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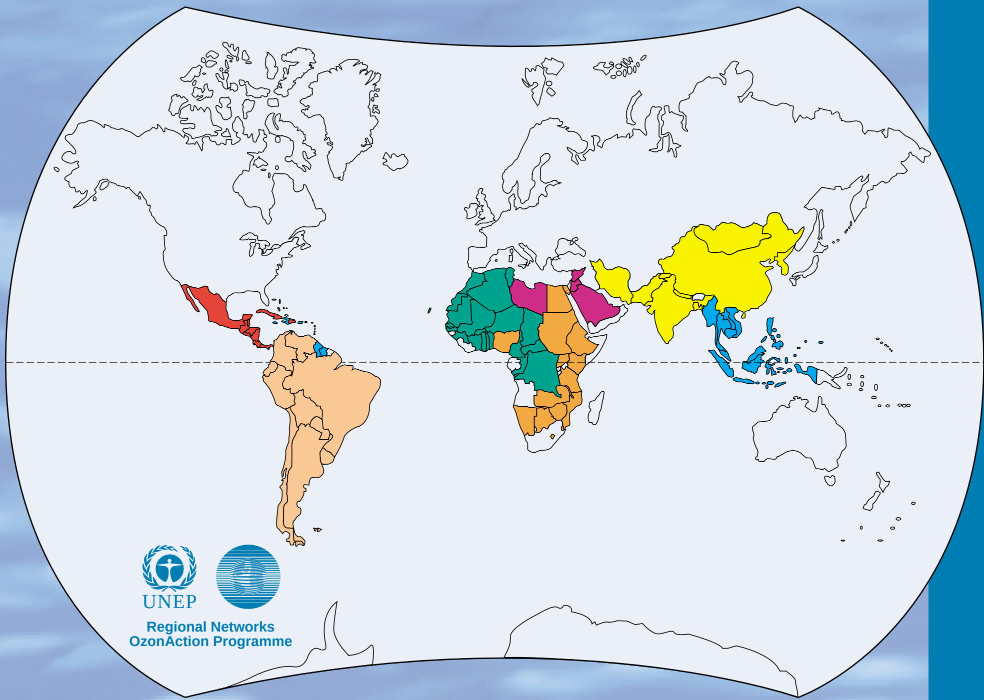

Refrigerants: Standards, Regulations, Safety and Liability Issues

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Refrigerants and the environment – a case study in international cooperation

Designation and safety classification of refrigerants – proposed changes to ISO standard 817

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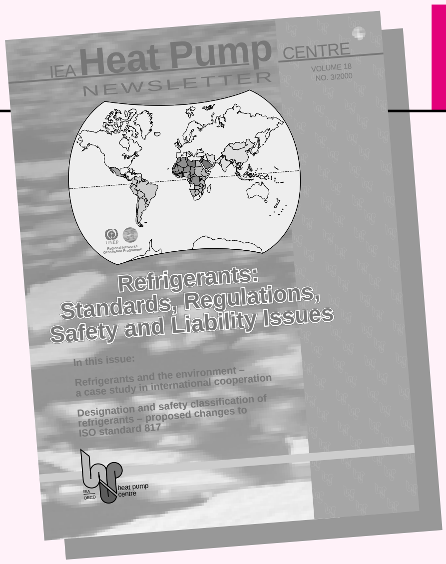

In this issue

Refrigerants: standards, regulations, safety and liability issues

The selection of a refrigerant depends not only on its thermodynamic properties. Standards and regulations for optimal safety for the individual and the global environment as well as liability issues determine our choices to a significant extent. This Newsletter focuses on standards and regulations for refrigerants and deals with both natural and synthetic refrigerants.

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UNEP OzonAction Programme Regional Networks

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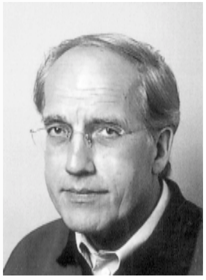
TOPICAL ARTICLES

HEAT PUMP NEWS

FEATURES

Safe refrigerants for our future



What does the future hold in store for heat pumps, refrigeration and air conditioning? In my opinion, environmental issues will dominate our industry and be the major driver for changes in the next few years. Environmental issues have been influencing our refrigerant choices continuously since 1987. CFCs have been phased out in developed countries and HCFCs will be phased out within the next few decades. The global warming potential of HFCs is also an environmental issue, but regulations limit an increased use of alternatives such as hydrocarbons and ammonia.

We know that leakage from existing installations is still high. At present, the average leakage percentage in the Netherlands for all refrigeration systems, air conditioners and heat pumps is probably 15%. Even though this percentage has dropped considerably and can drop further in the future, we should realise that such a drop may still be accompanied by an increase in absolute emissions in kilograms. We should also bear in mind that our synthetic refrigerants are stable chemicals, which should not be introduced into the atmosphere in large quantities.

The Netherlands has a consistent refrigerant registration and control system, which seems to be unique in the world. Many countries have regulations in place that forbid venting refrigerants into the atmosphere, but as these same refrigerants are not even registered, the likelihood of violators being caught is not very great. Better registration and control of refrigerants during their entire life span is one way of ensuring a safer future with regard to their use. Whether it is feasible to implement the Dutch approach on a global scale remains an open question.

For the future, I see only two sustainable options:
- *production of intrinsically tight systems with minimum leakage;*
- *use of natural refrigerants, whereby the energy efficiency of the equipment should not be compromised.*

For the refrigeration, air-conditioning and heat pump industry, this implies that new systems need to be developed, probably using natural refrigerants, and that older installations will need to be replaced sooner rather than later. The year 2000 should present us with some interesting challenges.

Ir. Bob van den Hoogen

Chairman of STEK (Dutch institute for certification of refrigeration)
Secretary/treasurer of NVvK (Dutch association of refrigeration)

Ground-coupled heat pumps in focus at ASHRAE annual meeting 2000

USA – Ground- and water-source heat pumps continue to be a focus of ASHRAE's meetings. Two symposiums and a seminar on ground-source heat pumps as well as a forum and a seminar on water-source heat pumps reflect the important position achieved by these technologies in the commercial and institutional market sectors in the USA.

Markets
In both the USA and Canada there is considerable market potential for ground-source heat pumps (GSHPs). Canada is planning to set up its own organisation to promote the use of these heat pumps. In Europe, ground-source heat pumps dominate the heating-only heat pump market. In 1999, more than 70% (3,400 installations) of the heat pumps installed in Germany in one- and two-family houses were ground-coupled. Important drivers for the growing interest in ground-source heat pumps are the environmental benefits and superior life cycle costs.

Installation problems
Installation problems have limited the rapid adoption of ground-source technology. However, not all problems are related to ground loop technology. An ASHRAE-sponsored study analysed the difficulties reported with GSHP systems in 23 buildings in the Northeast of the USA. In 9 buildings the problems were related to other technologies than the heating and cooling systems. Poor or outdated design was the cause in 11 buildings and construction errors were the cause in 3 buildings. The building types investigated covered a wide range and included schools, a library, manufacturing facilities, a medical centre, a museum, a post office, restaurants and office buildings. An important conclusion of the study was that all of the problems would have been discovered and corrected if the systems had been properly commissioned and started up.

The study concluded with a set of recommendations regarding design and installation, use of antifreeze compounds, heat pump components, internal controls and water flow/pumping. This study shows once again that lack of adequate design and installation skills leads to poor performance. In order to ensure proper system operation, ASHRAE plans to issue recommendations for a review of current technologies and for establishing adequate channels of communication and a proper commissioning procedure.

Systems approach
In another ASHRAE-sponsored study, the relationship between the design of ground-source heat pump installations and geology was analysed. The conclusion was that special attention should be paid to geological and hydrological aspects when designing ground-coupled heat exchangers. The study, based on many years of experience, gives a thorough overview of the factors and issues relevant to a successful ground-source installation. Factors covered include: drilling methods, geology, ground-heat exchangers, hydrology and open-loop systems, including standing column wells and alternative heat exchangers (pond loops, sewage water etc.). Relevant issues are:

- choice of heat exchanger length;
- test borings;
- choice between closed loop, groundwater system, or an alternative;
- minor issues that increase cost (site conditions, disposing of cuttings and bentonite, etc.).

Loop systems
The standing column well, which utilises rock well technology, has become a powerful option for use with ground-coupled heat pumps. Advantages include high energy capacities, lower investment cost and higher efficiency. A pump placed in the top or bottom of the well maintains water circulation. The pipes are made of Cu-Ni and are internally fluted.

Pond/lake systems are also cost-effective. With installed costs in the range of USD 350-400, they are cheaper than horizontal (USD 550-600) and vertical configurations (USD 1,000-1,200) in the US. Pond/lake systems can provide nearly unlimited cooling capacities and are aesthetically appealing. Examples can be found at http://www.loop-group.com.

LCC
One paper discussed the results of a comparative Life Cycle Cost Analysis for ground-coupled heat pumps compared to conventional heating, ventilation and air-conditioning systems for schools in Nebraska, USA. The conclusion was that when capital, operating and maintenance costs are considered, ground-coupled heat pumps have the lowest life cycle cost – about 15% lower than the next most attractive option. The heat pumps also have the lowest energy consumption and the lowest total pollutant emissions of any of the technologies considered. For this application, heat pumps also have a lower investment cost than any of the other systems currently used. These results are in line with a Canadian study carried out in 1999 (see Newsletter 17/3).

Variable-flow pumping
Variable-flow pumping is widely used in GSHP systems as it can save considerable amounts of energy compared to constant-speed pumping. Annual pumping energy use can equal or exceed compressor energy use in the case of constant-speed pumping. One paper assessed the savings achieved when using variable-flow pumping for four ground-coupled heat pump installations in a school, a restaurant, a retail building and a hotel. It was concluded that the magnitude of the savings depends on several factors, including the differential pressure set point used and whether the two-way valves on the heat pumps operate properly. The savings realised with variable-flow pumping compared to constant-speed pumping ranges from 36-88%, and the payback period is 1.7-3.8 years. The lesson to be learned here is that designers and installers must address

Position paper on refrigerants

ASHRAE is working on an update of its Position Paper on Ozone Depleting Substances (ODS). The position paper will provide unbiased information about ODS and clarify ASHRAE's official position. ASHRAE has already published a Climate Change Position Paper. The ODS Paper will be published in the fall of 2000.

all details of variable-flow installation to ensure the maximum possible savings.

Heat-recovery heat pumps

The meeting programme also featured a paper from Canada on heat-recovery heat pumps. There is a growing need in North America to quantify the environmental benefits of such heat pumps. Based on operating experiences with various heat pumps in the process industry, a set of guidelines has been developed. The guidelines allow the user to assess various aspects, such as savings in energy, water and chemical treatment. The guidelines present eight sites and worksheets covering three areas: simple heat-recovery heat pumps, heat pump dryers and mechanical vapour recompression heat pumps. The guidelines are intended to facilitate the technical/economical evaluation of possible benefits so that the process industry can more readily assess the benefits and adopt the relevant technologies.

Jos W.J. Bouma, IEA Heat Pump Centre
More details: http://www.heatpumpcentre.org

Director-at-large

ASHRAE installed Mr Gerald C. Groff as a director-at-large for the period 2000-2003. Mr Groff also serves as chairman of the IEA Heat Pump Programme Advisory Board and as a member of the IIR Scientific Council as President of Section E (air conditioning, heat pumps, energy recovery). As a director-at-large, he serves on the ASHRAE Board of Directors and on the Technology Council, which implements Board policy and administers the activities of the following committees: Environmental Health, Refrigeration, Research Administration, Research Promotion, Standards, Technical Activities, and Technology, Energy and Government Activities.

EPEE to influence European environmental policy

Italy – Air-conditioning firms have joined forces to form the European Partnership for Energy and the Environment, EPEE. EPEE's mission will be to support the continuing use of HFCs and to promote an understanding of the environmental and societal benefits of HFC refrigerants.

Through contacts with the European Commission and EU member states, EPEE will promote the responsible use of HFCs, which includes the following:

- refrigerant containment and minimum leakage rates;
- encouraging the use of recovery and recycling;
- support for voluntary minimum efficiency standards;
- recommending service agreements for commercial and industrial equipment;
- support for technical training.

EPEE will be a broad-based coalition with representatives from the air-conditioning and refrigeration industry as well as other associations and industry stakeholders such as car manufacturers etc. EPEE will be governed by a steering committee, a strategy working group and an advisory board. The initiative for the new organisation was taken by ARI, which organised a meeting on this issue that formally brought together US and European industry representatives.

