Simple Opportunities for Improving Energy Efficiency

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Abstract: Energy efficiency has become an important theme in the process industries, and many companies have implemented sophisticated strategies to improve both the design and the operation of their plants. However, efficiency improvements are often possible simply by doing basic things right. This article presents a number of examples that show how operators and process designers frequently overlook simple changes that can lead to dramatic gains, and provides guidance on how to avoid some of the pitfalls.

Introduction

Great stride shave been made in energy efficiency in recent years. Many factors have contributed to this progress, including the following:

- Step-change technological improvements, such as new catalysts that increase yields and reduce operating pressure. These changes are fundamental, and they can lower the inherent energy demand of a process.
- Equipment advances, including novel distillation systems and high efficiency pumps, compressors, turbines and motors. Improvements to components like these increase energy efficiency by eliminating avoidable losses without changing the underlying process.
- Improvements to process design procedures. These include the global improvements resulting from advances in simulation and physical properties, and also more specific gains in energy efficiency from design methods such as hierarchical decision procedures (1), heat integration using pinch analysis (2) and numerical optimization (3). These methodologies do not rely on new types of equipment or fundamentally different chemistry. Rather, they provide insights that allow engineers and designers to make better use of existing technologies.
- Process control and real time optimization. Advances in these areas allow us to get more out of our facilities and to operate at tighter tolerances. This often results in significant energy savings.
- A better focus on energy use in plant operations. Energy management is increasingly being highlighted in operator training. Many companies are also deploying operations support systems, such as “energy dashboards” (4) that provide real time information on energy performance and guidance when corrective action is needed.
- Focused maintenance activities, such as steam trap and steam leak programs, heat exchanger cleaning and furnace tuning. Keeping equipment in good condition is an important part of achieving optimum performance.

- Changes in corporate policies. For example, many companies have instituted corporate goals for energy efficiency, and these are often coupled to specific directives – e.g., incorporating energy efficiency into the procurement requirements for new equipment, or setting funds aside for energy efficiency investments.

However, in the midst of these sophisticated technologies and programs many basic opportunities are often missed. This article illustrates this fact by presenting a series of examples that have been observed by the author while conducting energy management projects at refineries and chemical plants in various parts of the world.

Example 1: One of the most frequent inefficiencies encountered is the unnecessary cooling of process streams that should be kept hot. Figure 1 shows an example of this (5), based on a study at a petrochemical facility.

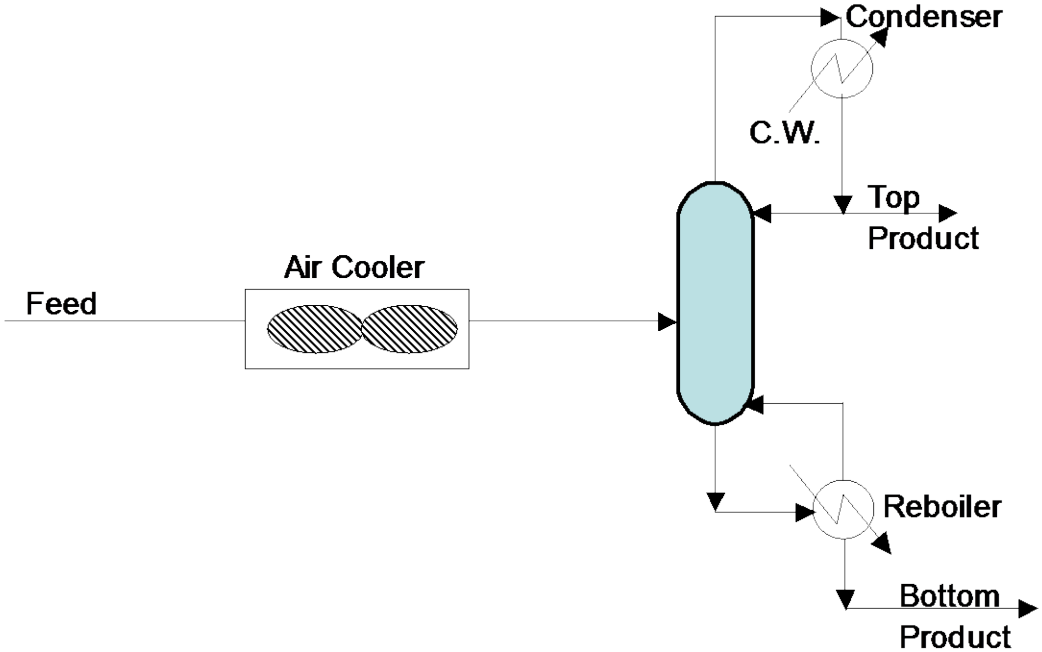

Figure 1: Inappropriate Cooling of Distillation Column Feed

In this example, the design of the distillation column includes an airfin cooler on the feed. This was installed to prevent overloading of the overhead condenser under certain abnormal operating conditions. However, the air cooler was operated continuously during normal operations, too. This removed heat from the feed, and consequently the heat load in the reboiler increased.

