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REVIEW OF REGULATIONS AND STANDARDS FOR THE USE OF REFRIGERANTS WITH GWP VALUES LESS THAN 20 IN HVAC&R APPLICATIONS

Final Report

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William Goetzler, Javier Burgos, Hirokazu Hiraiwa, and Timothy Sutherland

NAVIGANT CONSULTING, INC.
77 South Bedford St, Suite 400
Burlington, MA 01803

Prepared for

AIR-CONDITIONING AND REFRIGERATION TECHNOLOGY INSTITUTE, INC
2111 Wilson Boulevard, Suite 500, Arlington, Virginia 22201-3001

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List of Acronyms

AC or A/C	Air conditioning
ANSI	American National Standards Institute
ARTI	Air Conditioning and Refrigeration Technology Institute
ARTI-21CR	ARTI Research for the 21st Century Program
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
BSR	ANSI Board of Standards Review
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CFC	Chlorofluorocarbons
CO_2	Carbon dioxide
DOT	Department of Transportation
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
EU	European Union
GWP	Global warming potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HFO	Hydrofluoroolefin
HVAC&R	Heating, ventilation, air conditioning, & refrigeration
IBC	International Building Code
IEC	International Electrotechnical Commission
IFC	International Fire Code
IIAR	International Institute of Ammonia Refrigeration
IMC	International Mechanical Code
ISO	International Organization for Standardization
JISC	Japanese Industrial Standards Committee
LEPC	Local Emergency Planning Committee
LVD	Low Voltage Directive
MSDS	Material Safety Data Sheet
MVAC	Mobile vehicle air conditioning
ODP	Ozone depletion potential
OSHA	Occupational Safety and Health Administration
PED	Pressure Equipment Directive
PEL	Permissible Exposure Limit
PSMP	Project Safety Management Program
RMP	Risk Management Program
SAE	Society of Automotive Engineers
SERC	State Emergency Response Commission
SNAP	Significant New Alternatives Policy
UL	Underwriters Laboratories
US	United States

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1 Executive Summary

As concerns about the global warming potential (GWP) of common fluorocarbon refrigerants have mounted in recent years, many low-GWP refrigerants have garnered increasing attention. Among the options being evaluated are carbon dioxide (CO_2), ammonia, hydrocarbons, and newly developed refrigerants such as hydrofluoroolefins (HFO). However, the flammability, toxicity, and safety of some of these alternative refrigerants limit their applicability. Differences in regulation among regions and application and the diversity of relevant regulatory instruments create uncertainty and complexity for HVAC&R manufacturers who wish to implement these refrigerants. Manufacturers need guidance regarding the regulations, code requirements, and barriers relevant to low-GWP refrigerants.

This report presents the results of a comprehensive review of the regulatory issues in the United States (US), European Union (EU), and Japan that are relevant to the application of emerging low-GWP refrigerants. Specifically, this report focuses on regulatory barriers and issues that may impact the use of CO_2, ammonia, hydrocarbons, and lower-flammability fluids such as HFO-1234yf. Within each region, the categories of stationary refrigeration, stationary air conditioning, and vehicle air conditioning applications are addressed.

This report presents the following key findings, summarized by region for each refrigerant type:

1.1 Carbon Dioxide

Carbon Dioxide – United States

The largest regulatory barrier to using CO_2 refrigerant is achieving approval from the Environmental Protection Agency (EPA) Significant New Alternatives Policy (SNAP) Program. Currently, SNAP approval has been granted for mobile air conditioning in cars and trucks. The lethality of high concentrations of CO_2 in confined areas is of primary concern.

Product safety certification from Underwriters Laboratories (UL) could be used as part of the evidence to be supplied to EPA for evaluation of a SNAP application for each product category. Achieving UL listing for CO_2 will require additional safety measures due to the higher pressures required by CO_2 refrigerant systems.

Because carbon dioxide systems typically operate at higher pressures than other refrigerants, safety standards that require high safety factors can pose a significant barrier to CO_2 systems by requiring more complex and costly designs. For example, UL standard 984 requires pressure safety factors as high as five times the design pressure. UL and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) have begun to address these issues by lowering the safety factor required for carbon dioxide used in secondary loops. Further research on the safety requirements of carbon dioxide systems can help standards organizations determine reasonable, yet safe, standards.

In the area of human comfort, current standards and developing regulations may incentivize the use of carbon dioxide. ASHRAE Standard 15-2007 imposes limits on the use of non-A1 refrigerants in high-probability systems for human comfort. The 2006 IMC and 2006 UMC contain similar requirements as well. If hydrofluorocarbon (HFC) refrigerants are phased out in the US, carbon dioxide may become favored over other non-A1 refrigerants.

Carbon Dioxide – Europe

There do not appear to be any major EU-wide barriers for implementing CO_2 as a refrigerant. CO_2 is already being used and considered in applications such as cars, supermarket refrigeration systems, and industrial systems. Standards such as EN 378 and ISO 5149 provide allowances for non-toxic, non-flammable refrigerants, and do not impose the same restrictions on A1 refrigerants that exist for flammable and toxic refrigerants.

For mobile vehicle air conditioning applications, studies on appropriate concentration limits and leakage rates for carbon dioxide systems may assist in further understanding the appropriate requirements to ensure safety.

Carbon Dioxide – Japan

There appears to be a regulatory gap for safety standards pertaining to refrigerants in transportation-related applications. The High Pressure Gas Safety Act does not cover mobile applications. This is particularly relevant to CO_2, which requires higher pressures than most other refrigerants.

1.2 Ammonia

Ammonia – United States

Ammonia has achieved EPA SNAP approval in most refrigeration and stationary air conditioning applications, but many other restrictions apply. A major barrier facing ammonia is its toxicity—of the four alternative refrigerant classes, it is the only Class B substance. It is also classified as flammability class 2, but would be considered subclass 2L according to ASHRAE Standard 34-2007. In almost every major national standard, ammonia has separate additional safety requirements. These additional requirements do not necessarily constitute insurmountable barriers, but they can be a large burden to manufacturers and facilities.

One of the most significant burdens facing ammonia is the additional paperwork, processes, and procedures required to satisfy EPA and Occupational Safety and Health Administration (OSHA) requirements. Most of these requirements are aimed at mitigating major catastrophes in case of a major leak or complete release of the pressurized gas. One potential route for reducing the regulatory burden for ammonia would be to support changes to the EPA and OSHA regulations to make them more consistent with industry best practices. To support any such changes, the industry would need to conduct adequate risk assessment analyses and tests to demonstrate the safety of ammonia systems.

Additional regulatory burdens for ammonia may arise from individual state regulations. For example, some states heavily restrict industrial uses of ammonia, or have laws against toxic refrigerants that apply to ammonia.

In the area of human comfort, current standards and developing regulations may discourage the use of ammonia. In high-probability systems for human comfort, ASHRAE Standard 15-2007 limits the use of non-A1 refrigerants to 3 kg for residential occupancies and 10 kg for commercial occupancies. The standard does not impose charge limits on industrial occupancies. The 2006 IMC and 2006 UMC contain similar restrictions as well. ASHRAE Standard 15-2007 does exempt sealed absorption and unit systems, but this exemption is not included in the 2006 IMC or the 2006 UMC. Research on the safety of ammonia systems in human comfort applications may help to establish appropriate safety requirements to allow for alternative refrigerants such as ammonia in human comfort applications.

Ammonia – Europe

Ammonia is considered a toxic substance in the EU. Many of the major EU and International Organization for Standardization (ISO) standards include additional safety requirements pertaining specifically to ammonia.

Ammonia – Japan

There appears to be a regulatory gap for safety standards pertaining to refrigerants in transportation-related applications. Currently, the High Pressure Gas Safety Act (HPGSA) does not cover mobile applications, and there is uncertainty in how to regulate the use of flammable refrigerants in mobile air conditioning applications. It is anticipated that this gap will be closed by the Japanese government, but there may be opportunity to influence these regulations through additional research.

The High Pressure Gas Safety Act does apply to stationary applications, such as air conditioning and refrigeration. The HPGSA references several Ministry Ordinances, including the Refrigeration Safety Standards, Container Safety Standards and General Safety Standards, which contain additional safety measures for flammable and toxic refrigerants. These additional requirements may present additional burden on manufacturers, but are not likely to be prohibitive to implementing ammonia in stationary applications.

1.3 Hydrocarbons

Hydrocarbons – United States

Hydrocarbon refrigerants currently face a restrictive regulatory environment within the US. This is primarily due to the high flammability of hydrocarbons, which are designated as Class 3. In general, flammable substances have additional regulatory requirements for safety, leakage, and fire suppression, which can represent additional burdens on their use.

Hydrocarbons have not obtained EPA SNAP approval, and obtaining approval will require manufacturers to rigorously assess the risks attributable to equipment using hydrocarbon refrigerants. This will require a great deal of testing and investment.

In the area of human comfort, current standards do not favor the use of hydrocarbons. In high-probability systems for human comfort, ASHRAE Standard 15-2007 limits the use of non-A1 refrigerants to 3 kg for residential occupancies and 10 kg for commercial occupancies. The standard does not impose charge limits on industrial occupancies. The 2006 IMC and 2006 UMC contain similar restrictions as well. Research on the safety of hydrocarbon systems in human comfort applications may help to establish appropriate safety requirements to allow for alternative refrigerants such as hydrocarbons in these applications.

One of the main concerns about the use of hydrocarbons in HVAC&R applications is the potential for refrigerant leakage and consequent ignition. UL Standard 250 and UL Standard 471 currently permit larger amounts of flammable refrigerant as long as leak tests show that only a certain amount will leak during a leak event. There is much uncertainty about how to acceptably measure the safety risk from leakage of flammable refrigerant, and UL has proposed to change UL 250 to simply limit the refrigerant charge within the equipment. IEC standards do not require ventilation for flammable refrigerants, but simply prohibit products that would let the refrigerant accumulate in one area.

One potential breakthrough for hydrocarbon refrigerants is the recent testing of hydrocarbons in small commercial refrigeration units (e.g. ice cream machines). EPA approval for this purpose would represent a significant opportunity for hydrocarbon use in other applications. Current testing of these devices will potentially lead to more safety and reliability data for using hydrocarbon refrigerants in these applications.

Hydrocarbons – Europe

Regulations for hydrocarbon refrigerants are less restrictive in Europe compared to the US. Safety has been primarily addressed through charge limits for each application. Some specific applications have strict requirements, such as minimum room volume and charge limits, that make it infeasible to use hydrocarbons for those applications. This pertains mostly to residential and commercial packaged AC applications.

Current standard EN 378 sets charge limits based on the height of the equipment, with more restrictive limits reserved for low units. Research on the overall safety of hydrocarbon comfort units, including a comparison of systems at different heights, and an evaluation of safe charge sizes for floor-based units, may provide data to convince regulators to revise standard limits.

International Electrotechnical Commission (IEC) standards for commercial refrigeration set a universal charge limit of 150 g for commercial refrigeration systems used without restriction. This same limit applies to domestic refrigerators. This limit could impose a barrier to larger commercial refrigeration systems using hydrocarbons.

The Pressure Equipment Directive (PED) uses pressure and volume levels to categorize equipment with flammable and/or toxic refrigerants, which are stricter than the levels used for non-flammable refrigerants. Components using flammable refrigerants often require extra reporting and safety assessments by the manufacturer. This has deterred component manufacturers from investing in these products. An investigation of ways to promote equipment development, either through changes in the regulations or through other incentive programs, may help encourage the introduction of hydrocarbon systems.

Hydrocarbons – Japan

There appears to be a regulatory gap for safety standards pertaining to refrigerants in transportation-related applications. Currently, the High Pressure Gas Safety Act does not cover mobile applications, and there is uncertainty in how to regulate the use of flammable refrigerants in mobile air conditioning applications. It is anticipated that this gap will be closed by the Japanese government, but there may be opportunity to influence these regulations through additional research.

The High Pressure Gas Safety Act does apply to stationary applications, such as air conditioning and refrigeration. The HPGSA references several Ministry Ordinances, including the Refrigeration Safety Standards, Container Safety Standards and General Safety Standards, which contain additional safety measures for flammable and toxic refrigerants. These additional requirements may present additional burden on manufacturers, but are not likely to be prohibitive to implementing hydrocarbons in stationary applications.

1.4 A2L Fluids

A2L Fluids – United States

Flammability risk is one of the main safety concerns that must be addressed before A2L fluids are introduced within the US. Although the revised ISO Standard 817 will likely introduce a new A2L designation for refrigerants with lower flammability risk than traditional Class 2 refrigerants, many other important standards and codes make no distinction between Class 2 and Class 3 refrigerants. In the US, ASHRAE Standard 34-2007 Addendum ak recently added an optional 2L subclass to the existing Class 2 flammability classification, signifying class 2 refrigerants with a burning velocity less than or equal to 10 cm/s. Current drafts of ISO 5149 are considering separate, less restrictive requirements on electrical equipment, ventilation, and charge sizes for A2L fluids. Demonstration of the safety of these fluids is important, and further research in this area can help guide revisions to these standards.

A2L fluids will also require EPA SNAP approval for stationary AC and refrigeration applications. EPA and OSHA workplace exposure limits and associated regulations will need to be established for new refrigerants. Research on the safety of these refrigerants in these applications can assist in navigating the EPA SNAP approval process and for guiding

appropriate industry standards such as UL standards. The presence of industry standards can likewise facilitate the national and local adoption of A2L applications.

In the area of human comfort, current standards may not favor use of A2L fluids. In high-probability systems for human comfort, ASHRAE Standard 15-2007 limits the use of non-A1 refrigerants to 3 kg for residential occupancies and 10 kg for commercial occupancies. The standard does not impose charge limits on industrial occupancies. The 2006 UMC contains similar restrictions; however, the 2006 IMC does allow the use of A2 refrigerants in these systems. A2L fluids may be restricted in certain states based on the current mechanical and building code requirements. These restrictions will be important for air conditioning equipment that is too large to meet the 3 kg charge exception provided in ASHRAE Standard 15-2007.

A2L Fluids – Europe

Some European automakers have been moving towards using A2 refrigerants such as HFO-1234yf in mobile vehicle air conditioning systems, due in part to the mobile air conditioning directive that goes into effect in January 2011. Other stationary air conditioning and commercial refrigeration applications face barriers to the use of A2 refrigerants such as HFO-1234yf. These barriers include restrictions on use and charge limits in EU-wide standards. There may be an opportunity to relax or remove these barriers for stationary applications by adopting a new A2L designation in European standards, potentially recognizing that certain flammable refrigerants pose a lesser safety risk. Incorporation of this new designation will require information on the safety of these refrigerants. Research into each A2L refrigerant's safety can assist the adoption of these refrigerants.

IEC standards that set strict, absolute limits on refrigerant charges for refrigeration applications may present a barrier to the use of A2L fluids in larger refrigeration applications. These standards currently set a limit of 225g of A2 refrigerants in refrigeration products, which may not be sufficient for large and super-cold applications. To support the adoption of A2L fluids in large refrigeration applications, further research into appropriate and safe charge levels should be investigated. Draft versions of ISO 5149 currently incorporate less restrictive requirements on electrical equipment, ventilation, and charge limits for A2L fluids.

Large equipment using A2L fluids will likely fall under the scope of the PED. Components using flammable refrigerants often require extra reporting and safety assessments by the manufacturer. This has deterred component manufacturers from investing in these products, and makes it more difficult for equipment manufacturers to implement their products. An investigation on ways to promote equipment development, either through changes in the regulation or through incentive programs, may help encourage the introduction of A2L systems.

A2L Fluids – Japan

In Japan, the automobile industry is lobbying for re-evaluation of the High Pressure Gas Safety Act as it applies to HFO-1234yf. Currently, the HPGSA does not cover mobile applications, and there is uncertainty in how to regulate the use of flammable refrigerants in mobile air conditioning applications. It is anticipated that this gap will be closed by the Japanese government, but there may be opportunity to influence these regulations through additional research.

The High Pressure Gas Safety Act does apply to stationary applications, such as air conditioning and refrigeration. It references several Ministry Ordinances, including the Refrigeration Safety Standards, Container Safety Standards and General Safety Standards, which contain additional safety measures for flammable and toxic refrigerants. These additional requirements may present additional burden on manufacturers, but are not likely to be prohibitive to implementing A2L fluids in stationary applications.

2 Introduction

As concerns about the global warming potential (GWP) of common fluorocarbon refrigerants have mounted in recent years, many low-GWP refrigerants have garnered increasing attention. Among the options being evaluated are carbon dioxide (CO_2), ammonia, hydrocarbons, and newly developed refrigerants such as hydrofluoroolefins (HFO). However, the flammability, toxicity, and safety of some of these alternative refrigerants limit their applicability. Differences in regulation among regions and application and the diversity of relevant regulatory instruments create uncertainty and complexity for HVAC&R manufacturers who wish to implement these refrigerants. Manufacturers need guidance regarding the regulations, code requirements, and barriers relevant to low-GWP refrigerants.

This report presents the results of a comprehensive review of the regulatory issues in the United States (US), European Union (EU), and Japan that are relevant to the application of emerging low-GWP refrigerants. Specifically, this report focuses on regulatory barriers and issues that may impact the use of CO_2, ammonia, hydrocarbons, and lower-flammability fluids such as HFO-1234yf. Within each region, the categories of stationary refrigeration, stationary air conditioning, and mobile vehicle air conditioning applications are addressed.

The information gathered for this report was obtained from a comprehensive literature review of current and proposed federal and selected state and local environmental, health, and safety standards applicable to low-GWP refrigerants. The literature review examined the following sources:

- Regulatory documents
- Building codes
- International standards such as ISO Standards
- Industry standards such as ASHRAE Standards
- Product safety standards such as UL Standards
- Industry publications
- Industry presentations
- Government and agency websites
- Presentations by environmental organizations
- Position papers
- Magazine articles

To aid with this search, a number of key individuals were also consulted, including HVAC&R industry experts, environmental advocacy group representatives, and committee members of various ASHRAE and ISO Standards Committees.

The results of the literature survey and discussions with key individuals helped to identify key gaps in the regulatory treatment of the low-GWP refrigerants of interest, and to highlight major barriers that might inhibit the usage of these refrigerants in particular regions or applications.

To the extent possible, this report provides recommendations on research or other activities that might be advisable in order to remove barriers to acceptance of low-GWP refrigerants. It also identifies cases where the barriers are unlikely to be overcome.

This report is organized as follows:

- Chapter 3 provides a brief background describing the purpose of this study and related prior work.
- Chapter 4 provides a summary table of the regulations, standards, and codes relevant to each low-GWP refrigerant for each region and application type.
- Chapter 5 is a glossary providing a brief description of each of the major regulations, standards, and codes referenced throughout the report.
- Chapters 6 through 9 describe the regulations, standards, and codes relevant to each of the four categories of low-GWP refrigerants under consideration. Each of these chapters corresponds to one of the four refrigerant types. These chapters are organized into sections based on region (US, EU, Japan), and each regional section is further divided into sub-sections based on application type.
- Chapter 10 summarizes the major regulatory gaps and barriers that have been identified for each refrigerant and region.
- The Appendices contain more detailed information about some of the regulations referenced throughout the report.

3 Background

As concerns about the global warming potential of common fluorocarbon refrigerants have mounted in recent years, many low-GWP refrigerants have garnered increasing attention. Among the options being evaluated are carbon dioxide (CO_2), ammonia, hydrocarbons such as propane and isobutene, and newly developed refrigerants such as hydrofluoroolefins (HFO). However, the flammability, toxicity, and safety of some of these alternative refrigerants limit their application:

- Carbon dioxide is a working fluid with higher pressure than any commonly used refrigerants and can be lethal at high concentrations.
- Ammonia is a lower flammability refrigerant that is toxic and harmful to skin, eyes, and lungs, and is almost exclusively used in large industrial plants where special safety measures and installations are applied.
- Hydrocarbon refrigerants are highly flammable and would be prohibited by building codes in most residential and commercial buildings in the United States. In the EU, however, hydrocarbons may be used in domestic refrigerators and small portable air conditioners, provided that their charges do not exceed 150 grams.
- HFOs such as R-1234yf are currently classified by most standards as flammability Class A2 and may face a variety of restrictions depending on application and region. ASHRAE Standard 34 has recently introduced a new 2L subclass signifying Class 2 refrigerants with a burning velocity less than or equal to 10 cm/s.

One recent development is particularly important. ISO Standard 817 is currently undergoing revision and may incorporate a new flammability safety classification. The current standard is similar to ASHRAE Standard 34 and contains three flammability classifications: 1—no flame propagation, 2—lower flammability, and 3—higher flammability; and two toxicity classifications: A—lower toxicity, and B—higher toxicity. The current revision of ISO 817 may subdivide the traditional flammability Class 2 into two separate categories, 2 and 2L. Class 2L refrigerants would include those refrigerants which do show some flame propagation but have relatively low flammability and burning velocity. The relatively lower flammability risk of Class 2L refrigerants might have a better chance of achieving regulatory approval and market acceptance than traditional Class 2 refrigerants.

Clearly, differences in regulation among regions and application, and the diversity of relevant regulatory instruments (e.g. federal and state environmental, health and safety laws; federal and state building codes; independent safety standards from organizations such as ISO, ASHRAE, or UL) create uncertainty and complexity for HVAC&R manufacturers who wish to implement these refrigerants. In order to determine which types of products to produce, manufacturers of HVAC&R equipment, many of whom operate globally, need guidance regarding the regulations, code requirements, and barriers relevant to toxic and flammable low-GWP refrigerants. This report advances the state-of-the-art by thoroughly reviewing current regulations, standards, and code requirements, and identifying gaps and key barriers to safely applying these low-GWP refrigerants in HVAC&R applications.

Prior work on this topic includes the following:

- Jellinek et al. conducted a regulatory impact assessment of flammable zero-ozone depletion potential (ODP) substitutes. They focused on 15 possible compounds, all of which are flammable. They commissioned a broad survey of existing environmental, health and safety requirements to identify regulatory issues that could apply at any point in the life cycle of zero-ODP substitutes used as refrigerants and foam insulation blowing agents. (Jellinek 1995)
- In 2001, ARTI Research for the 21st Century Program (ARTI-21CR) sponsored a study to evaluate the potential use of ASHRAE Class A3 flammable refrigerants such as hydrocarbons in stationary air conditioning and refrigeration. The first phase of the study focused on regulatory issues in the US, Canada, and Mexico. This included analyses of federal, state and local building codes and regulations which could preclude use of flammable refrigerants and would need to be amended for these refrigerants to be widely accepted. The second phase of the study included a literature review of the performance (energy efficiency and capacity), benefits, safety risks, and costs of using A3 flammable refrigerants. (Goetzler 2001).
- Corberan et al. reviewed existing and proposed standards addressing maximum charge, room area limits, and specific requirements for air conditioning and refrigerating equipment using hydrocarbons. (Corberan 2008)

4 Summary Table of Regulations

Table 4-1 below provides a summary of the regulations, standards, and codes relevant to each low-GWP refrigerant for each region and application type. The table contains two major types of regulations:

- Regulations applying to the manufacturing facilities of products within each category
- Regulations applying to the design and installation of equipment within each category

Each cell within Table 4-1 indicates the corresponding table within the body of the report that contains more detailed descriptions of each relevant regulation. The standards underlined in the table are those that represent the most significant gaps or barriers to implementation, as discussed further in Chapter 10.

Table 4-1: Summary of regulations, standards, and codes relevant to each low-GWP refrigerant for each region and application type.

Refrigerant	Region	Refrigeration					Stationary AC			Mobile AC
		Small Comm. Stand-Alone C/F/R	Supermarket Systems	Walk-In Freezers & Coolers	Transport Refrigeration	Industrial Refrigeration Cold Storage	Residential AC (Ductless and Ducted Split)	Commercial AC (Rooftop Split, Packaged & PTAC)	Chillers	Cars & Trucks
CO_2 (A1)	USA	[Table 6-1] - ASHRAE 15-2007 - ASHRAE 34-2007 - DOT Shipping Requirements - **EPA SNAP** - EPCRA Sections 311-312 - Model Codes (IMC, UMC, IFC, UFC) - **OSHA PELs** & PSMP - **UL 471** (Small Comm. only) - **UL 1995** (Supermarket, Walk-In only) - **UL 984**			[Table 6-1] - ASHRAE 26-1996 (RA 2006) - DOT Shipping Requirements - **EPA SNAP** - EPCRA Sections 311-312 - **OSHA PELs** & PSMP - **UL 984**	[Table 6-1] - ASHRAE 15-2007 - ASHRAE 34-2007 - DOT Shipping Reqt's - EPA SNAP - EPCRA Sections 311-312 - Model Codes (IMC, UMC, IFC, UFC) - **OSHA PELs** & PSMP - **UL 984**	[Table 6-2] - ASHRAE 15-2007 - ASHRAE 34-2007 - DOT Shipping Requirements - **EPA SNAP** - EPCRA Sections 311-312 - Model Codes (IMC, UMC, IFC, UFC) - **OSHA PELs** & PSMP - **UL 984**, **UL 1995**			[Table 6-3] - DOT Shipping Reqt's - **EPA SNAP** - EPCRA Section 311-312 - **OSHA PELs** & PSMP - SAE Standard J639 - SAE Standards (others) - State-Level Hazardous Substances Lists
	EU	[Table 6-6] - ATEX Equipment Directive (Industrial Refrigeration only) - ATEX Workplace Directive - EN 378:2008 - EN 60079 - Pressure Equipment Directive (PED)					[Table 6-7] - ATEX Workplace Directive - EN 378:2008 - IEC 60335-2-40 - Pressure Equipment Directive - WEEE Directive (Residential only)		[Table 6-7] - **ATEX Equipment Directive** - ATEX Workplace Directive - EN 378:2008 - EN 60079 - PED	[Table 6-8] - ATEX Workplace Directive - ISO CD/13043
	Japan	[Table 6-9] - Electrical Appliances and Mat'l Safety Act - High Pressure Gas Safety Act - ISO 5149 (as referenced in JIS B8612) - JIS B8240			[Table 6-9] - High Pressure Gas Safety Act - JIS B8240	[Table 6-9] - EAMSA - High Pressure Gas Safety Act - JIS B8240	[Table 6-10] - High Pressure Gas Safety Act - JIS B8240 - JIS B8616, JIS B8620		[Table 6-10] - High Pressure Gas Safety Act - JIS B8240	[Table 6-11] - JIS B8240
Ammonia (B2L)	USA	[Table 7-1] - ASHRAE 15-2007 - ASHRAE 34-2007 - DOT Shipping Requirements - **EPA SNAP** - EPA RMP Program - EPCRA - IIAR Standards & Bulletins - Model Codes (IMC, UMC, IFC, UFC) - OSHA PELs & **PSMP** - UL 471 (Small Comm. only)			[Table 7-1] - **ASHRAE 26-1996 (RA 2006)** - **Clean Air Act** - DOT Shipping Reqt's - **EPA SNAP** - EPA RMP Program - EPCRA - OSHA PELs & **PSMP**	[Table 7-1] - ASHRAE 15-2007 - ASHRAE 34-2007 - DOT Shipping Reqt's - EPA SNAP - EPA RMP Program - EPCRA - IIAR Standards & Bulletins - Model Codes (IMC, UMC, IFC, UFC) - OSHA PELs & **PSMP**	[Table 7-2] - ASHRAE 15-2007 - ASHRAE 34-2007 - Clean Air Act - DOT Shipping Requirements - EPA RMP Program - EPA SNAP - EPRCRA - IIAR Standards & Bulletins - Model Codes (IMC, UMC, IFC, UFC) - OSHA PELs & **PSMP**			[Table 7-3] - Clean Air Act - DOT Shipping Reqt's - EPA RMP Program - **EPA SNAP** - EPCRA - OSHA PELs & **PSMP** - State-Level Hazardous Substances Lists
	EU	[Table 7-8] - ATEX Equipment Directive - ATEX Workplace Directive - EN 378:2008 - EN 60079 - **Pressure Equipment Directive (PED)**			[Table 7-8] - ATEX Workplace Directive - EN 378:2008 - **Pressure Equipment Directive**	[Table 7-8] - **ATEX Equipment Directive** - ATEX Workplace Directive - EN 378:2008 - EN 60079 - **PED**	[Table 7-9] - ATEX Workplace Directive - EN 378:2008 - **IEC 60335-2-40** - **Pressure Equipment Directive** - WEEE Directive (Residential only)		[Table 7-9] - **ATEX Equipment Directive** - ATEX Workplace Directive - EN 378:2008 - EN 60079 - **PED**	[Table 7-10] - ATEX Workplace Directive - ISO CD/13043
	Japan	[Table 7-11] - Electrical Appliances and Mat'l Safety Act - High Pressure Gas Safety Act (HPGSA) - ISO 5149 as referenced in JIS B8612 - JIS B8240 - Offensive Odor Control Act - Poisonous and Deleterious Substances Control Act (PDSA)			[Table 7-11] - High Pressure Gas Safety Act - JIS B8240 - Offensive Odor Control Act - PDSA	[Table 7-11] - EAMSA - HPGSA - JIS B8240 - Offensive Odor Control Act - Poisonous and Deleterious Substances Control Act	[Table 7-12] - EAMSA - High Pressure Gas Safety Act - JIS B8240 - JIS B8616, JIS B8620 - Offensive Odor Control Act - PDSA		[Table 7-13] - JIS B8240	[Table 7-11] - EAMSA - HPGSA - ISO 5149 as referenced in JIS B8612 - JIS B8240 - Offensive Odor Control Act - PDSA

Table 4-1, cont.

Refrigerant	Region	Refrigeration					Stationary AC			Mobile AC
		Small Comm. Stand-Alone C/F/R	Supermarket Systems	Walk-In Freezers & Coolers	Transport Refrigeration	Industrial Refrigeration Cold Storage	Residential AC (Ductless and Ducted Split)	Commercial AC (Rooftop Split, Packaged & PTAC)	Chillers	Cars & Trucks
Hydro-carbons (A3)	USA	[Table 8-1] - **ASHRAE 15-2007**, ASHRAE 34-2007 - Clean Air Act - DOT Shipping Requirements - EPA RMP Program - **EPA SNAP** - EPCRA Sections 311-312 - **Model Codes (IMC, UMC, IFC, UFC)** - OSHA PELs & PSMP - **UL 471**(Small Comm. only), - **UL 1995** (Supermarket, Walk-In only)			[Table 8-1] - **ASHRAE 26-1996 (RA 2006)** - Clean Air Act - DOT Shipping Reqt's - EPA RMP Program - **EPA SNAP** - EPCRA Sections 311-312 - OSHA PELs & PSMP	[Table 8-1] - ASHRAE 15-2007 - ASHRAE 34-2007 - DOT Shipping Reqt's - EPA RMP Program - EPA SNAP - EPCRA Sections 311-312 - Model Codes (IMC, UMC, IFC, UFC) - OSHA PELs & PSMP	[Table 8-2] - **ASHRAE 15-2007** - ASHRAE 34-2007 - Clean Air Act - DOT Shipping Requirements - EPA RMP Program - **EPA SNAP** - EPCRA Sections 311-312 - **Model Codes (IMC, UMC, IFC, UFC)** - OSHA PELs & PSMP - **UL 1995**			[Table 8-3] - Clean Air Act - DOT Shipping Reqt's - EPA RMP Program - **EPA SNAP** - EPCRA Sections 311-312 - OSHA PELs & PSMP - **State-Level Hazardous Substances Lists**
	EU	[Table 8-7] - ATEX Equipment Directive - ATEX Workplace Directive - EN 378:2008 - EN 60079 - **IEC 60335-2-75**, **IEC 60335-2-89** - **Pressure Equipment Directive**			[Table 8-7] - ATEX Workplace Directive - EN 378:2008 - **Pressure Equipment Directive**	[Table 8-7] - **ATEX Equipment Directive** - ATEX Workplace Directive - EN 378:2008 - EN 60079 - **Pressure Equipment Directive**	[Table 8-8] - ATEX Workplace Directive - **EN 378:2008** - **IEC 60335-2-40** - **Pressure Equipment Directive** - WEEE Directive (Residential only)		[Table 8-8] - **ATEX Equipment Directive** - ATEX Workplace Directive - **EN 378:2008** - EN 60079 - **Pressure Equipment Directive**	[Table 8-9] - ATEX Workplace Directive - ISO CD/13043
	Japan	[Table 8-10] - Electrical Appliances and Mat'l Safety Act - Fire & Disaster Management Act (FDMA) - High Pressure Gas Safety Act (HPGSA) - ISO 5149 as referenced in JIS B8612 - JIS B8240			[Table 8-10] - High Pressure Gas Safety Act - JIS B8240	[Table 8-10] - EAMSA - FDMA - High Pressure Gas Safety Act - JIS B8240	[Table 8-11] - EAMSA - Fire & Disaster Management Act - High Pressure Gas Safety Act - JIS B8240 - JIS B8616, JIS B8620		[Table 8-12] - JIS B8240	[Table 8-10] - EAMSA - FDMA - HPGSA - ISO 5149 / JIS B8612 - JIS B8240
A2L Fluids (A2L)	USA	[Table 9-1] - ASHRAE 15-2007, ASHRAE 34-2007 - Clean Air Act - DOT Shipping Requirements - **EPA SNAP** - EPCRA - **Model Codes (IMC, UMC, IFC, UFC)** - OSHA PELs & PSMP - **UL 471** (Small Comm. only) - **UL 1995** (Supermarket, Walk-In only)			[Table 9-1] - **ASHRAE 26-1996 (RA 2006)** - Clean Air Act - DOT Shipping Requirements - **EPA SNAP** - EPCRA - OSHA PELs & PSMP	[Table 9-1] - ASHRAE 15-2007 - ASHRAE 34-2007 - Clean Air Act - DOT Shipping Requirements - **EPA SNAP** - EPCRA - **Model Codes (IMC, UMC, IFC, UFC)** - OSHA PELs & PSMP	[Table 9-2] - **ASHRAE 15-2007** - ASHRAE 34-2007 - Clean Air Act - DOT Shipping Requirements - **EPA SNAP** - EPCRA - **Model Codes (IMC, UMC, IFC, UFC)** - OSHA PELs & PSMP - **UL 1995**			[Table 9-3] - Clean Air Act - DOT Shipping Reqt's - **EPA SNAP** - EPCRA - OSHA PELs & PSMP - SAE Standard J639 - SAE Standards (others) - **State-Level Hazardous Substances Lists**
	EU	[Table 9-4] - ATEX Equipment Directive - ATEX Workplace Directive - **EN 378:2008** - EN 60079 - **IEC 60335-2-75** - **IEC 60335-2-89** - **Pressure Equipment Directive**			[Table 9-4] - ATEX Workplace Directive - **EN 378:2008** - **Pressure Equipment Directive**	[Table 9-4] - **ATEX Equipment Directive** - ATEX Workplace Directive - **EN 378:2008** - EN 60079 - **Pressure Equipment Directive**	[Table 9-5] - ATEX Workplace Directive - **EN 378:2008** - **IEC 60335-2-40** - **Pressure Equipment Directive** - WEEE Directive (Residential only)		[Table 9-5] - **ATEX Equipment Directive** - ATEX Workplace Directive - **EN 378:2008** - EN 60079 - **Pressure Equipment Directive**	[Table 9-4] - ATEX Equipment Directive - ATEX Workplace Directive - **EN 378:2008** - EN 60079 - **IEC 60335-2-75** - **IEC 60335-2-89** - **PED**
	Japan	[Table 9-7] - Electrical Appliances and Mat'l Safety Act - Fire & Disaster Management Act (FDMA) - **High Pressure Gas Safety Act** - ISO 5149 as referenced in JIS B8612 - JIS B8240			[Table 9-7] - **High Pressure Gas Safety Act** - JIS B8240	[Table 9-7] - EAMSA - FDMA - **HPGSA** - JIS B8240	[Table 9-8] - Electrical Appliances and Material Safety Act - Fire & Disaster Management Act - **High Pressure Gas Safety Act** - JIS B8240 - JIS B8616, JIS B8620			[Table 9-9] - Chemical Substances Control Act - JIS B8240

5 Glossary - Descriptions of Applicable Regulations

5.1 United States

5.1.1 Overall Regulatory Summary

In the US, there are a series of national and state regulations applicable to refrigerants that are used in refrigeration, stationary AC, and mobile AC applications. Refrigerants must first seek the approval of EPA's SNAP program for each application in which the alternative refrigerant will be used. Refrigerants can be approved or denied for use in particular applications, and approval can be conditional on meeting certain use conditions prescribed by EPA.