Source: JARN, May 2000
More information: http://www.epeeglobal.org/overview.html

European Heat Pump News now available

The Netherlands – The first issue of the new quarterly newsletter of the European Heat Pump Association (EHPA), the *European Heat Pump News*, is now available. Its contents will include news from EHPA, the various European markets, standards and regulations relevant to heat pumps and much more.

The European Heat Pump News can be downloaded from http://www.ehpa.org. Furthermore, EHPA offers copies to European HPC Newsletter subscribers. The European Heat Pump News is produced by the same people that staff the Heat Pump Centre at Novem, the Netherlands. For subscriptions, contact the EHPA Secretariat.

EHPA Secretariat: Axel Lehmann,
FIZ Karlsruhe, Germany
E-mail: ale@fiz-karlsruhe.de

Teleconference on efficiency of ground-coupled systems for state, county and municipal buildings

USA – The Geothermal Heat Pump Consortium's (GHPC) tenth teleconference *GeoExchange – Bringing Efficiency to State, County and Municipal Buildings* will focus on explaining the energy and cost saving benefits of ground-coupled heat pump technology to state and local officials. It will be broadcast live via satellite, Wednesday 15 November 2000 from 12:30-14:30 EST (Eastern Standard Time). For the first time, the teleconference will also be available globally on the Internet through live audio-video streaming at the GHPC Internet site, http://www.geoexchange.org.

More information: Sara Quinn
Fax: +1-202-5085222
Internet: http://www.geoexchange.org

IPUHPC E-mail changed

IPUHPC, the International Power Utility Heat Pump Committee, discussed in HPC Newsletter 18/2, has a new contact E-mail address. Anyone interested in IPUHPC's activities should contact Mike Bell at mikebell2@sympatico.ca.

Ground-coupled heat pumps in Beijing

China/USA – For the first time, ground-coupled heat pumps will be used to heat and cool a 33-story luxury apartment building in Beijing, China. The building, the Concordia Plaza, is located in the downtown commercial centre of Beijing and will house more than 300 families. The Concordia Plaza project will use more than 500 heat pumps and is the first ground-coupled heat pump project of this size in China.

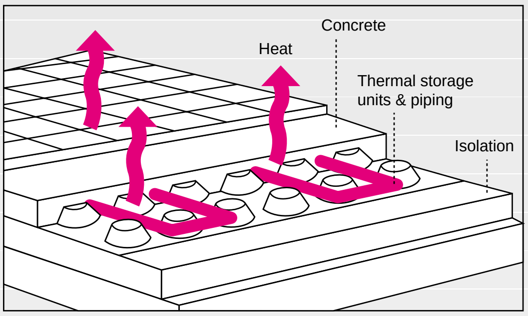
The project is a result of the efforts by the Geothermal Heat Pump Consortium (GHPC) to create opportunities for US products in the international marketplace. The US and Chinese partners signed the project agreement at the US Department of Energy Headquarters in February 2000.

Source: Earth Comfort Update 7/2

Phase-change heat storage in floor

The Netherlands – The Australian company TEAP (Thermal Energy Accumulator Products) has developed an Under-floor long-life heating system that relies on phase-change thermal storage. A solar panel on the roof or a heat pump heats water, which is pumped through pipes in a thermal bank under the floor and triggers the phase-change thermal storage units to absorb heat or release it to the room above, as required. The arrangement is shown in the Figure. The thermal storage units contain a mineral salt solution, which is non-flammable and non-toxic and enhances the storage capacity of a floor by a factor of about 10. The Dutch company LUWA BV markets the above system in the Netherlands with a phase-change temperature of 29ºC under the name of TH29.

▼ *Figure: Floor with thermal storage system.*



More information: LUWA BV
Tel.: +31-35-5415551
E-mail: infosustain.mrg@luwa.nl

ASHRAE Award for ground-coupled system for nursing facility

USA – The Quality Living Inc. (QLI) East Campus facility was granted one of the ASHRAE Technology Awards for the year 2000. QLI is a skilled nursing facility with over 100 nursing units, which provides unique therapies to promote brain injury rehabilitation.

The 8,900 m^2 facility is served by an 844 kW ground-source heat pump and an additional hot water boiler. A 20-year life cycle cost analysis showed that this would be the most energy efficient choice. Energy recovery ventilators (ERVs) with desiccant wheels capable of sensible and latent heat recovery are applied. The ERVs enhance indoor air quality and occupant comfort.

The soil conductivity testing that was done in the preliminary stages of the ground loop heat exchanger design contributed greatly to the cost effectiveness of the system. The actual test data helped to determine the optimum borehole depth, number of boreholes required and the most effective type of grout. Four different types of grout were tested during a two-day period. The test results justified a reduction in the required borehole depth, which saved 1,728 m of pipe.

Source: ASHRAE Journal, June 2000
More information: www.ashraejournal.org

Heat pump projects at Hanover EXPO 2000

Germany – The World Exposition EXPO 2000 in Hanover, Germany, will for the first time include projects from the surrounding region. One of the exhibits is the ‘Energy and environment boulevard’, created by the utility of Minden-Ravensburg (EMR), which exhibits three interesting heat pump projects.

The first two projects, one in the residential area of Spenge (140 residences) and the other in Herford (240 residences, mostly multi-family houses) both use industrial waste heat as a heat source for space heating and domestic hot water. A pumping station (with backup heater) distributes the industrial waste heat (around 20ºC) through uninsulated pipes to the residences. In Spenge each single-family home has its heat pump for space heating. The waste heat comes from a weaving mill. In Herford there is one heat pump per multi-family house, which produces heat at 35-50ºC for space heating and heat at 60ºC for domestic hot water. The waste heat comes from a dairy plant.

In the third heat pump project on the ‘Boulevard’ heat is extracted from the ground. A central heat pump and pumping plant raises the temperature of circulating water to 15ºC. It serves as a heat source for the heat pumps in individual residences.

Source: Wärmepumpe aktuell, June 2000
More information: http://www.emr.de

Residential CO_2 heat pump water heater

Japan – Denso Corp., Kariya, Japan and Tokyo Electric Power Co. (TEPCO), Japan have jointly developed a residential CO_2 heat pump water heater and are now carrying out demonstration tests with the aim of realising commercialisation within the year.

The new water heater is intended to supply hot water, which accounts for about 35% of energy consumption in the residential sector. Its COP will be high (over 3.0) and the operating costs low. Moreover, since CO_2 is utilised as the refrigerant, it is an environmentally friendly unit, which can contribute to the reduction of greenhouse gas emissions and help prevent ozone layer depletion.

Unlike conventional CFC heat pump water heaters, which can supply hot water at a maximum temperature of 60°C, the CO_2 water heater can heat water up to 90°C even in very cold districts, due to the excellent heating capacity of the CO_2 refrigerant. This is an important feature in Japan. In addition, the heat pump unit can be designed very compactly, thus allowing greater flexibility with regard to choice of installation area.

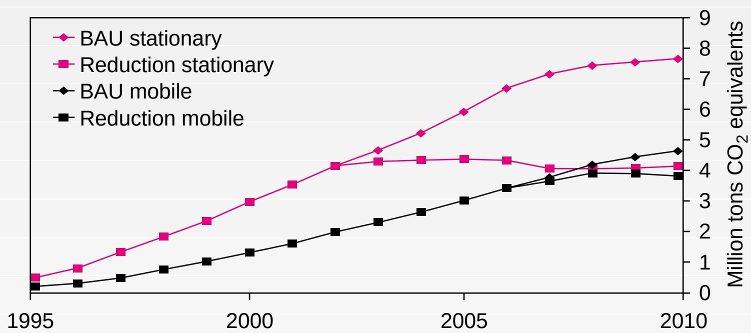
Source: JARN, April 2000

Germany predicts its HFC emissions

Germany – HFC emissions from refrigerating and air-conditioning equipment will probably constitute around 1.5% of the total German greenhouse gas emissions in CO_2 equivalents by the year 2010 (business as usual scenario). A study initiated by the German Federal Environmental Agency recommends mandatory regular inspection and maintenance for all heat pumping equipment as a means to reduce these emissions, with the exception of small appliances such as most residential heat pumps. Figure 1 shows emissions for a business as usual (BAU) and a reduction scenario for stationary and mobile applications.

For stationary refrigeration, the reduction scenario assumes mandatory inspection and maintenance of all equipment from 2003 onwards, except for the smallest appliances. Both scenarios assume that the use of different refrigerants, in particular ammonia and hydrocarbons, will not be a mainstream alternative in commercial refrigeration (>40% of stationary refrigerant stock). The indirect systems required for applying ammonia and hydrocarbons are not sufficiently attractive because of higher cost and perceived additional energy use.

Figure 1: Predicted CO_2 equivalent emissions from HFCs in Germany.



For mobile air conditioning, the significant growth in penetration of air conditioners in cars to 75% of total stock leads to the prediction that 95% of emissions from mobile air conditioning in 2010 will be from cars. In 1995, only 24% of new cars had air conditioners. Annual refrigerant emissions rates from car air conditioners have decreased from 30% of total charge in 1992 to 10% in new systems. R-134a is almost always used. The reduction scenario assumes that transcritical CO_2 will be introduced as a refrigerant from 2007 onwards.

Source: KI Luft- und Kältetechnik, 4/2000
More information: http://www.oekorecherche.de/

R-407C composition control system

Japan – Matsushita Refrigeration Co., Osaka, Japan has developed an R-407C composition control system – the first of its kind in the world. This system can yield annual energy savings of 25% and a 20% improvement in capacity, at low cost without using an inverter, by adjusting the R-407C mixing ratio to the operational load.

R-407C is a ternary refrigerant composed of three different HFCs, each of which has different properties. It is currently used in packaged air conditioners, reciprocating chillers, etc. The new system controls the composition of the refrigerant circulating through the cycle by means of a rectifying/separating circuit (rectifying column, storage unit, etc.). The capacity can be adjusted within a range of about 70-120% for the refrigeration system and about 50-150% for compressor capacity.

Matsushita Refrigeration plans to realise commercial application of the new control system for packaged air conditioners (PACs) in the latter half of 2001 and to facilitate its application for vending machines, etc.

Source: JARN, April 2000

France: requirements for leak detection

France – It is now a legal requirement that all air-conditioning and refrigeration systems in France holding more than 2 kg of refrigerant (including HFCs) must be subjected to annual inspection. If leaks are detected, operators have to pay a fine. The law was recently updated with the publication of a document defining accuracy limits for measuring equipment. Hand-held detectors should be able to measure leakage rates down to 5 g per year and ambient concentrations down to 10 ppm. An appraisal of eleven different commercially available detectors was recently published in France. All but one met the requirements.

Source: JARN, June 2000

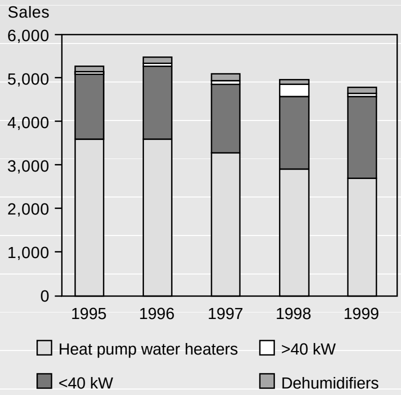
Austria: 1998 trends extend into 1999

Austria – In 1999, 4,723 heat pumps were installed in Austria with 38 MW of total heating capacity. The number of space-heating systems installed increased by 15% from 1998, whereas the figure for heat pump water heaters decreased by 19%. These percentages illustrate a stable trend - the figures were the same for the previous year. Figure 1 shows the development of the market for heat pump water heaters, space-heating heat pumps (in size classes < 40 kW and > 40 kW) and (swimming pool) dehumidifiers from 1995-99.

In 1999, ground-source heat pumps remained by far the most popular, accounting for 80.6% of the heat pumps installed for space heating.
Most of these (60.2%) were direct expansion installations. Next in popularity were water-to-water heat pumps (15.8%), while air-to-water types had only a small and apparently decreasing market share (3.6%).

The choice of working fluids is moving further in the direction of chlorine-free and natural substances. A rough estimate is that 74% of the heat pumps (including water heaters) use chlorine-free working fluids, with R-407C (35%), R-134a (24%) and R-1290 (9%) being the most popular.

