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13th Informatory Note on Refrigerants

Standards for Flammable Refrigerants

Over the past few years, the potential of global warming from greenhouse gases has raised interest in expanding the use of hydrocarbons as refrigerants. Changes to several current (in particular electrical) safety standards have been proposed to permit the use of hydrocarbons and other flammable refrigerants in applications such as household appliances and air conditioners and even in supermarkets. In order to adequately assess the wisdom of these changes, we should first examine current safety standards and the logic behind them.

Safety standards concerning flammable refrigerants address two fundamental issues: (1) defining which refrigerants are flammable and under what conditions, and (2) defining the circumstances under which flammable refrigerants can be safely used. In some cases both issues are addressed in a single standard (e.g., BS 4434, NF E35-400). Table 1 provides a sampling of relevant safety standards concerning the classification of flammable refrigerants and safe practices for their use.

Table 1: Examples of Standards for Classifying and Use of Flammable Refrigerants

	Classifying Flammable Refrigerants	Safe Use of Flammable Refrigerants
US	ASHRAE 34 US DOT (49CFR 173)	ASHRAE 15 UL 1995: heating & cooling equipment UL 250: household refrigerators & freezers
EUROPE	BS 4434 DIN 8960 (draft) NF E35-400 prEN 378 (draft)	BS 4434 DIN 8975 and DIN 7003 (draft) NF E35-400 & 402 prEN 378 (draft) IEC 60335-2-24: household refrigerators IEC 60335-2-40: heat pumps & air-conditioners
JAPAN	General High Pressure Gas Safety Regulation	Refrigeration Safety Regulation

Classification of Flammable Refrigerants (see table 2)

There are differences in:

– the number of classes

Japan and the US Department of Transportation simply have two classifications – flammable and non-flammable.
Both ASHRAE 34 and prEN 378 (along with current European national standards: NF E35-400, BS 4434 and DIN 8960) recognize that some flammable refrigerants are less hazardous than others. They thus have two classes for flammable refrigerants. Ammonia and flammable fluorocarbon refrigerants (e.g., R32, R143a, and R152a) are classified in the less hazardous Class 2, while hydrocarbons are classified in the more hazardous Class 3 flammability classification.

– criteria used to classify refrigerants for flammability

Ammonia is classified as non-flammable in the US DOT standard, whereas it is classified as flammable in the Japanese standard, although its properties would classify it as non-flammable; it is an exception in this standard, represented by (*) in table 2.
Despite the differences in criteria between Class 2 and Class 3, the results are remarkably similar. Only one refrigerant, R50 (methane), is classified differently by the three standards. ASHRAE 34 classifies methane as a Class 3, while BS 4434 and DIN 8960 classify it as Class 2.

– test conditions

Within the US, there is an effort underway to harmonize ASHRAE 34 and UL 2182 test conditions, which may lead to different classifications between US and other standards. Test apparatus and procedures differ between Japan and the US ASTM E681.

Use of Flammable Refrigerants

Underwriters Laboratories (UL) and International Electrotechnical Commission (IEC) standards generally cover safety for specific products. In the past, both of these standards have been very restrictive in allowing the use of flammable refrigerants. They either prohibited or severely restricted the use of all flammable refrigerants. ASHRAE 15, prEN 378 and current European national standards, like BS 4434, DIN 8975, DIN 7003, as well as NF E35-400, all provide broader general guidance on the safe use of refrigerants based on the refrigerant's hazard classification, to include its toxicity hazard as well as its flammability hazard, and the applications in which refrigerants of the same safety classification can be used safely. These standards recognize the inherent difference in the safety implications between Class 2 and Class 3 refrigerants. These standards allow the use of Class 2 flammable refrigerants in most applications with added safety measures. As far as Class 3 refrigerants are concerned, ASHRAE 15 and NF

E35-400 limit their use to industrial applications; whereas prEN 378, BS 4434, DIN 8975 and DIN 7003 allow their use in all or some other applications with added safety requirements, depending on the application and the refrigerant charge, but with high variations between those standards.
Several safety measures have been proposed and, in some countries, taken to address the expanded use of Class 3 flammable refrigerants. It is worth considering how effective these measures can be.

Reducing Leakage

New standards, like prEN 378, consider sealed systems with very slight leakage so as to increase safety in normal use. A safety hazard still exists in the manufacturing, service and end-of-life disposal/material recycling processes. Also, systems can leak as the result of accidental damage during transport, installation, service, or removal.