After EPA SNAP approval is secured, equipment must meet safety standards from OSHA-approved testing laboratories. Equipment must meet safety standards such as UL standards, which prescribe safety standards for particular equipment. UL standards may prescribe additional requirements on equipment using certain refrigerants, as deemed appropriate.

Individual states also establish building codes and legislative limits on the use of refrigerants, including safety requirements and use restrictions. These vary by state and can differ widely. The International Building Code (IBC) and International Mechanical Code (IMC) have been adopted by many states; this has served to harmonize many of these building codes across states.

Many of the requirements for alternative refrigerants are based on ASHRAE Standard 15, the Safety Standard for Refrigeration Systems. The IBC and IMC codes recognize ASHRAE Standard 15 as the industry standard. The standards for ammonia refrigeration systems set by the International Institute of Ammonia Refrigeration (IIAR) are also harmonized with ASHRAE Standard 15. EPA recommended that users follow all requirements and recommendations specified in ASHRAE Standard 15 in its ruling on carbon dioxide as an acceptable refrigerant in retail food refrigeration and cold storage warehouse applications. Changes in ASHRAE Standard 15 have also been used to justify changes in UL standards.

The handling, use, and transportation of substances considered hazardous are also subject to reporting requirements through the EPA's Risk Management Program (RMP), OSHA's Process Safety Management of Highly Hazardous Chemicals, and the Emergency Planning and Community Right-to-Know Act.

Some of the major regulations, standards, and codes for low-GWP refrigerants within the US are described in further detail below. The regulations are listed alphabetically.

5.1.2 ANSI/ASHRAE Standard 15-2007: Safety Standard for Refrigeration Systems

ASHRAE Standard 15-2007 is published by ASHRAE. The purpose of the standard is to specify the safe design, construction, installation, and operation of refrigeration systems. The standard applies to all refrigeration and stationary AC applications. Many building codes and bulletins

refer to ASHRAE Standard 15-2007; the International Mechanical Code recognizes ASHRAE Standard 15-2007 as the industry standard for refrigeration safety. Refrigerants classified as mildly or highly flammable or as highly toxic in ASHRAE Standard 34, described below, receive restrictions on their use in ASHRAE Standard 15. As the recognized leading standard, ASHRAE Standard 15 has moved towards harmonization with ISO Standard 5149, ANSI/IIAR-2, and various IEC standards.

5.1.3 ANSI/ASHRAE Standard 26-1996 (RA 2006): Mechanical Refrigeration and Air-Conditioning Installations Aboard Ship

ASHRAE Standard 26-1996 (RA 2006) is published by ASHRAE. The purpose of the standard is to provide requirements for refrigeration systems aboard ships with central refrigeration plants. Many of the requirements are derived from ASHRAE Standard 15 and altered to recognize the unique aspects of ship-board systems, including the difficulty of evacuating passengers in case of a refrigerant-related incident.

5.1.4 ANSI/ASHRAE Standard 34-2007: Designation and Safety Classification of Refrigerants

ASHRAE Standard 34-2007 is published by ASHRAE. The purpose of the standard is to provide a system for referencing refrigerants and classifying refrigerants based on toxicity and flammability. The different safety classifications developed in ASHRAE Standard 34-2007 are used in ASHRAE Standard 15-2007 to provide safety guidelines for the design and installation of refrigerating systems, based on the refrigerant that is used. In addition, ASHRAE Standard 34-2007 defines the permissible concentration limits allowed by ASHRAE Standard 15-2007.

5.1.5 ANSI/IIAR 2-2008: American National Standard for Equipment, Design, and Installation of Ammonia Mechanical Refrigerating Systems

ANSI/IIAR 2-2008 is published by the International Institute of Ammonia Refrigeration (IIAR). The purpose of the standard is to guide the design, manufacture, installation, and use of ammonia mechanical refrigerating systems with industrial occupancies. The standard applies to any closed circuit mechanical refrigerating systems using ammonia as a refrigerant. ANSI/IIAR 2-2008 has codified the industry best practices for using ammonia in industrial applications. ANSI/IIAR-2 is largely harmonized with ASHRAE Standard 15.

IIAR has published a series of bulletins to provide informative documents on the safety, design, components, and start-up of mechanical refrigeration systems that use ammonia refrigerant. These guidelines are not intended to be binding. IIAR is in the process of codifying the language of these bulletins to fit a series of eight IIAR standards. The collection of finished IIAR standards will include standards for: Definitions, Design, Valves, Installation, Startup, Operation, Maintenance, and Decommissioning. According to the IIAR President, all but the Decommissioning Standard will be published in 2010 as revisions to the existing standard or newly approved ANSI standards. (Badger 2009)

5.1.6 Clean Air Act (42 USC Sec. 7401 et seq.)

Section 608 of the Clean Air Act (42 USC Sec. 7671g) regulates the usage and disposal of refrigerants, including CFC, HCFC, and substitute refrigerants such as those covered in this report. The Clean Air Act prohibits the venting, release, or disposal of class I, class II, and most substitute refrigerants during maintenance, servicing, repair, or disposing of an appliance or industrial process refrigeration system that uses any such refrigerant, unless the EPA Administrator determines that doing so does not pose a threat to the environment. EPA has introduced exemptions to the venting prohibition for ammonia in commercial or industrial process refrigeration or in absorption units; hydrocarbons in industrial process refrigeration (processing of hydrocarbons); and carbon dioxide in any application.

5.1.7 Department of Transportation (DOT) Shipping Requirements

The US Department of Transportation sets requirements for the shipping of hazardous materials in 49 CFR 173. These include requirements for packaging, labeling, testing, and inspecting shipments for transportation. There are a set of specific requirements for compressed gases, including refrigerants. There are a series of exceptions for refrigerating machines, based on the type and amount of refrigerants used within them. DOT can also grant waivers for manufacturers on these requirements.

5.1.8 Emergency Planning and Community Right-to-Know Act (EPCRA) (also known as SARA Title III)

The Emergency Planning and Community Right-to-Know Act (EPCRA) established requirements designed to improve community access to information about chemical hazards and aid the development of chemical emergency response plans by state/tribe and local governments. The EPCRA requires facilities using threshold quantities of substances considered hazardous or extremely hazardous to create emergency plans and submit them to local authorities, coordinate with local authorities in the case of releases, and report any releases. EPA defines these substances and threshold quantities. In addition, state and local governments may have additional emergency planning and community right-to-know requirements. (EPA 2009a)

The EPCRA contains the following four major provisions:

(1) Emergency Planning Notification (Section 302(c))
(2) Emergency Release Notification (Section 304)
(3) Hazardous Chemical Storage Reporting Requirements (Sections 311-312)
(4) Toxics Release Inventory Reporting (Section 313)

5.1.9 EPA Risk Management Program (RMP) (40 CFR 68.130)

EPA issued the Chemical Accident Prevention Provisions rule in 1999, which requires all facilities with processes using extremely hazardous, toxic, and flammable substances at certain threshold quantities to participate in EPA's Risk Management Program.

The Risk Management Program requires facilities to develop and implement a risk management program (RMP), submit a risk management plan to EPA and local authorities, and to update the RMP every five years.

EPA lists all substances covered by the RMP and their threshold quantities in 40 CFR 68.130. Substances covered by the RMP are also subject to OSHA's Project Safety Management Program. (EPA 2009b).

5.1.10 EPA Significant New Alternatives Policy (SNAP) Program

EPA established the Significant New Alternatives Policy (SNAP) Program to evaluate and regulates substitutes for current Class I (CFC) and Class II (HCFC) ozone depleting refrigerants used in US industry. The EPA SNAP Program considers each refrigerant end use separately, including 16 different end uses for refrigeration and air conditioning.

At the end of an evaluation, EPA determines whether a particular refrigerant is deemed acceptable for use in a particular end use. Refrigerants can be deemed acceptable with certain restrictions in place. The four listings that are available are the following:

- Acceptable
- Acceptable subject to use conditions
- Acceptable subject to narrowed use limits
- Unacceptable

Substitute refrigerants found to be unacceptable for a particular end-use cannot be used for that end-use in the US. Substitutes do not have to be considered risk-free to be considered acceptable, but should minimize risk during use. Substitutes are evaluated based on the following criteria:

- Atmospheric effects
- Exposure assessments
- Toxicity data
- Flammability
- Other environmental impacts

In the past, the EPA SNAP Program has granted certain users limited permission to test equipment using substitute refrigerants not considered acceptable for their particular end-use. The purpose of these waivers is to assess the risk of using the particular refrigerant.

5.1.11 International Building Code (IBC) 2009

The International Building Code (IBC) provides standards for the construction, alteration, movement, enlargement, replacement, repair, equipment, use and occupancy, location, maintenance, removal, and demolition of every building or structure. The International Code Council publishes the IBC and updates it every three years. The latest version of the IBC code is IBC 2009, but many state building codes reference the older 2006 and 2003 versions. The IBC has

been adopted by the vast majority of states as their official building code, with and without amendments. The IBC defers to the International Mechanical Code for standards on HVAC&R equipment.

5.1.12 International Mechanical Code (IMC) 2009

The International Mechanical Code (IMC) provides safety regulations for the design, installation, construction, and repair of refrigeration systems that vaporize and liquefy a fluid during the refrigerating cycle. The International Code Council publishes the IMC and updates it every three years. The IMC draws many of its regulatory codes from ASHRAE Standard 15, though it does deviate from the standard in some places. The IMC is referenced by the International Building Code as the regulatory source for mechanical systems.

The latest version of the IMC code is IMC 2009, but many state mechanical codes reference the older 2006 and 2003 versions. The IMC has been adopted by nearly three-quarters of the states as their official mechanical code, with and without amendments. The IMC provides the same function as the Uniform Mechanical Code, and states can adopt either code.

5.1.13 Occupational Safety and Health Administration (OSHA) Standards

The Occupational Safety and Health Administration (OSHA) was created to help prevent work-related injuries, illnesses, and deaths. OSHA has created a series of standards with which all industries must comply. For chemicals considered potentially dangerous to employees' health, OSHA has created a series of requirements surrounding the use of hazardous substances, whether they are toxic, flammable, or reactive.

Relevant Subparts of the Occupational Safety and Health Standards (29 CFR 1910) include:

- Subpart H – Hazardous materials
- Subpart E – Exit routes, emergency action plans, and fire prevention plans
- Subpart I – Personal protective equipment
- Subpart S – Electrical
- Subpart Z – Toxic and hazardous substances

5.1.14 OSHA Permissible Exposure Limits (PEL)

OSHA maintains a list of permissible exposure limits (PEL) for substances that may cause harm to employees. These are listed in Subpart Z – Toxic and hazardous substances, under 29 CFR 1910.1000. An employee's exposure cannot surpass the permissible exposure limit at any time, and the general standards apply to all industries. OSHA has two types of PELs:

- 8-hour time weighted averages
- Ceiling values – either instantaneous or 15-minute time weighted average

To demonstrate compliance with the PEL requirements, industries must have controls and/or protective equipment in place to prevent exposure, certified by a competent industrial hygienist or other technically qualified person. (29 CFR 1910.1000) (OSHA 2009b)

5.1.15 OSHA Process Safety Management of Highly Hazardous Chemicals Standard (29 CFR 1910.119)

The Process Safety Management of Highly Hazardous Chemicals standard is found under Subpart H, for Hazardous Materials (OSHA 2009a). It regulates the management of hazardous substances in all industries. OSHA maintains a list of substances considered potentially hazardous. Process safety management regulations apply only to the following processes:

- Processes involving a chemical at or above the specified threshold quantities listed in the standard
- Processes involving a flammable liquid or gas on site in one location, in the quantity of 10,000 pounds (4535.9 kg) or more (with some minor exceptions)

These regulations do not apply to retail facilities but do apply to all industrial applications. The requirements under this standard include the following:

- Collecting and making available an information sheet (such as a Material Safety Data Sheet) to all employees on the hazardous substances used
- Documenting the compliance of equipment, such as refrigerating equipment and safety systems
- Developing and updating a process hazard analysis
- Providing clear instructions and procedures on the safe use of equipment and systems
- Providing training to all employees presently involved in operating a process
- Performing inspections and tests on process equipment
- Investigating and reporting of incidents
- Establishing and implementing an emergency action plan
- Performing compliance audits with respect to the standard at least every three years

5.1.16 Society of Automotive Engineers (SAE) Standards

The Society of Automotive Engineers (SAE) publishes a wide variety of standards for the mobile transportation industry. These standards govern, among other topics, the safety, design, maintenance and evaluation of mobile vehicle air conditioning systems, and the training and procedures required by technicians servicing these systems. The SAE standards relevant to this report are described below. The descriptions of each standard were obtained from the SAE website. (Atkinson 2009)

SAE Standard J2772: Refrigerant Passenger Compartment Concentrations Measurement Under A/C System Refrigerant Leakage Conditions

- The purpose of this SAE standard is to establish an industry standard for determining the refrigerant concentration inside a vehicle cabin arising from a refrigerant circuit leakage. This standard is restricted to refrigeration circuits that provide air conditioning for the passenger compartments of passenger and commercial vehicles. For generation of a refrigerant level in the vehicle compartment, an external refrigerant source is inserted into the HVAC module airflow to the passenger compartment. The

measurement shall cover vehicle compartment design boundaries, possible usage of the vehicle and the refrigerant system.

SAE Standard J2773: Refrigerant Guidelines for Safety and Risk Analysis for use in Mobile Air Conditioning Systems

- This SAE standard enumerates the processes and methods required to prove the compliance of relevant safety measures for complex technical systems. According to this standard, the safety requirements for alternative refrigerant vapor compression systems must be verified for the entire lifecycle of the vehicle. This requirement is restricted to systems that provide air conditioning for the passenger compartments of passenger and commercial vehicles. This standard focuses on requirements only and does not demand nor suggest concrete solutions.

SAE Standard J2842: HFO-1234yf and R-744 Evaporator Design Certification for OEM and Service Replacement

- This document covers the recommended design practices for application of mildly toxic and mildly flammable refrigerant for use in mobile air conditioning systems. It addresses issues that must be addressed by design engineers who design and develop systems for use with these refrigerants.

SAE Standard J2845: Technician Certification for Servicing and Refrigerant Containment of A/C Systems

- Technician training and certification is required to ensure safe, efficient and effective service and repair of mobile air conditioning systems using R-744, HFC-152a and HFO-1234yf. This standard outlines minimum content requirements for such training programs. The technician must be trained to recognize which refrigerant is being handled; how to handle it safely; and how to be equipped with the essential information, proper equipment, and tools, which may be unique to a single refrigerant.

SAE Standard J2683 [Revised]: R-744 Refrigerant Purity and Container Requirements for Refrigerant Used in Mobile Air-Conditioning Systems

- This SAE standard applies to carbon dioxide R-744 refrigerant used to service motor vehicle passenger air conditioning and heat pump systems. R-744, when used as a refrigerant in mobile air conditioning systems, shall contain an odorant as an identification of refrigerant leaking from the system. R-744 and R-134a used as refrigerants in mobile air conditioning systems are not interchangeable. Refrigerants must not be mixed together.

SAE Standard J2769: R-744 Service Hose, Fittings and Couplers for Mobile Refrigerant Systems Service Equipment

- This SAE standard covers fittings, couplers, and hoses intended for connecting from carbon dioxide (R-744) mobile refrigerant systems to refrigerant removal and charging equipment. These fittings and hoses differ in size and connection thread type from traditional fittings used with R-12 or R-134a equipment.

SAE Standard J2770: Service Standards for Mobile Air Conditioning Systems

- The purpose of this standard is to establish minimum requirements for handling of carbon dioxide (R-744) in the service environment.

SAE Standard J2771: R-744 Refrigerant Recovery-Charging Equipment for Mobile Automotive Air Conditioning Systems

- The purpose of this SAE standard is to provide equipment specifications for the controlled removal, evacuation, and charging of R-744 refrigerant for mobile refrigerant systems. System charging and service is challenging due to the high pressures. Recovery of used R-744 is not required. This standard is required for equipment used to service automobiles, light trucks, and other vehicles with similar R-744 refrigerant systems.

SAE Standard J2774: R-744 Refrigerant Minimum Performance Criteria for Electronic Leak Detectors

- This SAE standard is restricted to R-744 refrigeration circuits that provide air conditioning for the passenger compartments of passenger and commercial vehicles. The purpose is to establish an industry standard for electronic probe-type leak detectors intended for use in automotive air conditioning systems with R-744 refrigerant. This includes design and performance criteria, test procedures for the apparatus, and the best practice for usage.

SAE Standard J2775: R-744 Ultraviolet Leak Detection: Procedure for Use of Refrigerant Leak Detection Dyes for Service of Mobile Air-Conditioning Systems

- This SAE standard applies to fluorescent leak detection dyes and the corresponding injection equipment or other methods of installing the dye which are to be used when servicing a mobile air conditioning system's refrigerant circuit for the purpose of allowing the application of fluorescent leak detection. Dyes should also work with R-744 refrigerant with odorant added.

SAE Standard J2843: HFO-1234yf Refrigerant Recovery- Recycle - Charging Equipment for Mobile Automotive Air Conditioning Systems

- The purpose of this SAE standard is to establish the specific minimum equipment performance requirements for recovery of HFO-1234yf that has been directly removed

from a mobile air conditioning system. It also establishes requirements for equipment used to recharge HFO-1234yf to a specified accuracy level.

SAE Standard J2844: HFO-1234yf Refrigerant Purity and Container Requirements for Refrigerant Used in Mobile Air-Conditioning Systems

- This SAE standard applies to refrigerant used in motor vehicle passenger air conditioning systems designed to use HFO-1234yf.

SAE Standard J2851: HFO-1234yf Refrigerant Recovery-Only Equipment for Mobile Automotive Air Conditioning Systems

- The purpose of this SAE standard is to provide minimum performance and operating feature requirements for the recovery of HFO-1234yf refrigerant to be returned to a refrigerant reclamation facility that will process it to the appropriate standard or allow for recycling of the recovered refrigerant to SAE J2843 specifications by using J2843-certified equipment. It is not acceptable for refrigerant removed from a mobile air conditioning system with this equipment to be returned directly to a mobile AC system.

SAE Standard J2887 - HFO-1234yf Service Standards for Mobile Air Conditioning Systems

- The purpose of this standard is to establish minimum requirements for handling of HFO-1234yf in the service environment.

SAE Standard J2888: HFO-1234yf Service Hose, Fittings and Couplers for Mobile Refrigerant Systems Service Equipment

- This SAE standard covers fittings intended for connecting service hoses from mobile air conditioning systems to HFO-1234yf service equipment such as manifold gauges, vacuum pumps and air conditioning charging, recovery and recycling equipment.

SAE Standard J639: Safety Standards for Motor Vehicle Refrigerant Vapor Compression Systems

- This SAE standard is currently being revised to include standards for alternative refrigerants. A small number of states have begun to adopt SAE Standard J639 as a reference to replace older motor vehicle air conditioning refrigerant laws.

SAE Standard J639 [Revised]: Safety Standards for Motor Vehicle Refrigerant Vapor Compression Systems

- This SAE Standard Practice is restricted to commercial vehicle passenger compartments. This document provides design standards and safety for these systems. Also included are cautionary statements for the mobile air conditioning service industry to alert service technicians to the inadvisability and the possible health and safety effects associated with venting refrigerant during service. It is not intended to restrict the use, or further

development, of other types of refrigeration systems for passenger compartment cooling. This document addresses only CFC-12 (R-12), HFC-134a (R-134a), HFC152a (R-152a) and HFO-1234yf flammable gas, and carbon dioxide (R-744) refrigerants. To prevent system contamination, all refrigerants used in mobile air conditioning vapor compression systems require unique service fittings. The unique service fittings eliminate the potential for system refrigerant cross-contamination during service activity.

5.1.17 UL 207: Refrigerant-Containing Components and Accessories, Nonelectrical

UL Standard 207 is published by Underwriters Laboratories Inc., which is a Nationally Recognized Testing Laboratory recognized under OSHA's Directorate of Technical Support and Emergency Management. These standards help determine which products are fit for use in the US workplace based on OSHA safety requirements. UL Standard 207 provides safety requirements for nonelectrical refrigerant-containing components and accessories in refrigeration systems, air conditioning equipment, or both. It does not include equipment covered by ASME's Boiler and Pressure vessel code, section VIII.

5.1.18 UL 471: Commercial Refrigerators and Freezers

UL Standard 471 covers safety standards for unitary and remote commercial refrigerators and freezers, including display cases, reach-in cabinets, meat cases, frozen food, merchandising cabinets, beverage coolers, beverage cooler-dispensers, food service carts, ice cream cabinets, soda fountain units, door panel assemblies, and processing water coolers. Equipment not covered by UL Standard 471 includes refrigeration systems such as those used in cold-storage rooms, walk-in coolers, and similar places that are fabricated in the field.

Appendix C of this report contains additional information on UL 250: Household Refrigerators and Freezers. While residential refrigeration equipment falls outside the scope of this report, the current developments of UL 250 are potentially relevant to commercial refrigerators and freezers.

5.1.19 UL 484: Room Air Conditioners

UL Standard 484 covers safety standards for room air conditioners, including packaged terminal air conditioners, special purpose air conditioners, and recreational vehicle air conditioners.

5.1.20 UL 984: Hermetic Refrigerant Motor-Compressors

UL Standard 984 covers safety standards for hermetic refrigerant motor-compressors, rated 7200V or less, used in both air conditioning and refrigerating equipment.

5.1.21 UL 1995: Heating and Cooling Equipment

UL Standard 1995 covers safety standards for a variety of stationary heating and cooling equipment, including heat pumps, air conditioners, combination heating and cooling

equipment, liquid chillers, and condensing units. This equipment is intended for use in nonhazardous locations, rated 7200 V or less, single- or 3-phase.

5.1.22 Uniform Mechanical Code (UMC) 2009

The Uniform Mechanical Code (UMC) provides safety standards for the design, construction, installation, quality of materials, location, operation, maintenance or use of HVAC&R systems. The UMC is published by the International Association of Plumbing and Mechanical Officials and is updated every three years. The latest version of the UMC code is UMC 2009, but many state building codes refer to the older 2003 and 2006 versions. The UMC has been adopted by a small number of states, mostly in the western part of the United States. The UMC provides the same function as the International Mechanical Code, and states can adopt either code. The UMC draws many of its regulatory codes from ASHRAE Standard 15, though it does deviate from the standard in some places.

5.2 Europe

5.2.1 Overall Regulatory Summary

Regulations for refrigerants in the European Union (EU) are governed by both standards and directives. Directives are issued by the European Commission, and contain essential requirements for certain types of equipment, without providing the technical specifications for meeting these requirements. Standards are technical documents developed by one of three European standards organizations, containing technical specifications for the design, manufacturer, and/or operation of equipment. These standards are confirmed by individual nations and passed into law through legislative action at the national level. Many European standards are harmonized with the relevant European directives, so that by complying with the standard, manufacturers and users will also be in compliance with the harmonized directives.

The EU has three technical organizations that develop standards. European standards are issued by the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC), and the European Telecommunications Standards Institute (ETSI). CEN provides the majority of European standards. Refrigeration and air conditioning standards are usually issued by CEN and the CENELEC.

The relevant regulations, standards, and codes for low-GWP refrigerants within the EU are described in further detail below, listed alphabetically.

5.2.2 ATEX Directive (94/9/EC and 99/92/EC)

The ATEX Directive consists of two broad-reaching directives that pertain to the safe operation of electrical equipment in potentially explosive environments and workplace protections required for environments with potentially explosive atmospheres. “Explosive atmosphere” refers to a mixture with air, under atmospheric conditions, of flammable substances in the form of gases, vapors, mists, or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture (Directive 1999/92/EC).

Directive 94/9/EC, also called ATEX 95 or the ATEX Equipment Directive, covers equipment and protective systems intended for use in potentially explosive atmospheres, regardless if the equipment itself contains flammable or potentially explosive materials. This directive applies to companies that design, manufacture, or sell equipment or protective systems intended for use in potentially explosive atmospheres.

Directive 99/92/ED, also called ATEX 137 or the ATEX Workplace Directive, covers the health and safety protection of workers potentially at risk from explosive atmospheres. This directive describes the safety measures employers must implement to prevent and protect against explosions. It also classifies hazardous areas into different zones.

The following guidelines can be used to determine the applicability of the ATEX Directive (Danfoss 2009):

- Locations for "standard "refrigeration systems with CFC, HCFC, HFC, and Ammonia are normally not classified as hazardous areas.
- Refrigeration systems located in hazardous areas (e.g. in petro-chemical plants) must fulfill requirements for potentially explosive atmospheres regardless of the refrigerant.
- Industrial refrigeration systems with hydrocarbon refrigerants are normally classified as hazardous areas.
- "Potentially explosive atmospheres" do not occur inside a refrigeration system because no oxygen is present.
- "Potentially explosive atmospheres" can occur outside a refrigeration system (in the location of a refrigeration system).
- Refrigeration systems in "potentially explosive atmospheres" can contain flammable or non-flammable refrigerants.

The ATEX Workplace Directive likely applies to the facilities that manufacture HVAC&R equipment. The presence of large quantities of flammable refrigerants may create a potentially explosive atmosphere within the facility, as described by the Directive. Manufacturers would be required to take specific measures to protect the health and safety of workers at these facilities.

5.2.3 EN 378:2008 – Refrigerating Systems and Heat Pumps – Safety and Environmental Requirements

EN 378:2008 is published by CEN. The standard applies to nearly all refrigeration systems, including stationary AC and commercial refrigeration, within all member states of the EU. The standard was updated in 2008 to ensure its harmonization with the Pressure Equipment Directive and the Machinery Safety Directive. It is currently not harmonized with the ATEX Directive.

The standard contains four different parts, whose most recent versions are listed below:

- EN 378-1:2008: Basic requirements, definitions, classification, and selection criteria
- EN 378-2:2008/A1:2009: Design, construction, testing, marking, and documentation

- EN 378-2:2008: Installation site and personal protection
- EN 378-4:2008: Operation, maintenance, repair and recovery

Standard EN 378 covers nearly every phase of the design, construction, and operation of a refrigerating system. Compliance with the safety requirements of EN 378 will ensure compliance of all regulatory standards and documents. However, individual countries within the EU can specify additional requirements. EN 378 references several other European standards, including some of the standards listed here.

The current version of EN 378 also includes mobile vehicle air conditioning applications; however, CEN has recently removed these systems from the scope of this standard. MVAC systems will instead be covered by a new standard, ISO CD/13043, which is currently under development by ISO TC/22 WG 14.

Appendix A of this report lists the maximum charge limits mandated by EN 378 for A1, A2, A3, and B2 refrigerants.

5.2.4 EN 13313:2001 – Refrigerating Systems and Heat Pumps – Competence of Personnel

EN 13313:2001 is published by CEN. EN 13313:2001 establishes procedures for achieving and assessing the competence of persons who design, install, inspect, test and commission, maintain, repair and dispose of refrigerating systems and heat pumps with respect to health, safety, environmental protection, and energy conservation requirements. The standard in particular covers requirements for training, assessment, and maintenance of competence.

5.2.5 EN 60079 – Electrical Apparatus for Explosive Gas Atmospheres

EN 60079 is published by CENELEC and covers many different requirements for construction, safety, protection, and training for electrical systems in potentially explosive gas atmospheres. There are numerous parts to this standard, all published and updated at different times. One of the most important to the regulatory environment is EN 60079-15:2005, which is harmonized with the ATEX Directive for equipment in potentially explosive atmospheres. This standard covers a gap left by other European electrical equipment standards

5.2.6 EN / IEC Standard 60335

IEC Standard 60335 provides safety requirements for electrical appliances found in residential and light commercial settings. These appliances are not rated at more than 250 V for single-phase appliances, and 480 V for other appliances. The safety requirements address common hazards presented by these appliances. IEC Standard 60335 contains many sections addressing different types of equipment. A selection of these pertaining to commercial refrigeration and stationary air conditioning applications are addressed below.

5.2.7 EN 60335-2-40:2003+A2:2009 / IEC 60335-2-40

EN/IEC 60335-2-40 specifies requirements for electrical heat pumps, air conditioners, and dehumidifiers.

5.2.8 EN 60335-2-75:2004 / IEC 60335-2-75

EN/IEC 60335-2-75 specifies requirements for commercial dispensing appliances and vending machines, specifically for the delivery of food, drinks, and consumer products.

5.2.9 EN 60335-2-89:2002 / IEC 60335-2-89

EN/IEC 60335-2-89 specifies requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor. Some applications covered by this standard include refrigerated display and storage cabinets, service counters, and blast chillers.

5.2.10 ISO CD/13043

The current version of EN 378 includes mobile vehicle air conditioning applications; however, CEN has recently removed these systems from the scope of this standard. MVAC systems will instead be covered by a new standard, ISO CD/13043, which is currently under development by ISO TC/22 WG 14.

5.2.11 ISO 817:2005 – Refrigerants – Designation System

ISO 817:2005 is published by the International Organization for Standardization, and provides a system for numbering and classifying refrigerants. It is comparable to ASHRAE Standard 34, and both ASHRAE and ISO have taken steps to harmonize these two standards.

5.2.12 Low Voltage Directive (LVD) (2006/95/EC)

The Low Voltage Directive (LVD) was issued by the European Commission and took full effect on January 16, 2007. The LVD covers electrical equipment between 50 and 1000 V alternate current, and 75 and 1500 V direct current. Electrical equipment intended for use in a potentially explosive atmosphere is outside of the scope of this directive. The LVD provides safety requirements for equipment within the scope of the directive.

5.2.13 MAC Directive (2006/40/EC)

The MAC Directive was issued by the European Commission and will take full effect on January 1, 2011. The MAC Directive bans the use of refrigerants in mobile vehicle air conditioning systems with a global warming potential of greater than 150. Two subsequent regulations from the European Commission (Regulation No 706/2007/EC and Directive 2007/37/EC) provide more guidance and clarification on the implementation of this directive. Due to the MAC Directive, car manufactures in Europe have been required to convert their current mobile vehicle air conditioning systems from R-134a to other alternatives.

5.2.14 Machinery Directive (MSD) (2006/42/EC)

The Machinery Directive was issued by the European Commission to revise a previous Machinery Directive (98/37/EC) and harmonize the directive with other directives such as the Low Voltage Directive. The new directive will take full effect on December 29, 2009. The Machinery Directive provides health and safety requirements for a broad spectrum of equipment defined as machinery. It does not cover mobile applications. The requirements address the design, construction, operation, and safety features of the equipment covered within its scope. The latest version of European Standard EN 378 has been harmonized with the Machinery Directive.

