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Tech Paper #5

Regulatory & Code Implications for Low Charge Ammonia Systems

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Abstract

How is the regulatory burden impacted by installing low charge ammonia refrigeration systems? With the rapidly growing interest, development and application of limited or low charge ammonia systems, there is an increasing need for market awareness and definition of what the benefits and/or implications are from a regulatory and code perspective for such a system, as compared to larger traditional or existing ammonia systems. For example, codes and standards such as OSHA, IIAR, ASHRAE, IBC, IMC and UMC all have various design references and/or criteria related to the quantity of refrigerant in a system, and specify actions or designs that must be undertaken as a result of their specific refrigerant threshold quantity (TQ). This paper will seek to identify these regulated threshold quantities among the various applicable codes or standards so that designers, contractors and end users can better understand the fact or fiction of the various threshold requirements.

This is a very large and broad undertaking because there are so many regulations, codes and standards that may or may not apply to all users. Therefore, the paper is also meant to set the stage for continued investigation, collaboration and validation on the subject matter. Many of the regulations and codes have been coordinated over the years and contain some common requirements. However, as shown in this paper, there is a lack of refrigerant threshold quantities related to charge management, as well as a lack of discussion on refrigerant quantity guidelines. Nevertheless, technological advances and industry awareness now provide a real opportunity to incorporate new TQ's into the regulations and codes. This continued work needs to influence regulatory agencies and code writing bodies to update their documents and to keep pace with the tremendous benefits that low charge technology provides the ammonia refrigeration industry.

Background

As a first step we need to define what is meant by a low charge system. Much work has been, and continues to be done, in the field of reducing the refrigerant charge in refrigeration systems. To date, the majority of this work has been centered on commercial packaged products using HCFC, HFC or alternative hydrocarbon refrigerants such as Propane. By comparison, much less development work has centered on ammonia, and the much larger industrial refrigeration systems that it typically serves in the food and beverage industry and associated cold chain. Since the premise of this paper is understanding the regulatory or code impact of ammonia systems with varying size refrigerant charges per unit refrigeration load (lb/TR), the reader will want to understand the relationship between a "typical" ammonia refrigeration system and a "low charge" system, so both must be defined.

What is Low Charge?

In the recent paper *Low Ammonia Charge Refrigeration Systems for Cold Storage*, sponsored by IARW and authored by Terry L. Chapp, PE, it was put forth that "all systems under consideration would have to hold no more than 10 pounds of ammonia per ton of refrigeration" to be considered a low charge system. This is based on the premise that such a system would contain "no more than 50% of the charge of the optimized PRL (*Pumped Recirculated Liquid*) system)." This "typical" PRL system type is very common in the food and beverage industry and has a long and successful history due to many factors including:

1. The ability to handle critical and varying refrigeration applications in a dependable and reliable way.
2. Fluctuating operating conditions and rigorous duties that commercial DX equipment or designs may not handle.
3. Increasingly large system sizes and the proven technologies that have been successfully deployed in the industry to serve them.

These "typical" industrial ammonia refrigeration systems have generally been designed to contain up to 25 lbs per ton, and higher, of refrigerant. Therefore, by example a typical 500 TR refrigerated warehouse could contain 12,500 lbs or more of ammonia. However, with the awareness and focus on reducing this historically large average charge value over the last several years, an "optimized" system design has evolved in the industry using traditional system designs that can reduce this to an average value of 20 lb/TR, or 10,000 lb by the example. Therefore, by the aforementioned definition, a Low Charge System would be 50% (or less) of this *optimized value* and contain less than 5,000 lbs or less than a nominal value of 10 lb/TR.

One of the challenges of using rules of thumb like that stated above is the fact that refrigeration systems, including ammonia systems, come in all shapes and sizes. There is a tremendous variation in system sizes (i.e. 10TR to 10,000TR and higher), temperature levels (i.e. -60°F to +60°F) and diverse end user applications (from blood plasma storage, to a wide range of food processing applications, to cold storage facilities large and small). Referring again to the paper by Terry Chapp, the types of low charge systems that are being developed, and increasingly being adopted, in the industry include electronic DX systems, ammonia-CO_2 cascade systems, ammonia secondary fluid systems (including volatile brine CO_2) and modular based packaged systems. All of these, in varying degrees, can reduce the ammonia charge quantity as compared to the historical "typical" systems, and can put users well below the 10 lbs/TR rule of thumb value.

What is the goal?

With the ability to reduce the system ammonia charge in small to large amounts, it is important to understand the varying regulatory impacts. Or, if the regulatory impacts do not vary with the size of the ammonia charge, then perhaps they should, and code development initiatives should be encouraged to implement the appropriate TQ's, which further promote charge reductions.

Please note that this paper addresses the most common or prevalent industry codes or standards in the United States and is not meant to address every code in the individual states or municipalities, nor codes or standards that relate to the transportation industry, or those that may exist outside of the U.S. The regulatory review considers ASHRAE, IIAR, IBC, IMC, UMC, CMC, IFC, OSHA, EPA and a few others, in that order, in a rigorous fashion to find the charge related issues. Although the regulations and codes observed in other countries are not addressed in this paper, this low charge code review process should be continued so that all major code writing bodies communicate and coordinate requirements that are supportive of charge reduction.

This paper will attempt to provide a summary overview of the threshold quantities (TQ's) of ammonia in the codes and the resulting actions that must be taken or addressed. The easiest way to present this information is in tabular format and a narrative discussion relative to some important highlights for each regulation or code. The tables provided present design, installation and operating criteria related to ammonia systems and list specific relationships to a stated quantity of refrigerant charge where they exist. However, also shown are many other criteria that do not have a specific charge TQ identified. These non-TQ items are important to highlight because of the physical differences between low charge systems and "typical systems". Some of the non-TQ criteria are identified in the tables as "No Threshold" or "No – TQ", meaning that it applies to typical systems as well as low charge systems, while others are identified by the code criteria title they fall under. As a point of reference, it is also important to understand that the quantity of refrigerant for a given system is defined by ASHRAE to be that contained in the entire closed circuit refrigeration system, from the evaporator to the compressor, to the condenser and back. There is rarely any distinction between the low side or high side of the system as it relates to any threshold quantities.

As a disclaimer, this paper is obviously not intended to identity all the applicable criteria for ammonia systems, regardless of the type, so it is important that it be clear this is only intended to be a summary overview relative to issues that may be affected by low charge systems, and that many other relevant criteria and requirements are not listed or addressed.

The primary U.S. regulation that most people think of, and deal with, related to an ammonia TQ is the 10,000 lbs threshold for OSHA's Process Safety Management (PSM) program under OSHA rule 29CFR 1910.119. This is certainly an important threshold, and is becoming more important as outlined later in this paper. However, there are other thresholds less known, or less impactful, but important as the industry adopts more low charge systems and looks for additional regulatory relief. Therefore, this review will start with ASHRAE.