Source: G. Faninger, Wärmepumpenmarkt in Österreich 1999, Fax: +43-1-5050928

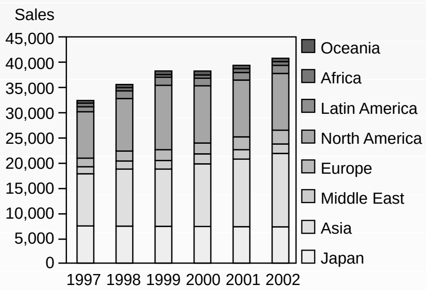


▲ *Figure 1: Austrian heat pump sales.*

Global market for air conditioners

Japan - The 1999 world shipments of room air conditioners (RACs) and packaged air conditioners (PACs) are estimated to be 38 million units, which shows a substantial increase of 3 million units compared to 1998.

In the USA, more air conditioners were sold than ever before, and the Chinese market surpassed Japan as the second market for air conditioners in the world with an estimated 8 million units sold in 1999. The European market is estimated to have expanded to 2.3 million units in 1999 (up about 30% from the previous year). Especially in southern Europe, air conditioners are increasingly regarded as necessary appliances. More than 50% of the European sales are reversible heat pumps.



▲ *Figure 2: Global market for air conditioners.*

Figure 2 shows the results of a survey of the Japan Refrigeration and Air Conditioning Industry Association (JRAIA) to estimate the global demand for air conditioners. The survey covered room air conditioners (RACs) and packaged air conditioners (PACs), collected and analysed data up to 1998 and estimated demand for 1999-2002 based on the perceived tendencies. The Asian (excluding Japan) and European markets are expected to show an annual growth of about 7%.

Major Japanese manufacturers produce RACs using R-410A, and variable refrigerant flow systems for commercial applications using R-407C. The range of HFC products is gradually increasing. Shipments of HFC-based RACs are estimated at 6-8% of the total in 1999. JARN notes that US manufacturers are slower to release new products with HFC refrigerants. Unlike Japan and Europe, US industry seems to shift directly toward R-410A instead of going through an intermediate phase utilising R-407C.

Source: JARN, May & June 2000

Germany: continued growth

Germany – In 1999, according to the statistics of IWP e.V. (Iniativkreis Wärmepumpe), 4,719 heat pumps for space heating were installed in Germany. This corresponds to an increase of 8% compared to 1998 (see Table below). Over the same period, housing construction decreased by 20%. Heat pump water heaters are not included in these statistics.

▼ *Table: Residential heat pump sales in Germany.*

1995	1,850
1996	2,310
1997	3,578
1998	4,367
1999	4,719

Ground-source heat pumps had a market share of 70%. Vertical collectors (30-100 m deep) were generally used, as the available surface area for newly built houses does not allow horizontal installation. Prices for installing vertical collectors have come down in recent years.

Source: Wärmepumpe aktuell, June 2000

IIR and IEA draft agreement on collaboration

The Netherlands – The International Institute of Refrigerati e (HPP) are working on an agreement on collaboration, which will be formalised before the end of 2000.

The missions of the IIR and HPP are complementary. The HPP plays a deployment and promotional role in the heat pump sector and related fields of technology; the IIR plays a scientific and technical role in the entire field of refrigeration technologies. The agreement will strengthen the collaboration between the two organisations for the benefit of both.

Source: IEA Heat Pump Centre

User experience with design tools

Contributors to the project are sought

The Netherlands – The Internet site of the IEA Heat Pump Centre will publish results of an assessment of user experience with design tools (software, design guides and handbooks), which is meant to facilitate the choice of these tools.

The scope of the project includes design programs and guides for heat pump system design (incorporation in a residential or commercial building or an industrial process), as well as design tools that allow sizing of heat pump components. Programs that are generally available and guides in the English language will be included; tools in other languages will not be considered in detail.

The results of the project are of special interest to designers, heat pump manufacturers and suppliers, contractors, installers and suppliers of the design tools. The project is carried out by Interduct, the Delft University Clean Technology Institute in the Netherlands (http://www.interduct.tudelft.nl).

The project team is looking for:

- design tools relevant for inclusion in the survey, including name and address of the supplier;
- suppliers of design tools;
- users of design tools.

If you want to contribute to the project, please send an E-mail to Mail@Interduct.tudelft.nl.

Source: IEA Heat Pump Centre
More information:
http://www.heatpumpcentre.org/tools

Annex 25 briefs

The Netherlands – The projects that will be contributed to Annex 25 *Year-round residential space conditioning using heat pumps* have taken shape. The objective of the Annex is to define and demonstrate the technical feasibility of new packaged heat pump systems for year-round space conditioning. Task 1 is in its final stage. It includes the analysis of existing systems and the definition of market needs. Tasks 2 and 3 aim to realise on-site field tests in collaboration with manufacturers.

In France, the theme of the on-site field tests will be residential floor heating and cooling in combination with fan coils on the upper floors. In the Netherlands, the focus will be on an integrated solar-assisted water-to-water heat pump for heating, free cooling, domestic hot water production and regeneration of the ground. Sweden will concentrate on a ground-coupled system with floor heating/cooling and domestic hot water production. The USA will focus on a comparison of various air and hydronic heat distribution systems and humidity control systems.

Source: IEA Heat Pump Centre
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Books and Software

Find actual information on Books and Software at the News section of our Internet site: http://www.heatpumpcentre.org/news

Ongoing Annexes

Red text indicates Operating Agent.

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IEA Heat Pump Programme participating countries: Austria (AT), Canada (CA), Denmark (DK), France (FR), Germany (DE), Italy (IT), Japan (JP), Mexico (MX), The Netherlands (NL), Norway (NO), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK), United States (US).

Refrigerants: standards and regulations for safety and sustainability

Gerdi Breembroek, IEA Heat Pump Centre

The future needs globally and locally safe heat pumps. This will require refrigerants with no ozone depletion potential, a minimum contribution to global warming and a minimum risk to their installers and users. This article discusses regulations that determine the choice of refrigerant.

The Montreal and Kyoto protocols are international agreements to combat the effects of ozone depletion and global warming respectively. An up-to-date phase-out schedule is published in the box on page 12 (Source: IIR).

Montreal Protocol

The Montreal Protocol, agreed on in 1987, has been ratified by 174 countries. It calls for the phase-out of CFCs and HCFCs, as these contribute to the depletion of the ozone layer. In the developed countries, CFCs have already been phased-out. Developing countries started the phase-out process last year. UNEP facilitates technology transfer to promote the phase-out; see article on page 22.

The article on page 15 discusses policies on emissions reduction and phase-out. It expresses concern that political decisions do not always serve the intended goal in the best possible way. In developed countries, there is concern over illegal trade and illegal dumping or venting. UNEP perceives a lack of control measures to phase out HCFCs.

The UNEP Technology and Economic Assessment Panel - Technical Options Committee Refrigeration, Air Conditioning and Heat Pumps - has started work on the 2002 Assessment Report, of which developing countries will become an integral part.

Kyoto Protocol

The Kyoto Protocol, agreed on in 1997, has not yet been ratified by a sufficient number of countries. The main aim of the 6th Conference of the Parties (COP 6, held in The Hague, the Netherlands, 13-24 November 2000) is to achieve increased ratification of the Protocol.

Under the Kyoto Protocol, each developed country has an individual target. By 2008-2012, their combined targets will reduce greenhouse gas emissions by at least 5% from 1990 levels. These commitments cover emissions of the six major greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluorides (SF_6).

Heat pumps contribute to global warming directly through emission of refrigerants and indirectly through emissions resulting from generation of the energy used by the heat pumps. The non-ozone depleting HFCs have a significant global warming impact. CO_2 emissions from electricity generation vary by method and technology status, from zero for hydropower plants to more than 1 kg CO_2/kWh_{el} for old coal-fired power plants. CO_2 emissions from energy use constitute some 90% of a heat pump's contribution to global warming whereas HFC refrigerants contribute less than 10%.

Emission reductions

The Kyoto Protocol calls for emission reductions rather than the phase-out of specific substances. Measures to reduce emissions should take into account the entire life cycle of the equipment. Reduction of refrigerant emissions should not lead to lower energy efficiency, as this generally leads to increased CO_2 emissions.

Such measures may include:

- charge reduction;
- refrigerant containment throughout equipment life cycle;
- (mandatory) plant monitoring and maintenance logbooks;
- refrigerant recovery throughout refrigerant life cycle;
- proper disposal;
- certification of installers and systems.

On a global level, measures to reduce non-CO_2 greenhouse gas emissions are still in their infancy. Some countries have a rigorous refrigerant management system; others have no regulations at all to prevent leakage. Denmark has proposed the phase-out of HFCs before 2006, and the UK proposes similar measures. The Dutch government has started a programme to subsidise initiatives that support its emission targets. It aims to reduce the annual non-CO_2 greenhouse gas emissions by 8,000,000 tons CO_2 equivalents by 2012. Starting in 2001, Japan will implement a law requiring the recycling of specific kinds of home appliances, including residential refrigerators and air conditioners.

Effective refrigerant recovery programmes will contribute significantly to emission reductions. The Heat Pump Centre recently started the project *Refrigerant recovery and recycling: an international assessment.* This is a survey to document recovery, reclamation, and recycling policies in major markets in Asia, Europe, and North America. The scope includes relevant standards and regulations, economic incentives, any evidence of reduced refrigerant leakage, an analysis to quantify emission reduction benefits, as well as an assessment of the effectiveness of the different approaches and how they can be transferred to other countries.

Standards for local safety

Manufacturers, installers or operators of heat pump systems consider local safety (i.e. prevention of accidents) of equal importance to global safety. Since the first electrical code was implemented in 1897, safety standards have been developed for many appliances. Standardisation bodies are continually adapting such standards to meet the ever-changing demands of new technologies.

Safety standards pertinent to refrigerants used in refrigeration, air conditioning and heat pump equipment are formulated by the ICE and ISO, both of which are international bodies. National and regional standardisation bodies set their own agendas but cooperate with these international bodies in the interest of efficiency. The article on page 13 discusses the structure of and collaboration between international standardisation bodies.

The use of ammonia and hydrocarbons as refrigerants does not pose a threat to the environment. Unfortunately, they do present local safety concerns, relating respectively to toxicity and flammability. CO_2, as a refrigerant in a transcritical cycle, offers an alternative with no ODP and negligible GWP, which is non-toxic and non-flammable, but requires higher operational pressures than conventional refrigerants. Interest in CO_2 is increasing rapidly, and the first CO_2 heat pump water heater is expected to come out next year (see page 7).

Requirements

How do standards set directives for the safe use of refrigerants? First, they must define parameters that can be used to classify refrigerants with regard to safety, such as flammability, toxicity, occupancy type of the building etc. Different situations require different safety measures. For example, the informative annex of European EN378 gives maximum charges for various refrigerants, depending on:

- safety classification of the refrigerant;
- occupancy type of the building (ranging from open to the general public to only accessible for persons who know the safety requirements);
- type of installation/system (direct, indirect)
- installation in human occupied space, special machinery room or outdoors.

Status worldwide

On a global level, work on requirements for safe refrigerant use was taken up by a joint working group of IEC/SC61D and ISO/TC86/SC1 (TC = technical committee, SC = subcommittee). It was set up to achieve a joint basis for refrigerant safety requirements in an amendment to IEC 60355-2-40 (Safety of household and similar electrical appliances - Part 2: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers) and ISO 5149 (Mechanical refrigerating systems used for cooling and heating - Safety requirements). Recently, ISO/TC86 directed its subcommittee 8 to include refrigerant safety classifications in ISO 817 as well. The article on page 17 presents the activities of the working group subsequently established to do this.

The joint working group and ISO/TC86/SC8 address such issues as:

- flammability classification; the article on page 19 discusses the problems associated with current criteria and proposes the R-ratio to distinguish low-flammable from high-flammable gases;
- permissible refrigerant charge in a room; depending on air circulation in the room, refrigerants heavier than air may accumulate near the floor and present an additional risk.

An overview of safety standards applicable to refrigerants in heat pumps is given in HPC-WR21: Natural working fluids – a challenge for the future (1999).

Status in Europe

Standard EN378:2000 (Refrigerating systems and heat pumps – safety and environmental requirements) has been accepted. The informative annex of this standard gives maximum charge criteria for all refrigerants, and states that the use of hydrocarbons is not allowed in direct, indirect open or indirect vented open systems for air-conditioning and heating for human comfort. EN378 takes precedence over the corresponding national standards.

