RAGAGEP: CODES, STANDARDS, AND GOOD ENGINEERING PRACTICES

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Introduction

The arena of codes, standards, and regulations can be confusing, frustrating, and often intimidating. The barrage of acronyms: IMC, UMC, IFC, ASHRAE, IIAR, etc. can stump even a seasoned engineer trying to answer the simple question, "What am I required to do?". To complicate matters, model codes and standards are regularly revised, often on a three-year cycle, which causes many to feel as though they are trying to hit a moving target. It is the intention of this paper to attempt to bring clarity to the topic of "*recognized and generally accepted good engineering practices*" (RAGAGEP) for the ammonia refrigeration industry by providing an overview of codes, standards, and practices that make up the core of RAGAGEP. Emphasis will be placed on the International Institute of Ammonia Refrigeration's (IIAR) suite of standards which address minimum best practices for all aspects of ammonia refrigeration systems from initial design until final decommission. Additionally, this paper will attempt to address the following important RAGAGEP issues:

- Model Codes and Standards Applicable to Ammonia Refrigeration
- RAGAGEP Conflicts
- Grandfathering
- Addressing New RAGAGEPs

Regulatory Basis

Both the USEPA's Risk Management Program (Title 40 §68) and OSHA's Process Safety Management regulation (Title 29 §1910.119) are "performance-based" standards. This means that the government has defined "what must be done", but has not specified "how to do it". As a result, best practices for RMP-PSM implementation vary greatly between industries. The performance-based nature of RMP-PSM is best seen in the references to "good engineering practice" and "recognized and generally accepted good engineering practice" which are used in, and throughout both regulations:

Risk Management Program (RMP) RAGAGEP References

- **Title 40 §68.65(d)(2) Process Safety Information**
  The owner or operator shall document that equipment complies with **recognized and generally accepted good engineering practices**.
- **Title 40 §68.73(c)(2) Mechanical Integrity**
  Inspection and testing procedures shall follow **recognized and generally accepted good engineering practices**.
- **Title 40 §68.73(c)(2) Mechanical Integrity**
  The frequency of inspections and tests of process equipment shall be consistent with applicable manufacturers' recommendations and **good engineering practices**, and more frequently if determined to be necessary by prior operating experience.

Process Safety Management (PSM) RAGAGEP References

- **Title 29 §1910.119(d)(3)(ii) Process Safety Information**
  The employer shall document that equipment complies with **recognized and generally accepted good engineering practices**.
- **Title 29 §1910.119(j)(4)(ii) Mechanical Integrity**
  Inspection and testing procedures shall follow **recognized and generally accepted good engineering practices**.
- **Title 29 §1910.119(j)(4)(iii)) Mechanical Integrity**
  The frequency of inspections and tests of process equipment shall be consistent with applicable manufacturers' recommendations and **good engineering practices**, and more frequently if determined to be necessary by prior operating experience.

Additionally, both PSM and RMP require that the "information pertaining to the equipment in the process shall include: Design codes and standards employed" (Title 29 §1910.119(d)(3)(i)(F), Title 40 §68.65(d)(vi)). "Design codes" and "standards" are documents which address "good engineering practices" within the scope of the document. As such, "design codes and standards" are synonymous to RAGAGEP in the remainder of this paper.

RAGAGEP Regulatory Citations

This emphasis on RAGAGEP in RMP-PSM has resulted in a heightened importance on model codes, standards, and other industry literature. Both OSHA and EPA have used the RAGAGEP references contained within industry documents as the basis of RMP-PSM citations. Appendix A includes details from five separate instances of ammonia refrigeration facilities receiving OSHA citations for failure to comply with RAGAGEP. The citations are intended to demonstrate how RAGAGEP documents are used by government agencies during inspections.

Ammonia Refrigeration RAGAGEP

Not every document is considered RAGAGEP. Generally, a published document must be widely adopted (e.g. model codes) or developed through a consensus process to receive RAGAGEP status. OSHA issued an internal memorandum on May 11, 2016 regarding "RAGAGEP in Process Safety Management". In the memorandum, OSHA provides the following four examples of RAGAGEP:

1. **Widely adopted codes**
   Certain consensus standards have been widely adopted by federal, state, or municipal jurisdictions. For example, many state and municipal building and other codes incorporate or adopt codes such as the National Fire Protection Association (NFPA) 101 *Life Safety* and NFPA 70 *National Electric* codes.
2. **Consensus documents**
   Certain organizations like the American Society of Mechanical Engineers (ASME) follow the American National Standards Institute's (ANSI) *Essential Requirements: Due process requirements for American National Standards* (Essential Requirements) when

developing consensus standards and recommended practices. Under the ANSI and similar requirements, these organizations must demonstrate that they have diverse and broadly representative committee memberships. Examples of consensus documents include the ASME B31.3 *Process Piping Code* and the International Institute of Ammonia Refrigeration's (IIAR) ANSI/IIAR 2-2008 — *Equipment, Design, and Installation of Closed-Circuit Ammonia Mechanical Refrigerating Systems*. Such consensus documents are widely used as sources of RAGAGEP by those knowledgeable in the industry.

3. **Non-consensus documents**
   Some industries develop non-consensus engineering documents using processes not conforming to ANSI's Essential Requirements. Where applicable, the practices described in these documents can be widely accepted as good practices. For example, the Chlorine Institute's (CI) "pamphlets" focus on chlorine and sodium hypochlorite (bleach) safety and are used by some companies handling these materials. Note that OSHA also recognizes applicable manufacturer's recommendations as potential sources of RAGAGEP.
4. **Internal standards**
   The preamble to the PSM standard recognizes that employers may develop internal standards for use within their facilities. The preamble states, in relevant part:

   > The phrase suggested by rulemaking participants: "recognized and generally accepted good engineering practices" is consistent with OSHA's intent. The Agency also believes that this phrase would include appropriate internal standards of a facility…

RAGAGEP Organizations

There are numerous organizations which publish RAGAGEP documents which impact the ammonia refrigeration industry. The following is a summary of the key organizations:

<u>International Institute of Ammonia Refrigeration (IIAR)</u>

Founded in 1971, IIAR is the primary RAGAGEP organization for the ammonia refrigeration industry. The vision and mission of IIAR, as published on the IIAR website are:

- *Our **Vision** is to be globally recognized as the leading advocate for the safe, reliable and efficient use of ammonia and other natural refrigerants.*
- *Our **Mission** is to provide advocacy, education, and standards for the benefit of the global community in the safe and sustainable design, installation and operation of ammonia and other natural refrigerant systems.*

