Scroll Chillers:
Conversion from HCFC-22 to HFC-410A and HFC-407C

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Hydrofluorocarbon (HFC) refrigerants are critical to the safe and cost-effective phase-out of ozone depleting chlorofluorocarbon (CFC) and hydrochloroflurocarbon (HCFC) refrigerants in developing and developed countries (IPCC/TEAP 2005). As replacements for less energy-efficient, older equipment, HFC systems conserve energy and reduce the generation of global warming gases at electric power plants. These systems are being used in accordance with responsible-use principles, which range from recovery and reuse of HFCs, to well-designed HFC-production plants that aim to achieve zero HFC emissions.

For scroll chillers, the most popular HCFC-22 (R-22) replacement options include:

- **HFC-410A** (R-410A) a zeotropic mixture of 50% HFC-32 and 50% HFC-125 with a low glide of 1°F)
- **HFC-407C** (R-407C) a zeotropic mixture of 23% HFC-32, 25% HFC-125, and 52% HFC-134a.

R-407C requires the least changes for component and system manufacturers, as well as installation and service contractors. The safety classification and handling characteristics are similar to R-22 (non-flammable, low toxicity). R-410A requires significant changes for component and system manufacturers but has offsetting benefits. The safety classification is the same as R-22.

Scroll Chiller –Transition from R-22 to R-410A Equipment

Operating pressures in a R-410A refrigerant system are about 50% higher than a comparable R-22 system. As a result, R-410A cannot be used as a direct, functional replacement in R-22 systems.

While the higher operating pressures in R-410A systems may seem to be a negative characteristic, the effect has been positive. R-410A equipment has been specifically designed to operate at higher pressure, with a thicker compressor shell, heavier wall tubing and superior control and protections (Figure 1). The more robust materials, in turn, enable manufacturers to create heavier, better welds at joints, helping to improve their resistance to abuse. In addition, consistent field experience indicates that R-410A offers greater compressor sound reduction than those units using R-22. Field-testing and the product history to date for R-410A equipment suggest that these units are more reliable than R-22 units.

R-410A has a low temperature glide of 1°F (0.5 K) resulting in a negligible effect on heat exchanger performance versus R-22. Chiller systems that utilize R-410A have small compressor displacements. R-410A evaporates with a 35% higher heat-transfer coefficient and 28% lower pressure drop compared to R-22. When systems are optimized for R-410A, heat exchangers can be reduced in size (because of the improved heat transfer characteristics) and still achieve comparable capacity and efficiency as R-22. This reduces the internal volume of the system, thereby reducing the refrigerant charge. In addition, due to the reduced sensitivity to pressure drop, optimum tube diameters will be smaller for R-410A than R-22, further reducing the refrigerant charge. Another property that reduces the required amount of refrigerant is the lower liquid density of the refrigerant. This leads to a 12% reduction in the mass of the refrigerant required. The total of these effects is an overall reduction of 25% to 30% charge reduction in fully optimized R-410A systems.