Working group 6 of CEN/TC182 was established to update the current version of EN378 and to harmonise it with the EU Pressure Equipment Directive (PED) as well as the EU Machinery Directive. Working group 5 of CEN/TC182 *Risk assessment of use of flammable refrigerants* is now working on domestic refrigerators; other equipment will probably follow.

Installers

Safe installation and operation not only requires safe equipment, but also skilled installers. The USA has certification programmes for installers. ARI (http://www.ari.org) supplies information on this. Although the EU SAVE project *Certification of heat pump technologies and installers* initiated action to arrive at a common European approach, much more needs to be done. This topic will be the subject of a workshop on 13 December 2000 in Paris; see page 27. Austria also has an installers' certification programme (see Newsletter 17/4), and the first installers have already been certified.

Regional choices

Differing priorities lead to different choices of refrigerants. In the US legal climate, where product liability suits and jury awards for millions of dollars in damages are common, manufacturers are held strictly liable for the safe use of their products. As a result, they are not likely to choose for hydrocarbons and the local risks associated with these compounds. In addition, these refrigerants often do not comply with US standards and regulations.

In Europe, the liability climate is different. Hydrocarbons and ammonia are considered a sound ecological choice in various European countries. A Swiss legal expert has made it clear that the use of these refrigerants will not be considered defective, and that manufacturers will not be held liable as long as their equipment complies with relevant standards and certain safety precautions have been taken (see also Newsletter 18/2).

Currently, Japanese manufacturers actively market heat pumps with HFC refrigerants. Japan recognises that a high energy efficiency mitigates global warming. Ambitious energy efficiency targets for room air conditioners have been set. When used in small quantities, low-flammable working fluids may be acceptable. Some of these working fluids also have excellent thermodynamic properties. The article on page 19 presents the Japanese views on this subject.

Conclusions

In developed countries, regulations based on the Montreal Protocol have for the most part already been established. Even though some hurdles for a successful phase-out still exist, they will be overcome and the intended result is clear. The policies needed to implement the Kyoto Protocol have not yet taken firm root. Various countries have differing policies on emission reduction of HFCs, varying from a proposed phase-out to regulations for refrigerant containment.

Safety standards had to be adapted in response to the changes brought about by the Montreal Protocol. Worldwide, standards organisations are now engaged in the difficult process of formulating their views regarding the safe use of HFCs, hydrocarbons, ammonia and possibly CO_2 in heat pump, air conditioning and refrigeration systems.

Gerdi Breembroek
IEA Heat Pump Centre

International regulations	CFCs Montreal Protocol[1]	HCFCs Montreal Protocol[1]	HFCs Kyoto Protocol
Montreal Protocol[1]			
developed countries			
- production	banned as of 1 January 1996	[2]	
- consumption	banned as of 1 January 1996	banned as of 1 January 2030	
developing countries			
- production	banned as of 1 January 2010	[2]	
- consumption	banned as of 1 January 2010	banned as of 1 January 2040	
Kyoto Protocol[3]			
industrialised countries[4]			
- emissions			mean reduction of 5.2%[4] with differentiation on a per-country basis
European regulations	**New regulation[5]**	**New regulation[5]**	
- production	banned as of 1 January 1995	banned as of 1 January 2025	
- sale	banned as of 1 January 2000[6]	banned as of 1 January 2010	
- use	banned as of 1 January 2001[6]	banned as of 1 January 2001 in certain new plants[7] and banned as of 1 January 2010 in maintenance and servicing operations[8]	
- recovery of refrigerants	compulsory for all equipment with the exception of household appliances[9]	compulsory for all equipment with the exception of household appliances[9]	
- leak tightness check	annual if the refrigerant charge is >3 kg	annual if the refrigerant charge is >3 kg	

Footnotes

1. The Montreal Protocol and subsequent Amendments, including those concluded in Vienna and Montreal
2. The Beijing Amendment signed in 1999 but which has not yet come into force: this Amendment stipulates a ban on production of HCFCs as of 2004 in developed countries and as of 2016 in developing countries
3. The Kyoto Protocol: this protocol has not yet come into force; as of August 7, 2000 it had been signed by 84 Parties and ratified by 23 Parties
4. Mean emission reductions for the GHGs (greenhouse gases) included in the basket in 38 industrialised countries over the 2008-2012 period with respect to 1990 or 1995 levels. Reduction objectives: -8% in the European Community; -7% in the US; and -6% in Japan
5. The new European regulation had not yet come into force at the time this article was being written and remains subject to changes; it will supersede Regulation 3093/94 dated 15.12.94 presently in force
6. Ban on use in maintenance and servicing of plant
7. Ban on use in the following new plants: storage depots and warehouses in the public sector and sale of equipment with shaft power of 150 kW or more; the ban on use applies to the manufacturing of all new refrigerating or air-conditioning equipment as of 1 January 2001, with the exception of certain dispensations applying up until 1 January 2004
8. Ban on the use of new HCFCs in plant maintenance and servicing
9. Compulsory recovery of refrigerants from all refrigeration and air-conditioning plants, with the exception of household refrigerators and freezers.

▲ *Table 1: Worldwide and European regulations concerning CFCs, HCFCs and HFCs: summary. Source: IIR (International Institute of Refrigeration).*

Refrigerants: regulations and standards

Daniel Colbourne, UK

The introduction of the Montreal Protocol (MP) induced massive change in the global refrigeration industry by forcing the move from chlorofluorocarbons (CFCs), and soon hydrochlorofluorocarbons (HCFCs), to other alternatives. Due to environmental awareness and competition between suppliers of various refrigerant options, major changes in refrigerant usage and practices took place. This article aims to identify the various levels of legislation and standards that affect refrigerant application.

The Montreal Protocol and its Amendments call for a phase out of CFCs and HCFCs. Deadlines set by signatories to the Protocol and by the European Union are shown in the Table on page 12.

Use of ozone depleting substances (ODSs)

National legislation has not necessarily followed the official deadlines. Concerning CFCs, for example, Indonesia has prohibited manufacture and import of CFCs since 1998. India has just published its new ODS regulation which states that no new units or appliances may be manufactured or sold after 1 January 2003. Production and consumption of CFCs in China will be stopped by 1 January 2010. Concerning HCFCs, the USA has set deadlines of 2010 and 2020 for HCFC-22 and HCFC-123 respectively.

Use of greenhouse gases

The threat of global warming from the emission of greenhouse gases (GHGs) has led to another international treaty, the Kyoto Protocol (KP) of 1997, formulated within the United Nations Framework on Climate Change Convention (UNFCCC). Unlike the MP, the Kyoto Protocol aims to reduce emissions rather than ban any specific substance. The overall aim is to reduce total global GHG emissions to 5% below 1990 emission levels. A basket of gases, including carbon dioxide and hydrofluorocarbons (HFCs), were designated as those to be reduced.

By late 1999, 84 Parties had signed the KP, but only 19 Parties had ratified it. After more than 55 Parties have ratified it, accounting for over 55% of global GHG emissions, the KP will enter into force. The aim is to achieve this by 2002.

Within Europe, the European Parliament has published its "Council decision for a monitoring mechanism of community CO_2 and other greenhouse gas emissions". The objective is full commitment by the European Commission (EC) to the limitation of GHG emissions. This equates to a reduction of EU emissions to 8% below 1990 levels. Both the Danish and UK governments have already issued draft policies that include the limitation of HFCs in refrigeration, heat pump and air-conditioning applications.

The Danish policy specifies fixed phase-out dates for HFC in various equipment types, ranging from 1/1/2003 to 1/1/2006. In some types, where there is no suitable alternative, phase-out dates are not provided. The proposals apply only to new products; existing products may continue to use HFCs until the end of their lifetime. The proposals apply only to products used in Denmark, implying that equipment for export may continue to contain HFCs. The marketing and sale of imported products containing HFCs will also become prohibited in Denmark.

The UK Department of the Environment, Transport and the Regions has published a draft programme on climate change, which outlines strategies to deal with global warming emissions. Its goal is similar to the Danish, stating: "Although HFCs are necessary in some applications to meet Montreal Protocol commitments, the Government is concerned that emissions from these sources are forecast to grow strongly in the near future. It believes that this trend is unsustainable in the longer term and that action should be taken to limit the projected growth." This is a clear signal from the Government meant to allow industry and users to make investment decisions with more certainty. The key elements of the UK policy on HFCs are:

- HFCs are not a sustainable technology in the long term. HFCs are only necessary to replace ozone-depleting substances in some applications. The government believes that continued technological developments will lead to complete replacement of HFCs;
- HFCs should only be used if there are no safe, technically feasible, cost-effective and more environmentally acceptable alternatives;
- HFC emission-reduction strategies should not undermine commitments to phase out ozone depleting substances under the Montreal Protocol;
- HFC emissions will not be allowed to rise unchecked.

The legislation resulting from the review and public consultation of the Danish and UK draft policies is likely to be published towards the end of 2000.

Standards

Various standards exist concerning the use of refrigerants, including those for refrigerant quality, properties and system performance, but safety standards are the most significant for application issues. On an international level, standards activities are progressing in the International Organisation for Standardisation (ISO) and the International Electrotechnical Commission (IEC). In Europe, similar activities take place within the Comité Européen de Normalisation (CEN; European Committee for Standardisation) and the Comité Européen de Normalisation Electrotechnique (CENELEC; European Committee for Electrotechnical Standardisation), and locally within the relevant national standards organisations. The standards most relevant to the application of refrigerants are summarised in **Figure 1**. IEC standards generally deal with issues relating to electrical equipment and appliances, and ISO standards with other general matters. For refrigeration and air-conditioning, ISO standards apply to industrial and large-scale commercial sectors and IEC standards concern domestic and small-scale commercial sectors.

Within Europe, standards for electrical equipment are first agreed on by the relevant international committee (IEC) and once ratified under the IEC/CENELEC Dresden Agreement, they are passed on to CENELEC for consideration as a European standard. Once ratified on a European level, these standards achieve the designation ‘EN’ instead of ‘IEC’. They must be adopted as a national standard by the European member states within six months of publication to become – for example within the UK – prefixed with ‘BS EN’. The Vienna Agreement formalises a similar transition process between ISO and CEN. An ISO or IEC standard does not take precedence over a national or European standard unless it has first been adopted by CEN, CENELEC or the national standards organisation. Countries outside the EU have similar processes for formulating standards.

Key international standards relevant to refrigerant usage are:

- ISO 817:1974 *Organic refrigerants - number designation*;
- ISO 5149:1993 *Mechanical refrigerating systems used for cooling and heating - safety requirements*;
- IEC 60335-2-24, *Ed.5: Particular requirements for refrigerating appliances, ice-cream appliances and ice-makers*;
- IEC 60335-2-40, *Ed.3: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers.*

In Europe, the recently ratified EN 378:2000 *Refrigerating systems and heat pumps - safety and environmental requirements* covers most refrigerant applications. Outside the EU, many countries have their own national safety standards such as AS/NZS 1977: 1998 (Australia and New Zealand) and ASHRAE-15 (North America). Countries without a national standard tend to rely on international standards or another country’s national standard.

Safety standards indicate industry best practice and do not have legal status, unless relevant national legislation exists. In most societies, conformity to the relevant safety standard can be used as defence in a court of law to prove that adequate safety measures were taken.

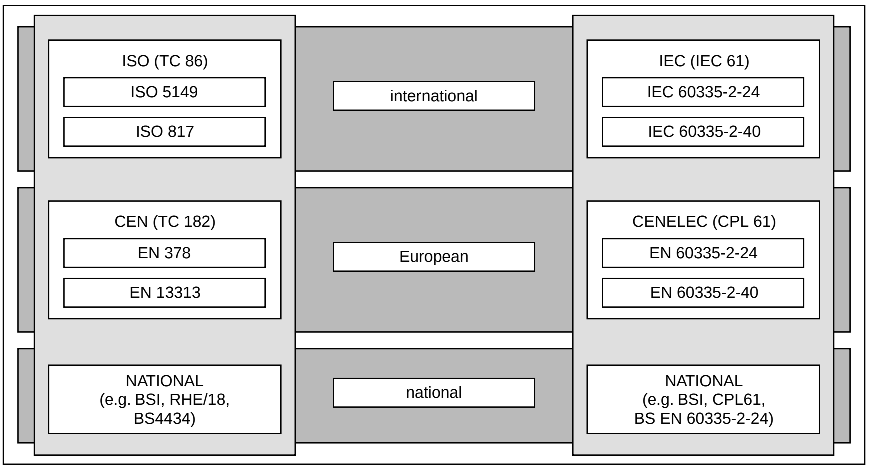
Other regulations

Besides environmental legislation and safety standards, there are numerous national and European regulations that indirectly effect refrigerant use, for example additional EU directives from a health and safety perspective. Regional safety standards often include provisions from these regulations, such as EN378, which includes requirements from the Pressure Equipment Directive.