As a result of the study the procedures were changed and the air cooler fan was shut off during normal operations. This reduced the reboiler duty by more than 30%, a saving worth more than $1,000,000/year, at no cost to the facility.

Even with the fan off there was still a significant loss of heat due to convection in the air cooler. This loss can be eliminated by installing a bypass around the air cooler (Figure 2), a small project that saves an additional $200,000/year with a very good payback.

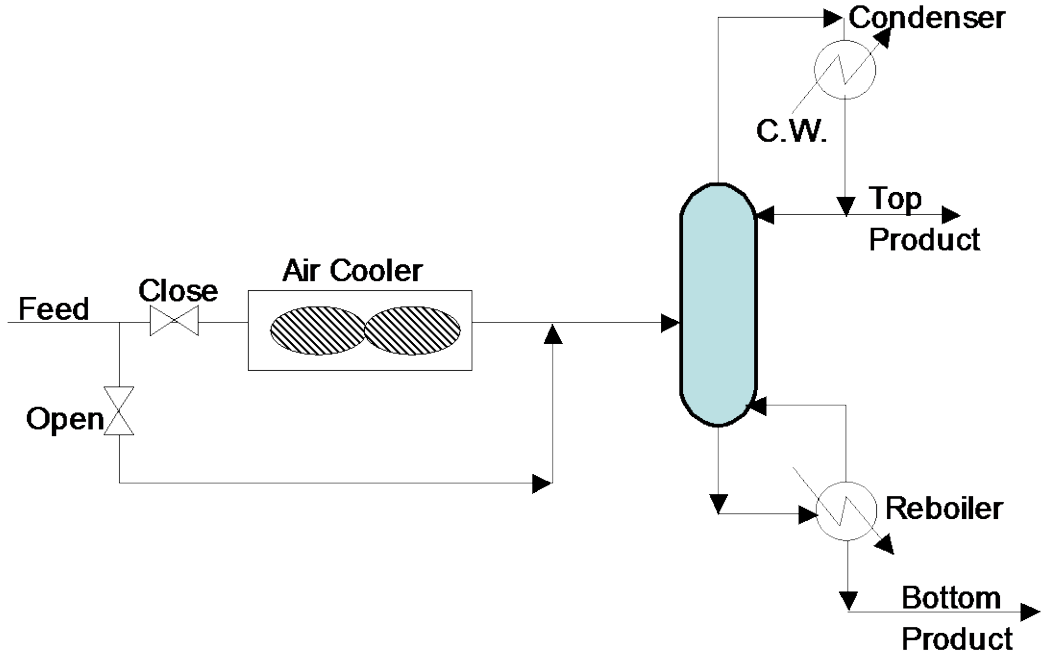

Figure 2: Inappropriate Cooling Corrected by Bypassing Cooler on Distillation Column Feed

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

Example 2: The second example also illustrates an inefficiency caused by poor operation. However unlike the previous example, where placing equipment in service inappropriately caused a loss of energy efficiency, the converse is true in the present example.

Figure 3 shows a pumparound on one of the distillation columns at an oil refinery (5). It has two heat exchangers, the first to transfer heat to distillation column feed, and the second to reject excess heat to cooling water. However, the operators opened a bypass around the feed-preheat exchanger because the pumparound duty became too high during the winter, and they did not subsequently close the bypass in the summer. As a result, heat was unnecessarily rejected to cooling water for an extended period time.

