Easy Ways to Improve Energy Efficiency

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Managing the energy consumption of a process does not need to be complicated. Here are some examples of less-complicated strategies.

The chemical process industries (CPI) have made great strides toward energy efficiency. New, high-yield catalysts, equipment advances, improvements to process design procedures, process control and real-time optimization, energy-focused maintenance programs, and changes in corporate policies have contributed to this progress. In addition to these sophisticated strategies, simple, often-overlooked changes and activities can yield dramatic gains in energy efficiency.

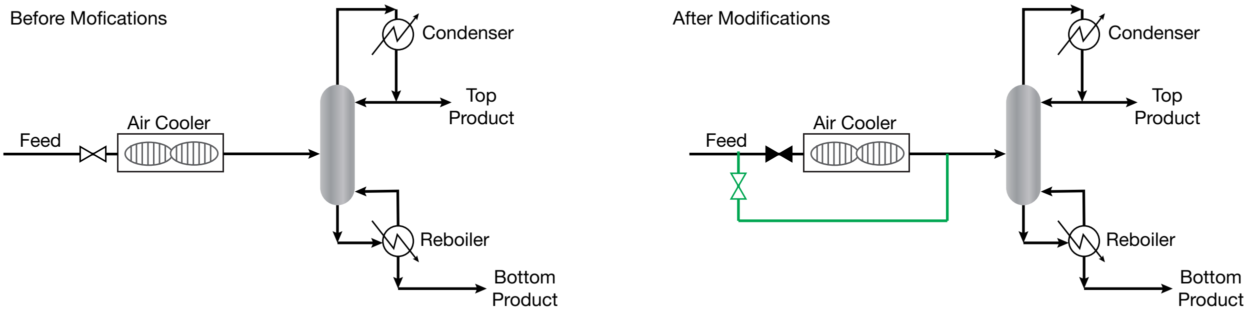
This article presents several effective — and relatively easy — changes that operators and process engineers can implement to minimize energy consumption, and provides guidance on how to avoid some of the common pitfalls.

Unnecessary cooling of process streams

A common inefficiency in a chemical plant or refinery is the cooling of process streams that should not be cooled.

A petrochemical facility installed an air cooler on the feed line of a distillation column (Figure 1) to prevent the condenser from being overloaded during certain abnormal operating conditions *(1)*. Although the air cooler was designed for use only during abnormal conditions, it ran continuously during normal operations. Removing heat from the feed during normal conditions required the reboiler to work harder, thereby increasing the boiler's heat load.

Changing operating procedures to reflect the original intent of the air cooler — shutting off the air cooler fan dur-



▲ **Figure 1.** A distillation column was designed with an air cooler on the feed line. Although the cooler was designed for use only during abnormal conditions, it was run continuously, resulting in an increased reboiler heat load. Shutting off the air cooler during normal operations did not completely solve the problem, as a significant amount of heat was wasted due to convection in the cooler. A simple fix: Install a bypass line around the air cooler (green).

ing normal operations — reduced the reboiler duty by more than 30% and saved the plant more than $1 million/yr, at no cost to the facility.

Turning the air cooler off during normal operations was a good first step. However, a significant amount of heat was still being wasted due to convection in the air cooler. This loss was eliminated by installing a bypass around the air cooler (Figure 1, green) — a small project that saved an additional $200,000/yr.

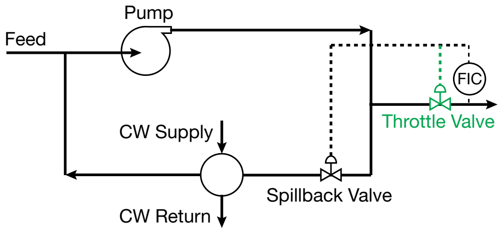
This example illustrates the importance of understanding the purpose of all the equipment in a process. Operators often place equipment in service inappropriately, and once these inappropriate operating norms have been established, they sometimes stay in place for years. Good operating procedures combined with training, including frequent refresher courses or continuing education, can go a long way toward minimizing this type of equipment misuse.

Pump power

In a plastics facility *(2)*, a large high-pressure feed pump with a fixed-speed electric drive was operated with spillback control (Figure 2). In this arrangement, the pump operated at constant flow and delivery pressure, and adjustments to the opening of the spillback valve accommodated changes in the process demand. A cooler was incorporated in the spillback line to avoid overheating.