Table 2: Refrigerant Flammability Classifications, Test Conditions and Criteria

STANDARDS	NF E35-400 prEN 378 BS 4434 DIN 8960	ASHRAE 34 (USA)	49 CFR 23 (US DOT)	Japan Refrigeration Safety Regulation
CLASSIFICA	Class 1 Non-flammable Class 2 Low flammability LFL < 3.5% Class 3 High flammability	Class 1 Non-flammable Class 2 Low flammability LFL ⌨ 0.10 kg/m^3 HC 🖰 19 MJ/kg Class 3 High flammability	Non-flammable LFL ⌨ 13% or Δ 🖰 12% Flammable	Non-flammable * LFL < 10% or Δ 🖰 20% Flammable
TEST CONDITIONS	20°C Dry Air	23°C **(1)** Humid Air **(2)**	20°C Dry Air	20°C Dry Air
CRITERIA **(3)**	LFL (% V/V)	LFL (mass/unit Vol.) and HC	LFL (% V/V) and Δ	LFL (% V/V) and Δ

UFL - Upper Flame Limit **Δ** = Flammability range = UFL-LFL
LFL - Lower Flame Limit **HC** = Heat of Combustion
% V/V - percent volume of refrigerant per volume of air
(1) Proposed ASHRAE Addendum recommends changing test temperature to 100°C/60°C to harmonize with UL 2182
(2) Humid Air is prescribed at 0.0068 ± 0.0004 grams of water per gram of dry air.
(3) When using LFL, all regulations refer to volume percentage except ASHRAE, which refers to mass refrigerant per unit volume (kg/m^3), the equivalent of which in volume per unit of volume varies for each refrigerant.

Precluding Leaked Refrigerants from Achieving a Flammable Concentration

Charge size limitations, also known as "practical limits" or "refrigerant quantity limits", are established in ASHRAE 15, BS 4434, DIN 8975, DIN 7003, and NF E35-400. They are set so that if the charge did leak into a given space, it would not reach a flammable concentration when diffused in that space. This is normally established at 20% (for ASHRAE 15 and BS 4434) or at 25% (for DIN 7003) of the refrigerant quantity required to reach the lower flammability limit when leaked into a prescribed volume. Two problems exist with this safety concept. First, unless calculated for each installation, a unit could be installed in a space smaller than the prescribed space. Second, experimental studies (Clodic, 1997) have shown that even when the charge is limited by the practical limit, hydrocarbons that are heavier than air (e.g., propane and isobutane) can initially pool near the floor in flammable concentrations for considerable periods of time before they disperse into the full volume of the room. This indicates, at the very least, that a practical limit based on 20% of the LFL does not eliminate all risks of a fire in the worst laboratory conditions. Whether these worst case conditions occur in various applications sectors or not will be studied by an IEC-directed, international risk assessment.

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Varying Levels of Added Safety Features Based on the Size of the Charge

Varying safety measures on the size of the charge should take into consideration the difference in the potential hazards of Class 2 and Class 3 flammable refrigerants, given an ignition. The heats of combustion of the Class 3 are considerably higher than those of the Class 2 refrigerants, therefore the energy released (and potential damage) from the ignition of a Class 3 refrigerant will be greater than from an equivalent mass of a Class 2 refrigerant.

Eliminating Ignition Sources

If there are no ignition sources present, then leaked refrigerant will safely dissipate over time to concentrations that are below the flammability limit. However, equipment manufacturers, can only eliminate ignition sources in the equipment they sell. This might be a good measure for installations in controlled facilities, but not for homes and other public areas in which ignition sources can be unwittingly introduced by residents, workers or visitors.

Limit Exposure to Damage or Injury

ASHRAE 15, BS 4434, DIN 8975, DIN 7003, and NF E35-400 identify specific safety practices for the use of flammable refrigerants:

- Use in controlled spaces where the number of exposed workers is limited and the workers are informed of the potential hazard and are familiar with safety precautions.
- Physical separation of flammable containing components (i.e., secondary loop systems and mechanical rooms).

These measures recognize the potential hazard, but limit the risk by limiting exposure to people and facilities.

CONCLUSION

Many current standards (like ASHRAE 15, BS 4434, DIN 8975, NF E35-400, as well as prEN 378) recognize the higher potential hazards of Class 3 refrigerants. However, there are different views on the safe use of Class 3 flammable refrigerants. The US ASHRAE 15 and, in France, NF E35-400, limit the use of Class 3 flammable refrigerants to industrial applications or other applications that severely limit exposure to the public at large. Several European national standards and prEN 378 have taken a less stringent safety approach by allowing a broader range of applications with various safety precautions based on the charge quantity and physical location or separation of components containing Class 3 flammable refrigerants. Expanding the use of Class 3 flammable refrigerants in home appliances and in publicly occupied spaces has been presented as a solution to global warming problems, but this changes past safety practices and should be done with great care to ensure that the safety of the public is maintained.

Abbreviations

AFNOR	Association Française de Normalisation (France)
ANSI	American National Standards Institute (US)
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers (US)
ASTM	American Society for Testing and Materials (US)
BS	British Standard (UK)
DIN	Deutsches Institut für Normung (Germany)
DOT	Department of Transportation (US)
EN	European Norm
IEC	International Electrotechnical Commission
NF	Norme Française (France)
UL	Underwriters Laboratories Inc. (US)

References

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ANSI/ASHRAE Standard 15-1994, Safety Code for Mechanical Refrigeration (US)
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