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Safety, properties & use of fluorocarbons

Created: December 2013
Updated: January 2016

# Alternative refrigerants or HFCs: an obvious choice ? Safety first when choosing a refrigerant!

The refrigeration and air-conditioning industry selects refrigerants on the basis of a number of criteria which include safety, energy efficiency and environmental impact[1]. Fluorocarbons (HFCs) are often perceived as environmentally unfriendly due to their relatively high global warming potential (GWP) values. This perception, however, completely fails to take into account their contribution to the lowering of the Total Equivalent Warming Impact (TEWI) thanks to their great energy efficiency. In addition, they have a favourable safety profile since they display low flammability and low toxicity characteristics.

Nevertheless, environmental organizations continue to favour and promote alternative refrigerants[2] such as ammonia, hydrocarbons and $CO_2$ for all applications. In current practice, however, these substances are used on a much more limited basis than the fluorocarbons (HFCs) because they do not easily meet the currently applicable standards and local codes designed to provide safety in use for the general public, and to contribute to safe servicing and maintenance for engineers. It is, for example, well-known that ammonia is toxic, that hydrocarbons are extremely flammable and that $CO_2$ is an asphyxiant that requires very high pressure to operate. As highly flammable or toxic refrigerants can only be used under restrictions and require careful consideration of charge sizes, applications and locations (e.g. access to the general public), HFCs on many occasions remain the first choice refrigerants and currently still serve the widest application range.

As refrigerant use practices are constantly evolving, not least to establish whether flammable or toxic refrigerants can be used in a wider range of applications, EFCTC has decided to compile some objective basic accident and incident statistics for all refrigerants types, including alternative refrigerants and Fluorocarbons. It is self-evident that the replacement of a higher GWP refrigerant by an alternative should not result in an unacceptable risk to the general public or the maintenance engineer.

[1] Also mentioned in the Montreal Protocol October 2013 Decision on Alternative refrigerants to ozone depleting substances.

[2] Alternative refrigerants such as ammonia, hydrocarbons and $CO_2$ are often described as "natural" as the substances can occur naturally in the environment. However, when these substances are to be used as refrigerants they are typically produced in large industrial plants, and transported in bulk road or rail tankcars before being delivered to the final user.

## Published refrigerant-related accidents

The presented overview is based on a 2006-2013 global Google search for news reporting on incidents with fluorocarbons, ammonia, hydrocarbons and $CO_2$ used as refrigerants. It does not claim to be comprehensive but provides a general view on the situation. Before stating any figure, it should be mentioned that the incidence of refrigerant-related accidents is influenced by two important factors:

- The current prevalence of the refrigerants in the air-conditioning and refrigeration industry:
  Except for ammonia, which historically has a very widespread use, there are not that many hydrocarbons installations (beside domestic refrigerators/freezers) and even fewer CO2 ones, so the number of incident reports on the latter will automatically be lower.
- The specific risks related to the molecules:
  HFC refrigerants are typically non-flammable and display low toxicity. Due to the lack of spectacular explosions or severe health effects the media simply might not pick up fluorocarbon (CFCs, HCFCs or HFCs)-related accidents, even though they are by far the most extensively used. This is completely different for the highly flammable (hydrocarbons), toxic (ammonia) or very high pressure (CO2) molecules, which lead to much more sensational stories more easily covered by the press and in incident reports.

Overall the performed survey captured a large number of incidents over the past 8 years, dominated by ammonia-related events, which on its own, caused [1]:

- 981 people to be physically injured,
- 236 to be severely harmed (after inhalation),
- 95 fatalities.

In many cases, ammonia releases prompted the evacuation of several thousands of people.

Propane (a hydrocarbon) caused one fatality and a few severely injured people, while $CO_2$ caused a few people to be injured and prompted mass evacuation when a leak took place in a supermarket. $CO_2$ accidents in fire extinguishing systems were not considered.

One fatality due to a fluorocarbon accident is reported.

The survey also shows that, despite the gradual introduction of good practice recommendations, safety guidelines and other safety instructions, the frequency of accidents does not appear to have decreased during the examined period.

[1] These numbers do not include the catastrophic June 2013 ammonia explosion in China, which caused 119 fatalities and injured 54 other workers, due to a domino effect.

These findings confirm an earlier report on refrigerants safety, which observed that e.g. the calculated risk for the use of ammonia was underestimated and that the risk of fatalities with fluorocarbons was several orders of magnitude lower [1].

