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Containment of Refrigerants within Refrigeration, Air Conditioning and Heat Pump Systems

24th Informatory Note on Refrigeration Technologies

This informatory note has been prepared by the IIR Working Party "Mitigation of Direct Emissions of Greenhouse Gases in Refrigeration" on behalf of the IIR Science and Technology Council. It provides information about the impact of leakage, why containment is beneficial from both environmental and economic perspectives, where and how leakage can be reduced, legislation and initiatives that have been developed to help containment and reference to sources of further information. This note is an update of a previous informatory note[1] and presents a series of measures to be taken. Although the main focus is often on the environmental impact of refrigerant leakage from refrigeration, air conditioning and heat pump (RACHP) systems, leakage also has a big impact on system reliability, efficiency and the economics of operation.

Background

There has been good progress on reducing refrigerant emissions in many countries, as a result of various regulatory actions, fiscal and voluntary initiatives, as well as technological developments. This reduction is exemplified in Figure 1, which shows the annual refrigerant leakage rates reported in several studies between 2000 and 2011[2] and Figure 2, which shows the annual leakage of refrigerant reported by two large end users in the UK retail (supermarket) sector[3].

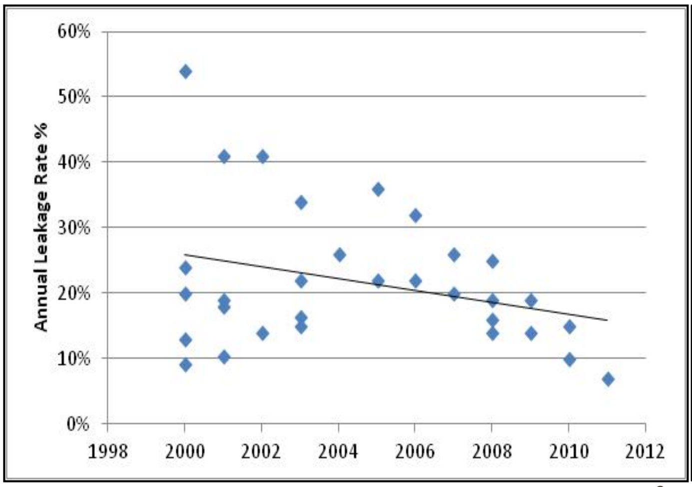

Figure 1. Reported leakage rates from studies[2]

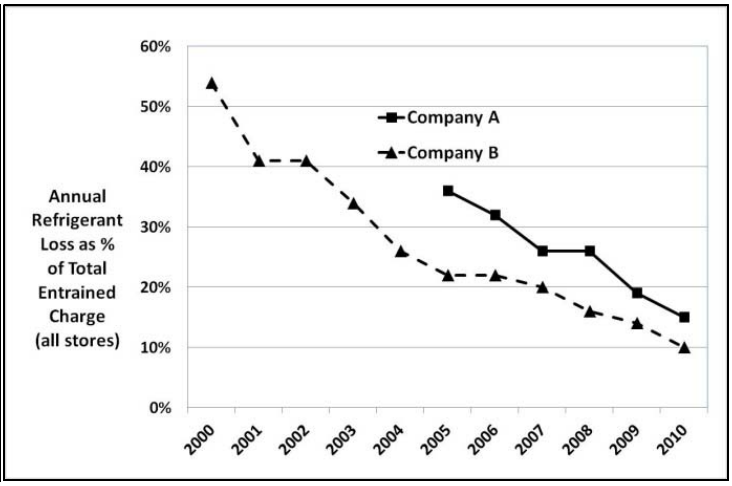

Figure 2. Leakage rates reported by two end users (supermarkets)[3]

Hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs) continue to be the most commonly used refrigerant types for RACHP. Figure 3 shows projections of refrigerant banks and emissions reported by UNEP[4], based on an emissions mitigation scenario which includes reduced refrigerant losses and improved recovery rates. The figure indicates that global HCFC refrigerant banks and emissions are predicted to change by only a small amount between 2002 and 2020, while at the same time HFC refrigerant banks and emissions are forecast to increase by 400% and 137% respectively. The combined HCFC and HFC refrigerant emissions projections indicate an increase of nearly 50% in the global warming impact associated with refrigerant emissions between 2001 and 2020.