<u>ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers)</u>

ASHRAE was founded in 1894 and is the leading global organization that supports the larger HVAC&R industry. ASHRAE standards address a wide variety of topics including: Energy efficiency, building systems, indoor air quality, refrigeration, ventilation, and sustainability. The vision and mission of ASHRAE are:

- ***Vision**: ASHRAE will be the global leader, the foremost source of technical and educational information, and the primary provider of opportunity for professional growth in the arts and sciences of heating, ventilating, air conditioning and refrigerating.*
- ***Mission**: To advance the arts and sciences of heating, ventilation, air conditioning and refrigeration to serve humanity and promote a sustainable world.*

American Society of Mechanical Engineers (ASME)
ASME was founded in 1880 as a society of machine builders working together to address concerns of accelerating mechanization during the industrial revolution. Today, ASME has more than 130,000 members in 151 countries and publishes standards that address: Boilers, pressure vessels, process piping, welding, and heat exchangers. ASME's mission statement is:

- ***Mission Statement**: To serve diverse global communities by advancing, disseminating and applying engineering knowledge for improving the quality of life; and communicating the excitement of engineering.*

American National Standards Institute (ANSI)
ANSI oversees the creation of thousands of documents in nearly every sector of American life. The term "ANSI" has come to represent *conformity* and *credibility* when included in the title of a document. ANSI's mission is:

- ***Mission**: To enhance both the global competitiveness of U.S. business and the U.S. quality of life by promoting and facilitating voluntary consensus standards and conformity assessment systems, and safeguarding their integrity.*

International Code Council (ICC)
ICC is an association dedicated to developing model codes. ICC codes have been adopted by most U.S communities as the required minimum practice for new construction. ICC is committed to the following:

- ***Vision**: Protect the health, safety and welfare of people by creating safe buildings and communities.*
- ***Mission**: To provide the highest quality codes, standards, products and services for all concerned with the safety and performance of the built environment.*

International Association of Plumbing and Mechanical Operators (IAPMO)
IAPMO is dedicated to the development of model plumbing and mechanical codes. Widely adopted in the Western U.S., IAPMO's influence is very important, as summarized in their own stated organizational goals:

- *The International Association of Plumbing and Mechanical Officials shall be recognized by the building industry and the general public, both at home and abroad, as the world-wide leader in the plumbing and mechanical industry for:*

- *protecting health and safety*
- *supporting sustainability and emerging technology*
- *and delivering code education.*

<u>National Fire Protection Association (NFPA)</u>
NFPA was established in 1896 and is committed to the reduction in damage caused by fire and electrical hazards. NFPA publishes hundreds of documents including the National Electrical Code (NFPA 70), Fire Code (NFPA 1), and Flammable and Combustible Liquids Code (NFPA 30). NFPA's website succinctly describes the organization as:

- *NFPA is widely known as a codes and standards organization – that's the backbone of what we do, and it always will be. Our mission is to provide you with the information and knowledge you need to do your job well in today's ever-changing environment. Our 300 codes and standards are designed to minimize the risk and effects of fire by establishing criteria for building, processing, design, service, and installation around the world.*

<u>International Safety Equipment Association (ISEA)</u>
For more than 75 years, ISEA has been developing documents which have set the standard for personal protective technologies. ISEA's mission and vision are:

- ***ISEA Mission**: The mission of the International Safety Equipment Association is to support and promote the common business interests of its member companies. ISEA members are united in the goal of protecting the health and safety of people worldwide exposed to hazardous and potentially harmful environments.*
- ***ISEA Vision**: To be the preeminent thought leader and unite the safety equipment industry worldwide through knowledge, networking and advocacy.*

RAGAGEP Documents
While it is necessary to familiarize with the organizations listed in the previous section, it is of greater importance to be familiar with the documents that they have published, since it is the contents of these documents that are considered RAGAGEP.

<u>IIAR</u>
IIAR publishes standards that are specifically focused on ammonia (and CO_2) refrigeration. As such, it is essential to be familiar with IIAR's literature which has often been cited as RAGAGEP by EPA and OSHA. Prior to developing bona fide "standards", IIAR published a series of "bulletins" that provided "guidelines" on a wide range of ammonia refrigeration topics:

- IIAR Bulletin No. 107 *Guidelines for: Suggested Safety and Operating Procedures When Making Ammonia Refrigeration Plant Tie-ins*
- IIAR Bulletin No. 108 *Guidelines for: Water Contamination in Ammonia Refrigeration Systems*

- IIAR Bulletin No. 109 *Guidelines for: IIAR Minimum Safety Criteria for a Safe Ammonia Refrigeration System*
- IIAR Bulletin No. 110 *Guidelines for: Start-up, Inspection and Maintenance of Ammonia Mechanical Refrigerating Systems*
- IIAR Bulletin No. 111 *Guidelines for: Ammonia Machinery Room Ventilation*
- IIAR Bulletin No. 112 *Guidelines for: Ammonia Machinery Room Design*
- IIAR Bulletin No. 114 *Guidelines for: Identification of Ammonia Refrigeration Piping and System Components*
- IIAR Bulletin No. 116 *Guidelines for: Avoiding Component Failure in Industrial Refrigeration Systems Caked by Abnormal Pressure or Shock*
- IIAR Bulletin No. R1 *A Guide to: Good Practices for the Operation of an Ammonia Refrigeration System*

Note: IIAR Bulletins No. 106, 113, and 115 were never published and the gaps in numbering were likely holding places for planned documents that were never written.

At the time that these bulletins were published, it was not known that these documents would be viewed as RAGAGEP and enforceable by OSHA and EPA. The above-mentioned bulletins do not use "code language" (words such as "shall", "must", etc.) and are peppered with vague and optional requirements (words such as "can", "should", "may", etc.). For example, IIAR Bulletin No. 110 §6.4.2 reads as follows [emphasis mine]:

> *The system should be checked regularly for the presence of non-condensable gases which should be purged as necessary from the receiver(s) and/or condenser(s), preferably into a noncondensable gas remover or purger but alternatively into water. Where an automatic purger is fitted, its correct operation should be monitored. If there is a large accumulation of noncondensable gases the reason should be investigated and the cause should be corrected.*

As OSHA/EPA began to use the IIAR bulletins as enforceable RAGAGEP, it became clear that the best way to address the short-comings in the bulletins was to retire them altogether and replace them with standards written in code language. To date, the following standards have been published by IIAR:

