The phasing down of R-22 production is well underway, and operators are now looking for guidance on what options are available after R-22. A wide range of “drop-in” refrigerant options are available to retrofit existing systems, typically consisting of blends of hydrofluorocarbons (HFCs). These have been developed to operate at similar pressures to R-22 at specific operating conditions and require minimal modifications to the system. Alongside these are the existing HFC refrigerants such as R-404A and R-507, which can also be retrofitted in R-22 systems, albeit this usually requires significant changes to the system. Finally, there is the option to move to natural refrigerants including ammonia, hydrocarbons and CO₂. This may be possible with modifications to an existing system, but in most cases, it is more cost effective to install a completely new plant.

At first glance, with so many options available, it would suggest that the transition from R-22 to an alternative fluid is going to be easy. It is only when getting into the detail that the challenges appear. Plant condition, refrigerant glide, material compatibility, oil, cooling capacity, power, leakage, downtime and system pressure are just a few of the issues operators need to look at when changing refrigerant. There is also the question of long-term viability of HFCs. Fortunately, the U.S. can look to Europe during this time of transition and take advantage of the lessons learned from their R-22 phaseout process, which comes to a conclusion at the end of 2014.

When the time comes to change

R-22 refrigeration system designs differ in many ways. There are various system types, sizes, materials of construction, operating temperatures and associated system pressures. When assessing options for an alternative refrigerant, all of these criteria need to be considered. There are also non-technical criteria including future legislation, corporate environmental commitments and the ongoing cooling requirements of the business while equipment is upgraded or replaced.

The two most common types of refrigeration systems are direct expansion (DX) and pumped circulation. Direct expansion is widely used in small- to medium-sized applications and has the advantages of low capital cost, low refrigerant charge and relative simplicity. Pumped circulation is typically used for medium- to large-scale applications with distributed pipework and evaporators.

Drop-in refrigerants

The use of a drop-in refrigerant may be an option, but the following should be considered:

Leakage—Evidence suggests that HFC refrigerants are far less forgiving in terms of leakage than R-22. Where a system has a history of leakage and this cannot be resolved, the use of drop-in refrigerants should not be considered. Replacing lost refrigerant is expensive and it is likely that knowingly adding to a leaking system will contravene environmental legislation. Even if an existing R-22 system does not have a history of gas loss, changing to HFCs could result in leakage. Factors contributing to this increased risk of leakage...
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include higher system operating pressure, shrinkage of existing seal and gasket materials and the general condition of the plant into which the new refrigerant has been retrofitted. Particular areas of concern are seals on compressors and valves that may swell when in contact with R-22 and mineral oil but then shrink back to their original size or less when in contact with HFCs and the replacement oils. An overhaul and replacement of seals and gaskets should be a part of any replacement gas-assessment process and be included into the cost of the work. Where copper has been used for heat exchangers and pipework, it is possible that this has work hardened over time, and although the original material may have been suitably rated for R-22, its strength may have weakened over time. This is particularly of concern for evaporators with hot-gas or electric defrost.

Oil change—In addition to changing refrigerant where mineral oil is currently used, it is recommended that this is replaced with POE oil. POE is miscible with mineral oil, so while the system must be drained of old oil, it is not critical to ensure that every last drop of old oil is removed.

Operating pressure—Changing refrigerant could result in higher operating pressures due to the different properties of the new fluid. When assessing the suitability of an alternative refrigerant, consideration should be given to these new operating pressures and whether the existing system components are suitably designed. This includes an assessment of pipework and vessel design pressures, along with thickness tests and visual inspection for signs of corrosion. Pressure relief valves should also be assessed for the new operating pressures and changed where necessary. In addition to the theoretical assessment, strength and leak tests should be performed to ensure that the rating of components and pipework is still valid. Corrosion and work hardening can and will reduce the strength of the system and its components.

An overhaul and replacement of seals and gaskets should be a part of any replacement gas-assessment process and be included into the cost of the work.

Application temperature—It is crucial that the refrigerant type is matched to the application. Differing blends have been developed for low-, medium- and high-temperature and care must be taken to select the correct blend.

Refrigerant glide—R-22 is a single component refrigerant that boils and condenses at a fixed temperature. Many of the replacement refrigerants are blends of fluids that boil and condense over a temperature range often referred to as “glide.” Glide has two significant effects on system performance. First, it results in a reduction in heat-exchanger performance when the original evaporator or condenser has been designed for R-22. Second, for systems where there are one or more receiver vessels (low-pressure receivers or high-pressure receivers), it can also lead to separation of the blend components and a change in the circulating refrigerant composition. Glide and separation both result in a reduction in cooling capacity and increase in power consumption.
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The uncertainty over the future of HFC refrigerants has resulted in an increased interest in the use of natural refrigerants.

Remember, converting from R-22 to a drop-in HFC does not provide a new system. Existing system issues will not go away. In fact, they are likely to get worse and new challenges can also appear.