5.2.15 Pressure Equipment Directive (PED) (97/23/EC)

The Pressure Equipment Directive (PED) was issued by the European Commission and took full effect on May 29, 2002. The PED covers equipment subject to pressure hazards such as heat exchangers, vessels, boilers, industrial piping, and related safety equipment, among others. The PED provides essential safety requirements covering design, manufacture, and testing for equipment meeting certain thresholds. It also requires a CE Marking for such equipment. The latest version of European Standard EN 378 has been harmonized with the Pressure Equipment Directive.

The PED divides equipment into four categories, dependent on the type of refrigerant used and the combination of pressure and volume of refrigerant in the system. Category I is the least stringent category, and manufacturers can self-certify products in this category. Categories II and III have a greater number of test and documentation requirements, some of which may require third-party verification. Category IV has the most stringent requirements, and requires many third-party verifications of the manufacturers' safety tests and analysis. The PED provides a series of guidelines and pressure/volume charts to help manufacturers determine the category into which their equipment falls. Manufacturers who comply with the PED place a CE Marking on their equipment.

5.2.16 Regulation on the Classification, Labeling, and Packaging of Substances and Mixtures

The new Regulation on the Classification, Labeling, and Packaging of Substances and Mixtures took effect on January 20, 2009, and replaced older directives (Directive 67/548/EEC and Directive 1999/45/EC) that addressed the same issue. The Regulation was issued to incorporate the criteria set forth by the Globally Harmonized System of Classification and Labeling of Chemicals, a system agreed to at the United Nations level. The Regulation requires companies to classify, label, and package appropriately their hazardous chemicals before placing them on the market.

5.2.17 Waste Electrical and Electronic Equipment (WEEE) Directive

The WEEE Directive became law in February 2003 and establishes collection, recycling, and recovery targets for certain types of electrical and electronic equipment. The current scope of

this directive includes residential AC equipment. It does not include commercial or industrial equipment.

5.3 Japan

Regulations for refrigerants in Japan are governed by a few key statutes and standards. While some statutes cover extremely broad range of topics (e.g., the High Pressure Gas Safety Act covers the production, storage, sales, transport, disposal, and usages of any and all high-pressure gases), the Ministry of Economy, Trade, and Industry issues ministerial ordinances to supplement them with additional details on how these broad statutes apply to refrigerant use. Many Japanese standards, all established by the Japanese Industrial Standards Committee (JISC), are based on, or harmonized with, relevant international standards established by the IEC.

The relevant regulations, standards, and codes for low-GWP refrigerants within Japan are described below in further detail. The regulations are listed alphabetically.

5.3.1 Chemical Substances Control Law

The Chemical Substances Control Law mandates prior evaluation of certain hazardous properties of new chemical substances which are intended to be manufactured or imported to Japan. The law was enacted in 1973, originally in response to environmental pollution caused by polychlorinated biphenyls (PCBs). In 2003 the law was amended to introduce a focus on the impact of chemical substances on flora and fauna, and the possibility of discharge into the environment. The law consists of two parts: 1) prior assessment of new chemical substances, and 2) regulations based on their properties.

5.3.2 Electrical Appliance and Material Safety Act

The Electrical Appliance and Material Safety Act regulates manufacturing, import, and sales of electrical appliances. This regulation sets maximum charge limits of 150g for flammable refrigerants used in natural convection systems, corresponding to IEC Standard 60335-2-24, and 100 grams for flammable refrigerants used in forced air circulation systems.

5.3.3 Fire and Disaster Management Act

The Fire and Disaster Management Act regulates general handling (including production, storage, and transportation) of flammable substances. Flammable substances are defined as substances with either the ignition point lower than 100°C, or the flash point lower than -20°C and boiling point lower than 40°C.

5.3.4 High Pressure Gas Safety Act

The High Pressure Gas Safety Act regulates the handling (including production, storage, sale, and transportation) and consumption of high-pressure gases in a stationary setting, as well as the manufacture and handling of their containers. The Japanese Ministry of Economy, Trade,

and Industry has issued Ministerial Ordinances to establish relevant safety standards, including Refrigeration Safety Standards, Container Safety Standards, and General Safety Standards.

5.3.5 ISO 5149:2005 – Mechanical Refrigerating Systems Used for Cooling and Heating – Safety Requirements

ISO 5149:2005 is published by the International Organization for Standardization (ISO), and provides safety requirements on the design, construction, installation, and operation of refrigerating systems. The standard applies to all refrigerating systems where the refrigerant is evaporated and condensed in a closed circuit, including heat pumps and absorption systems. It is comparable to ASHRAE Standard 15, and both ASHRAE and ISO have taken steps to harmonize these two standards. The A2L requirements within the latest proposed draft version of ISO 5149 are shown in Appendix B.

5.3.6 JIS B8240: Construction of Pressure Vessels for Refrigeration

JIS B8240 is published by JISC. It is a safety standard for refrigeration equipment that uses refrigerant with a boiling point lower than -150°C.

5.3.7 JIS B8612: Commercial Refrigeration Cabinets

JIS B8612 is a safety standard developed by JISC. It refers to JISC B8620 for its refrigerant leakage testing procedure.

5.3.8 JIS B8620: Safety Code for Small Refrigerating Equipment

JIS B8620 is a safety standard developed by JISC. It specifies the construction of parts subjected to refrigerant pressure in order to ensure the safety of small refrigerating equipment that use a compressor.

5.3.9 Offensive Odor Control Act

Under the Offensive Odor Control Act, each prefecture defines how and where the control of odorous substances is enforced. This regulation explicitly identifies ammonia as one of the controlled substances.

5.3.10 Poisonous and Deleterious Substances Control Act

The Poisonous and Deleterious Substances Control Act regulates the production, import, sale, storage, transportation, and display of toxic substances for non-medical purposes. This regulation explicitly identifies ammonia as a deleterious substance.

6 Carbon Dioxide Regulatory Review

This chapter describes the regulations, codes, and standards relevant to carbon dioxide (CO_2) refrigerant for the United States, Europe, and Japan. The descriptions are organized by application type for each of the three regions.

Carbon dioxide is classified by ASHRAE as a Class A1 refrigerant and is designated as R-744.

6.1 Carbon Dioxide - United States

Table 6-1 below summarizes the regulations, codes, and standards affecting the use of CO_2 refrigerant in commercial refrigeration applications within the US.

Table 6-2 below summarizes the regulations, codes, and standards affecting the use of CO_2 refrigerant in stationary AC applications within the US.

Table 6-3 below summarizes the regulations, codes, and standards affecting the use of CO_2 refrigerant in mobile AC applications within the US.

Some of the broader regulations that apply to multiple applications are described in further detail following the tables below.

Table 6-1: Regulations affecting CO_2 refrigerant in commercial refrigeration applications within the United States.

CO_2 >> United States >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Small Commercial Stand-Alone Coolers/ Freezers/ Refrigerators **Supermarket Systems** **Walk-In Freezers/ Coolers**	ASHRAE 15-2007	ASHRAE Standard 15-2007 received an addendum in June 2009 regarding the use of CO_2 as a refrigerant. It specified the minimum design pressures that a refrigerating system must adhere to for safety. The change allows the use of R-744 as a secondary coolant or refrigerant in certain situations. It allows limited releases of R-744 to the atmosphere during unusual events, such as an extended power failure with coincident heat gains that would otherwise cause system pressure to rise above component design pressures. The addendum also explains that the current design pressure requirements for refrigerating systems were restrictive and unnecessary for systems using R-744. In particular, the change targets cascade systems being used in supermarkets, refrigerated warehouses, and industrial plants. Addendum f also adds the following sections to ASHRAE 15-2007: **9.2.6** When a refrigerating system utilizes carbon dioxide (R-744) as a heat transfer fluid, the minimum design pressure for system components shall comply with the following: **9.2.6.1** In a circuit without a compressor, the design pressure shall be at least 20% higher than the saturation pressure corresponding to the warmest location in the circuit. **9.2.6.2** In a cascade refrigerating system, the highside design pressure shall be at least 20% higher than the maximum pressure developed by a pressure-imposing element, and the lowside pressure shall be at least 20% higher than the saturation pressure corresponding to the warmest location in the circuit. See the description of ASHRAE Standards below for additional details.
	ASHRAE 34-2007	See description of ASHRAE Standards below for additional details.
	DOT Shipping Requirements	See description of DOT Shipping Requirements below for details.

Table 6-1, cont.

CO_2 >> United States >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
(continued) **Small Commercial Stand-Alone Coolers/ Freezers/ Refrigerators** **Supermarket Systems** **Walk-In Freezers/ Coolers**	EPA SNAP	CO_2 as a refrigerant has been approved for use without restriction, as a substitute for Class II substances in air conditioning and refrigeration applications, in the following applications (as of September 30, 2009): • Retail food refrigeration (Includes grocery cases, convenience store reach-in cases, and restaurant walk-in refrigerators) CO_2 as a refrigerant has been approved for use without restriction, as a substitute for Class I substances in commercial refrigeration applications, in the following applications (as of September 30, 2009): • Retail food refrigeration (Includes: grocery cases, convenience store reach-in cases, and restaurant walk-in refrigerators) CO_2 as a refrigerant has not been approved for the following applications: • Vending machines • Ice machines • Water coolers See below for additional relevant EPA regulations.
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	Model Codes	See description of Model Codes below for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.
	UL 471 (Small Commercial Stand-Alone only)	Underwriters Laboratories published the following excerpt in the November 2009 Edition of UL Refrigeration News and Notes: "A Joint Task Group (JTG) was formed for the purpose of drafting requirements for large scale refrigeration equipment using R-744 (CO_2) as the refrigerant. The JTG was comprised of representatives from equipment manufacturers, UL, and other safety organizations. Requirements have been drafted and submitted to the appropriate Standards Technical Panels (STPs) for comment and vote. The draft requirements are based on a proposed revision to clause 9.2.6 of ASHRAE 15. Current designs of such equipment use the refrigerant in a sub-critical manner, so the proposed requirements are not intended to cover the use of CO2 in transcritical applications." (UL Refrigeration Notes 2009) The carbon dioxide requirements have been published in UL 471, the Standard for Commercial Refrigerators and Freezers and UL 1995, the Standard for Heating and Cooling Equipment (see UL 1995 below).
	UL 984	UL 984 requires pressure safety factors as high as five times the design pressure, which may create a large burden on manufacturers due to the higher design pressures required for CO_2 systems.
	UL 1995	As of November 2009, requirements for equipment using trans-critical carbon dioxide as a refrigerant were added to UL 471 and UL 1995. These changes were based on addendum f to ASHRAE Standard 15-2007, which modified the design pressure requirements for cascade refrigerating systems. The new requirements lessen the restrictions on using carbon dioxide in a secondary system, without requiring a high-side pressure five times that which is experienced during normal operation – which would be highly restrictive for CO_2. Instead, in secondary systems using carbon dioxide as a refrigerant (without a compressor), the system design pressure must be 20% larger than the expected operating pressure.

Table 6-1, cont.

CO_2 >> United States >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Transport Refrigeration	ASHRAE 26-1996 (RA 2006)	There are a number of allowances for ships using CO_2 as a refrigerant that apply to the area of transport refrigeration: • Section 5.5.1.2 details refrigerant requirements for ships that are not intended for carrying passengers. For direct and indirect cargo or process refrigeration systems, only refrigerants of groups A1, B1, and B2 can be used, which includes carbon dioxide. Section 5.2.4 states that carbon dioxide cannot be used in an atmospheric free state unless proper precautions are taken to prevent hazard to life through a deficiency of oxygen.
	DOT Shipping	See description of DOT Shipping Requirements below for details.
	EPA SNAP	CO_2 as a refrigerant has not been approved for refrigerated transport. See below for additional EPA regulations.
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.
	UL 984	UL 984 requires pressure safety factors as high as five times the design pressure, which may create a large burden on manufacturers due to the higher design pressures required for CO_2 systems.
Industrial Refrigeration Cold Storage	ASHRAE 15-2007	See description of ASHRAE 15-2007 above for Small Commercial Stand-Alone Coolers/Freezers/Refrigerators for details.
	ASHRAE 34-2007	See description of ASHRAE Standards below for additional details.
	DOT Shipping	See description of DOT Shipping Requirements below for details.
	EPA SNAP	CO_2 as a refrigerant has been approved for use without restriction, as a substitute for Class II substances in air conditioning and refrigeration applications, in the following applications (September 30, 2009): • Very low temperature refrigeration CO_2 as a refrigerant has been approved for use without restriction, as a substitute for Class I substances in non-commercial refrigeration applications, in the following applications: • Industrial process refrigeration CO_2 as a refrigerant has been approved for use without restriction, as a substitute for Class I substances in commercial refrigeration applications, in the following applications (September 30, 2009): • Non-mechanical heat transfer • Very low temperature refrigeration
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	Model Codes	See description of Model Codes below for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.
	UL 984	UL 984 requires pressure safety factors as high as five times the design pressure, which may create a large burden on manufacturers due to the higher design pressures required for CO_2 systems.

Table 6-2: Regulations affecting CO_2 refrigerant in stationary AC applications within the United States.

CO_2 >> United States >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Residential AC **Commercial AC** **Chillers**	ASHRAE 15-2007	A1 refrigerants used in high-probability systems for human comfort are not subject to the charge limits established for non-A1 refrigerants.
	ASHRAE 34-2007	See description of ASHRAE Standards below for additional details.
	DOT Shipping	See description of DOT Shipping Requirements below for details.
	EPA SNAP	While EPA SNAP approval has been granted for a number of commercial refrigeration applications, carbon dioxide has not been approved as an acceptable refrigerant substitute in stationary A/C applications. Manufacturers seeking to introduce this technology into the US will have to seek EPA SNAP approval for this technology.
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	Model Codes	See description of Model Codes below for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.
	UL 984	UL 984 requires pressure safety factors as high as five times the design pressure, which may create a large burden on manufacturers due to the higher design pressures required for CO_2 systems.
	UL 1995	As of November 2009, requirements for equipment using trans-critical carbon dioxide as a refrigerant were added to UL 471 and UL 1995. These changes were based on addendum f to ASHRAE Standard 15-2007, which modified the design pressure requirements for cascade refrigerating systems. The new requirements lessen the restrictions on using carbon dioxide in a secondary system, without requiring a high-side pressure five times that which is experienced during normal operation – which would be highly restrictive for CO_2. Instead, in secondary systems using carbon dioxide as a refrigerant (without a compressor), the system design pressure must be 20% larger than the expected operating pressure.

Table 6-3: Regulations affecting CO_2 refrigerant in mobile AC applications within the United States.

CO_2 >> United States >> Mobile AC		
Application	**Applicable Regulations**	**Description**
Cars & Trucks	DOT Shipping Regulations	Refrigerant accumulators for motor vehicles being shipped must be designed with a burst pressure of not less than five times their charged pressure at 70° when shipped. (49 CFR Part 173.306) Exemptions can be obtained through the Office of Hazardous Materials within the DOT, but require proof that the safety of the equipment is equivalent to that specified under the regulation. (Taddonio 2008).
	EPA SNAP	CO_2 was approved as an acceptable substitute refrigerant for CFC-12 in mobile vehicle air conditioning in 2006, subject to certain use conditions. EPA proposed use conditions because of the potential risk of exposure to elevated concentrations of CO_2 within the passenger compartment due to a leak in the MVAC system. In 2006, EPA proposed to amend the acceptability of R-744 to include the use condition that MVAC systems must be designed to avoid occupant exposure to concentrations above the CO_2 short-term limit exposure limit of 3% averaged over 15 minutes. EPA is considering a ceiling limit of 4% R-744, or 40,000 ppm, which should not be exceeded for any duration inside the passenger compartment. CO_2 has not been approved as an acceptable refrigerant substitute for HCFC-22 in mobile vehicle air conditioning for buses or passenger trains.
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.
	SAE Standard J639	SAE Standard J639 is currently being revised to include standards for alternative refrigerants. A small number of states have begun to adopt SAE Standard J639 as a reference to replace older MVAC refrigerant regulations.
	SAE Standards: J2772, J2773, J2842, J2845, J639 [Revised], J2683 [Revised], J2769, J2770, J2771, J2774, J2775	The Society of Automotive Engineers (SAE) has recently published a group of new and revised standards on the safety, design, maintenance, and technician training requirements for MVAC systems. In total, as of February 2009, there are eleven new or revised standards that deal with the use of CO_2 as a refrigerant in MVAC systems. These standards are described in greater detail in the Section 5 Glossary.
	State-Level Hazardous Substance Lists	Carbon dioxide is not considered a toxic substance by any relevant state regulations.

Some of the broader regulations from the tables above that apply to carbon dioxide systems within the US are described in further detail below.

ASHRAE Standards

Unlike A2, A3, B2, and B3 refrigerants, there are no restrictions on the total amount of A1 refrigerant that can be used in the occupied areas and machinery rooms of institutional occupancies. Refrigerating systems installed in public corridors or lobbies are restricted to A1 or B1 refrigerants in specified amounts. Carbon dioxide is exempt from the ban on open flames that use combustion air from the machinery room, as well as the requirement for combustion equipment to include additional features when installed in the same room as refrigerant-containing equipment. Also, for special cases, machinery rooms containing CO_2 are not required to meet Class 1, Division 2 of the National Electric Code.

For A1 refrigerants, unlike all other refrigerant classes, there are no requirements for the use of a protective metal enclosure for annealed copper tubes erected on the premises or for brazing of joints for refrigerant-containing copper tube that are made by the addition of filler material.

Table 6-4 below shows the ASHRAE 34-2007 refrigerant concentration limits for carbon dioxide.

Table 6-4: ASHRAE Standard 34-2007 refrigerant concentration limits for carbon dioxide.

ASHRAE Standard 34-2007 Concentration Limits for Carbon Dioxide			
Refrigerant	Refrigerant Concentration Limits		
	ppm v/v	g/m3	Lb/Mcf
Carbon dioxide	40,000	72	4.5

Source: ASHRAE Standard 34-2007(modifies ASHRAE 15 based on addendum c to ASHRAE 15)

DOT Shipping Requirements

Carbon dioxide is considered a non-flammable compressed gas under DOT shipping regulations. According to Part 173.306 in subpart G, refrigerating machines are exempt from meeting certain requirements for packaging and shipping of compressed gases if, for machines using A1 refrigerants, they contain no more than 5,000 lbs. of refrigerant, they contain shut-off valves, and they meet the safety requirements specified by ASHRAE Standard 15.

According to Part 173.307 in subpart G, refrigerating machines are exempt from the requirements for compressed gasses if they use 20 kg (44 lbs.) or less of a Group A1 refrigerant.

EPA Regulations

Risk Management Program (RMP)
Carbon dioxide is not listed as a regulated substance under the risk management program.

Emergency Planning and Community Right-to-Know Act (SARA III) (EPCRA) Sections 311-312: Hazardous Chemical Storage Reporting Requirements
Carbon dioxide is recognized as a hazardous substance by OSHA, and thus qualifies for

reporting under the Hazardous Chemical Storage Reporting Requirements. For facilities containing 10,000 lbs. or more of carbon dioxide, facilities must maintain a material safety data sheet (MSDS) and submit the MSDS to their State Emergency Response Commission (SERC), Local Emergency Planning Committee (LEPC), and local fire department. Facilities must also report an annual inventory of these chemicals by March 1 of each year to their SERC, LEPC and local fire department. The information must be made available to the public.

Model Codes

The 2006 IMC closely follows many requirements laid out in ASHRAE Standard 15, but there are a number of important differences with respect to carbon dioxide. The largest difference with ASHRAE 15 is the amount of refrigerant allowed by the 2006 IMC, as discussed further in Appendix E. The 2006 IMC allows carbon dioxide to be used in any system and occupancy without additional restrictions because of its low-toxicity and non-flammability. Systems using A1 refrigerants such as carbon dioxide are exempt from some requirements that reduce the risk of fire, especially requirements regarding surface temperatures of equipment and open flames.

The 2006 UMC also follows many of the requirements laid out by ASHRAE Standard 15, but is not as faithful to the language and content of the standard as the 2006 IMC. A1 refrigerants can be used in any system and any occupancy, and the quantity requirements of the 2006 UMC match the requirements of ASHRAE Standard 15. However, unlike the IMC, the 2006 UMC does not distinguish between industrial occupancies and non-industrial occupancies. Because of this, some equipment using A1 refrigerant in a non-industrial setting may require a machinery room.

OSHA Regulations

Permissible Exposure Limits
Carbon dioxide is listed as a hazardous substance by OSHA. OSHA has set the Permissible Exposure Limits for carbon dioxide as shown below in Table 6-5.

Table 6-5: OSHA permissible exposure limits for carbon dioxide.

OSHA Permissible Exposure Limits		
Substance	**ppm**	**mg / m^3**
Carbon dioxide	5,000	9,000

Process Safety Management of Highly Hazardous Substances
Carbon dioxide is not listed as a highly hazardous substance under the process safety management program.

6.2 Carbon Dioxide - Europe

Table 6-6 below summarizes the regulations, codes, and standards affecting the use of CO_2 refrigerant in commercial refrigeration applications within Europe.

Table 6-7 below summarizes the regulations, codes, and standards affecting the use of CO_2 refrigerant in stationary AC applications within Europe.

Table 6-8 below summarizes the regulations, codes, and standards affecting the use of CO2 refrigerant in mobile AC applications within Europe.

Some of the broader regulations that apply to multiple applications are described in further detail following the tables below.

Table 6-6: Regulations affecting CO_2 refrigerant in commercial refrigeration applications within Europe.

CO_2 >> Europe >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
All Commercial Refrigeration Applications	ATEX 94/9/EC	The ATEX Equipment Directive applies to systems installed in facilities or locations that contain potentially explosive environments. This is particularly important for industrial refrigeration cold storage applications. The ATEX Equipment Directive excludes commercial transport refrigeration applications. For electrical equipment covered by the ATEX Equipment Directive, IEC 60079 provides safety requirements for preventing ignition in potentially explosive atmospheres.
	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378:2008	See description of EN 378 below for details.
	EN 60079	EN Standard 60079 is harmonized with the ATEX Directive. It provides requirements for electrical systems used in potentially explosive atmospheres. The standard establishes three different categories of environments that present certain dangers when using electrical equipment and sets technical requirements for electrical equipment used in these environments. These requirements can include explosion-proof enclosures, automatic cut-off switches, and location of the equipment, depending on the environmental conditions.
	Pressure Equipment Directive	Under Article 9 of the PED, carbon dioxide is considered a Group 2 fluid. Manufacturers using carbon dioxide must use Table 1 of Annex 2 of the PED to determine their equipment category and the restrictions placed upon its design, manufacture, and testing. Descriptions of all equipment categories and associated restrictions are described in Appendix D of this report.

Table 6-7: Regulations affecting CO_2 refrigerant in stationary AC applications within Europe.

CO_2 >> Europe >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Residential AC **Commercial AC**	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378: 2008	See description of EN 378 below for details.
	IEC 60335-2-40	Refrigerant charge limits for IEC 60335-2-40 depend on the lower flammability limit of the refrigerant, the size of the room in which the equipment is installed, and the ventilation that is provided for the equipment. These restrictions are similar to those used by EU 378. For carbon dioxide, the restrictions apply mainly to systems installed in human-occupied spaces. These restrictions are not expected to constitute a major barrier to implementation.
	Pressure Equipment Directive	Under Article 9 of the PED, carbon dioxide is considered a Group 2 fluid. Manufacturers using carbon dioxide must use Table 1 of Annex 2 of the PED to determine the equipment category and the restrictions placed upon its design, manufacture, and testing. Descriptions of all equipment categories and associated restrictions are described in Appendix D of this report.
	WEEE Directive	The Waste Electrical and Electronic Equipment Directive establishes collection, recycling, and recovery targets for residential AC equipment. It does not include commercial or industrial equipment.
Chillers	ATEX 94/9/EC	The ATEX Equipment Directive applies to systems installed in facilities or locations that contain potentially explosive environments. It excludes residential applications.
	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378:2008	See description of EN 378 below for details.
	EN 60079	EN Standard 60079 is harmonized with the ATEX Directive. It provides requirements for electrical systems used in potentially explosive atmospheres. The standard establishes three different categories of environments that present certain dangers when using electrical equipment and sets technical requirements for electrical equipment used in these environments. These requirements can include explosion-proof enclosures, automatic cut-off switches, and location of the equipment, depending on the environmental conditions.
	Pressure Equipment Directive	Under Article 9 of the PED, carbon dioxide is considered a Group 2 fluid. Manufacturers using carbon dioxide must use Table 1 of Annex 2 of the PED to determine the equipment category and the restrictions placed upon its design, manufacture, and testing. Descriptions of all equipment categories and associated restrictions are described in Appendix D of this report.

Table 6-8: Regulations affecting CO_2 refrigerant in mobile AC applications within Europe.

CO_2 >> Europe >> Mobile AC		
Application	**Applicable Regulations**	**Description**
Cars & Trucks	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	ISO/CD 13043	The current version of EN 378 includes mobile vehicle air conditioning applications; however, MVAC has recently been removed from the scope of this standard and will be covered by ISO/CD 13043. The ISO Technical Committee for road vehicles (TC 22) is working on publishing this new standard, ISO/CD 13043. The name of the standard is "Road vehicles – refrigerant systems used in Mobile Air Conditioning systems (MAC) – Safety Requirements." The standard is under development and will provide safety requirements for mobile vehicle air conditioning systems.

Some of the broader regulations from the tables above that apply to carbon dioxide systems within Europe are described in further detail below.

EN Standard 378

In Europe, EN Standard 378 applies to nearly all refrigeration systems, including commercial refrigeration and stationary A/C applications, within all member states. Mobile vehicle air conditioning systems have been removed from the scope of EN 378 and will be covered by the new ISO CD/13043 standard. The following sections describe how EN 378 relates to all applications of carbon dioxide refrigerant. Please see Appendix A for a table of charge limits included in EN 378:2008.

EN 378-1: Basic requirements, definitions, classification, and selection criteria
The requirement in Annex C to separate potential sources of ignition from potential sites of refrigerant leakage does not apply to carbon dioxide systems.

EN 378-2: Design, construction, testing, marking, and documentation
Systems using carbon dioxide as a refrigerant are not included in a requirement in Section 6.2.3.3, which requires that valves and joints be inaccessible to the general public. For carbon dioxide, they simply must be protected from tampering.

Systems employing carbon dioxide cannot use fusible plugs as the sole pressure relief device between a refrigerant-containing component and the atmosphere in systems with a charge greater than 2.5 kg.

EN 378-3: Installation site and personal protection
Systems using carbon dioxide are exempt from the requirement in Section 5.6 that prohibits open flames in the machinery room or special machinery room.

According to Section 5.10, carbon dioxide systems are also permitted to discharge refrigerant into the machinery room, unlike non-A1 refrigerants, which must be vented away from the building.

EN 378-4: Operation, maintenance, repair and recovery
There are no specific requirements pertaining to carbon dioxide.

6.3 Carbon Dioxide - Japan

Table 6-9 below summarizes the regulations, codes, and standards affecting the use of CO_2 refrigerant in commercial refrigeration applications within Japan.

Table 6-10 below summarizes the regulations, codes, and standards affecting the use of CO_2 refrigerant in stationary AC applications within Japan.

Table 6-11 below summarizes the regulations, codes, and standards affecting the use of CO_2 refrigerant in mobile AC applications within Japan.

Table 6-9: Regulations affecting CO_2 refrigerant in commercial refrigeration applications within Japan.

CO_2 >> Japan >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Small Commercial Stand-Alone Coolers/ Freezers/ Refrigerators **Supermarket Systems** **Walk-In Freezers/ Coolers**	Electrical Appliance and Material Safety Act	Manufacturing, import, sales and safety practices of electrical appliances must comply with the guidelines and specifications established by the Electrical Appliance and Material Safety Act.
	High Pressure Gas Safety Act (HPGSA)	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	ISO 5149	(As referenced by JIS B8612). JIS B8612 specifies materials and appropriate usage for refrigerated display cases for food retail applications. It refers to ISO 5149 as the guideline for refrigerant safety for commercial refrigerators.
	JIS B8240	JIS B8240 specifies the materials, design and construction of pressure vessels (e.g. storage tanks) for equipment that uses vapor-compression or evaporative cooling.
Transport Refrigeration	High Pressure Gas Safety Act (HPGSA)	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	JIS B8240	JIS B8240 specifies the materials, design and construction of pressure vessels (e.g. storage tanks) for equipment that uses vapor-compression or evaporative cooling.
Industrial Refrigeration Cold Storage	Electrical Appliance and Material Safety Act	Manufacturing, import, sales and safety practices of electrical appliances must comply with the guidelines and specifications established by the Electrical Appliance and Material Safety Act.
	HPGSA	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	JIS B8240	JIS B8240 specifies the materials, design and construction of pressure vessels (e.g. storage tanks) for equipment that uses vapor-compression or evaporative cooling.

Table 6-10: Regulations affecting CO_2 refrigerant in stationary AC applications within Japan.

CO_2 >> Japan >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Residential AC Commercial AC	HPGSA	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	JIS B8240	JIS B8240 specifies the materials, design and construction of pressure vessels (e.g. storage tanks) for equipment that uses vapor-compression or evaporative cooling.
	JIS B8616, JIS B8620	JIS B8616 (Packaged Air Conditioners) specifies the materials, design, and testing procedure of packaged AC systems intended to provide comfort to building occupants. JIS B8616 refers to JIS B8620 (Safety Code for Small Refrigeration Equipment) for its refrigerant leakage testing procedure.
Chillers	HPGSA	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	JIS B8240	JIS B8240 specifies the materials, design, and construction of pressure vessels (e.g. storage tanks) for equipment that uses vapor-compression or evaporative cooling.

Table 6-11: Regulations affecting CO_2 refrigerant in mobile AC applications within Japan.

CO_2 >> Japan >> Mobile AC		
Application	**Applicable Regulations**	**Description**
Cars & Trucks	JIS B8240	JIS B8240 specifies the materials, design and construction of pressure vessels (e.g. storage tanks) for equipment that uses vapor-compression or evaporative cooling.

7 Ammonia Regulatory Review

This chapter describes the regulations, codes, and standards relevant to ammonia refrigerant for the United States, Europe, and Japan. The descriptions are organized by application type for each of the three regions.

Ammonia is classified by ASHRAE as a Class B2 refrigerant and is designated as R-717.

7.1 Ammonia - United States

Table 7-1 below summarizes the regulations, codes, and standards affecting the use of ammonia refrigerant in commercial refrigeration applications within the US.

Table 7-2 below summarizes the regulations, codes, and standards affecting the use of ammonia refrigerant in stationary AC applications within the US.

Table 7-3 below summarizes the regulations, codes, and standards affecting the use of ammonia refrigerant in mobile AC applications within the US.

Some of the broader regulations that apply to multiple applications are described in further detail following these tables.

Table 7-1: Regulations affecting ammonia refrigerant in commercial refrigeration applications within the United States.

Ammonia >> United States >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Small Commercial Stand-Alone Coolers/ Freezers/ Refrigerators **Supermarket Systems** **Walk-In Freezers & Coolers**	ASHRAE 15-2007	See description of ASHRAE Standard 15 below for details.
	ASHRAE 34-2007	See description of ASHRAE Standard 34 below for additional details.
	DOT Shipping Reqt's	See description of DOT Shipping Requirements below for details.
	EPA SNAP	Ammonia as a refrigerant has been approved for use without restriction, as a substitute for Class I substances in commercial refrigeration applications, in the following applications: • Cold storage warehouse systems (ammonia vapor compression) • Retail food refrigeration (ammonia vapor compression) • Ice machines (ammonia vapor compression) Ammonia as a refrigerant has been approved for use without restriction, as a substitute for Class II substances in air conditioning and refrigeration applications, in the following applications: • Cold storage warehouse systems (vapor compression or absorption systems) • Retail food refrigeration (vapor compression with secondary loop) - grocery cases, convenience store reach-in cases, and restaurant walk-in refrigerators • Ice machines (vapor compression or absorption systems) Ammonia has not been approved for vending machines, refrigerated transport, or water coolers.
	EPA RMP Program	See description of EPA Regulations below for details.
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	IIAR Standards & Bulletins	See description of IIAR Standards & Bulletins below for details.
	Model Codes	See description of Model Codes below for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.
	UL 471	Equipment using ammonia as a refrigerant is exempt from the charge limits listed in the supplemental section for flammable refrigerants.

Table 7-1, cont.

Ammonia >> United States >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Transport Refrigeration	ASHRAE Standard 26-1996 (RA 2006)	There are a number of allowances for ships using ammonia as a refrigerant that apply to the area of transport refrigeration. Section 5.5.1.2 details refrigerant requirements for ships that are not intended for carrying passengers. For direct and indirect cargo or process refrigeration systems, only refrigerants of groups A1, B1, and B2 can be used, which includes ammonia. Section 5.2.6 states that any machinery components using a class 2 (or 3) refrigerant must have an automatic fire-extinguishing system using water sprinklers installed. Section 5.4 details requirements for shipboard systems using a B-class refrigerant, such as ammonia. These include: • Gas-tight compartment separate from other living or working spaces • Provisions for natural supply and forced exhaust ventilation • Minimum 200 cfm of ventilation for every 100 lb of refrigerant for the first 1000 lbs of refrigerant, and 80 cfm for every 100 lbs above that • Provisions to prevent fumes from the system entering living or working spaces • Controls for exhaust ventilation shall be located outside the refrigerating machinery space Section 5.5 also contains a requirement specifically for ammonia systems. Water sprinklers cannot be directed at vessels or storage cylinders containing liquid ammonia. It also recommends that a carbon dioxide sprinkler system be installed in addition to the water based system, to deal with the liquid ammonia areas. Section 8.11 contains requirements for the pipes, valves, fittings, flanges and design pressures for systems using ammonia as a refrigerant. It also states that electrical features of control mechanisms shall conform to the latest revision of IEEE Standard 45-1983.
	Clean Air Act	Intentional venting of refrigerants during maintenance, servicing, repair, or disposing of equipment is currently prohibited by Section 608 of the Clean Air Act, with the exception of ammonia in commercial or industrial process refrigeration or in absorption units. Recovery equipment must follow Section 609 of the Clean Air Act.
	DOT Shipping Reqt's	See description of DOT Shipping Requirements below for details.
	EPA SNAP	Ammonia has not been approved for refrigerated transport.
	EPA RMP Program	See description of EPA Regulations below for details.
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.