- ANSI/IIAR 1 *Definitions and Terminology Used in IIAR Standards*
- ANSI/IIAR 2 *Standard for Safe Design of Closed-Circuit Ammonia Refrigeration Systems*
- ANSI/IIAR 3 *Ammonia Refrigeration Valves*
- ANSI/IIAR 4 *Installation of Closed-Circuit Ammonia Mechanical Refrigeration Systems*
- ANSI/IIAR 5 *Start-up and Commissioning of Closed-Circuit Ammonia Refrigeration Systems*
- ANSI/IIAR 7 *Developing Operating Procedures for Closed-Circuit Ammonia Mechanical Refrigerating Systems*

- ANSI/IIAR 8 *Decommissioning of Closed-Circuit Ammonia Mechanical Refrigeration Systems*

The language in these standards supersedes the content in Bulletins No. 107, 111, 112, and R1. As such, these bulletins have been "retired" and are no longer available for purchase. As of the date of publication of this paper, two additional standards are in the process of being written or currently subject to public review:

- IIAR 6 *Standard for Inspection, Testing, and Maintenance of Safe Closed-Circuit Ammonia Refrigeration Systems*
- IIAR 9 *Standard for Recognized and Generally Accepted Good Engineering Practice (RAGAGEP) for Existing Closed-Circuit Ammonia Refrigeration Systems*

Until IIAR 6 is published, IIAR Bulletins No. 108, 109, 110, and 116 will continue to be published and available for purchase, but upon completion of IIAR's entire suite of standards, all bulletins will be officially retired. IIAR Bulletin No. 114 is a guideline and its content will likely remain in publication, possibly as part of the IIAR Ammonia Refrigeration Piping Handbook.

It is appropriate to make special emphasis on the importance of IIAR 2. The current version, ANSI/IIAR 2-2014, is the first published "safety standard" to address the design of closed-circuit ammonia refrigeration systems. IIAR 2 was originally published in 1974, but from initial publishing until the current version, was not written as a "safety standard" and therefore, not widely recognized by the larger code community. With the significant changes to the standard that occurred in 2014, the document is now widely recognized by model codes and other standards. A subsequent section of this paper will investigate this topic in greater detail, including examples of IIAR references in code documents.

ASHRAE

ASHRAE publishes numerous standards, but two have had particular impact on the ammonia refrigeration industry for decades:

- ASHRAE 15 *Safety Standard for Refrigeration Systems*
- ASHRAE 34 *Designation and Safety Classification of Refrigerants*

ASHRAE 15 has been the foundational safety standard for the larger refrigeration community, both ammonia and synthetic refrigerants. The document was first published in 1978 and has been republished ten times since. Originally, ASHRAE 15 was written to replace American Standard B9 *Safety Code for Mechanical Refrigeration*, the premier refrigeration standard dating back to 1930.

It is currently proposed that ASHRAE 15 remove ammonia refrigeration from the scope of the document and simply reference IIAR 2 for minimum requirements when ammonia is the refrigerant in a refrigeration system. This is the likely trajectory for this document and when finalized, will result in ASHRAE 15 no longer being considered RAGAGEP for ammonia refrigeration systems.

ASME
ASME standards typically address a wide array of industries. The organization's flagship standard, *Boiler and Pressure Vessel Code*, is referenced in a vast array of industries including ammonia refrigeration. A summary of ASME standards that impact the ammonia refrigeration industry include:

- Boiler and Pressure Vessel Code (B&PVC), Section VIII, Division 1 *Rules for the Construction of Pressure Vessels*
- ASME B31.3 *Process Piping*
- ASME B31.5 *Refrigeration Piping and Heat Transfer Components*
- ASME A13.1 *Scheme for the Identification of Piping Systems*

It is important to emphasize that ASME B31.3 is not applicable to ammonia refrigeration piping. It was included on this list because it is a widely referenced standard and may be cited incorrectly by OSHA or EPA. It is important to familiarize with popular RAGAGEPs to be able to intelligently apply (or not apply) them to a given industry.

ICC
ICC's model codes are widely adopted throughout the United States. While all of the ICC codes have the potential to impact ammonia refrigeration facilities, the following two documents have chapters / sections which specifically address refrigeration:

- International Fire Code
- International Mechanical Code

IFC Section 606 *Mechanical Refrigeration* and IMC Chapter 11 *Refrigeration* are the most important sections of the ICC literature for determining ammonia refrigeration RAGAGEP. In California, the governing fire code, California Fire Code, is a derivative of the International Fire Code.

It is worth highlighting that the 2015 IMC and 2015 IFC both require ammonia refrigeration systems to comply with IIAR 2.

IAPMO
IAPMO's plumbing and mechanical model codes are less widely adopted than ICC's codes, but still important. IAPMO's Uniform Mechanical Code (UMC) is used in several western states, including California which has adopted the California Mechanical Code, a derivative of the UMC. The 2015 UMC requires ammonia refrigeration systems to comply with IIAR 2, IIAR 3, and IIAR 5.

NFPA

NFPA standards have the potential to impact many aspects of ammonia refrigeration facilities, but typically, the following three standards have the most effect:

- NFPA 1 *Fire Code*
- NFPA 70 *National Electric Code*
- NFPA 704 *Identification of the Hazards of Materials for Emergency Response*

ISEA

ISEA standards are less commonly known than some of the previous standards discussed, but ANSI/ISEA Z358.1 *Emergency Eyewash and Shower Equipment* has had considerable impact on the ammonia refrigeration industry with regard to eyewash and safety shower location. ISEA Z358.1 is a reference document in IIAR 2.

RAGAGEP Confusion

RAGAGEP is often confusing due to the number of codes and standards implicitly able to be invoked by reference. In addition to the sheer number of published documents, it is also common practice for one code/standard to reference another; adding yet another layer of confusion.

In Amy A. Duz's presentation at the 2013 RETA Conference, she cleverly stated that code compliance "*is the Russian nesting doll of regulation. Once you open regulations, you find codes, open a code and you find another, open that code and you find a consensus standard, maybe another, and on and on.*"

To illustrate, imagine an ammonia refrigeration system that is being built in an area where the 2015 International Mechanical Code is the governing code enforced by the Authority Having Jurisdiction (AHJ). Chapter 11 of 2015 IMC references two standards for compliance:

> **2015 IMC §1101.6 General**
> Ammonia-refrigerating systems shall comply with this code and, except as modified by this code, **ASHRAE 15** and **IIAR 2**.

Each of these standards in turn, references several other codes/standards:

> **ANSI/IIAR 2-2014 §5.7.2.1**
> Cast iron, malleable iron, nodular iron, steel, cast steel, and alloy steel shall be permitted in accordance with **ASME B31.5** or **ASME B&PVC, Section VIII, Division 1**…

> **ANSI/IIAR 2-2014 §6.7.3**
> Emergency eyewash/safety shower unit installations shall comply with **ANSI/ISEA Z358.1**.

