BSR/IIAR 2-2026

Standard for Design of Closed-Circuit Ammonia Refrigeration Systems

Public Review #1 DRAFT

(2026.06.19)

Following are supplementary instructions for submitting comments:

1. The commenter should supply their contact information including name, Email address and phone number(s) if available.
2. Each comment should be submitted as a separate item and should identify the specific Section, table, figure, appendix, or definition as the subject of each comment.
3. When providing the comment:
    a. Clearly state the concern or objection.
    b. Provide proposed wording or a specific action that would resolve the concern. If no wording change is proposed, clearly describe the requested action, such as deletion, relocation, or clarification.
    c. Show proposed additions and deletions. If formatting is available, additions should be shown by underlining, and deletions should be shown by strikethrough. Alternatively, if markup formatting is not available the commenter may identify the proposed wording using “Proposed language:” followed by the recommended text.
    d. Provide a brief substantiation explaining the rationale for the comment including supporting justification, technical basis, data, references, or other backup information where applicable. If the substantiation is lengthy, provide a brief abstract or summary.
    e. Identify whether supporting attachments are included. Electronic file formats such as .doc, .docx, or .pdf are preferred.
    f. Write the comment as an actionable public review comment rather than as an unsupported opinion or general question.
4. Commenters are encouraged to review the relevant material carefully before submitting comments. Questions about the public review process or how to submit comments may be directed to IIAR technical staff before close of the public review period.

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Notes on the Standard Text

Metric Policy

IIAR metric policy for American National Standards Institute (ANSI) standards and all IIAR publications is to use the common engineering “inch-pound” (IP) unit system as the primary unit of measure and the International System of Units (SI), as defined in United States National Institute of Standards and Technology (NIST) Special Publication 330 *The International System of Units*, for secondary units.

Normative/Informative Elements

This standard includes normative (required) provisions. The foreword and appendices are nonmandatory. Informative material shall never be regarded as a requirement. It has not been processed according to ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. If options presented within the appendices are implemented, they must comply with the normative provisions of this standard.

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ANSI Status of this Document

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Foreword

(Informative)

This document is a standard for the design of closed-circuit ammonia refrigeration systems. Its provisions are intended to reduce risks to persons and property located at or near the premises where the refrigeration systems are located. Additional measures may be necessary because of particular circumstances, project specifications, or other jurisdictional considerations. This standard is not intended to serve as a comprehensive technical design manual and shall not be used as such.

Experience shows that ammonia is very stable under normal conditions and rarely ignites when a release occurs because the flammability range in air is narrow and the minimum flammable concentration in air is very high as compared with other ignitable gases. Ammonia has a published flammability range of 160,000 ppm to 250,000 ppm by volume. This concentration far exceeds ammonia's odor detection threshold and the 50 ppm permissible exposure limit (PEL) published by the Occupational Safety and Health Administration (OSHA).

Ammonia's strong odor alerts those nearby to its presence at levels well below those that present either flammability or health hazards. This "self-alarming" odor is so strong that a person is unlikely to remain voluntarily in an area where ammonia concentrations are hazardous.

The principal hazard to persons is ammonia vapor, because exposure occurs more readily by inhalation than by other routes. As with any hazardous vapor, adequate ventilation will dilute the vapor and greatly reduce exposure risk.

Ammonia in vapor form is lighter than air. Typically, ammonia vapor rises and diffuses simultaneously when released into the atmosphere. It is biodegradable and, when released, combines readily with water and/or carbon dioxide to form relatively harmless compounds. Ammonia may also neutralize acidic pollutants in the atmosphere. Additional information regarding the properties of ammonia is published in the *IIAR Ammonia Data Book*.

This standard was first issued in March of 1974 by IIAR as IIAR 74-2. The standard was first approved as an American National Standard by the American National Standards Institute (ANSI) in March 1978 as ANSI/IIAR 74-2-1978. A revision of the standard, ANSI/IIAR 2-1984 was approved by ANSI in July 1985, as were subsequent revisions in December 1992, August 1999, June 2008, August 2010, and December 2012. ANSI/IIAR 2-2014 was approved by ANSI in September 2015 and was published in November 2015. ANSI IIAR 2-2014, Addendum A, was approved by ANSI in June 2019 and published in July 2019. ANSI/IIAR 2-2021 was approved by ANSI in July 2021 and published in August 2021. This edition of ANSI/IIAR 2 was approved by ANSI in <MONTH> <YEAR> and published in <MONTH> <YEAR>.

This standard was prepared using the ANSI consensus method, whereby organizations and individuals having interest in the subject of the standard were contacted prior to the approval of this revision for participation on the Consensus Body and in public reviews. The standard was prepared and approved for submittal to ANSI by the IIAR Standards Committee and the IIAR Board of Directors.

IIAR 2: Changes for the 2026 Edition

The descriptions below do not depict every change that has been made for this version of the standard but serves to call readers' attention to the most significant changes that affect design. As always, readers should examine the document carefully to determine the minimum requirements for the design of safe ammonia refrigeration systems. PLEASE NOTE: This section will be modified as the changes are confirmed through the Public Review process.

Chapters in Part 1: General

Chapter 1: Purpose, Scope, and Applicability. Scope has been updated to clarify that the standard applies to heat pump systems and their ancillary equipment. Applicability has been modified to clarify that adopted codes not modified by this standard remain applicable. Modifications and alternative materials and methods are permissible when authorized by the AHJ. And finally, this section was updated for installations that are outside of the US, to permit nationally recognized standards in place of referenced standards.

Chapter 2: Definitions. This chapter contains new definitions used within the standard and removes those already present in IIAR 1.

Chapter 3: Reference Standards. This chapter includes updated normative references.

Chapters in Part 2: Design and Installation Considerations Affecting Construction

Chapter 4: Location of Ammonia Refrigeration Equipment. Chapter 4 has been restructured based on occupancy.

Chapter 5: General System Design Requirements. Added minimum design pressure guidance for heat pumps. Clarified requirements for oil collection vessels. Consolidated requirements for piping and equipment supports from sections that were previously located in Chapter 6.

Chapter 6: Machinery Rooms. Support and vibration control moved from Chapter 6 to Chapter 5. Requirements for equipment with open flames or hot surfaces have been clarified and rewritten, from exceptions to permitted actions. Requirements for equipment access doors vs personnel door features have been added.