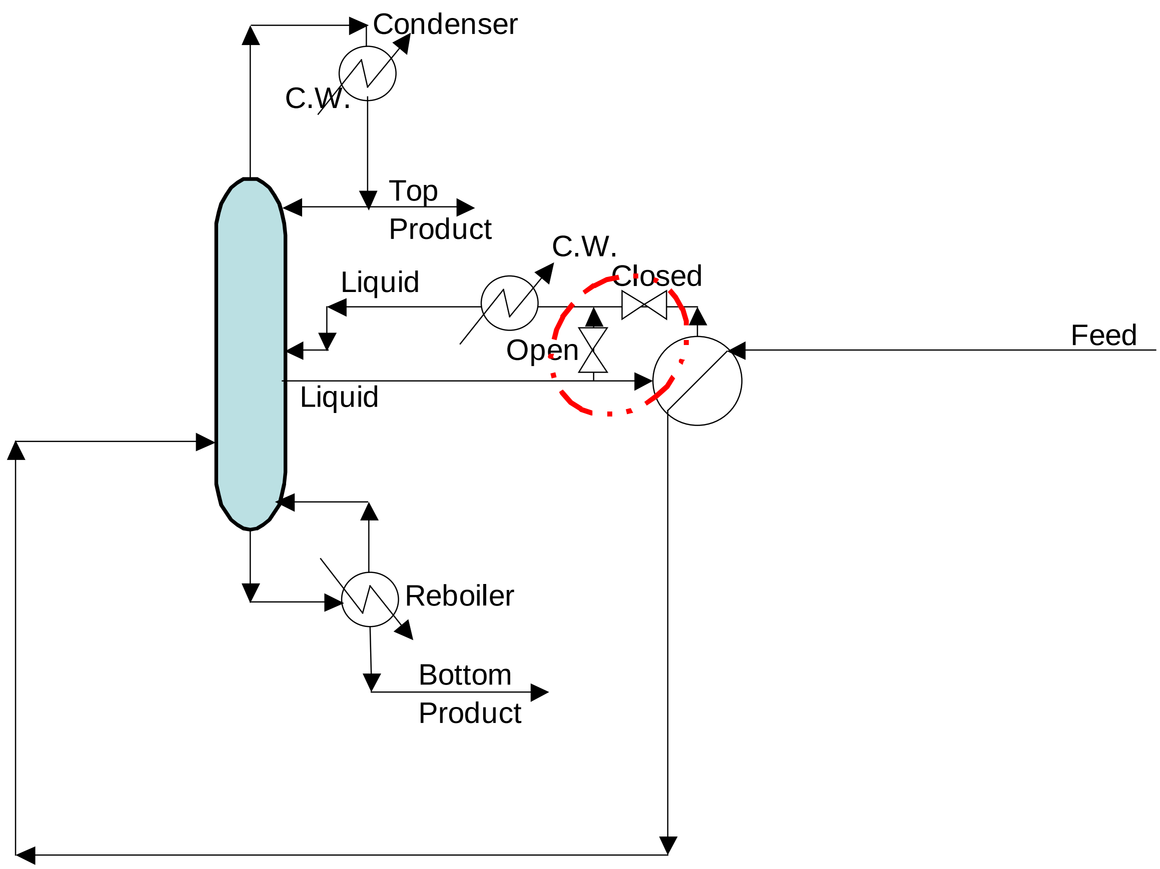

Figure 3: Unnecessary Bypassing of Heat Recovery Equipment

This inefficiency was readily corrected by closing the bypass, saving $600,000/year (Figure 4). In addition, a change was made to the operating procedures to ensure that the bypass valve position is routinely monitored. Further energy savings are possible with improved control systems.

In this example it is the unnecessary bypassing of heat recovery equipment that resulted in a lost opportunity. Permanent changes in operating procedures, together with operator training, help prevent the plant reverting to the incorrect operating practices. Automation, improved process control, and monitoring via DCS and data historian systems can also facilitate operating with lower tolerances. This can lead to significant energy savings.