## Conclusion

**If more and more HFCs will be mandatorily replaced by potentially harmful alternative refrigerants, the risk of harm to people will only increase. Viewing the severity of the potential effects, EFCTC continues to emphasize that the safety aspects should always be taken into consideration before imposing the use of any alternative refrigerant.**

## References

1. Working Fluid Safety : annex 20. J. Berghmans - Sittard, NL : IEA Heat Pump Center Annex Report no. HPP-AN20-1 (October 1994), to be ordered through http://www-v2.sp.se/hpc/publ/HPCOrder/default.aspx#75

*See also the list of compiled accidents (PDF file)*

*See also Appendix 1 for some more elaboration on the survey and Appendix 2 for more detail on the safety aspects of the different refrigerant types.*

## APPENDIX 1: Basic survey on accidents/incidents involving refrigerants

A non-comprehensive survey/collection of the global frequency of accidents due to refrigerant releases has been set up in order to assess the safety of fluorocarbons, ammonia (R-717), hydrocarbons (mainly propane R-290, propylene R-1270, butane R-600, isobutane R-600a ), and $CO_2$ (carbon dioxide R-744).

The results of the survey covering a time span of nearly 8 years can be summarized as follows:

| Refrigerant | Reports on incidents/accidents (2006-2013) |
|---|---|
| **Ammonia** | • 981 people to be physically injured<br>• 236 to be severely harmed (after inhalation)<br>• 95 fatalities |
| **$CO_2$** [2] | • few people to be injured,<br>• mass evacuation prompted when leak took place in a supermarket |
| **Propane (a hydrocarbon)** | • few severely injured people,<br>• 1 fatality |
| **Fluorocarbons** | • 1 fatality |

In the case of ammonia, these numbers correspond to minimum average frequencies of 120 injured, 30 severely harmed and 12 fatalities each year. In addition, these accidents prompted the evacuation of several thousands of people, to keep them away from harmful gases. By comparison, a US survey on ammonia accidents showed an average frequency of 7 accidents and 2 fatalities/year between 1995 and 2006.

It must be stated, however, that the survey is not comprehensive for different reasons. Firstly, it is mainly based on regular Google Searches. Therefore the results depend on the coverage Google makes of different countries (some being intensively covered, some less so, and some practically not) and on the choice the search engine makes among the websites (local newspapers, firefighters websites, etc.).

Secondly, there is an obvious bias due to the varying consequences of refrigerant releases in terms of severity, types of harmful effects, extent of the damages, … The most damaging events attract far more media attention than the least damaging incidents. The latter might explain why HFC or HCFC accidents are practically unreported within our survey, whereas they are known to have occurred.

Since the survey is non-comprehensive, the collected incidents represent a lower estimate of refrigerant-related accidents. Collecting data on all the accidents that occur is an exercise in which no researcher has succeeded to date.

[2] The survey did not cover $CO_2$ accidents in fire extinguishing systems.

As most refrigeration accidents are due to equipment failure, poor maintenance or human factors, there is little reason to expect significantly different accident frequencies for different refrigerants. The damages from refrigerant leakages differ essentially as a consequence of the dangerous properties of the refrigerant itself.

Despite good practice recommendations, safety guidelines, and several other safety instructions, the frequency of accidents does not appear to have decreased during that period and remains rather stable.

These findings cast doubt on some theoretical risk assessments which conclude that the use of hydrocarbons or ammonia is considered safe, provided stringent safety measures and standards are followed. Calculated risk assessment has led to accident frequency 10-100 times smaller than those observed.

## APPENDIX 2: Some safety aspects of the different refrigerant types

The following characteristics should certainly be kept in mind when choosing the ideal refrigerant for a specific application:

***Ammonia***

Ammonia is a colourless gas with a very sharp odour. Ammonia is strongly caustic and corrosive and the main health effects consist of burns at the sites of direct contact (i.e., skin, eyes, respiratory tract, …). These burns might be serious enough to cause permanent blindness, lung disease, or death due to airway blockage and respiratory insufficiency. Due to its high toxicity, ammonia represents the most frequent cause of accidents. Its dispersion can significantly increase the number of affected people and often requires the evacuation of the neighborhood of the concerned place. Firefighters need special equipment to respond to ammonia accidents.

***Hydrocarbons***

Hydrocarbons are very flammable but their release will only cause accidents if an ignition source is present. Otherwise, the gas is readily dispersed and the risk is rapidly decreased. For this reason and because the number of installed hydrocarbon installations is not very high, except for very small charge sizes and factory sealed equipments, such as those of domestic refrigerators/freezers, the number of reported accidents is much lower.

***Carbon dioxide***

$CO_2$ refrigeration units function at higher pressures, which can cause dangerous equipment ruptures and projections of metallic parts at high energy, potentially causing severe physical injuries. In addition, $CO_2$ is harmful when exposed to it for several hours at low concentrations (1-3%). At concentrations above 10% it may cause fatalities due to the lack of oxygen uptake potentially leading to suffocation and asphyxia.

***Fluorocarbons***

Fluorocarbons used in refrigeration typically display low toxicity characteristics, are non-flammable and disperse rapidly. Their major risk is suffocation and asphyxia due to the lack of oxygen, a risk encountered with any inert gas in confined or non-ventilated areas. The number of fatalities reported is orders of magnitude lower than for ammonia systems, even though there are by far more fluorocarbons systems in use.

## Selected bibliography


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