Table 7-1, cont.

Ammonia >> United States >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Industrial Refrigeration Cold Storage	ASHRAE 15-2007	See description of ASHRAE Standard 15 below for details.
	ASHRAE 34-2007	See description of ASHRAE Standard 34 below for additional details.
	DOT Shipping Reqt's	See description of DOT Shipping Requirements below for details.
	EPA RMP Program	See description of EPA Regulations below for details.
	EPA SNAP	Ammonia as a refrigerant has been approved for use without restriction, as a substitute for Class I substances in commercial refrigeration applications, in the following applications: • Cold storage warehouse systems (ammonia vapor compression) • Retail food refrigeration (ammonia vapor compression) • Ice machines (ammonia vapor compression) Ammonia as a refrigerant has been approved for use without restriction, as a substitute for Class II substances in air conditioning and refrigeration applications, in the following applications: • Cold storage warehouse systems (vapor compression or absorption systems) • Retail food refrigeration (vapor compression with secondary loop) - grocery cases, convenience store reach-in cases, and restaurant walk-in refrigerators • Ice machines (vapor compression or absorption systems) Ammonia has not been approved for vending machines, refrigerated transport, or water coolers.
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	IIAR Standards & Bulletins	See description of IIAR Standards & Bulletins below for details.
	Model Codes	See description of Model Codes below for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.

Table 7-2: Regulations affecting ammonia refrigerant in stationary AC applications within the United States.

Ammonia >> United States >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Residential AC **Commercial AC** **Chillers**	ASHRAE 15-2007	See description of ASHRAE Standard 15 below for additional details.
	ASHRAE 34-2007	See description of ASHRAE Standard 34 below for additional details.
	Clean Air Act	Intentional venting of refrigerants during maintenance, servicing, repair, or disposing of equipment is currently prohibited by Section 608 of the Clean Air Act, with the exception of ammonia in commercial or industrial process refrigeration or in absorption units. Recovery equipment must follow Section 609 of the Clean Air Act.
	DOT Shipping Reqt's	See description of DOT Shipping Requirements below for details.
	EPA SNAP	Ammonia as a refrigerant has been approved for use without restriction, as a substitute for Class II substances in air conditioning and refrigeration applications, in the following applications: • Household and light commercial A/C (absorption systems) • Commercial comfort air conditioning (absorption chillers and vapor compression with secondary loop) • Industrial process air conditioning (vapor compression or absorption systems) Ammonia as a refrigerant has been approved for use without restriction, as a substitute for Class I substances in air conditioning applications, in the following applications: • Centrifugal chillers (ammonia vapor compression, ammonia / water absorption) Ammonia has not been approved for: • Reciprocating and screw chillers • Industrial process A/C
	EPA RMP Program	See description of EPA Regulations below for details.
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	IIAR Standards & Bulletins	See description of IIAR Standards & Bulletins below for details.
	Model Codes	See description of Model Codes below for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.

Table 7-3: Regulations affecting ammonia refrigerant in mobile AC applications within the United States.

Ammonia >> United States >> Mobile AC		
Application	**Applicable Regulations**	**Description**
Cars & Trucks	Clean Air Act	Intentional venting of refrigerants during maintenance, servicing, repair, or disposing of equipment is currently prohibited by Section 608 of the Clean Air Act, with the exception of ammonia in commercial or industrial process refrigeration or in absorption units. Recovery equipment must follow Section 609 of the Clean Air Act.
	DOT Shipping Regulations	Refrigerant accumulators for motor vehicles being shipped must be designed with a burst pressure of not less than five times their charged pressure at 70° when shipped. (49 CFR Part 173.306) Exemptions can be obtained through the Office of Hazardous Materials within the DOT, but require proof that the safety of the equipment is equivalent to that specified under the regulation. (Taddonio 2008).
	EPA SNAP	Ammonia has not been considered as a refrigerant in mobile vehicle air conditioning, and is not listed as an acceptable substitute for this application (for either mobile vehicle A/C or buses and trucks). Should ammonia be submitted for approval in mobile vehicle air conditioning, it will likely be subject to scrutiny concerning exposure limits within the passenger cabin, and for its toxicity.
	EPA RMP Program	See description of EPA Regulations below for details.
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.
	State Hazardous Substance Lists	The following states have bans on using toxic or flammable refrigerants in mobile vehicle air conditioning that may apply to ammonia (Taddonio 2009): • Louisiana • North Dakota • Oklahoma • Kansas (Planning to change regulations) • Maryland (Planning to change regulations) • Texas (Planning to change regulations - draft bill adopted EPA SNAP amendment) Within the past few years, a number of states that previously banned toxic refrigerants have since amended these regulations. For example, Texas has drafted a bill to adopt an amendment allowing refrigerants that obtain EPA SNAP approval. In general, states have adopted one of the following two options: • Allowing refrigerants approved by the EPA SNAP program • Abiding by the safety regulations described in SAE Standard J639

Some of the broader regulations that apply to ammonia systems within the US are described in further detail below.

ASHRAE Standard 15

Ammonia is classified as a B2 refrigerant in ASHRAE Standard 15-2007, but in the standard it is often treated as a separate type of refrigerant. Ammonia is provided with specific requirements that can differ from requirements for both non-flammable refrigerant classifications (A1 and B1) and the higher flammability classifications (A2, B2, A3, and B3). However, ammonia is still subject to restrictions for B2 refrigerants that do not exclude ammonia specifically.

ASHRAE Standard 15-2007 provides a special table for the maximum charge allowed for various occupancies using ammonia equipment. Use of ammonia is not allowed in any institutional occupancy, defined as a premise that houses occupants who cannot easily leave the location, such as nursing homes and hospitals. Ammonia sealed absorption and unit systems can be used in some high-probability systems for human comfort, which applies to all specific applications of stationary air conditioning.

Ammonia is not subject to the restriction on flammable refrigerants in section 7.5.1.1, which states that the total of all A2, B2, A3, and B3 refrigerants (excluding ammonia) shall not exceed 1100 lb. (500 kg). Ammonia is, however, subject to the restrictions placed on flammable refrigerants in a machinery room in section 7.4.2.

In section 8.12 ("Machinery Room, Special Requirements"), ammonia systems do not have to meet the requirements of Class 1, Division 2 of National Electric Code as long as two conditions are met:

(1) The mechanical ventilation system in the machinery room is run continuously and failure of the mechanical ventilation system actuates an alarm, or
(2) The machinery room is equipped with a detector, conforming to Section 8.11.2.1, except the detector shall alarm at 1000 ppm.

Machinery rooms where ammonia is the only refrigerant and internal combustion engines are used as the prime mover for the compressors are not subject to the restriction in Section 8.11.6 that states that combustion equipment cannot be installed in the same machinery room with refrigerant-containing equipment.

Unlike other refrigerant classes, ammonia is not subject to the ban on open flames and surfaces exceeding 800°F in industrial occupancies and refrigerated rooms. In addition, ammonia is not subject to the requirement that all electrical equipment conforms to Class 1, Division 2, of NFPA 70 in industrial occupancies and refrigerated rooms.

Ammonia may be used in corridors and lobbies of certain occupancies and sealed ammonia absorption and unit systems as specified in ASHRAE Standard 15-2007. However, ammonia is severely restricted in public/large mercantile occupancies, and can only be used in systems

located in places other than public hallways and lobbies. Table 7-4 below, which replicates Table 2 of ASHRAE Standard 15-2007, shows the quantity limits for sealed ammonia/water absorption systems and self-contained systems.

Table 7-4: Special quantity limits for sealed ammonia/water absorption and self-contained systems.

ASHRAE Standard 15-2007 Special Quantity Limits for Sealed Ammonia/Water Absorption and Self-Contained Systems				
	Maximum lb. (kg) for Various Occupancies			
Type of Refrigeration System	Institutional	Public / Large Occupancies	Residential	Commercial
Sealed Ammonia/Water Absorption System				
In public hallways or lobbies	0 (0)	0 (0)	3.3 (1.5)	3.3 (1.5)
In adjacent outdoor locations	0 (0)	0 (0)	22 (10)	22 (10)
In other than public hallways or lobbies	0 (0)	6.6 (3)	6.6 (3)	22 (10)
Unit Systems				
In other than public hallways or lobbies	0 (0)	0 (0)	6.6 (3)	22 (10)

Source: ASHRAE Standard 15-2007

Per section 8.13, emergency discharge or diffusion arrangements for ammonia refrigerants can be required for ammonia systems, depending on the local requirements. Section 9.7.2.8 of ASHRAE Standard 15-2007 contains information on methods for discharging ammonia from a system. Informative Appendix B within ASHRAE Standard 15-2007 contains guidelines for emergency discharge of refrigerant when required by local codes. It contains guiding requirements for the different components that make up the emergency discharge system.

ASHRAE Standard 34

Table 7-5 below shows the ASHRAE 34-2007 refrigerant concentration limits for ammonia.

Table 7-5: ASHRAE Standard 34-2007 refrigeration concentration limits for ammonia.

ASHRAE Standard 34-2007 Concentration Limits for Ammonia			
Refrigerant	Refrigerant Concentration Limits		
	ppm v/v	g/m3	Lb/Mcf
Ammonia	320	0.22	0.014

Source: ASHRAE Standard 34-2007(modifies ASHRAE 15 based on addendum c to ASHRAE 15)

DOT Shipping Requirements

Ammonia is considered a poisonous and flammable gas under DOT shipping regulations. According to Part 173.306 in subpart G, refrigerating machines are exempt from meeting certain requirements for packaging and shipping of compressed gases if, for machines not using A1 refrigerants, they contain no more than 50 lbs. of refrigerant, they contain shut-off valves, and they meet the safety requirements specified by ASHRAE Standard 15.

According to Part 173.307 in subpart G, refrigerating machines are exempt from the requirements for compressed gasses if they use 12 L (3 gallons) or less of ammonia solution.

EPA Regulations

Risk Management Program (RMP)
Ammonia is listed as a regulated substance under the EPA's Chemical Accident Prevention Provisions. Facilities that produce, handle, process, distribute or store anhydrous ammonia in quantities larger than the establish threshold quantity fall under the requirements of the Risk Management Program.

Emergency Planning and Community Right-to-Know Act (SARA III) (EPCRA)
EPCRA has four major provisions: one addresses emergency planning and the three others address chemical reporting. Ammonia is listed as an extremely hazardous substance, and facilities housing ammonia must report at lower threshold quantities than regular hazardous substances, as shown in Table 7-6 below. Facilities using extremely hazardous substances must also notify local authorities of any shipments to the facility and of any release of the substance over the minimal reportable quantity. Facilities must also report release and waste management information to the EPA, state, and local authorities.

Table 7-6: EPCRA reportable and threshold planning quantities for ammonia.

EPCRA Reportable and Threshold Planning Quantities		
Substance	**Reportable Quantities (lbs.)**	**Threshold Planning Quantity (lbs).**
Ammonia	100	500

IIAR Standards

ANSI/IIAR 2-2008
This standard provides requirements for the design, manufacture, installation, and use of ammonia mechanical refrigerating systems with industrial occupancies. ANSI/IIAR 2-2008 is harmonized with ASHRAE Standard 15, and presents the best practices available for use of ammonia in industrial occupancies.

ANSI/IIAR 3-2005: Ammonia Refrigeration Valves
This standard provides requirements for the valves used in ammonia refrigeration systems. This standard will undergo a public review in 2010.

BSR/IIAR 3-200X
When enacted, Standard BSR/IIAR 3-200X will cover five distinct operating processes:

(1) Start-up procedures
(2) Normal operating procedures
(3) Normal shutdown procedures
(4) Emergency shutdown procedures
(5) Temporary operating procedures.

Standard BSR/IIAR 3-200X will also cover personal protective equipment and use of the buddy system.

IIAR 5-200X: Start-up and Commissioning of Closed-Circuit Ammonia Mechanical Refrigerating Systems
This standard is currently being developed. The public review period has closed, and a review of all comments submitted is underway.

BSR/IIAR 7-200X
This standard is currently being developed and is described as follows:

> "…intended to define the minimum requirements for developing operating procedures for closed-circuit ammonia mechanical refrigerating systems… This standard is intended for those who develop, define, and/or review the operating procedures for ammonia refrigerating systems. This standard shall apply only to closed-circuit mechanical refrigerating systems utilizing ammonia as the refrigerant. This document does not address the commissioning of ammonia refrigerating systems or system components. It supplements existing general refrigeration standards issued by IIAR and other organizations such as ASHRAE, ASME, and ANSI. It is not intended to supplant existing safety codes (e.g., model mechanical or fire codes or ASHRAE Standard 15)."

IIAR Bulletins

IIAR has published a series of bulletins to provide informative documents on the safety, design, components, and start-up of mechanical refrigeration systems based on ammonia. These guidelines are not intended to be binding. IIAR is in the process of codifying the language of these bulletins to fit a series of eight IIAR standards. The collection of finished IIAR standards will include standards for the following: Definitions, Design, Valves, Installation, Startup, Operation, Maintenance, and Decommissioning. All but the Decommissioning Standard are planned to be published in 2010 as revisions to the existing Standard or newly approved ANSI standards. (Badger 2009).

IIAR Bulletins- For Use with Ammonia Mechanical Refrigeration Systems

- IIAR Bulletins: Bulletin 107 - Guidelines for: Suggested Safety and Operating Procedures when Making Refrigeration Plant Tie-Ins
- IIAR Bulletins: Bulletin 108 - Guidelines for: Water Contamination in Ammonia Refrigeration Systems
- IIAR Bulletin: Bulletin 109 – Guidelines for: IIAR Minimum Safety Criteria for a Safe Ammonia Refrigeration System
- IIAR Bulletin: Bulletin 110 - Guidelines for: Start-Up, Inspection and Maintenance of Ammonia Mechanical Refrigerating Systems
- IIAR Bulletin: Bulletin 111 - Guidelines for: Ammonia Machinery Room Ventilation
- IIAR Bulletin: Bulletin 112 - Guidelines for: Ammonia Machinery Room Design

- IIAR Bulletin: Bulletin 114 - Guidelines for: Identification of Ammonia Refrigeration Piping and System Components
- IIAR Bulletin: Bulletin 116 - Avoiding Component Failure in Industrial Refrigeration Systems Caused by Abnormal Pressure or Shock

Model Codes

The 2006 IMC follows many of the same requirements as ASHRAE 15-2007, and also includes a clause stating that ammonia systems must adhere to IIAR Standard 2. As described further in Appendix E of this report, the permitted amounts in the 2006 IMC are largely similar to those in ASHRAE 34-2007, except that the 2006 IMC also includes a time-weighted-average exposure limit. However, due to the strong self-alarming properties of ammonia when even minute amounts are leaked, it is unlikely that the allowable time-weighted-average limit will present a large burden to ammonia systems.

Ammonia absorption systems are mostly exempt from many of the restrictions imposed on B2 refrigerants in ASHRAE 15-2007, and the 2006 IMC includes many of these same exemptions. This includes exemptions from restrictions on the total amount of refrigerant allowed in a room, the required hazard level of machinery rooms, and the surface temperature of equipment. The 2006 IMC also limits the permitted quantities for ammonia systems in institutional occupancies. Unlike ASHRAE 15-2007, the 2006 IMC does not exempt sealed absorption systems from a ban on using B2 refrigerants in high-probability systems for human comfort. The 2006 IMC also requires an emergency pressure control system for systems using more than 6.6 lbs. of a flammable and/or toxic refrigerant.

The 2006 UMC contains some of the same requirements and exemptions for ammonia systems as the 2006 IMC. It also contains additional requirements regarding specific components within ammonia systems. In particular, the UMC contains requirements for a discharge system for equipment using ammonia, including tank sizes, piping requirements, and water guidelines.

Ammonia and other flammable refrigerants face more restrictions under the UMC than under the IMC. One important additional requirement of the UMC is that all systems using non-A1 refrigerants require a machinery room (except for ammonia-water absorption systems located outside), and all direct and indirect-fired absorption systems also require machinery rooms. The UMC contains fewer exemptions for ammonia compared to ASHRAE 15-2007 and the 2006 IMC. As a result, under the UMC, it is much more difficult to use ammonia in high-probability systems in non-industrial occupancies.

The International Fire Code (IFC) and the NFPA 1 Code – Uniform Fire Code, limit the amount of flammable and toxic gases that can be stored and used in a defined control area. While these limits are identical for indoor control areas, the IFC allows greater quantities to be used and stored in outdoor control areas (up to twice or four times as much as the NPFA 1 code in some cases). The IFC and UFC also restrict or prohibit the use and storage of flammable and toxic refrigerants for certain occupancies, defined in each code.

OSHA Regulations

Permissible Exposure Limits

Ammonia is listed as a hazardous substance by OSHA. OSHA has set the Permissible Exposure Limits for ammonia, as shown in Table 7-7 below.

Table 7-7: OSHA permissible exposure limits for ammonia.

OSHA Permissible Exposure Limits		
Substance	**ppm**	**mg / m³**
Ammonia	50	35

Process Safety Management of Highly Hazardous Substances

Anhydrous ammonia is listed as a highly hazardous substance under the Process Safety Management Program, under 1910.199 App A- List of Highly Hazardous Chemicals, Toxics and Reactives. Facilities using this amount of anhydrous ammonia or more are subject to the requirements of OSHA's Process Safety Management Program. The threshold quantity for anhydrous ammonia is 10,000 pounds.

7.2 Ammonia - Europe

Table 7-8 below summarizes the regulations, codes, and standards affecting the use of ammonia refrigerant in commercial refrigeration applications within Europe.

Table 7-9 below summarizes the regulations, codes, and standards affecting the use of ammonia refrigerant in stationary AC applications within Europe.

Table 7-10 below summarizes the regulations, codes, and standards affecting the use of ammonia refrigerant in mobile AC applications within Europe.

Some of the broader regulations that apply to multiple applications are described in further detail following these tables.

Table 7-8: Regulations affecting ammonia refrigerant in commercial refrigeration applications within Europe.

Ammonia >> Europe >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Small Commercial Stand-Alone Coolers/ Freezers/ Refrigerators **Supermarket Systems** **Walk-In Freezers/Coolers**	ATEX 94/9/EC	The ATEX Equipment Directive may apply to systems installed in facilities or locations that contain potentially explosive environments.
	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378:2008	See description of EN 378 below for details.
	EN 60079	EN Standard 60079 is harmonized with the ATEX Directive. It provides requirements for electrical systems used in potentially explosive atmospheres. The standard establishes three different categories of environments that present certain dangers when using electrical equipment and sets technical requirements for electrical equipment used in these environments. These requirements can include explosion-proof enclosures, automatic cut-off switches, and location of the equipment, depending on the environmental conditions.
	Pressure Equipment Directive	Ammonia is considered a group 1 fluid due to its toxicity and flammability. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. Equipment in group 1 must utilize Table 2 in Annex 2 of the PED to determine the category of equipment and the restrictions placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.
Transport Refrigeration	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378:2008	See description of EN 378 below for details.
	Pressure Equipment Directive	Ammonia is considered a group 1 fluid due to its toxicity and flammability. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. Equipment in group 1 must utilize Table 2 in Annex 2 of the PED to determine the category of equipment and the restrictions placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.

Table 7-8, cont.

Ammonia >> Europe >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Industrial Refrigeration Cold Storage	ATEX 94/9/EC	The ATEX Equipment Directive may apply to systems installed in facilities or locations that contain potentially explosive environments.
	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378:2008	See description of EN 378 below for details.
	EN 60079	EN Standard 60079 is harmonized with the ATEX Directive. It provides requirements for electrical systems used in potentially explosive atmospheres. The standard establishes three different categories of environments that present certain dangers when using electrical equipment and sets technical requirements for electrical equipment used in these environments. These requirements can include explosion-proof enclosures, automatic cut-off switches, and location of the equipment, depending on the environmental conditions.
	Pressure Equipment Directive	Under Article 9 of the PED, ammonia is considered a group 1 fluid, due to its toxicity and flammability. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. Equipment in Group 1 must utilize table 2 in Annex 2 of the PED to determine what category of equipment their equipment falls into, and thus what restrictions are placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.

Table 7-9: Regulations affecting ammonia refrigerant in stationary AC applications within Europe.

Ammonia >> Europe >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Residential AC **Commercial AC**	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378:2008	See description of EN 378 below for details.
	IEC 60335-2-40	Refrigerant charge limits for IEC 60335-2-40 depend on the lower flammability limit of the refrigerant, the size of the room in which the equipment is installed, and the ventilation that is provided for the equipment. These restrictions are similar to those used by EU 378. For ammonia, the charge limits will be similar to those for HFO-1234yf, since both are classified as class 2L and the charge limits are based on flammability only. The following charge limits apply to systems using HFO-1234yf: • Under 1.16 kg: No significant restrictions • 1.16 kg < Charge < 7.5 kg: Charge limit depends on the size of the room • 7.5 kg < Charge < 37.6 kg: Appliance requires mechanical ventilation • Greater than 37.6 kg: EN 60335-2-40 does not apply; see EN 378 These charge limits could pose a major barrier to using ammonia refrigerant in large commercial equipment.
	Pressure Equipment Directive	Under Article 9 of the PED, ammonia is considered a group 1 fluid, due to its toxicity and flammability. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. Equipment in Group 1 must utilize table 2 in Annex 2 of the PED to determine what category of equipment their equipment falls into, and thus what restrictions are placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.
	WEEE Directive (Residential only)	The WEEE Directive establishes collection, recycling, and recovery targets for residential AC units.

Table 7-9, cont.

Ammonia >> Europe >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Chillers	ATEX 94/9/EC	The ATEX Equipment Directive applies to systems installed in facilities or locations that contain potentially explosive environments. It excludes residential applications.
	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378:2008	See description of EN 378 below for details.
	EN 60079	EN Standard 60079 is harmonized with the ATEX Directive. It provides requirements for electrical systems used in potentially explosive atmospheres. The standard establishes three different categories of environments that present certain dangers when using electrical equipment and sets technical requirements for electrical equipment used in these environments. These requirements can include explosion-proof enclosures, automatic cut-off switches, and location of the equipment, depending on the environmental conditions.
	Pressure Equipment Directive	Under Article 9 of the PED, ammonia is considered a group 1 fluid, due to its toxicity and flammability. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. Equipment in Group 1 must utilize table 2 in Annex 2 of the PED to determine what category of equipment their equipment falls into, and thus what restrictions are placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.

Table 7-10: Regulations affecting ammonia refrigerant in mobile AC applications within Europe.

Ammonia >> Europe >> Mobile AC		
Application	**Applicable Regulations**	**Description**
Cars & Trucks	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	ISO/CD 13043	The current version of EN 378 includes mobile vehicle air conditioning applications; however, MVAC has recently been removed from the scope of this standard and will be covered by ISO/CD 13043. The ISO Technical Committee for road vehicles (TC 22) is working on publishing this new standard, ISO/CD 13043. The name of the standard is "Road vehicles – refrigerant systems used in Mobile Air Conditioning systems (MAC) – Safety Requirements." The standard is under development and will provide safety requirements for mobile vehicle air conditioning systems.

Some of the broader regulations that apply to ammonia systems within the EU are described in further detail below.

EN Standard 378:2008

In the EU, EN Standard 378 applies to nearly all refrigeration systems, including commercial refrigeration and stationary A/C applications, within all member states. MVAC applications have been removed from the scope of EN 378 and will be covered by the new ISO CD/13043 standard. The following sections describe how EN 378 relates to all applications of ammonia refrigerant. Appendix A of this report includes a table of charge limits included in EN 378:2008 and a description of requirements affecting specific ammonia applications.

EN 378-1: Basic requirements, definitions, classification, and selection criteria
The requirement in Annex C to separate potential sources of ignition from potential sites of refrigerant leakage does not apply to ammonia. Annex C contains a note that, for:

> …sealed refrigerating systems using flammable refrigerants (A2, B2, A3, B3), but excluding R-717 [ammonia], no sources of ignition shall be associated with parts of the equipment that could come in contact with leaked refrigerant. All potential sources of ignition shall be sealed according to the methods detailed in EN 378-2.

En 378-2: Design, construction, testing, marking, and documentation
In this section, there is at least one design requirement specific to systems using ammonia. This requirement states that ammonia should not come into contact with a material such as zinc or zinc alloys.

Systems using refrigerants other than A1 refrigerants fall under the requirement in Section 6.2.3.3 that valves and joints must be inaccessible to the general public.

System containing A2, B1, B2, A3, B3 refrigerants cannot employ fusible plugs as relief devices.

Indirect systems using more than 500 kg of flammable refrigerants (A2, B2, A3, and B3) are not permitted to release the refrigerant into the areas served by the secondary heat transfer fluid, and are required to implement safety measures such as the following:

- Automatic air/refrigerant separator
- Double wall heat exchanger
- Maintaining the pressure of the secondary circuit greater than that of the primary circuit around the contact area

EN 378-3: Installation site and personal protection
Section 5.17 sets requirements for the location and rating of the emergency exhaust ventilation. For example, the fan must be rated for hazardous areas or remain outside of the refrigerant airflow. Section 5.17.2 cites the following requirements for machine rooms containing ammonia systems:

- A catchment system to prevent ammonia contamination from spills must be designed and installed in the machine room
- Eye wash facilities must be easily accessible, or for larger systems (1000 kg charge) an emergency shower must be outside the emergency exit
- There must be no fire sprinkler systems in the machinery room

Ammonia systems also have the following additional alarm system requirements for systems with charges above 3000 kg:

- The central alarm station must be located at a permanently attended station
- Specialized personnel must arrive to the site of the incident within 60 minutes of an alarm

Machinery rooms using ammonia as a refrigerant must protect filament light fittings using safe splash covers, following the requirement that illumination be provided for safety in spaces containing refrigerating equipment (Section 5.11). Machine rooms with flammable refrigerants (A2, B2, A3, and B3) cannot have combustion equipment or hot surfaces within 100 K of the auto-ignition temperature of the refrigerant (Section 5.17.5). For machine rooms above the practical limit for flammable refrigerants, access to the outdoors shall be provided (Section 5.17.6).

Ammonia systems are not required to comply with the requirements for electrical equipment in hazardous areas, according to Section 6.3.

All refrigerating systems with charges above 25kg and refrigerants with any ODP or GWP require detection systems. Ammonia and similar chemicals possess a certain odor characteristic that exempts it from this requirement.

For some applications, such as special machinery rooms, ammonia systems require ammonia detectors for safety purposes. Section 8.7 provides the specifications for such a detector, which must operate at two distinct times, and should be integrated with the operation and adjoining parts of the system.

Annex A of EN 378-3:2008 requires a set of protective equipment for all personnel doing maintenance, repair, and recovery of a refrigerant system, independent of refrigerant type. In addition, ammonia systems must provide respiratory protection devices, in accordance with European standards. Annex A also requires the presence of eye wash facilities, and for large facilities (1000 kg), an emergency shower.

Personnel may be alerted to the incident through electronic means, and not just by the actual alarm

EN 378-4: Operation, maintenance, repair and recovery
Annex A of En 378-4:2008 provides system requirements for the “oil draining apertures” and equipment of an ammonia refrigeration system.

7.3 Ammonia – Japan

Table 7-11 below summarizes the regulations, codes, and standards affecting the use of ammonia refrigerant in commercial refrigeration applications within Japan.

Table 7-12 below summarizes the regulations, codes, and standards affecting the use of ammonia refrigerant in stationary AC applications within Japan.

Table 7-13 below summarizes the regulations, codes, and standards affecting the use of ammonia refrigerant in mobile AC applications within Japan.

Table 7-11: Regulations affecting ammonia refrigerant in commercial refrigeration applications within Japan.

Ammonia >> Japan >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Small Commercial Stand-Alone Coolers/ Freezers/ Refrigerators **Supermarket Systems** **Walk-In Freezers/ Coolers**	Electrical Appliance and Material Safety Act	Manufacturing, import, sales and safety practices of electrical appliances must comply with guidelines and specifications established by the Electrical Appliance and Material Safety Act. In particular, the act establishes maximum refrigerant charge limits for flammable refrigerants used in forced air cooling and convection cooling systems.
	High Pressure Gas Safety Act	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards, and General Safety Standards.
	ISO 5149	JIS B8612 (Commercial Refrigeration Cabinets) specifies materials and appropriate usage for refrigerated display cases for food retail applications. It refers to ISO 5149 as the guideline for refrigerant safety for commercial refrigerators.
	JIS B8240	JIS B8240 (Construction of Pressure Vessels for Refrigeration) specifies the materials, design and construction of pressure vessels (e.g. storage tank) for equipment that uses vapor-compression or evaporative cooling.
	Offensive Odor Control Act	Use of odorous substances must be controlled in accordance with guidelines established in the Offensive Odor Control Act. Under this Act, ammonia is identified as a controlled substance. The act directs each prefecture to define how and where the control of odorous substances would be enforced.
	Poisonous and Deleterious Substances Control Act	Production, import, sale, storage, transportation and display of toxic substances for non-medical purposes must comply with guidelines and specifications established by the Poisonous and Deleterious Substances Control Act. This act classifies ammonia as a deleterious substance, which requires additional safety requirements in production, handling, transport and disposal.
Transport Refrigeration	High Pressure Gas Safety Act	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards, and General Safety Standards.
	JIS B8240	JIS B8240 (Construction of Pressure Vessels for Refrigeration) specifies the materials, design and construction of pressure vessels (e.g. storage tank) for equipment that uses vapor-compression or evaporative cooling.
	Offensive Odor Control Act	Use of odorous substances must be controlled in accordance with guidelines established in the Offensive Odor Control Act. Under this act, ammonia is identified as a controlled substance. The act directs each prefecture to define how and where the control of odorous substances would be enforced.
	Poisonous and Deleterious Substances Control Act	Production, import, sale, storage, transportation and display of toxic substances for non-medical purposes must comply with guidelines and specifications established by the Poisonous and Deleterious Substances Control Act. The Act classifies ammonia as a deleterious substance, which requires additional safety requirements in production, handling, transport and disposal.

Table 7-11, cont.

Ammonia >> Japan >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Industrial Refrigeration Cold Storage	Electrical Appliance and Material Safety Act	Manufacturing, import, sales and safety practices of electrical appliances must comply with guidelines and specifications established by the Electrical Appliance and Material Safety Act. In particular, the act establishes maximum refrigerant charge limits for flammable refrigerants used in forced air cooling and convection cooling systems.
	High Pressure Gas Safety Act	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	JIS B8240	JIS B8240 (Construction of Pressure Vessels for Refrigeration) specifies the materials, design and construction of pressure vessels (e.g. storage tank) for equipment that uses vapor-compression or evaporative cooling.
	Offensive Odor Control Act	Use of odorous substances must be controlled in accordance with guidelines established in the Offensive Odor Control Act. Under this Act, ammonia is identified as one of the control substances. The act directs each prefecture to define how and where the control of odorous substances would be enforced.
	Poisonous and Deleterious Substances Control Act	Production, import, sale, storage, transportation and display of toxic substances for non-medical purposes must comply with guidelines and specifications established by the Poisonous and Deleterious Substances Control Act. The Act classifies ammonia as a deleterious substance, which requires additional safety requirements in production, handling, transport and disposal.

Table 7-12: Regulations affecting ammonia refrigerant in stationary AC applications within Japan.

Ammonia >> Japan >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Residential AC **Commercial AC** **Chillers**	Electrical Appliance and Material Safety Act	Manufacturing, import, sales and safety practices of electrical appliances must comply with guidelines and specifications established by the Electrical Appliance and Material Safety Act. In particular, the act establishes maximum refrigerant charge limits for flammable refrigerants used in forced air cooling and convection cooling systems.
	High Pressure Gas Safety Act	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	JIS B8240	JIS B8240 (Construction of Pressure Vessels for Refrigeration) specifies the materials, design and construction of pressure vessels (e.g. storage tank) for equipment that uses vapor-compression or evaporative cooling.
	JIS 8616, JIS B8620	JIS 8616 (Packaged Air Conditioner) specifies the materials, design and testing procedure of packaged AC system intended to provide comfort to building occupants. JIS 8616 refers to JIS 8620 (Safety Code for Small Refrigeration Equipment) for refrigerant leakage testing procedure.
	Offensive Odor Control Act	Use of odorous substances must be controlled in accordance with guidelines established in the Offensive Odor Control Act. Under this Act, ammonia is identified as a controlled substance. The act directs each prefecture to define how and where the control of odorous substances would be enforced.
	Poisonous and Deleterious Substances Control Act	Production, import, sale, storage, transportation and display of toxic substances for non-medical purposes must comply with guidelines and specifications established by the Poisonous and Deleterious Substances Control Act. This act classifies ammonia as a deleterious substance, which requires additional safety requirements in production, handling, transport and disposal.

