SMART REFRIGERANT SELECTION FOR ICE RINKS

Part II. What you need to know about safety and health

EXECUTIVE SUMMARY

The global refrigeration industry is responding to a regulatory-driven transition toward a new generation of environmentally sustainable refrigerant solutions. This shift has major impacts on the private and community ice rinks, both large and small, operating in North America.

Part I of this white paper outlined the environmental, regulatory, cost, and energy-efficiency considerations. Part II focuses on the safety, health, and operational profile of common refrigerants used in rink chillers. This two-part white paper provides the key facts decision makers need to select the best refrigerant option for their ice rinks.

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EXECUTIVE SUMMARY (continued)

Apart from environmental, regulatory, and cost concerns, rink owners and operators must also consider a range of health and safety risks when selecting a refrigerant for an ice rink chiller system. Risks such as toxicity, pressure hazards, and flammability are associated with various refrigerants. These risks can be managed with refrigerant selection, chiller-system design, engineering controls, and other mitigation strategies.

The "ideal" refrigerant would have the following health and safety properties:

- Nonflammable (safe for occupants and service technicians and operators)
- Nontoxic (safe for rink occupants in the event of leak or release)
- Low operating pressures and temperatures (safe for service technicians and operators)
- No unusual or unexpected properties, handling, or storage requirements
- No negative environmental impact
- No ozone depleting potential (ODP)
- Low global warming potential (GWP)

While no refrigerant meets the definition of an "ideal" refrigerant, there are refrigerants that can be safely and effectively used. Rink owners and operators should select a product that best meets the desired safety and health profile, while still delivering the performance, regulatory, sustainability, and cost requirements addressed in Part I.

Unpacking Health and Toxicity

> Fundamental to toxicology is the simple fact that the "dose makes the poison." All substances can exert toxic effects at some dose or concentration; but, likewise, there are doses or concentrations that do not produce toxic effects.

For example, toxic effects have been observed for common substances like table salt, oxygen, and water in very large quantities, but their general safety is something demonstrated in normal everyday activities.

For rink owners and operators, there are two key groups of people to consider. The first are the rink occupants (members of the general population, such as customers, players, coaches, skaters, fans, and rink visitors). The second group consists of rink operators and employees.

Occupant Safety

Occupants are the most vulnerable to the potential health risks of short-duration exposures of high refrigerant levels—such as a leak due to a refrigerant system, piping, or component failure. From this perspective, the preferred ice rink refrigerant would have a low short-term health risk, including low risk of escape impairment due to central nervous system effects or irritation of eyes, nose, or lungs.

For rink occupants, it is the acute toxicity exposure limit (ATEL) that is the appropriate "safe" concentration for members of the general population.

Refrigerant	Acute Toxicity Exposure Limit	Other Escape-Impairing Effects
R-717 (Ammonia)	320 ppm	Eye, Nose, and Respiratory Irritation
R-744 (CO_2)	30,000 ppm	None
R-134a	50,000 ppm	None
R-22	59,000 ppm	None
Opteon™ XP10 (R-513A)	72,000 ppm	None
Opteon™ XP40 (R-449A)	100,000 ppm	None
R-410A	170,000 ppm	None

LOWEST RISK > > > > > > HIGHEST RISK

Note: ATEL values are derived by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). The lower the exposure limits, the greater the short-term risk for workers and occupants.

For rink occupants: Opteon™ XP40 and XP10 provide a safety profile better than other common refrigerants (see ATEL data).

Worker Safety

Ice rink operators and employees should be protected against adverse health effects from short-term exposures just like the general public; but, in addition, a preferred ice rink refrigerant would have low long-term health risk to protect workers from health effects associated with daily exposure to the refrigerant throughout their lifetime.

Industry Standards and Workplace Exposure Limits

Refrigerants are classified by ASHRAE Standard 34 based on their long-term toxicity and flammability properties as indicated below.

Refrigerant Safety Classification per ASHRAE Standard 34

	A: Lower Toxicity	B: Higher Toxicity	
1 - No Flame Propagation	A1	B1	No LFL, based on modified ASTM E681-85
2L - Lower Flammability	A2L	B2L	Burning velocity <10 cm/sec
2 - Flammable	A2	B2	LFL <0.010 kg/m^3 and heat of combustion >19,000 kJ/kg
3 - Higher Flammability	A3	B3	LFL <0.1 kg/m^3 or heat of combustion >19,000 kJ/kg

Safety class A (lower toxicity) is reserved for refrigerants with occupational exposure limit (OEL) values of 400 ppm and higher, while class B is for refrigerants with OELs of less than 400 ppm. While the cutoff value of 400 ppm is relatively arbitrary and should not be viewed as a clear line between safe and unsafe refrigerants, it is nevertheless used by code officials and designers to identify and manage refrigerants with the highest potential to cause harm from long-term exposure.

For rink workers: Opteon™ XP40 and XP10 are both listed by ASHRAE as class A1: nonflammable, low-toxicity refrigerants.

Hazards

Pressure Hazards

All chiller systems must be designed to operate safely for the pressures that will be encountered during normal operation as well as unusual events, such as a power failure.

Lower GWP hydrofluoroolefin (HFO) refrigerants operate at pressures similar to today's systems and do not present any issues or hazards when compared to the traditional hydrochlorofluorocarbon (HCFC-22) refrigerants being replaced.

CO_2 (R-744) systems operate at considerably higher pressures than traditional systems and must be designed for high-pressure operation, including pressure relief devices and safe discharge venting. Similarly, due to its pressure-temperature characteristics, care must be taken to ensure liquid CO_2 is never isolated in a pipe or line and allowed to warm up, potentially causing catastrophic line rupture.