Training

Training and certification in refrigerant handling are very important, but minimum acceptable values vary considerably. Whilst legal or voluntary requirements tend to be more rigorous in Northern Europe and North America, it is still possible in some countries for anyone to purchase some copper pipe, a brazing torch and a bottle of refrigerant and do whatever they wish with them. The USA has rigorous minimum qualifications that apply to all refrigerants, and in Australia and Germany, engineers need a trade certificate, which is only issued after successful qualification. India’s new legislation also requires technicians to obtain a licence for handling CFCs. Some distributors of hydrocarbon refrigerants in Europe, Asia and Australia require proof of training in flammable refrigerant handling before allowing the sale of these products.

The new EU regulation requires member states to define their own minimum qualifications for handling



▲ *Figure 1: Structure of standards organisations.*

refrigerants, but falls short as it applies only to ODSs. However, there is a draft European Standard, prEN13313: *Competence of personnel*, which defines minimum competencies for refrigeration engineers and service technicians.

Conclusions

Legislation for phasing out CFCs has led to significant changes in the global refrigeration industry. In many countries, the resulting momentum has led to more stringent regional regulations, forcing industry to deal with damaging substances in a more responsible manner. The range of ODS legislation is very broad, with regional variations between phase-out dates of several years or more, but technological advances by some nations tend to filter through to countries with longer-term ODS phase-out dates, reducing some of the variation.

In addition, international environmental legislation aimed at climate change can also influence the use of refrigerants. Some countries, for example, are proposing restrictions on the use of HFCs, which would favour the increased use of environmentally benign working fluids such as ammonia, carbon dioxide, hydrocarbons and water. Such pressures have led to new developments and revisions in safety standards, which also affect the use of refrigerants.

These global trends indicate a move towards different refrigerant systems using a variety of fluids that meet the criteria of efficiency, safety and leak-tightness. To deal with such requirements, application engineers and service technicians will have to become even more skilled in design considerations and handling issues for a wider variety of refrigerants.

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Refrigerants and the environment – a case study in international cooperation

François Billiard and Jean-Luc Dupont, France

Two environmental issues profoundly affect the refrigeration sector: ozone depletion and global warming due to greenhouse gas emissions. In the former case, CFC and HCFC refrigerants are the main culprits, while in the latter CFCs, HCFCs and HFCs are among the substances incriminated. Everyone is aware that strict rules must be applied to effectively combat both these global threats.

The fact that the Montreal Protocol (1987) and its Copenhagen Amendment (1992) have been signed demonstrates that international mobilisation can make things happen. It has proved possible to launch a stringent CFC reduction campaign by implementing common measures in all developed countries and by involving developing countries, particularly through the setting up of the Multilateral Fund. However, the latest meetings of the Montreal Protocol actors, held in Montreal in 1997 and in Beijing in 1999, have illustrated that these international actions have their limits. When it was proposed that Parties accelerate the phase-out schedule, as adopted by the European Union, national interests came to the surface and overshadowed the international dimension. Yet, in spite of divergent priorities, the Montreal Protocol still demonstrates that international cooperation is the foundation on which any large-scale actions must be built.

New European measures

In the ozone-depletion field, the European Union is about to adopt a new regulation that will supersede Regulation 3093/94 of December 1994. This regulation comprises a set of measures, especially an accelerated schedule for phasing out the production, sale and use of CFCs and HCFCs (see table on page 12). This approach appears legitimate, but the regulatory framework thus defined has raised a number of issues that were expressed in a position statement made by the IIR in late 1999. This statement contained a series of comments on the draft version of the new regulation and was sent to 114 members of the Commission on Environment of the European Parliament.

Unforeseen consequences

One of the major issues is whether these measures will in fact do more harm than good with regard to the environment. For instance, the ban on recharging CFCs in plants as of 31 December 2000 is based on a commendable principle. However, users who have been caught unprepared because they were unaware of this measure will be faced with three unsatisfactory alternatives:

- to retrofit in order to use HCFCs that are already destined to be phased out within the same framework of measures;
- to perform costly, difficult retrofitting in order to use other alternative refrigerants;
- or to totally renew plant.

Another problem users will have to solve is what to do with the CFCs removed. Reuse and recycling in developing countries is now banned, so these CFCs will have to be destroyed. Concern over massive release of CFCs into the atmosphere (which is the exact opposite of the impact desired) has arisen, given the cost of destroying CFCs, the total lack of information on this process and the lack of financial incentives.

This is just one example, but it does illustrate that in order to achieve the desired impact, these measures must have built-in features that take into account the situation encountered in the field. In this context, the refrigeration practitioners' influence on decision-making processes remains limited in spite of efforts by national and international associations. Increased consultation between politicians and practitioners will no doubt increase the likelihood of achieving the desired results. The IIR, as a provider of scientific and technical information and thanks to its 61 member-countries worldwide, can and does play a role in this process of cooperation.

Reducing greenhouse gases

Phasing out CFCs in favour of HCFCs and then phasing out HCFCs in favour of HFCs, or phasing out CFCs and directly replacing them with HFCs in order to combat ozone depletion was and is still a major challenge for the refrigeration sector. Gradual implementation of measures designed to reduce global warming due to greenhouse gases now constitutes the second challenge for the refrigeration sector. Here again, at an international level, the Kyoto Protocol has shown that 159 countries are capable of action to achieve a common goal, although it was preceded by difficult negotiations before its adoption in 1997. This common goal is a major one, since it is designed to reduce emissions of six greenhouse gases including HFCs, by an average of 5.2% compared to 1990 levels, during the period 2008-2012. By contrast, if no measures were taken, an increase of 5-10% would be forecast. At the time this article was being written, only 23 Parties (none of which are developed countries) had ratified the Kyoto Protocol. It is thus not clear whether the Kyoto Protocol will come into force. However, several countries have already implemented emission-reduction programmes enabling significant reductions in emissions of greenhouse gases.

Setting priorities

CFCs and HCFCs have an even greater impact on global warming than HFCs but are not covered by the Kyoto Protocol as they are due to be phased out. Therefore, the refrigeration sector is left to concentrate its anti-global-warming actions on HFCs. However, it should be borne in mind that HFCs, PFCs and SF_6, taken together, represent only 2% of total emissions of the six Kyoto-controlled "basket" gases in terms of CO_2 equivalents. Only about 1% of total emissions is HFC-related. It is also important to realise that about 85% of the global-warming impact of refrigerating plants is due to the indirect effect of CO_2 emissions related to the production of the electricity required to operate the plants. For this reason, arbitrarily regulating the use of HFCs, which many refrigeration contractors and users have turned to (and adapted their plants accordingly), is not the way to solve the problem.

Effective incentives should focus priorities on:

- development and promotion of highly energy-efficient plants (such as heat pumps where applicable) that enable reduction of the indirect global-warming effect;
- implementation of efficiency standards and labelling, which are the tools required in this context;
- research and development of alternative technologies with no direct global-warming impact (absorption and adsorption systems, air cycles etc.), combined with improved energy efficiency;
- research and development of low-charge systems;
- plant containment and achieving tightness at the component level, with stricter regulations and inspection procedures;
- use of natural refrigerants (ammonia, hydrocarbons, CO_2, or even water vapour);
- systematic training in good practices for all actors involved (recovery, recycling or destruction of refrigerants);
- qualification of firms and operators using procedures parallel to those already set up in many countries.

Conclusion

The Montreal and Kyoto Protocols illustrate that international cooperation is the basis upon which common objectives can be defined that reflect the primordial international stakes in the environmental protection field. Developing and implementing these objectives at national or international levels will have a far greater chance of succeeding, in terms of achieving the desired results, if a dialogue between all the authorities and actors involved is maintained throughout the process of defining the required measures. Initiatives promoting the development of refrigeration and related applications in a manner ensuring that environmental objectives are met must be encouraged.

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Designation and safety classification of refrigerants – proposed changes to ISO Standard 817

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The discovery that chlorofluorocarbons (CFCs) could destroy stratospheric ozone resulted in the Montreal Protocol on Substances that Deplete the Ozone Layer. In response to the global environmental threat, the industry has developed and introduced replacement refrigerants with very low or zero ozone depletion potential (ODP). An ISO working group is developing means to designate and classify new refrigerants for inclusion in an updated ISO Standard 817, with the proposed title: Refrigerants – designation and safety classification.

Introduction

ISO Standard 817 establishes a simple system of referring to common organic refrigerants instead of using the chemical name, formula or trade name. It includes a table of refrigerants with the number designation, chemical name, formula and molecular mass. The standard was last updated in 1974 and the list of refrigerants does not include many of the refrigerants being used to replace CFCs and HCFCs.

A revision to the standard, which is currently in the Draft International Standard (DIS) stage, adds several new refrigerants to the tables listing refrigerant designations along with some new definitions. It also includes a numbering scheme for mixtures that differentiates azeotropic and zeotropic refrigerants and optional composition-designating prefixes (i.e. CFC, HCFC, HFC). When this DIS was prepared, it was recognised that ISO Standard 817 will require frequent updating as new refrigerants are introduced in response to environmental needs. As a result, the ISO-secretariat has agreed to determine if there is a fast-track procedure that could be used to expedite the addition of new refrigerants to the standard.

Shortly after the DIS was completed, ISO Technical Committee 86 (TC 86), *Refrigeration and air conditioning*, directed Subcommittee 8 (TC86/SC8), *Refrigerants and refrigeration lubricants* to include safety classifications of refrigerants in future revisions of ISO 817. This was done at the request of SC1, *Safety of refrigeration systems*, which has an active working group revising ISO Standard 5149, *Mechanical refrigerating systems used for cooling and heating – safety requirements*. As a result, a call for experts was issued for a working group (ISO TC86/SC8/WG5) to begin drafting text that would define how safety classifications are to be assigned and then to add the safety classifications to the table of refrigerants. In addition, SC8 was directed to add refrigerant quantity limits to ISO 817, which would be referenced by ISO 5149.

Reviewing standards

At its first meeting, the working group reviewed existing national and international standards and agreed on the basic elements that would be used in the first draft of the revised standard. The reviewed standards were:

- ISO 5149 *Mechanical refrigerating systems used for cooling and heating – safety requirements;*
- ASHRAE Standard 34 *Designation and safety classification of refrigerants;*
- prEN 378-1 *Refrigerating systems and heat pumps – safety and environmental requirements. Part 1: Basic requirements, definitions, classifications and selection criteria*;
- BS 4434 *Specification for safety and environmental aspects in the design, construction and installation of refrigerating appliances and systems*.

At the next meeting, the ISO TC86/SC8/WG5 committee reached a consensus on three principles that will guide the work as the standard is revised:

- the working group should be focusing on concentration limits as opposed to quantity limits;
- the working group should consider the historical use of refrigerants as well as new test data in evaluating the Refrigerant Concentration Limits;
- pending establishment of the capability within ISO TC86/SC8 to develop and establish refrigerant designations, ISO will draw on the designations established by ASHRAE. ISO TC86/SC8/WG5 will continue to work towards developing a means to designate and classify new refrigerants.

The working group has proposed changing the title from *Organic refrigerants – number designation* to *Refrigerants – designation and safety classification*.

The proposed scope now reads: "This International Standard provides an unambiguous system for assigning designations to refrigerants. It also establishes a system for assigning a safety classification to refrigerants based on toxicity and flammability data and provides a means of determining the refrigerant concentration limit. Tables listing the refrigerant designations, safety classifications and the refrigerant concentration limits are included."

Refrigerant designation

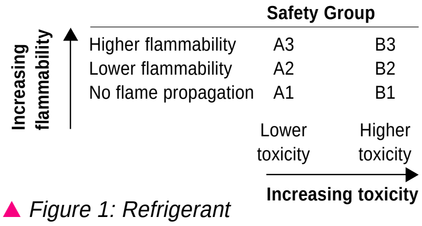
The designation scheme used in ASHRAE Standard 34 is recognised throughout the world and has been adopted in other national and international standards. The ISO working group has no intention of changing the current system. The language to be used in the ISO Standard has been modified somewhat to make it more acceptable to an international audience, but is equivalent to that used in existing standards. It will result in the same designation being applied to a particular refrigerant.

