing on small/medium capacity plants, demand for LRCs is projected to be far



ELECTROLYSIS PROCESS
Figure 1. Most chlorine is produced using the process of electrolysis, where chlorine, hydrogen gas and caustic soda are produced from salt brine.

higher than for competing technologies, such as centrifugal compressors.

In addition to cost, the projected increase in demand for liquid ring compressors (LRC) is also driven by the unique characteristics of Liquid Ring Technology:

Safety. The isothermal properties of the liquid ring allow LRCs operate at much lower temperatures than other technologies, lowering the risk of corrosion and damage.

Compatibility. LRCs can support a number of different "seal liquids," allowing them to be easily tailored to the application. In dry chlorine applications sulfuric acid is the only seal liquid allowed.

Reliability. With a single moving part, LRCs exhibit less opportunity for failure, and are able to handle occasional carry-over of particles such as salt or organic materials.

Affordability. LRCs exhibit longer mean time between failure (MTBF) and a lower total cost of ownership (TCO) than competing technologies.

Functionality. In addition to their ability to fully dry chlorine during compression, LRCs are also able to handle a smaller gas flow, as well as effectively manage sulphuric acid mist emitted from the drying tower.

DRY CHLORINE HIGH/LOW PRESSURE APPLICATIONS

Most chlorine is produced using the process of electrolysis, where chlorine, hydrogen gas and caustic soda are produced from salt brine (Figure 1). Upon leaving the electrolytic cells the gas, which is saturated with moisture, passes through coolers and a sulfuric acid drying tower. The dry chlorine (defined as containing less than 100 ppm water vapor) gas then enters the LRC to begin the compression/liquefaction process.

During the drying process, the gas sustains a slight pressure loss, and usually reaches the compressor at a negative pressure of 4–10 in. of water, though newer generation electrolyzers ensure a higher pressure to LRC (0.1 bar g). To reduce moisture, and in turn corrosion, the temperature of the gas at the compressor inlet should be no more than 100°F (37.8°C).

Additionally, using a seal liquid with a high concentration of sulfuric acid (typically 96, 97%, but more effectively at 98%) allows the process to be handled by steel or iron equipment.

Once compressed, the chlorine gas is then liquefied through cooling. The cooling process requires strict temperature and pressure controls to work effectively. Compressors play a key role in the cooling process by ensuring that the required discharge pressure is achieved prior to the chlorine being passed to the after-condenser for the condensation process. Discharge pressure is determined by the temperature of the coolant being used, as well as the condensing temperature of chlorine.

LIQUID RING COMPRESSORS
Figure 2. Liquid ring compressors are ideal for plants where the maximum reachable capacity does not exceed approximately 5–6 units running in parallel.

Depending on the end use, chlorine can be compressed at either low-pressure (LP) or high-pressure (HP). In both instances, the chlorine gas can be sent directly to users, or it can be further purified (Table 1).

Dry chlorine is a lethal, toxic, and extremely corrosive gas. Low pressure chlorine gas applications using high concentration sulfuric acid can be handled by a standard nodular cast iron (containing +1.5% nickel) compressor. With lower operating temperatures and sulfuric acid as a seal liquid, there is little to no risk of rust occurring in the iron, making cast iron a more cost-effective choice than more exotic materials such as austenitic stainless steel or Hastelloy C.

Conversely, HP applications require a compressor casing made from austenitic stainless steel (316L or HC276 for certain applications), with ancillaries in the steel to cater for proper corrosion allowances. Functioning at higher temperatures, and with a lower concentration of sulfuric acid (94–95%), austenitic stainless steel provides a far greater resistance to corrosion when compared to cast iron.

For both low- and high-pressure applications, a stainless steel shaft with specialized gaskets and packing is used. Additionally, in both instances, it is recommended that a seal liquid with a high concentration of sulfuric acid be used.

With this in mind, chlorine compressors are usually designed with Hastelloy C shaft sleeves, and utilize special stuffing boxes, packing, or mechanical seals which can withstand harsh service and use of an acid-based seal.

TYPICAL CONSIDERATIONS

A number of considerations must be taken into account when working with compressed chlorine gas:

Concentration of the acid seal. The seal liquid used must contain a high concentration of sulfuric acid. The absolute minimum is 94% H_2SO_4, with chlorine plants usually opting for 96–98% H_2SO_4. The required concentration is often determined by the compressor material used, with cast iron being able to withstand a minimum concentration of 96%, compared to stainless steels 94% minimum. Compressor life and reliability is directly tied to the concentration of the seal liquid, as compressor parts can rapidly deteriorate when acid concentration falls below the minimum threshold.