Although the spillback control system provided operational stability and protected the pump from shut-in (a condition that could cause damage to the equipment), it did so at the expense of significant energy inefficiency. During normal operation, the pump ran at high throughput and relatively low head, with a large recycle flow, and thus high power requirements (Figure 3).

Many options are available to reduce pump power requirements. These include the use of variable-speed drives or high-efficiency pumps and motors, trimming or replacing impellers, and adding a smaller pump for use during periods of low throughput. For various reasons, these options were not viable for the plastics facility in this example. However, throttle control — *i.e.*, the addition of a throttle valve in the line feeding the user of the pumped fluid — offers a simple alternative (Figure 2, green).



▲ **Figure 2.** A high-pressure feed pump in a plastics facility was operated with spillback control. This arrangement provides for operational stability, but at the expense of energy inefficiency. A throttle valve was added (green) to the high-pressure feed pump system to allow the pump to operate during normal conditions at a lower flowrate and thus lower power requirement.

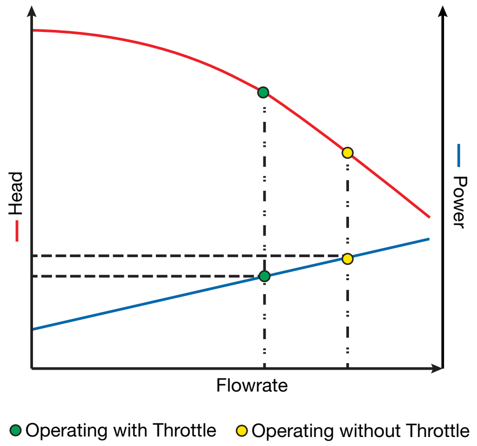
When a throttle valve is used for flow control with a fixed-speed pump, the flow through the pump is equal to the amount of feed required by the process user. This is significantly lower than the pump flowrate with spillback control. Throttling also introduces a backpressure on the pump, and this, together with the reduced flowrate, moves the operating point on the pump curve up and to the left, which corresponds to a reduced power requirement (Figure 3). It is important to keep the spillback valve in the system because of its ability to prevent the pump from being shut-in; the spillback valve opens if the process feed requirement falls below a predetermined minimum allowable flowrate.

Installing throttle control in this system reduced the pump power by about 10%, which resulted in savings of about $150,000/yr. The only expenditures required were for the throttle valve and associated equipment, and reprogramming of the control system.

This example highlights a common tendency of engineers and operators to accept the design of their control systems as long as the equipment functions reliably and safely. Safety and reliability are, of course, top priorities. However, many control systems are designed without regard to the energy losses they create. It is well worth reassessing these systems and questioning the losses.

Maintenance tracking and communication

While working in a refinery, one of the authors (Rossiter) noticed that a heat exchanger was out of service — which was not unusual, as heat exchangers often require maintenance. However, the records showed that this particular heat exchanger had been idle for more than three months after



▲ **Figure 3.** The pump curve for the pump shown in Figure 2 compares the operating point with and without throttle control.

being taken out of service for cleaning. The work had been completed within a few weeks, at which point the maintenance supervisor notified the shift supervisor that the heat exchanger was ready for use. But plant personnel were occupied with other activities, so the heat exchanger could not be put back into service at that time. The shift supervisor failed to pass the information on to the next shift, and no follow-up action was taken until the idle equipment was pointed out.

Once the unit manager was informed of the situation, the heat exchanger was placed back in service within hours. The energy loss incurred during the 2.5 months that the heat exchanger had been left idle was worth over $100,000 *(1)*.

Management of heat-exchanger cleaning programs has become increasingly sophisticated, with both improved cleaning techniques and better tools for assessing appropriate cleaning intervals for the heat exchangers in the circuit. However, the best cleaning methods and the most elegant optimization of cleaning intervals are of little use when communication fails.

In this example, better systems were needed for tracking the status of maintenance jobs on the unit. A simple electronic reminder system, for example, could have alerted the operators of the need to bring the heat exchanger back online.

Optimizing steam systems

Steam systems — including boilers, steam distribution lines, and power generation with steam turbines — present significant opportunities for improving energy efficiency. The final two examples illustrate this point.