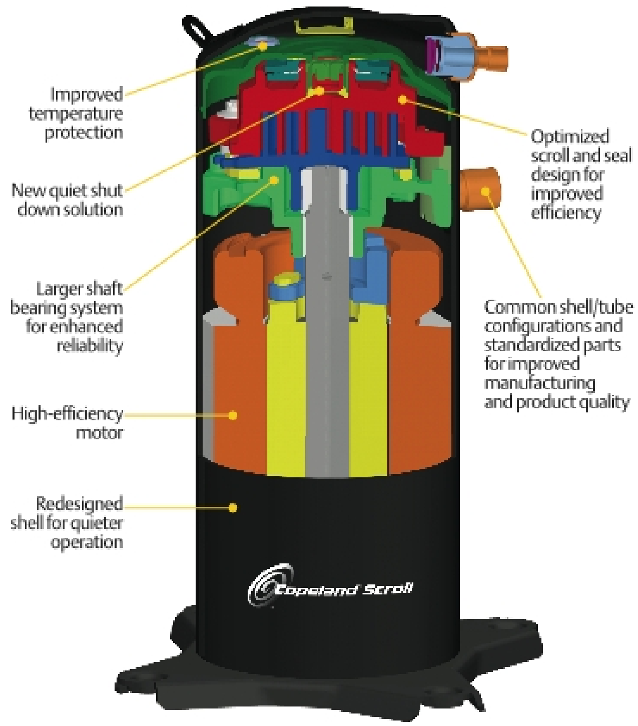

Figure 1 – Design changes in an R-410A versus HCFC compressor

To date, optimized system testing has shown that R-410A delivers higher system efficiency than R-22. In addition, systems that use R-410A refrigerant have been specially designed to use less tubing, less refrigerant, and smaller heat exchangers. The use of fewer materials, along with reduced refrigerant charge and better cycle performance, make R-410A systems very cost-effective. R-410A is currently regarded as one of the leading long-term refrigerant choices for new residential and small commercial equipment worldwide, based on currently available commercial technologies

R-410A has an ODP of zero and no scheduled phase out date, making it a long-term environmental solution to ozone depletion. It has been designated an A1 refrigerant in ASHRAE Standard 34 – Designation and Safety Classification of Refrigerants.

Service Training Considerations

Because the characteristics of R-410A are considerably different than those of R-22, training should be required for technicians as they must be knowledgeable and have the proper tools to safely handle this refrigerant.

In addition to addressing the handling of higher pressure equipment, the training should address the type of lubricant used in the system and its handling, as described further below.

Scroll Chiller: Transition from R-22 to R-407C

R-407C has capacity and pressure close to R-22. In fact, its operating characteristics are so similar to HCFC-22 that it can be used in either existing R-22 systems (requires some changes such as the oil) or in new systems that were originally designed for R-22.

Unlike R-410A, the system efficiency of R-407C is somewhat lower than R-22 (~5% lower), especially in systems that were originally designed for R-22. R-407C is a zeotropic blend, meaning the resulting mixture does not act as a single compound. At a given pressure, it evaporates over a range of temperatures, rather than at a single temperature. Its high glide – approximately 8°F (4.4 K) – can lead to concerns about maintaining composition control during the distribution, installation, and servicing of products using this refrigerant.

R-407C has been used considerably in Europe, where the phase out of ozone depleting refrigerants (including R-22) was accelerated, and manufacturers did not have time to re-design systems for higher pressure R-410A refrigerant. In systems in which glide is acceptable, R-407C has become a popular option for manufacturers who want to move quickly to an HFC alternative. In the long run, however, the lower-efficiency performance of this refrigerant may make it a less attractive alternative compared to R-410A for medium and high-temperature applications.

R-407CA has an ODP of zero and no scheduled phase out date. It has been designated an A1 refrigerant in ASHRAE Standard 34 – Designation and Safety Classification of Refrigerants.

System Design and Servicing Considerations

R-407C temperature glide must be considered both in the system design and in servicing the system. Manufacturers must understand and convey to the field the impact of leaks on zeotropic blends. Systems containing a zeotropic refrigerant must be liquid charged to ensure that the proper component mixtures are added. Temperature glide when matched with DX cooler modifications, can improve energy efficiency input. A DX evaporator designed as a counterflow heat exchanger where refrigerant and water enter at opposite ends, and the leaving refrigerant temperature can be greater than the leaving chilled water temperature as shown in Figure 2. The higher leaving refrigerant temperature means the compressor does less work resulting in lower power consumption.