ANSI/IIAR 2-2014 §6.15.1
Buildings and facilities with refrigeration systems shall be provided with placards in accordance with **NFPA 704** and the **Mechanical Code**.

ANSI/ASHRAE 15-2013 §11.2.2(b)
Systems containing more than 110 lb (50 kg) of refrigerant shall be provided with durable signs having letters not less than 0.5 in. (12.7 mm) in height designating:

b. …Valves or piping adjacent to valves shall be identified in accordance with **ANSI A13.1, Scheme for Identification of Piping Systems**.

ANSI/ASHRAE 15-2013 §8.5
Electrical Safety. Electrical equipment and wiring shall be installed in accordance with the **National Electrical Code** and the requirements of the AHJ.

A visual depiction of the codes / standards referenced in this example is illustrated below:

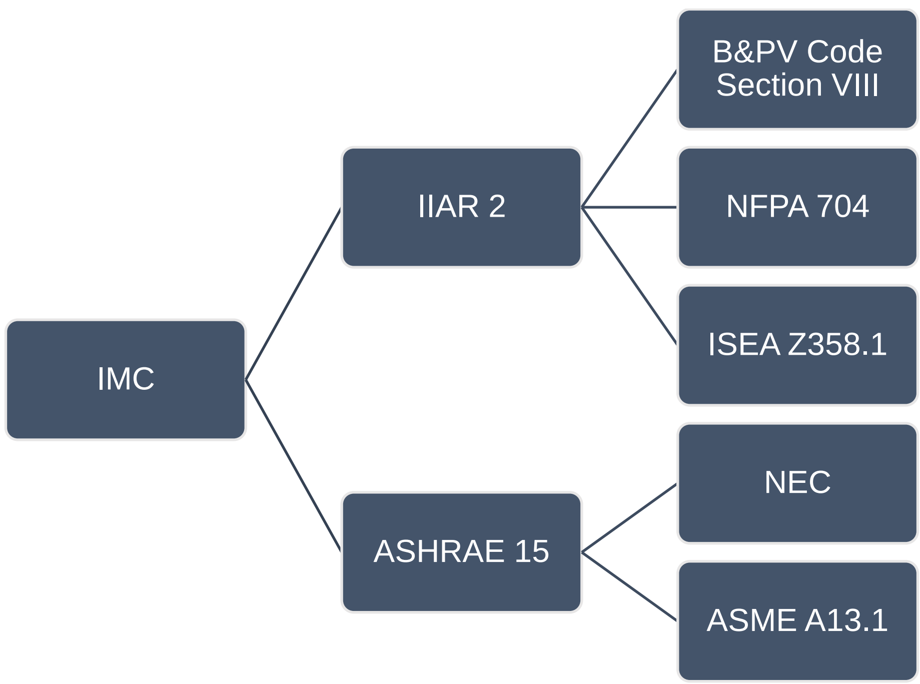

Figure 1 Interconnections of Codes and Standards

IIAR and Model Codes
While the importance of IIAR standards to ammonia refrigeration RAGAGEP has already been emphasized, the following code references provide evidence that IIAR standards have become "codified" by direct reference within every major model code:

2015 IFC §606.12.1.1 Ammonia refrigeration. Refrigeration systems using ammonia refrigerant and the buildings in which such systems are installed shall comply with **IIAR-2** for system design and installation and **IIAR-7** for operating procedures.

2015 NFPA 1 §53.1.3 Reference Codes and Standards. Refrigeration systems shall be in accordance with ASHRAE 15 and the mechanical code. Refrigeration systems using ammonia as a refrigerant shall also comply with **ANSI/IIAR 2**, Standard for Equipment, Design and Installation of Closed-Circuit Ammonia Mechanical Refrigerating Systems.

2015 UMC §1102.1 General. Refrigeration systems shall comply with this chapter and ASHRAE 15.
Exception: Ammonia refrigeration systems shall comply with **IIAR 2**, **IIAR 3**, and **IIAR 5**.

2015 IMC §1101.6 General. Refrigeration systems shall comply with the requirements of this code and, except as modified by this code, ASHRAE 15. Ammonia-refrigerating systems shall comply with this code and, except as modified by this code, ASHRAE 15 and **IIAR 2**.

NFPA 70-2017 §505.5 Refrigerant machinery rooms that contain ammonia refrigeration systems and are equipped with adequate mechanical ventilation that operates continuously or is initiated by a detection system at a concentration not exceeding 150 ppm shall be permitted to be classified as “unclassified” locations. Informational Note: For further information regarding classification and ventilation of areas involving closed-circuit ammonia refrigeration systems, see ANSI/ASHRAE 15-2013, Safety Standard for Refrigeration Systems, and **ANSI/IIAR 2-2014**, Standard for Safe Design of Closed-Circuit Ammonia Refrigeration Systems.

While it is acknowledged that the model codes do not uniformly reference the same IIAR standards, the reference to IIAR 2 in each model code once again emphasizes the importance of IIAR 2 to ammonia refrigeration RAGAGEP. The “trajectory” of the model codes has been to avoid adding new prescriptive ammonia refrigeration requirements and to simply reference IIAR standards for compliance.

RAGAGEP Conflicts

Due the vast amount of RAGAGEP documents, it is inevitable that conflicts will occasionally arise between RAGAGEPs. The subsequent sections of this paper will summarize two historical ammonia refrigeration RAGAGEP conflicts and provide best practice recommendations for dealing with conflicts that may arise.

Conflict 1: Maximum Length of Relief Valve Discharge Piping

Up until 2015, the International Mechanical Code and the Uniform Mechanical Code used a different basis/equation for calculating the allowable length of relief valve discharge piping:

2012 Uniform Mechanical Code §1118.1 General
The maximum length of the discharge piping permitted to be installed on the outlet of a pressure-relief device shall be determined by:

$$L = \frac{9P^2d^5}{16C^2}$$

Where

C = Minimum required discharge capacity, pounds of air per minute

d = Internal diameter of pipe, inches

L = Length of discharge pipe, inches

P = (rated pressure in psig x 1.1) + 14.7

2012 International Mechanical Code §1105.8 Ammonia discharge.
Pressure relief valves for ammonia systems shall discharge in accordance with ASHRAE 15.

ASHRAE 15-2010 §9.7.8.5
The maximum length of the discharge piping installed on the outlets of pressure-relief devices and fusible plugs discharging to the atmosphere shall be determined by the method in Normative Appendix E. See Table 3 for the flow capacity of various equivalent lengths of discharge piping for conventional relief valves.