Temperature of the acid seal. Corrosion of the liquid ring compressor and its parts is directly related to temperature. To keep corrosion to a minimum, temperature of the liquid seal should be kept as low as possible, without dropping below 68°F (20°C) to prevent issues with viscosity. Depending on the application, chilled or cooling water is typically used to maintain correct acid seal temperature. Low pressure applications normally use chilled water, whereas high pressure applications typically require cooling water, particularly where liquefaction is performed without an additional chilling unit.

Operating discharge temperature and LRC method of cooling. Low pressure, cast iron units cannot operate at temperatures higher than 113°F (45°C) due to issues that arise due to corrosion. High pressure processes, on the other hand, require higher operating temperatures to avoid chlorine condensation/liquefaction inside LRC unit.

Quantity of sulfuric acid. In order to cool the seal liquid and maintain the temperatures required for safe and reliable operation, operators need to know the amount of acid that is required to create the seal. Inaccurate volumes can lead to miscalculations, which can accelerate wear and corrosion of equipment, affecting the efficiency, reliability, and safety of the system.

Dry Chlorine High/Low Pressure Range and Application

PRESSURE RANGE		APPLICATION
Low Pressure	36–65 psig (2-4.5 bar)	Chlorine gas can be sent directly to users, or further purified through a liquefaction process, by using an additional, dedicated liquefaction package, which eliminated pollutants like oxygen, nitrogen and hydrogen gas.
High Pressure	72–123 psig (5-8.5 bar)	Chlorine gas can be sent directly to users, or further purified through a liquefaction process, using a simple gas liquefier to eliminate pollutants like oxygen, nitrogen, and hydrogen gas by simple cooling of the high pressure compressed gas at dew point.

Table 1. Depending on the end use, chlorine can be compressed at either low-pressure (LP) or high-pressure (HP).

Compressor sizing. To ensure 100% capacity on long term operations, liquid ring compressors for dry chlorine applications are typically over-sized by 15% on the projected requirements.

Other considerations. Operators also need to consider the acid coolers required for their installation. Acid coolers are classed as specialty equipment that needs to be configured to a particular system/installation, as such it is advised that they are obtained from heat exchanger manufacturers with extensive experience in dry chlorine applications.

Additionally, the discharge separator needs to be large enough to allow retention time for heavy material from the recirculated system to settle, and also needs to be periodically flushed. Manual or automatic acid make up is also required to maintain the acid concentration within the required specification. Hastelloy C membrane type instruments (level and pressure transmitters) are also normally recommended to reduce overall material corrosion.

LIQUID RING TECHNOLOGY FOR WET CHLORINE APPLICATIONS

Liquid ring systems for wet chlorine applications (defined as > 100 ppm water vapor) are similar to those used for dry chlorine, with the exception of the materials used in the system and seal liquid. In wet chlorine applications, titanium compressors are required. Titanium also is necessary for the seal cooler, separator tank and system piping. If capital expenditure is a concern, different materials, such as CS PTFE-lined piping and valves, and CS PTFE or fiberglass reinforced plastic (FRP) separators can be used.

Due to the fact that there is no need to dry the chlorine, water is used as the recirculated seal liquid in wet chlorine processes.

As a result, wet chlorine processes require compressors constructed from titanium to eliminate the risk potential and risk of corrosion.

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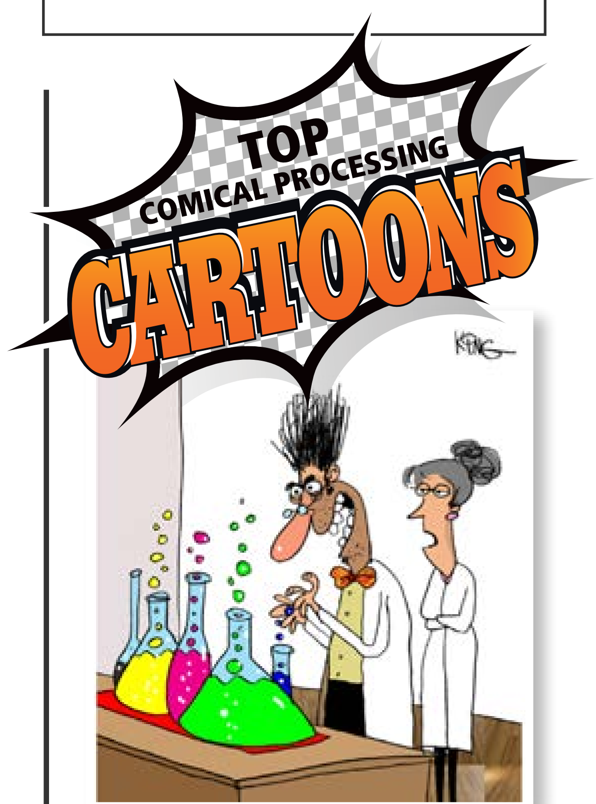

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