Table 7-13: Regulations affecting ammonia refrigerant in mobile AC applications within Japan.

Ammonia >> Japan >> Mobile AC		
Application	**Applicable Regulations**	**Description**
Cars & Trucks	JIS B8240	JIS B8240 (Construction of Pressure Vessels for Refrigeration) specifies the materials, design and construction of pressure vessels (e.g. storage tank) for equipment that uses vapor-compression or evaporative cooling.

8 Hydrocarbons Regulatory Review

This section describes the regulations, codes, and standards relevant to hydrocarbon refrigerants for the United States, Europe, and Japan. The descriptions are organized by application type for each of the three regions.

Hydrocarbons are classified by ASHRAE as Class A3 refrigerants, and the three primary hydrocarbon refrigerants are designated as R-290 (propane), R-600 (butane), and R-600a (isobutane).

8.1 Hydrocarbons - United States

Table 8-1 below summarizes the regulations, codes, and standards affecting the use of hydrocarbon refrigerants in commercial refrigeration applications within the US.

Table 8-2 below summarizes the regulations, codes, and standards affecting the use of hydrocarbon refrigerants in stationary AC applications within the US.

Table 8-3 below summarizes the regulations, codes, and standards affecting the use of hydrocarbon refrigerants in mobile AC applications within the US.

Some of the broader regulations that apply to multiple applications are described in further detail following these tables.

Table 8-1: Regulations affecting hydrocarbon refrigerants in commercial refrigeration applications within the United States.

Hydrocarbons >> United States >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Small Commercial Stand-Alone Coolers/ Freezers/ Refrigerators **Supermarket Systems** **Walk-In Freezers/ Coolers**	ASHRAE 15-2007	See description of ASHRAE Standards below for details.
	ASHRAE 24-2007	See description of ASHRAE Standards below for details.
	Clean Air Act	Intentional venting of refrigerants during maintenance, servicing, repair, or disposing of equipment is currently prohibited by Section 608 of the Clean Air Act, with the exception of hydrocarbons in industrial process refrigeration applications. Recovery equipment must follow Section 609 of the Clean Air Act.
	DOT Shipping	See description of DOT Shipping Requirements below for details.
	EPA RMP Program	See description of EPA Regulations below for details.
	EPA SNAP	Currently these applications are not EPA SNAP approved. However, two companies have submitted petitions to EPA for approval. See description of EPA SNAP below for more details.
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	Model Codes	See description of Model Codes below for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.
	UL 471	Commercial refrigeration equipment using hydrocarbon refrigerants are limited to a total charge of 150g of refrigerant. This amendment was recently added by UL in 2009. The 150g limit should not restrict the use of hydrocarbons in applications such as reach-in refrigerators, vending machines, and glass-door merchandisers, but may prove problematic to applications such as ice machines, frozen ice cream machines, and frozen carbonated beverage machines (Galvin 2009). Changes to the charge limits for A3 refrigerants in UL 250 (from 50g to 60g) may influence future development of UL 471. See Appendix C for more details.
	UL 1995	UL 1995 does not include any provisions for the listing of heating and cooling equipment using hydrocarbon refrigerants. UL is not anticipating changing the standard unless there are significant changes to ASHRAE 15. Without provisions for flammable refrigerants, equipment using these refrigerants will not be listed by UL, and will likely be unable to meet EPA and model code safety requirements.

Table 8-1, cont.

Hydrocarbons >> United States >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Transport Refrigeration	ASHRAE Standard 26-1996 (RA 2006)	There are two restrictions for ships using hydrocarbons as a refrigerant that apply to the area of transport refrigeration. • Section 5.5.1.2 details refrigerant requirements for ships that are not intended for carrying passengers. For direct and indirect cargo or process refrigeration systems, only refrigerants of groups A1, B1, and B2 can be used, which excludes hydrocarbon refrigerants. Section 5.2.6 states that any machinery components using a class 2 (or 3) refrigerant need to have an automatic fire-extinguishing system using water sprinklers installed.
	Clean Air Act	Intentional venting of refrigerants during maintenance, servicing, repair, or disposing of equipment is currently prohibited by Section 608 of the Clean Air Act, with the exception of hydrocarbons in industrial process refrigeration applications. Recovery equipment must follow Section 609 of the Clean Air Act.
	DOT Shipping	See description of DOT Shipping Requirements below for details.
	EPA RMP Program	See description of EPA Regulations below for details.
	EPA SNAP	See description of EPA SNAP below for more details.
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.

Table 8-1, cont.

Hydrocarbons >> United States >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Industrial Refrigeration Cold Storage	ASHRAE 15-2007	Section 7.2.2 states that industrial occupancies and refrigerated rooms do not have to conform to the volume calculations in section 7.3 as long as certain conditions are met in these rooms. The conditions that pertain to hydrocarbon refrigerants are listed below: (1) Open flames and surfaces exceeding 800°F (426.7°C) are not permitted where any Group A2, B2, A3, or B3 refrigerant other than R-717 (ammonia) is used. (2) All electrical equipment conforms to Class 1, Division 2, of NFPA 70 where the quantity of any Group A2, B2, A3, or B3 refrigerant other than R-717, ammonia, in an independent circuit would exceed 25% of the lower flammability limit upon release to the space based on the volume determined by Section 7.3. Section 7.4.2 of ASHRAE Standard 15-2007 states that machinery rooms using A2, B2, A3, and B3 refrigerants shall conform to both the general requirements and the special requirements for a refrigerating machinery room. The special requirements intended for flammable refrigerants include the following: • No flame-producing equipment or hot surfaces may be permanently installed in the machinery room • All doors shall be approved, self-closing, tight-fitting, fire doors • Walls, floor and ceiling shall be tight and of noncombustible material, and those surfaces adjoining other occupied areas shall be of at least one-hour fire-resistive construction • The refrigerating machinery room shall contain a door that opens directly to the outside air or through a vestibule equipped with self-closing, tight fitting doors • All pipes piercing the interior walls, ceiling, or floor of such rooms shall be tightly sealed to the walls, ceiling, or floor through which they pass The Machinery room shall conform to Class 1, Division 2, of the National Electric Code whenever flammable refrigerants are used.
	ASHRAE 34-2007	See description of ASHRAE Standards below for details.
	DOT Shipping	See description of DOT Shipping Requirements below for details.
	EPA RMP Program	See description of EPA Regulations below for details.
	EPA SNAP	Propane, Propylene, Butane, HC Blend A, and HC Blend B have been approved for use without restriction as a substitute for Class I substances in Industrial Process Refrigeration, under non-commercial refrigeration.
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	Model Codes	See description of Model Codes below for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.

Table 8-2: Regulations affecting hydrocarbon refrigerants in stationary AC applications within the United States.

Hydrocarbons >> United States >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Residential AC **Commercial AC** **Chillers**	ASHRAE 15-2007	Addendum i was added to ASHRAE Standard 15-2007 on June 24, 2009. Addendum i adds the following exception to Section 7.5.3 for portable-unit systems: • This restriction does not apply to listed portable-unit systems containing no more than 0.331 lb (150 g) of Group A3 refrigerant, provided that the equipment is installed in accordance with the listing and the manufacturer's installation instructions. This removes an inconsistency in the treatment of small portable cooling appliances, explained in the ASHRAE Standard 15 addendum i forward as follows: • Small portable cooling appliances and/or self-contained refrigeration systems are generally not regulated by the model codes that form the basis for most local regulation (see the 2006 International Mechanical Code, Section 106.2). Requiring specific local approvals from the authority having jurisdiction for systems using small amounts of flammable refrigerant charge would be impractical, and inconsistent with national code practice. This addendum allows the use of such systems through an exception to Section 7.5.3 See the description of ASHRAE Standards below for more details.
	ASHRAE 34-2007	See description of ASHRAE Standards below for additional details.
	Clean Air Act	Intentional venting of refrigerants during maintenance, servicing, repair, or disposing of equipment is currently prohibited by Section 608 of the Clean Air Act, with the exception of hydrocarbons in industrial process refrigeration applications. Recovery equipment must follow Section 609 of the Clean Air Act.
	DOT Shipping Requirements	Hydrocarbons are considered flammable gases under DOT shipping regulations. According to Part 173.306, refrigerating machines are exempt from meeting certain requirements for packaging and shipping of compressed gases if, for machines not using A1 refrigerants, they contain no more than 50 lbs. of refrigerant, they contain shut-off valves, and they meet the safety requirements specified by ASHRAE Standard 15. According to Part 173.307, refrigerating machines are exempt from the requirements for compressed gasses if they use 12 kg (25 lbs.) or less of a flammable, non-toxic gas or 100 g (4 ounces) or less of a flammable, non-toxic liquefied gas.
	EPA RMP Program	See description of EPA Regulations below for details.
	EPA SNAP	See description of EPA SNAP below for more details.
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	Model Codes	See description of Model Codes below for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.
	UL 1995	UL 1995 does not include any provisions for the listing of heating and cooling equipment using hydrocarbon refrigerants. UL is not anticipating changing the standard unless there are significant changes to ASHRAE 15. Without provisions for flammable refrigerants, equipment using these refrigerants will not be listed by UL, and will likely be unable to meet EPA and model code safety requirements.

Table 8-3: Regulations affecting hydrocarbon refrigerants in mobile AC applications within the United States.

Hydrocarbons >> United States >> Mobile AC		
Application	**Applicable Regulations**	**Description**
Cars & Trucks	Clean Air Act	Intentional venting of refrigerants during maintenance, servicing, repair, or disposing of equipment is currently prohibited by Section 608 of the Clean Air Act, with the exception of hydrocarbons in industrial process refrigeration applications. Recovery equipment must follow Section 609 of the Clean Air Act.
	DOT Shipping Regulations	Refrigerant accumulators for motor vehicles being shipped must be designed with a burst pressure of not less than five times their charged pressure at 70° when shipped. (49 CFR Part 173.306) Exemptions can be obtained through the Office of Hazardous Materials within the DOT, but require proof that the safety of the equipment is equivalent to that specified under the regulation. (Taddonio 2008).
	EPA RMP Program	See description of EPA Regulations below for details.
	EPA SNAP	See description of EPA SNAP below for more details.
	EPCRA	See description of EPCRA below (under EPA Regulations) for details.
	OSHA	See description of OSHA Permissible Exposure Limits and Process Safety Management below for details.
	State-Level Hazardous Substances Lists	The following states have bans on using toxic or flammable refrigerants in mobile vehicle air conditioning, which may apply to hydrocarbons (Taddonio 2009): • Louisiana • North Dakota • Oklahoma • Kansas (Planning to change regulation) • Maryland (Planning to change regulation) • Texas (Planning to change regulation) Within the past few years, a number of states that previously banned toxic refrigerants have since amended these regulations. For example, Texas has drafted a bill to adopt an amendment allowing refrigerants that obtain EPA SNAP approval. In general, states have adopted one of the following two options: • Allowing refrigerants approved by the EPA SNAP program • Abiding by the safety regulations described in SAE Standard J639 The following states have bans on using hydrocarbon refrigerants in mobile vehicle air conditioning (Taddonio 2009): • Iowa: Statute 661—51.102(101) states that the distribution, sale or use of refrigerants containing liquefied petroleum gas, as defined in Iowa Code section 101.1, for use in mobile air–conditioning systems is prohibited. • Wisconsin: Administrative Code 139.04 (11) prohibits the sale of flammable substances containing butane, propane, mixtures of butane and propane, or other gaseous hydrocarbons for use as refrigerants in mobile air conditioner.

Some of the broader regulations that apply to hydrocarbon refrigerant applications within the US are described in further detail below.

ASHRAE Standards

Section 7.5.3, Higher Flammability Refrigerants, of ASHRAE 15-2007 requires that Group A3 and B3 refrigerants shall not be used except where approved by the authority having jurisdiction. The section lists two exceptions to this general ban on the use of A3 and B3 refrigerants:

(1) Laboratories with more than 100 ft2 (9.3 m2) of space per person, or
(2) Industrial occupancies.

ASHRAE Standard 34-2007 lists the allowable refrigerant concentration limits for all refrigerants, including hydrocarbons. These limits are referenced in ASHRAE Standard 15-2007 and are shown in Table 8-4 below.

Table 8-4: ASHRAE Standard 34-2007 allowable hydrocarbon refrigerant concentrations

ASHRAE Standard 34-2007 - Table 1 Refrigerants and Amounts			
Refrigerant	**Refrigerant Concentration Limits (RCL)**		
	ppm v/v	*g/m3*	*Lb/Mcf*
Propane	5,300	9.5	0.56
Butane	4,000	9.6	0.6
Isobutane			
Pentane	1000	2.9	0.2
Isopentane			

Source: ASHRAE Standard 34-2007(modifies ASHRAE 15 based on addendum c to ASHRAE 15)

Section 7.2.1 of ASHRAE Standard 15-2007 limits the amount of all A2, B2, A3 and B3 refrigerants found in institutional occupancies to half of the refrigerant concentration limits listed in Table 8-4 above. It also limits the total amount of all A2, B2, A3, and B3 in the occupied areas and machinery rooms of institutional occupancies to 550 lbs (250 kg). Equipment containing not more than 6.6 lb (3 kg) of refrigerant, regardless of its refrigerant safety classification, is exempt from these limitations.

Section 7.5.1.1 of ASHRAE Standard 15-2007 states that the total amount of all A2, B2, A3, and B3 refrigerants other than ammonia shall not exceed 1100 lb (500 kg) without approval by the authority having jurisdiction.

In addition, Section 7.5.1.2 states that refrigerating systems located in a public corridor or lobby must be either of the following:

(1) Unit systems containing A1 or B1 refrigerants in determined quantities, or
(2) Sealed absorption and unit systems having refrigerant quantities less than or equal to those indicated in Table 2 of ASHRAE Standard 15-2007 (shown in Table 7-4 in this report).

Section 7.5.2 prohibits use of A2, B2, A3, and B3 refrigerants in high-probability systems for human comfort, except for sealed absorption and unit systems having refrigerant quantities less than or equal to those indicated in Table 2 of ASHRAE Standard 15-2007 (shown in Table 7-4 in this report). This restriction does not apply to industrial occupancies.

Section 9.7.8 states that any system containing A3 or B3 refrigerants and using pressure-relief devices and fusible plugs shall have a number of limitations on the discharge of the refrigerant, including distance from the adjoining ground level (15ft) and distance from windows or openings (20 ft).

Under Section 9.13, unprotected refrigerant-containing copper pipe and tubing using all refrigerant types except A1 must provide protective metal enclosures for annealed copper tube.

The last section is also of particular interest to hydrocarbon refrigerant applications. It states that equipment listed by an approved, nationally recognized testing laboratory and identified, as part of the listing, as being in conformance with this standard meets all the requirements set for by ASHRAE Standard 15-2007.

DOT Shipping Requirements

Hydrocarbons are considered flammable gases under DOT shipping regulations.

According to Part 173.306 in subpart G, refrigerating machines are exempt from meeting certain requirements for packaging and shipping of compressed gases if, for machines not using A1 refrigerants, they contain no more than 50 lbs. of refrigerant, they contain shut-off valves, and they meet the safety requirements specified by ASHRAE Standard 15.

According to Part 173.307 in subpart G, refrigerating machines are exempt from the requirements for compressed gasses if they use 12 kg (25 lbs.) or less of a flammable, non-toxic gas or 100 g (4 ounces) or less of a flammable, non-toxic liquefied gas.

EPA Regulations

EPA Risk Management Program

Propane, butane, and isobutane are all listed under the Chemical Accident Prevention Provisions rule as Regulated Flammable Substances due to their labeling as flammable gases. Any facility that produces, handles, processes, distributes, or stores these substances in quantities above their threshold quantity are subject to the requirements of the Risk Management Plan rule. These quantities are shown below in Table 8-5.

Table 8-5: EPA threshold quantities for hydrocarbon refrigerants

Chemical Accident Prevention Provisions Rule Regulated Flammable Substances – Threshold Quantities	
Substance	**Threshold Quantity (lbs.)**
Propane	10,000
Butane	10,000
Isobutane	10,000

Emergency Planning and Community Right-to-Know Act (SARA III) (EPCRA)
Propane is recognized as a hazardous substance by OSHA, and thus qualifies for reporting under the Hazardous Chemical Storage Reporting Requirements. For facilities containing 10,000 lbs. or more of propane, facilities must maintain a material safety data sheet (MSDS), and submit the MSDS (or a list of the chemicals) to their State Emergency Response Commission (SERC), Local Emergency Planning Committee (LEPC), and local fire department. Facilities must also report an annual inventory of these chemicals by March 1 of each year to their SERC, LEPC and local fire department. The information must be made available to the public.

EPA SNAP

Propane, Propylene, Butane, Hydrocarbon Blend A, and Hydrocarbon Blend B have been approved for use without restriction as a substitute for Class I substances in industrial process refrigeration. EPA specifies that these substitutes are prohibited for other end-uses.

OZ-12 (Hydrocarbon Blend A) and HC-12a (Hydrocarbon Blend B) have been listed as unacceptable substitute refrigerants in all end-uses other than retrofit and new industrial process refrigeration. EPA cites a lack of adequate risk assessment that characterizes incremental flammability risk as the reason for this decision.

All flammable refrigerants have been deemed unacceptable substitute refrigerants in motor vehicle air conditioning applications due to a lack of adequate assessment that characterizes incremental flammability risk.

EPA is currently evaluating a hydrocarbon freezer, submitted by Ben and Jerry's company, which uses propane as a refrigerant (Dominguez 2009). Additionally, General Electric announced in October 2008 that it was submitting a petition to the EPA to use isobutane in household refrigerators. This petition may also have an impact on the approval of hydrocarbons in other refrigeration applications. (Adams 2009)

OSHA Regulations

Permissible Exposure Limits
Propane is listed as a hazardous substance by OSHA. OSHA has set the Permissible Exposure Limits for propane as shown in Table 8-6 below.

Table 8-6: OSHA permissible exposure limits for propane.

OSHA Permissible Exposure Limits		
Substance	**ppm**	**mg / m³**
Propane	1,000	1,800

Process Safety Management of Highly Hazardous Substances
No hydrocarbons are listed as a highly hazardous substance under the process safety management program, under 1910.199 App A- List of Highly Hazardous Chemicals, Toxics and Reactives.

Model Codes

The 2006 IMC follows many of the same requirements as ASHRAE 15-2007. The permitted amounts and exposure limits allowed by the 2006 IMC and ASHRAE 15-2007 are largely similar, as described further in Appendix E. The 2006 IMC prohibits the use of A3 and B3 refrigerants in non-industrial occupancies and includes many of the requirements for flammable refrigerants contained in ASHRAE 15-2007. Both documents also include the same exemption on refrigerant restrictions for equipment with charges of 6.6 lbs of refrigerant or less, which is particularly relevant for systems using hydrocarbons. The 2006 IMC also includes the ASHRAE 15-2007 limits on the total amount allowed in a room, requirements for the hazard level of machinery rooms using A3 refrigerants, and special requirements for reducing flammability risks in machinery rooms (including emergency pressure control systems).

The 2006 UMC also includes many of the ASHRAE 15-2007 requirements for flammable refrigerants. However, the 2006 UMC does not ban the use of A3 and B3 refrigerants in non-industrial occupancies; instead, it requires that all equipment using non-A1 refrigerants use a machinery room. Unlike the 2006 IMC, the 2006 UMC does not contain an exemption for equipment with charges under 6.6 lbs. The 2006 UMC also contains requirements on the hazard level of machinery rooms, requirements for reducing flammability risks inside machinery rooms, and requirements for ventilation systems.

The International Fire Code (IFC) and the NFPA 1 Code – Uniform Fire Code limit the amount of flammable and toxic gases that can be stored and used in a defined control area. While these limits are identical for indoor control areas, the IFC allows greater quantities to be used and stored in outdoor control areas (up to twice or four times as much in some cases). The IFC and UFC also restrict or prohibit the use and storage of flammable and toxic refrigerants for occupancies defined in each code.

8.2 Hydrocarbons - Europe

Table 8-7 below summarizes the regulations, codes, and standards affecting the use of hydrocarbon refrigerant in commercial refrigeration applications within Europe.

Table 8-8 below summarizes the regulations, codes, and standards affecting the use of hydrocarbon refrigerant in stationary AC applications within Europe.

Table 8-9 below summarizes the regulations, codes, and standards affecting the use of hydrocarbon refrigerant in mobile AC applications within Europe.

Some of the broader regulations that apply to multiple applications are described in further detail following these tables.

Table 8-7: Regulations affecting hydrocarbon refrigerants in commercial refrigeration applications within Europe.

Hydrocarbons >> Europe >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Small Commercial Stand-Alone Coolers/ Freezers/ Refrigerators **Supermarket Systems** **Walk-In Freezers/ Coolers**	ATEX 94/9/EC	The ATEX Equipment Directive may apply to systems installed in facilities or locations that contain potentially explosive environments.
	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378:2008	See description of EN 378 below for details.
	EN 60079	EN Standard 60079 is harmonized with the ATEX Directive. It provides requirements for electrical systems used in potentially explosive atmospheres. The standard establishes three different categories of environments that present certain dangers when using electrical equipment and sets technical requirements for electrical equipment used in these environments. These requirements can include explosion-proof enclosures, automatic cut-off switches, and location of the equipment, depending on the environmental conditions.
	IEC 60335-2-75	Commercial dispensing appliances are limited to a total charge of 150g of flammable A3 refrigerant. Equipment under this limit can be used in any occupancy or setting. Equipment using larger quantities of flammable refrigerant is regulated by European Standard EN 378.
	IEC 60335-2-89	Commercial refrigeration equipment is limited to a total charge of 150g of flammable A3 refrigerant. Equipment under this limit can be used in any occupancy or setting. Equipment using larger quantities of flammable refrigerants is regulated by European Standard EN 378.
	Pressure Equipment Directive	Under Article 9 of the PED, hydrocarbons are considered group 1 fluids. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. This classification requires manufacturers using hydrocarbons to utilize table 2 in Annex 2 of the PED to determine the category of equipment and the restrictions placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.
Transport Refrigeration	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378:2008	See description of EN 378 below for details.
	Pressure Equipment Directive	Under Article 9 of the PED, hydrocarbons are considered group 1 fluids. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. This classification requires manufacturers using hydrocarbons to utilize table 2 in Annex 2 of the PED to determine the category of equipment and the restrictions placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.

Table 8-7, cont.

Hydrocarbons >> Europe >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Industrial Refrigeration Cold Storage	ATEX 94/9/EC	The ATEX Equipment Directive may apply to systems installed in facilities or locations that contain potentially explosive environments.
	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378-2	Indirect systems using more than 500 kg of flammable refrigerants (A2, B2, A3, B3) are not permitted to release the refrigerant into the areas served by the secondary heat transfer fluid, and are required to employ safety measures such as the following: • Automatic air/refrigerant separator • Double wall heat exchanger • Maintaining the pressure of the secondary circuit greater than that of the primary circuit around the contact area See the description of EN 378 below for further details.
	EN 60079	EN Standard 60079 is harmonized with the ATEX Directive. It provides requirements for electrical systems used in potentially explosive atmospheres. The standard establishes three different categories of environments that present certain dangers when using electrical equipment and sets technical requirements for electrical equipment used in these environments. These requirements can include explosion-proof enclosures, automatic cut-off switches, and location of the equipment, depending on the environmental conditions.
	Pressure Equipment Directive	Under Article 9 of the PED, hydrocarbons are considered group 1 fluids. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. This classification requires manufacturers using hydrocarbons to utilize table 2 in Annex 2 of the PED to determine the category of equipment and the restrictions placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.

Table 8-8: Regulations affecting hydrocarbon refrigerants in stationary AC applications within Europe.

Hydrocarbons >> Europe >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Residential AC **Commercial AC**	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378-1	Annex C contains an exception for certain factory sealed refrigerating systems. Systems containing less than 0.15 kg of A2 or A3 refrigerant have no restrictions when placed in an occupied space which is not a special machinery room. Section 3 of Annex C also describes charge limitations due to flammability for AC systems or heat pumps for human comfort. This section provides mathematical formulas for the following: • Calculating the maximum charge size allowed in a room for an AC system with a flammable refrigerant. • Calculating the maximum charge size for non-fixed factory sealed AC systems and pumps with a limited charge. • Calculating the maximum charge of an A2 or A3 refrigerant for equipment with a mechanically vented enclosure for the refrigerant circuit that does not directly interact with the ventilated room. See the description of EN 378 below for additional details.
	IEC 60335-2-40	Refrigerant charge limits for standard IEC 60335-2-40 depend on the lower flammability limit of the refrigerant, the size of the room the equipment is installed in, and the ventilation that is provided for the equipment. These restrictions are similar to those used by EU 378. The following charge limits apply to propane: • Under 150 g: No significant restrictions • 150 g < Charge < 1 kg: Charge limit depends on the size of the room • 1 kg < Charge < 4.9 kg: Appliance requires mechanical ventilation • Greater than 4.9 kg: EN 60335-2-40 does not apply; see EN 378
	Pressure Equipment Directive	Under Article 9 of the PED, hydrocarbons are considered group 1 fluids. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. This classification requires manufacturers using hydrocarbons to utilize table 2 in Annex 2 of the PED to determine the category of equipment and the restrictions placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.
	WEEE Directive	The WEEE Directive establishes collection, recycling, and recovery targets for residential AC units.

Table 8-8, cont.

Hydrocarbons >> Europe >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Chillers	ATEX 94/9/EC	The ATEX Equipment Directive presents a separate set of requirements from those cited in EN 378 and its harmonized directives. Large chillers using flammable refrigerants have the potential to fall within the scope of the ATEX Equipment Directive. To avoid falling within the scope of this directive, the following measures can be taken to eliminate the possibility of the chiller becoming a flammable volume: • Provide a means of extracting dangerous gases using an a ventilation system, or • Install a detector to terminate operation of the chiller once refrigerant levels reach a certain percentage of the lower flammability limit of the refrigerant, or • Seal all electronics according to EN 378
	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378	See description of EN 378 below for details.
	EN 60079	EN Standard 60079 is harmonized with the ATEX Directive. It provides requirements for electrical systems used in potentially explosive atmospheres. The standard establishes three different categories of environments that present certain dangers when using electrical equipment and sets technical requirements for electrical equipment used in these environments. These requirements can include explosion-proof enclosures, automatic cut-off switches, and location of the equipment, depending on the environmental conditions.
	Pressure Equipment Directive	Under Article 9 of the PED, hydrocarbons are considered group 1 fluids. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. This classification requires manufacturers using hydrocarbons to utilize table 2 in Annex 2 of the PED to determine the category of equipment and the restrictions placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.

Table 8-9: Regulations affecting hydrocarbon refrigerants in mobile AC applications within Europe.

Hydrocarbons >> Europe >> Mobile AC		
Application	**Applicable Regulations**	**Description**
Cars & Trucks	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	ISO/CD 13043	The current version of EN 378 includes mobile vehicle air conditioning applications; however, MVAC has been removed from the scope of this standard and will be covered by ISO/CD 13043. The ISO Technical Committee for road vehicles (TC 22) is working on publishing this new standard, ISO/CD 13043. The name of the standard is "Road vehicles – refrigerant systems used in Mobile Air Conditioning systems (MAC) – Safety Requirements." The standard is under development and will provide safety requirements for MVAC systems.

Some of the broader regulations that apply to hydrocarbon refrigerants within the EU are described in further detail below.

EN Standard 378

Please see Appendix A of this report for a table of charge limits included in EN 378:2008.

EN 378-1: Basic requirements, definitions, classification and selection criteria
Hydrocarbons must adhere to a requirement in Annex C to separate potential sources of ignition from potential sites of refrigerant leakage. Annex C contains a note that, for:

> …sealed refrigerating systems using flammable refrigerants (A2, B2, A3, B3), but excluding R-717, no sources of ignition shall be associated with parts of the equipment that could come in contact with leaked refrigerant. All potential sources of ignition shall be sealed according to the methods detailed in EN 378-2.

En 378-2: Design, construction, testing, marking, and documentation
Systems using refrigerants other than A1 refrigerants fall under the requirement in Section 6.2.3.3 requiring that valves and joints be inaccessible to the general public.

System containing A2, B1, B2, A3, B3 refrigerants cannot employ fusible plugs as relief devices.

EN 378-3: Installation site and personal protection
Section 5.17 of EN 378-3 presents several requirements for machinery rooms housing systems using flammable refrigerants (A2, B2, A3, and B3). The first requirement states that the machinery room shall be located in accordance with local and national regulations. The second section sets requirements for the location and rating of the emergency exhaust ventilation. For example, the fan must be rated for hazardous areas or remain outside of the refrigerant airflow.

Section 5.17.3 provides an additional requirement for machine rooms containing A2 or A3 refrigerants. Machine rooms that possess a risk of explosion must comply with the requirements of hazardous areas (i.e. be explosion proof). Some explosion relief (e.g. frangible wall or roof) shall be provided.

In addition, machine rooms with flammable refrigerants (A2, B2, A3, and B3) cannot have combustion equipment or hot surfaces within 100 K of the auto-ignition temperature of the refrigerant. (Section 5.17.5)

For machine rooms above the Practical Limit (EN 378 Appendix A, Annex E) for flammable refrigerants, access to the outdoors shall be provided.

Section 8.8, for detectors of A2 and A3 refrigerants, requires an alarm that operates at least 25 percent of the lower limit of concentration of the flammability range in air for the refrigerant. The detector must also automatically sound an alarm, start the ventilation system, and stop the system when activated.

8.3 Hydrocarbons – Japan

Table 8-10 below summarizes the regulations, codes, and standards affecting the use of hydrocarbon refrigerant in commercial refrigeration applications within Japan.

Table 8-11 below summarizes the regulations, codes, and standards affecting the use of hydrocarbon refrigerant in stationary AC applications within Japan.

Table 8-12 below summarizes the regulations, codes, and standards affecting the use of hydrocarbon refrigerant in mobile AC applications within Japan.

Table 8-10: Regulations affecting hydrocarbon refrigerants in commercial refrigeration applications within Japan.

Hydrocarbons >> Japan >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Small Commercial Stand-Alone Coolers/ Freezers/ Refrigerators **Supermarket Systems** **Walk-In Freezers/ Coolers**	Electrical Appliance and Material Safety Act	Manufacturing, import, sales and safety practices of electrical appliances must comply with guidelines and specifications established by the Electrical Appliance and Material Safety Act. In particular, the act establishes maximum refrigerant charge limits for flammable refrigerants used in forced air cooling and convection cooling systems.
	Fire and Disaster Management Act (FDMA)	General handling of flammable substances, including production, storage and transportation, must comply with safety guidelines and specifications established by the Fire and Disaster Management Act. Hydrocarbon refrigerants fall under the classification of Special Flammable Substances under this act, which require additional safety measures (e.g. explosion-proof equipment design).
	High Pressure Gas Safety Act	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	ISO 5149	JIS B8612 (Commercial Refrigeration Cabinets) specifies materials and appropriate usage for refrigerated display cases for food retail applications. It refers to ISO 5149 as the guideline for refrigerant safety for commercial refrigerators.
	JIS B8240	JIS B8240 (Construction of Pressure Vessels for Refrigeration) specifies the materials, design and construction of pressure vessels (e.g. storage tank) for equipment that uses vapor-compression or evaporative cooling.
Transport Refrigeration	High Pressure Gas Safety Act	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	JIS B8240	JIS B8240 (Construction of Pressure Vessels for Refrigeration) specifies the materials, design and construction of pressure vessels (e.g. storage tank) for equipment that uses vapor-compression or evaporative cooling.
Industrial Refrigeration Cold Storage	Electrical Appliance and Material Safety Act	Manufacturing, import, sales and safety practices of electrical appliances must comply with guidelines and specifications established by the Electrical Appliance and Material Safety Act. In particular, the act establishes maximum refrigerant charge limits for flammable refrigerants used in forced air cooling and convection cooling systems.
	Fire and Disaster Management Act (FDMA)	General handling of flammable substances, including production, storage and transportation, must comply with safety guidelines and specifications established by the Fire and Disaster Management Act. Hydrocarbon refrigerants fall under the classification of Special Flammable Substances under this act, which require additional safety measures (e.g. explosion-proof equipment design).
	High Pressure Gas Safety Act	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	JIS B8240	JIS B8240 (Construction of Pressure Vessels for Refrigeration) specifies the materials, design and construction of pressure vessels (e.g. storage tank) for equipment that uses vapor-compression or evaporative cooling.

Table 8-11: Regulations affecting hydrocarbon refrigerants in stationary AC applications within Japan.

Hydrocarbons >> Japan >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Residential AC **Commercial AC** **Chillers**	Electrical Appliance and Material Safety Act	Manufacturing, import, sales and safety practices of electrical appliances must comply with guidelines and specifications established by the Electrical Appliance and Material Safety Act. In particular, the act establishes maximum refrigerant charge limits for flammable refrigerants used in forced air cooling and convection cooling systems.
	Fire and Disaster Management Act (FDMA)	General handling of flammable substances, including production, storage and transportation, must comply with safety guidelines and specifications established by the FDMA. Hydrocarbon refrigerants fall under the classification of Special Flammable Substances, which require additional safety measures (e.g. explosion-proof equipment design).
	High Pressure Gas Safety Act	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	JIS B8240	JIS B8240 (Construction of Pressure Vessels for Refrigeration) specifies the materials, design and construction of pressure vessels (e.g. storage tank) for equipment that uses vapor-compression or evaporative cooling.
	JIS 8616, JIS B8620	JIS 8616 (Packaged Air Conditioner) specifies the materials, design, and testing procedure of packaged AC system intended to provide comfort to building occupants. JIS 8616 refers to JIS 8620 (Safety Code for Small Refrigeration Equipment) for refrigerant leakage testing procedure.