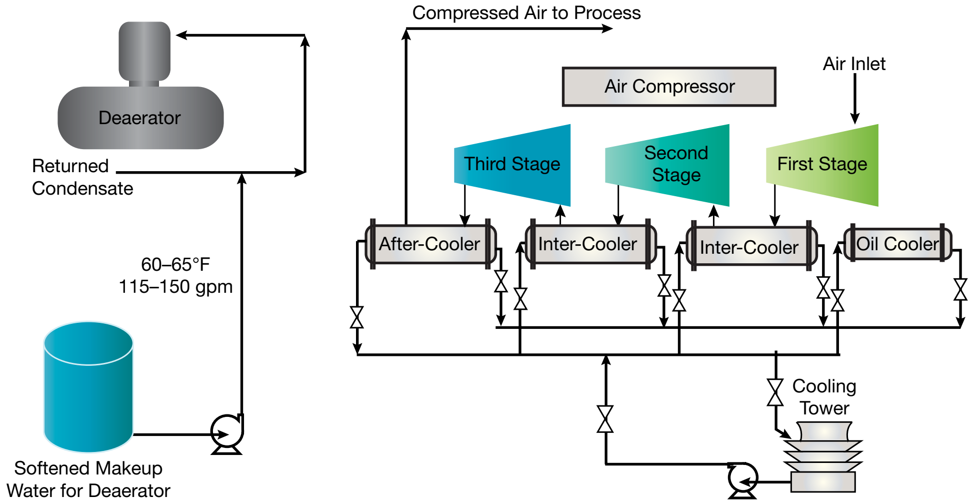
Preheating deaerator feedwater. Steam systems used for process heating in oil refineries and chemical plants commonly employ thermal deaerators to drive off oxygen and other dissolved gases from boiler feedwater. In principle, only a small amount of steam is needed to do this. However, the temperature of the incoming water is often much lower than the saturation temperature in the deaerator, so a substantial amount of additional steam is used to preheat the water. Preheating the feedwater to a deaerator can consume 10%, or even 15%, of the total steam generated on a site. For this reason, strategies are often developed to preheat deaerator feedwater with recovered waste process heat.

In this example, the deaerator in a chemical plant processed a combination of warm returned condensate and softened makeup water that is available only at ambient temperature. Within the boiler house there were also several water-cooled air compressors (Figure 4), one of which was experiencing chronic maintenance problems in its cooling tower.

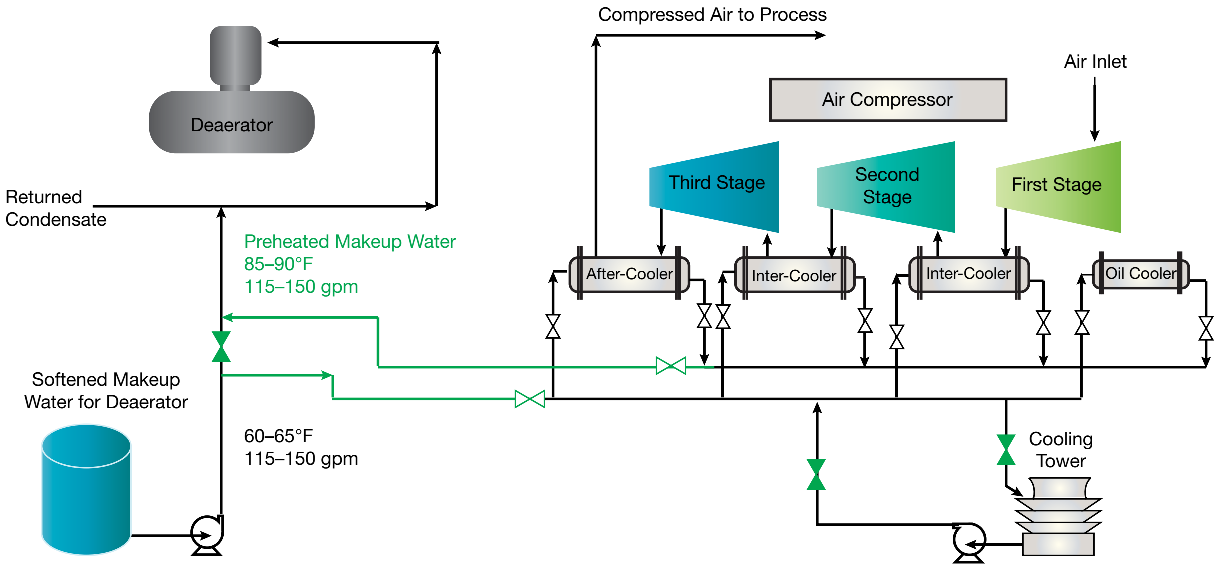
During a project to replace this cooling tower, one of the authors (Venkatesan) noticed that the average quantity of softened makeup water (at ambient temperature) going to the deaerator (115–150 gpm) was almost identical to the amount of cooling water needed for the air compressor (120 gpm). Based on this observation, a new project was proposed to route the makeup water through the air compressor and isolate the cooling tower with blinds (Figure 5). The new proposal was evaluated and accepted, and the piping modifications were completed within two months.

