UNIVERSITY of HOUSTON

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Texas Industrial Energy Efficiency Program
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Greetings, from the Texas Industrial Energy Efficiency Program!

Spring Recap

Spring is a busy time of year for TIEEP. This year we had three major outreach events, two of them hybrid and the other one virtual. You can find recordings and presentation materials in the archive section of the TIEEP webpage.

The annual TIEEP Water Forum took place on March 3 as a hybrid meeting, in collaboration with STS-AIChE. The topic was *The Water/Energy Nexus*. The connection between water and energy has many facets. In this year's Water Forum, the program included talks on *Water Conservation Technologies in Evaporative Cooling*, *Floating Solar Panels*, and *The Use of Steam Plasmas to Produce Steam and Hydrogen from Wastewater*.

The Spring Energy Forum, *Decarbonizing the Process Industries III*, on May 5, was also a hybrid meeting, in collaboration with STS-AIChE. This was our third session on decarbonization, which has become a major focus in the process industries. The topics in the forum included use of electric motors as a key component of electrification, and carbon capture in two different types of processes – ethylene production and power generation. The theme of decarbonization will be continued in our next event – see Upcoming TIEEP Energy Forum, below.

Electric motors are key components for electrification of the process industries. Source: USDOE

Our other spring event was the TIEEN Webinar, *Improve Your Bottom Line and Resiliency, and Meet ESG Goals, With New Federal Resources*, which took place virtually on April 13. The webinar presented an overview of the trillion-dollar Infrastructure Investment and Jobs Act (IIJA) – popularly called the infrastructure bill – and other sources of government funding. It also provided a primer on how to access government funding, and shared real-world experiences from companies that have secured government funding in the past – crucial information for companies that would like access to these valuable resources.

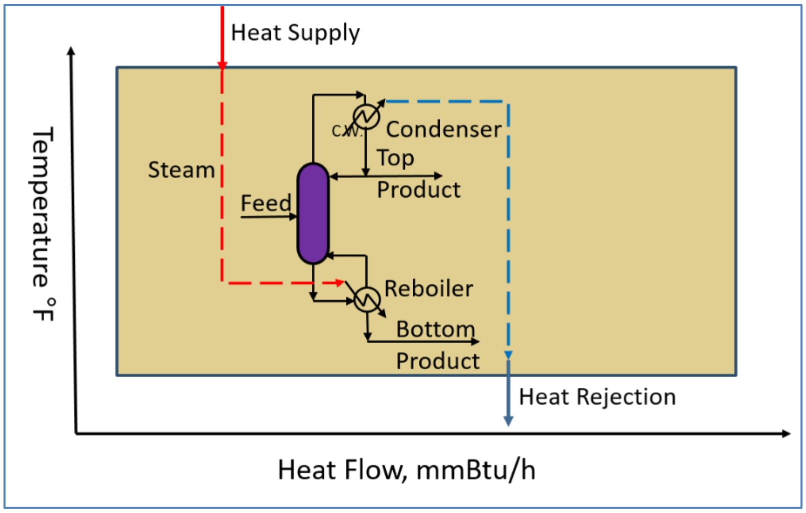
The webinar also showcased the work of our partners in the Texas Industrial Energy Efficiency Network. TIEEN is a network of publicly supported industrial energy-efficiency organizations (TMAC, SPEER, Texas A&M University Industrial Assessment Center, the Texas PACE Authority, and the US DOE Southcentral CHP Technical Assistance Program). These organizations provide valuable services for Texas manufacturers, identifying plant improvement opportunities, defining better operating strategies, and providing effective financing options, amongst other things.

Upcoming TIEEP Energy Forum

Thursday, September 29, 2022, 9:15 am to 12:15 pm: TIEEP's Fall Energy Forum, ***Decarbonizing the Process Industries IV***, will be presented at the AIChE Southwest Process Technology Conference, Houston Marriott Sugar Land, where it doubles as the Energy and Decarbonization session at the conference. For more details, go to https://www.aiche.org/conferences/southwest-process-technology-conference/2022. Updates will also be posted on the TIEEP website.

From the Casebook: How Inefficient Are the Process Industries – Really?

Roughly 51% of the energy supplied to industrial consumers ends up as rejected energy[(1)]. This headline number, and similar ones from other sources, have created the impression that industry is an inefficient user of energy, and hence also a major emitter of carbon dioxide and toxic combustion products that exacerbate climate change and have an oversized impact on air quality. There must be scope for major improvements within the sector, especially in the area of waste heat recovery. However, the reality is a bit more nuanced.



<u>Figure 1:</u> Distillation column heat supply and rejection

Many processes in industry depend on heat cascading from high temperatures to low temperatures. Within the process sector, this is seen most clearly in distillation, the dominant method for separating liquid streams. High temperature heat is supplied to the reboiler. This evaporates volatile liquids, which then condense at a much lower temperature – often so low that the heat is no longer useful, and it has to be rejected to the ambient environment as a waste (Figure 1).