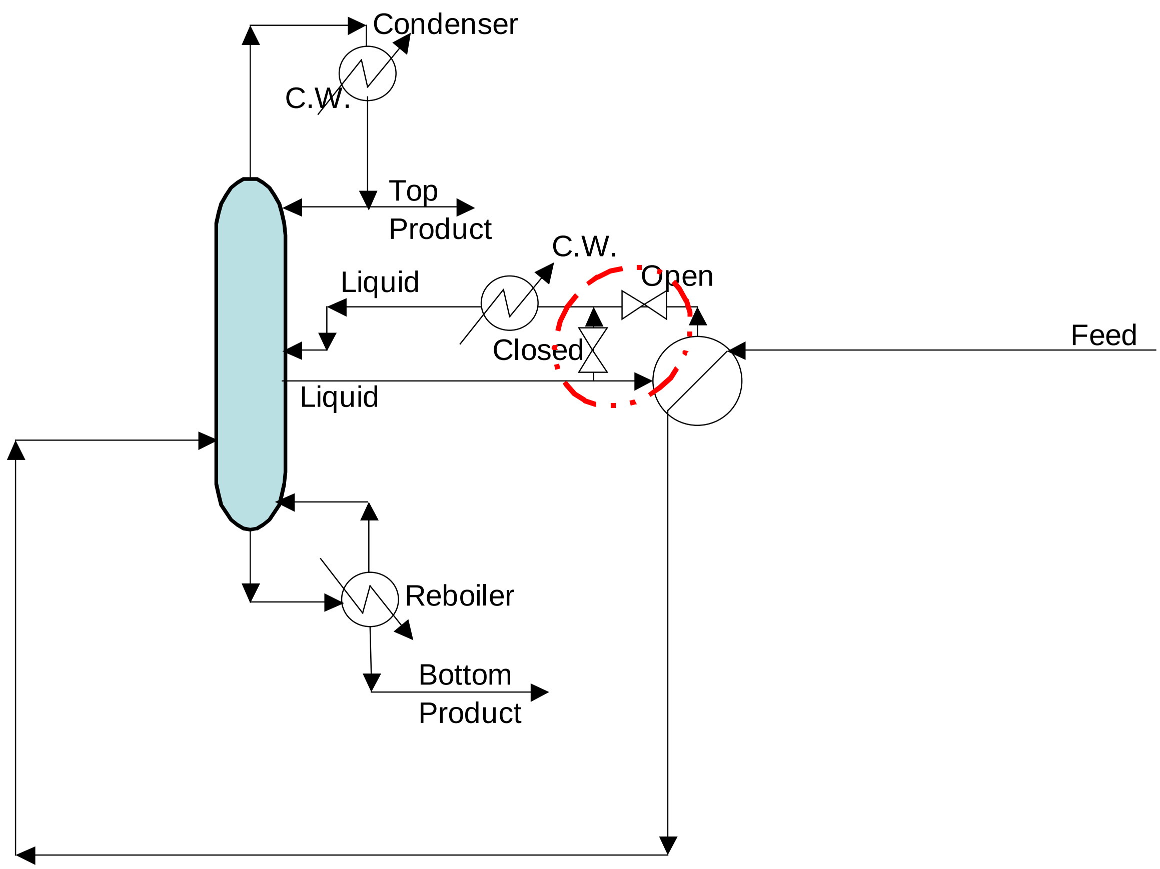

Figure 4: Closing the Bypass Restores Heat Recovery

Example 3: The third example relates to a pump in a plastics facility (6). A major high pressure feed pump is operated with spillback control (Figure 5). In this arrangement the pump itself operates at constant flow and constant delivery pressure, and any change in the process demand is satisfied by adjusting the opening of the spillback valve. This facilitates stable operation of the process, and it also ensures that the pump is never shut in, a condition that could damage to the equipment. A cooler is incorporated in the spillback line to avoid overheating.

Although the spillback control system offers very stable process conditions, this is accomplished at the cost of significant energy inefficiency. In normal operation the pump runs at high throughput and relatively low head, with a large recycle flow (see Figure 6).

There are numerous options for reducing pump power requirements. These include variable speed drives, high efficiency pumps and motors, trimming or replacing impellers, and adding a smaller pump for use during periods of low throughput. For various reasons none of these options was viable in the present case. However throttle control (Figure 7) does offer a simple alternative.