Chapter 7: Refrigeration Equipment Located in Areas Other than Machinery Rooms. Minor edits to referenced sections in Chapter 5.

Chapters in Part 3: **Equipment**

Chapter 8: Compressors. Minor edits to referenced sections in Chapter 5. Additional edits for requirement clarifications for compressors in low ambient temperature locations to prevent or remove condensation.

Chapter 9: Refrigerant Pumps. No major changes

Chapter 10: Condensers. Minor edits to referenced sections that were previously in Chapter 5 to new section in Chapter 4.

Chapter 11: Evaporators. Added bare tube evaporators requirements to the table.

Chapter 12: Pressure Vessels. Updated chapter where NPS is used to remove reference to the converted metric equivalent dimension.

Chapter 13: Piping and Hoses. Removed previously permitted rubber-constructed hose and referenced standard for permanently installed ammonia hoses. Provided further clarification on pipe flanges.

Chapter 14: Packaged Systems and Equipment. Minor updates to language to corresponding Chapter 4 references that were previously Chapter 5.

Chapter 15: Overpressure Protection Devices. This Chapter has been substantially reorganized and expanded to better address overpressure protection configurations that discharge internally to the closed-circuit refrigeration system. The updated chapter includes guidance for evaluating downstream pressure drop for vapor-service internal relief valves, acknowledges the added complexity of liquid refrigerant relief due to two-phase flow, and establishes limits for allowable built-up back pressure. These additions now enable designers to determine how best to engineer the overpressure protection to comply with RAGAGEP and maintaining system safety.

Chapter 16: Instrumentation and Controls. Minor updates to language to corresponding Chapter 4 references that were previously Chapter 5.

Chapter 17: Ammonia Detection and Alarms. Clarified power requirements for ammonia detection and alarm installations.

Chapter 18: Absorption Refrigeration. Minor updates to language to corresponding Chapter 4 references that were previously Chapter 5.

Part 4: **Appendices**

Informative Appendix A has been updated as necessary to provide supporting explanations of the normative content.

Informative Appendix B is unchanged.

Informative Appendix C is unchanged.

Informative Appendix D is unchanged.

Informative Appendix E is unchanged.

Informative Appendix F is unchanged.

Informative Appendix G is unchanged.

Informative Appendix H is unchanged.

Informative Appendix I is unchanged.

Informative Appendix J is unchanged.

Informative Appendix K is unchanged.

Informative Appendix L is unchanged.

Informative Appendix M is unchanged.

Informative Appendix N is unchanged.

Informative Appendix O is unchanged.

Informative Appendix P is unchanged.

Informative Appendix Q, Guidelines for Identification of Ammonia Refrigeration Piping and System Components, has been removed from the standard because the information, originally included in the IIAR *Piping Handbook*, is now published as the stand-alone document, *Guidelines for the Identification of Ammonia Refrigeration Piping and System Components*. This document is referenced directly within the informative sections of the standard and remains under the ownership and control of the Piping Committee. The new **Informative Appendix Q**, Application Examples for Internal Overpressure Relief Protection**,** demonstrates the use of the newly added requirements in Chapter 15 for internal relief for two of the most common configurations: oil pot connected to a low-side vessel and for a thermosiphon oil cooling heat exchanger

Informative Appendix R, References and Sources of References, has been edited to include updated references.

At the time of publication of the 2026 edition, the IIAR Standards Committee included the following members:

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The subcommittee responsible for developing the 2026 edition of the standard had the following members at the time of publication:

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Part 1. General

Chapter 1. Purpose, Scope, and Applicability

1.1 *Purpose. This standard specifies safety design requirements for closed-circuit ammonia refrigeration systems.

1.2 *Scope. Stationary closed-circuit vapor compression, absorption refrigeration systems, heat pump systems, and their ancillary equipment utilizing anhydrous ammonia as the refrigerant shall comply with this standard. This standard shall not apply to:

1. Replacement in-kind;
2. Equipment and systems and the buildings or facilities in which they are installed that existed prior to the legal effective date of this standard. Such equipment, systems, and building and facilities shall remain in accordance with the adopted codes and standards that applied at the time of installation or construction and in accordance with ANSI/IIAR 9.

1.3 Applicability.

1.3.1 **Compliance with Other Adopted Codes.** Refrigeration systems designed in accordance with this standard shall also comply with all other laws, codes, ordinances, and regulations adopted by the authority having jurisdiction (AHJ).
Where this standard is adopted by reference within another code, the requirements of this standard shall apply to the design of ammonia refrigeration systems as specified by the adopting code. Requirements of the adopting code that are not expressly modified by this standard shall remain applicable.
Where the authority having jurisdiction (AHJ) has specific requirements that are in conflict with those herein, such requirements shall prevail.

1.3.2 **Modifications.** Where there are practical difficulties involved in carrying out the provisions of this standard, the Authority Having Jurisdiction (AHJ) shall have the authority to grant modifications for individual cases upon application of the owner or owner's authorized agent, provided that the AHJ shall first find that the special individual reason makes the strict letter of this standard impractical and the modification is in compliance with the intent and purpose of this standard and does not lessen health, life, and safety requirements. The modifications shall be documented in the design documents.

1.3.3 **Alternative Materials and Methods.** The provisions of this standard are not intended to prevent any devices, materials, or methods not prescribed by this standard, providing that any such alternative has been approved by the AHJ. An alternative device, material, or method shall be approved where the AHJ finds that the alternative is satisfactory and complies with the intent of the standard, and that the device, material, or method offered is, for the purpose intended, not less than the equivalent of that prescribed in this standard in quality, strength, effectiveness, fire resistance, durability, and safety. The alternative shall be documented in the design documents.

1.3.4 **Applicable Nationally Recognized Standards.** For installations outside the United States, applicable nationally-recognized standards shall be permitted to be used in place of requirements in this standard.

Chapter 2. Definitions

2.1 *General. Definitions shall be in accordance with this chapter and ANSI/IIAR 1.