ASHRAE-34

ASHRAE is the recognized authority in the U.S. for all refrigerants through publication of its many Standards, including *ASHRAE Standard 34 – Designation and Safety Classification of Refrigerants*, which establishes the fundamental Classifications and concentration limits for refrigerants. These refrigerant Concentration Limits are then related to the type of occupancy that a particular building is designed for and the required refrigerant thresholds that must be adhered to related to occupancy classifications. Ammonia is prohibited from being used in a direct cooling system for human comfort cooling by ASHRAE-15, section 7.5.2 in all occupancies except industrial occupancies. An industrial occupancy is defined by ASHRAE as "a premise or that portion of a premise that is not open to the public, where access by authorized persons is controlled, and that is used to manufacture, process, or store goods such as chemicals, food, ice, meat, or petroleum". Looking into the future, as low charge ammonia systems are further developed and charges are reduced, it is very possible that a tiered approach to acceptable ammonia TQ's could influence changes to the codes that relax the criteria for other comfort cooling occupancy applications.

One of the first comparisons to make is how ammonia compares to some common HCFC, HFC, HFO and Hydrocarbon refrigerants that are found in large cooling systems. Table 1 is based on data from ASHRAE 34 for several popular refrigerants and illustrates the different threshold concentration limits between the refrigerants, above which, a facility is required to have the refrigeration equipment located in a "Machine Room" or outdoors. This data is then extrapolated to a hypothetical 1,000,000 cubic foot refrigerated warehouse, and the theoretical refrigerant charge that is permissible without mandating a machine room. The machine room threshold is an important criterion because it has a direct relationship to system safety, cost, accessibility and equipment types. These relationships are what the paper attempts to identify as it relates to charge thresholds found in the codes.

Refrigerant (Name)	Refrigerant Classification & Type	Ozone Depletion Potential (ODP)/ Global Warming Potential (GWP)	ASHRAE 34 Concentration Limit (lb/1000 cu. ft.)	Permissable Charge W/ No Machine Room (Or Outside) For A Hypothetical 1,000,000 Ft3 Refrigerated Warehouse (lb)
R-22	A1, HCFC	0.055 /1700	13	13,000
R-123	B1, HCFC	0.02 / 77	3.5	3,500
R-134a	A1, HFC	0 / 1300	13	13,000
R-290 (Propane)	A3, Hydrocarbon	0 / (-)20	0.56	560
R-404A	A1, HFC	0 / 3800	31	31,000
R-410	A1, HFC	0 / 2000	25	25,000
R-449A	A1, HFO	0 / 1397	23	23,000
R-507	A1, HFC	0 / 3900	32	32,000
R-717 (Ammonia)	B2, Inorganic	0 / 0	0.014	14
R-744 (CO2)	A1, Inorganic	0 / 1	4.5	4,500

Table 1: Common Refrigerants & Concentration Limits

As shown in Table 1, a 1,000,000 cubic foot warehouse (~30,000 sq. ft. facility with a 33 ft. high ceiling) being cooled by an R-22 system, would not be required to have its refrigeration equipment located in a Machine Room (or located outdoors) if the system charge was less than 13,000 lb. By contrast, if the system's refrigerant were ammonia instead of R-22, this TQ is reduced all the way down to only 14 lb versus 13,000 lbs. This is indeed a stark contrast between refrigerants and highlights how ammonia is subjected to significant regulatory and code constraints because its fundamental Concentration Limit is extremely low as compared to the other refrigerants. The very low Concentration Limit is obviously justified and understandable given the high toxicity of ammonia, however, the beneficial impact of the new low charge technologies should be evaluated for possible changes in the codes through prescribed TQ's. After all, the 0 OPD and 0 GWP values show that ammonia is the most environmentally friendly refrigerant, not to mention the long standing fact that it is also the most energy efficient refrigerant.

As a point of interest, one of the leading new synthetic refrigerants developed to help solve the rapidly increasing climate change regulations on HFC's, is R-449A, which is a HFO (hydrofluoro-olefin) and is a replacement for R-404A and R-507 HFC's. It has a concentration limit of 23 lb/1000 cubic feet, therefore, in the above example, for a 1,000,000 cubic foot warehouse, this new HFO refrigerant could have a system charge up to 23,000 lbs before it was mandated to be housed in a machine room. However, R-449A has a GWP rating of 1397. This illustrates that even the new HFO refrigerants may be subject to future restrictions being driven by the global warming regulatory environment.

ASHRAE-15

Since ASHRAE is the recognized authority for refrigerant related "Standards" in the U.S., this overview will continue with a review of *ASHRAE-15 – Safety Standard for Refrigeration Systems*, the basis of many other building air-conditioning and refrigeration codes and regulations. In addition to the refrigerant concentration limits discussed above, ASHRAE also establishes the Refrigerant System Classification through definition of Direct and Indirect system types. This classification can provide an indication of the relative quantity of ammonia in a system and the regulatory impact of the same. For example, in instances where it fits an application, some users have long been converting their direct ammonia systems to indirect ammonia systems as a method of reducing the charge, by pumping a secondary fluid to the cooling coils instead of ammonia. Despite the loss of system efficiency and higher operating costs of the indirect system (or secondary cooled fluid) it could be worth it to the end user if the outcome dramatically reduces the ammonia charge necessary to satisfy the cooling loads. As a result, secondary fluid–indirect systems have gained in popularity.

The definition of each system type is found in the first two rows of Table 2, followed by the corresponding ASHRAE definitions of "High-Probability System" and "Low-Probability System." The regulatory benefit of an indirect system is that ASHRAE classifies it as a "Low-Probability System" for refrigerant leaks into an occupied space, and the regulatory drawback of a direct system is that ASHRAE classifies it as a "High-Probability System" for refrigerant leaks into the occupied space.* This System Classification is also recognized by all other major codes, making it a fundamental basis of design criteria.

