FACT SHEET 10
Water chillers for air-conditioning

1. Description of market sector

This market sector includes water chillers that are used for building air-conditioning and some industrial cooling applications. Many large buildings that require air-conditioning are cooled using pumped chilled water systems with a central chiller installation. In some countries, relatively small buildings also use water chillers (in competition with the larger "air-to-air" air-conditioning systems described in Fact Sheet 9).

Market sub-sectors

The sector has been split into two sub-sectors

a) Small and medium sized chillers

b) Large sized chillers

Typical system design

Most chillers systems use a vapour compression cycle. In large buildings, chillers are located in a mechanical equipment room. Chilled water is pumped to air handling units or terminal units that deliver conditioned air. Condenser water is pumped to a cooling tower. For smaller buildings, chillers may be located outdoors and use air cooled condensers.

- **Small and medium sized chillers** often use a direct expansion (DX) evaporator and an air cooled condenser. They usually use scroll, reciprocating or small sized screw compressors.
- **Large sized chillers** usually use a flooded evaporator, a water cooled condenser and a large screw or centrifugal compressor.

Variable speed drives are a popular addition that improves part load efficiency

Alternative technologies

Heat driven absorption chillers, usually based on a water-lithium bromide system, can be used in place of electrically driven vapour compression systems. Solid adsorption systems (e.g. water / silica gel) can also be considered. Sorption systems are only cost effective if there is a suitable source of waste heat, as they are less efficient than vapour compression systems. They might also be used in locations where the electricity grid is unreliable or low in capacity.

Changes driven by ODS phase out

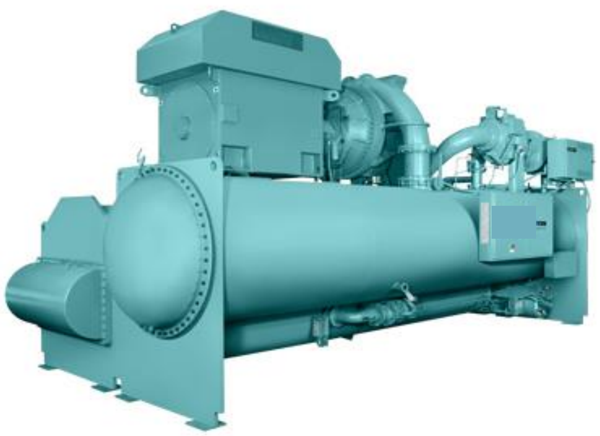
Prior to 1990 this sector used CFC-11 and CFC-12 for large centrifugal chillers and HCFC-22 for small / medium sized chillers. By 1995 large CFC-12 chillers were replaced with new designs based on HFC-134a; CFC-11 chillers moved to HCFC-123. From around 2000, small and medium sized chillers moved from using HCFC-22 to R-407C and then to R-410A. In non-Article 5 countries HCFC-123 has a phase-out date of 2020. As the 2020 phase out approaches the market for HCFC-123 chillers is diminishing. New chillers using HCFC-123 and HCFC-22 are still available in Article 5 countries.

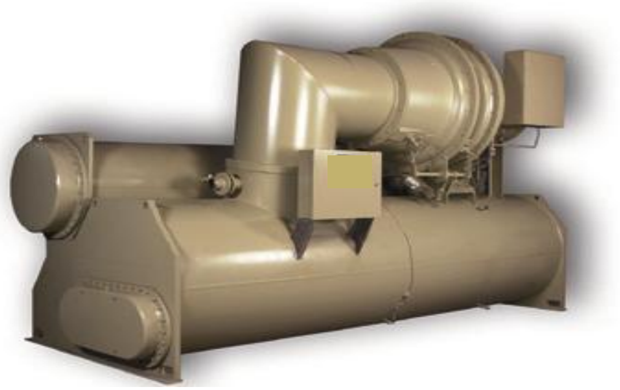
Typical small air cooled chiller for outdoor operation

Table 1: Chillers for air-conditioning: summary of characteristics for HFC equipment

Market sub-sector:		Small / medium sized chillers*	Large chillers*
Typical refrigerant charge		40 to 500 kg	500 to 13 000 kg
Typical cooling duty		50 to 750 kW	750 to 10 000 kW
HFC refrigerants widely used		R-407C (GWP[1] 1774) R-410A (GWP 2088)	HFC-134a (GWP 1430)
Typical refrigeration circuit design		DX evaporator, air cooled condenser Scroll, reciprocating or small screw compressor	Flooded evaporator, water cooled condenser Large screw or centrifugal compressor
Manufacture / installation		Factory built, often pre-charged with refrigerant. Some large systems charged with refrigerant during installation.	
Typical location of equipment		Machinery room (water cooled) or outdoors (air cooled)	
Typical annual leakage rate		2% to 4%	2% to 4%
Main source of HFC emissions		Operating leakage	Operating leakage
Approx. split of annual refrigerant demand	New systems	65%	50%
	Maintenance	35%	50%

* The sizes indicated in Table 1 are approximate. Smaller and larger sizes may be available.