2.2 Defined Terms. The following words and terms, which are used in this standard, shall be defined as specified in this chapter.

absorption refrigeration system: A refrigeration system that does not use mechanical vapor compression, but instead uses heat to create the refrigeration effect. Ammonia is evaporated within a heat exchanger(s). The ammonia vapor is then absorbed by an absorbent medium. The ammonia vapor is subsequently expelled from the medium by heating at a higher partial vapor pressure. The ammonia vapor is then condensed for recirculation back to the heat exchanger(s).

absorption system, liquid-vapor: An absorption refrigeration system that uses liquid to absorb ammonia vapor to produce a refrigeration effect.

absorption system, solid-vapor: An absorption refrigeration system that uses metal inorganic salts such as alkali, alkali-earth, or transition metals, as sorbents to absorb ammonia vapor, which forms a complex compound and produces a refrigeration effect.

direct system: a system in which air or other substances are heated or cooled with an evaporator or condenser that is in direct contact with the air or other substances.

full vacuum: The condition where the internal absolute pressure is 0 psia (0kPa) and the external absolute pressure on the system is 15 psia (103 kPa).

heat exchanger: equipment used to transfer heat from one substance to another without direct contact of the substances.

heat pump: A vapor compression or absorption refrigeration system that recovers heat from a lower-temperature source and delivers that heat at a higher temperature, typically to meet a process or space heating requirement.

hydrostatic pressure relief valve: A pressure relief valve designed to automatically open to relieve liquid pressure in excess of its design relief setting and is primarily used for the protection of piping or equipment where liquid refrigerant could become trapped between two valves and subject to thermal expansion. In the specific application of trapped liquid in a pressure vessel or any other ASME stamped equipment, the ASME B&PV Code requires ASME rated and certified relief valves known as “liquid pressure” or “liquid service” relief valves.

limited charge system: A system in which the design pressure will not be exceeded when the compressor(s) is idle and the ammonia has completely evaporated such that only vapor is present in the idle system.

non-volatile liquid: A liquid that is not expected to change phase when heat is transferred to or from it at its working pressure.

PPM: Parts per million concentration, by volume unless otherwise stated.

supervised wire runs: a control method in which the electrical circuit is continuously monitored to detect fault conditions, including open circuits, short circuits, and ground faults, with automatic annunciation of such conditions.

Chapter 3. (Normative) Reference Standards

3.1 American Society of Mechanical Engineers (ASME) standards as follows:
ASME B&PVC, Section VIII, Division 1 (2025), *Boiler and Pressure Vessel Code, Pressure Vessels*.
ASME B&PVC, Section XIII, (2025), *Rules for Overpressure Protection*
ASME B16.5 (2025), *Pipe Flanges and Flanged Fittings.*
ASME B16.11 (2021), *Forged Fittings, Socket-Welding and Threaded.*
ASME B16.20 (2023), *Metallic Gaskets for Pipe Fittings.*
ASME B16.21 (2021), *Nonmetallic Flat Gaskets for Pipe Flanges.*
ASME B31.5 (2022), *Refrigeration Piping and Heat Transfer Components*.

3.2 American Society of Testing and Materials (ASTM) standards as follows:
ASTM A53/A53M-24 (2024), *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.*
ASTM A197/A197M-00 (2023)e1, *Standard Specification for Cupola Malleable Iron.*

3.3 IIAR standards as follows:

ANSI/IIAR 1 (2022), *Definitions and Terminology Used in IIAR Standards*

ANSI/IIAR 6 (2025), *Inspection, Testing, and Maintenance of Closed-Circuit Ammonia Refrigeration Systems.*

ANSI/IIAR 9 (2020), Addendum A-2024, *Minimum System Safety Requirements for Existing Closed-Circuit Ammonia Refrigeration Systems.*

3.4 International Safety Equipment Association (ISEA), ANSI/ISEA Z358.1-2014 (R2020), *World Safety Standard for Emergency Eyewash and Shower Equipment.*

3.5 National Fire Protection Association (NFPA). standards as follows:
NFPA Standard 70 (2026), *National Electrical Code (NEC).*
NFPA Standard 704 (2022), *Identification of the Hazards of Materials for Emergency Response.*

3.6 Occupational Safety and Health Administration (OSHA), U.S Department of Labor, regulations as follows:
29 CFR 1910.212 (2012), *General Requirements for All Machines.*
29 CFR 1910.219 (2012) *Mechanical Power Transmission Apparatus*.

3.7 ANSI/ASHRAE Standard 34 (2024), *Designation and Safety Classification of Refrigerants*.

3.8 United States National Institute of Standards and Technology (NIST). *Special Publication 330 (2019), The International System of Units***.**

3.9 UL, LLC, UL-61010-1, Edition 3 revised Nov 15, 2024, *Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use.*

3.10 International Organization for Standardization (ISO), ISO 10380 (2012), *Pipework-Corrugated Metal Hoses and Hose Assemblies.*

3.11 International Society of Automation (ISA), ANSI/ISA 92.00.01-2010 (R2015), *Performance Requirements for Toxic Gas Detectors.*

Part 2. Design and Installation Considerations Affecting Construction

Chapter 4. Location of Ammonia Refrigeration Equipment

4.1 General. The location of ammonia refrigeration equipment and design of closed-circuit ammonia refrigeration systems shall comply with this chapter. Listed equipment described in Section 4.3 shall be permitted in a location and occupancy as described in Section 4.2.

4.1.1 **Use of Ammonia Refrigeration with Secondary Coolants**

4.1.1.1 **Indirect Systems.** Secondary coolants used for heating or cooling, circulated through an ammonia refrigeration system that is configured as an indirect closed system, indirect vented closed system, or double indirect open spray system, are permitted to serve any occupancy. The ammonia containing equipment shall be located in compliance with Section 4.2 and the secondary coolant loop shall be designed in accordance with the mechanical code.

4.1.1.2 **Direct Systems.** Secondary coolants used for heating or cooling, circulated through an ammonia refrigeration system that is configured as a direct system or an indirect open spray system shall only serve industrial occupancies. The ammonia containing equipment shall be located in compliance with Section 4.2 and the secondary coolant loop shall be designed in accordance with the mechanical code.

4.1.2 **Use of Ammonia Refrigeration with Secondary Refrigerants.** Secondary refrigerants shall be designed to the relevant adopted standards and/or codes when used in conjunction with an ammonia refrigeration system.

4.2 *Permissible Equipment Installation Locations. Ammonia-containing refrigeration equipment shall be located only in those areas explicitly listed as permitted in this section.

4.2.1 ***Industrial Occupancies.** Ammonia-containing refrigeration equipment serving industrial occupancies is permitted to be located as follows.