* *Definitions do not address classifications of Open Spray Systems*

SECTION	THRESHOLD	ACTION OR REQUIREMENT
5.1.1	Direct Systems	The evaporator or condenser of the refrigerating system is in direct contact with the air or other substances to be cooled or heated
5.1.2	Indirect Systems	Secondary coolant cooled or heated by the refrigerating system is circulated to the air or other substance to be cooled or heated
5.2.1	High-Probability System	Is such that a leakage of refrigerant from a failed connection, seal, or component will enter the occupied space
5.2.2	Low-Probability System	Is such that leakage of refrigerant from a failed connection, seal, or component cannot enter the occupied space
7.2	0.014 lb/1000 cubic feet	Ammonia Concentration limit for all occupied spaces except Industrial Occupancies (see 7.2.2)
7.2.2	Industrial Occupancies	The Concentration Limit in 7.2 does not apply to Industrial Occupancies and refrigerated rooms if the following are met: • Space containing the machinery is separated from other occupancies by tight construction and tight fitting doors • Restricted access • Minimum of 100 square feet per occupant in equipment room • Ammonia sensor • All refrigerant containing parts, except evaporators, in systems exceeding 100 HP compressor drive power must be in a Machine Room or outdoors
7.4	0.014 lb/1000 cubic feet	Equipment required to be located outdoors or in a Machine Room required above this limit

SECTION	THRESHOLD	ACTION OR REQUIREMENT
7.5.2	Direct Systems–No Threshold	Ammonia in a direct system cannot be used for human comfort except for Industrial Occupancies
8.10	Access–No Threshold	Piping crossing over open passageway shall not be less than 7'3" unless it is against the ceiling
8.11 & 8.12	All Machine Rooms	Must have: • 7'3" clear height for passageways • Tight fitting doors opening outward • 1 hour fire resistive partition between machine room and occupied space • Ammonia sensor that turns on ventilation • Restricted access • No open flames or hot surfaces above 800F • Ventilation fan w/ alarm • E-stop and remote ventilation switch outside room.
8.13	(AHJ) Local Authority Having Jurisdiction	Manual emergency discharge or diffusion arrangements required if required by AHJ
9.12.4	Above 6.6 lb	Stop valves required on compressor suction & discharge unless system is equipped with pump-out provisions.
9.12.4	Above 110 lb	Stop valves required on compressor, compressor unit or condensing unit suction & discharge, inlet & outlet on receiver and inlet & outlet on Condenser, unless system is equipped with pump-out provisions.
11.5	Above 330 lb	Cannot store ammonia in excess of this quantity in cylinders with no relief valves.
11.7	Above 55 lb	Person in charge of premises to make available to operators a system schematic and emergency shutdown procedures.

Table 2: Review of ASHRAE-15

As shown in Table 2, one of the primary takeaways is that much of ASHRAE-15, as it relates to an ammonia system charge, specifies the requirements of the machine room or the components in it. The noteworthy threshold that does not require a machine room is listed in 7.2.2, where systems below 100 HP compressor power may not be required to be in a Machine Room. However all the other criteria of that section must still be met (sealed and restricted room that has refrigerant detection), essentially making it very much like a machine room.

Also, the 1 hour fire rating between the machine room and an occupied space as called for in 8.11 may have a real impact on some low charge systems. This is because some low charge systems are small packaged or enclosed systems, wherein it is difficult or costly to provide such a fire rated partition. This is another example of where the code writing body should incorporate changes that represent safe ammonia TQ's for which the 1 hour fire rated partition is of no benefit.

IIAR-2

The next regulation or standard to consider is *IIAR-2, Equipment, Design, and Installation of Closed-Circuit Ammonia Mechanical Refrigeration Systems*. At the time of authoring this paper IIAR-2 is under major revision and out for its third public review. The formal issuance of the new IIAR-2 is anticipated to be in early to mid-2015, and contains a large number of changes to the last issuance in 2008, many of which are related to the subject of this paper. (Note that references to the draft standard is subject to change before final publication.) One of the reasons the Standard has undergone a major rewrite is to help close the gaps in differing requirements between ASHRAE-15, UMC, NFPA-1, IMC and the IFC. The revisions to this standard have also been undertaken to transition it to a "safety standard" as opposed to being a "design standard." Therefore, because of these significant reasons, the following review in Table 3 is based on the public review version #3 issued in November 2014, in lieu of the current formally adopted 2008 version.

SECTION	THRESHOLD	ACTION OR REQUIREMENT
2.2 Definitions	No Threshold	Draft Standard now includes basic definitions of "Equipment Enclosures" and "Packaged Systems."
4.2	Equipment Locations	"Ammonia Refrigeration Machinery" does NOT have to be located in a Machine Room if: • The charge is less than 6.6 lb. It can then also be used for any occupancy. • It is located outdoors (other criteria apply) • For Industrial Occupancy if compressor HP is less than 100 • For Public Assembly, Commercial & Large Mercantile Occupancies if complete charge discharge into room(s) does not exceed 300 PPM
5.5	Secondary Coolants	Ammonia refrigeration machinery located in a machinery room or outdoors shall be permitted to be used in conjunction with a secondary coolant that serves any occupancy, provided that the system is one of the following types and that use of the secondary coolant is in accordance with the Mechanical Code: 1. Indirect closed system. 2. Indirect open-spray system (other criteria apply). 3. Double-indirect open-spray system.
5.6.1.2	Less than 22 lb	Portions of the system that are protected by a pressure-relief device shall not be required to have a design pressure that exceeds the set pressure of the pressure relief protection
5.14.1	Access – No TQ	Equipment shall be accessible for maintenance, as required by the Mechanical Code.
5.14.6	Isolation valves	Packaged systems and portions of built-up systems shall be permitted to have pump-down arrangements that provide for the removal or isolation of ammonia for servicing one or more devices in lieu of isolation valves
5.18	Equipment Enclosures	Very general criteria provided

SECTION	THRESHOLD	ACTION OR REQUIREMENT
6.2	Machine Rooms	Shall be separated from the remainder of the building by tight-fitting construction having a one-hour fire-resistance rating. Exception granted if room has automatic fire sprinklers
6.7	Access & Egress – No TQ	Must comply with building code, mechanical code and manufacturers recommendations
6.3.3	Access to valves – No TQ	Emergency valves must be accessible from floor level or provided with a platform or chain operated.
6.7.1	Eyewash/Safety Shower – No TQ	Must have minimum of one within 55 ft.
6.8.2	Electrical – No TQ	Machine rooms that do not meet ventilation requirements must be designed as Cl.1/Div.2/Gr.D Hazardous classification
6.14.8.1	Limited Charge Systems	Emergency mechanical ventilation shall not be required for a limited-charge refrigeration system that will not yield an ammonia concentration exceeding 40,000 ppm in the machinery room following a release of the entire charge from the largest independent refrigerant circuit,
7.2	Equipment Located Outside of a Machine Room	The area containing the system or equipment must have: • Separation from other occupancies by tight construction • Restricted access • Egress per building code • Ammonia detection & alarms • Physical protection • Suitable for environment • Lighting • Access per mechanical codes • Penthouses open to refrigerated space are considered part of the space, while those that are isolated from the space are considered equipment enclosures per 5.18

SECTION	THRESHOLD	ACTION OR REQUIREMENT
7.3	Not exceeding 100 HP	Complete systems with less than 100 HP compressor power not in a Machine room shall: • Have emergency ventilation. If entire release under 40,000 PPM. Ventilation is not required. • Ammonia detection & alarms
14	Packaged Systems	• Access & clearances to be per manufactures requirements, and allow for safe egress • If enclosed, ventilation for proper operation of equipment & emergency ventilation in case of leak is required. • Contain pump out connections • Designed for applicable low & high ambient conditions • Proper labeling required • If enclosed, ammonia detection required • Piping & installation shall comply with IIAR-2 and referenced standards • Unit to be pressure tested & shipped with Nitrogen holding charge.
15	Pressure relief – No TQ	Requirements for pressure relief devices & piping same for low charge system & typical systems.
17	Ammonia detection – No TQ	Requirements for ammonia detection same for low charge system & typical systems.