Table 8-12: Regulations affecting hydrocarbon refrigerants in mobile AC applications within Japan.

Hydrocarbons >> Japan >> Mobile AC		
Application	**Applicable Regulations**	**Description**
Cars & Trucks	JIS B8240	JIS B8240 (Construction of Pressure Vessels for Refrigeration) specifies the materials, design and construction of pressure vessels (e.g. storage tank) for equipment that uses vapor-compression or evaporative cooling.

9 A2L Fluids Regulatory Review

This section describes the regulations, codes, and standards relevant to A2L-designated refrigerants for the United States, Europe, and Japan. The descriptions are organized by application type for each of the three regions.

One of the commonly referenced A2 fluids is HFO-1234yf. HFO-1234yf is a refrigerant substitute developed jointly by Honeywell and DuPont. It is considered to be a candidate for A2L classification based on its flammability and toxicity characteristics and its burning velocity. There are only two substances classified as A2L in the 2006 draft version of ISO 817, ISO/CD 817:200x – difluoromethane (R-32) and 1,1,1-trifluoroethane (R-143a). HFO-1234yf is currently classified as an ASHRAE Class A2 refrigerant and is designated as R-1234yf.

9.1 A2L Fluids - United States

Table 9-1 below summarizes the regulations, codes, and standards affecting the use of A2L refrigerants in commercial refrigeration applications within the US.

Table 9-2 below summarizes the regulations, codes, and standards affecting the use of A2L refrigerants in stationary AC applications within the US.

Table 9-3 below summarizes the regulations, codes, and standards affecting the use of A2L refrigerants in mobile AC applications within the US.

Some of the broader regulations that apply to multiple applications are described in further detail following these tables.

Table 9-1: Regulations affecting A2L fluid refrigerants in commercial refrigeration applications within the United States.

A2L Fluids >> United States >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Small Commercial Stand-Alone Coolers/ Freezers/ Refrigerators **Supermarket Systems** **Walk-In Freezers/ Coolers**	ASHRAE 15-2007	ASHRAE Standing Standard Project Committee (SSPC) 15 has been considering the implications of a new 2L subclass in ASHRAE 15 within subcommittees. No new revisions or addenda to ASHRAE Standard 15-2007 have been proposed yet for the 2L designation. The SSPC may consider the A2L requirements of the latest draft version of ISO 5149, shown in Appendix B of this report.
	ASHRAE 34-2007	Addendum ak recently introduced a new 2L subclass to the existing Class 2 flammability classification, signifying class 2 refrigerants with a burning velocity less than or equal to 10 cm/s. The addendum also includes flammability testing requirements for substance applications seeking to be designated as 2L substances.
	Clean Air Act	Intentional venting of refrigerants during maintenance, servicing, repair, or disposing of equipment is currently prohibited by the Clean Air Act, Section 608. Recovery equipment must follow Section 609 of the Clean Air Act.
	DOT Shipping Requirements	Any A2L fluids would likely be considered flammable gases under DOT shipping regulations. According to Part 173.306 in subpart G, refrigerating machines are exempt from meeting certain requirements for packaging and shipping of compressed gases if, for machines not using A1 refrigerants, they contain no more than 50 lbs. of refrigerant, they contain shut-off valves, and they meet the safety requirements specified by ASHRAE Standard 15. According to Part 173.307 in subpart G, refrigerating machines are exempt from the requirements for compressed gasses if they use 12 kg (25 lbs.) or less of a flammable, non-toxic gas or 100 g (4 ounces) or less of a flammable, non-toxic liquefied gas.
	EPA SNAP	All potential substitute refrigerants for refrigeration and air conditioning applications must be approved for use by the EPA SNAP Program on a case by case basis. EPA approval of substitute refrigerants may be subject to conditions of use or narrow use limits. For A2L Fluids that demonstrate some flammability behavior, EPA will likely apply conditions to limit the amount of refrigerant leakage that can occur, based on the lower flammability limit of the refrigerant. These limits will also be determined by the amount of danger posed to a user. Similar restrictions have been proposed in the current HFO-1234yf rulemaking for motor vehicle air conditioning systems.
	EPCRA	See description of EPCRA below for details.
	Model Codes	See description of Model Codes below for details.
	OSHA	See description of OSHA Regulations below for details.

Table 9-1, cont.

A2L Fluids >> United States >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
(continued) **Small Commercial Stand-Alone Coolers/ Freezers/ Refrigerators**	UL 471	Commercial refrigeration equipment using refrigerants classified as A2 by ASHRAE 34 are limited to using a total charge of 225 g of refrigerant. This amendment was recently added by UL in 2009. UL is not currently anticipating changing the standard based on the potential A2L subclass unless significant changes to ASHRAE 15 are made. The 150g limit should only restrict the use of A2L fluids in applications with smaller charge requirements. These applications may include reach-in refrigerators, vending machines, and glass-door merchandisers. Applications that require more cooling and that may prove to be problematic are ice machines, frozen ice cream machines, and frozen carbonated beverage machines. Changes to the charge limits for A2 refrigerants in UL 250 (from 225g to 270g) may influence future development of UL 471. See Appendix C for more details.
Supermarket Systems **Walk-In Freezers/ Coolers**	UL 1995	UL 1995 does not include any provisions for the listing of heating and cooling equipment using A2 refrigerants. UL is not currently anticipating changing the standard based on the potential A2L subclass unless significant changes to ASHRAE 15 are made. Without provisions for flammable refrigerants, equipment using these refrigerants will not be listed by UL, and will likely be unable to meet EPA and model code safety requirements.
Transport Refrigeration	ASHRAE Standard 26-1996 (RA 2006)	There are some restrictions for ships using A2 fluids as a refrigerant, which apply to the area of transport refrigeration. Section 5.5.1.2 details refrigerant requirements for ships that are not intended for carrying passengers. For direct and indirect cargo or process refrigeration systems, only refrigerants of groups A1, B1, and B2 can be used, which excludes any A2 refrigerants. Section 5.2.6 states that any machinery components using a class 2 (or 3) refrigerant must have an automatic fire extinguishing system using water sprinklers installed.
	Clean Air Act	Intentional venting of refrigerants during maintenance, servicing, repair, or disposing of equipment is currently prohibited by the Clean Air Act, Section 608. Recovery equipment must follow Section 609 of the Clean Air Act.
	DOT Shipping Requirements	Any A2L fluids would likely be considered flammable gases under DOT shipping regulations. According to Part 173.306 in subpart G, refrigerating machines are exempt from meeting certain requirements for packaging and shipping of compressed gases if, for machines not using A1 refrigerants, they contain no more than 50 lbs. of refrigerant, they contain shut-off valves, and they meet the safety requirements specified by ASHRAE Standard 15. According to Part 173.307 in subpart G, refrigerating machines are exempt from the requirements for compressed gasses if they use 12 kg (25 lbs.) or less of a flammable, non-toxic gas or 100 g (4 ounces) or less of a flammable, non-toxic liquefied gas.

Table 9-1, cont.

A2L Fluids >> United States >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
(continued) **Transport Refrigeration**	EPA SNAP	All potential substitute refrigerants for refrigeration and air conditioning applications must be approved for use by the EPA SNAP Program on a case by case basis for each potential use. EPA approval of substitute refrigerants may be subject to conditions of use or narrow use limits. For A2L Fluids that demonstrate some flammability behavior, EPA will likely apply conditions to limit the amount of refrigerant leakage that can occur, based on the lower flammability limit of the refrigerant. These limits will also be determined by the amount of danger posed to a user. Similar restrictions have been proposed in the current HFO-1234yf rulemaking for motor vehicle air conditioning systems.
	EPCRA	See description of EPCRA below for details.
	OSHA	See description of OSHA Regulations below for details.
Industrial Refrigeration Cold Storage	ASHRAE 15-2007	ASHRAE Standing Standard Project Committee (SSPC) 15 has been considering the implications of a new 2L subclass in ASHRAE 15 within subcommittees. No new revisions or addenda to ASHRAE Standard 15-2007 have been proposed yet for the 2L designation. The SSPC may consider the A2L requirements of the latest draft version of ISO 5149, shown in Appendix B of this report.
	ASHRAE 34-2007	Addendum ak recently introduced a new 2L subclass to the existing Class 2 flammability classification, signifying class 2 refrigerants with a burning velocity less than or equal to 10 cm/s. The addendum also includes flammability testing requirements for substance applications seeking to be designated as 2L substances.
	Clean Air Act	Intentional venting of refrigerants during maintenance, servicing, repair, or disposing of equipment is currently prohibited by the Clean Air Act, Section 608. Recovery equipment must follow Section 609 of the Clean Air Act.
	DOT Shipping Requirements	Any A2L fluids would likely be considered flammable gases under DOT shipping regulations. According to Part 173.306 in subpart G, refrigerating machines are exempt from meeting certain requirements for packaging and shipping of compressed gases if, for machines not using A1 refrigerants, they contain no more than 50 lbs. of refrigerant, they contain shut-off valves, and they meet the safety requirements specified by ASHRAE Standard 15. According to Part 173.307 in subpart G, refrigerating machines are exempt from the requirements for compressed gasses if they use 12 kg (25 lbs.) or less of a flammable, non-toxic gas or 100 g (4 ounces) or less of a flammable, non-toxic liquefied gas.
	EPA SNAP	All potential substitute refrigerants for refrigeration and air conditioning applications must be approved for use by the EPA SNAP Program on a case by case basis for each potential use. EPA approval of substitute refrigerants may be subject to conditions of use or narrow use limits. For A2L Fluids that demonstrate some flammability behavior, EPA will likely apply conditions to limit the amount of refrigerant leakage that can occur, based on the lower flammability limit of the refrigerant. These limits will also be determined by the amount of danger posed to a user. Similar restrictions have been proposed in the current HFO-1234yf rulemaking for motor vehicle air conditioning systems.

Table 9-1, cont.

A2L Fluids >> United States >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
(continued) Industrial Refrigeration Cold Storage	EPCRA	See description of EPCRA below for details.
	Model Codes	See description of Model Codes below for details.
	OSHA	See description of OSHA Regulations below for details.

Table 9-2: Regulations affecting A2L fluid refrigerants in stationary AC applications within the United States.

A2L Fluids >> United States >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Residential AC **Commercial AC** **Chillers**	ASHRAE 15-2007	ASHRAE Standing Standard Project Committee (SSPC) 15 has been considering the implications of a new 2L subclass in ASHRAE 15 within subcommittees. No new revisions or addenda to ASHRAE Standard 15-2007 have been proposed yet for the 2L designation. The SSPC may consider the A2L requirements of the latest draft version of ISO 5149, shown in Appendix B of this report.
	ASHRAE 34-2007	Addendum ak recently introduced a new 2L subclass to the existing Class 2 flammability classification, signifying class 2 refrigerants with a burning velocity less than or equal to 10 cm/s. The addendum also includes flammability testing requirements for substance applications seeking to be designated as 2L substances.
	Clean Air Act	Intentional venting of refrigerants during maintenance, servicing, repair, or disposing of equipment is currently prohibited by the Clean Air Act, Section 608. Recovery equipment must follow Section 609 of the Clean Air Act.
	DOT Shipping Requirements	Any A2L fluids would likely be considered flammable gases under DOT shipping regulations. According to Part 173.306 in subpart G, refrigerating machines are exempt from meeting certain requirements for packaging and shipping of compressed gases if, for machines not using A1 refrigerants, they contain no more than 50 lbs. of refrigerant, they contain shut-off valves, and they meet the safety requirements specified by ASHRAE Standard 15. According to Part 173.307 in subpart G, refrigerating machines are exempt from the requirements for compressed gasses if they use 12 kg (25 lbs.) or less of a flammable, non-toxic gas or 100 g (4 ounces) or less of a flammable, non-toxic liquefied gas.

Table 9-2, cont.

A2L Fluids >> United States >> Stationary AC		
Application	**Applicable Regulations**	**Description**
(continued) **Residential AC** **Commercial AC** **Chillers**	EPA SNAP	All potential substitute refrigerants for refrigeration and air conditioning applications must be approved for use by the EPA SNAP Program on a case by case basis for each potential use. EPA approval of substitute refrigerants may be subject to conditions of use or narrow use limits. For A2L Fluids that demonstrate some flammability behavior, EPA will likely apply conditions to limit the amount of refrigerant leakage that can occur, based on the lower flammability limit of the refrigerant. These limits will also be determined by the amount of danger posed to a user. Similar restrictions have been proposed in the current HFO-1234yf rulemaking for motor vehicle air conditioning systems.
	EPCRA	See description of EPCRA below for details.
	Model Codes	See description of Model Codes below for details.
	OSHA	See description of OSHA Regulations below for details.
	UL 1995	UL 1995 does not include any provisions for the listing of heating and cooling equipment using A2 refrigerants. UL is not currently anticipating changing the standard based on the potential A2L subclass unless significant changes to ASHRAE 15 are made. Without provisions for flammable refrigerants, equipment using these refrigerants will not be listed by UL, and will likely be unable to meet EPA and model code safety requirements.

Table 9-3: Regulations affecting A2L fluid refrigerants in mobile AC applications within the United States.

A2L Fluids >> United States >> Mobile AC		
Application	**Applicable Regulations**	**Description**
Cars & Trucks	Clean Air Act	Intentional venting of refrigerants during maintenance, servicing, repair, or disposing of equipment is currently prohibited by the Clean Air Act, Section 608. Recovery equipment must follow Section 609 of the Clean Air Act.
	DOT Shipping Regulations	Refrigerant accumulators for motor vehicles being shipped must be designed with a burst pressure of not less than five times their charged pressure at 70° when shipped. (49 CFR Part 173.306) Exemptions can be obtained through the Office of Hazardous Materials within the DOT, but require proof that the safety of the equipment is equivalent to that specified under the regulation. (Taddonio 2008).

Table 9-3, cont.

A2L Fluids >> United States >> Mobile AC		
Application	**Applicable Regulations**	**Description**
(continued) **Cars & Trucks**	EPA SNAP	Honeywell and DuPont submitted a SNAP application to EPA for use of HFO-1234yf in motor vehicle air conditioning systems on July 8, 2008. On October 19, 2009, EPA published a proposed rule to find HFO-1234yf acceptable, subject to use conditions as a substitute for CFC-12 in motor vehicle air conditioning. EPA proposed the following use conditions: • HFO-1234yf MVAC systems must incorporate engineering strategies and/or devices so that leaks into the passenger compartment do not result in HFO-1234yf concentrations at or above the lower flammability limit (LFL) of 6.2% v/v for more than 15 seconds • HFO–1234yf MVAC systems must incorporate engineering strategies and/or devices so that leaks into the engine compartment or vehicle electric power source storage areas do not result in HFO-1234yf concentrations at or above the LFL of 6.2% v/v for any period of time • HFO–1234yf MVAC systems must incorporate protective devices, isolation and/or ventilation techniques in areas where processes, procedures or upset conditions such as leaks have the potential to generate HFO-1234yf concentrations at or above 6.2% v/v in proximity to hybrid/electric vehicle electric power sources and exhaust manifold surfaces • HFO–1234yf MVAC systems must use unique fittings to be identified pursuant to SAE standard J639 and subject to EPA approval • HFO–1234yf MVAC systems must include a detailed label identifying the refrigerant and that the refrigerant is flammable • HFO–1234yf MVAC systems must have a high-pressure compressor cutoff switch installed on systems equipped with pressure relief devices; and • Manufacturers must conduct and keep on file Failure Mode and Effect Analysis on the MVAC as stated in SAE J1739 Note that these proposed use conditions are preliminary only and are likely to change when the rule becomes final.
	EPCRA	See description of EPCRA below for details.
	OSHA	See description of OSHA Regulations below for details.
	SAE Standard J639	SAE Standard J639 is currently being revised to include standards for alternative refrigerants. A small number of states have begun to adopt SAE Standard J639 as a reference to replace older MVAC refrigerant regulations.
	SAE Standards: J2772, J2773, J2842, J2845, J639, J2843, J2844, J2851, J2887, J2888	The Society of Automotive Engineers has recently published a group of new and revised standards on the safety, design, maintenance, and technician training requirements for mobile vehicle air conditioning systems. In total, there were nine new or revised standards (as of February 2009) that dealt with the use of HFO-1234yf as a refrigerant in mobile vehicle air conditioning systems. These standards are described above in the Section 5 Glossary. (Atkinson 2009)

Table 9-3, cont.

A2L Fluids >> United States >> Mobile AC		
Application	**Applicable Regulations**	**Description**
(continued) **Cars & Trucks**	State-Level Hazardous Substances Lists	The following states have bans on using toxic or flammable refrigerants in mobile vehicle air conditioning, which could apply to A2L fluids (Taddonio 2009): • Louisiana • North Dakota • Oklahoma • Kansas (Planning to change regulation) • Maryland (Planning to change regulation) • Texas (Planning to change regulation) Within the past few years, a number of states that previously banned toxic refrigerants have since amended these regulations. For example, Texas has drafted a bill to adopt an amendment allowing refrigerants that obtain EPA SNAP approval. In general, states have adopted one of the following two options: • Allowing refrigerants approved by the EPA SNAP program • Abiding by the safety regulations described in SAE Standard J639

Some of the broader regulations that apply to A2L refrigerant applications within the US are described in further detail below.

EPA Regulations

Emergency Planning and Community Right-to-Know Act (SARA III) (EPCRA)
OSHA identifies substances that are potentially hazardous in large quantities (usually 10,000 lbs. or greater), generally due to their toxicity in large quantities. Substances classified as A2L fluids are likely to be identified as potentially hazardous, and would fall under sections 311 and 312 of EPCRA.

The EPCRA regulations for most hazardous substances are as follows: For facilities containing 10,000 lbs. or more of the substance, facilities must maintain a material safety data sheet (MSDS) and submit the MSDS (or a list of the chemicals) to their State Emergency Response Commission (SERC), Local Emergency Planning Committee (LEPC), and local fire department. Facilities must also report an annual inventory of these chemicals by March 1 of each year to their SERC, LEPC and local fire department. The information must be made available to the public.

Model Codes

The 2006 IMC follows many of the same requirements as ASHRAE 15-2007. Both documents include the same exemption on refrigerant restrictions for equipment with charges of 6.6 lbs of refrigerant or less, which is particularly important for systems using flammable refrigerants. The 2006 IMC includes most of the ASHRAE 15-2007 limits on the total amount allowed in a room, requirements for the hazard level of machinery rooms using A2 refrigerants, and special requirements for reducing flammability risks in machinery rooms (including emergency pressure control systems). However, unlike ASHRAE 15-2007, the 2006 IMC does not prohibit A2 refrigerants from being used in high-probability systems for human comfort.

The 2006 UMC also has many of same requirements for flammable refrigerants as ASHRAE 15-2007. However, the 2006 UMC requires that all equipment using non-A1 refrigerants use a machinery room, and does not contain the same exemption for equipment with charges under 6.6 lbs. The 2006 UMC also contains requirements on the hazard level of machinery rooms, requirements for reducing flammability risks inside machinery rooms, and requirements for ventilation systems. Overall, the 2006 UMC is more restrictive on A2 refrigerants than the 2006 IMC, since under the 2006 UMC, A2 refrigerants cannot be used in high-probability systems in non-industrial occupancies.

These model codes have not yet considered adopting the A2L subclass within their codes. However, given the close relationship between the model codes and ASHRAE 15-2007, any changes in ASHRAE 15-2007 may eventually be reflected in the model codes. It is likely that exemptions on regulations for A2L fluids will be more readily accepted in the IMC, and may be more difficult to implement in the UMC.

The International Fire Code (IFC) and the NFPA 1 Code – Uniform Fire Code have limits on the amount of flammable and toxic gases that can be stored and used in a defined control area. While these limits are identical for indoor control areas, the IFC allows greater quantities to be used and stored in outdoor control areas (up to twice or four times as much in some cases). The IFC and UFC also restrict or prohibit the use and storage of flammable and toxic refrigerants for occupancies defined in each code. Both codes do not distinguish between A2 or A3 refrigerants when regulating flammable refrigerants.

OSHA Regulations

OSHA sets permissible exposure limits (PEL) in workplaces to regulate the amount that workers can be exposed to a substance. Each new refrigerant introduced into the market must be evaluated and obtain a designated PEL and Immediately Dangerous to Life or Health (IDLH) limit. These limits will determine worker and equipment safety requirements by placing limits on the amount of refrigerant that can be released in the event of a leak or system failure. Refrigerants are evaluated by their toxicity and flammability; toxicity determines the PEL and IDLH levels, while flammability determines the limits on the total amount allowed in a location per fixed volume. PEL levels for A2L fluids are still being established as of the publication of this report.

9.2 A2L Fluids - Europe

Table 9-4 below summarizes the regulations, codes, and standards affecting the use of A2L refrigerant in commercial refrigeration applications within Europe.

Table 9-5 below summarizes the regulations, codes, and standards affecting the use of A2L refrigerant in stationary AC applications within Europe.

Table 9-6 below summarizes the regulations, codes, and standards affecting the use of A2L refrigerant in mobile AC applications within Europe.

Some of the broader regulations that apply to multiple applications are described in further detail following these tables.

Table 9-4: Regulations affecting A2L fluid refrigerants in commercial refrigeration applications within Europe.

A2L Fluids >> Europe >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Small Commercial Stand-Alone Coolers/ Freezers/ Refrigerators **Supermarket Systems** **Walk-In Freezers/ Coolers**	ATEX 94/9/EC	The ATEX Equipment Directive may apply to systems installed in facilities or locations that contain potentially explosive environments.
	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378:2008	See description of EN 378 below for details.
	EN 60079	EN Standard 60079 is harmonized with the ATEX Directive. It provides requirements for electrical systems used in potentially explosive atmospheres. The standard establishes three different categories of environments that present certain dangers when using electrical equipment and sets technical requirements for electrical equipment used in these environments. These requirements can include explosion-proof enclosures, automatic cut-off switches, and location of the equipment, depending on the environmental conditions.
	IEC 60335-2-75	Commercial dispensing appliances are limited to a total charge of 150g of flammable A3 refrigerant. Equipment under this limit can be used in any occupancy or setting. Equipment using larger quantities of flammable refrigerant is regulated by European Standard EN 378.
	IEC Standard 60335-2-89	Commercial refrigeration equipment using refrigerants classified as A2 by ASHRAE 34 are limited to a total charge of 225 g of refrigerant. Equipment under this limit can be used in any occupancy or setting. Equipment using larger quantities of flammable refrigerant is regulated by EN 378.
	Pressure Equipment Directive	Under Article 9 of the PED, HFOs are considered group 1 fluids. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. Manufacturers using HFOs must utilize Table 2 in Annex 2 of the PED to determine the equipment category and the restrictions placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.
Transport Refrigeration	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378:2008	See description of EN 378 below for details.
	Pressure Equipment Directive	Under Article 9 of the PED, HFOs are considered group 1 fluids. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. Manufacturers using HFOs must utilize Table 2 in Annex 2 of the PED to determine the equipment category and the restrictions placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.

Table 9-4, cont.

A2L Fluids >> Europe >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Industrial Refrigeration Cold Storage	ATEX 94/9/EC	The ATEX Equipment Directive may apply to systems installed in facilities or locations that contain potentially explosive environments.
	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378-2	Indirect systems using more than 500 kg of flammable refrigerants (A2, B2, A3, B3) must not release the refrigerant into the areas served by the secondary heat transfer fluid, and are required to employ safety measures such as the following devices: • Automatic air/refrigerant separator • Double wall heat exchanger • Maintaining the pressure of the secondary circuit greater than that of the primary circuit around the contact area See the description below for additional details regarding EN 378.
	EN 60079	EN Standard 60079 is harmonized with the ATEX Directive. It provides requirements for electrical systems used in potentially explosive atmospheres. The standard establishes three different categories of environments that present certain dangers when using electrical equipment and sets technical requirements for electrical equipment used in these environments. These requirements can include explosion-proof enclosures, automatic cut-off switches, and location of the equipment, depending on the environmental conditions.
	Pressure Equipment Directive	Under Article 9 of the PED, HFOs are considered group 1 fluids. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. Manufacturers using HFOs must utilize Table 2 in Annex 2 of the PED to determine the equipment category and the restrictions placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.

Table 9-5: Regulations affecting A2L fluid refrigerants in stationary AC applications within Europe.

A2L Fluids >> Europe >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Residential AC **Commercial AC**	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378:2008-1	Annex C contains an exception for certain factory sealed refrigerating systems. Systems containing less than 0.15 kg of A2 or A3 refrigerant have no restrictions when placed in an occupied space which is not a special machinery room. Section 3 of Annex C also describes charge limitations due to flammability for A/C systems or heat pumps for human comfort. This section provides mathematical formulas for the following: • Calculating the maximum charge size allowed in a room for an AC system with a flammable refrigerant • Calculating the maximum charge size for non-fixed factory sealed AC systems and pumps with a limited charge • Calculating the maximum charge of an A2 or A3 refrigerant for equipment with mechanically vented enclosure for the refrigerant circuit that does not directly interact with the ventilated room See the description of EN 378 below for additional details.
	IEC Standard 60335-2-40	Refrigerant charge limits for standard IEC 60335-2-40 depend on the lower flammability limit of the refrigerant, the size of the room the equipment is installed in, and the ventilation provided for the equipment. These restrictions are similar to those provided in EN 378. The following charge limits apply to systems using HFO-1234yf: • Under 1.16 kg: No significant restrictions • 1.16 kg < Charge < 7.5 kg: Charge limit depends on the size of the room • 7.5 kg < Charge < 37.6 kg: Appliance requires mechanical ventilation • Greater than 37.6 kg: EN 60335-2-40 does not apply; see EN 378 These charge limits could pose a major barrier to using HFO-1234yf in large commercial equipment.
	Pressure Equipment Directive	Under Article 9 of the PED, HFOs are considered group 1 fluids. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. This classification means that manufacturers using HFOs must utilize table 2 in Annex 2 of the PED to determine what category of equipment their equipment falls into, and thus what restrictions are placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.
	WEEE Directive (Residential only)	The WEEE Directive establishes collection, recycling, and recovery targets for residential AC units.

Table 9-5, cont.

A2L Fluids >> Europe >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Chillers	ATEX 94/9/EC	The ATEX Equipment Directive presents a separate set of requirements from those cited in EN 378 and its harmonized directives. Large chillers using flammable refrigerants have the potential to fall within the scope of the ATEX Equipment Directive. To avoid falling within the scope of this directive, the following measures can be taken to eliminate the possibility of the chiller becoming as a flammable volume: • Provide a means of extracting dangerous gases using an a ventilation system, or • Install a detector to terminate operation of the chiller once refrigerant levels reach a certain percentage of the lower flammability limit of the refrigerant, or • Seal all electronics according to EN 378
	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	EN 378:2008	See description of EN 378 below for details.
	EN 60079	EN Standard 60079 is harmonized with the ATEX Directive. It provides requirements for electrical systems used in potentially explosive atmospheres. The standard establishes three different categories of environments that present certain dangers when using electrical equipment and sets technical requirements for electrical equipment used in these environments. These requirements can include explosion-proof enclosures, automatic cut-off switches, and location of the equipment, depending on the environmental conditions.
	Pressure Equipment Directive	Under Article 9 of the PED, HFOs are considered group 1 fluids. Group 1 is reserved for refrigerants that are flammable, explosive, toxic, or oxidizing; all other refrigerants are considered group 2 fluids. This classification means that manufacturers using HFOs must utilize table 2 in Annex 2 of the PED to determine what category of equipment their equipment falls into, and thus what restrictions are placed upon its design, manufacture, and testing. Descriptions of all equipment categories and their restrictions are found in Appendix D of this report.

Table 9-6: Regulations affecting A2L fluid refrigerants in mobile AC applications within Europe.

A2L Fluids >> Europe >> Mobile AC		
Application	**Applicable Regulations**	**Description**
Cars & Trucks	ATEX 99/92/ED	The ATEX Workplace Directive may apply if these refrigeration systems are manufactured in facilities that contain potentially explosive environments.
	ISO/CD 13043	The current version of EN 378 includes mobile vehicle air conditioning applications; however, MVAC has been removed from the scope of this standard and will be covered by ISO/CD 13043. The ISO Technical Committee for road vehicles (TC 22) is working on publishing this new standard, ISO/CD 13043. The name of the standard is "Road vehicles – refrigerant systems used in Mobile Air Conditioning systems (MAC) – Safety Requirements." The standard is under development and will provide safety requirements for mobile vehicle air conditioning systems.

Some of the broader regulations that apply to A2L fluids within the EU are described in further detail below.

EN 378

Please see Appendix A for a table of charge limits included in EN 378:2008.

EN 378-1: Basic requirements, definitions, classification and selection criteria. Any A2 fluids must currently adhere to a requirement in Annex C to separate potential sources of ignition from potential sites of refrigerant leakage.

Annex C contains a note that, for:

> …sealed refrigerating systems using flammable refrigerants (A2, B2, A3, B3), but excluding R-717, no sources of ignition shall be associated with parts of the equipment that could come in contact with leaked refrigerant. All potential sources of ignition shall be sealed according to the methods detailed in EN 378-2.

En 378-2: Design, construction, testing, marking, and documentation
Systems using refrigerants other than A1 refrigerants fall under the requirement in Section 6.2.3.3 requiring that valves and joints be inaccessible to the general public. System containing A2, B1, B2, A3, B3 refrigerants cannot employ fusible plugs as relief devices.

EN 378-3: Installation site and personal protection
Section 5.17 of EN 378-3 presents several requirements for machinery rooms housing systems using flammable refrigerants (A2, B2, A3, B3). The first requirement states that the machinery room shall be located in accordance with local and national regulations. The second section sets requirements for the location and rating of the emergency exhaust ventilation. For example, the fan must be rated for hazardous areas or remain outside of the refrigerant airflow.

Section 5.17.3 provides an additional requirement for machine rooms containing A2 or A3 refrigerants. Machine rooms that possess a risk of explosion must comply with the requirements of hazardous areas (i.e. be explosion proof). Some explosion relief (e.g. frangible wall or roof) shall be provided. In addition, machine rooms with flammable refrigerants (A2, B2, A3, and B3) cannot have combustion equipment or hot surfaces within 100 K of the auto-ignition temperature of the refrigerant. (Section 5.17.5)

For machine rooms above the Practical Limit (EN 378 Appendix A, Annex E) for flammable refrigerants, access to the outdoors shall be provided.

Section 8.8, for detectors of A2 and A3 refrigerants, requires an alarm that operates at least 25 percent of the lower limit of concentration of the flammability range in air for the refrigerant. The detector must also automatically sound an alarm, start the ventilation system, and stop the system when activated.

9.3 A2L Fluids - Japan

Table 9-7 below summarizes the regulations, codes, and standards affecting the use of A2L refrigerant in commercial refrigeration applications within Japan.

Table 9-8 below summarizes the regulations, codes, and standards affecting the use of A2L refrigerant in stationary AC applications within Japan.

Table 9-9 below summarizes the regulations, codes, and standards affecting the use of A2L refrigerant in mobile AC applications within Japan.

Table 9-7: Regulations affecting A2L fluid refrigerants in commercial refrigeration applications within Japan.

A2L Fluids >> Japan >> Commercial Refrigeration		
Application	**Applicable Regulations**	**Description**
Small Commercial Stand-Alone Coolers/ Freezers/ Refrigerators **Supermarket Systems** **Walk-In Freezers/ Coolers**	Electrical Appliances and Material Safety Act	Manufacturing, import, sales and safety practices of electrical appliances must comply with guidelines and specifications established by the Electrical Appliance and Material Safety Act. In particular, the act establishes maximum refrigerant charge limits for flammable refrigerants used in forced air cooling and convection cooling systems.
	Fire and Disaster Management Act	General handling of flammable substances, including production, storage and transportation, must comply with safety guidelines and specifications established by the FDMA. A2L fluids would fall under the classification of Special Flammable Substances under this act, which require additional safety measures (e.g. explosion-proof equipment design).
	High Pressure Gas Safety Act	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	ISO 5149	JIS B8612 (Commercial Refrigeration Cabinets) specifies materials and appropriate usage for refrigerated display cases for food retail applications. It refers to ISO 5149 as the guideline for refrigerant safety for commercial refrigerators.
Transport Refrigeration	High Pressure Gas Safety Act	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	JIS B8240	JIS B8240 (Construction of Pressure Vessels for Refrigeration) specifies the materials, design and construction of pressure vessels (e.g. storage tank) for equipment that uses vapor-compression or evaporative cooling.
Industrial Refrigeration Cold Storage	Electrical Appliances and Material Safety Act	Manufacturing, import, sales and safety practices of electrical appliances must comply with guidelines and specifications established by the Electrical Appliance and Material Safety Act. In particular, the act establishes maximum refrigerant charge limits for flammable refrigerants used in forced air cooling and convection cooling systems.
	Fire and Disaster Management Act	General handling of flammable substances, including production, storage and transportation, must comply with safety guidelines and specifications established by the FDMA. A2L fluids would fall under the classification of Special Flammable Substances under this Act, which require additional safety measures (e.g. explosion-proof equipment design).
	High Pressure Gas Safety Act	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	JIS B8240	JIS B8240 (Construction of Pressure Vessels for Refrigeration) specifies the materials, design and construction of pressure vessels (e.g. storage tank) for equipment that uses vapor-compression or evaporative cooling.

Table 9-8: Regulations affecting A2L fluid refrigerants in stationary AC applications within Japan.