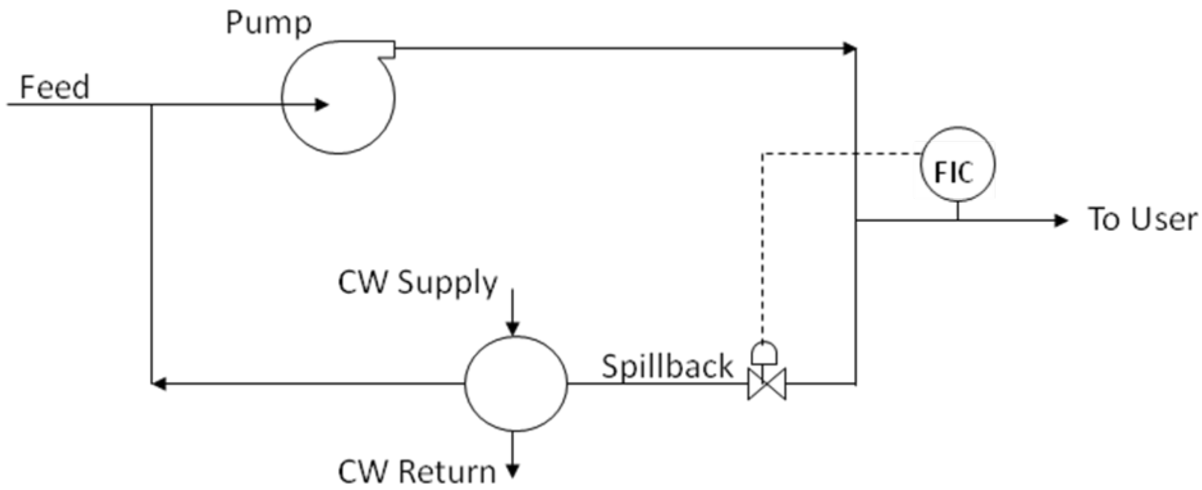

Figure 5: High Pressure Feed Pump with Spillback Control

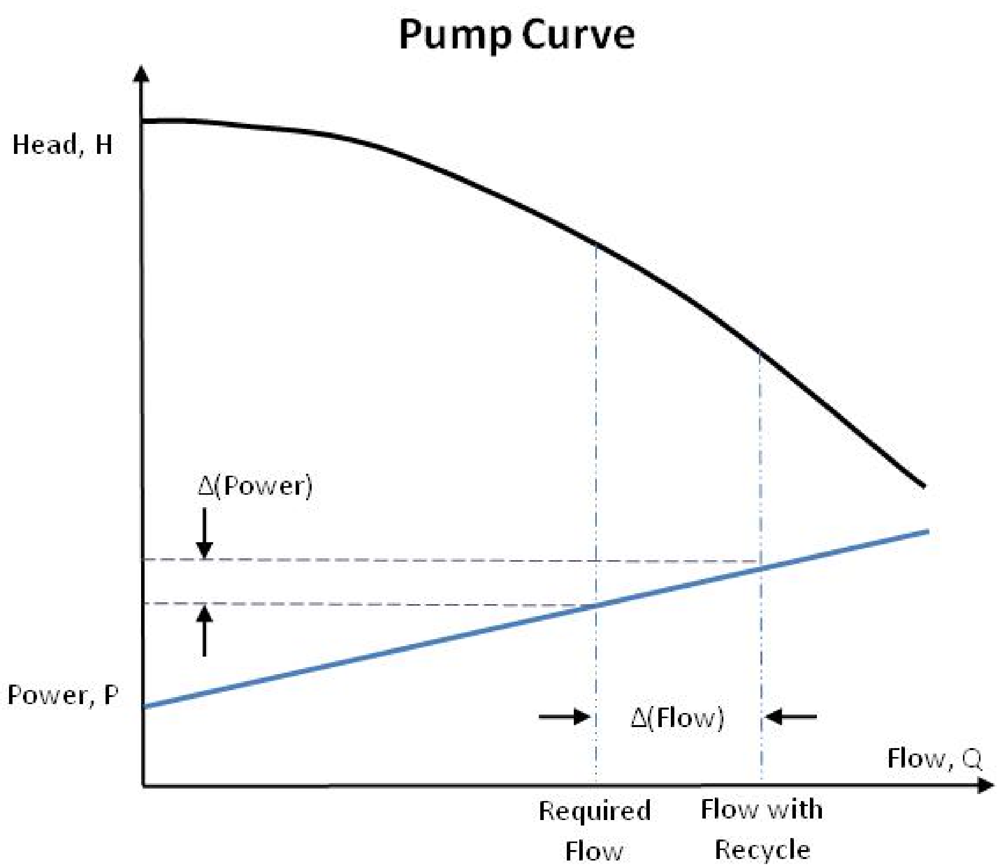

Figure 6: Pump Curve Comparing Spillback and Throttle Control

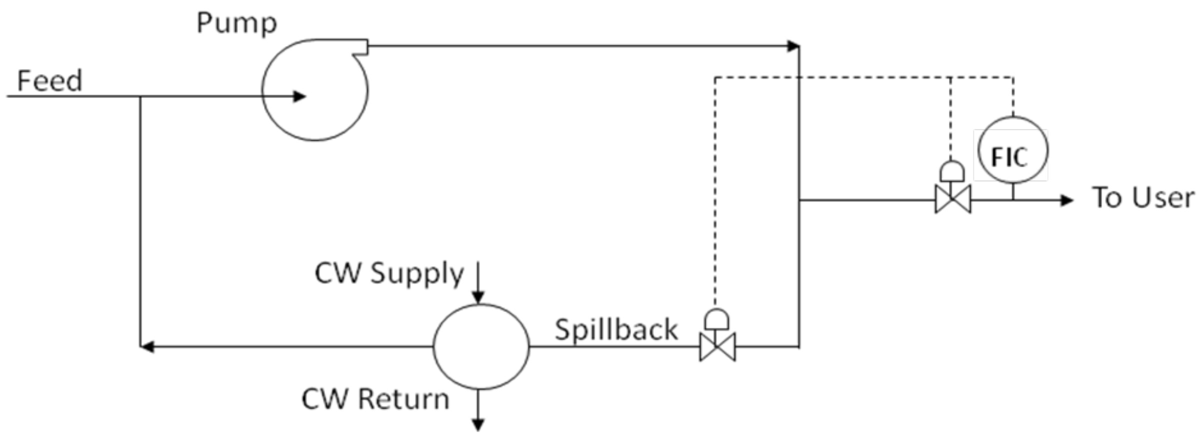

Figure 7: High Pressure Feed Pump with Throttle Control

With the throttle arrangement the flow through the pump in normal operation is equal to the amount of feed required by the process user ("Required Flow" on Figure 6). This is significantly less [by Δ(Flow)] than the normal flow through the pump with recycle using spillback control. Throttling also introduces a backpressure on the pump and this, together with the reduced flow rate, moves the operating point upwards and to the left on the pump curve (Figure 6). From the pump power curve (also on Figure 6) it is clear that the pump power is reduced by Δ(Power). It is still important to ensure that the pump is never shut in, so the spillback valve is retained and opens if the process feed requirement falls below a predetermined minimum allowable flow.

The only new facilities in this example are the throttle valve and associated equipment, together with reprogramming of the control system. The pump power is reduced by roughly 10%, worth $150,000/year.

Engineers and operators tend to accept the design of their control systems as long as the equipment functions reliably and safely. Reliability and safety 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 challenging the losses.