ASHRAE 15-2010 Appendix E Allowable Equivalent Length of Discharge Piping
The design back pressure due to flow in the discharge piping at the outlet of pressure-relief devices and fusible plugs, discharging to atmosphere, shall be limited by the allowable equivalent length of piping determined by Equation E-1 (I-P or SI). See Table 3 for the flow capacity of various equivalent lengths of discharge piping for conventional relief valves.

$$L = \frac{0.2146d^5(P_0^2 - P_2^2)}{fC_r^2} - \frac{d \times ln(P_0/P_2)}{6f}$$

Where

L = equivalent length of discharge piping, ft (m)

C_r = rated capacity as stamped on the relief device in lb/min (kg/s), or in SCFM multiplied by 0.0764, or as calculated in Section 9.7.7 for a rupture member or fusible plug, or as adjusted for reduced capacity due to piping as specified by the manufacturer of the device, or as adjusted for reduced capacity due to piping as estimated by an approved method

f = Moody friction factor in fully turbulent flow

d = inside diameter of pipe or tube, in.

P_2 = absolute pressure at outlet of discharge piping, psi

P_0 = allowed back pressure (absolute) at the outlet of pressure relief device, psi

As can be seen above, two ammonia refrigeration systems built in 2012 could have different relief valve discharge termination piping designs depending on whether the IMC or the UMC was used as RAGAGEP. Consider the hypothetical scenario of a 250 psig relief valve with a rated capacity of 100 lb/min_{air} equipped with 2" schedule 40 outlet piping. Comparing the equations above results in the following allowable length of discharge piping:

- UMC: 14.8 ft
- IMC: 83.9 ft

Refer to Appendix B for complete analysis.

Conflict 2: Special Discharge Requirements for Ammonia

There has been a two decade RAGAGEP conflict between the UMC and the IMC relative to relief valve discharge piping location. Since 1994, this conflict has resulted in the installation of ammonia diffusion tanks on ammonia refrigeration systems in California and other jurisdictions adhering to the UMC, while jurisdictions following the IMC have terminated relief valves directly to atmosphere.

2012 Uniform Mechanical Code §1120.0 Ammonia Discharge

Ammonia shall discharge into a tank of water that shall be used for no purpose except ammonia absorption. Not less than 1 gallon (4 L) of fresh water shall be provided for each pound (kg) of ammonia that will be released in 1 hour from the largest relief device connected to the discharge pipe…

2012 International Mechanical Code §1105.8 Ammonia Discharge.

Pressure relief valves for ammonia systems shall discharge in accordance with ASHRAE 15.

ANSI/ASHRAE 15-2013 §9.7.8.2 Ammonia Discharge.

Ammonia from pressure-relief valves shall be discharged into one or more of the following:

a. The atmosphere, per Section 9.7.8

b. A tank containing one gallon of water for each pound of ammonia (8.3 liters of water

for each kilogram of ammonia) that will be released in one hour from the largest relief device connected to the discharge pipe. The water shall be prevented from freezing. The discharge pipe from the pressure-relief device shall distribute ammonia in the bottom of the tank but no lower than 33 ft (10m) below the maximum liquid level. The tank shall contain the volume of water and ammonia without overflowing.
c. Other treatment systems that meet the requirements of the AHJ

This RAGAGEP conflict has been partially resolved in the 2015 versions of the UMC and the IMC. The 2015 UMC has removed all references to diffusion tanks, but unfortunately "special discharge requirements" still apply to ammonia refrigeration systems. While diffusion tanks have been removed as a requirement, 2015 UMC §1114.1 now requires all discharge to atmosphere to be through a flaring device unless the "*Authority Having Jurisdiction determines upon review of a rational engineering analysis that fire, health, or environmental hazards will not result from the proposed atmospheric release.*"

Best Practices
The key to addressing RAGAGEP conflicts is to clearly document the codes and standards that were followed in the design and installation of the ammonia refrigeration system. Often this information will be contained in the "notes" section of the engineering drawings, but other forms of documentation are also acceptable. Appendix C includes a sample form that can be used to document the codes and standards used to design and install a refrigeration system.

Additionally, clear communication regarding RAGAGEP conflicts is essential. The communication should include, but not be limited to the following:

- Owner
- Authority Having Jurisdiction (AHJ)
- Design Engineer
- Contractor
- Consultant/PHA Team

Grandfathering

The term *grandfather* is often used in reference to requirements contained within new codes and standards. The typical situation that occurs is that a facility or system is built according to the "codes" in place at the time of design and construction. Over the course of time, new codes and standards are released which contain new requirements which were not implemented during the initial design and construction. Is the facility exempt from the new requirements because they are "*grandfathered*" to the earlier codes? The answer is likely "Yes", but the scenario below will assist in providing further explanation:

Scenario:

- Cold Storage Facility with an ammonia refrigeration system was built in 1969 in accordance with the 1967 Uniform Mechanical Code (UMC).
- In 1998, modifications were made to the machinery room
  - One (1) new compressor installed
  - AHJ required ventilation and detection to be upgraded
  - All changes were performed in accordance with 1997 UMC
- In 2014, the facility hired a contractor to construct a new cold storage room
  - No machinery room modifications were required
  - New room complied with 2012 International Mechanical Code (IMC) and ANSI/IIAR 2-2008 Addendum B
  - The facility elected to upgrade the ammonia detection system for entire facility to comply with 2012 IMC

In this example, all four RAGAGEPs would be applicable at the facility, but their applicability would vary based on when the equipment was installed at the facility. 1967 UMC would continue to be the RAGAGEP for the originally installed and unmodified parts of the system. 1997 UMC would apply as RAGAGEP for the machinery room modifications that took place in 1998. 2012 IMC and ANSI/IIAR 2-2008 Addendum B would be RAGAGEP for the ammonia detection system and new cold storage room.