[1] IIR (1999), *14th IIR Informatory Note on Refrigerants: "Reduction of emissions of refrigerants and containment in systems"*, International Institute of Refrigeration, www.iifiir.org

[2] Updated from Cowan D, Gartshore J, Chaer I, Francis C, Maidment G. (2010), REAL Zero – reducing refrigerant emissions & leakage - feedback from the IOR project, *Proceedings of the Institute of Refrigeration*, Proc. Inst. R. 2009-10. 7-1

[3] Cowan D, Beermann K, Chaer I, Gontarz G, Kaar K, Koronaki I, Maidment G, Reulens W. (2011), *Improving F-Gas containment in the EU – results from the REAL SKILLS EUROPE project.* 23rd IIR International Congress of Refrigeration, Prague, Czech Republic, www.iifiir.org

[4] UNEP (2009), *Task force decision XX/8 report; assessment of alternatives to HCFCs and HFCs and update of the TEAP 2005 supplement report data*, UNEP Technology and Economic Assessment Panel, Nairobi, Kenya. ozone.unep.org/Assessment_Panels/TEAP/Reports/TEAP_Reports/index.shtml

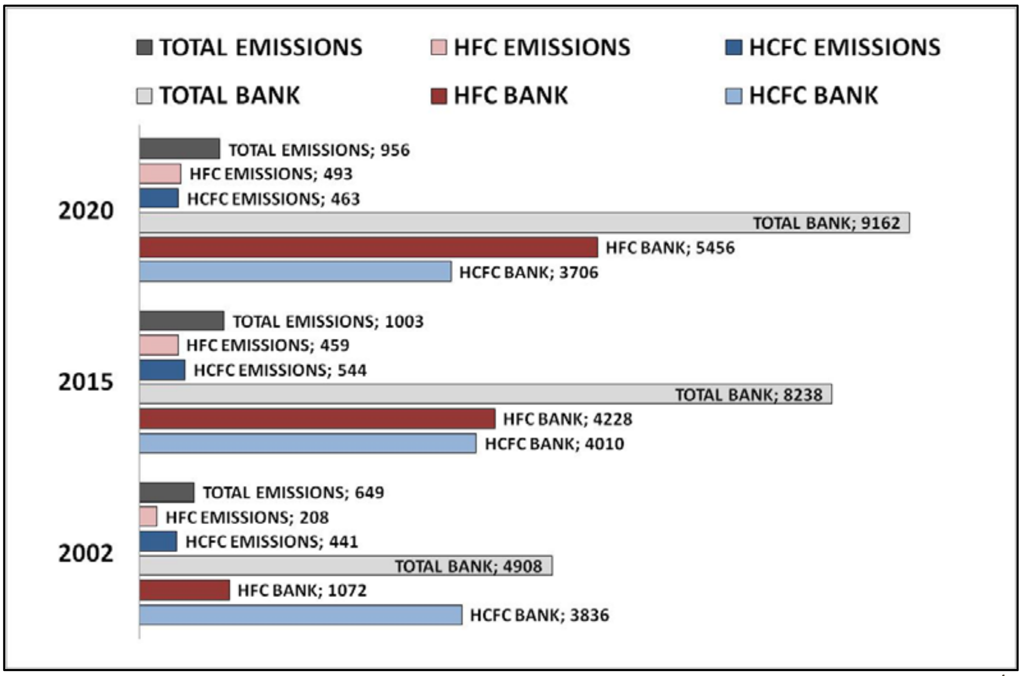

Figure 3. Global refrigerant banks and emissions projections 2002–2020 ($MTCO_2e$)[4]

The Impact of Refrigerant Leakage

A systems approach such as TEWI[5] or LCCP[6], expressed as a carbon dioxide equivalent mass, is frequently used to assess the total direct and indirect emissions over the lifetime of the equipment. The relative weighting between direct and indirect emissions from a RACHP system depends on several factors, including the global warming potential (GWP) of the refrigerant, refrigerant charge, the rate of refrigerant leakage, the cooling load, hours of operation and external temperature and efficiency of the cooling system.

Figure 4 demonstrates the potential impact of refrigerant leakage on TEWI for a high GWP refrigerant (R404A) in typical low temperature (LT) and high temperature (HT) direct expansion supermarket refrigeration systems. The worked examples[7] indicate that annual leakage rates in the range 10% - 20% can double the TEWI of a refrigeration system when using high GWP refrigerants. However, although the direct emissions would be considerably lower from an equivalent system with a similar leakage rate but using a low GWP refrigerant, a less efficient refrigerant could result in increased energy use and higher indirect emissions.