Example 4. Heat exchanger cleaning programs are important in maintaining the performance of heat recovery systems, most notably crude unit preheat trains in refineries. Refinery management is becoming increasingly sophisticated in this area, 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 the course of a project in a refinery the author noted that a heat exchanger was out of service – 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. Further investigation revealed that the heat exchanger had been taken out of service for cleaning. The work had been completed within a couple of weeks, and the maintenance supervisor then notified the shift supervisor that the heat exchanger was ready for use. However, due to other activities the heat exchanger could not be brought back into service immediately. The shift supervisor failed to pass the information on to the next shift, and there was no follow up action until the author drew attention to the idle equipment.

When the unit manager was informed of the situation it required only a few hours to bring the heat exchanger back in service. The energy loss during the two and a half months that the heat exchanger had been left idle after the cleaning was worth over $100,000 (5).

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 to the need to bring the heat exchanger back on-line.

Example 5. Steam is commonly used as a heat transfer medium in oil refineries and chemical plants. Most steam systems use thermal deaerators (Figure 8) to drive off oxygen and other dissolved gases from boiler feed water. In principle only a small amount of steam is needed to do this. However, as the incoming water is often far below the saturation temperature in the deaerator a substantial amount of additional steam is consumed in preheating the water. Because of this it is not uncommon to consume 10% or even 15% of the total steam make in deaerators. Not surprisingly, many facilities install deaerator feed water preheat projects to reduce this steam load.