Table 3. IIAR-2 (Public Review #3)

IIAR-2 reinforces the numerous requirements associated with a machine room as ASHRAE-15 dictates. However, it did not contain the 100HP compressor power threshold ASHRAE states, below which not having a machine room is permissible.

The public review version of IIAR-2 outlined above shows that there could be some significant additions to the code relative to low charge systems if this version is adopted as written. This includes the 100 HP compressor threshold, outline of equipment enclosures, a fairly detailed set of criteria for packaged systems and ventilation design criteria for limited charge systems. Presently, the ventilation criteria is the first time a code has addressed reduced ventilation criteria specifically for low charge ammonia systems.

Section 4.2 does a good job of specifying the different locations that refrigeration equipment can and should be located in a facility, along with the associated thresholds that stipulate the proper location. This information is helpful regarding low charge packaged systems, which often arrange equipment in different locations than typical field erected ammonia systems.

A noteworthy proposed deletion from the current 2008 version of IIAR-2 is detailed criteria pertaining to access requirements, which states "all serviceable components".... are to have a "readily accessible opening and passageway not less than 36" in width by 7.25' in height for equipment and components of the system requiring routine maintenance". In the current public review issue this requirement has been replaced with "Equipment shall be accessible for maintenance, as required by the Mechanical Code." This change is most likely due to the fact that there is some variation between the mechanical codes on this subject and the specific criteria can be set by the local AHJ mechanical code. The "36" in width by 7.25' in height" access requirements also appear in the Uniform Mechanical code (UMC) so additional discussion can be found at the end of that section. This is an important issue relative to packaged low charge systems so the reader is encouraged to review that section of the UMC.

The above IIAR items are all very helpful to the continued development of low charge systems as they provide design criteria where little existed before. Hopefully, by the time his paper is formally issued, the Public Review #3 version outlined above will be adopted as the new IIAR-2.

International Building Code

All states and most local jurisdiction have adopted required compliance with the International Building Code (IBC) for the construction of buildings or facilities. IBC is a model building code developed by the International Code Council (ICC) and has been adopted throughout most of the United States. It contains a few specific refrigeration requirements as shown in Table 4, but refers you to the International Mechanical Code (IMC) for more comprehensive requirements of refrigeration systems.

SECTION	THRESHOLD	ACTION OR REQUIREMENT
IBC, Sec. 101, 101.4.2	Refers refrigeration systems to IMC	Must adhere to International Mechanical Code (IMC)
1015.4 & 5	Machine Room & Refrigerated Spaces	• Machine Rooms or refrigerated spaces > 1000 sq. ft. must have no less than 2 exits • Occupant must be within 150 ft. of an exit in a M.R. • Door swing in direction of egress
1613.1	Seismic	Every structure, and portion thereof, including nonstructural components that are permanently attached to structures and their supports and attachments, shall be designed and constructed to resist the effects of earthquake motions….. The *seismic design category* for a structure is permitted to be determined in accordance with Section 1613 or ASCE 7.

Table 4. Review of International Building Code (IBC) Regulations

Even though IBC refers you to IMC for refrigeration systems, it still can be the governing code related to seismic compliance, which is an important issue for our topic. Five editions of the IBC (2000, 2003, 2006, 2009 or 2012) have been adopted and are effective at the local or state level in all 50 states. Once adopted, the IBC provisions become enforceable regulations governing the design of buildings structures and mechanical and electrical components. This can have significant implications for ammonia systems that have high seismic design criteria related to the sites Seismic Design Category (SDC), the classification assigned to a structure based on its occupancy category, and the severity of the design earthquake ground motion, or Design Spectral Accelerations (SDS & SD1 factors).

The implications of these requirements on typical field erected ammonia systems versus the packaged low charge systems can be significant for sites that have high seismic impact on the structural design of the system. The obvious benefit of low charge systems is refrigerant safety and the reduced amount of ammonia in a system that could be subject to a seismic event versus a larger amount of ammonia in a "typical" system. Packaged low charge systems can also be better suited to address seismic compliance needs, than the larger field erected systems, which are much more dispersed throughout a building or facility and could have more acceleration points. Packaged systems, with shorter piping runs and close coupled, smaller equipment, naturally result in a more structurally robust system. It is also more feasible for manufacturers of standardized packaged systems to obtain pre-approved IBC compliance through analysis or even shake table testing. Since field erected ammonia refrigeration systems are project specific, each specific design must be analyzed and the specific design needs to be complete before an analysis can occur. Whereas, the compliance liability for pre-engineered packaged systems resides more with the manufacturer of the packaged system than the building engineer or contractor.

International Mechanical Code

The International Mechanical Code (IMC) shown in Table 5 has been adopted by 46 states (partially in some states at the local level) for regulated compliance and contains a lot of the same requirements as ASHRAE-15 and IIAR-2. In fact it stipulates compliance with IIAR-2 for ammonia systems. Noteworthy, it does permit limited ammonia applications for comfort cooling in certain non-industrial occupancies for indirect systems and if the charge is extremely small at 6.6 lb for indirect systems. With the development of new low charge packaged systems, particularly indirect systems, this TQ should be raised.

IMC, like ASHRAE, also has an allowance for an ammonia refrigeration system, in an industrial occupancy, to be located outside of a machine room, provided several criteria are met. These criteria are listed under section 1104.2.2 in Table 5, including the same 100 HP threshold contained in ASHRAE. This is a useful allowance, however, the 100 HP value does not have a fixed relationship to a specific quantity of ammonia, which is the more important value. A 100 HP system could have a large range of capacity (TR's) and/or charge (lb/TR), making it an ambiguous TQ related to ammonia charge. Therefore, it is recommended that the code writing bodies develop a TQ based on an acceptable ammonia charge value to replace the 100 HP value. For example, this value could be based on maximum concentration (PPM) levels of ammonia that are permissible for such a space. This would be beneficial because it could also apply to parts of a system that did not contain a compressor motor, such as an area that contained a pumped liquid recirculation package, which is far below 100 HP, but could contain a large quantity of ammonia.