Safety classification of refrigerants

Safety classifications for refrigerants are based on *toxicity* and *flammability* data. One of the first tasks the working group undertook was to review the safety classification schemes being used in other standards and arrive at a consensus as to the method to be used in the international standard. Criteria must be established to make it clear to which safety group a refrigerant will be assigned, once the appropriate data are collected and reviewed. Some of the existing standards use three classifications while others use six. The working group agreed that three is inadequate and that the criteria set out in ASHRAE Standard 34 using six groupings would be proposed for use in ISO 817. The six groupings are shown in **Figure 1** and are defined below.

Toxicity classifications

There are currently two safety groups based on toxicity, class A and class B. These safety groups are based on the exposure limit for an 8-hour day, 40-hour week. With input from toxicologists, the ISO working group will review the exposure limits that are assigned by other groups before assigning a toxicity classification to a refrigerant. The proposed language in the current draft reads as follows: "Refrigerants shall be assigned to one of two classes – A or B – based on allowable exposure:



▲ *Figure 1: Refrigerant safety group classification.*

Class A (lower toxicity):
Refrigerants with a time weighted average concentration not having an adverse effect on nearly all workers who may be exposed to it day after day for a normal 8-hour workday and a 40-hour workweek whose value is equal to or above 400 ml/m^3 (400 ppm by volume).

Class B (higher toxicity):
Refrigerants with a time weighted average concentration not having an adverse effect on nearly all workers who may be exposed to it day after day for a normal 8-hour workday and a 40-hour workweek whose value is below 400 ml/m^3 (400 ppm by volume)."

Flammability classifications

The proposed flammability classification has three groups for flammability based on the lower flammability limit (LFL) and the heat of combustion for single compound refrigerants as described below:

Class 1 (no flame propagation)
A single compound refrigerant shall be classified as Class 1 if the refrigerant does not show flame propagation when tested as specified in the standard.

Class 2 (lower flammability)
A single compound refrigerant shall be classified as Class 2 if the refrigerant meets all three of the following conditions. The refrigerant:
(1) exhibits flame propagation when tested as specified in the standard;
(2) has an LFL>3.5%;
(3) has a heat of combustion <19,000 kJ/kg.

Class 3 (higher flammability)
A single compound refrigerant shall be classified as Class 3 if the refrigerant meets both of the following conditions:
(1) exhibits flame propagation when tested as specified in the standard;
(2) has an LFL ≤3.5% or it has a heat of combustion that is ≥19,000 kJ/kg.

For refrigerant blends, the basic criteria indicated above still hold. However, the exact compositions to be tested must be determined in accordance with the instructions that will be included in the standard.

The working group is reviewing an alternative method of assigning a flammability classification. A proposal before the group calls for use of a new factor, referred to as the "R factor", see article on page 19. Both methods have advantages and disadvantages that cannot be covered adequately here. The working group is considering the proposal and weighing its merits against the current system.

Refrigerant blends

Refrigerant blends require additional considerations because their composition may change in the event of a leak. The working group is considering the merits of a single classification versus a dual classification. ASHRAE Standard 34 currently uses a dual classification for blends, where the first classification is for the blend as formulated, and the second classification is for the blend composition at the worst case of fractionation. However, ASHRAE SSPC 34 (Standing Standard Project Committee) has proposed an amendment to ASHRAE Standard 34 that would eliminate the dual classification and lists only the classification at the worst case of fractionation. The standard defines the worst case of fractionation for both toxicity and flammability.

Refrigerant concentration limits

The working group has proposed that the Refrigerant Concentration Limit (RCL) be defined as the maximum refrigerant concentration, in air, determined in accordance with this standard and established to reduce the risks of acute toxicity, asphyxiation and flammability hazards. The working group is currently reviewing the criteria to be used to establish the concentration limits. Similar work is underway by ASHRAE SSPC 34 and the ISO working group is monitoring that activity closely.

The proposed refrigerant concentration limit will consider acute toxicity indicators such as mortality, cardiac sensitisation, anaesthetic effect and other escape-impairing symptoms and permanent injury. In addition, these criteria will take into consideration asphyxiation by setting an Oxygen Deprivation Limit (ODL) and refrigerant flammability by establishing a Flammable Concentration Limit (FCL). The RCL will be based on the indicator that results in the lowest concentration when considering all the indicators listed above.

Conclusions

ISO TC86/SC8/WG5 is developing a means to designate and classify new refrigerants for inclusion in ISO Standard 817. The safety classifications currently being used in various national standards were reviewed and are being considered in revising ISO 817. Although a draft of the standard has been developed, there is still much work to be done. Pending establishment of the capability within ISO TC86/SC8 to develop and establish refrigerant designations, ISO will draw on the designations established by ASHRAE.

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Flammability index for refrigerant standards

Osami Kataoka, Japan

From an environmental point of view, flammable refrigerants are preferred for various applications, including heat pumps, due to their lower GWP (Global Warming Potential). However, adequate safety standards are necessary if they are to be used safely. Several indices are available for assessing the flammability of refrigerants, and these are used in various standards. This article discusses the differences between these indices and some of their drawbacks. A new index is proposed that may be better than current indices, but replacing the current criteria by new ones may take many years.

Introduction

Flammable gas is generally explosive and (except for ammonia) has been avoided for decades as a refrigerant for safety reasons. However, since flammable refrigerants generally have a lower GWP and sometimes a better COP (Coefficient of Performance), they are preferred for many applications. The environmental advantages of flammable refrigerants make it all the more important to be able to assess and classify such refrigerants with regard to safety.

The Japanese General High Pressure Gas Safety Regulations define a flammable gas as follows: “A flammable gas has an LFL (lower flammable limit concentration) in volume equal to or less than 10%, or has a flammability range, which is the difference between UFL (upper flammable limit concentration) and LFL, equal to 20% or more.” This means that a gas that has an LFL of more than 10% and flammability range of less than 20% is not classified as a flammable gas. A similar definition of flammable gas is found in the US DOT (Department of Transportation) regulations. In contrast, the ASHRAE 34 standard *Designation and classification of refrigerants (1997)*, and the ISO 5149 standard *Mechanical refrigerating systems used for cooling and heating – Safety requirements (1993)* categorise any refrigerant that propagates a flame as a flammable refrigerant. However, these regulations identify two classes of flammable refrigerants, lower flammable and higher flammable. The question is then “What is lower flammability?”

Due to the low flammability of some gases, the risk involved when using them in small amounts may be considered acceptable. Use of such refrigerants could significantly reduce the global warming impact due to refrigerants. R-32 is an example of such a refrigerant. The Japanese General High Pressure Gas Safety Regulations do not classify R-32 as a flammable gas, as it burns slowly under limited conditions. Its GWP is about 40% of that for R-410A, a popular HFC refrigerant for mini-split heat pumps. The amount of R-32 needed in a heat pump system is only 50-80% of the amount of R-410A needed. This means that the direct warming impact is reduced by up to 80% if R-32 is used to replace R-410A. In addition, the COP of a heat pump using R-32 is better than that for R-410A.

However, the ASHRAE 34 and ISO 5149 regulations place R-152a in the same flammability class as R-32 even though R-152a burns readily under most conditions. If R-152a is classified as a lower flammable refrigerant, then the application standard for lower flammable refrigerants will have to be restrictive. The use of any flammable refrigerant then becomes problematic. In order to avoid such inconsistencies, an accurate and internationally harmonised flammability index and classification system for refrigerants is necessary.

Evaluation of current indices

Table 1 shows a comparison of the flammability rankings obtained for various substances when using different indices. Hydrogen and carbon monoxide (CO) are included in the comparison even though they are not used as refrigerants. The results obtained for these highly flammable gases provide a useful illustration of the positive and negative aspects of the indices.

ASHRAE 34 uses LFL by weight (LFL_W) as one of the indices, and 0.1 kg/m^3 as the cut-off criterion. The first column of Table 1 shows the results of sorting the refrigerants according to this index. The LFL_W of R-152a is 0.129 kg/m^3 while that of ammonia is 0.106 kg/m^3. This suggests that R-152a is less flammable than ammonia. However, our combustion tests clearly show that R-152a is more flammable than ammonia. In addition, if we use this index and the cut-off criterion, CO will be classified as a lower flammability substance. However, CO is obviously a highly flammable gas, even though it has an LFL_W of 0.146 kg/m^3.

Similar problems exist when the following characteristics are used in an index:

- the heat of combustion per unit weight (HoC), which is the second index employed in ASHRAE 34 (see second column of Table 1). Ethylene is ranked below methane even though unsaturated hydrocarbons appear to be more flammable than saturated ones;
- LFL by volume (LFL_V), which is employed by ISO 5149 and (pr)EN378 *Refrigerating systems and heat pumps – Safety and environmental requirements (Part 1, 1999)*. The cut-off criterion for a higher flammable refrigerant is an LFL_V below 3.5% (see third column of Table 1). The problem with the results for ammonia and R-152a is solved if this method is employed.

LFL_W	kg/m^3	HoC	kJ/kg	LFL_V	%	R	-	
						hydrogen	7.22	high flammability ↑
						ethylene	2.42	
						CO	2.37	
hydrogen	0.003	hydrogen	119,920			propane	1.92	
ethylene	0.031	methane	51,776			methane	1.9	
methane	0.033	iso-butane	47,652	iso-butane	1,8	iso-butane	1.74	
propane	0.039	propane	47,571	propane	2,1	R-152a	1.65	
iso-butane	0.044	ethylene	47,138	ethylene	2,7	R-143a	1.53	
ammonia	0.106	ammonia	18,614	hydrogen	4,1	ammonia	1.46	low flammability ↓
R-152a	0.129	R-152a	15,583	R-152a	4,7	R-142b	1.4	
CO	0.146	CO	10,123	methane	5	R-32	1.36	
R-143a	0.217	R-143a	10,072	R-143a	6,2	R-141b	1.06	
R-32	0.275	R-142b	8,951	R-142b	6,8			
R-142b	0.285	R-32	8,501	R-141b	9			
R-141b	0.439	R-141b	8,146	CO	12,5			
				R-32	12,7			
				ammonia	15			

[black box] readily burning under most conditions
[pink box] extremely flammable

LFL_W = lower flammability limit by weight
HoC = heat of combustion
LFL_V = lower flammability limit by volume
R = flammability index R

▲ *Table 1: Comparison of various flammability indices [1, 2].*

However, both CO and hydrogen are classified as lower flammable substances, which is obviously unacceptable.

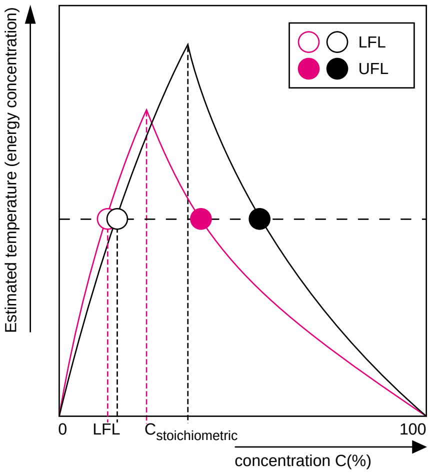
Possible causes for inconsistencies

The LFL is the boundary condition, i.e. the critical concentration of a gas, below which a flame will not be able to sustain itself. Calculations indicate that, for most flammable gases, the minimum temperature required to initiate the chain reaction of combustion at the LFL concentration is similar. However, at LFL conditions, even highly flammable substances such as hydrocarbons burn only slowly and the combustion reaction is barely self-sustaining regardless of the substance. In other words, such test conditions do not discriminate very well between different gases. It should therefore not be surprising that a classification system based on test results under such 'non-discriminating' conditions should not always yield consistent flammability rankings.

The heat of combustion might appear to be a more appropriate parameter, as it represents the total energy released by combustion. However, it does not take into account the effect of oxygen concentration in air or the effect of gas volume. Oxygen accounts for only approximately 21% of air. One cubic metre of a stoichiometric (ideal concentration for reaction) mixture of ammonia and air can generate 3077 kJ of heat, while for CO the comparable figure is 3724 kJ. This calculation suggests that CO combusts more readily than ammonia, but the heat of combustion index gives the opposite result.