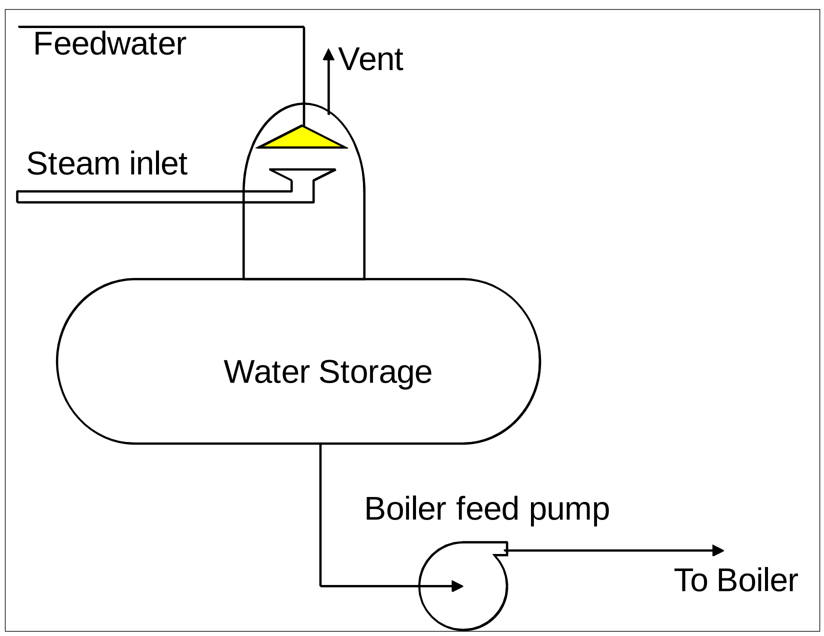

Figure 8: Thermal Deaerator – Main Components

An energy management project at a petrochemicals complex included a new heat exchanger to preheat deaerator feed water, using a product rundown stream as the heat source (5). The deaerator operates at 10 psig (240°F saturation temperature). The rundown stream was available at 350°F, and it went directly to an air cooler which cooled it to around 90°F. The project was intended to reduce the heat load in the air cooler, and at the same time reduce the steam demand in the deaerator.

In order for the deaerator to operate properly it was necessary to limit the deaerator feed water temperature to 230ºF. The design therefore included temperature control, as shown in Figure 9.

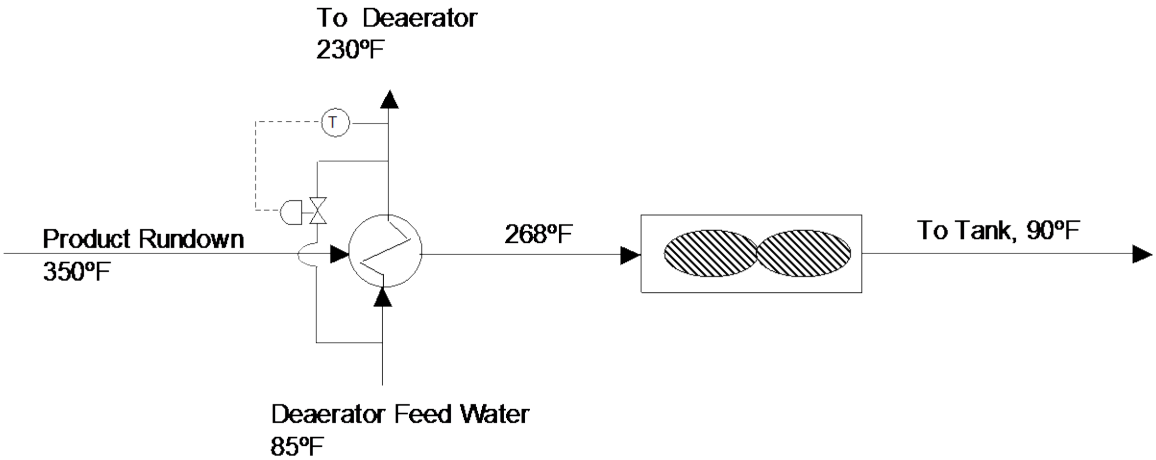

Figure 9: Deaerator Feed Water Preheat Project, as Originally Implemented

Shortly after the project came on line operators started reporting problems. The water preheat temperature frequently exceeded the 230ºF limit, and the pressure drop in the deaerator feed line was excessive due to vapor locking in the new heat exchanger. After numerous attempts to fix the problem by modifying plant operations the heat exchanger was taken out of service, using existing manual bypasses and isolation valves.

The underlying problem was in the control scheme. Bypassing deaerator feed water around a heat exchanger is effective in reducing heat pick-up. However as the heat pick-up goes down, so does the amount of water passing through the heat exchanger. Consequently the temperature of the water leaving the heat exchanger rises as the bypass opens, and it can easily reach its boiling point. This accounts for the observed difficulty in controlling temperature and the associated vapor locking.

The simplest interim solution to this problem is to open the existing manual bypass on the product rundown stream, as shown in Figure 10. This reduces the flow of the rundown stream through the heat exchanger while maintaining the water flow, thus ensuring that the water does not overheat. However, the manual bypass valve has to be about half open to ensure that the water does not boil in the heat exchanger under any of the anticipated operating conditions. This means that in some situations the temperature of the water going to the deaerator is much less than the target value of 230ºF. However, this simple strategy does allow the plant to obtain a significant percentage of the potential benefits with no additional investment.