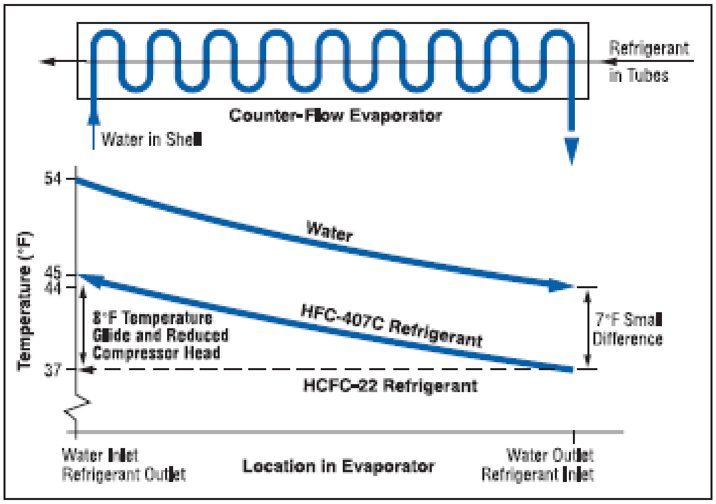

Figure 2 – HFC-407C temperature in a counter-flow evaporator

Manufacturing Issues for R-410A and R-407C

R-410A and R-407C applications typically require synthetic polyolester lubricant (POE). POE lubricants are more hydroscopic and require enhanced manufacturing process control to ensure low system moisture level. When converting from an HCFC to an HFC, the electrical insulation materials typically used are generally unchanged. HFC refrigerants are not miscible with silicone oils, phthalate oils, paraffin oils or waxes. Their use should be avoided in fabrication processes for components that contact the refrigerant. Common concerns are motor winding lubricants, cutting fluids in machining operations and drawing lubricants. Careful attention to system cleanliness is required to avoid contaminants. Trace contaminants can promote long term chemical degradation within the system, which can reduce cooling capacity or cause system breakdown. Necessary process controls are not technically complex but do require competent manufacturing practices and attention to detail.

Lubricant Design Considerations

Mineral Oil vs. POE

R-407C and R-410A systems use POE or Polyvinylether (PVE) lubricant, whereas R-22 chiller systems use napthenic mineral oil. The main reason these lubricants are used with a given refrigerant is to ensure proper miscibility between the refrigerant and the lubricant in order to enable the lubricant to return to the compressor. Lubricants are tailored to the compressor specifications and differ in additives, viscosity, polarity, structure, and chemistry. Some critical specifications to keep in mind when discussing POE lubricants are:

- *Moisture:* The POE lubricants used in R-410A chiller units are more hydroscopic, i.e., they absorb moisture from the air. This moisture, if not removed, causes decomposition within the refrigeration materials. This in turn creates unwanted acids and alcohols, thus affecting system chemistry. Also, moisture has been known to create copper plating on metals.
- *Acidity:* High moisture may cause corrosion, reduce thermal stability, and promote higher hydrolytic decomposition.
- *Purity:* Purity or lack of purity in the lubricant has a great effect on the general stability of the product.

Overall, the performance advantages of POE over Napthenic Mineral Oil (NMO) are as follows:

- HFC miscibility is good with POE; very poor with NMO
- The thermal stability of POE is better than NMO
- The lubricity of POE is better than NMO
- Materials compatibility with POE is good

Overall, POE lubricants are excellent solvents, and as a result, contaminants left on refrigerant-bearing parts are eliminated by using HFC refrigerants. Some of these common contaminants are residual detergents from cleaning, drawing compounds, rust preventatives, plasticizers and lubricant additives, or in the case of a retrofitted R-22 unit, mineral oil. Fortunately, if POE and NMO are inadvertently mixed together, there is no chemical reaction.

The following are recommendations for handling POE lubricants:

- In order to avoid moisture absorption from the air, POE must be **kept sealed**.
- Compressors and systems in general must not be left open to moisture exposure for **over 15 minutes**.
- A system must be vacuumed to at least **500 microns absolute pressure**
- Non-chemically “bonded” moisture may be removed utilizing filter dryers, vacuums etc.
- Using a high capacity filter is recommended

The Manufacturing Transition Strategy from HCFC-22 to HFCs

In developed countries, leading HVAC industries are still manufacturing R-22 units, but most have almost completely moved from R-22 to HFCs. In general terms, many manufacturers are opting for the following type of transition:

1) Introduce R-410A units on a small scale or pilot production with emphasis on reliability.
2) Gradually reduce R-22 and increase R-410A production, reaching an equilibrium.
3) Phase out R-22 completely by 2010

Technology Transfer

Effective HFC technology transfer is of utmost importance in reducing the use of R-22 and should be within the framework of existing working relationships/licensed agreements with technology suppliers established for this purpose. Funding may be required to help developing countries move to new HFC technology. Development costs will depend on the specifics of the license contract and the interaction between partners.

In case of no technical license or contacts with developed HFC manufacturers, local manufacturers (in developing countries) could decide to start pre-development, development and testing on their own. This would dramatically increase the risk of success and investment.

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