Transitioning to Alternative Refrigerants: Implications for Heat Exchanger Design

Webinar Questions and Answers

Questions addressed directly in the webinar:

1. AIM and the Kigali Amendment are designed to reduce HFCs, but CARB's rule is using GWP as the gauge. Do we know if R-32, which technically is an HFC, will soon not be a viable option? Or is R-32 exempt? It is unclear if should we skip R-32 and go directly to a non-HFC or if the industry's consensus is to use R-32 for a few years, but then change it again when other alternatives are more mature.

It is still not very clear what the next level of policy will look like or what the industry is going to settle on in terms of the next refrigerant or GWP limit. However, there are new regulations going into effect on a regular basis. The type of refrigerant will depend on the type of application, as changes to a refrigerant that is further out may require more time or more significant changes to the compressor or other components of the system. Whether a refrigerant makes sense for the product or business in mind comes down to how close a solution can be found using the refrigerant at the high-pressure level. Some may benefit from sticking with R-32 for the years to come, but others may benefit from going straight to a much lower GWP solution if the engineering design work has already been done to support this change.

2. When you changed refrigerant in your case studies, did you keep the same system subcooling and superheat? If not, how do you define the new subcooling and superheat?

Yes, we kept the same subcooling and superheat values for these case studies.

3. Slide 25, 5mm vs. 7mm tube comparison, which dP is shown in the graph? Air side or refrigerant side? Why do we focus on air side pressure drop? Isn't the refrigerant side dP more important for the cycle?

The pressure drop shown in this slide is air side pressure drop. When looking at new fins or small diameter tubes, we are concerned with the ratio of heat transfer to air side pressure drop to maintain equivalent terms. This is to be aware of increases in fan power or lower air flow rate through the heat exchanger. Even though there is more pressure drop on the refrigerant side in this case, it was relatively small and the system was able to tolerate this pressure drop so there was not a big degradation in cycle efficiency.

4. Future R410A replacements will likely have noticeable temperature glide. How will this impact heat exchanger design?

One of the big pieces of the transition to a significantly different refrigerant, especially in a transition to smaller diameter tubes, is the consideration of circuiting. Recircuiting of the heat exchanger may need to occur in order to make these changes to a different refrigerant and designing the flow direction of the circuitry to match glide to air temperature could be a way to make positive use of the glide. It is important to have a software that can capture the effects of glide and allow the evaluation or different circuitries and different designs that can tolerate it.

Additional questions raised from the audience not directly discussed in the webinar:

1. "Drop in" refrigerants to replace R410A were mentioned on several slides. Are there any oil compatibility concerns liked we faced with R22 to 407C replacements?

The focus of this webinar was intended to be on heat exchanger design, but there are of course other considerations that come into play and this material compatibility issue is an important one. Each refrigerant is going to be a different story and ideally this is something that is resolved before it gets to the heat exchanger designer's hands. The refrigerant manufacturer should have a good picture of the chemistry and material compatibility and the compressor manufacturer is going to have paired the right oil with the new compressor. So here "drop in" still doesn't refer to dropping it into the same physical system without replacing the compressor with one matched to the new fluid. For other considerations when picking oil to minimize corrosion, specifically with R32, see this paper.

2. Is the cost of refrigerants a big share of the HX design cost? Are there any considerations about the cost of producing some of the alternative refrigerants?

This definitely factors into the design process – some of the newer refrigerants have a cost that is not trivial compared to the heat exchanger material cost. One of the values of doing rigorous optimization is that we can define a detailed cost function that includes refrigerant cost and the solver will identify the lowest cost design that meets the performance requirements. In cases with high refrigerant cost, an optimized design may have smaller internal volume to minimize refrigerant charge.

3. Are there any leak-detection components that will be necessary to install near heat exchangers when designing for A2L refrigerants?

This is likely going to be required in some markets and will contribute to total system cost. Designers may face the tradeoff of a lower-cost A2L heat exchanger that requires a sensor versus a higher-cost, less-efficient A1 system that doesn't require a sensor. The exact balance of cost-effectiveness might come down to the specifics of the installation.

4. Is there always a tradeoff between refrigerant stability (flammability and toxicity) and its environment impact? It seems to be uncommon to find refrigerants that are both safe and good for environment. Is there a reason for that?

There are some emerging HFOs that have both low GWP and A1 non-flammable status. Many are in the early stages of development and the other area they must demonstrate success in is material compatibility with oils and avoidance of corrosion of brass/copper components. Chemical companies are still working to perfect new refrigerants that might check all these boxes and there are some promising candidates. CO_2 is also a good option in a lot of applications (water heating, some refrigeration, etc.) which has no flammability, toxicity concerns and a GWP of 1. But implementing it efficiently at some operating conditions is a challenge.

5. Are there other exchanger designs that can help manufacturers meet optimization goals such as plate-fin exchangers or pin-fin coils?

Advanced and next generation heat exchangers offer significant potential gains in heat exchanger compactness and performance. (See past work at CEEE at the University of Maryland and OTS for some inspiration!) But in most of these cases, these new technologies represent a significant departure from the manufacturing techniques currently employed by OEMs in the HVAC&R industry. These changes require higher capital costs to invest in new tooling but can yield significant gains in performance or savings in unit cost. Recognizing that these capital investments may not be feasible for many manufacturers, this webinar focused instead on optimizing current state of the art (tube-fin) heat exchangers to meet goals without major changes to processes and system architecture.