Refrigerant leakage is, however, not just about emissions and global warming because it lso increases costs through:

- reduction in reliability
- increased down-time
- reduced efficiency
- reduced system capacity
- additional costs for replacement refrigerant, service and repairs.

[5] TEWI, Total Equivalent Warming Impact (operation only)

[6] LCCP, Life Cycle Climate Performance (entire live cycle of plant)

[7] Cowan (2013), TEWI calculation using data for refrigeration systems in a UK supermarket chain's 'model store'

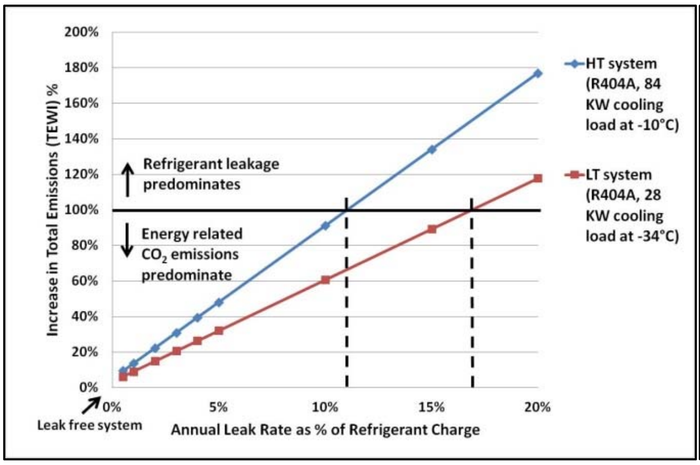

Figure 4. Impact of refrigerant leakage on TEWI for typical R404A refrigeration systems[7]

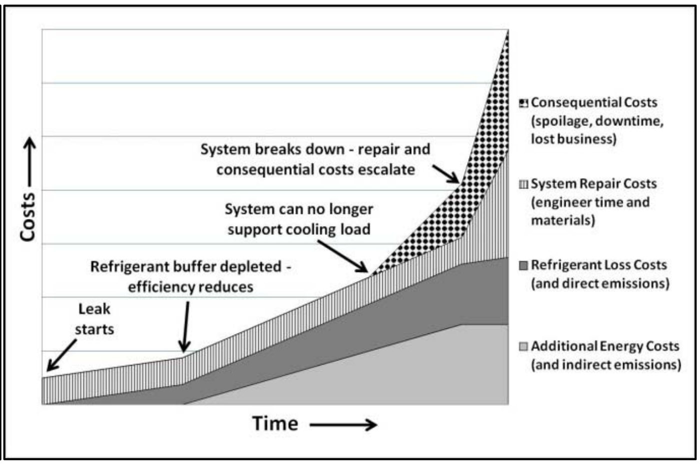

Figure 5. Escalating cost of an unchecked refrigeration system leak[8]

The economic consequences of refrigerant leakage are indicated qualitatively in Figure 5[8]; the actual cost profile will depend on the application, the size of the leak and the time taken to identify and repair it. It should be recognized that even a relatively small leak may significantly increase the annual energy costs for the system. The economic impacts are not restricted to systems employing HFC and HCFC refrigerants, but will also apply to those containing natural refrigerants, such as CO_2, ammonia and hydrocarbons.

Reported refrigerant leakage rates vary considerably between different types of system and in different countries. Table 1 is based on the IPCC 2006 guidelines for reporting greenhouse gas inventories[9] and provides a range of emissions factors for installation and commissioning, operation of the system over its life and at disposal. The emissions factors are typically at the lower end of the range for developed countries and towards the higher end of the range in developing countries. The values for refrigerant remaining and recovered at end of life indicate that in many cases there is no recovery of refrigerant from RACHP equipment at disposal.

Table 1: Range of values for charge and emission factors for RACHP systems[9]

Type of Equipment	Typical Range in Charge Capacity (kg)	Installation Emission Factor (% of initial charge)	Operating Emissions (% of initial charge/ year)	Refrigerant remaining at disposal (% of initial charge)	Refrigerant recovered (% of remaining charge)
Domestic Refrigeration	0.05 - 0.5	0.2 - 1.0	0.1 - 0.5	0 - 80	0 - 70
Stand-alone Commercial Applications	0.2 - 6	0. 5 - 3	1 - 15	0 - 80	0 - 70
Medium & Large Commercial Applications	50 - 2,000	0.5 - 3	10 - 35	50 - 100	0 - 70
Transport Refrigeration	3 - 8	0.2 - 1	15 - 50	0 - 50	0 - 70
Industrial Refrigeration (inc. food processing and cold storage)	10 - 10,000	0.5 - 3	7 - 25	50 - 100	0 - 90
Chillers	10 - 2,000	0.2 - 1	2 - 15	80 - 100	0 - 95
Residential and Commercial A/C including Heat Pumps	0.5 - 100	0.2 - 1	1 - 10	0 - 80	0 - 80
Mobile Air Conditioning	0.5 - 1.5	0.2 - 0.5	10 - 20	0 - 50	0 - 50