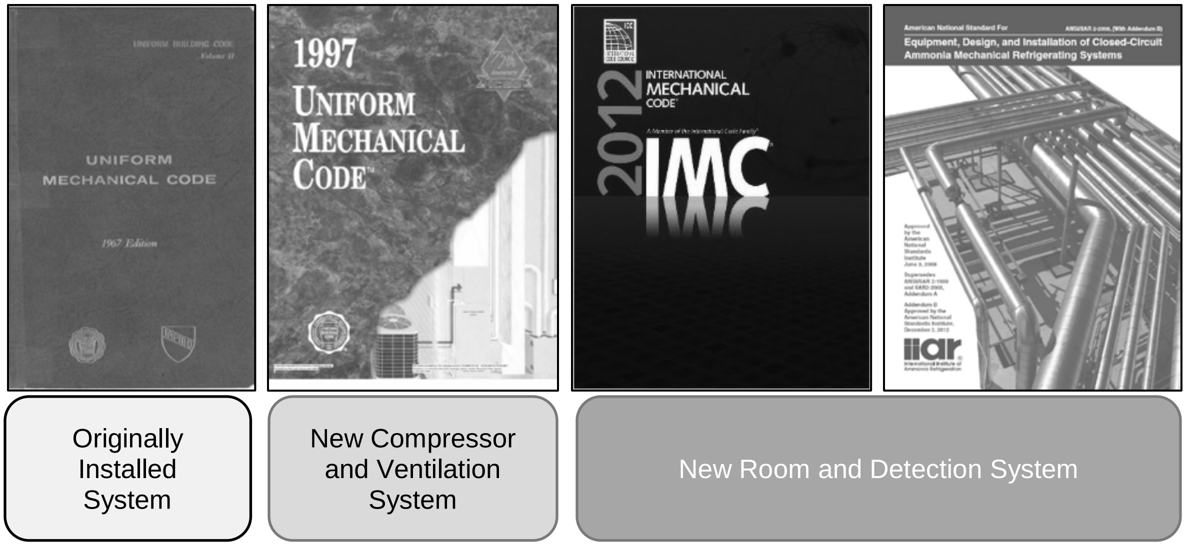

Figure 2 Applicability of Codes/Standards

It is important to note that some RAGAGEPs are applicable to all systems as soon as they are published. For example, ANSI/IIAR 5-2013 *Start-up and Commissioning of Closed-Circuit Ammonia Refrigeration Systems* addresses the "*basic minimum requirements for the safe start-up and commissioning of completed closed-circuit mechanical refrigerating systems utilizing ammonia as the refrigerant and to additions and modifications made to such systems.*" Therefore, this standard would apply to the start-up and commissioning activities for all newly completed or modified ammonia refrigeration systems, regardless of when the system was built.

Consideration of New RAGAGEPs

The previous section helped clarify how RAGAGEPs apply to facilities that have been built or modified in phases over several years. What about the hypothetical facility that was built decades ago and has not been modified since? The following sections will address how such a facility should respond to new and changing RAGAGEPs which were not applicable on the date of original design and installation.

Role of Process Safety Information

Facilities subject to PSM are required to document that "*equipment complies with recognized and generally accepted good engineering practices*" (Title 29 §1910.119(d)(3)(ii)). While this does not translate to modifying the system for every code change, it does require acknowledgement that codes and standards are consensus documents that represent the general opinion of a specific industry. Therefore, while a single code change may not be significant, if that code change becomes a perpetual requirement in consecutive code cycles, it may eventually become enforceable RAGAGEP. For example, the UMC did not require ammonia detection for machinery rooms until 1994. Facilities built prior to that date would not have been expected to have ammonia detection as part of the system installation. Since 1994, the UMC has required ammonia detection in eight consecutive releases of the document. The consistent inclusion of ammonia detection as a requirement in the UMC and all other codes/standards makes ammonia detection a prime example of RAGAGEP. In other words, an ammonia refrigeration system which is not equipped with ammonia detection would not comply with RAGAGEP regardless of the age of the system.

Role of the Process Hazard Analysis

Every five years, facilities subject to PSM are required to perform or revalidate their Process Hazard Analysis (PHA). While it is beyond the scope of this paper to discuss PHAs in depth, the following PHA requirements (emphasis mine) are worth special consideration:

- The process hazard analysis shall address the identification of any **previous incident** which had a likely potential for catastrophic consequences in the workplace.
- The process hazard analysis shall be performed by a team with **expertise in engineering** and process operations.

As previous incidents are analyzed during a PHA study, it is a natural progression for RAGAGEP changes to be considered. For example, if a contributing cause of a previous incident was inadequate access to ventilation controls, it would be appropriate for the PHA to consider (and possibly recommend) that the ventilation system controls be upgraded to meet the current requirements for remote ventilation controls.

Additionally, since the PHA is required to be performed by a team which includes engineering expertise, it is expected that the PHA would include consideration of the latest engineering innovations and best practices.

Role of Mechanical Integrity

Mechanical Integrity (MI) is a cornerstone element of PSM which requires regular inspections and tests of process equipment. As was previously stated, MI inspection procedures and frequency must comply with RAGAGEP. Over the course of time, it is to be expected that MI inspections and tests will reveal deficiencies which require repair or replacement. When components require repair or replacement, this provides a good opportunity to consider the most current RAGAGEPs rather than the RAGAGEPs that were in place at the time of initial design and installation.

Conclusion

Navigating the realm of *"recognized and generally accepted good engineering practice"* can be challenging due to the transient nature of code documents. Having a proper understanding of the organizations and documents that represent industry-specific RAGAGEP is essential to demonstrating compliance with RMP and PSM. While it is acknowledged that conflicts still exist, the trajectory of ammonia refrigeration RAGAGEP is pointed toward IIAR as the premier standard writing organization and IIAR's suite of standards as the primary RAGAGEPs for this industry. This is a welcomed direction, as it allows ammonia refrigeration best practices to be shaped by the experts within their industry.

Appendix A: OSHA RAGAGEP Citations

Agency	Inspection Number	Issuance Date	Type of Violation	Proposed Penalty
OSHA	1100762	4/20/16	Serious	$7,000

Regulatory Basis	Violation
29 CFR 1910.119(G)(4)(iii): The frequency of inspections and tests of process equipment was not consistent with applicable manufacturers' recommendations and good engineering practices, and more frequently if determined to be necessary by prior operating experience	a) A check valve (GHX2.05) had not been tested or replaced in the intervals consistent with applicable manufacturer's recommendations. Employer had not determined alternative good engineering practices. b) The employer's replacement intervals for the ammonia sensors were not consistent with the applicable manufacturer's recommendations. Employer had not determined alternative good engineering practices.

