THUMBS UP

CHRIS WAJCIECHOWSKI, ALFA LAVAL, USA, **OUTLINES WHY RULES OF THUMB SHOULD BE DISMISSED IN ORDER TO UNLOCK IMPROVED PROCESS PERFORMANCE.**

In the hydrocarbon processing industry, the demands on operating performance have never been higher. Whether it is an existing process unit undergoing a capacity increase or a grassroots refining complex; engineers and designers strive to improve the performance of the process and therefore maximise the value for operating companies. Substantial improvements in operating performance have been achieved through chemical engineering principles by challenging the status quo designs and operations. However, one huge area of improvement often gets overlooked and it affects the very core of process designs. This potentially game changing area is 'the rule of thumb'.

Used correctly, rules of thumb can be powerful estimation tools that compress the time and effort required to evaluate multiple process scenarios. When used incorrectly, often a 'state of the art process' is nothing more than a modified collection of outdated rules and technologies. It is the discretion of the process designer to accept the rules of thumb or to challenge them, since it could extend the time required and the complexity of evaluating designs. Application of 'rules of thumb' to heat exchangers and their limitations will be explored in this article.

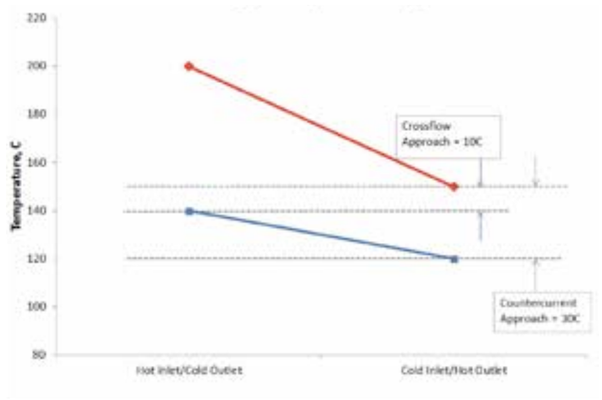

Figure 1. Approach temperatures for typical heat exchanger flows.

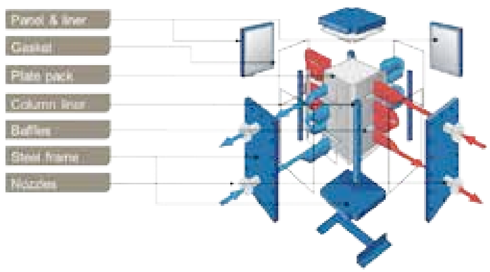

Figure 2. Alfa Laval Compabloc heat exchanger components.

Figure 3. FCC OVHDS Compabloc installed in parallel with shell and tube exchangers.

In heat transfer engineering, rules of thumb are used to estimate the optimum design performance of a heat exchanger; weighing the capital cost (CAPEX) with the operating cost (OPEX) of its performance. Many times a minimum approach temperature (pinch temperature) is used to approximate the optimum design point. In reality, the optimum design point varies widely for each situation and heat transfer technology; and the optimum is rarely chosen for a given design. Even the term 'temperature approach' is dependent on the geometry of the heat exchanger; causing more confusion (Figure 1). This problem is particularly evident in the design of heat exchangers for condensing and boiling services; where application of high performance heat exchanger technology results in impressive gains in process performance. Several case studies are given as real world experience on using improved heat exchanger technology that challenges the rule of thumb.

Case studies

Cooling media in condensers

In the majority of refinery distillation columns, overheads vapours are condensed with air coolers or cooling water heat exchangers, respecting a certain 'rule of thumb' temperature difference between the hot and cold sides. In cooling water exchangers with traditional shell side condensing, many times the cold side outlet temperature is used to respect the minimum process temperature. In practice the temperature difference can be assumed as 10 – 20 ˚C (18 – 36 ˚F) based on the rule of thumb, but what benefit can be assumed by challenging this rule? What if a temperature difference of 2 – 3 ˚C (4 – 5 ˚F) is used instead? This is exactly the rule that was challenged by the North and South American refineries in this article.

A major North American refinery set out to design a reformate splitter tower as part of its MSAT II regulation implementation. In the calculation of tower design, the column pressure was set based on the allowable condensing temperature according to the rule of thumb. It became evident that challenging that rule resulted in a lower condensing temperature that affected the column pressure, the reboiling temperature, and energy needed to perform the separation. The end result was a more efficient separation and the ability to use a lower temperature heating media for the reboiler; saving steam cost.

The heat exchanger technology chosen to perform the duty was an Alfa Laval Compabloc heat exchanger (Figure 2), with corrugated plates and high efficiency to allow for close temperature approaches while also minimising pressure drop. This particular condenser operates in cross flow with a 3 ˚F (1.6 ˚C) temperature approach and has been operating since 2009.

In another case, a South American refinery was revamping their FCC unit and required additional capacity in their main fractionator overheads condensers. Already being condensed with shell and tube exchangers with cooling water, the revamp simply needed to add additional shells to the service to accomplish the additional duty. However, space constraints forced them to evaluate other technologies to perform the required duty; leading them to Alfa Laval to consult on the best technology and potential performance in fluid catalytic cracker (FCC) overheads (OVHDS) service.