Heat from the air compressor is now recovered by preheating the softened water, saving $80,000/yr in deaerator steam usage. Implementation was very inexpensive, as it required only local piping changes. In addition, the project eliminated the need to maintain or replace the cooling tower, thus significantly reducing costs.

This example illustrates the benefits of preheating deaerator feedwater. Perhaps even more importantly, it shows how a single project can achieve multiple objectives — in this case, save energy and eliminate a chronic maintenance problem. It also illustrates the importance of looking for creative ways to redeploy



▲ **Figure 4.** A deaerator in a chemical plant processes a combination of warm returned condensate and softened makeup water at ambient temperature. Extra steam is consumed in this configuration to heat the softened makeup water. Coincidentally, the average quantity of softened makeup water going to the deaerator was almost identical to the amount of cooling water needed for one of the air compressors within the boiler house.

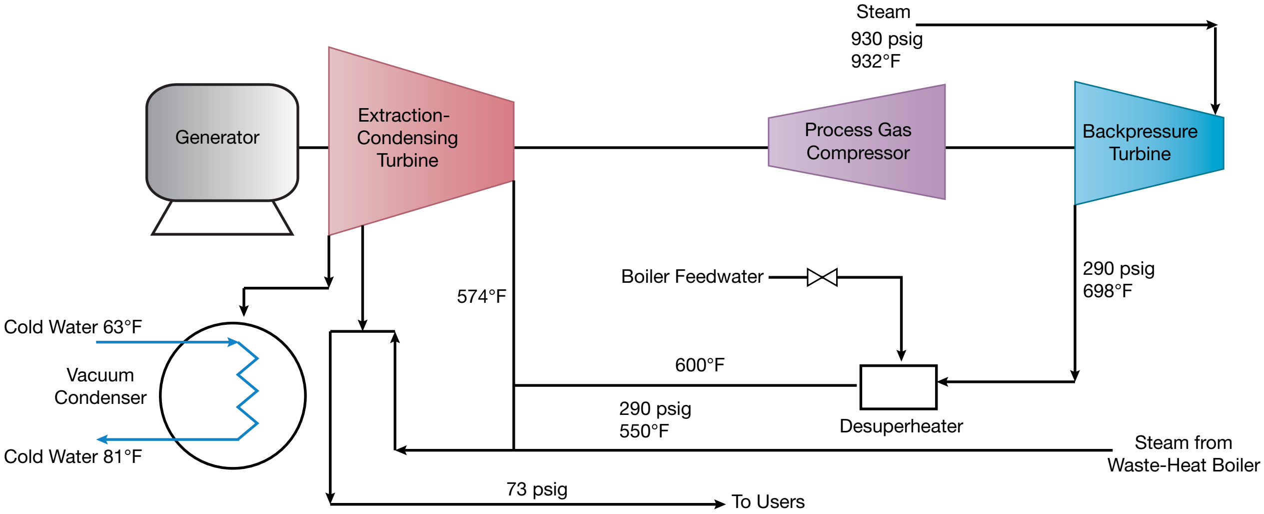


▲ **Figure 5.** To eliminate some of the extra steam required to heat the softened makeup water for the deaerator shown in Figure 4, the makeup water was rerouted (green) through the air compressor, which heats the water from 60–65°F to 85–90°F.