SECTION	THRESHOLD	ACTION OR REQUIREMENT
1101.2	Is system UL listed?	If not then must comply with this code. If the system is UL listed then it is deemed to meet this code.
1101.6	Refrigeration System	Must comply w/ASHRAE 15 & IIAR-2
1103.2	Occupancy	Occupancy class is industrial for typical applications
1103.3	System type	Low-Probability System and High probability systems mirror ASHRAE-15 definitions
1104	Machine Room	Criteria for requiring a Machine Room same as ASHRAE 15
1104.2	6.6 lb	Machinery rooms are not required below system charge of 6.6 pounds
1104.2.1	Institutional occupancies – Maximum of 550 lb in Machine Room	can use ammonia if occupancy concentration limit is 50% of ASHRAE value of .014 lb/1000 FT3 (or .007 lb/1000FT3) and the maximum permissible ammonia charge must be below 550 lb
1104.2.2	No Machine Room	Permitted only in Industrial Occupancies and refrigerated rooms for manufacturing (processing rooms), if the following conditions are met: • Equipment area separated from other occupancies by tight construction and doors • Restricted access • 100 sq. ft. per occupant minimum • Refrigerant detection • Maximum 800F surface temp. • Equipment ≤ 100 HP drive power
1104.3.1 & 2	Air conditioning for comfort cooling other than Industrial occupancy	Ammonia cannot be used unless it is an Indirect system or the total direct system charge is below 6.6 lb

SECTION	THRESHOLD	ACTION OR REQUIREMENT
1105 & 6	Machine Room	Requirements: • .2–any low pressure ducts must be sealed • .3–ammonia detection per IFC • .4–periodic tests of ventilation • .5–no fuel burning appliances • .6–must have ventilation as specified • .7–relief devices terminate outside 15" and/or 20' away from the ground or machine room opening • .8–ammonia discharge per ASHRAE 15 • .9–must have emergency pres. control station per IFC! Special Requirements: • Emergency ventilation required • Emergency stop switch • Emergency ventilation switch • Emergency signage per IFC
1107.2	Access – No TQ	Piping over passageways must be 7'-3" above floor unless against ceiling.
1107.8	Equipment Valves	Same locations required as ASHRAE.
1107.8.1	100 lb	Systems with 100 lb or more charge shall have stop valves on inlet to receiver.
1108	Pressure testing	Pressure testing required for field erected systems.
1108.4	55 lb	Test certificate required for all pressure tests on systems with over 55 lb

Table 5. Review of International Mechanical Code (IMC) Regulations (2012)

Uniform Mechanical Code:

The Uniform Mechanical Code (UMC) shown in Table 6 contains many of the same fundamental requirements of ASHRAE-15 and specifies compliance with IIAR-2 for ammonia systems. Of note, it explicitly states that "Refrigerant quantities in evaporators and piping with rooms or spaces used exclusively for processing or storage of materials under refrigerated conditions shall not be limited, provided that exiting is provided per the Building Code and…." the space has leak detection and is sealed from other parts of the building. Other noteworthy items with no ammonia threshold include:

- Ammonia equipment & piping must have supports and anchorage designed in accordance with the requirements of Building Code Occupancy Category H hazardous facilities, even if the building occupancy category is not H.
- 1 hour fired rated separation from exits and machine rooms with $>$ 5HP compressors or $<$ 10 Ft away.
- Access clearances more definitive than IIAR.
- Ammonia discharge shall go into a water dispersion tank.

The important take-away from the above items is, no ammonia threshold for the listed requirements, so they apply to all ammonia systems, regardless of the charge quantity. This is an example of where the code should be modified to relax these respective requirements, or incorporate specific ammonia TQ's for low charge systems, because it would then help promote system charge reduction. If water dispersion tanks are required on packaged low charge ammonia systems, many of which are 3 to 5 lb/TR of refrigerant charge, it very well could discourage contractors and end users from purchasing and installing them, and instead opting for the traditional systems which contain much larger quantities of ammonia. Additional discussion on this topic can be found in the next section titled International Fire Code.

UMC does contain an ammonia TQ, wherein if a system contains less than 35 lb of ammonia it does not require a machine room. However, 35 lb is extremely low as compared to the large refrigeration loads that exist in typical ammonia systems. Despite this, for low charge systems, particularly small packaged systems, it could be an advantageous threshold to achieve. Conceivably, if a small packaged system has less than 35 lb of ammonia it could be an enclosed "reach in" style package (as opposed to walk-in style), similar to what is commonly available with HCFC or HFC ("Freon") roof top air-conditioning equipment. However, robust safety measures must be incorporated into such a design to adequately protect personnel during service and maintenance activities. Even for an ammonia system with less than 35 lb a water dispersion tank is required. This proves the need for implementing additional TQ's into the code which allow for relaxing of code requirements at lower specific charge thresholds.

SECTION	THRESHOLD	ACTION OR REQUIREMENT
1105.3	Evaporator & piping in refrigerated space	Ammonia quantity shall not be limited, just need leak detection and sealed room
1106.2	Supports & anchorage – No TQ	Must comply with Building Code Occupancy Category H hazardous facilities for supporting the ammonia equipment & piping, even for buildings classified as non-hazardous occupancy.
1106.8	Compressors > 5HP shall be at least 10 Ft. from an exit	If less than 10 Ft. then must be separated by 1 hr. fire rated wall.
1107.1.4, (4)	< 35 lb and located in an approved exterior location	If system has less than 35 lb R-717 it does not need a machine room
1107.2	Access – No TQ	36"W x 80"H passageway access for maintenance & operation. Wording is more definitive than ASHRAE, IIAR and IMC.

SECTION	THRESHOLD	ACTION OR REQUIREMENT
1108.7	Ventilation Discharge Treatment	Not required for Ammonia
1120.0	Water Diffusion Tank – No TQ	Water Diffusion Tank required for Ammonia
1122.0	Emergency Pressure Control System – No TQ	Needed when required by AHJ fire code
1123.0	> 3 Ft3 internal volume & > 10 HP	Labeling & signage required
1124.4	55 lb	Test certificate required for all pressure tests on systems with over 55 lb

Table 6. Review of Uniform Mechanical Code (UMC) Regulations (2009)

As shown in section 1107.2 of the UMC, access passageways of 36" wide x 80" high are required for operation and maintenance to serviceable items. This criterion was also mentioned in the earlier section on IIAR-2, as an important item for packaged low charge systems and here is why. It is common in modular or packaged low charge systems that the physical size of the system and its components have been reduced, as compared to a typical ammonia system, in an effort to reduce the internal refrigerant volume and charge. This in turn facilitates the system to be packaged and enclosed. This is where the maintenance access requirements in IIAR, ASHRAE and UMC have a meaningful impact. The required access passageways can be difficult to accomplish in a packaged low charge or enclosed system, where one of the goals is to also reduce the physical size of the components and system, however, this access requirement is very important to provide in order to assure the safe operation and maintenance of the equipment.

Successfully balancing the reduction in physical sizing criteria, to reduce the charge, with that of component accessibility requirements is very important. In addition, for large loads, multiple packaged low charge modules or systems may be required, versus the typical larger field erected ammonia systems that have a central machine room that is piped to the remote evaporators to serve the loads. This results in different access scenarios for each system type that may be difficult to compare one system type to another. For example, a typical field erected refrigeration system may have valves or instruments that have the required access clearance, but could be located high above the floor in a tall machine room, requiring a lift or ladder to reach them. Conversely, a packaged low charge system could have those valves and instruments at an easy to reach elevation within the packaged machine room, but the packaged system could be located on the roof, requiring operators to go to the roof to access them.