4.2.1.1 **Machinery Rooms.** Equipment with any amount of ammonia is permitted to be installed in a machinery room in compliance with Chapter 6.

4.2.1.2 **Rooms other than a machinery room.** The following equipment, installed in areas other than a machinery room, in industrial occupancies complying with Chapter 7, is permitted:

4.2.1.2.1 Refrigeration systems with a total connected compressor drive power not exceeding 100 HP (74.6 kW)

4.2.1.2.2 Heat exchangers and associated surge drums (if equipped) used for space cooling, space heating, space dehumidification, process cooling, or process heating;

4.2.1.2.3 Low-probability pumps;

4.2.1.2.4 Piping, including but not limited to control and pressure-relief valves;

4.2.1.3 ***Outdoors.** Equipment with any amount of ammonia refrigerant is permitted outdoors provided the equipment is either; (a) located 20 feet or more from any building opening; or (b) located within 20 feet of any building opening that opens to a machinery room or an area classified as industrial occupancy complying with section 7.2. The ammonia-containing equipment located outdoors shall be installed in accordance with Sections 7.2.2, 7.2.4, 7.2.5, 7.2.6, 7.2.7, 7.2.10 and 7.3.2.

4.2.1.3.1 Ammonia-containing piping is permitted outdoors without restriction in regards to distance from building openings.

4.2.2 **Public Assembly and Large Mercantile Occupancies.** Ammonia-containing refrigeration equipment serving Public Assembly and Large Mercantile occupancies is permitted to be located as follows.

4.2.2.1 **Any area.** Listed equipment containing no more than 6.6 lbs.(3 kg) ammonia, meeting all the requirements of 4.3.2 is permitted.

4.2.2.2 ***Rooms other than public hallways or lobbies.** Equipment, listed or unlisted, is permitted in rooms other than public hallways or lobbies when the quantity of ammonia is limited such that a complete discharge from any independent refrigerant circuit will not result in an ammonia concentration exceeding 300 ppm in the room or area where the ammonia-containing equipment is located. The calculation procedure for determining the concentration level shall comply with Section 5.2.

4.2.2.3 **Machinery Rooms.** Equipment with any amount of ammonia is permitted to be installed in a machinery room in compliance with Chapter 6.

4.2.2.4 **Outdoors.** Equipment with any amount of ammonia refrigerant is permitted outdoors provided the equipment is either; (a) located 20 feet or more from any building opening; or (b) located within 20 feet of any building opening that opens to a machinery room or an area classified as industrial occupancy complying with section 7.2. The ammonia-containing equipment located outdoors shall be installed in accordance with Sections 7.2.2, 7.2.4, 7.2.5, 7.2.6, 7.2.7, 7.2.10 and 7.3.2.

4.2.2.4.1 Ammonia-containing piping is permitted outdoors without restriction in regards to distance from building openings.

4.2.3 **Commercial Occupancies.** Ammonia-containing refrigeration equipment serving commercial occupancies is permitted to be located as follows:

4.2.3.1 **Any area.** Listed, sealed equipment containing no more than 3.3 lbs.(1.5 kg) ammonia, meeting all the requirements of 4.3.4, is permitted in any room, including public hallways or lobbies.

4.2.3.2 **Rooms other than public hallways or lobbies.** Listed equipment containing no more than 22 lbs.(10 kg) ammonia, meeting all the requirements of 4.3.3, is permitted in rooms other than public hallways or lobbies.

4.2.3.2.1 *Equipment, listed or unlisted, is permitted in rooms other than public hallways or lobbies when the quantity of ammonia is limited such that a complete discharge from any independent refrigerant circuit will not result in an ammonia concentration exceeding 300 ppm in the room or area where the ammonia-containing equipment is located. The calculation procedure for determining the concentration level shall comply with Section 5.2.

4.2.3.3 **Machinery Rooms.** Equipment with any amount of ammonia is permitted to be installed in a machinery room in compliance with Chapter 6.

4.2.3.4 **Outdoors.** Equipment with any amount of ammonia refrigerant is permitted outdoors provided the equipment is either; (a) located 20 feet or more from any building opening; or (b) located within 20 feet of any building opening that opens to a machinery room or an area classified as industrial occupancy complying with section 7.2. The ammonia-containing equipment located outdoors shall be installed in accordance with Sections 7.2.2, 7.2.4, 7.2.5, 7.2.6, 7.2.7, 7.2.10 and 7.3.2.

4.2.3.4.1 Ammonia-containing piping is permitted outdoors without restriction in regards to distance from building openings.

4.2.4 **Residential Occupancies.** Ammonia-containing refrigeration equipment serving residential occupancies is permitted to be located as follows:

4.2.4.1 **Any area.** Listed, sealed equipment containing no more than 3.3 lbs.(1.5 kg) ammonia, meeting all the requirements of 4.3.4, is permitted in any room, including public hallways or lobbies.

4.2.4.2 **Rooms other than public hallways or lobbies.** Listed equipment containing no more than 6.6 lbs.(3 kg) ammonia, meeting all the requirements of 4.3.3, is permitted in rooms other than public hallways or lobbies.

4.2.4.3 **Machinery Rooms.** Equipment with any amount of ammonia is permitted to be installed in a machinery room in compliance with Chapter 6.

4.2.4.4 **Outdoors.** Equipment with any amount of ammonia refrigerant is permitted outdoors provided the equipment is either; (a) located 20 feet or more from any building opening; or (b) located within 20 feet of any building opening that opens to a machinery room, or an area classified as industrial occupancy complying with section 7.2. The ammonia-containing equipment located outdoors shall be installed in accordance with Sections 7.2.2, 7.2.4, 7.2.5, 7.2.6, 7.2.7, 7.2.10 and 7.3.2.

4.2.4.4.1 Ammonia-containing piping is permitted outdoors without restriction in regards to distance from building openings.

4.2.5 **Institutional Occupancy.** Ammonia-containing refrigeration equipment serving institutional occupancies is permitted to be located as follows:

4.2.5.1 **Machinery Rooms.** Equipment with any amount of ammonia is permitted to be installed in a machinery room in compliance with Chapter 6.

