Peering Into the Present and Future of Refrigerants

Here's an overview of what's happened thus far with refrigerants and a look at current and projected developments, including a couple that may surprise you

BY GUS ROLOTTI

The refrigeration and air conditioning industries have undergone significant changes since the first days of the Montreal Protocol and Clean Air Act. However, our industry continues to change today, because some of the regulations related to the refrigerant phaseout have not yet taken effect.

Other regulations, such as the minimum SEER rating for air conditioners, which had undergone lengthy litigation, have just now finally settled so we can begin to see what its effects will be. The fact is, our industry has been, and will continue to be in flux for some time to come.

In the U.S., the manufacture of CFCs was required by law to be discontinued by the beginning of 1996, and HCFC-141b[1] by the beginning of 2003. We are now preparing for the next big step in the phaseout timetable: Jan. 1, 2010. From that date on, U.S. system manufacturers will stop production of new equipment using HCFC-22. Given how extensive the use of R-22 is in both refrigera-

tion and air conditioning, this will have a major impact.

Let's look at what the industry has done so far in terms of refrigerant development. The greatest portion of the hvacr industry has used R-11, R-12, R-502 and R-22. Some of the other refrigerants, such as R-500 or R-114, were designed more for specific applications and, therefore, were used in much smaller quantities compared to R-12, R-502 and R-22.

Equipment oems extensively analyzed the different refrigerant alternatives available to them and settled on a number of products. Once a new refrigerant had been selected, they re-engineered their equipment (not a trivial process by any means) and began manufacturing new equipment for use with the new refrigerants. In these cases, some clear winners emerged.

Previously, R-11 was used mostly in low-pressure chillers. The only substitute currently available is HCFC-123, though its use has not been widely embraced by the industry in spite of its clear benefits regarding reduced emissions and superior efficiency and perfomance.

Concerns for R-123 are its low level of toxicity (measured as time weighted average or TWA) and the fact that, being an HCFC, it might be scheduled for phaseout, although at a later date than R-22. While the industry continues to lobby legislators to allow the use of R-123 indefinitely, some others have begun manufacturing systems using R-134a.

For most of the applications using R-12, HFC-134a became the clear dominating choice. All auto air conditioning and medium- to high-temperature refrigeration, especially in the appliance sector, have been using R-134a.

For medium- and low-temperature refrigeration applications previously using R-502, equipment oems for the most part selected R-404A or R-507A[2]. Some decided to use R-22 as a temporary solution due to its cost and the availability of system components.

This is ironic since R-502 was originally designed to replace R-22 in low-temperature refrigeration. In addition, R-410A, which so far has only been considered in air conditioning, is now being tested as a potential refrigeration fluid as well.

From a technical point of view, R-410A works well in the refrigeration range of temperatures, and it could even have better capacity and efficiency than R-404A. However, equipment redesign will be necessary to compensate for the higher compressor discharge temperatures and the higher operating pressures.

What would it take for R-410A to become a viable option for refrigeration? It could be a combination of factors: Regulations in the U.S. or in the European Union (EU) making the use of R-404A more difficult due to global warming; marketing strategy from a compressor or system oem; or a market demand for one fluid instead of two. At this point, R-410A is getting a hard look, and if any company believes that it will gain an advantage over the competition by using it, it may happen.

Mark Sullivan of Atofina's Calvert City, Ky., plant labels freshly painted R-22 cylinders. In time, the number of refrigerants should begin to consolidate to a select few.

The choice of R-404A vs. R-507A has not been yet settled. R-404A is a three-component blend derived from the two-component R-507A. The main difference in composition is the addition of a small amount of R-134a to R-404A to reduce its operating pressure. Overall, sales of R-404A are about four to five times those of R-507A.

Most major refrigerant manufacturers and wholesalers offer both refrigerants and most components are now rated for both refrigerants as well. There is no technical need for these two refrigerants because either one could replace the other quite easily. The market, oems and contractors ultimately will have to select only one.

Retrofit refrigerants emerge

While the oems decided what would be the next generation refrigerant for their new equipment, they could not easily control what refrigerant went into equipment already in use. This created a whole new market in the form of the retrofits.

Retrofit refrigerants are "interim" refrigerants used in equipment designed for other refrigerants (the oem refrigerant), but still allow the equipment to operate. While oem

refrigerants were few, retrofit refrigerants were many.

Contractors and service techs became annoyed and confused with the "refrigerant-of-the-day," and complained about the number of cylinders they had to carry in their vans to service retrofitted units. After the dust settled, just a handful of retrofit refrigerants, such as R-409A and R-408A, that had been proven to work well and were offered by a number of reputable companies, maintained a considerable position in the marketplace. In any case, the heyday for retrofits from R-12 and R-502 has passed, although a healthy market still remains.

The next refrigerant to be phased out in the U.S. is R-22. Because of R-22's use in both the refrigeration and air-conditioning sectors, more than one replacement refrigerant will be needed to replace it entirely.

In the refrigeration market, R-22 is being substituted with R-404A/R-507A. In the air-conditioning market, mostly in the residential and light commercial sectors, R-410A is the leading candidate. Keep in mind that while these new refrigerant substitutes are currently available, and many companies are making equipment and components for them, R-22 can be used for equipment service indefinitely.