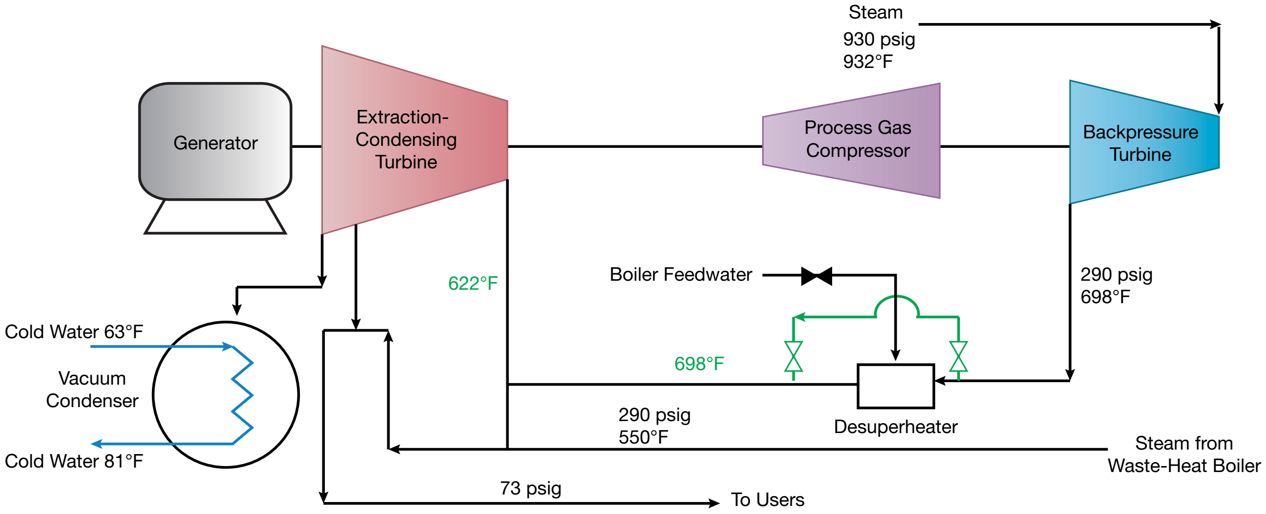
existing equipment *in situ* to save energy. Of course, it is always essential to check equipment limitations and follow appropriate management-of-change procedures when making process modifications. In addition, when implementing steam-saving projects, one should consider the overall fuel and steam balances of the plant, and not focus purely on improving the efficiency of individual equipment *(3)*.

Adding excessive safety margins to steam consumption. In a commodity chemical plant in Europe, two steam turbines drove a large air compressor and an electric generator in a single-shaft arrangement. The first turbine, a backpressure turbine, was used to let down high-pressure (HP), 930-psig steam to medium-pressure (MP), 290-psig steam. The second turbine, an extraction-condensing turbine, received MP steam, which was extracted as low-pressure (LP), 73-psig steam (in the extraction section) for process use, and the remaining MP steam was expanded into a vacuum condenser (Figure 6).

In the original design, only the exhaust steam from the backpressure turbine was used to supply MP steam to the extraction-condensing turbine. Because the temperature of the outlet steam from the backpressure turbine was higher than 660°F (the maximum allowable steam inlet tempera-



▲ **Figure 6.** At a commodity chemicals plant in Europe, two steam turbines (a backpressure turbine and an extraction-condensing turbine) drove a large air compressor and an electric generator. A desuperheater reduced the temperature of the MP backpressure steam before it entered the extraction-condensing turbine together with steam from a waste-heat boiler.



▲ **Figure 7.** A study showed that the desuperheater in Figure 6 was unnecessary. A bypass line (green) was installed around the desuperheater and the desuperheating water was shut off, increasing power production by 500 kW.

ture specified for the extraction-condensing turbine), before entering the turbine, the MP steam went through a desuperheater to reduce its temperature. The desuperheater was designed to produce MP steam at 600°F — providing for a 60°F safety margin. (Note that the amount of work extracted from a steam turbine decreases as the inlet temperature goes down, so adding the desuperheater reduced the amount of work generated by the extraction-condensing turbine.)

The original design was later modified to add steam from a waste-heat boiler to the steam from the backpressure turbine outlet, which increased the steam flow to the extraction-condensing turbine and thus raised its power output. The temperature of the steam from the waste-heat boiler was 550°F — significantly cooler than the exhaust steam from the backpressure turbine. When the designers made this modification, they did not re-evaluate the use of the desuperheater.

A subsequent study of this system by one of the authors (Venkatesan) found that the maximum temperature that can be reached with the combined steam flow to the extraction-condensing turbine is below 660°F, and desuperheating of the backpressure turbine exhaust steam can be safely eliminated. Based on this finding, a bypass line was installed around the desuperheater, and the water supply to the desuperheater was shut off (Figure 7, green). This change increased the amount of electricity generated by the turbine by 500 kW, resulting in an annual energy cost saving of $400,000.

This example illustrates the need to challenge existing operating practices, and also to re-evaluate conditions when process changes are made. While it is always essential to operate within design limits, excessively large margins of safety can result in unnecessary losses of energy efficiency.

Final thoughts

No matter how sophisticated our energy management strategies become, it is imperative that we continue to pay attention to basic principles. We must understand the purpose and limitations of the equipment in our processes. And when changes are made to our facilities, we must consider their impact on all processes. Key principles of human interactions — especially communication — are also essential to all of our activities. CEP

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