Drop-in refrigerants are being viewed as temporary solutions that enable the customer to continue operating their system knowing that it is only a matter of time before it needs to be replaced. They have been widely used in small-to medium-sized DX applications but less so in large flooded systems and rarely for pumped circulation applications.

**Non-drop-in HFC refrigerants**

The challenges with replacing R-22 with widely used HFC refrigerants, including R-404A, R-507 or R-134a, are the same as those highlighted above but there are further complications, including:

- **Oil**—It is necessary when changing from R-22 to other HFC refrigerants such as R-404A, R-507 or R-134a that all mineral oil is removed and the system is flushed. This is time consuming and will add to the cost and duration of the conversion program.

- **Capacity**—The thermodynamic properties of these refrigerants are different from R-22 and will lead to a change in cooling capacity, operating temperature/pressures, pipework pressure drop and overall performance. It is likely that considerable changes have to be made, including replacing major components and pipework in order for the system to provide a similar cooling capacity.

Where these factors make conversion unattractive from a capital cost perspective, system replacement is often the best option.

**Natural refrigerants**

The uncertainty over the future of HFC refrigerants has resulted in an increased interest in the use of natural refrigerants. For small-scale applications (up to 50 TR), hydrocarbons and more recently CO₂ have grown in popularity. In some cases, CO₂ has been used in cascade with HFC or hydrocarbon plant.

Larger applications have typically switched to direct ammonia or ammonia with secondary glycol or CO₂. Where the conversion to a new refrigerant proves to be too expensive, customers have installed new equipment alongside the existing R-22 equipment and carried out a phased changeover to the new system.

**Non-technical considerations**

Refrigeration engineers often focus on the technical side of R-22 phaseout, but there are other challenges that need to be considered. These include:

- **Company environmental policy**—A growing number of businesses of all sizes have environmental policies that pledge to move towards natural refrigerants.

- **Long-term future of HFCs**—The U.S. has followed Europe in the phasing out of CFCs and HCFC refrigerants. With Europe now adopting a timetable for HFC phase down, it is highly likely that the U.S. will follow this lead. Replacing R-22 with a replacement HFC gas may buy time but, eventually, the system will need to be replaced.

- **Conversion period**—Changing refrigerant is not simply a case of removing the R-22 and having the new solution up and running the same day. The system may be out of operation for a period of time, which could range from days to weeks depending on the size and complexity. For small, simple DX system undergoing a refrigerant change, this may take a matter of days. For larger, pumped circulation systems it could take more than a week just to remove the old refrigerant.

- **Maintaining temperature**—In some cases a loss of cooling for a prolonged period is not an option. For these applications a new refrigeration system is typically installed alongside the
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existing plant. The new system is installed and prepared for operation before existing R-22 equipment is replaced as part of a phased program.

Two systems operating together—The necessity to keep an existing R-22 plant running while the new plant is commissioned means that two systems are often operating at the same time. This brings more challenges, including:

- **Machinery room:** There may be insufficient space in the existing machinery room for new equipment and this may mean that a new machinery room is required.
- **Electrical supplies:** It may be necessary to provide power to the new equipment prior to decommissioning the R-22 plant. The additional power to run the new and existing equipment in parallel has to be considered.

- **Building structure:** Where new equipment is installed in place of existing units, an assessment of the existing building structure has to be carried out to determine if existing steelwork is of a suitable size.

- **Customer disruption:** Installing new equipment on an operational facility can be challenging. This requires careful planning and coordination to ensure that work can continue without disrupting the customer’s business.

**Next steps**

For customers with R-22 refrigeration systems, phaseout is a reality and needs to be on your agenda today. Experience in Europe has shown that those businesses that have addressed the issue of phaseout early have benefited in the long term. A plan should be developed to look at alternatives to R-22 and assess the business impacts in terms of capital cost and program. For customers with smaller systems, this may simply require the allocation of funds to replace existing equipment. For customers with larger, distributed systems, a more detailed plan is required taking into account the many factors mentioned above.

Those customers that switched to natural refrigerants will avoid the double step of moving to HFCs and then having to switch again at a later date. They will also reap the added benefit of improved reliability and efficiency offered by modern natural refrigerant systems.

The key is for your customers to plan early and ensure that the R-22 phaseout is built into their business plans as early as possible—this will benefit their business in the long term.

Derek Hamilton is the Business Development Manager for Star Refrigeration. Based in San Francisco, CA, he heads up Azane, the U.S. subsidiary of Star Refrigeration specializing in the manufacture of low-charge, package ammonia refrigeration solutions. Hamilton has a keen interest in the promotion of low-charge ammonia as an excellent solution for R-22 system replacement and an ideal alternative to HFCs in many applications. For more information, email info@azane-inc.com or visit www.azane-inc.com.
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