Agency	**Inspection Number**	**Issuance Date**	**Type of Violation**	**Proposed Penalty**
OSHA	1119789	6/13/16	Serious	$7,000

Regulatory Basis	**Violation**
29 CFR 1910.119(d)(3)(ii): The employer did not document that equipment complies with recognized and generally accepted good engineering practices (RAGAGEP's).	On or about January 20, 2016, at XXXXXXXX facility, XXXXXXXX, the employer did not document that it [sic] complied with recognized and generally accepted good engineering practices (RAGAGEP) exposing employees to the hazards of inhalation of toxic ammonia and/or fire/explosion in the following instances, see A through E: A. The employer failed to document compliance with RAGAGEP, such as IIAR Bulletin 114 "Identification of Ammonia Refrigeration Piping and System Components" Section 4.1 "Piping Markers" and Section 5.0 (a-d) "Marker Location", March 2014, as the employer failed to mark and/or label ammonia refrigeration equipment, including: 1. Engine Room 5, Evaporating Condenser, tower EC-1 2. Engine Room 6, Evaporating Condenser, tower EC-2 3. Engine Room 7, Evaporating Condenser, towers EC-1 and EC-2 4. Engine Room 8, Evaporating Condenser, towers EC-1, EC-2 and EC-3 5. Engine Room 11, Evaporating Condenser, tower EC-1, EC-2 and EC-3 B. Failure to document compliance with RAGAGEP, such as IIAR Bulletin 110 "Guidelines for: Startup, Inspection and Maintenance of Ammonia Mechanical Refrigerating Systems" Section 6.6 Valves and Sensing Devices Subsection 6.6.l Shut-off Valves, as the employer failed to change out ammonia refrigeration system safety relief valves prior to their 5 year due dates from the date of installation, including: 1. Engine Room 6, Heat Exchangers l, 2 and 3. These are dual relief systems using Hansen Valves.

	i Relief Valve - HE2 (#5), manufactured by Hansen was not changed at or before date. Some of the valves due date are July, November and December 2015. C. The employer failed to document compliance with RAGAGEP, such as ASHARAE 15-2013, Section 9.4.3.l and 9.4.3.2 as the employer failed to provide hydrostatic relief for a section of piping in the Engine Room 8 thermos-syphon return line that could trap liquid ammonia between valves leading to an overpressure scenario and rupture the piping resulting in a release of ammonia. D. The employer failed to document compliance with RAGAGEP, such as ASHRAE-15-2013, Section 8.11.4, as the employer failed to safely install ventilation fans in that the inlets of two ventilations fans are located in the north wall and a small fan located near the inlet louver south wall allowing for exhausted ammonia vapors to be drawn back into Engine Room 8. E. The employer failed to document compliance with RAGAGEP, such as ASHARAE 15-2013 Safety Standard for Refrigeration Systems, Section 9.7.8 as the employer failed to locate discharges from safety relief valves (SRV) in safe locations in that the header relief system for Engine Room 8 had an SRV that was located adjacent to Condenser # 2 such that it would discharge to a ladder and catwalk area that is used by employees.

Agency	Inspection Number	Issuance Date	Type of Violation	Proposed Penalty
OSHA	1100500	4/8/16	Serious	$7,000
Regulatory Basis			**Violation**	
29 CFR 1910.119(d)(3)(ii): The employer did not document that equipment complies with recognized and generally accepted good engineering practices (RAGAGEP).	a. On or about 10/20/2015, at the XXXXXXXX facility located in XXXXXXXX, the employer did not document that it complied with recognized and generally accepted good engineering practice such as ANSI/ ASHRAE-15 (American Society of Heating Refrigeration Air Conditioning and Engineering) and ANSI/IIAR-2 (International Institute Ammonia Refrigeration) as it failed to install visual and audible alarms outside the engine room entrance doors exposing employees to the hazards of dangerous concentrations of ammonia following a release in the engine room. b. On or about 10/20/2015, at the XXXXXXXX facility located in XXXXXXXX, the employer did not document that it complied with recognized and generally accepted good engineering practice such as ANSI/ ASHRAE-15 (American Society of Heating Refrigeration Air Conditioning and Engineering) when it failed to set ammonia detectors in the engine room at a value not greater than TLV-TWA (Threshold limit value-time weighted average) exposing employees to toxic hazards of ammonia exposure. c. On or about 10/20/2015, at the XXXXXXXX facility located in XXXXXXXX, the employer did not document that it complied with recognized and generally accepted good engineering practice such as ANSI/ASHRAE-15 (American Society of Heating Refrigeration Air Conditioning and Engineering) when it failed to ensure that alarms would activate upon failure of the ventilation system in the machine room exposing employees to fire, explosion, and toxic hazards following an ammonia release. d. On or about 10/20/2015, at the XXXXXXXX facility located in XXXXXXXX, the employer did not document that it complied with recognized and generally accepted good engineering practice such as ANSI/ ASHRAE-15 (American Society of Heating Refrigeration Air Conditioning and Engineering) and ANSI/IIAR-2 (International Institute Ammonia Refrigeration) when it failed to post an authorized personnel sign on the West entrance door of the			

	engine room exposing employees to toxic hazards of ammonia exposure. e. On or about 10/20/2015, at the XXXXXXXX facility located in XXXXXXXX, the employer did not document that it complied with recognized and generally accepted good engineering practice such as ANSI/IIAR-2 (International Institute Ammonia Refrigeration) when it failed to install an accessible eyewash and body shower station outside of the engine room exit exposing employees to toxic hazards of ammonia exposure.

Agency	Inspection Number	Issuance Date	Type of Violation	Proposed Penalty
OSHA	1100500	4/8/16	Serious	$7,000

Regulatory Basis	Violation
29 CFR 1910.119G)(4)(iii): The frequency of inspections and tests of process equipment to maintain its mechanical integrity, was not consistent with applicable manufacturers' recommendations and good engineering practices, and more frequently if determined to be necessary by prior operating experience.	a) On or about 10/20/2015, at the XXXXXXXX facility located in XXXXXXXX, the employer failed to ensure that safety inspections for the ventilation system in the engine room was conducted at a frequency consistent with recognized and generally accepted good engineering practice such as IIAR Bulletin No.109 and the employer's Mechanical Integrity (Ml) procedure. This condition exposed employees to the hazards of inhalation of ammonia and fire/ explosion. b) On or about 10/20/2015, at the XXXXXXXX facility located in XXXXXXXX, the employer did not ensure that inspections and tests are conducted at a frequency consistent with recognized and generally accepted good engineering practice such as IIAR Bulletin No.110 and the employer's Mechanical Integrity (Ml) procedures for specific safety systems that include but are not limited to the following: 1. Oil Pressure Differential Cut Outs for the Compressor, HS-1 2. High and Low Pressure Cut Out for the compressor, HS-2 3. High Temperature Cut Out for Compressor, BC-1 4. High and Low Level Controls for Re-circulator, V-4 5. High and Low Level Controls for High Pressure Receiver, V-1 6. Emergency Stop Buttons for the ammonia refrigeration system This condition exposed employees to the hazards of inhalation of ammonia and fire/explosion. c) On or about 10/20/2015, at the XXXXXXXX facility located in XXXXXXXX, the employer did not ensure that inspections and tests are conducted at a frequency consistent with recognized and generally accepted good engineering practice such as the employer's Mechanical Integrity (Ml) procedures and IIAR Bulletin No.110 for compressors and pumps that include but are not limited to the following:

	1. High Stage Compressor, HS-1 2. Booster Compressor, BC-1 3. Recirculator Pump, RP-1 4. Recirculator Pump, RP-2 This condition exposed employees to the hazards of inhalation of ammonia and fire/explosion. d) On or about 10/20/2015, at the XXXXXXXX facility located in XXXXXXXX, the employer did not ensure that inspections and tests are conducted at a frequency consistent with recognized and generally accepted good engineering practice such as IIAR Bulletin No.110 and the employer's Mechanical Integrity (MI) procedures for piping that include but are not limited to the following: 1. 10" LTRS (Low Temperature Recirculation suction) header 2. 6" HSD (High Stage Discharge) from High Stage Compressors to Evaporated Condensers (EC-l&EC-2) 3. 3" HPL (High Pressure Liquid) from the King Valve to the Intercooler V-3. 4. 6" BD (Booster Discharge) from Booster compressors to the Intercooler V-3. This condition exposed employees to the hazards of inhalation of ammonia and fire/explosion.