4.2.5.2 **Outdoors.** Equipment with any amount of ammonia refrigerant is permitted outdoors provided the equipment is either; (a) located 20 feet or more from any building opening; or (b) located within 20 feet of any building opening that opens to a machinery room or an area classified as industrial occupancy complying with section 7.2. The ammonia-containing equipment located outdoors shall be installed in accordance with Sections 7.2.2, 7.2.4, 7.2.5, 7.2.6, 7.2.7, 7.2.10 and 7.3.2.

4.2.5.2.1 Ammonia-containing piping is permitted outdoors without restriction in regards to distance from building openings.

4.2.6 **Laboratory Occupancies.** Ammonia-containing refrigeration equipment serving laboratory occupancies is permitted to be located as follows:

4.2.6.1 **Any area.** Listed equipment containing no more than 6.6 lbs.(3 kg) ammonia, meeting all the requirements of 4.3.2, is permitted.

4.2.6.2 **Laboratory Floor.** Listed equipment, containing any quantity of ammonia, meeting all the requirements of 4.3.1, is permitted when laboratory floor area is more than 100 ft^2 (9.3 m^2).

4.2.6.3 **Machinery Rooms.** Equipment with any amount of ammonia is permitted to be installed in a machinery room in compliance with Chapter 6.

4.2.6.4 **Outdoors.** Equipment with any amount of ammonia refrigerant is permitted outdoors provided the equipment is either; (a) located 20 feet or more from any building opening; or (b) located within 20 feet of any building opening that opens to a machinery room or an area classified as industrial occupancy complying with section 7.2. The ammonia-containing equipment located outdoors shall be installed in accordance with Sections 7.2.2, 7.2.4, 7.2.5, 7.2.6, 7.2.7, 7.2.10 and 7.3.2.

4.2.6.4.1 Ammonia-containing piping is permitted outdoors without restriction in regard to distance from building openings.

4.2.7 **Mixed Occupancies.** Ammonia-containing equipment serving mixed occupancies is permitted provided the ammonia equipment meets the requirements of each occupancy in which it is located.

4.3 Listed Equipment. Equipment descriptions satisfying the requirements of section 4.2 are shown below:

4.3.1 **Listed Equipment, No Charge Limit.** Listed equipment containing any amount of ammonia, installed in accordance with the listing, and the manufacturer's installation instructions.

4.3.2 **Listed Equipment, Limited Charge.** Listed equipment installed in accordance with the listing and the manufacturer's instructions.

4.3.3 **Listed Packaged Vapor Compression or Absorption Systems, Limited Charge.** Listed packaged vapor compression or absorption systems, with no refrigerant containing parts that are joined in the field by other than mating valves that permit sections of the system to be joined before opening the valves.

4.3.4 **Listed, Sealed Packaged Vapor Compression or Absorption Systems, Limited Charge.** Listed, sealed packaged vapor compression or absorption systems, with no refrigerant containing parts that are joined in the field by other than mating valves that permit sections of the system to be joined before opening the valves.

Chapter 5. General System Design Requirements

5.1 *Anhydrous Ammonia Specifications

5.1.1 ***Purity.** Anhydrous ammonia used for the initial and subsequent charging of ammonia refrigeration systems using mechanical compression shall meet the purity requirements shown in Table 5.1.1.

Table 5.1.1
Purity Requirements

Ammonia Content	99.5% minimum
Water	0.5% maximum
Oil & Other	0.1% maximum

5.2 *Volume Calculation for Determining Concentration of an Ammonia Release. For the purpose of applying Sections 4.2.2, 4.2.3, 5.13.3, 6.14.7, and Section 7.3.1.2, the volume used to calculate the potential ammonia concentration in the event of a release shall comply with this section. The volume used to calculate the potential ammonia concentration shall be the gross volume of a room or space into which released ammonia disperses based on the smallest gross volume in which the release will accumulate.

5.2.1 ***Wall Openings.** Where spaces adjacent to those containing refrigeration systems, equipment, or portions thereof are connected by permanent wall openings, the volume of such adjacent spaces shall not contribute to the calculated volume used for ammonia release concentration calculations unless, based on the size and elevation of permanent wall openings or a mechanical ventilation system, the designer determines that migration and dilution of a release over the combined spaces will occur. The volume shall be the combined space, provided that the openings or mechanical ventilation are clearly identified as the basis for the design analysis.

5.2.2 **Spaces Above Suspended Ceilings.** The space above a suspended ceiling shall not be included in the volume calculation unless the space above the ceiling functions as part of the air distribution system.

5.2.3 ***Interconnected Floor Levels and Mezzanines.** Where a refrigeration system, or portion thereof, is located in a room or space containing multiple floor levels connected through an open atrium or where a mezzanine is open to a room or space, the combined volume of interconnected floors and mezzanines is permitted in the volume calculation.

5.2.4 ***Mechanical Ventilation Considerations.** Where a refrigeration system, or portion thereof, is located 1) in an area served by a mechanical ventilation system that also serves additional spaces, 2) within an air handler, or 3) in an air distribution duct system, the volume of the rooms or spaces connected by the ventilation or duct system, including the volume of the connected supply and return air ducts exterior to the room and any connecting plenum, shall be used.

EXCEPTION: The smaller of the volumes on either side of a damper shall be used where portions of the ventilation or duct system are subject to being isolated by dampers, other than 1) fire dampers, 2) smoke dampers, 3) combination fire and smoke dampers, or 4) dampers that continuously maintain not less than 10% airflow.

5.3 *System Design Pressure. Design pressure shall be in accordance with this section.

5.3.1 **General**

5.3.1.1 **Margin Settings for Pressure-Limiting and Pressure-Relief Devices**. In determining the set pressure of pressure limiting and pressure-relief devices, a margin shall be provided between the system operating pressure and the set pressure to avoid equipment shutdown or loss of ammonia during normal operation. The system shall be designed to have a margin of at least 25 psig (173 kPa) or 10% of the PRV set pressure value, whichever is greater, between the pressure limiting device set-point and the PRV set-point.

5.3.1.2 **Equipment Connected to a Pressure Vessel.** Equipment connected to pressure vessels and subject to the same pressure as the pressure vessel shall have a design pressure that is equal to or greater than the set pressure of the pressure relief protection for the pressure vessel or shall be separately protected at a pressure no greater than its design pressure.

5.3.1.3 **Piping Connected to a Pressure Vessel**. Piping connected to pressure vessels and subject to the same pressure as the pressure vessel shall have a design pressure that is equal to or greater than the design pressure of the pressure vessel or shall be separately protected at a pressure no greater than its design pressure.