Minimizing Leakage over the System Life Cycle

Minimization of emissions must be achieved throughout the entire life cycle of refrigerants (production; storage; transport; operation; recovery; recycling; regeneration and destruction) and there are effective steps that can be taken to reduce leakage at all stages in the life cycle of RACHP plants (design; manufacture; operation; service and repair; decommissioning).

Actions required depend on the type of equipment concerned, and can be divided into broad categories including:

- integrated systems: small commercial and household appliances (refrigerators, freezers, small air conditioners, etc.). Most of these appliances are fully brazed and tightness depends on the quality of brazing: generally, less than 1 or 2 out of 10,000 appliances present defects
- chillers: all components of these systems are normally located in machine rooms, thus facilitating indication of leakage though detection of emissions
- direct-expansion systems with long refrigerant circuits: these systems are used in commercial and industrial refrigeration (particularly in the food industry) and residential space conditioning, and tend to be leak-prone

[8] After ETSU (1997), *Cutting the cost of refrigerant leakage*, Good Practice Guide 178, Energy Technology Support Unit, Didcot, UK.

[9] IPCC (2006), *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston HS, Buendia L, Miwa K., Ngara T, Tanabe K (eds). Published: IGES, Japan.

- vehicle air-conditioning systems: these systems have flexible elastomer hoses and open-type directly driven compressors, so tend to be leak-prone

Emission levels vary according to the type of system and thus require containment policies that are appropriate to the system type and application. Several good initiatives have been taken internationally. One such example is a Code of Conduct[10] that was developed by the UK Carbon Trust, British Refrigeration Association (BRA) and UK Institute of Refrigeration (IoR) and describes a framework and best practice for refrigerant containment. A European initiative that provides information and training in refrigerant leakage reduction skills is REALSkillsEurope[11].

The endeavour to design systems with low charge per kW cooling capacity has been very successful. Application of new types of heat exchangers and designs without receivers has limited the amount of installed refrigerant considerably. However, these systems tend to be even more sensitive to system tightness and leakage has to be minimized to ensure long term proper functioning of the system. These issues have been thoroughly addressed by the IIR Working Party on Refrigerant Charge Reduction[12].

IIR Recommendations

The IIR advises users to take into account suggestions in this note. Above all, the IIR stresses the need:

- in national, international and corporate policy, to give top priority to reducing emissions, and in the case of global warming, to bear in mind the major impact of indirect emissions from energy conversion on global warming when implementing measures;
- to promote the setting up of coherent national plans covering recovery, recycling and destruction;
- to enforce regulations, particularly with respect to illegal refrigerant imports and sale;
- to utilize a life cycle approach in the design, selection installation and operation of RACHP systems;
- to implement financial and regulatory incentives in order to promote recovery, refrigerant emissions reduction and use of low-GWP replacement refrigerants;
- to promote staff and company training and certification in order to ensure compliance with good practice procedures;
- to provide assistance to developing countries in training and certification programmes on refrigerant uses in the framework of official development assistance by developed countries and United Nations agencies.

Such economic policies are enriched by discussions between the partners involved: national delegates of the IIR, organizations representing the various parties concerned, national associations and national refrigeration committees can be key partners.
The IIR is willing to continue to work in liaison with the various United Nations organizations implementing the Montreal Protocol, as well as with committees, professional organizations and governments of its member countries, in order to develop coherent policies.

This Informatory Note was prepared by David Cowan, Issa Chaer, Per Lundquist (Chairman of the IIR Working Party), Graeme Maidment and Didier Coulomb.

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[10] IOR (2010), *Code of Conduct for carbon reduction in the retail refrigeration sector (3 volumes)*. Available on-line from www.ior.org.uk/retail-refri

[11] REALSkillsEurope, *Refrigerant emissions and leakage skills for Europe*. www.realskillseurope.eu

[12] Groupe de Travail de l'IIF sur la réduction de charges en frigorigène, www.iifiir.org/userfiles/file/about_iir/working_parties/WP14_Refrigerant_Charge_Reduction.pdf