New index

If the minimum temperature needed to initiate combustion at the LFL concentration is similar regardless of the substance, the ratio of stoichiometric concentration ($C_{stoichiometric}$) to LFL concentration (C_{LFL}) is a measure of the strength of reaction under stoichiometric



▲ *Figure 1: Concept of flammability index R.*

conditions, i.e. ideal combustion conditions. We define this ratio R as follows:

$$R = \frac{C_{stoichiometric}}{C_{LFL}}$$

Figure 1 illustrates this concept. The energy released by combustion in a space increases almost linearly with the fuel concentration until the stoichiometric concentration is reached. It then decreases as the fuel concentration increases due to insufficient oxygen. The index R is proportional to the energy concentration at $C_{stiochiometric}$, and will be highest for substance 2 [blue].

For example, R-152a and hydrogen have a similar LFL_V of 4.7% and 4.1% respectively. However, the stoichiometric concentration is 7.7% and 29.6% respectively. The R-values then work out to 1.6 and 7.2 respectively. The R index thus assigns a far higher flammability to hydrogen than to R-152a. The last column of Table 1 shows the results obtained when using this new index; the ranking appears reasonable.

From the chemical energy viewpoint, the energy released by the combustion reaction at the LFL is equal to the energy required to maintain the elevated temperature of the gas mixture. The ratio R is proportional to the excess energy generated at the stoichiometric concentration that is available to feed the chain reaction and, as such, is an indication of the strength or speed of the reaction.

Ammonia is considered a substance at the boundary between higher and lower flammability, as historically it has been used as a representative lower flammability substance. Since ammonia has an R-value of 1.46, R=1.5 is proposed as the cut-off criterion to distinguish lower from higher flammability.

Comparison with other flammability indices

An evaluation was made of the relationship between R and the pressure rise coefficient, which is an index of pressure rise during an explosion and is considered the most critical factor for refrigerant flammability. R correlates well with the pressure rise coefficient, except in the case of sulphur compounds (which can be explained theoretically).

The relationships between R and flame speed and between R and minimum ignition energy were also evaluated. The correlation of flame speed to R, LFL_V and LFL_W is shown in **Figure 2**. Of these three indices, R has the best correlation with flame speed.

Gases with an LFL_V of more than 13% and a flammability range of less than 12% are not considered flammable in the US DOT regulations. The cut-off boundaries set by these regulations correspond to an R-value of less than 1.5. For instance, the US DOT regulation corresponds to an R-value of less than 1.4, using an equal ratio of $C_{stoichiometry}/LFL$ and $UFL/C_{stoichiometry}$. Therefore, the new index R has a certain similarity to this conventional method. However, the latter method classifies R-141b as a lower flammability substance, whereas R-141b is classified as a safe, non-flammable substance by the European Union PED (Pressure Equipment Directive).

Conclusion

Conventional indices of refrigerant flammability have drawbacks that are difficult to accept. A new index R has been proposed to classify flammable refrigerants. This index was shown to provide more reasonable results than the current indices. It is under evaluation by the international standard working group (ISO TC86 SC8 WG5) and the ASHRAE 34 flammability subcommittee. If this index is used in the standards, it will clarify the position of the refrigerants with lower flammability, allow maximum use of these refrigerants and minimise the impact of refrigerants on climatic change. However, replacing the current criteria for refrigerant standards by new criteria may take many years.

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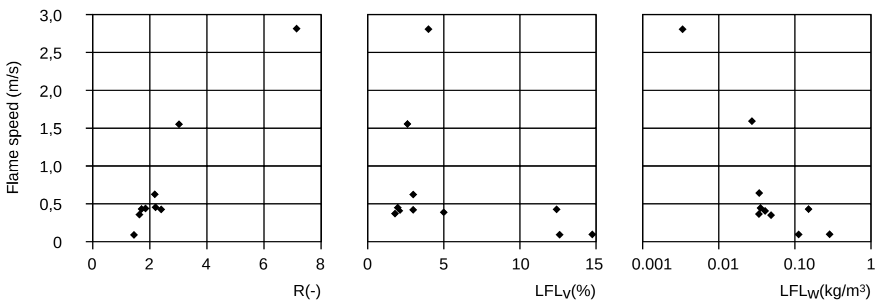

▲ *Figure 2: Correlation of flame speed with various indices.*

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The Montreal Protocol at the cross-roads of the millenniums

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The Montreal Protocol is entering the new millennium with the definite goal of finishing the remaining job quickly. The stratospheric ozone layer has not yet recovered – it may well take most of the next century for that to happen. The world community, however, can at least be proud of the initial chapters of this story. These chapters will serve as the driving force to face the remaining challenges. How large is this initial element of success in terms of hard numbers and what remains to be done? What has the United Nations Environment Programme (UNEP) been doing to facilitate this first-ever fruitful North-South exercise in cooperation in the history of environmental protection? This article presents an overview of the experiences so far and explains the role of UNEP.

On 16 September 1987 history was made when the world adopted the Montreal Protocol on Substances that deplete the Ozone Layer. It was the first global treaty ever which, based on precautionary principles, took action to prevent global catastrophe. Three years later, the Parties to the Montreal Protocol took a landmark decision, based on the principle that “the polluter pays”, to establish the Multilateral Fund (MF) to provide financial and technical assistance to the developing countries to enable them to implement the phase-out of ozone-depleting substances (ODS).

The Montreal Protocol represents an achievement of which everyone involved can be proud, i.e.:

- the scientists, who discovered the link between CFCs and ozone depletion and who gave appropriate policy advice over a twenty-year period;
- the governments, which heeded this advice and decided to do away with many versatile, profitable chemicals, whatever the cost, to save the ozone layer;
- the technologists and the industry players, who came up with alternatives;
- the NGOs and media, who kept up the pressure on all the parties involved;
- the UNEP, which provided the framework for international action, marshalled the information, options and legal expertise needed for decision-making and catalysed international consensus to respond to the crisis.

Global participation

The first and most significant achievement of the Montreal Protocol is the level of global participation: 174 countries, representing nearly all of humanity, are Parties to the Protocol. Starting with only 24 countries, the Protocol has become a sweeping movement to protect the environment (see **Figure 1**).

Phase-out progress

The industry has provided alternative substances and technologies for almost all the uses of ODS. Industrialised countries have phased out consumption of a million tons of CFCs since 1986 to meet the provisions of the Montreal Protocol (see **Figure 2**). At present, they consume only about 11,000 tons for essential uses approved by the Meetings of the Parties – mostly for medical aerosols for which alternatives are not yet available.

The abundance of CFCs and other ODS in the atmosphere has been measured since about 1978. Over much of that period, the annual growth rates for these gases have increased. However, the data of recent years clearly show that the growth rates are slowing down for many of the ODS, and the abundance of some is actually decreasing. This clearly demonstrates the success of the Protocol.

Science-driven consensus

The Protocol has set a trend for policy-making based on scientific, environmental and technological global assessments. The original Protocol in 1987 did not stipulate the complete elimination of production and consumption of CFCs and halons. However, based on the global assessments, the Protocol has called for a phase-out, tightened various control measures and advanced the phase-out schedules. Since 1989, a network of experts from nearly 40 countries has worked on UNEP’s Scientific Assessment Panel, Environment Assessment Panel, and Technology and Economic Assessment Panel. They regularly produced reports and, through consensus, gave their interpretation of the observations and findings.

Participation of developing countries

Getting commitments from developing countries to comply with the Montreal Protocol was a milestone. Bringing the environment into the mainstream of everyday life is quite difficult for developing countries, where basic human necessities such as food, water and shelter are the key issues. It should be obvious how difficult yet how important it is to place the issue of ozone protection high on the environmental agenda of these countries.

The Montreal Protocol is the first international agreement that has recognised the common but differentiated responsibilities of the industrialised and developing countries concerning global environmental problems. Industrialised countries in 1985 accounted for 85% of the world's ODS consumption. Hence, they took the lead in the phase-out and agreed to a grace period for developing countries to implement control measures. They also agreed to contribute to a Multilateral Fund to meet the extra costs to be borne by developing countries for the phase-out of ODS. The Protocol recognised that the spread of alternative technologies is the key to its success and thus provided for the transfer of such technologies to developing countries as well as the strengthening of their capacities to adopt them.

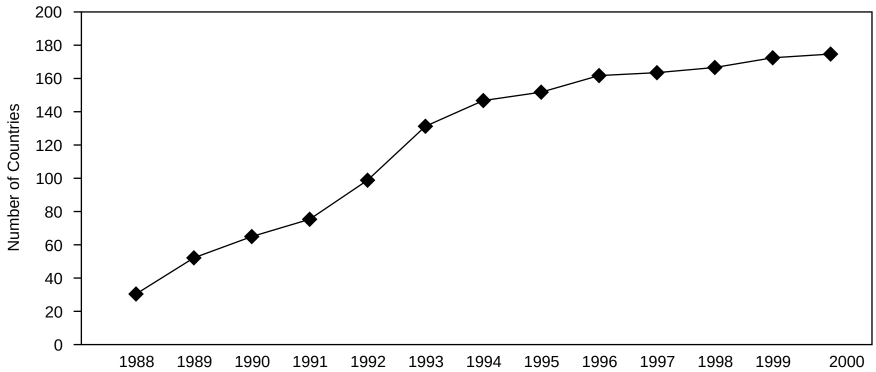
The financial mechanism was agreed to in 1990. The Multilateral Fund, which is part of this financial mechanism, was established in 1991. It is managed by an Executive Committee of 14 parties - 7 each from the developing and industrialised countries - appointed annually by the Meetings of the Parties. A Fund secretariat located in Montreal assists the committee. UNDP (United Nations Development Programme), UNEP, UNIDO (United Nations Industrial Development Organization) and the World Bank are the implementing agencies for the Fund's programmes in the developing countries.

UNEP's role

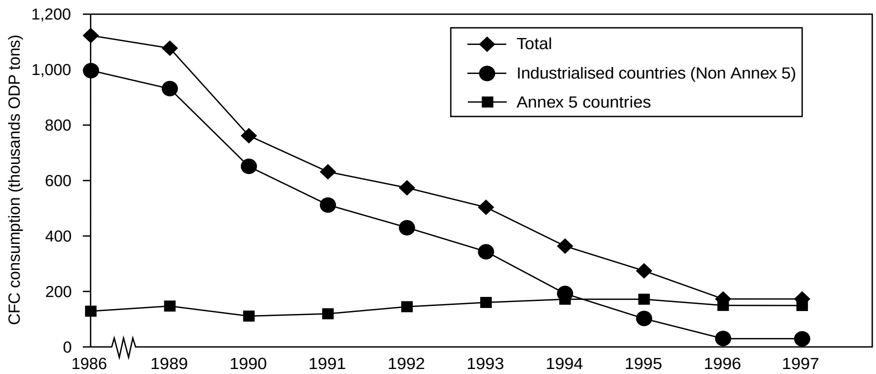
UNEP is the guardian of the Montreal Protocol and performs four main roles through the following offices:

- Ozone Secretariat in Nairobi, which assists the Meetings of the Parties;
- Treasurer of the Multilateral Fund in Nairobi, which serves the Executive Committee;
- Implementing Agency in Paris, through the OzonAction Programme of the Division of Technology, Industry and Economics, which serves developing countries and countries with economies in transition (CEITs);
- Secretariat of the Multilateral Fund in Montreal, which facilitates the work of the Executive Committee.

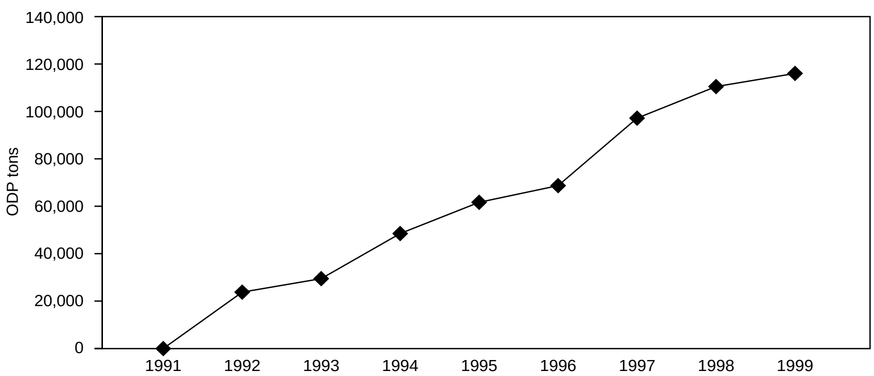
OzonAction is an 'enabling programme', which builds up the local expertise required for the responsible management of ODS phase-out projects with minimal external intervention. UNEP helps in capacity development and in enabling developing countries to comply with the control measures. It builds cooperative linkages of global partnership between developed and developing countries, which is fundamentally necessary for developing countries. UNEP as an implementing agency provides assistance to the developing countries and CEITs through country programmes and institutional strengthening projects,



▲ *Figure 1: Progressive ratification of Montreal Protocol.*



▲ *Figure 2: World CFC consumption trend 1986-97.*



▲ *Figure 3: Progressive phase-out of ODS from projects under the Multilateral Fund.*

through acting as an information clearinghouse, and through training and networking.