5.3.1.4 **Compressors Used as Boosters.** Compressors used as boosters and discharging into the suction side of another compressor shall be considered as part of the low-pressure side for the purpose of determining the design pressure.

5.3.1.5 ***Connecting to Existing Low-Pressure Equipment.** Where new low-pressure side equipment is connected to an existing system that was in operation prior to the adoption of this standard by the AHJ, the design pressure of the new low-pressure side portion of the system shall be constructed for a minimum design pressure of 250 psig per Section 5.3.3. All other requirements of this standard shall apply.

5.3.2 **Pressure Developed during Operation, Standby, or Shipping Conditions.** The design pressure shall be equal to or greater than the maximum pressure that could occur during operation, standby, or shipping conditions. The manufacturer shall provide operating pressure limit information.

5.3.2.1 **Normal Operation Conditions.** The design pressure shall be equal to or greater than the maximum pressures that could occur during normal operation conditions, including conditions created by expected fouling of heat-exchange surfaces.

5.3.2.2 ***Standby Conditions.** The design pressure shall be equal to or greater than the maximum pressure that could occur during standby conditions, which shall include conditions that can normally occur when the system is not in operation. For low-pressure side equipment, the design pressure shall be equal to or greater than the pressure developed in the low-pressure side of the system from equalization with the high side or heating due to changes in ambient temperature after a system has stopped.

5.3.2.3 **Shipping.** The design pressure for both low-pressure side and high-pressure side equipment that is shipped as part of a gas-charged or ammonia-charged system shall equal or exceed the maximum internal pressures associated with the highest anticipated temperature exposure during shipment.

5.3.3 **Saturation Pressure and Minimum Permissible Design Pressure.** The design pressure shall not be less than the saturation gauge pressure corresponding to the following temperatures and shall not be less than the specified minimum.

1. **Low-pressure side:** The minimum low-side design pressure shall be the greater of 250 psig (1,724 kPa) or the saturation pressure corresponding to a temperature of 10°F (5.6°C) higher than the cooling 1% dry-bulb temperature for the installation location.
2. **High-pressure side of water-cooled systems:** The minimum high-side pressure shall be the greater of 250 psig (1,724 kPa), or the saturation pressure corresponding to 15°F (8.3°C) higher than the highest "design-leaving condensing-water temperature" for which the equipment is designed.
3. **High-pressure side of evaporatively cooled systems:** The minimum high-side design pressure shall be the greater of 250 psig (1,724 kPa) or the saturation pressure that corresponds to 30°F (16.7°C) higher than the evaporation 1% wet-bulb temperature for the location.
4. **High-pressure side of air-cooled systems:** The minimum high-side design pressure shall be 30°F (16.7°C) higher than the cooling 1% dry-bulb for the location or the minimum design pressure of 300 psig (2,069 kPa), whichever is greater.
5. **Design Pressure for Heat Pump Systems:** The minimum design pressure for the suction side shall be 250 psig (1,724 kPa). The minimum design pressure for the discharge side of a heat pump system shall be the greater of 250 psig (1,724 kPa) or the saturation pressure corresponding to 20°F (11.1°C) higher than the design condensing temperature.
6. *Ammonia systems shall be designed to resist collapse when internal pressure is at full vacuum and external pressure is atmospheric, or internal pressure is 14.7 psig below external pressure.

5.4 System Design Temperature. Equipment shall be designed to operate within the full range of temperatures associated with the system design and for the full range of ambient temperatures to which equipment will be exposed at the installation location. The manufacturer shall provide operating temperature limit information.

5.5 Materials

5.5.1 **General**

5.5.1.1 Materials used in the construction of a closed-circuit ammonia refrigeration system shall be suitable for contact with ammonia refrigerant within the closed-circuit system at the coincident temperature and pressure to which the system will be subjected.

5.5.1.2 *Materials that deteriorate in the presence of ammonia, refrigerant lubricating oil, or a combination of both, shall not be used.

5.5.2 **Metallic Materials**

5.5.2.1 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. Other metallic materials, including but not limited to aluminum, aluminum alloys, lead, tin, and lead-tin alloys shall be permitted in accordance with Section 5.5.1. Where tin and tin-lead alloys are used, the alloy composition shall be verified as suitable for temperature exposures, as specified in Section 5.4.

5.5.2.2 Zinc, copper, and copper alloys shall not be used to contain or be in contact with ammonia. Copper-containing anti-seize and lubricating compounds shall not be used. Copper, as a component of brass alloys, shall be permitted in rotating shaft bearings and other non-refrigerant-containment uses.

5.5.3 **Nonmetallic Materials**

5.5.3.1 Nonmetallic materials shall be permitted in accordance with Section 5.5.1.

5.5.3.2 Nonmetallic materials shall be permitted in accordance with ASME B31.5 or ASME B&PVC, Section VIII, Division 1.

5.6 Purging. Means shall be provided to remove air and other non-condensable gases from the refrigeration system. Purging discharge piping shall be compatible with ammonia.

5.6.1 Automatic purging systems shall discharge non-condensable gases to a water column or another approved treatment system.

5.6.2 For systems that use manual purging, discharge piping that is permanently installed shall conform to Section 13.4 for support.

EXCEPTION: A means for purging is not required for packaged vapor compression and absorption systems with refrigerant quantities that do not exceed 22 lbs. (10 kg).

5.7 Oil Management

5.7.1 **General.** Provisions shall be made in the design for removing oil from locations in piping and equipment where oil accumulation is expected.

5.7.2 **Compressors.** Compressor oil systems shall have a means to sample oil for periodic oil analysis when required by the manufacturer's recommendations.

5.7.3 ***Oil Collection Vessels.** Vessels designed for collecting and removing oil from the system, not including oil separators, shall be equipped with a shut-off valve in series with a self-closing shut-off valve. All piping to atmosphere for oil collection vessels shall be designed to be capped when not in use.

5.8 Insulation

5.8.1 ***Condensation and Frost Control.** Piping and equipment surfaces not intended for heat exchange shall be insulated, treated, or otherwise protected to mitigate effects of condensation and excessive frost buildup to a level that interferes with valve operation or creates damage to piping, equipment or supports. Portions of a system that have the potential for condensation shall not be placed above electrical equipment unless the electrical equipment is protected from damage caused by condensation.