Typical medium pressure R-134a (left) and low pressure R-123 (right) Centrifugal Chillers

[1] All GWP values are based on the IPCC 4th Assessment Report

2. Alternatives to currently used HFC refrigerants

Table 2: Lower GWP alternatives for water chillers

Refrigerant	GWP	Flammability[2]	Comments
Chillers with centrifugal compressors			
HFO-1234ze	7	2L	Being developed for large centrifugal chillers as an alternative to HFC-134a.
HFO-1233zd HFO-1336mzz	5 9	1 1	New fluids suitable for low pressure centrifugal chillers as an alternative to HCFC-123.
R-718 (water)	0	1	Water can be used as a refrigerant in chiller systems, but requires very large compressor swept volume.
Chillers with positive displacement compressors			
HFO-1234ze	7	2L	Already available in a range of small and medium sized chillers.
HFC-32	675	2L	Has performance similar to R-410A and is suitable for small and medium sized chillers.
R-446A R-447A	460 582	2L 2L	Newly developed blends with properties similar to R-410A. Being considered for small and medium sized chillers.
R-717 (ammonia)	0	2L	Suitable for medium and large sized chillers with screw compressors. More commonly used for industrial chillers but can also be applicable for air-conditioning.
HC-290 HC-1270	3 2	3 3	Suitable for small and medium sized chillers. Available widely in Europe.
R-450A R-513A	601 631	1 1	Newly developed blends with properties similar to HFC-134a, suitable for medium sized chillers using screw compressors.

There is a range of different low GWP options that are well suited to chillers. Most chillers are located in a machinery room or in an outdoors location. This makes it easier to deal with safety issues related to both flammability and toxicity, allowing the use of large charges for the refrigerants listed in Table 2. Flammable refrigerants require special safety considerations and compliance with building codes. Some machinery rooms are located in "difficult access" locations such as a basement. The use of flammable and higher toxicity refrigerants in such locations can be more problematic.

Testing of new, lower-GWP refrigerants for chillers started several years ago. Some alternative refrigerants have been introduced into product ranges, although it is not yet clear which ones may be selected for broader commercialisation. Trade-offs are apparent between GWP, energy efficiency, safety, and installed cost. The product development costs for a full range of compressors and chiller products are substantial.

[2] Flammability classes based on ISO 817 and ISO 5149
3 = higher flammability; 2 = flammable; 2L = lower flammability; 1 = no flame propagation

3. Discussion of key issues

Safety and practicality

Provided a chiller is located in a machinery room or an outdoors location there are few restrictions on the refrigerant charge that can be used for various suitable refrigerants. This provides chiller manufacturers with a wide range of low GWP options. Safety requirements for the appropriate flammability and toxicity category must be followed.

For some refrigerants there could be limitations to applicability in basements and other "difficult access" locations.

Commercial availability

Various designs of chiller using low GWP alternatives are already commercially available, including HFO-1234ze, HFO-1233zd, HCs and R-717.

Many new chiller models with low GWP refrigerants are expected to become available within the next few years.

Cost

HFO-1234ze chillers will be of similar or slightly higher cost to HFC-134a chillers.

HC chillers are cost competitive with R-410A systems, but site installation cost may be higher due to flammability safety measures.

Ammonia chillers are considerably more expensive, especially for smaller capacities. Costs of low pressure centrifugal chillers using HFO-1233zd or HFO-1336mzz are not yet clear, but are expected to be competitive with prices for HCFC-123 chillers.

Energy efficiency

There have been excellent improvements in the efficiency of water chillers over the past 10 years through the introduction of numerous technical improvements. It is expected that good efficiency can be achieved for all the refrigerants listed in Table 2 if best practice designs are used.

Applicability in high ambient

Small / medium chillers: Many smaller chillers are air-cooled and will operate at very high condensing temperatures in high ambient. HC-290 and HC-1270 chillers can be designed to operate well at high ambient. HFC-32, R-446A and R-447A have a higher critical temperature than R-410A and can be expected to perform better than R-410A at high ambient but not always as well as HCFC-22.

Large chillers: Most large chillers are water cooled and are relatively easy to use in high ambient if the cooling water is evaporatively cooled in a cooling tower. This helps avoid extremely high condensing temperatures. However, if water is scarce, a cooling tower may not be appropriate. If a dry air cooler is used, the condensing temperature will be much higher. Refrigerants such as HFO-1234ze, 1233zd and 1336mzz have high critical temperatures which make them reasonably well suited to high condensing temperatures, although a high compression ratio could create difficulties for some types of centrifugal compressor.

Opportunities to retrofit existing equipment

Centrifugal chillers: It is not appropriate to retrofit existing HFC chiller equipment that uses centrifugal compressors.

Positive displacement chillers: It is technically feasible to retrofit small and medium sized positive displacement chillers. This has been done widely to replace HCFC-22 in water chillers. However, there is currently little or no retrofit activity related to HFC chillers.

Technician training

Lower flammability HFCs/ HFOs: Training will be essential for maintenance of chillers with lower flammability refrigerants. Training is being provided by manufacturers of new models of chillers using these refrigerants.

HCs: Technicians doing maintenance need training that addresses handling of higher flammability refrigerants. There are established training courses available although only a small proportion of air-conditioning technicians have skills to deal with large HC systems.

R-717: Technicians doing maintenance need training that addresses handling of R-717, especially in relation to use of a higher toxicity refrigerant. There are well established training courses available for R-717 technicians in many countries, although not many air-conditioning technicians are familiar with R-717.

Minimising HFC emissions from existing equipment

Chiller systems are factory built and have the potential for very low levels of leakage if best practice design and maintenance is carried out.

Chillers have large refrigerant charge and it is essential that appropriate recovery equipment is used during maintenance and at end-of-life.

Low pressure chillers (e.g. using HCFC-123 or HCFO-1233zd) may operate with an evaporator at below atmospheric pressure. This creates the possibility of air leaking into the refrigerant circuit. Appropriate automatic air-purge equipment should be used to avoid refrigerant emissions when air is removed.