There are various ways to improve the efficiency of distillation columns. These include modifications to column internals (e.g., use of various packing materials), which can improve contacting and separation of fluids inside the column, and reduce the pressure drop through the column. Other options are based on waste heat recovery – for example, using the hot bottoms stream from a distillation column to preheat the cold feed (feed/bottoms heat exchange), or use of the overheat vapor from a high-pressure distillation column, which operates at a high temperature, to reboil a column that operates at a lower pressure and temperature (double-effect distillation).

Interestingly, although these methods do reduce energy consumption, they do not necessarily reduce the percentage of the heat that is rejected. Consider double-effect distillation. Let's suppose we have two distillation columns that require the same amount of reboiler heat, 10 mmBtu/h. Let's also assume that all the heat passes through the columns, and then leaves in their overhead vapor streams. If the two columns are operated separately, all the overhead heat is rejected to ambient through the overhead condensers. In this case, the heat supplied to the reboilers is 2x10 = 20 mmBtu/h, and the rejected heat is also 2x10 = 20 mmBtu/h. The percentage of the heat that is rejected is therefore 20/20x100 = 100%.

When we couple the two columns in a double-effect configuration, the high-pressure overhead discharges its heat to the low-pressure reboiler (Figure 2). We only supply external heat (10 mmBtu/h) to the high-pressure reboiler, and we only reject heat (10 mmBtu/h) from the low-pressure overhead vapor. The percentage of the heat that is rejected is therefore 10/10x100 = 100%. What went wrong? Nothing. We simply used all the heat twice before rejecting it. We therefore halved our energy consumption, while still rejecting all the heat.

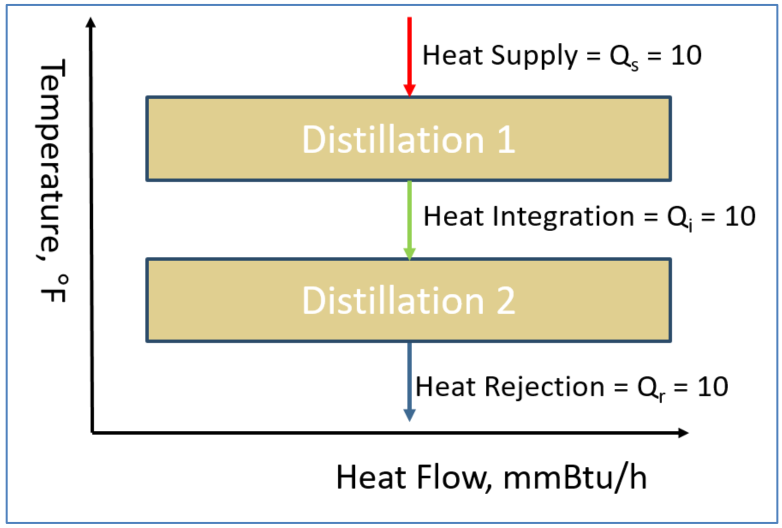


Figure 2: Heat flow through double-effect distillation

Let's now consider the energy impact of double-effect distillation on a complete chemical plant or refinery unit (Figure 3). Let's assume the plant's energy input is 100 mmBtu/h, and its rejected energy is 50 mmBtu/h, or 50%. The plant contains the two separate distillation columns that we just discussed. Each column consumes and rejects 10 mmBtu/h of heat, and these heat flows are included in the plant's total energy input of 100 mmBtu/h, and its total rejected energy of 50 mmBtu/h.

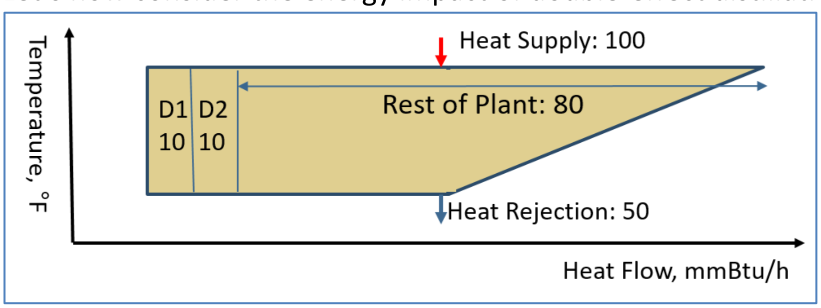


Figure 3: Heat flow through plant with 2 distillation columns

We now reconfigure the columns as a double-effect system. From our earlier discussion, we know that this reduces both the heat input and the rejected energy by 10 mmBtu/h. The overall percentage of the energy rejected by the plant is now (50-10)/(100-10)x100, or 44.4%. In other words, even though the double-effect arrangement