EXCEPTIONS:

1. Valve groups and other equipment shall be permitted to be uninsulated where necessary for service access provided that the vapor retarder is sealed to the piping or equipment where insulation of adjoining piping terminates.
2. Piping and fittings constructed of corrosion-resistant materials or protected with a corrosion-resistant treatment shall be permitted to be uninsulated if they are routinely defrosted or are otherwise managed to limit ice accumulation. Where defrost will be the method of ice control, a means to control and drain condensate shall be provided where such condensate will present a nuisance or a hazard.

5.9 Piping, Tubing, and Equipment Supports

5.9.1 ***General.** Structural supports and anchorage shall be provided for refrigeration piping, tubing, and equipment. Such supports, and the associated foundations and structures by which they are supported, shall be designed to withstand the forces due to static, dynamic and seismic load inputs as defined by adopted codes and standards.

5.9.1.1 Equipment supported from the ground shall rest on and be anchored to a concrete foundation or shall be furnished with a support base for anchoring to the foundation.

5.9.2 **Combustibility.** Foundations, floor slabs, structural supports, and anchorage for piping, tubing, and other equipment shall not be made of combustible material. Where supports are mounted on the roof, pressure-treated lumber and synthetic materials shall be permitted under structural supports to distribute the load and protect the roofing system.

5.9.3 **Seismic Joints and Restraints.** Seismic joints and restraints shall be provided as defined by adopted codes and standards.

5.9.4 **Expected Loads.** Foundations, housekeeping pads, structural supports, and anchorage for equipment including compressors, condensers, and vessels shall be capable of supporting the expected static and dynamic loads imposed by such units including those loads associated with attached piping.

Equipment structures, assemblies, and piping connections shall be designed to withstand the expected loads and shall meet equipment manufacturer’s recommendations.

5.9.4.1 Designers shall provide documentation that defines the basis for the foundation support design including the anticipated loads, demonstration that the design is adequate for the anticipated loads, and that they meet or exceed the equipment manufacturer’s recommendations.

5.9.4.2 Equipment manufacturers shall provide maximum expected loads imposed on foundations, housekeeping pads, structural supports, and anchorage.

5.9.4.3 Equipment manufacturers shall provide maximum allowable static and dynamic load specifications for nozzles, flanges, and other points of connection.

5.9.4.4 Where vibration prevention is recommended by the manufacturer, isolation materials shall be permitted between the foundation or support structure and the equipment or piping.

5.10 Service and Accessibility Provisions

5.10.1 ***General.** Equipment shall be accessible for maintenance, in accordance with adopted codes and standards.

5.10.2 **Charging Connection Security.** Refrigeration system charging connections shall be designed to accommodate a check valve to prevent the backflow of refrigerant from the system during charging. The charging connection shall be designed to be plugged or capped when not in use. When located outdoors, charging connections shall be designed to be locked or otherwise restricted to access by authorized personnel only.

5.10.3 ***Maintenance and Functional Testing.** Design provisions for maintenance and functional testing of safety controls shall be provided. Such provisions shall be permitted to include but are not limited to shut-off valves and capped or plugged connection points that comply with this standard.

5.10.4 ***Service Isolation Valves.** Serviceable equipment and control valves shall have manual isolation valves. Where multiple pieces of serviceable equipment are readily isolated by a single set of hand isolation valves, the use of a single set of valves meets the intent of this section.

EXCEPTION: 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.

5.10.5 **Access to Valves**

5.10.5.1 *Manually operated valves that are inaccessible from floor level shall be operable from portable/mobile platforms, fixed platforms, ladders, or by use of a chain or a remote-actuated manual operator.

5.10.5.2 Manually operated system emergency valves identified as being part of the system emergency shutdown procedure that are inaccessible from floor level shall be operable from a fixed permanent work surface, or by use of a chain or a remote-actuated manual operator that shall be readily accessible from the floor or a permanent work surface. Ready access and clearance to operate the valves while wearing emergency response personal protective equipment shall be provided.

5.10.6 **Equipment Pumpout.** Provisions for pumpout of equipment and control valves shall be provided for maintenance and service**.**

5.11 Testing

5.11.1 **Strength Testing.** Equipment containing ammonia shall be strength tested to the minimum pressure exceeding the design pressure specified in Chapter 8 through Chapter 16, subsequently leak tested, and proven by the manufacturer to be tight at a pressure not less than the design pressure.

5.11.2 **Ultimate Strength.** Pressure-containing equipment shall comply with Sections 5.11.2.1 and 5.11.2.2.

EXCEPTIONS: The following shall be permitted to comply with Section 5.11.2.3 in lieu of complying with Sections 5.11.2.1 and 5.11.2.2:

1. Pressure gauges; and
2. Control mechanisms.

5.11.2.1 Pressure-containing equipment shall be in accordance with one of the following:

1. Listed individually;
2. Listed as part of the complete refrigeration system;
3. Listed as a subassembly;
4. Designed, constructed, tested and assembled, in accordance with ASME B31.5; or
5. Designed, constructed, tested and assembled, in accordance with ASME B&PVC, Section VIII, Division 1.

5.11.2.2 *Secondary coolant sides of equipment exempted from ASME B&PVC, Section VIII, Division 1, shall be designed, constructed, and assembled to have ultimate strength sufficient to withstand the greater of 150 psig (1,035 kPa gauge) or two times the design pressure for which they are rated.

5.11.2.3 Equipment designs based on the exceptions to Section 5.11.2 shall be required to comply with additional requirements in ASME B31.5 as applicable.

5.12 Signage, Labels, and Pipe Marking

5.12.1 ***System Signage.**

5.12.1.1 Signage or schematic drawings for each system containing more than 22 lbs. of ammonia shall be posted at a location that is readily accessible to trained refrigeration staff and trained emergency responders. Schematic drawings or signage shall include the following information:

1. Instructions with details and steps for shutting down the system in an emergency;
2. The contact information for whom to contact in an emergency;
3. Maximum intended inventory of ammonia in the system;
4. Type of refrigerant compressor oil(s).
5. Lowside and highside design pressures.