International Fire Code

The International Fire Code (IFC) is in use or adopted in 42 states (partially in some states at the local level). It specifies a 30 lb threshold for requiring access to all ammonia equipment, periodic testing of safety controls as well as signage requirements. However, the noteworthy items in Table 7 are certainly the requirements for Emergency Pressure Control Systems (EPCS) and Ammonia Water Diffusion. These two items have created some challenges in the refrigeration industry for years, however it is believed the IFC will modify or relax these requirements in its upcoming revision expected in 2015. In its current form, IFC requires both items regardless of the quantity of ammonia in permanently installed systems so it could apply to all systems (except for system charges below 6.6 lb, the Emergency Pressure Control Systems are not required).

Common practice for the EPCS and Dispersion Tank requirements is outlined below.

- EPCS: Provide an emergency pressure control system (EPCS) consisting of pressure sensors, independent compressor cut-off controls and automatically controlled crossover valves that will permit a high-pressure portion of a system to connect to a lower pressure portion of a system when opened. Note that the EPCS replaces the historically more complicated, manual valve, pressure control panel ("Dump Panel").

- Ammonia Water Diffusion Tank: In jurisdictions governed by the IFC (or UMC) a Diffusion Tank is required. Alternatives and exceptions may be permitted on a project by project basis, from the applicable AHJ fire code official to eliminate the requirement for an ammonia "treatment system" (Diffusion into a water tank). This allowance has been added to IFC in section 606.12.5. This is often granted because ASHRAE-15 already permits atmospheric discharge via properly designed and installed relief discharge systems (unless the UMC or the California Mechanical Code has jurisdiction at the site as well).

There are no TQ's in the IFC, other than the very low 6.6 lb, so low charge systems must provide the required access, testing, machine room characteristics, EPCS and Diffusion tank as typical ammonia systems are required to do. However, they should be able to attain an exception from fire code officials, for not having to provide discharge treatment systems (dispersion tank), since the potential discharge should be significantly smaller than typical systems.

SECTION	THRESHOLD	ACTION OR REQUIREMENT
606.5, 6 & 7	30 lb	• Access required to equipment • Periodic testing of safety controls • Signage
606.8	Machine Room.	• Leak detection & ventilation • Remote controls for Emergency equipment shutoff & ventilation
606.10	Emergency Pressure Control System	Requires emergency pressure control system for systems > 6.6lb of ammonia
606.12.3	Ammonia Diffusion Tank	Requires ammonia "treatment system" (dispersion into water tank), "or other approved means." Exception also permitted when allowed by fire code official

Table 7. Review of International Fire Code Regulations

OSHA

Since its adoption in 1991, OSHA's 29CFR 1910, and its Process Safety Management (PSM) safety program, has been one of the leading regulations regarding the use of ammonia. Its 10,000 lb threshold quantity for ammonia, above which it is mandatory to comply with PSM's 14 prescriptive sections (see Table 8), has been very impactful over the years and created industry attention to the size of the ammonia charge in industrial refrigeration systems. The increasing adoption rate of indirect systems, using secondary cooled fluids, over the last two decades is in great part due to the effort to reduce system ammonia charges because of the implications of the PSM regulation, and the desire to remain below the 10,000 lb threshold.

Although not covering systems below 10,000 lb, PSM has still set the safety criteria benchmark for ammonia refrigeration systems below 10,000 lb as well. The requirements for PSM are very comprehensive and good for the industry, however the compliance burden it has set has proven to be a significant financial and liability hurdle. The 10,000 lb threshold is such an impactful regulatory hurdle that owners and designers of refrigerated facilities actively develop system and plant designs in an attempt to stay below the threshold.

Beyond the PSM program OSHA can inspect facilities of all sizes and enforce safety guidelines it deems appropriate under its General Duty Clause 29 U.S.C. 654, 5(a) 1. Under this authority a facility could be held culpable by OSHA for willful or repeated violations of applicable safety regulations or standards. Since many best practices and generally accepted safety standards are contained within the PSM program, it is in an owner's interest to understand the requirements of the PSM program even if they do not reach the 10,000 lb TQ.

OSHA is currently in a formal review process of the PSM regulation as a result of Presidential Executive Order 13650 and the Texas fertilizer plant explosion in 2013. It is believed at the time of this writing that the 10,000 lb threshold will not be altered as part of the current review process, however it is possible that it could be in the future. Table 8 outlines the above named OSHA regulations.

SECTION	TRESHOLD	ACTION OR REQUIREMENT
OSHA: 29CFR 1910.119	10,000 lb or more	Must comply with the 14 sections of Process Safety Management (PSM) regulation: 1. Process Safety Information 2. Process Hazard Analysis 3. Operating Procedures 4. Training 5. Contractors 6. Mechanical Integrity 7. Hot Work 8. Management of Change 9. Incident Investigation 10. Compliance Audits 11. Trade Secrets 12. Employee Participation 13. Pre-startup Safety Review 14. Emergency Planning and Response
OSHA 29 U.S.C. 654, 5(a) 1:	General duty clause	No threshold on charge. The General Duty Clause reads" "(a) Each employer: (1) shall furnish to each of its employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees; (2) shall comply with occupational safety and health promulgated under this Act. (b) Each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to this Act which are applicable to his own actions and conduct. The expectation in the industry is that the General Duty Clause is used by OSHA to take action against willful or repeat violations.

Table 8. Review of Occupation Health& Safety Administration Regulation

EPA

The handling of ammonia is subject to several federal environmental regulations, most of which are imposed by the Environmental Protection Agency (EPA). Their intent is obviously related to the possible release or spill of ammonia to the environment. The primary EPA regulations relative to ammonia include those issued by:

- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
- Emergency Planning and Community Right-to-Know Act (EPCRA)
- Hazardous Material Transportation Act (HMTA)
- Risk Management Plan (RMP)
- Clean Air Act (CAA)

Local AHJ's are also very important to the EPA regulations, as they are part of the first responders to ammonia releases. This includes:

- Local Emergency Planning Committees (LEPC)
- State Emergency Response Commission (SERC)

Table 9 below identifies several important ammonia TQ's that can be considered in the design and installation of low charge systems.