Agency	Inspection Number	Issuance Date	Type of Violation	Proposed Penalty
OSHA	1094769	3/29/16	Serious	$70,000

Regulatory Basis	Violation
29 CFR 1910.119(d)(3)(ii): The employer did not document that the equipment in the process complied with recognized and generally accepted good engineering practices.	The employer failed to document that equipment in the process complied with recognized and generally accepted good engineering practices (RAGAGEP). a) The violation was observed on or about October 01, 2015 and at times prior thereto in "new" and "old" engine rooms when the employer failed to document that detectors activate visual and audible alarms outside each entrance to refrigeration machinery rooms in accordance with RAGAGEP such as ANSI/IIAR 2-2008 where employees were exposed to fire or inhalation hazards of ammonia. b) The violation was observed on or about October 01, 2015 and at times prior thereto in engine room when the employer failed to document that ventilation controls were located outside the principal entrance to engine room in accordance with RAGAGEP such as ANSI/IIAR 2-2008 and/or ANSI/ ASHRAE 15-2010 where employees were exposed to fire or inhalation hazards of ammonia. c) The violation was observed on or about October 01, 2015 and at times prior thereto in engine room when the employer failed to document that emergency stops were located immediately outside principal entrance to engine room in accordance with RAGAGEP such as ANSI/IIAR 2-2008 and/or ANSI/ ASHRAE 15-2010 where employees were exposed to fire or inhalation hazards of ammonia d) The violation was observed on or about October 01, 2015 and at times prior thereto in engine room when the employer failed to document that the allowable piping discharge lengths were in accordance with RAGAGEP such as ANSI/ASHRAE 15-2010 where employees were exposed to fire or inhalation hazards of ammonia.

Appendix B: Comparison of Allowable Length of Relief Valve Discharge Piping in 2012 UMC and 2012 IMC

Scenario:

- Relief Valve Set Pressure: 250 psig
- Relief Valve Capacity: 100 lb/min$_{air}$
- Outlet Pipe Installed: 2" Schedule 40

2012 Uniform Mechanical Code §1118.1 General
The maximum length of the discharge piping permitted to be installed on the outlet of a pressure-relief device shall be determined by:

$$L = \frac{9P^2d^5}{16C^2}$$

Where

C = Minimum required discharge capacity, pounds of air per minute

d = Internal diameter of pipe, inches

L = Length of discharge pipe, inches

$$L = \frac{9[(250psig \times 1.1) + 14.7]^2 \times (2.067in)^5}{16\left(100\frac{lb}{min_{air}}\right)^2}$$

$$L = 178.1\ in$$

$$L = 14.8\ ft$$

2012 International Mechanical Code §1105.8 Ammonia discharge.
Pressure relief valves for ammonia systems shall discharge in accordance with ASHRAE 15.

ASHRAE 15-2010 §9.7.8.5
The maximum length of the discharge piping installed on the outlets of pressure-relief devices and fusible plugs discharging to the atmosphere shall be determined by the method in Normative Appendix E. See Table 3 for the flow capacity of various equivalent lengths of discharge piping for conventional relief valves.

ASHRAE 15-2010 Appendix E Allowable Equivalent Length of Discharge Piping
The design back pressure due to flow in the discharge piping at the outlet of pressure-relief devices and fusible plugs, discharging to atmosphere, shall be limited by the allowable

equivalent length of piping determined by Equation E-1 (I-P or SI). See Table 3 for the flow capacity of various equivalent lengths of discharge piping for conventional relief valves.

$$L = \frac{0.2146 d^5 (P_0^2 - P_2^2)}{f C_r^2} - \frac{d \times ln(P_0/P_2)}{6f}$$

Where

L = equivalent length of discharge piping, ft (m)

C_r = rated capacity as stamped on the relief device in lb/min (kg/s), or in SCFM multiplied by 0.0764, or as calculated in Section 9.7.7 for a rupture member or fusible plug, or as adjusted for reduced capacity due to piping as specified by the manufacturer of the device, or as adjusted for reduced capacity due to piping as estimated by an approved method

f = Moody friction factor in fully turbulent flow

d = inside diameter of pipe or tube, in.

P_2 = absolute pressure at outlet of discharge piping, psi

P_0 = allowed back pressure (absolute) at the outlet of pressure relief device, psi

$$L = \frac{0.2146(2.067in)^5((0.15 \times 250psi + 14.7psi)^2 - (14.7psi)^2)}{0.0190 \times \left(100 \frac{lb}{min_{air}}\right)^2} - \frac{(2.067in) \times ln\left(\frac{0.15 \times 250psi + 14.7psi}{14.7psi}\right)}{6 \times 0.0190}$$

$$L = 83.9\ ft$$

Appendix C: Documenting RAGAGEP

Design and Installation Codes and Standards Employed

To the best of the undersigned's knowledge, the **Ammonia Refrigeration Project** at Company XYZ was designed and installed in accordance with the following codes and standards:

- 2013 California Mechanical Code Chapter 11 *Refrigeration*
- 2013 California Fire Code Section 606 *Mechanical Refrigeration*
- ANSI/IIAR 2-2014 *Standard for Safe Design of Closed Circuit Ammonia Refrigeration Systems*
- ANSI/IIAR 4-2015 *Installation of Closed-Circuit Ammonia Refrigeration Systems*
- ANSI/IIAR 5 *Start-up and Commissioning of Closed-Circuit Ammonia Refrigeration Systems*
- ANSI/ASHRAE 15-2013 *Safety Standard for Refrigeration Systems*
- ASME B31.5-2013 *Refrigeration Piping and Heat Transfer Components*
- 2015 ASME Boiler & Pressure Vessel Code Section VIII *Rules for Construction of Pressure Vessels, Division 1*

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Print Name Signature Date

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