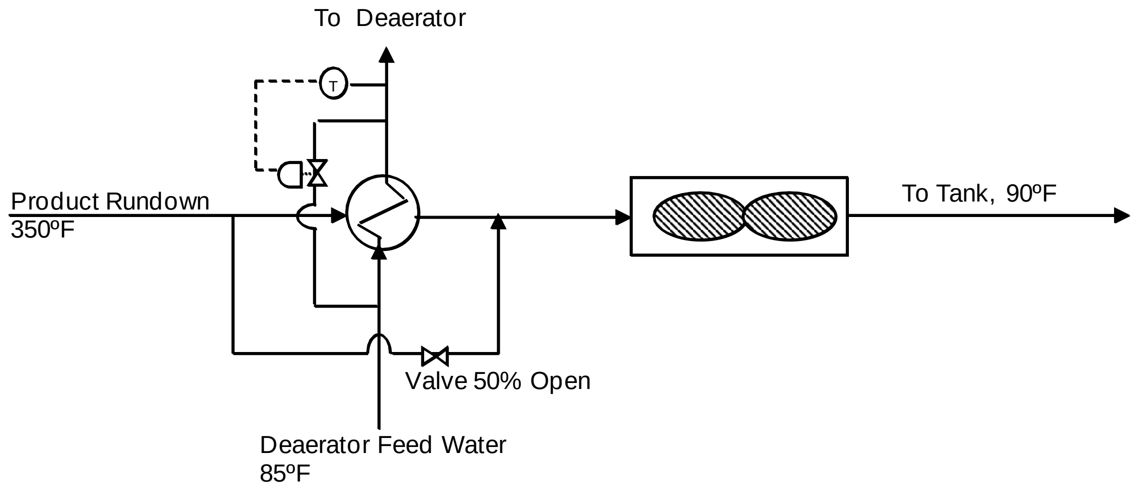

Figure 10: Deaerator Feed Water Preheat Project, with Manual Bypass on Product Rundown

A more complete solution requires the temperature control valve to be relocated on the product rundown bypass (Figure 11). With this arrangement the target deaerator feed water temperature is achievable in all of the anticipated operating conditions.

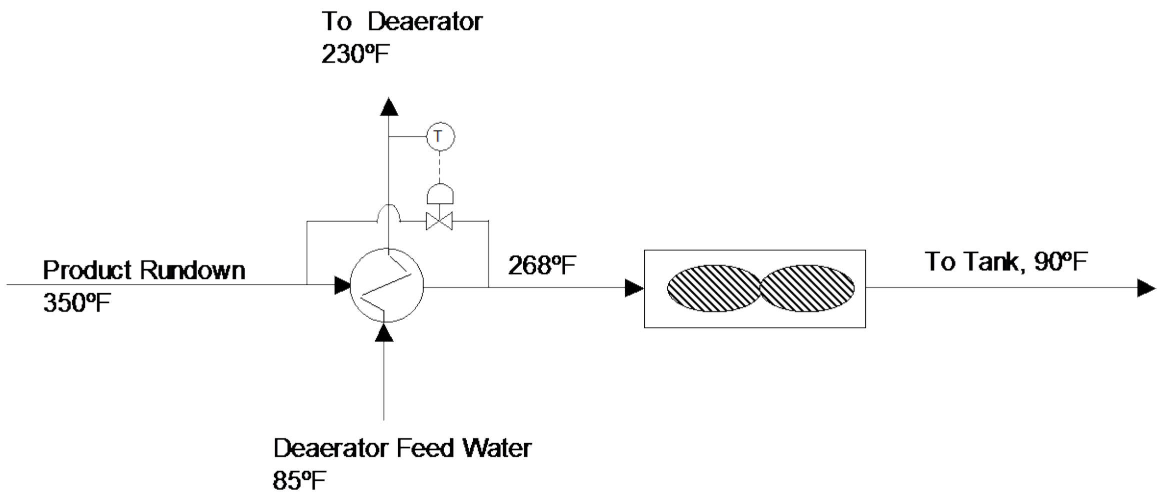

Figure 11: Deaerator Feed Water Preheat Project, with Automatic Temperature Control on Product Rundown Bypass

Heat integration schemes are generally developed from an evaluation of available heat sources and heat sinks at steady state conditions, often using pinch analysis. This is generally a very effective way of identifying opportunities. However, the final design must account for the inevitable variations in process conditions and how they will affect the operation of the equipment. In this particular example the variation in flows, temperatures and heat loads were recognized, but a basic physical property of water (it boils at 240ºF under 10 psig pressure) was not. The key message is that we must never lose sight of basic principles, whatever we do.

Conclusions

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 also the physical properties of the materials we handle. Key principles of human interactions – especially communication – are also essential to all of our activities. This article has illustrated how these basics are often overlooked, how these oversights can undermine our best efforts at energy efficiency. It also provided insights on how to correct these problems.

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