*Country programmes and institutional strengthening project*s are implemented in order to strengthen national capacities to enable national ozone units to coordinate and monitor phase-out activities. Starting with 13 countries in 1993, UNEP has now assisted 83 countries in preparing their country programmes and 75 countries in institutional strengthening projects.

The information clearinghouse helps build awareness and assists with identifying, selecting and implementing alternative technologies and policies through handbooks, self-help guides, technology source books and case studies.

Training is at the regional level and support is extended to national activities. It is aimed at building up skills to implement phase-out activities in the field of refrigerant management, halon-bank management and the monitoring of ODS.

Networking is an innovative element of UNEP's OzonAction Programme. The networks of 100 countries in eight separate regions are being facilitated by UNEP. Each network consists of 10 to 20 ODS-offices from developing countries and two to three developed countries. They meet twice a year to share their implementation experiences and forward planning.

The first network was established in the Southeast Asia and the Pacific Region in 1991-92, with financial assistance from the Government of Sweden. Based on the success of this network, seven more regional networks have been established (see front page of the Newsletter). These knowledge-sharing networks have proved to be very useful in promoting South-South and North-South cooperation. They have resulted in a cost-effective implementation of the Protocol. The examples from colleagues in the same position create powerful leverage and inspiration to achieve results. Specifically, networking has resulted in:

- building up political and regional consensus on key technology and policy issues;
- increased technology awareness; enhanced cooperation among networking countries to effectively adapt public-awareness material produced by members;
- peer pressures and exchange of views resulting in strategy and action plans for expeditious phase-out; policy setting;
- increased awareness of the member countries of Montreal Protocol matters and the Multilateral Fund.

Progress in developing countries

So far, the Multilateral Fund has financed nearly 3,000 projects in 110 developing countries over the past nine years for over USD 1,000 million. These cover a wide range of technology transfers through investment projects in aerosols, foams, fire extinguishing, refrigeration (more than 30 million CFC-free refrigerators will be produced with the Fund's assistance), metal cleaning and other sectors. This has eliminated more than 120,000 tons of ODS in developing countries (see **Figure 3**).

The Multilateral Fund of the Montreal Protocol is one of the best-subscribed funds under the United Nations. More than 85% of the contributions are made on time. The arrears are mainly from countries from the former Soviet Union. Developed countries have pledged another USD 446 million for the next 'triennium', i.e. 2000-02.

Assistance for the phase-out of the production of CFCs in China and India and of halons in China has been approved.

Progress in CEITs

The Global Environment Facility (GEF) has funded projects for nearly USD 150 million in CEITs where ODS consumption has been reduced by over 90% since 1986. UNEP provides the same kind of assistance to CEITs as it does to developing countries.

Issues for the new millennium

The Montreal Protocol can be said to serve as a pilot for other international conventions. However, full-scale success has not yet been achieved. A number of new emerging concerns need to be addressed. If they are not, then the initial success achieved in the past millennium may be threatened by activities in the new millennium:

- developing countries are now the biggest producers and consumers of ODS and their commitment and participation are required to ensure the success of the Montreal Protocol;
- illegal trade in CFCs is proliferating in Europe and the US;
- there are still loopholes and omissions in the Protocol concerning: quarantine and pre-shipment exemption of methyl bromide; lack of control measures to phase out production of HCFCs; slow progress on alternatives to MDS (Metered Dose Inhalers); lax interpretation of controls on process agents; lack of a mechanism to implement the recommendations of the HFC/PFC task force of TEAP;
- linkages between the conventions (example: the Montreal and Kyoto Protocols) are reappearing as a key focal element. Today, linkages may seem to be an academic issue and impacts (example: HFCs/PFCs) may appear insignificant. Yet, they may prove to be important in ultimately achieving success.

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Safety standards for L3 refrigerants in Switzerland

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The use of natural substances for refrigeration instead of synthetics has certain advantages. In Switzerland, the use of (natural) hydrocarbons in small installations has increased over the past few years. This article describes Swiss safety standards for the use of refrigerants in safety class L3, which includes hydrocarbons.

Advantages

Natural substances used as refrigerants present neither an ozone depletion potential nor a relevant global warming potential. Their long-term toxic and carcinogenic effects, in contrast to the effects of synthetic refrigerants, are known to be harmless for man and the environment. Their thermodynamic properties and miscibility with compressor lubricants are excellent. In the case of hydrocarbons, simple trouble-free use is possible at higher supply temperatures, such as those in retrofit or hot water production applications. In Switzerland, the use of hydrocarbons in small installations (up to 25 kW heating capacity) has increased over the past few years.

Classifications

The low flammability limit of L3 refrigerants (<3.5 volume %), which include hydrocarbons, makes special safety standards necessary. In Switzerland, the requirements with respect to the installation location for refrigerating installations using L3 refrigerants are specified in standard SN 253130 [1] with safety classes from SN 253120:

Installation locations:
A = generally accessible;
B = accessible to limited number of persons;
C = accessible only to authorised personnel with knowledge of safety precautions.

Safety classes:
L1 = non-flammable, scarcely toxic;
L2 = lower flammability, low to higher toxicity;
L3 = higher flammability, low to higher toxicity.

Series-produced heat pumps with L3 refrigerants (propane, propylene etc.) and electrically driven compressors are generally used in location category A rooms or are installed outside. Indoor installation is permitted if the equipment is permanently closed, i.e. welded or soldered, and the quantity of refrigerant does not exceed 5.0 kg. If the installation is below ground level and contains more than 1.0 kg of refrigerant, mechanical ventilation with a given volume flow is required – generally speaking, the air in the enclosing space or casing must be changed 15 times per hour. Stricter requirements apply to installations built on site.

L3 refrigerants may not be used for comfort air-conditioning installations of the direct, indirect open and indirect ventilated construction type. The exact requirements can be found in the Swiss standards named above, which are based on EN378 [2] and IEC 60335-2-40 [3].

Swiss standard SN 253130

SN 253130, published in 1998, was supplemented in March 2000 with amendment A2 [1]. In addition to the need for an editorial correction, the reason for the amendment was an accident, which was fortunately harmless. It was caused by bursting of the condenser on defrosting (cycle reversal), which resulted in refrigerant entering the hot water circuit and igniting when the heating system was vented. The amendment includes the following requirements:

a) Prevention of freezing of heat exchangers has to be ensured. For brine systems, the brine concentration is to be so selected that on freezing no bursting can occur (remark: for corrosion protection, a lower limit of 20 volume % should be maintained for commonly used frost protection substances based on ethylene glycol).

b) Safety valves built into the refrigerant system must vent the fluid into the open air.

c) Minimum requirements for corrosion resistance and static pressure testing are explicitly mentioned. Because of the low pressure-volume ratios of heat exchangers of heat pumps, acceptance by an approval authority (EU: ‘notified body’) is usually not necessary. For export into EU countries (CE conformity), the specifications of the European Pressure Equipment Directive [4] must be observed. Since 29 November 1999, these also apply in Switzerland.

According to a study carried out on behalf of the Federal Office for Energy [5], the risk associated with hydrocarbon refrigerants is highest during installation and servicing. Few accidents have been reported worldwide; those reported were caused mainly by faulty operation. It has not yet proved possible to odorise hydrocarbons. The odour-producing substance would need to have a partial pressure similar to that of the refrigerant to guarantee a sufficient quantity in the liquid and gas phase. It should also not decompose during the life span of the installation and not damage any materials in the refrigerant circuit.

The amendment to SN 253130 therefore also specifies:

d) Assembly and commissioning should be effected by specialists.

e) Manufacturers of the installation or appliance must offer appropriate training to installers and operators.

SN253130 will remain in effect even after EN378 comes into force. A discussion is currently taking place on whether servicing procedures, similar to those in the current amendment of IEC 60335-2-40 [3], should be included in the standards. Red markings on valves could reinforce vigilance, and detailed servicing instructions depicted on equipment should help minimise faulty operation.

CEN and ISO standards

On an international level, the following standards are of importance to heat pumps and refrigerating installations using L3 refrigerants:

- EN378, Part 1-4 [2];
- IEC 60335-2-40 [3];
- IEC 60335-2-24 [6];
- EU PED 97/23/EC [4].

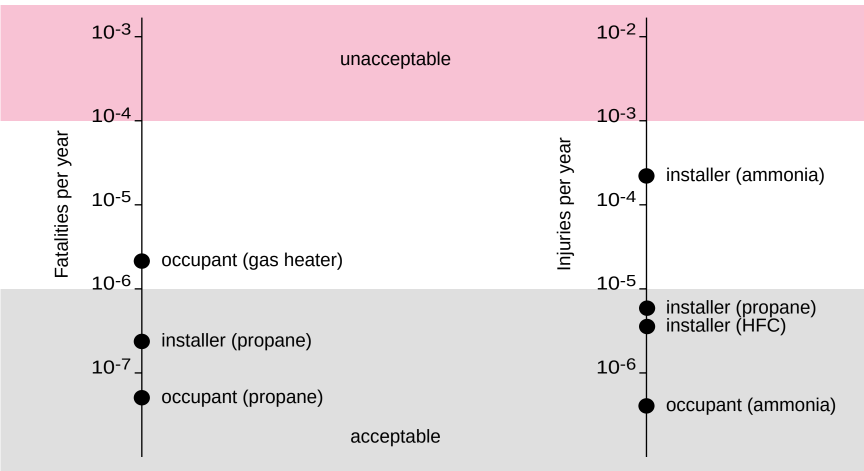
The Swiss Federal Office of Energy is active in various technical commissions, e.g. CEN TC182 and CEN TC113, in order to facilitate the safe and environmentally friendly use of natural refrigerants.

Risk analysis

In a risk analysis completed in 1999 [5], the individual risks related to various types of residential heating were surveyed. Heat pumps with ammonia, propane and HFC-134a, and a gas-fired boiler were compared.

The individual risk of using a residential heat pump with 1 kg of propane or ammonia is shown in **Figure 1**. It was assumed that occupants spend 100% of their time inside the building. If the installation is outdoors, the risk to the occupant is negligible and there is only a risk to the installer. The survey shows that an occupant is subject to 1-2 orders of magnitude less risk with propane or ammonia heat pumps than with gas-fired heating, which is generally accepted.

A risk study carried out by Arthur D. Little on behalf of Calor Gas Ltd. [7] for cooling and freezing equipment that uses hydrocarbons estimated a personal injury risk through fire of $<10^{-7}$. The risk analysis performed in Switzerland for heat pumps gave a similar result. The risk of death by a traffic accident in Europe is 10^{-4}, a thousand times higher.



▲ *Figure 1: Individual risks of using a heat pump in a separate room in the cellar of a one-family house compared to the acceptance criteria.*

Conclusions

Risks associated with the use of natural refrigerants and Swiss measures to minimise them are described and analysed in this article. Heat pumps with natural refrigerants are not dangerous as such. The risks associated with residential heat pumps using ammonia or hydrocarbons as refrigerants are more than 10 times smaller than for heating with gas-fired boilers, which are widely accepted.

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[5] M. Wolfer, E. Seitz: *Ammoniak und Kohlenwasserstoffe als Kältemittel: Risikoanalyse, Produktehaftpflicht und Strafrecht*, Schlussbericht BFE-Forschungsprogramm Umgebungswärme, Zürich, CH (86 pages) (Complete report at http://www.waermepumpe.ch/fe under 'Berichte').
[6] IEC 60335-2-24: *Safety of household and similar electrical appliances - Part 2-24: Particular requirements for refrigerating appliances and ice-makers*, IEC, Geneva, CH, 1999.
[7] *Risk assessment of flammable refrigerants*, Calor Gas Ltd., Warwick, UK (25 pages)

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Next Issue

Heating heat pumps for retrofit

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International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among its participating countries, to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development.

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The IEA Heat Pump Centre is operated by

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