SECTION	**THRESHOLD**	**ACTION OR REQUIREMENT**
EPA: CERCLA, Sec. 103(a)	100 lb Release in 24 hour period	Reportable Quantity (RQ) threshold wherein the release must be reported to the EPA's National Response Center (NRC)
EPA: EPCRA, Sec. 304(a)	100 lb Release	Reportable Quantity (RQ) threshold to State SERC & Local LEPC & Fire Dept.
EPA: HMTA	Release during transport causing injury, death, $50k damage, evacuation order or street closure	Notice to Department of Transportation. Research and Special Programs Administration (RSPA), required
EPA: EPCRA 302 & 303	500 lb "TPQ"	Must provide emergency planning & must report to SERC & LEPC when they reach Threshold Planning Quantity (TPQ).
311	500 lb	Must submit MSDS to SERC & LEPC.
312	500 lb	Must submit annual inventory report to SERV & LEPC
313	10 employees & 10,000 lb	Must submit form "R" to EPA & SERC
EPA: RMP, CAA 112	10,000 lb	Off-site consequence analysis and increasing RMP tiers: • "P3" criteria & Full PSM • Hazard Assessment • Response Plan • Management Plan • Prevention Plan

Table 9. Review of Environmental Protection Agency Regulations

Other Regulations and Codes

Outlined in Table 10 are a few other notable federal regulations affecting the use of ammonia. Included at the bottom of the table is Executive Order 13650 and the related CFATS program which are new to the industry. These are currently being rolled out by the Department of Homeland Security (DHS) to industries containing hazardous chemicals which fall under the PSM regulation. As the program is still being developed, its eventual impact is not yet entirely known. The initial impact involves end users reporting their ammonia inventories and process information to DHS.

REGULATION	THRESHOLD	ACTION OR REQUIREMENT
Clean Air Act Sec 612	SNAP Program (Significant New Alternatives Policy)	Permits ammonia as an acceptable alternative to CFC's and R-502
NPDES (Clean Water Act)	To discharge ammonia to lakes, rivers, streams, etc.	Must Obtain NPDES PERMIT
CERCLA (Transportation Regulations)	RQ of 100 lb	Requires specific labeling and reporting for shipments great than 100 lb NOTE: low charge systems will benefit from easier compliance due to smaller shipments of refrigerant
Executive Order 13650	Facilities subject to PSM	The Executive Order directs the Federal Government to improve operational coordination with state and local partners; improve Federal agency coordination and information sharing; modernize policies, regulations, and standards; and work with stakeholders to identify best practices

REGULATION	THRESHOLD	ACTION OR REQUIREMENT
CFATS	Facilities subject to PSM	As part of Executive Order 13650, changes could be coming to the Chemical Facility Anti-Terrorism Standards, or CFATS, program run by the Department of Homeland Security, which could mean the agency will issue revised regulations and seek increased collaboration within the ammonia refrigeration industry

Table 10. Review of Miscellaneous Regulations

Notable State Requirements

California Mechanical Code

The California Mechanical Code (CMC) has historically followed the UMC so the requirements are very similar with some nuances as highlighted in Table 11. The occupancy and refrigerant concentration threshold limits are of course based on ASHRAE standards. The most notable item in the CMC relevant to low charge systems is in section 1107.1, wherein if a system contains less than 35 lb of ammonia it does not require a machine room. This is the same allowance that is provided in the Uniform Mechanical Code so the discussion on this TQ will not be repeated here. In addition, the California Mechanical Code calls for the use of ammonia-water diffusion tanks, which can be a challenge to provide for the packaged or modular style low charge systems, since this device is typically configured for large central plant or machine room configurations. A waiver from the AHJ, eliminating the need for a dispersion tank, should be sought for low charge systems as outlined in the IFC section above.

SECTION	THRESHOLD	ACTION OR REQUIREMENT
1105.2 & 3	Classification	Occupied space classification includes refrigerated storage and machine room areas. Exception granted if ammonia detection in room and room has vapor tight doors
1106.3	Access – No TQ	36"W X 80"H unobstructed access or opening shall be provided to compressor and "portions of the system requiring routine maintenance. — Exception granted for ceiling hung evaporators.
1107.1(4)	35 lb	If system has less than 35 lb R-717 it does not need a machine room
1107.2	Access – No TQ	Unobstructed walking space of 36" width x 80" high required on (2) sides of moving machinery and approaching stop valves
1107, 8 & 9	Machine Room	Machine Rooms to have: • Refrigerant detection and ventilation • Separation from other portions of building • Exhaust system to limit temp to 104°F and emergency purge for ammonia at 30 air changes/hr. • Break glass type switch outside M.R. to shut off equipment
1117.2	Vessels	Pressure vessels $<$ 10ft.^{3} can use a single relief valve
*1120	Fire	Ammonia water dispersion tank shall be provided
1122.1	Fire	Emergency pressure control system shall be provided when required by the fire code
1123.2	System Label	Equipment having an internal volume greater than 3ft.^{3} shall have a permanent label stating the refrigerant type
1123.3	10 HP	System of more than 10 HP shall have a permanent sign in the M.R. stating name of installing contractor, refrigerant name & number, and charge (lb)
1124.2	Pressure Test	Components and systems that are factory pressure tested do not need to be field pressure tested
1124.4	55 lb	Field testing for system with more than 55lb Shall have a "Declaration" signed by installer

Table 11: Review of California Mechanical Code

California Energy Code – Title 24

Title 24, which is specific to the state of California, does not have threshold quantities of ammonia, however, Section 120.6, (a) does distinguish between Refrigerated Spaces larger than 3,000 square feet that are served by a central machine room (common compressor and condensers) versus those that are not (i.e. served by separate compressors and condensers). Both system types must comply with the rules for thermal insulation, underfloor heating, evaporators, infiltration barriers and system acceptance. However, if a system is not served by a common machine room, and has separate compressor and condensers, then there is an exception granted for having to comply with the rules applying to compressors and condensers under 120.6, (a) 4. & 5. of the regulation. As a result, this exception would benefit packaged systems (and low charge packaged systems) that serve separate areas of the refrigerated spaces, as it would alleviate some of the requirements for variable speed drives and system control criteria

California Accidental Release Prevention – CalARP

The purpose of the CalARP program is to prevent accidental releases of the regulated substances, minimize the damage if releases do occur, and to satisfy community right-to-know laws. This is accomplished by requiring businesses with a process that contains more than a threshold quantity of a regulated substance to develop a Risk Management Plan (RMP). For ammonia, CalARP has established a threshold of 500 lb for the enforcement of varying levels of RMP programs. The 500 lb TQ applies to a "process" that is defined as "any group of vessels that are interconnected, or separate vessels that are located such that a regulated substance could be involved in a potential release, shall be considered a single process". Therefore, as practiced, standalone individual closed loop ammonia refrigeration systems, that are separated, each have an individual 500 lb TQ. This is of great benefit to individual low charge systems that contain less than 500 lb because, even if a facility contains multiple independent systems under 500 lb, the facility should not be subject to the CalARP program.

If a facility (or a system) does exceed the 500 lb TQ it leads to three levels, or "Programs," of prescribed enforcement. A refrigerated warehouse, or food and beverage facility, falls under Program 1 if it has had no significant accidents (as defined) for 5 years, or alternatively under Program 2 if it has (other criteria apply as well).