CO_2 can be safe to use, but these special considerations increase system-design costs. In addition, the need for service technicians to receive additional training and be equipped with dedicated and appropriately rated equipment (e.g., gauges, recovery machines, hoses, etc.) is another requirement.

Other Unusual Hazards

A hazard unique to R-744 refrigerant is the potential to form dry ice, a solid form of CO_2, inside of a system under certain conditions of temperature and pressure. It is important that every service technician who works on an R-744 system be specifically trained to understand and safely deal with this unusual hazard that is unique to R-744 systems.

Flammability

The flammability of a refrigerant is addressed through a number of industry standards, such as ASHRAE Standard 34. National and local building codes typically adopt these industry standards.

Refrigerant	Flammability Class	Designation
R-717	2L	Lower Flammability
R-744	1	Nonflammable
R-134a	1	Nonflammable
R-22	1	Nonflammable
Opteon™ XP10 (R-513A)	1	Nonflammable
Opteon™ XP40 (R-449A)	1	Nonflammable
R-410A	1	Nonflammable

In typical ice arenas, all refrigerants, including Opteon™ XP40 and XP10, are nonflammable, except ammonia (R-717), which is classified by ASHRAE as class 2L: mildly flammable.

The flammability of ammonia (R-717) requires it to be confined to only locations where the flammability hazards can be managed, such as outdoors or in a machine room with controlled access and dedicated and appropriately rated equipment. While the toxic properties of ammonia typically dominate discussions of its use as a refrigerant, the fact that it is flammable should not be ignored.

In system retrofits, where a new refrigerant replaces an existing refrigerant, such as R-22, rink owners and operators should note that the new alternative should be of the same flammability class as the original product.

While the industry continues to drive to lower GWP refrigerants, at some point flammable refrigerants may become part of the solution. Fortunately, there are several mildly flammable (A2L), low toxicity products in development based on HFO technology. These will avoid the need for highly flammable or explosive (class 3) risks like R-290 (propane); they're also safer from a toxicity standpoint than R-717 (ammonia).

Conclusion

With excellent short- and long-term safety and health profiles, as well as low GWP and zero ODP, HFO refrigerants are becoming a popular choice. While they may not be the only solution for every application or system, HFOs are excellent choices for rinks looking to achieve long-term compliance with an optimal balance of performance, safety, and cost.

As leaders in the refrigeration industry for nearly 100 years, Chemours and our original equipment manufacturer (OEM) and mechanical partners are here to answer all your questions and help you navigate through this transition. Please reach out to us through your local Chemours contact or at optforbetter.com/nhl.

Appendix

Safety Classification and Standards

It is important to keep in mind that occupational exposure limits (OELs) are used to maintain safe workplace concentrations to protect workers over their entire working lifetime. It is not appropriate to use the OEL to assess the safe use of refrigerants in the general population, as the general population is potentially exposed via accidental refrigerant releases and for intermittent or short periods of time. In other words, the acute toxic exposure limit (ATEL) is the appropriate "safe" concentration for members of the general population exposed to refrigerants, and the OEL is the appropriate "safe" workplace concentration.

The table at right provides short-term toxicity data that is the basis for establishing the safe refrigerant concentration in an occupied space.

When calculating a substance's ATEL, the focus is on acute toxicity with attention to lethality, cardiac sensitization, anesthetic effects, and other escape-impairing effects. While it would not be meaningful to make decisions on refrigerant safety based on minor ATEL differences, refrigerants with relatively low ATELs should be carefully assessed for health effects before selection. The table at right provides an illustration of the range of ATEL concentrations (short-term concentrations "presumed safe") documented in ASHRAE Standard 34 and ISO817.

	Short-Term Toxicity		
Refrigerant	Acute Toxicity Exposure Limit (ASHRAE 34)	Acute Toxicity Exposure Limit (ISO817)	Other Escape-Impairing Effects
R-717 (Ammonia)	320 ppm	320 ppm	Eye, Nose, and Respiratory Irritation
R-744 (CO_2)	30,000 ppm	30,000 ppm	None
R-134a	50,000 ppm	50,000 ppm	None
R-22	59,000 ppm	59,000 ppm	None
Opteon™ XP10 (R-513A)	72,000 ppm	72,000 ppm	None
Opteon™ XP40 (R-449A)	100,000 ppm	100,000 ppm	None
R-410A	170,000 ppm	170,000 ppm	None

Safety Classification and Standards
(continued)

Long-term toxicity safety for workers is generally described in terms of OELs. OELs are exposure concentrations averaged over an eight-hour workday that are designed to protect healthy workers throughout a working lifetime.

The table at right provides an illustration of the range of OEL concentrations (i.e., long-term, workplace concentrations that are "presumed safe") documented in ASHRAE Standard 34 and ISO817. There are two safety classifications for refrigerants, A and B, where safety class A (lower toxicity) is reserved for refrigerants with OEL values of 400 ppm and higher, while class B is for refrigerants with OEL values lower than 400 ppm.

OELs are not appropriate for use in conducting health safety assessments for short-term exposures or any exposures involving the general population. OELs have several sources, such as the workplace environmental exposure level (WEEL), threshold limit value (TLV), and permissible exposure limit (PEL). All the mentioned OELs are set using similar processes, but they originate from different organizations. ASHRAE and International Organization for Standardization use OELs to assign safety classifications.

	Long-Term Toxicity	
Refrigerant	Occupational Exposure Limit (OEL)	ASHRAE Safety Class
R-717 (Ammonia)	25 ppm	B
Opteon™ XP10 (R-513A)	650 ppm	A
Opteon™ XP40 (R-449A)	830 ppm	A
R-410A	1,000 ppm	A
R-22	1,000 ppm	A
R-134a	1,000 ppm	A
R-744 (CO_2)	5,000 ppm	A

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