Early in the discussions with Alfa Laval, it became apparent that a close temperature approach would give clear benefits to the process capacity; so a study was made with different temperature approaches, different heat exchanger technologies, and flow configurations (cross flow or counter current flow). Alfa Laval engineers evaluated the configurations and decided on ideal designs based on process performance, not the rule of thumb. The optimum configuration was determined to be a counter current flow heat exchanger with a 2.5 ˚C (4.5 ˚F) cold end temperature approach (hot out – cold in) and up to a 25 ˚C (45 ˚F) temperature cross; meaning the hot side outlet temperature crosses the cold side outlet temperature in a single heat exchanger. This heat exchanger (Figure 3) was installed in parallel with the existing shell and tube heat exchangers and even after four years of operation the operating data shows it has been meeting the design temperature approaches.

Heat recovery with condensers

In a refinery, it is not common to recover heat from distillation column OVHDS due to the relatively low temperature of these streams and the limited opportunity to recover that heat when following the rule of thumb. Often a substantial amount of heat is expelled to cooling water or air coolers since rules of thumb limit the amount of heat that can be extracted from the stream. Further limiting the available heat recovery is the convention to operate a cross flow heat exchanger that limits the possibility of an economical temperature cross. Challenging the old rules can lead to some interesting benefits, as the following refiners have realised.

A major European refinery decided to switch from energy wasting air coolers in atmospheric crude tower OVHDS service to recovering the heat into crude oil.[1] Instead of just accepting the limitations of the rule of thumb, the refinery set out with Alfa Laval to study heat exchanger technologies that could recover the maximum amount of heat into crude oil, saving valuable energy. After a thorough search that included a visit to another refinery already using the improved technology, this refinery chose the Alfa Laval Compabloc heat exchanger in counter current flow configuration. Two heat exchangers in parallel were installed in the first stage of crude preheating, adding 50 ˚C (90 ˚F) in heat to the crude while also cooling the crude OVHDs to the greatest extent possible. (Figure 4) These heat exchangers operate in counter current flow with a 20 ˚C (36 ˚F) cold end approach and a 30 ˚C (54 ˚F) temperature cross. Also being a corrosive service, the refinery chose an alloy that was impervious to corrosion in the crude OVHDs environment; a decision made economical due to the efficient use of surface area with the Compabloc technology. Last, the compact size and light weight of the technology allowed the refinery to install the heat exchangers on an existing structure, saving installation costs. According to the refinery, they are saving € 3 million (US$ 4.2 million/y) in energy after commissioning the heat exchangers. After four years of trouble free operation, the investment has paid for itself many times over; savings that will continue over the long life of the equipment.

Several refineries around the world have chosen to improve heat recovery in sour water stripper columns by recovering heat from the OVHDs stream into the column feed (Figures 5 and 6). The process scheme in itself was not new, however the gains in efficiency were limited by the rules of thumb of traditional heat exchangers. For example, by adopting the scheme where the feed was preheated with column OVHDs, the temperature approach on the feed/bottoms heat exchanger was reduced to the point where economical heat recovery was not possible unless improved heat exchanger technology was also used in the feed/bottoms heat exchanger. As is often the case, challenging the rules of thumb for one heat exchanger position will require the designer to also challenge existing rules for other parts of the process as well. Doing so will result in impressive gains, in these examples the heat recovery was improved 25% by optimising the process around improved technology.

Figure 4. Crude tower OVHDS condensers preheat crude from 20 - 70 ˚C while condensing OVHDS to 40 ˚C.

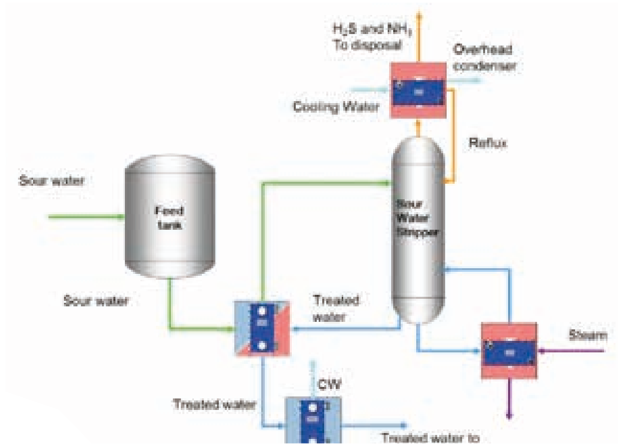

Figure 5. Traditional sour water stripper flow scheme.

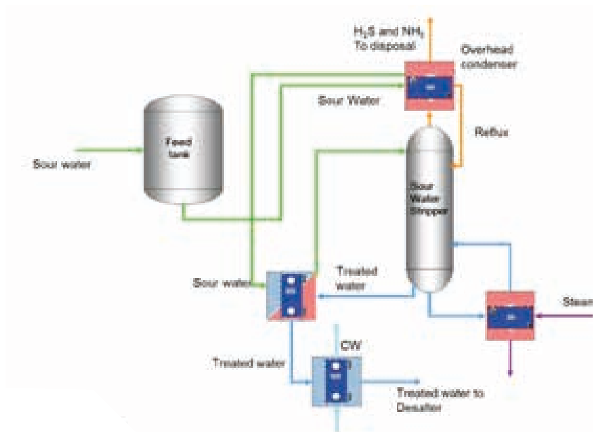

Figure 6. Improved flow scheme with heat recovery to OVHDS.

Conclusion

As demonstrated by examples in this article, the application of rules of thumb to heat exchangers in various process designs can be sub optimal when it comes to process performance. Finding the optimal process performance often requires consultation at an early stage with heat transfer specialists that understand both the process and the operating limits of different technologies. This consultation can add time to the process design, but the operating benefit so far outweighs the cost in design that it should be integrated in the process design procedures.

References

1. LYMAN, Eric J., *'Refinery Revolution', here Magazine, November 2011, pp. 26 – 29.*