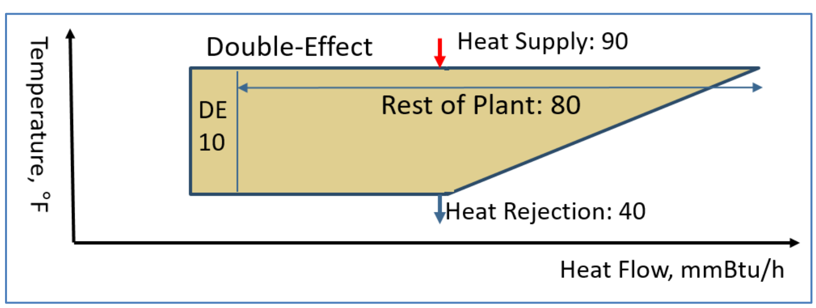


Figure 4: Heat flow through plant with double-effect distillation

does not change the percentage of the energy rejected by the distillation system, it does reduce the percentage of energy rejected by the overall plant.

This is a highly idealized example. For example, the reboiler heat load in a distillation column is rarely equal to the overhead heat load. However, the overall concept is sound. Due to the types of equipment that currently dominate the process industries, high percentages of heat rejection are inevitable.

Several approaches have been proposed, and in some cases implemented, to reduce that heat rejection. These include:

Radical redesign of processes. These include new chemical pathways and new feedstocks. Recent examples include the Dow/BASF hydrogen peroxide to propylene oxide (HPPO) process (35% energy reduction) and Shell's OMEGA catalytic EO/EG process (20% steam saving). Process intensification – a design approach that aims to combine multiple process steps in single equipment items, could also lead to significant energy savings in future plants.

Efficiency improvements of existing types of equipment. This includes the improvements to distillation internals discussed earlier, as well as improvements to compressors, turbines, pumps, and heat exchangers, as well as many other types of equipment.

Increased electrification. This is an important path to decarbonization. When we hear the term "electrification," we typically think of electric heating and the use of electric motors instead of steam turbines. These technology substitutions do eliminate on-site fuel-firing, and the associated emissions, though they don't always improve energy efficiency. However, there are also other technologies that rely on electricity as an energy source. Membrane separations[(2)], for example, rely on pressure differences across semi-permeable membranes to separate components in gaseous or liquid mixtures, and those pressure differences are created by pumps and compressors, most of which are powered by electricity. Membrane systems could one day replace distillation in many applications. The electrical energy for the associated pumps and compressors can, in some cases, be less than the heating requirement for an equivalent distillation process. Other electric technologies (e.g., microwave-enhanced chemistry, where microwave heating is used in reaction systems) could potentially lead to major improvements in rate, yield, and selectivity, with attendant energy savings, but this technology has not yet been used at large scales.

Organic Rankine Cycles. One energy-saving technology that has gain renewed attention recently is organic Rankine cycles (ORCs)[(3)], which are widely used for geothermal power generation. ORCs function in a similar way to steam turbines, but instead of using water and steam, the working fluid is a low-boiling organic fluid. This means that ORCs can recover heat from processes at fairly low temperatures, typically between 190 and 300°F. A portion of the heat in the working fluid is converted to power, so less heat is ultimately rejected to the environment.

There are challenges to this technology, though. The main issue is inherent in thermodynamics, specifically, the Second Law. If the temperature of the waste heat is low, the maximum efficiency (useful power out/total heat in) is also low. Typically, ORCs have an efficiency between 5% and 15%. Even if you assign zero cost to the waste heat supplied to the ORC, you must still install a significant amount of equipment (ducting, heat exchangers, expander, electric generator, etc.), and it is difficult to achieve an acceptable rate of return. However, some of the equipment costs have been falling, and the drive for decarbonization, which in some cases translates into government incentives, has made ORCs more attractive in certain cases. These factors are changing the relationship between cost and benefit. It may be time to re-evaluate ORC applications in the process industries.

Citations

1. Lawrence Livermore National Laboratories Energy Flow Charts: Estimated US Energy Consumption in 2020, https://flowcharts.llnl.gov/. Accessed February 19, 2022.
2. Introduction to Membranes, http://www.separationprocesses.com/Membrane/MT_Chp01.htm. Accessed February 20, 2022.
3. Alan Rossiter, "Consider ORCs for Waste Heat Recovery," Chemical Processing, Vol. 82, No. 12, p. 12, December 2020.

Adapted from *Trends in Waste Heat Recovery Practices in the Process Industry*, Alan Rossiter, HTRI Horizons Symposium, Baltimore, MD, April 21-22, 2022

In Closing…

Thank you for taking the time to read along with us. We hope you found the information useful, and that you'll join us in our upcoming events.

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