It would seem logical to assume that a need to retrofit R-22 equipment would not develop until 2010 or later, especially considering that R-22 will continue to be produced for service until 2020. However, in the hvacr market, logic may have nothing to do with reality, since a small market for retrofits appears to have begun recently.

There are several reasons for this development. First is the need of some industry sectors to be more "green" due to international pressure from environmental groups. Next are doomsday predictions about R-22 shortages and price increases. Third is the U.S. Environmental Protection Agency's (EPA) intention to redistribute allocations for the production/importation of HCFCs in 2009, creating uncertainty.

Finally, EPA's heavy refrigerant emission fines coupled with an offer to reduce or eliminate some fines if ozone-depleting substances (ODS) were completely eliminated ahead of schedule – such as in the bakery and supermarket industries – are additional reasons for an emerging R-22 retrofit market.

There are a number of refrigerants that can be used as retrofits for R-22, depending in part on the application. In refrigeration, refrigerants such as R-404A/R-507A, R-407C and R-417A are being mentioned, with the last one promoted as a drop-in. For air conditioning, only R-407C or R-417A are mentioned.

Our lab data, as well as that of several other independent testing facilities, show that while the fluids will work adequately, none will match the performance of R-22. R-404A and R-407C is the closest in performance, but requires an oil change to a polyol ester (POE) oil.

R-417A makers claim the refrigerant works with the current oil in the system, but at the cost of a performance loss. In all cases, retrofitting will force the end user to compromise. Note that R-410A, the leading oem refrigerant, is not a retrofit candidate because its much higher operating pressures are not compatible with the design of R-22 systems.

What about the others?

Three other refrigerants are worthy of discussion: hydrocarbons (HC), ammonia (NH3) and carbon dioxide (CO_2). They have all been used, or are currently in use, in hvacr. These refrigerants are viewed as "green" or at least "greener" than current HFC choices, especially with regard to global warming. Additionally, recently proposed legislation in the EU may make some of them more popular there.

Hydrocarbons have been used for a few years in refrigerators, competing for market share with R-134a in some EU member states. However, they have not been used in the U.S. Hydrocarbons are relatively inexpensive, compatible with mineral oil and have a low direct global warming potential.

On the down side, they are highly flammable and their use is severely restricted by building and fire codes across the U.S. Additionally, their use increases equipment cost (to eliminate all possible ignition sources) and their overall global warming index (direct and indirect)[4] is comparable and, in many cases, worse than that of applicable HFCs. Hydrocarbons will probably get very little use, if any, in the U.S.

Ammonia has been used for many years. It is best suited for relatively large applications such as industrial process cooling where it appears to have seen small growth. Ammonia exhibits good thermodynamic properties and low direct global warming potential.

Its use is limited by its incompatibility with copper, a common material used in refrigerant lines and heat exchangers, and by its flammability and toxicity rating of B2 by ASHRAE's Standard 34. Its use also is limited by building and fire codes, so it is best applied in relatively remote locations where it can be contained easily or where its release would not affect surrounding populations.

Carbon dioxide (CO_2) is not used much in commercial applications today, although it was used many years ago before being displaced by refrigerants such as CFCs. CO_2 has seen a strong resurgence due to several European car manufacturers' interest in using it to replace R-134a in mobile air conditioning (MAC), mostly for environmental

reasons linked to global warming.

CO_2 offers a very low direct global warming potential and comparable performance to R-134a systems. It performs better than R-134a in the heating mode of heat pump applications.

The downsides for CO_2 are the extremely high operating pressures (approximately 10 times those of R-134a), greater system weight and cost than a comparable R-134a system and poor performance at higher ambient temperatures (greater than 90° F). Overall, CO_2 is thought to be slightly inferior or comparable to enhanced R-134a automobile a/c systems based on TEWI.

There is legislation pending before the European Commission parliament that proposes the banning of R-134a in auto a/c systems beginning with some new 2009 models and all models in 2011. This legislation, which appears to be based only on the refrigerant's direct global warming value, would only allow the use of CO_2 in auto a/c systems after R-134a. The current draft of the legislation also excludes R-152a, a flammable HFC.

At this point, even though much wider proposed legislation affecting R-134a was defeated in Europe, the future of R-134a in auto a/c is still unclear. Automakers seem to be balking at the high cost to convert production to CO_2, especially after the estimated $5 billion-plus (in U.S. dollars) price tag of converting from R-12 to R-134a just a few years ago.

After eight years of the CFC phaseout and with only six years until the HCFC phaseout, it is still not clear or certain which refrigerants are here to stay. For the U.S. at least, it looks like R-134a, R-404A/R-507A and R-410A are pretty sure bets.◆

Gus Rolotti is technical and applications lab manager, King of Prussia Technical Center, Atofina Chemicals Inc. For more information, visit forane.com or atofinachemicals.com.

Footnotes

1. While R-141b had limited use as a refrigerant, its earlier phase out avoided a drastic reduction in R-22 production, which would have directly impacted the hvacr sector more directly.
2. The ASHRAE Standard 34 designation for this refrigerant is R-507A; R-507 also is accepted and used.
3. This is measured as total equivalent warming index (TEWI) or life cycle climate performance (LCCP). Both TEWI and LCCP take into account the direct and the indirect portion of a refrigerant by considering factors such as efficiency, energy used and end-of-life disposal.