Program 1 requires an analysis of the "worst cast release scenario," "five year accident history," coordination with local responders, and criteria for responders to not enter the release area. In addition, if a user falls under Program 2, he must implement an RMP Management System, conduct a hazard assessment, implement defined "prevention steps" and implement an emergency program.

As a result, there are clear and tangible benefits to having a "process" ammonia charge fall below the defined threshold of 500 lb. If an owner is able to keep his charge(s) below this level he may avoid a significant amount of state enforced regulatory work, oversight and associated cost.

Review of New Jersey Regulations

New Jersey's regulations NJSA 34:7 and NJAC 12:90 for Boilers, Pressure Vessels And Refrigeration Plants, establishes requirements for state licensing of operators of non-Group 1 refrigeration systems (of which ammonia is one), as well as state inspection rules and criteria. These state laws have very effectively limited the use of ammonia in New Jersey by imposing requirements that only state licensed individuals may operate ammonia refrigeration systems larger than the threshold of 24 TR's. This licensing requirement is enforced with fees and penalties for non-compliance by the Department of Labor's Division of Workplace Standards, while annual inspections are also conducted for ammonia systems above the threshold of 3 TR by the Mechanical Inspection Bureau. The costs and regulatory burden imposed by these NJ laws above 24 TR and 3 TR thresholds have no association with the amount of ammonia in a refrigeration system and have deterred its use, regardless of any attempt to reduce the ammonia charge in a system.

The NJ regulations outlined above are not expected to change in the near future, however, there has been some recent indication that the NJ Department of Labor may provide temporary relief for some of the requirements on a project by project basis if the following thresholds are met:

- Ammonia system to be in compliance with IIAR-2.
- The total system charge is less than 5,200 lb as called out in NJ's Toxic Catastrophe Prevention Act (TCPA) Program.
- The facility has an operating engineer who has been certified by RETA.
- The ammonia system has an automatic control system.

From a long term perspective, if the existing New Jersey regulations were to be formally revised by adopting the above criteria, it would be a step in the right direction. The justification for changing the NJ regulations is recognition of the significant increases in federal laws and regulations governing the use of ammonia, since the NJ law was originally adopted in 1986. Since that time the implementation of OSHA's Process Safety Management program, and the comprehensive code development of IIAR, have established robust ammonia regulations, safety standards, best practices and operational criteria. In addition, the benefits of low charge systems should, at a minimum, allow for the implementation of ammonia TQ's, below which licensing is not required.

Conclusion

Coupled all together, ammonia's environmentally friendly attributes, new low charge system technology, existing federal regulation and robust code enforcement bodies, are all documented milestones that should strongly influence state regulators to deregulate the use of ammonia over time. This can happen by empowering federal regulators and national code writing bodies to integrate new ammonia TQ's into the existing regulations and codes, which reflect the safety, environmental and efficiency benefits of ammonia, and promote reduced charge systems. These synergistic events need to motivate regulators to keep up with the technological developments inherent in the new low charge systems and represent these developments in the regulations.

Bottom line: the regulations and codes outlined in this paper, to a great extent, treat low charge systems and "typical" systems much the same, and that is the problem. Most of the criteria contained in the listed codes and standards applies to both types of systems and must be complied with regardless of the amount of ammonia in the system. There are certainly some differences as identified but since low charge systems are relatively new, many of the requirements are the same for both system types. This may be a motivation for code writing bodies to consider the differences with greater scrutiny and over time update the codes as deemed appropriate. This will certainly incentivize the industry to continue to reduce the quantity of ammonia contained in refrigeration systems. A good example of this is the current IFC requirements for EPCS and Water Diffusion Tanks, which should have a new TQ established in the code to allow low charge systems to not have to include these items.

The industry and regulating authorities have already set in motion the evolving trend of reducing the amount of ammonia contained in refrigeration systems due to safety requirements. Therefore, the industry stake holders need to have quality information that promotes informed decisions. The review outlined above is one of many ongoing efforts to provide this information. Some of the highlights can be summarized as follows:

- The regulatory reviews outlined above show that the code writing bodies have done a good job thus far in developing similar code requirements with limited contradictions or conflicts between them.
- All ammonia systems require a machine room and its mandated attributes. There are a couple exceptions to this like ASHRAE-15's 100HP and below threshold or California's 35 lb and below threshold. Another example of this requirement is a packaged ammonia system that has an enclosure over it. If the enclosed package has no refrigerant detection, ventilation, sufficient access, emergency controls, or

all the other required safety provisions, it must itself reside within a sealed room that contains all the attributes of a machine room in order to satisfy all of the code requirements (unless it is located outdoors).

- Due to the safety issues with ammonia, a common theme throughout the codes is the requirement to maintain sufficient access for operations, maintenance and emergency activities. Since some of the exciting new low charge technologies involve packaged or enclosed modular systems, where space is at a premium, it is important that the required access be provided.
- OSHA's General Duty Clause regulation makes it very important for designers, installers and owners, of all types and sizes of ammonia refrigeration systems, to understand the safety intent of the 29CFR1910.119 PSM regulation, even for systems below the 10,000 TQ. This is because the content of PSM programs have become the industry's benchmark for "best practices".
- A notable allowance through all the codes are systems that have sufficient pump-out provisions, and are permitted to not contain isolation valves on the compressor, condenser and receiver. This is common practice in the commercial packaged Freon air-conditioning market, but is certainly new to the ammonia market. The industry will need to reconcile this difference.
- Seismic code compliance is an important element of ammonia system design and installation. Low charge systems can help mitigate this requirement and risk.
- As the industry continues to successfully develop low, and lower charge ammonia systems, the application of these products can expand into other air-conditioning and process cooling applications, provided the relevant code writing bodies allow it. Where this will have great benefit is for owners that require or desire a "natural refrigerant" but have limited solutions currently available. Low charge packaged ammonia cooling systems are the solution that can serve this need. In addition, if an owner is building a LEED facility, the use of ammonia can earn him a LEED point because of its 0 ODP and 0 GWP ratings.

The list of regulations and codes outlined herein is long, and it becomes even longer when we add the many others not included. This becomes even more daunting when you consider the new regulations that have been recently enacted such as Executive Order 13650. In a parallel path, the world of "Freon" refrigerants has its own long list of regulations and they are changing more rapidly than the ammonia regulations, due to federal activism related to climate change policy. A strong example of this is the recently proposed accelerated phase out of HFC R-507 and R-404A under the Significant New Alternatives Policy (SNAP) Program. As a result, users of ammonia refrigeration systems have no good alternatives that can universally compete with the superior performance of ammonia. The answer to this dilemma is leveraging ammonia's superior energy efficiency, 0 ODP, 0 GWP and cost effectiveness through low charge systems, and implementing regulatory and code changes that promote and facilitate the low charge trend.

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