A2L Fluids >> Japan >> Stationary AC		
Application	**Applicable Regulations**	**Description**
Residential AC **Commercial AC** **Chillers**	Electrical Appliances and Material Safety Act	Manufacturing, import, sales and safety practices of electrical appliances must comply with guidelines and specifications established by the Electrical Appliance and Material Safety Act. In particular, the act establishes maximum refrigerant charge limits for flammable refrigerants used in forced air cooling and convection cooling systems.
	Fire and Disaster Management Act	General handling of flammable substances, including production, storage and transportation, must comply with safety guidelines and specifications established by the FDMA. A2L fluids would fall under the classification of Special Flammable Substances under this Act, which require additional safety measures (e.g. explosion-proof equipment design).
	High Pressure Gas Safety Act	Handling and use of any and all high pressure gases in stationary applications (as well as their containers) must comply with safety guidelines and specifications established by the High Pressure Gas Safety Act. Ministry Ordinances associated with this act include Refrigeration Safety Standards, Container Safety Standards and General Safety Standards.
	JIS B8240	JIS B8240 (Construction of Pressure Vessels for Refrigeration) specifies the materials, design and construction of pressure vessels (e.g. storage tank) for equipment that uses vapor-compression or evaporative cooling.
	JIS 8616, JIS B8620	JIS 8616 (Packaged Air Conditioner) specifies the materials, design, and testing procedure of packaged AC system intended to provide comfort to building occupants. JIS 8616 refers to JIS 8620 (Safety Code for Small Refrigeration Equipment) for refrigerant leakage testing procedure.

Table 9-9: Regulations affecting A2L fluid refrigerants in mobile AC applications within Japan.

A2L Fluids >> Japan >> Mobile AC		
Application	**Applicable Regulations**	**Description**
Cars & Trucks	Chemical Substances Control Act	Honeywell has announced that its new A2L refrigerant for MVAC applications, HFO-1234yf, has been reviewed and approved by the Ministry of the Environment in accordance with the Chemical Substances Control Law. Approval of this new refrigerant means that it can be imported into Japan without volume or use restrictions and that no special controls or special monitoring are required.
	JIS B8240	JIS B8240 (Construction of Pressure Vessels for Refrigeration) specifies the materials, design and construction of pressure vessels (e.g. storage tank) for equipment that uses vapor-compression or evaporative cooling.

10 Regulatory Gaps and Barriers

10.1 Carbon Dioxide

10.1.1 Carbon Dioxide - United States

The largest regulatory barrier to using CO_2 refrigerant is achieving EPA SNAP approval for all potential applications. SNAP approval has already been achieved for mobile air conditioning in cars and trucks. Currently, EPA is assisting in clarifying the regulations regarding CO_2 for mobile applications. One of the primary challenges for the EPA is developing short-term maximum exposure limits for vehicle safety. The lethality of high concentrations of CO_2 in confined areas is of primary concern. The EPA has established preliminary limits based on a study of the toxicological impacts of short-term exposure within a confined space – in this case, a vehicle cabin. Similar studies will have to be performed to remove some of the barriers posed by this hazard.

If products using CO_2 were evaluated and achieved product safety certification from Underwriters Laboratories (UL), this assessment could be used as part of the evidence to be supplied to EPA for evaluation of a SNAP application for a product category. Achieving UL approval for CO_2 will require additional safety measures due to the higher pressures required by CO_2 refrigerant systems. Further research may be needed to certify the safety of carbon dioxide systems, possibly including the study of current carbon dioxide based systems. PepsiCo is currently testing a small sample of vending machines in the Washington D.C. area to provide safety and reliability data for EPA SNAP approval (Geller 2009).

Once EPA SNAP approval is achieved for other applications, there should be relatively few regulatory barriers to implementation within the US. Other products such as small commercial refrigeration and supermarket systems already exist in Europe and China.

Safety standards requiring high safety factors can pose a significant barrier to carbon dioxide systems, which typically operate at higher pressures than other refrigerants. UL standards such as UL 984, which require pressure safety factors as high as five times the design pressure, have been cited as creating a large burden on manufacturers because they require costly designs. UL and ASHRAE have begun to address these issues by lowering the safety factor required for carbon dioxide used in secondary loops. Further research on the safety requirements for carbon dioxide systems can help standards organizations determine reasonable, yet safe, standards.

In the area of human comfort, current standards and developing regulations may incentivize the use of carbon dioxide. ASHRAE Standard 15-2007 imposes limits on the use of non-A1 refrigerants in high-probability systems for human comfort. The 2006 IMC and 2006 UMC contain similar requirements as well. If HFC refrigerants are phased out in the US, carbon dioxide may become favored over other non-A1 refrigerants. This will be especially important for conditioning equipment that is too large to meet the charge limits provided in ASHRAE Standard 15-2007.

10.1.2 Carbon Dioxide - Europe

There do not appear to be any major EU-wide barriers for implementing CO_2 as a refrigerant. CO_2 is already being used and considered in applications such as cars, supermarket refrigeration systems, and industrial systems. Standards such as EN 378 and ISO 5149 provide allowances for non-toxic, non-flammable refrigerants, and do not impose the same restrictions on A1 refrigerants that exist for flammable and toxic refrigerants. However, authorities and manufacturers must be willing to certify components such as compressors that use carbon dioxide refrigerant. Research on the reliability and safety of these components may be needed to ensure their availability.

For mobile vehicle air conditioning applications, studies on appropriate concentration limits and leakage rates for carbon dioxide systems may assist in further understanding the appropriate requirements needed to ensure safety. Another potential barrier could arise if individual EU members impose stricter standards within their respective countries.

10.1.3 Carbon Dioxide - Japan

There appears to be a regulatory gap for safety standards pertaining to refrigerants in transportation-related applications. The High Pressure Gas Safety Act does not cover mobile applications. This is particularly relevant to CO_2, which requires higher pressures than most other refrigerants.

10.2 Ammonia

10.2.1 Ammonia - United States

Ammonia is one of the best-understood alternative refrigerants. Ammonia has achieved EPA SNAP approval in most refrigeration and stationary air conditioning applications, but many other restrictions apply. A major barrier facing ammonia is its toxicity—of the four alternative refrigerant classes, it is the only Class B substance. It is also classified as flammability class 2, or subclass 2L according to ISO 817. In almost every major standard (for example, ASHRAE 15-2007), ammonia has separate additional safety requirements. These additional requirements do not necessarily constitute insurmountable barriers, but they can present a large burden to manufacturers and facilities.

One of the largest burdens facing ammonia is the additional paperwork, processes, and procedures required to satisfy EPA and OSHA requirements. Most of these requirements are aimed at mitigating major catastrophes in case of a major leak or complete release of the pressurized gas. Satisfying these regulations requires special safety equipment and safety procedures to be in place. Keeping ammonia on-premises also requires developing a Risk Management Program as well as a Project Safety Management Program, which also creates additional burden. One potential route for reducing the regulatory burden for ammonia would be to support changes to the EPA and OSHA regulations to make them more consistent with industry best practices. In order to support any such changes, the industry would need to

conduct adequate risk assessment analyses and tests to demonstrate the safety of ammonia systems.

Additional regulatory burdens for ammonia may arise from individual state regulations. For example, some states heavily restrict industrial uses of ammonia, or have laws against toxic refrigerants that apply to ammonia.

In the area of human comfort, current standards and developing regulations may discourage the use of ammonia. In high-probability systems for human comfort, ASHRAE Standard 15-2007 limits the use of non-A1 refrigerants to 3 kg for residential occupancies and 10 kg for commercial occupancies. The standard does not impose charge limits on industrial occupancies. The 2006 IMC and 2006 UMC contain similar restrictions as well. ASHRAE Standard 15-2007 exempts sealed absorption and unit systems, but this exemption is not included in the 2006 IMC or the 2006 UMC. If HFCs are phased out in the US, A1 refrigerant alternatives may be favored over ammonia for use in high-probability systems for human comfort. These restrictions will be especially important for conditioning equipment that is too large to meet the charge limits provided in ASHRAE Standard 15-2007. Research on the safety of ammonia systems in human comfort applications may help to establish appropriate safety requirements to allow for alternative refrigerants such as ammonia in human comfort applications.

10.2.2 Ammonia - Europe

Ammonia is considered a toxic substance in the EU. For equipment using flammable and/or toxic refrigerants, the Pressure Equipment Directive limits the pressure and volume levels to much stricter levels than for non-flammable refrigerants.

European standard IEC 60335-2-40 places charge limits on air conditioning equipment containing ammonia refrigerant. These restrictions depend on the lower flammability limit of the refrigerant, the size of the room in which the equipment is installed, and the ventilation provided for the equipment. These charge limits may present a barrier to implementing ammonia refrigerant in large commercial equipment.

European standard EN 378 contains requirements for machine rooms using ammonia, which include installation of a catchment system and emergency washing facilities. Other requirements state that ammonia must not come into contact with materials such as zinc. EN 378 also contains allowances that exempt equipment using ammonia from certain requirements for flammable systems; for example, unlike other flammable refrigerants, equipment using ammonia is not required to have potential ignition sources sealed off.

10.2.3 Ammonia - Japan

There appears to be a regulatory gap for safety standards pertaining to refrigerants in transportation-related applications. Currently, the High Pressure Gas Safety Act does not cover mobile applications, and there is uncertainty in how to regulate the use of flammable refrigerants in mobile air conditioning applications. It is anticipated that this gap will be closed

by the Japanese government, but there may be opportunity to influence these regulations through additional research.

The High Pressure Gas Safety Act does apply to stationary applications, such as air conditioning and refrigeration. The HPGSA references several Ministry Ordinances, including the Refrigeration Safety Standards, Container Safety Standards and General Safety Standards, which contain safety measures for flammable and toxic refrigerants. These additional requirements are not likely to be prohibitive to implementing ammonia in stationary applications. Ammonia applications will, however, be required to satisfy certain safety additional safety measures, such as the explosion-proof structure requirement in the General Safety Standards, to satisfy the Ministry Ordinances.

The Road Transport Vehicle Act regulates flammable substances for mobile applications, but the scope is limited to fuels.

10.3 Hydrocarbons

10.3.1 Hydrocarbons - United States

Hydrocarbon refrigerants currently face a restrictive regulatory environment within the US. This is primarily due to the high flammability of hydrocarbons, which are designated as Class 3. In general, flammable substances have additional regulatory requirements for safety, leakage, and fire suppression, which can represent additional burdens on its use.

Hydrocarbons have not obtained EPA SNAP approval. Obtaining approval will require manufacturers to rigorously assess the risks attributable to equipment that uses hydrocarbon refrigerants. This will require a great deal of testing and investment.

In the area of human comfort, current standards do not favor the use of hydrocarbons. In high-probability systems for human comfort, ASHRAE Standard 15-2007 limits the use of non-A1 refrigerants to 3 kg for residential occupancies and 10 kg for commercial occupancies. The standard does not impose charge limits on industrial occupancies. The 2006 IMC and 2006 UMC contain similar restrictions as well. If HFCs are phased out in the US, A1 refrigerant alternatives may be favored over hydrocarbons for use in high-probability systems for human comfort. These restrictions will be especially important for conditioning equipment that is too large to meet the charge limits provided in ASHRAE Standard 15-2007. Research on the safety of hydrocarbon systems in human comfort applications may help to establish appropriate safety requirements to allow for alternative refrigerants such as hydrocarbons in human comfort applications.

After changes are approved for industry standards such as ASHRAE Standard 15-2007, UL may consider changing the UL 1995 standard accordingly. UL currently does not evaluate hydrocarbon refrigerants in UL 1995, and has no plans to implement this in the near future.

One of the main concerns about the use of hydrocarbons in HVAC applications is the potential for refrigerant leakage. UL 250 and UL 471 currently permit larger amounts of flammable refrigerant, provided that leak tests show that only a certain amount will leak during a leak event. However, there is much uncertainty about how to acceptably measure the safety risk from leakage of flammable refrigerant, and UL has proposed to change UL 250 to simply limit the refrigerant charge within the equipment. Developing accurate knowledge and tests of the safety risks associated with flammable refrigerant leakage will permit regulators to establish appropriate charge limits while allowing manufacturers flexibility to use these refrigerants.

One potential breakthrough for hydrocarbon refrigerants is the recent testing of hydrocarbons in small commercial refrigeration units (e.g. ice cream machines). EPA approval for this purpose would represent a significant opportunity for hydrocarbons use in all applications. Current testing of these devices will potentially lead to more safety and reliability data for using hydrocarbon refrigerants in these applications.

Ben and Jerry's ice cream company submitted a petition to use hydrocarbon refrigerants in freezers based on extensive safety data and commercial experience with hydrocarbon freezing technology in Europe in 2008. They successfully petitioned the EPA to test ice cream cabinets within the United States. EPA will evaluate the freezers as Ben and Jerry's conducts a US-based trial over the next two years. Ben and Jerry's ice cream cabinets use propane as a refrigerant. (Dominguez 2009)

10.3.2 Hydrocarbons - Europe

Regulations for hydrocarbon refrigerants are less restrictive in Europe compared to the US. Safety has been primarily addressed through charge limits for each application.

Some specific applications have strict requirements, such as minimum room volume and charge limits, that make it infeasible to use hydrocarbons for those applications. This pertains mostly to residential and commercial packaged AC applications. In particular, floor standing units currently face restrictions on charge sizes that make low-level comfort units impractical (Cox 2009). Current standard EN 378 sets charge limits based on the height of the equipment, with more restrictive limits reserved for low units. The current standards favor ceiling and elevated systems. Research on the overall safety of hydrocarbon comfort units, including comparison of systems at different heights, and an evaluation of safe charge sizes for floor based units, may provide safety data to convince regulators to amend the standards.

IEC standards for commercial refrigeration set a universal charge limit of 150 g for commercial refrigeration systems used without restriction. This same limit is applied to domestic refrigerators. This limit may prove to be a barrier to larger commercial refrigeration systems using hydrocarbons. Research that can provide a greater understanding of the appropriate charges for large refrigeration systems, based on safety requirements and use settings, would assist in establishing appropriate charge limits for all potential uses of hydrocarbons as refrigerants.

The Pressure Equipment Directive uses pressure and volume levels to categorize equipment using flammable and/or toxic refrigerants, and these are stricter than the levels used for non-flammable refrigerants. Components such as compressors that use flammable refrigerants often require extra reporting and safety assessments by the manufacturer. This has deterred component manufacturers from investing in these products, and makes it more difficult for equipment manufacturers to implement their products. An investigation on ways to promote equipment development, either through changes in the regulations or through incentive programs, may help encourage the adoption of hydrocarbon refrigerant systems.

10.3.3 Hydrocarbons - Japan

There appears to be a regulatory gap for safety standards pertaining to refrigerants in transportation-related applications. Currently, the High Pressure Gas Safety Act does not cover mobile applications, and there is uncertainty in how to regulate the use of flammable refrigerants in mobile air conditioning applications. It is anticipated that this gap will be closed by the Japanese government, but there may be opportunity to influence these regulations through research.

The High Pressure Gas Safety Act does apply to stationary applications, such as air conditioning and refrigeration. The HPGSA references several Ministry Ordinances, including the Refrigeration Safety Standards, Container Safety Standards and General Safety Standards, which contain safety measures for flammable and toxic refrigerants. These additional requirements are not likely to be prohibitive to implementing hydrocarbons in stationary applications. Hydrocarbon applications will, however, be required to satisfy certain safety additional safety measures, such as the explosion-proof structure requirement in the General Safety Standards, to satisfy the Ministry Ordinances.

The Road Transport Vehicle Act regulates flammable substances for mobile applications, but the scope is limited to fuels. This is particularly relevant to hydrocarbons, which are highly flammable.

10.4 A2L Fluids

10.4.1 A2L Fluids - United States

Flammability risk is one of the main safety concerns that must be addressed before A2L fluids are introduced within the US. Although the revised ISO 817 Standard will likely introduce a new A2L designation for refrigerants with lower flammability risk than traditional Class 2 refrigerants, many other important standards and codes make no distinction between Class 2 and Class 3 refrigerants.

To facilitate the introduction of A2L fluids, regulations will need to be revised to reflect the lower-flammability risk presented by these refrigerants, in the same way that many standards currently provide special considerations for ammonia. Revising major standards is a long, intensive process, and due to the cyclical nature of standard revisions, it may take several years

to complete these revisions. Current drafts of ISO 5149 are considering separate less restrictive requirements on electrical equipment, ventilation, and charge sizes for A2L fluids. Demonstration of the safety of these fluids is important, and further research in this area can help guide revisions to these standards.

A2L fluids will also require EPA SNAP approval for stationary AC and refrigeration applications. EPA and OSHA workplace exposure limits and associated regulations will need to be established for new refrigerants. Research on the safety of these refrigerants in these applications can assist in navigating the EPA SNAP approval process and for setting appropriate industry standards such as UL standards. The presence of industry standards can likewise facilitate the national and local adoption of A2L applications.

The MVAC industry offers a good example of how development and adoption of national regulations and standards such as the EPA SNAP list and SAE J639 can greatly assist in the removal of many barriers to implementation. A few states limit the use of flammable refrigerants in MVAC, but these regulations primarily target hydrocarbons. Many states have adopted regulations that refer to the consensus standards, and this has removed regulatory barriers in sixteen states (Taddonio 2008). Demonstration of the safety of A2L systems (such as HFO-1234yf) through research and safety demonstrations would assist in developing appropriate national safety requirements.

Ultimately, many building codes and standards are guided by national safety standards such as ASHARE Standard 15 and Standard 34. Amendments to these standards can potentially provide changes in the diverse national landscape, but only after safety is proven. In the US, ASHRAE Standard 34-2007 Addendum ak recently added an optional 2L subclass to the existing class 2 flammability classification, signifying class 2 refrigerants with a burning velocity less than or equal to 10 cm/s. Revisions to ASHRAE Standard 15-2007 based on the 2L subclass are still being negotiated.

In the area of human comfort, current standards may not favor use of A2L fluids. In high-probability systems for human comfort, ASHRAE Standard 15-2007 limits the use of non-A1 refrigerants to 3 kg for residential occupancies and 10 kg for commercial occupancies. The standard does not impose charge limits on industrial occupancies. The 2006 UMC contains similar restrictions; however, the 2006 IMC does allow the use of A2 refrigerants in these systems.

If HFCs are phased out in the US, A2L refrigerant alternatives must meet these standards and codes, and A2L fluids may be restricted in certain states based on current mechanical and building code requirements. These restrictions will be especially important for conditioning equipment that is too large to meet the charge limits provided in ASHRAE Standard 15-2007.

Obtaining UL listings of equipment using A2L refrigerants is also important for meeting safety standards, and higher charge limits will allow more equipment to become eligible for UL listings. Research on the safety of A2L fluid systems in human comfort applications may help to

establish appropriate safety requirements to allow a consensus for use of alternative refrigerants such as A2L fluids in these applications.

10.4.2 A2L Fluids - Europe

Some European automakers have been moving towards using A2 refrigerants such as HFO-1234yf in mobile vehicle air conditioning systems, due in part to the mobile air conditioning directive that takes effect in January 2011. Other stationary air conditioning and commercial refrigeration applications face barriers to the use of flammable refrigerants such HFO-1234yf, currently designated as an A2 refrigerant. These barriers include restrictions on use and charge limits in national standards. There may be an opportunity to relax or remove these barriers for stationary applications by adopting a new A2L designation in European standards, similar to the subclass being proposed in draft versions of ISO 817, potentially recognizing that certain flammable refrigerants pose a lesser safety risk. Incorporating this new designation will require information on the safety of these refrigerants. Research into each A2L refrigerant's safety can assist the adoption of these refrigerants.

IEC standards that set strict, absolute limits on refrigerant charges for refrigeration applications may present a barrier to the use of A2L fluids in larger refrigeration applications. These standards set a limit of 225g of A2 refrigerants in refrigeration products, which may not be sufficient for large and super-cold applications. To support the adoption of A2L fluids in large refrigeration applications, further research into appropriate and safe charge levels should be investigated.

As mentioned above, draft versions of ISO 5149 currently incorporate less restrictive requirements on electrical equipment, ventilation, and charge limits for A2L fluids, compared to requirements for A2 refrigerants. The structure of ISO 5149 is similar to the structure of EN 378, and any changes to ISO 5149 can potentially be incorporated into EN 378.

Large equipment using A2L fluids will likely fall under the scope of the Pressure Equipment Directive. The PED uses pressure and volume levels to categorize equipment using flammable and/or toxic refrigerants, which are stricter than the levels used for non-flammable refrigerants. Components such as compressors often require extra reporting and safety assessments by the manufacturer. This has deterred component manufacturers from investing in these products, and makes it more difficult for equipment manufacturers to implement their products. An investigation on ways to promote equipment development, either through changes in the regulations or through incentive programs, may help encourage the adoption of A2L systems.

10.4.3 A2L Fluids - Japan

In Japan, the automobile industry is lobbying for re-evaluation of the High Pressure Gas Safety Act as it is applied to HFO-1234yf. Currently, the HPGSA does not cover mobile applications, and there is uncertainty in how to regulate the use of flammable refrigerants in mobile air conditioning applications. It is anticipated that this gap will be closed by the Japanese government, but there may be opportunity to influence these regulations through additional research.

The High Pressure Gas Safety Act does apply to stationary applications, such as air conditioning and refrigeration. The HPGSA references several Ministry Ordinances, including the Refrigeration Safety Standards, Container Safety Standards and General Safety Standards, which contain safety measures for flammable and toxic refrigerants. These additional requirements are not likely to be prohibitive to implementing A2L fluids in stationary applications. A2L fluid applications will, however, be required to satisfy certain safety additional safety measures, such as the explosion-proof structure requirement in the General Safety Standards, to satisfy the Ministry Ordinances.

Implementing HFO-1234yf in these applications would require an explosion-proof structure based on the General Safety Standards under the High Pressure Gas Safety Act.

Appendix A – EN 378

The tables below show the amount of allowable charge a system can use according to EN Standard 378. Charge limits are shown for A1, A2, A3, and B2 refrigerants. The following abbreviations are used in the tables:

- All other – All other refrigerating systems
- Direct comm. – Direct communication
- NR – No restriction
- PL – Practical Limit
- SAS – Sealed Absorption Systems

Table A-1: EN 378 charge limits for A1, A2, A3, and B2 refrigerants

Refrigerant safety group – A1		
Location of the Refrigerating System	**General occupancy – Class A**	
	Direct Systems	***Indirect Systems***
Human occupied space which is not a Machinery Room (MR)	Max charge = PL x Room Vol.	Considered Direct System
Compressor and Liquid receiver in an unoccupied MR or in the open air	Max charge = PL x Room Vol.	No restriction
All refrigerant containing parts in an unoccupied MR or in the open air	No restriction	No restriction
	Supervised occupancy – Class B	
	Direct Systems	***Indirect Systems***
Human occupied space which is not a Machinery Room (MR)	Exit restriction = General Occ. Otherwise = No restriction	Considered Direct System
Compressor and Liquid receiver in an unoccupied MR or in the open air	No restriction	No restriction
All refrigerant containing parts in an unoccupied MR or in the open air	No restriction	No restriction
	Occupancy with authorized access only – Class C	
	Direct Systems	***Indirect Systems***
Human occupied space which is not a Machinery Room (MR)	Exit restriction = General Occ. Otherwise = No restriction	Considered Direct System
Compressor and Liquid receiver in an unoccupied MR or in the open air	No restriction	No restriction
All refrigerant containing parts in an unoccupied MR or in the open air	No restriction	No restriction

*Note: The total volume of all the rooms cooled or heated by air from one system is used as the volume for calculation, if the air supply to each room cannot be restricted below 25% of its full supply.

Table A-1, cont.

Refrigerant safety group – A2		
Location of the Refrigerating System	**General occupancy – Class A**	
	Direct Systems	***Indirect Systems***
Human occupied space which is not a Machinery Room (MR)	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = PL x Room Vol. and not exceeding 38 x LFL	Considered Direct System
Compressor and Liquid receiver in an unoccupied MR or in the open air	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = PL x Room Vol. and not exceeding 38 x LFL	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = PL x Room Vol.
All refrigerant containing parts in an unoccupied MR or in the open air	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = PL x Room Vol. and not exceeding 132 x LFL	No restriction if exit to the open air and no direct comm. with categories A and B.
	Supervised occupancy – Class B	
	Direct Systems	***Indirect Systems***
Human occupied space which is not a Machinery Room (MR)	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = 10 kg	Considered Direct System
Compressor and Liquid receiver in an unoccupied MR or in the open air	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = 25 kg	No restriction, if MR has no direct communication with occupied space
All refrigerant containing parts in an unoccupied MR or in the open air	A/C Systems and HP for Human Comfort – See C.3 All Other: No restriction, if MR has no direct communication with occupied space	No restriction, if MR has no direct communication with occupied space
	Occupancy with authorized access only – Class C	
	Direct Systems	***Indirect Systems***
Human occupied space which is not a Machinery Room (MR)	A/C Systems and HP for Human Comfort – See C.3 Max charge = 10 kg or 50 kg if density of personnel is < 1/10 m^2 and sufficient exits are available	Considered Direct System
Compressor and Liquid receiver in an unoccupied MR or in the open air	A/C Systems and HP for Human Comfort – See C.3 Max charge = 25 kg or No restriction if density of personnel is < 1/10 m^2	No restriction
All refrigerant containing parts in an unoccupied MR or in the open air	A/C Systems and HP for Human Comfort – See C.3 All other: No restriction	No restriction

*Note: The total volume of all the rooms cooled or heated by air from one system is used as the volume for calculation, if the air supply to each room cannot be restricted below 25% of its full supply.

Table A-1, cont.

Refrigerant safety group – A3		
Location of the Refrigerating System	**General occupancy – Class A**	
	Direct Systems	***Indirect Systems***
Human occupied space which is not a Machinery Room (MR)	A/C Systems and HP for Human Comfort – See C.3 All Other: Only sealed systems with Max Charge = PL x Room Vol. and not exceeding 1.5 kg	Considered Direct System
Compressor and Liquid receiver in an unoccupied MR or in the open air	A/C Systems and HP for Human Comfort – See C.3 All Other: Only sealed systems with Max Charge = PL x Room Vol. and not exceeding 1.5 kg	A/C Systems and HP for Human Comfort – See C.3 Max Charge = PL x Room Vol. and not exceeding 1.5 kg
All refrigerant containing parts in an unoccupied MR or in the open air	A/C Systems and HP for Human Comfort – See C.3 All Other: Only sealed systems with Max Charge = PL x Room Vol. and not exceeding 1 kg below or 5 kg above ground floor level.	A/C Systems and HP for Human Comfort – See C.3 All Other: Only sealed systems with Max Charge = PL x Room Vol. and not exceeding 1 kg below or 5 kg above ground floor level.
	Supervised occupancy – Class B	
	Direct Systems	***Indirect Systems***
Human occupied space which is not a Machinery Room (MR)	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = PL x Room Vol. and not exceeding 1 kg below or 2.5 kg above ground floor level.	Considered Direct System
Compressor and Liquid receiver in an unoccupied MR or in the open air	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = PL x Room Vol. and not exceeding 1 kg below or 2.5 kg above ground floor level.	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = PL x Room Vol. and not exceeding 1 kg below or 2.5 kg above ground floor level.
All refrigerant containing parts in an unoccupied MR or in the open air	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = PL x Room Vol. and not exceeding 1 kg below or 10 kg above ground floor level.	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = PL x Room Vol. and not exceeding 1 kg below or 10 kg above ground floor level.
	Occupancy with authorized access only – Class C	
	Direct Systems	***Indirect Systems***
Human occupied space which is not a Machinery Room (MR)	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = 1 kg below or 10 kg above ground floor level.	Considered Direct System
Compressor and Liquid receiver in an unoccupied MR or in the open air	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = 1 kg below or 25 kg above ground floor level.	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = 1 kg below or 25 kg above ground floor level.
All refrigerant containing parts in an unoccupied MR or in the open air	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = 1 kg below or NR above ground floor level.	A/C Systems and HP for Human Comfort – See C.3 All Other: Max Charge = 1 kg below or NR above ground floor level.

*Note: The total volume of all the rooms cooled or heated by air from one system is used as the volume for calculation, if the air supply to each room cannot be restricted below 25% of its full supply.

Table A-1, cont.

Refrigerant safety group – B2		
Location of the Refrigerating System	**General occupancy – Class A**	
	Direct Systems	***Indirect Systems***
Human occupied space which is not a Machinery Room (MR)	Max charge = 2.5 kg for SAS; all other systems: max charge = PL x Room Vol.	Considered Direct System
Compressor and Liquid receiver in an unoccupied MR or in the open air	Max charge = 2.5 kg for SAS; all other systems: max charge = PL x Room Vol.	Max charge = 2.5 kg for SAS; all other systems: max charge = PL x Room Vol.
All refrigerant containing parts in an unoccupied MR or in the open air	Max Charge = 2.5 kg	No restriction if exit to the open air and no direct comm. with categories A and B.
	Supervised occupancy – Class B	
	Direct Systems	***Indirect Systems***
Human occupied space which is not a Machinery Room (MR)	Max Charge = 10 kg	Considered Direct System
Compressor and Liquid receiver in an unoccupied MR or in the open air	Max Charge = 25 kg	No restriction, if MR has no direct communication with occupied space
All refrigerant containing parts in an unoccupied MR or in the open air	No restriction, if MR has no direct communication with occupied space	No restriction, if MR has no direct communication with occupied space
	Occupancy with authorized access only – Class C	
	Direct Systems	***Indirect Systems***
Human occupied space which is not a Machinery Room (MR)	Max charge = 10 kg or 50 kg if density of personnel is < 1/10 m^2 and sufficient exits are available	Considered Direct System
Compressor and Liquid receiver in an unoccupied MR or in the open air	Max charge = 25 kg or No restriction if density of personnel is < 1/10 m^2	No restriction
All refrigerant containing parts in an unoccupied MR or in the open air	No restriction	No restriction

*Note: The total volume of all the rooms cooled or heated by air from one system is used as the volume for calculation, if the air supply to each room cannot be restricted below 25% of its full supply.

Appendix B – ISO 5149

Draft Version of ISO 5149

The proposed ISO standard 5149 is divided into four sections, listed as follows:

- ISO/DIS 5149-1 – Definitions, classification, and selection criteria
- ISO/DIS 4159-2 – Design, construction, testing, marking, and documentation
- ISO/DIS 5149-3 – Installation Site
- ISO/DIS 5149-4 – Operation, maintenance, repair, and recovery

The most notable changes to the proposed version of ISO 5149-1 are the charge limit requirements established for the proposed 2L classification. Whereas the Class 2 classification is restricted by maximum and situational charge limits for nearly all types of systems, the 2L classification has no restrictions for most indirect systems (locations II or III), and less restrictive charge limits, in terms of the allowable charge size. Most direct systems using Class 2 refrigerants would have maximum charge restrictions based on the lower flammability limit (LFL) of the refrigerant, while direct systems using 2L refrigerants would be restricted based on a single weight.

Table B-1 below shows the proposed charge limit requirements for Class 2L fluids.

Table B-1: ISO 5149 proposed charge limit requirements for Class 2L fluids.

<table>
<tr><th colspan="7">Table A.3 of ISO/DIS 5149-1 – Charge Limit Requirements for refrigerating systems for 2L</th></tr>
<tr><th rowspan="2">Occupancy</th><th rowspan="2">Location</th><th colspan="3">Direct System</th><th colspan="2">Indirect System</th></tr>
<tr><th>I</th><th>II</th><th>III</th><th>II</th><th>III</th></tr>
<tr><td rowspan="2">A</td><td>Human comfort</td><td colspan="3">A.4</td><td>A.4</td><td>No restrict. If exit to open air</td></tr>
<tr><td>Other</td><td colspan="2">PL x Room Vol and Max of 38 x LFL</td><td>PL x Room Vol and max of 189 x LFL</td><td colspan="2" rowspan="5">No restriction</td></tr>
<tr><td rowspan="2">B</td><td>Human Com.</td><td colspan="3">A.4</td></tr>
<tr><td>Other</td><td>PL x Room Vol and max of 10 kg</td><td>PL x Room Vol and max of 25 kg</td><td>No restriction</td></tr>
<tr><td rowspan="3">C</td><td>Human com.</td><td colspan="3">A.4</td></tr>
<tr><td>Other</td><td>PL x Room Vol and max of 10 kg</td><td>PL x Room Vol and max of 25 kg</td><td rowspan="2">No Restriction</td></tr>
<tr><td>< 1 person per 10 m^2</td><td>PL x Room Vol and max of 50 kg</td><td>No restriction</td></tr>
</table>

PL = practical limit of refrigerant, Room Vol = volume of the room where refrigerating system is located

There are no specific requirements or allowances for A2L refrigerant in ISO/DIS 5149-2.

In ISO/DIS 5149-3, under Section 6.3 for ventilation, systems using A2 refrigerants must abide by the requirements for mechanical ventilation in Section 6.3.3.

Under Section 7 for electrical installation, electrical equipment in machinery rooms containing class 2L flammability refrigerant is not subject to the restrictions for hazardous areas.

There are no specific requirements or allowances for A2L refrigerant in ISO/DIS 5149-4.

Appendix C – UL 250

UL Standard 250 - Household Refrigerators and Freezers

UL 250 is the UL standard for household refrigerators and freezers. In 2000, UL 250 incorporated requirements for refrigerators using flammable refrigerants. Although residential refrigeration systems are outside the scope of this report, the incorporation of flammable refrigerants is potentially relevant to commercial refrigerators and freezers. UL established a leakage limit for equipment using A3 refrigerants at 50g per event, and a leakage limit for equipment using A2 refrigerants at 225g per event. However, the standard stipulates that larger amounts of refrigerant can be used if leak tests show that only 50g of refrigerant would escape in the event of a leak (150g for A2 refrigerants). Table C-1 below shows the flammable refrigerant charge limits established by UL 250.

Table C-1: Flammable refrigerant charge limits established by UL 250

UL 250 - Household Refrigerators and Freezers – Flammable Refrigerant Charge Limits			
Refrigerant Classification	**Maximum Leakage per Event**	**Proposed Hard Limit**	**Status of Standard**
A3	50 g	60 g	Revision to hard charge limit has been proposed; will go through comment period
A2	225 g	270 g	Revision to hard charge limit has been proposed; will go through comment period

The 50g limit for A3 refrigerants represents a change from the 150g charge limit set by IEC 60335-2-24 in Europe. Currently, UL is holding a comment period on a proposed change to the flammable refrigerant limits set by UL 250, among other changes. The proposed change would eliminate the provision that allows for larger amounts of refrigerant than the standard allows (given leak testing), and set a maximum charge limit for A3 refrigerants at 60g, and A2 refrigerants at 270 g. UL indicated that there is interest within the industry in raising the maximum charge limit of A3 refrigerants to 150g to match international standards. The initial 50g limit was based on the amount of hydrocarbon refrigerant required to leak that could be ignited from an external ignition source within the immediate vicinity of the refrigerator. Changes in this standard could conceivably spur revisions to UL 471, the UL standard for commercial refrigerators and freezers (Haseman 2010).

Appendix D – Pressure Equipment Directive

Pressure Equipment Directive Requirements for Equipment Categories

PED Equipment Categories as presented in Tables 1 and 2 of the PED:

Equipment Category	Requirement for Each Equipment Category
No Category	Article 3, paragraph 3 (no modules)
Category I	Module A
Category II	Modules A1, D1, E1
Category III	Modules B1+D, B1+F, B+E, B+C1, H
Category IV	Modules B + D, B+F, G, H1

Requirement	Title of Requirement
A/A1	Internal Production Control (A1 has additional requirements)
B /B1	EC type examination (B = product examination, B1 = design examination)
C1	Conformity to Type
D/D1	Production Quality assurance (D1 requires technical documentation)
E/E1	Product Quality assurance (E1 requires technical documentation)
F	Product verification
G	EC Unit verification
H/H1	Full Quality Assurance (H1 has additional requirements)

Description of Equipment Categories and Reporting Requirements for each:

No Category

Equipment that has low pressure and/or volume requirements may not fall under any equipment category, but simply be subject to Article 3, paragraph 3 of the PED. Manufacturers are simply charged with producing safe equipment that contains both instructions and markings identifying the manufacturer. This paragraph reads as follows:

> "Article 3, Paragraph 3. Pressure equipment and/or assemblies below or equal to the limits in sections 1.1, 1.2 and 1.3 and section 2 respectively must be designed and manufactured in accordance with the sound engineering practice of a Member State in order to ensure safe use. Pressure equipment and/or assemblies must be accompanied by adequate instructions for use and must bear markings to permit identification of the manufacturer or of his authorized representative established within the Community. Such equipment and/or assemblies must not bear the CE marking referred to in Article 15."

Category I

Equipment in category I must maintain a declaration of conformity with the Directive, and keep technical documentation on hand for inspection by national authorities if needed. The technical documentation includes equipment descriptions, engineering designs and drawings (and accompanying explanations), results of design calculations, and any test reports. No third-party involvement is required.

Category II

Equipment in category II must follow the requirements of category I equipment, and in addition must select a third party to oversee final assessment of the equipment, through use of unexpected visits. Non-conformity with directives may result in action by the body. In addition, manufacturers must operate an approved quality system for production and for the final pressure equipment inspection and testing, which includes oversight by a third party through audits, checks of documentation, and unexpected visits. Manufacturers must also produce and keep technical documentation to support assessment of these systems.

Category III

Equipment in category III must be produced under an approved quality system for production and for the final pressure equipment inspection and testing, similar to category II but without the requirement for maintaining technical documentation. In addition, manufacturers are subject to product verification by a third party that must verify that all components and fixtures conform to the Directive. Equipment in category III is also subject to module H in Annex II, requiring full quality assurance confirmation. This requires that a third-party oversee an approved quality system for design, manufacture, final inspection, and testing of equipment. Manufacturers are thus subject to quality checks throughout the product development cycle, instead of at the end, and this requires more extensive documentation of all aspects of the product. Manufacturers are subject to audits, checks of documentation, and unexpected visits.

Category IV

Equipment in category IV is subject to product verification by a third party, and quality assurance oversight of design, manufacture, final inspection and testing of equipment, much like category III equipment. In addition, manufacturers must submit an application for approval of the design, and are subject to additional surveillance during the final assessment of equipment. Category IV equipment is also subject to module G in Annex II, which requires that the design, construction and testing of each item of the design be verified by a third-party, using more extensive technical documentation.

Appendix E – Comparison of Model Codes

Summary of Model Codes

Mechanical Codes and Building Codes
Requirements on the design, construction, installation, maintenance, and repair of air conditioning and refrigeration systems are most often prescribed by a state's local mechanical code. Most states have adopted either the International Mechanical Code (IMC) or the Uniform Mechanical Code (UMC), which has helped standardize requirements across the country. Building codes provide requirements for construction, use, and repair of buildings, and may contain equipment requirements.

International Mechanical Code

The International Code Council publishes the International Mechanical Code (IMC) and updates it every three years. The latest version of this code is the 2009 IMC, but many state codes reference the older 2003 and 2006 versions. The IMC has been adopted by nearly three-quarters of the states as their official mechanical code, with and without amendments.

The scope of the IMC is as follows: "This [code] shall govern the design, installation, construction and repair of refrigeration systems that vaporize and liquefy a fluid during the refrigerating cycle. Refrigerant piping design and installation, including pressure vessels and pressure relief devices, shall conform to this code. Permanently installed refrigerant storage systems and other components shall be considered as part of the refrigeration system to which they are attached."

Uniform Mechanical Code

The Uniform Mechanical Code (UMC) is published by the International Association of Plumbing and Mechanical Officials (IAPMO) and is updated every three years. The latest version of the UMC code is the 2009 UMC, but state building codes can refer to the older 2003 and 2006 versions.

The scope of the UMC is as follows: "The purpose of this code is to provide minimum standards to safeguard life or limb, health, property, and public welfare by regulating and controlling the design, construction, installation, quality of materials, location, operation, and maintenance or use of heating, ventilating, cooling, and refrigeration systems; incinerators; and other miscellaneous heat-producing appliances within this jurisdiction."

International Building Code

The International Code Council publishes the International Building Code (IBC) and updates it every three years. The latest version of the IBC code is the 2009 IBC, but many state building codes reference the older 2003 and 2006 versions. The IBC has been adopted by the vast

majority of states as their official building code, with and without amendments. The IBC defers to the IMC in setting requirements for HVAC&R equipment.

The scope of the IBC is as follows: "The provisions of this code shall apply to the construction, alteration, movement, enlargement, replacement, repair, equipment, use and occupancy, location, maintenance, removal and demolition of every building or structure or any appurtenances connected or attached to such buildings or structures."

International Fire Code

The International Code Council publishes the International Fire Code (IFC) and updates it every three years. The latest version of the IFC code is the 2009 IFC, but many state fire codes reference the older 2003 and 2006 versions.

The scope of the IFC is as follows: "The purpose of this code is to establish the minimum requirements consistent with nationally recognized good practice for providing a reasonable level of life safety and property protection from the hazards of fire, explosion or dangerous conditions in new and existing buildings, structures and premises and to provide safety to fire fighters and emergency responders during emergency operations."

National Fire Protection Association Codes

The National Fire Protection Association (NFPA) develops, publishes, and disseminates more than 300 consensus codes and standards to guard against the risk of fire. Flammable refrigerants may pose a risk of fire, and equipment using flammable refrigerants can fall within the jurisdiction of these codes. However, these codes deal with associated building environments, storage containers, and electrical equipment, and not with the actual refrigeration or air conditioning equipment itself.

NFPA 1 – Uniform Fire Code (UFC)
The purpose of this code is to prescribe minimum requirements necessary to establish a reasonable level of fire and life safety and property protection from the hazards created by fire, explosion, and dangerous conditions.

NFPA 30 – Flammable and Combustible Liquids Code
The purpose of this code is to provide reasonable requirements for the safe storage and handling of flammable and combustible liquids.

NFPA 58 – Liquefied Petroleum Gas Code
This code only applies to petroleum gas when used as a fuel, but not when used as a refrigerant. It is outside the scope of this project.

NFPA 70 – National Electric Code (NEC)
The purpose of this code is the practical safeguarding of persons and property from hazards

arising from the use of electricity. The NEC covers requirements for electrical equipment and conductors in nearly all settings.

Comparisons of US Model Codes (by refrigerant type)

The model codes apply to all equipment except MVAC applications. Unless otherwise noted, the information below describes the International Mechanical Code (IMC) and Uniform Mechanical Code (UMC).

Carbon Dioxide

Refrigerant Quantities
The IMC and the UMC provide a list of allowable refrigerant quantities, usually similar to the list provided by ASHRAE Standard 34. These requirements regulate that amount of refrigerant that can be immediately released into the environment. The IMC and the UMC also provide an additional requirement on the amount of refrigerant that can be released when measured on a time-weighted average (TWA) basis.

Table E-1 below lists the permitted amounts of carbon dioxide refrigerant according to ASHRAE 34-2007, IMC 2006, and UMC 2006. The table includes the Immediately Dangerous to Life or Health (IDLH) limits, the Time-Weighted Average (TWA) limit, and the allowable number of pounds of refrigerant in a system per 1,000 cubic feet of room volume.

Table E-1: Permitted amounts of carbon dioxide refrigerant according to ASHRAE 34, IMC, and UMC

Carbon Dioxide – Permitted Amounts			
	IDLH (ppm)	TWA (ppm)	Lbs per 1000 cf.
ASHRAE 34-2007	40,000	N/A	4.5
IMC 2006	40,000	5,000	4.5
UMC 2006	50,000	5,000	5.7

Building Supports
Section 1106.2 of the 2006 UMC states that supports for refrigeration equipment must be noncombustible, unless the equipment uses Group A1 refrigerants. The 2006 IMC does not address supports.

Equipment Surface Temperature and Open Flames
Carbon dioxide is one of three exceptions to the requirement in Section 1104.3.4 of the 2006 IMC, which states that a hood and exhaust system must be provided for rooms that have any device having an open flame or surface temperature greater than 800°F (427°C) in a room containing more than 6.6 pounds (3 kg) of refrigerant in a single independent circuit.

Walkways
In the 2006 UMC, Section 1106.3 states that an unobstructed readily accessible opening and passageway not less than thirty-six (36) inches (914 mm) in width and six (6) feet (1829 mm)

eight (8) inches (203 mm) in height shall be provided and maintained to the compressor, valves, or other portions of the system requiring routine maintenance. Cooling equipment that uses A1 refrigerants in an attic or furred space can have a smaller passageway (22 inches by 30 inches); and cooling equipment that uses A1 or B1 refrigerants on a roof or on an exterior wall can have access such as that prescribed for furnaces. Furnace access as prescribed by the 2006 UMC must allow easy entry and movement within the equipment enclosure, and must have a clearance of at least 30 inches between equipment service panels and enclosure walls while having a reasonable height.

Machinery Room Required
The 2006 IMC requires a machinery room for components that are not located outside and exceed the quantities allowed in Table 1103.1. The 2006 IMC makes an exception for listed equipment with no more than 6.6 lbs. of refrigerant, regardless of refrigerant, when installed according to the listing.

The 2006 UMC is much stricter than the 2006 IMC. A machinery room is required when the refrigerant exceeds a certain allowable amount, or when the refrigerant used is not an A1 refrigerant (with some exceptions for ammonia systems located outside, as detailed below). It also requires a machinery room when direct- and indirect-fired absorption equipment is used. A machinery room is also required when an A1 system has an aggregate combined compressor horsepower of 100hp or more. This requirement may be particularly relevant to large carbon dioxide systems.

Ammonia

Table E2 below lists the permitted amounts of ammonia refrigerant according to ASHRAE 34-2007, IMC 2006, and UMC 2006. The table includes the Immediately Dangerous to Life or Health (IDLH) limits, the Time-Weighted Average (TWA) limit, and the allowable number of pounds of refrigerant in a system per 1,000 cubic feet of room volume.

Table E-2: Permitted amounts of ammonia refrigerant according to ASHRAE 34, IMC, and UMC

Ammonia – Permitted Amounts			
	IDLH (ppm)	**TWA (ppm)**	**Lbs per 1000 cf.**
ASHRAE 34-2007	320	N/A	0.014
IMC 2006	500	25	0.022
UMC 2006	500	5,012	0.022

Use of IIAR Standard 2
The 2006 IMC states that all refrigeration systems must meet the requirements of ASHRAE 15, and all ammonia refrigerant systems must meet the requirements of IIAR Standard 2.

Restrictions on Refrigerant Use
Section 1104.3.1 of the IMC states that other than industrial occupancies where the quantity in a single independent circuit does not exceed a specified amount, Group B1, B2 and B3 refrigerants

shall not be used in high-probability systems for air conditioning for human comfort. This clause is less restrictive than a similar clause in ASHRAE 15, which includes A2 and A3 refrigerants as well.

Section 1104.3.2 of the 2006 IMC states that in nonindustrial occupancies, Group A2 and B2 refrigerants shall not be used in high-probability systems where the quantity of refrigerant in any independent refrigerant circuit exceeds a specified amount. Group A3 and B3 refrigerants shall not be used except where approved.

Section 1104.3.3 of the 2006 IMC states that the total of all Group A2, B2, A3 and B3 refrigerants other than R-717 (ammonia) shall not exceed 1,100 pounds (499 kg) except where approved.

Machinery Room Required
The 2006 IMC requires a machinery room for components that are not located outside and exceed the quantities specified in Table E-2 above. The 2006 IMC makes an exception for listed equipment with no more than 6.6 lbs. of refrigerant, regardless of refrigerant, when installed according to the listing. This exception can be used to allow use of ammonia refrigerants in small quantities without restriction.

The 2006 UMC is much stricter than the 2006 IMC. A machinery room is required when the refrigerant exceeds the allowable amount, or when the refrigerant used is not an A1 refrigerant (with some exceptions for ammonia systems located outside, detailed below). It also requires a machinery room when direct- and indirect-fired absorption equipment is used, or when an A1 system has an aggregate combined compressor horsepower of 100hp or more.

The exceptions for ammonia systems are as follows:

1) It is an ammonia-water absorption system installed outdoors, provided that the refrigerant amount is within specified limits and the system can shield and disperse any discharge; or
2) The system contains less than 35 lbs. of R-717 and is located in an approved exterior location.

Machinery Room Requirements
In the 2006 IMC, machinery rooms using ammonia are exempt from section 1106.4, which requires that machinery rooms using A2, A3, B2, or B3 refrigerants conform to the Class 1, Division 2, hazardous location classification requirements of the ICC Electrical Code.

A significant requirement from the 2006 UMC is that fans and associated equipment intended to operate the emergency purge of other than Group Al or Group B1 refrigerants in a machinery room shall meet the requirements for a Class I, Division 1 hazardous location as specified in the Electrical Code.

Ammonia Discharge Requirements
The 2006 UMC contains requirements for the discharge of ammonia by any system, with the

exception of ammonia-water absorption systems installed outdoors serving a dwelling unit where the discharge is shielded and dispersed. In addition, Section 1119 states that systems containing other than Group Al or B1 refrigerants shall discharge to atmosphere only through an approved flaring device, unless it is an ammonia system listed in the code or the relevant authority grants an exception after a safety and environmental review.

The 2006 IMC states within the general requirements for machinery rooms that pressure relief valves for ammonia systems shall discharge in accordance with ASHRAE Standard 15.

Ammonia Ventilation Requirements
The 2006 IMC states that, for machinery rooms using ammonia, ventilation systems shall be operated continuously at the emergency ventilation rate determined in accordance with Section 1105.6.4. The 2006 UMC states that controls should provide for emergency purging of ventilation if the detection system senses refrigerant levels at 25 percent of the LFL or 50 percent of the IDLH, whichever is lower.

Model Codes – International Fire Code and NFPA 1 – UFC
The International Fire Code and NFPA 1, the Uniform Fire Code, set limits on the amount of hazardous materials than can be used and stored within a defined control area. They also define where these materials can and cannot be used and stored.

IFC, UFC Quantity Limits
The IFC and UFC include sets of tables that list the maximum allowable quantities per control volume of hazardous materials under certain use conditions.

Limitations on Use by Occupancy – IFC and NFPA
The 2006 IFC places a number of limitations on the use and storage of flammable gases. Flammable gases cannot be present (used or stored) in the following occupancies:

- Group A – Assembly Occupancy
- Group B – Business Occupancy
- Group E – Educational Occupancy
- Group I – Institutional Occupancy
- Group R – Residential Occupancy

Exemptions are granted for small cylinders used for maintenance, operations, or patient care, and gases used for food service operations.

The 2006 IFC also contains requirements on the use and storage of highly toxic and toxic materials. Highly toxic and toxic compressed gases cannot be used or stored in the following occupancies:

- Group A – Assembly Occupancy
- Group E – Educational Occupancy
- Group I – Institutional Occupancy

- Group R – Residential Occupancy
- Group U – Miscellaneous Occupancy
- Office, retail sales, and classrooms (part of Groups B, F, M, or S)

For groups A, E, I and U, "cylinders not exceeding 20 cubic feet" are exempted from this requirement. General requirements include a ventilation system, automatic fire detection system, alarms, and acceptable cabinets for storage.

NFPA 1 also has requirements on the use and storage of hazardous substances. NFPA 1 does not prohibit the use of flammable and combustible liquids, but restricts their use to amounts needed for maintenance, operation, and laboratory work in a number of occupancies. The restrictions are in place for the following occupancies:

- Assembly Occupancies
- Office portions of Business and Industrial Occupancies
- Mercantile or Storage Occupancies
- Educational Occupancies
- Daycare, Healthcare, Ambulatory healthcare Occupancies
- Detection and Correctional Occupancies
- Residential Occupancies

NFPA 1 prohibits the use of toxic and highly toxic compressed liquids stored in the following occupancies:

- Assembly Occupancies
- Offices or Classrooms of Business or Industrial Occupancies
- Offices or Classrooms of Mercantile or Storage Occupancies
- Educational Occupancies
- Daycare, Healthcare, Ambulatory healthcare Occupancies
- Detection and Correctional Occupancies
- One- or Two-Family Dwelling Occupancies
- Lodging and Rooming Houses, Hotels and Dormitory Occupancies
- Residential board or care occupancies

Hydrocarbons

The IMC and the UMC provide a list of allowable refrigerant quantities, usually similar to the list provided by ASHRAE Standard 15. These requirements regulate that amount of refrigerant that can be immediately released into the environment. The IMC and the UMC also provide an additional requirement on the amount of refrigerant that can be released when measured on a time-weighted average (TWA) basis.

Table E-3 below lists the permitted amounts of several hydrocarbon refrigerants according to ASHRAE 34-2007, IMC 2006, and UMC 2006. The table includes the Immediately Dangerous to Life or Health (IDLH) limits, the Time-Weighted Average (TWA) limit, and the allowable number of pounds of refrigerant in a system per 1,000 cubic feet of room volume.

Table E-3 Permitted amounts of hydrocarbon refrigerant according to ASHRAE 34, IMC, and UMC

Propane (R-290)			
	IDLH (ppm)	**TWA (ppm)**	**Lbs per 1000 cf.**
ASHRAE 34-2007	5,300	N/A	0.56
IMC 2006	5,000	2,500	0.56
UMC 2006	4,400	1,000	0.5
Butane (R-600)			
	IDLH (ppm)	**TWA (ppm)**	**Lbs per 1000 cf.**
ASHRAE 34-2007	4,000	N/A	0.6
IMC 2006	N/A	N/A	N/A
UMC 2006	3,400	800	0.51
Isobutane (R-600a)			
	IDLH (ppm)	**TWA (ppm)**	**Lbs per 1000 cf.**
ASHRAE 34-2007	4,000	N/A	0.6
IMC 2006	2,500	800	0.51
UMC 2006	3,400	800	0.51

The 2006 IMC states that any equipment or appliance (regardless of refrigerant) does not need to use a machinery room if it is listed by the manufacturer and contains less than 6.6 lbs of refrigerant. This is an important exception that mirrors a recent amendment to ASHRAE Standard 15 that allows the use of hydrocarbons refrigerants in equipment if the equipment is listed by UL. The 2006 UMC does not contain this allowance.

Restrictions on Refrigerant Use
Section 1104.3.2 of the 2006 IMC states that in nonindustrial occupancies, Group A3 and B3 refrigerants shall not be used except where approved. This requirement is identical to a requirement found in ASHRAE Standard 15-2007.

Section 1104.3.3 of the 2006 IMC states that the total of all Group A2, B2, A3 and B3 refrigerants other than R-717 (ammonia) shall not exceed 1,100 pounds (499 kg) except where approved. This is identical to a requirement in ASHRAE 15-2007.

Machinery Room Required
The 2006 IMC requires a machinery room for components that are not located outside and exceed the specified quantities allowed. The 2006 IMC makes an exception for listed equipment with no more than 6.6 lbs. of refrigerant, regardless of refrigerant, when installed according to the listing. This exception can be used to allow use of hydrocarbon refrigerants in small quantities without restriction.

The 2006 UMC is much stricter than the 2006 IMC. A machinery room is required when the refrigerant exceeds the allowable amounts, or when the refrigerant used is not an A1 refrigerant (with some exceptions for ammonia systems located outside). It also requires a machinery room when direct- and indirect-fired absorption equipment is used, or when an A1 system has an aggregate combined compressor horsepower of 100hp or more.

Machinery Room Requirements
In the 2006 IMC, machinery rooms using A2, A3, B2, or B3 refrigerants must conform to the Class 1, Division 2, hazardous location classification requirements of the ICC Electrical Code.

A significant requirement from the 2006 UMC is that fans and associated equipment intended to operate the emergency purge of other than Group Al or Group B1 refrigerants in a machinery room must meet the requirements for a Class I, Division 1 hazardous location as specified in the Electrical Code.

Model Codes – International Fire Code and NFPA 1 – UFC
The International Fire Code and NFPA 1, the Uniform Fire Code, set limits on the amount of hazardous materials than can be used and stored within a defined control area. They also define where these materials can and cannot be used and stored.

IFC, UFC Quantity Limits
The IFC and UFC include sets of tables that list the maximum allowable quantities per control volume of hazardous materials under certain use conditions.

Limitations on Use by Occupancy – IFC and NFPA
The 2006 IFC places a number of limitations on the use and storage of flammable gases. Flammable gases cannot be present (used or stored) in the following occupancies:

- Group A – Assembly Occupancy
- Group B – Business Occupancy
- Group E – Educational Occupancy
- Group I – Institutional Occupancy
- Group R – Residential Occupancy

Exemptions are granted for small cylinders used for maintenance, operations, or patient care, and gases used for food service operations.

NFPA 1 also has requirements on the use and storage of hazardous substances. NFPA 1 does not prohibit the use of flammable and combustible liquids, but restricts their use to amounts needed for maintenance, operation, and laboratory work in a number of occupancies. The restrictions are in place for the following occupancies:

- Assembly Occupancies
- Office portions of Business and Industrial Occupancies
- Mercantile or Storage Occupancies
- Educational Occupancies
- Daycare, Healthcare, Ambulatory healthcare Occupancies
- Detection and Correctional Occupancies
- Residential Occupancies

A2L Fluids

The 2006 IMC states that any equipment or appliance, regardless of refrigerant, does not need to use a machinery room if it is listed by the manufacturer and contains less than 6.6 lbs of refrigerant. The 2006 UMC does not make this allowance.

Restrictions on Refrigerant Use
Section 1104.3.1 of the 2006 IMC states that other than industrial occupancies where the quantity in a single independent circuit does not exceed a specified amount, Group B1, B2 and B3 refrigerants shall not be used in high-probability systems for air conditioning for human comfort. This clause is less restrictive than a similar clause in ASHRAE 15-2007, which includes A2 and A3 refrigerants as well.

Section 1104.3.2 of the 2006 IMC states that in nonindustrial occupancies, Group A2 and B2 refrigerants shall not be used in high-probability systems where the quantity of refrigerant in any independent refrigerant circuit exceeds a specified amount. This requirement is slightly less restrictive than the requirements found in ASHRAE 15, which do not allow A2 or B2 refrigerants in direct-systems used for human comfort applications.

In non-industrial and non-storage occupancies, the 2006 UMC is more stringent than the 2006 IMC because it allows high-probability systems to use only Group A1 refrigerants, without the exception for A2 and B2 refrigerants provided in the 2006 IMC. Because of this, low-risk refrigerants classified as B1 or A2 are generally less restricted within the 2006 IMC than in the 2006 UMC. This is important to note when considering the adoption of regulations for A2L fluids. Both model codes are likely to follow any changes made to ASHRAE Standard 15.

Section 1104.3.3 of the 2006 IMC states that the total of all Group A2, B2, A3 and B3 refrigerants other than R-717 (ammonia) shall not exceed 1,100 pounds (499 kg) except where approved. This is identical to a requirement in ASHRAE 15-2007.

Machinery Room Required
The 2006 IMC requires a machinery room for components that are not located outside and exceed the specified quantities allowed. The 2006 IMC makes an exception for listed equipment with no more than 6.6 lbs. of refrigerant, regardless of refrigerant, when installed according to the listing. This exception can be used to allow use of A2L refrigerants in small quantities without restriction.

The 2006 UMC is much stricter than the 2006 IMC. A machinery room is required when the refrigerant exceeds a specified amount, or when the refrigerant used is not an A1 refrigerant (with some exceptions for ammonia systems located outside). It also requires a machinery room when direct- and indirect-fired absorption equipment is used, or when an A1 system has an aggregate combined compressor horsepower of 100hp or more.

Machinery Room Requirements
In the 2006 IMC, machinery rooms using A2, A3, B2, or B3 refrigerants must conform to the Class 1, Division 2, hazardous location classification requirements of the ICC Electrical Code.

A significant requirement from the 2006 UMC is that fans and associated equipment intended to operate the emergency purge of other than Group Al or Group B1 refrigerants in a machinery room shall meet the requirements for a Class I, Division 1 hazardous location as specified in the Electrical Code.

Model Codes – International Fire Code and NFPA 1 – UFC
The International Fire Code and NFPA 1, the Uniform Fire Code, set limits on the amount of hazardous materials than can be used and stored within a defined control area. They also define where these materials can and cannot be used and stored.

IFC, UFC Quantity Limits
The IFC and UFC include sets of tables that list the maximum allowable quantities per control volume of hazardous materials under certain use conditions.

Limitations on Use by Occupancy – IFC and NFPA
The 2006 IFC places a number of limitations on the use and storage of flammable gases. Flammable gases cannot be present (used or stored) in the following occupancies:

- Group A – Assembly Occupancy
- Group B – Business Occupancy
- Group E – Educational Occupancy
- Group I – Institutional Occupancy
- Group R – Residential Occupancy

Exemptions are granted for small cylinders used for maintenance, operations, or patient care, and gases used for food service operations.

NFPA 1 also has requirements on the use and storage of hazardous substances. NFPA 1 does not prohibit the use of flammable and combustible liquids, but restricts their use to amounts needed for maintenance, operation, and laboratory work in a number of occupancies. The restrictions are in place for the following occupancies:

- Assembly Occupancies
- Office portions of Business and Industrial Occupancies
- Mercantile or Storage Occupancies
- Educational Occupancies
- Daycare, Healthcare, Ambulatory healthcare Occupancies
- Detection and Correctional Occupancies
- Residential Occupancies

Appendix F – State Adoption of Model Codes

Mechanical Codes

The following states use the uniform mechanical code (UMC):

- California
- Nevada
- New Mexico

The following states have adopted their own mechanical code:

- Massachusetts

The following states have not adopted any state-wide mechanical code. Many of these states adopt mechanical code requirements only at the local level:

- Arizona
- Delaware
- Hawaii
- Illinois
- Maine
- Mississippi
- Missouri
- Nebraska
- Texas
- Vermont

All other states have adopted the international mechanical code (IMC) as the state mechanical code (with some state-specific amendments).

Building Codes

States also adopt building codes that set requirements on the design, construction, alteration and use of any building or structure. These building codes often require that the state's mechanical code is followed when including any air conditioning or refrigeration equipment. Of all 50 states and the District of Columbia, 45 have adopted the international building code (IBC) as their official state building code.

Differences between the IMC and the UMC

There are a number of important differences between the IMC and UMC.

The IMC and UMC both define two classes of refrigeration systems: high-probability systems and low-probability systems. These definitions are based on the design of a particular system; it depends on the probability that the system may leak refrigerant into a public area in the event of a failed connection, seal, or component. The UMC defines these systems very broadly, ultimately defining a high-probability system as one whose design and location makes it possible for a leakage into a public space to occur. The IMC classifies different designs of

refrigerant systems as low-probability or high-probability, and does not leave classification up to the interpretation of the code official. The system's classification as high-probability or low-probability is important because, in both the IMC and the UMC, only A1 refrigerants can be used in non-industrial high-probability systems and all refrigerant types can be used in low-probability systems. Both definitions are taken from ASHRAE Standard 15; ASHRAE 15 defines high-probability and low-probability systems broadly, and also defines systems that are typically considered high-probability and low-probability.

Low-probability systems (IMC):

- Double-indirect open-spray systems
- Indirect closed systems
- Indirect vented closed systems

High-probability systems (IMC):

- Direct systems
- Indirect open-spray systems
- Exception: If pressure of secondary coolant is higher than refrigerant pressure at all times

Refrigerant systems are classified not only by the design of the system, but also by the setting in which they are used. Both the IMC and the UMC define a number of occupancies that have different regulations on the type of equipment used. For example, regulations on occupancies such as hospitals and nursing homes are much stricter than regulations on industrial settings. The IMC defines six different types of occupancy settings (mirroring the specifications in ASHRAE Standard 15), while the UMC defines 10 different occupancy settings (with up to seven divisions per occupancy). The UMC occupancies are more narrowly defined than the IMC occupancies, and allow for a more focused application of the code.

However, the UMC does not apply different regulations based on the occupancy, while the IMC specifies additional regulations depending on the occupancy in which the equipment is installed. For example, in the IMC, institutional occupancies are restricted to 50% of the amount usually specified, and the total amount of non-A1 or B1 refrigerants is restricted to 550 pounds. Instead of these charge restrictions, the UMC restricts high-probability systems in these occupancies to A1 refrigerants or no refrigerants at all, and allows any type of refrigerant for low-probability systems (provided the regulated refrigerant amounts are followed).

Additional Standards

There are a few key differences between the IMC and the UMC. First, the IMC states that listed and labeled self-contained, factory-built equipment and appliances must be tested to UL standards 207, 412, 471 or 1995, as appropriate. When installed in accordance to their listing and the manufacturer's installation instructions, this equipment must meet the design, manufacture and factory test requirements of the IMC. The UMC makes this a requirement as well by stating that all listed appliances must be installed according to the listing, but does not specify the UL standards.

Second, the 2006 IMC states that all refrigeration systems must meet the requirements of ASHRAE Standard 15, and all ammonia-refrigerating systems must meet the requirements of IIAR Standard 2.

Exception for Small Equipment

Finally, the 2006 IMC states that any equipment or appliance (regardless of refrigerant) does not need to use a machinery room if it is listed by the manufacturer and contains less than 6.6 lbs of refrigerant. This is an important exception that mirrors a recent amendment to ASHRAE Standard 15 that allows the use of refrigerants such as HFO-1234yf and hydrocarbons in small equipment as long as it is listed by UL. The 2006 UMC does not make this allowance.

Fire Codes

Building and equipment requirements to reduce risks associated with fire are outlined in state fire codes. The National Fire Protection Association (NFPA) publishes a number of fire codes that cover a wide variety of equipment and buildings, and the ICC also publishes an International Fire Code (IFC).

Currently, 28 states have a fire code based on the IFC. Seventeen have codes solely based on NFPA codes, and five have state-specific fire codes. Most fire codes have portions that refer to the NFPA codes, regardless of their initial model code. Three states (Mississippi, Missouri, and Texas) do not have a state-wide fire code; however, many states (including these three) adopt codes at a local level. Table F-1 below lists the fire codes used by each state.

Table F-1: Fire codes adopted by each state

States with state-specific fire codes	States that use the IFC as a model code (28 in total)			
Delaware	Alabama	Georgia	Nevada	South Carolina
Florida	Alaska	Idaho	New Mexico	South Dakota
Massachusetts	Arizona	Indiana	New York	Tennessee
Michigan	Arkansas	Iowa	North Carolina	Utah
Oregon	California	Kansas	Ohio	Virginia
	Connecticut	Kentucky	Oklahoma	Washington
	D.C.	Minnesota	Pennsylvania	Wyoming
All other states not mentioned rely solely on NFPA codes such as NFPA 1, the Uniform Fire Code, and NFPA 101, the Life Safety Code.				

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ANSI/ASHRAE Standard 34-2007: Designation and Safety Classification of Refrigerants

ANSI/ASHRAE Standard 26-1996 (RA 2006): Mechanical Refrigeration and Air-Conditioning Installations Aboard Ship

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