5.12.1.2 Additional machinery room signage is required and shall comply with Section 6.15.

5.12.2 ***NFPA 704 Placards.** Buildings and facilities with refrigeration systems shall be provided with placards that display information in accordance with NFPA 704. Placards shall be located at restricted entrances to rooms or areas identified as likely to be accessed by emergency response personnel. For equipment located outdoors, the placard shall display the following degrees of hazard: Health-3, Flammability-1, Instability-0. For equipment located indoors, the placard shall display the following degrees of hazard: Health-3, Flammability-3, Instability-0.

5.12.3 ***Equipment Labels.** Refrigeration equipment shall be uniquely labeled in a manner consistent with system documentation.

5.12.4 ***Emergency Shut-off Valve Identification and Tagging.** Valves listed as emergency shut off valves in the system emergency shutdown procedure shall be clearly and uniquely identified at the valves themselves and in the system schematic drawings.

5.12.5 **Nameplates**

5.12.5.1 Equipment shall have a nameplate with minimum data that describes or defines the manufacturer's information and design limits and purpose as specified in Chapter 8 through Chapter 16.

5.12.5.2 The original nameplate for pressure vessels shall be affixed as specified in ASME B&PVC, Section VIII, Division 1, Section UG-119.

5.12.5.3 *Duplicate nameplates shall be applied in accordance with the following:

1. Where duplicate nameplates are required for pressure vessels and heat exchangers constructed in accordance with ASME B&PVC, Section VIII, Division 1, the duplicate nameplate shall comply with ASME B&PVC, Section VIII, Division 1, Section UG-119(f).
2. A duplicate nameplate, if used, shall be installed on the skirt, support, jacket, or other permanent attachment to a vessel.
3. Duplicate nameplates shall be permanently marked "DUPLICATE."
4. Duplicate nameplates shall be obtained only from the original equipment manufacturer or the manufacturer's assignee.

5. The installer shall certify to the manufacturer that the duplicate nameplate has been applied to the proper vessel, in accordance with the governing edition of ASME B&PVC, Section VIII, Division 1, Section UG-119(d). The installer shall provide a copy of the certification to the owner, in accordance with Section UG-120, who shall retain the copy with the U1A form for the vessel.

5.12.6 ***Pipe Marking.** Ammonia piping mains, headers, and branches shall be identified with the following information:

1. "AMMONIA";
2. Physical state of the ammonia;
3. Relative pressure level of ammonia, being low or high as applicable;
4. Pipe service, which shall be permitted to be abbreviated; and
5. Direction of flow.

The marking system shall either be one established by a recognized model code or standard or one described and documented by the facility owner or the owner's agent.

5.13 Equipment Enclosures

5.13.1 ***General.** Enclosures for ammonia equipment shall be suitable for the installation location and shall be provided with protection from physical and environmental damage as required for the installed location.

5.13.2 ***Access.** Operational and maintenance service access shall be provided by access panels or doors, or the design shall provide for removal of equipment to a remote location for service and subsequent reinstallation.

5.13.3 ***Ammonia Detection and Interlocks.** Enclosures that have the potential to reach a concentration of 40,000 ppm (by volume) from a refrigerant release from the largest independent circuit within the enclosure and have either 1) open flames or hot surfaces as described in Section 6.5 or 2) have unclassified electrical equipment, shall be provided with ammonia detection and interlocks that will disable the ignition source(s) at or below a concentration of 40,000 ppm.

5.14 General Safety Requirements

5.14.1 ***Moving Parts.** Exposed moving parts shall be protected with screens or guards in accordance with OSHA 29 CFR 1910.212 and 29 CFR 1910.219.

5.14.2 **Used Equipment.** Used equipment to be installed as a replacement for equipment on an existing system shall comply with the requirements of the standard that regulated the installation of the existing system, including the minimum design pressure. Used equipment to be installed in connection with a new system shall meet the requirements of this standard. Used equipment to be installed as an expansion to an existing system shall be permitted to have a design pressure equal to that of the existing system and shall meet all other requirements of this standard.

5.14.3 ***Static and Dynamic Loads.** Equipment shall be designed to structurally withstand the expected static and dynamic loads.

5.14.4 ***Illumination of Equipment Areas**. Illumination shall be available for refrigeration equipment work areas in accordance with adopted codes and standards.

5.14.5 ***Means of Egress.** Means of egress shall comply with adopted codes and standards.

5.14.6 **Refrigerant Piping**. Refrigerant piping having an external surface temperature of 140°F (60°C) or higher and located outside the machinery room at a height less than 7.25 ft (2.2 m) above the floor or working surfaces, located adjacent to passageways, aisles, walkover stairs, or landings, shall have means to prevent contact by personnel such as insulation, guards, fence or railing barriers or other means in compliance with local, state or federal regulation.

5.14.7 **Electrical Safety.** Electrical equipment and wiring shall be installed in accordance with the electrical code.

Chapter 6. Machinery Rooms

6.1 General. Where a machinery room is required by **Error! Reference source not found.** to contain equipment, the machinery room shall comply with this chapter.

6.2 Construction. Machinery rooms shall be constructed in accordance with adopted codes and standards and the requirements of this section**.**

6.2.1 ***Separation and Fire Protection.** The machinery room shall be separated from the remainder of the building by tight-fitting construction having a one-hour fire-resistance rating. Doors shall comply with Section 6.10.

EXCEPTION: The one-hour fire-resistance rating shall not be required where the machinery room is equipped with an automatic fire sprinkler system. Tight-fitting construction must still be provided.

6.2.2 **Airflow from Occupied Spaces.** Air shall not flow to or from any portion of a premises that is routinely accessible to or occupied by people on a part-time or full-time basis through a machinery room unless the air is ducted and sealed to prevent ammonia leakage from entering the airstream. Access doors and panels in ductwork and air-handling units located in a machinery room shall be gasketed and tight-fitting.

6.3 Access and Egress

6.3.1 **General.** Equipment installed in machinery rooms shall be located in such a manner as to allow egress from any part of the room in the event of an emergency, and to provide clearances required for maintenance, operation, and inspection according to manufacturers' instructions.

6.3.2 **Maintenance Access.** Maintenance access shall comply with Section 5.10.1.

6.3.3 **Restricted Access.** Access to a machinery room shall be restricted to authorized personnel. Signage on machinery room doors shall comply with Section 6.15.

6.4 *Combustible Materials. Combustible materials or flammable liquids shall not be stored in machinery rooms outside of approved fire-rated storage containers.

EXCEPTION: This provision shall not apply to spare parts, tools, incidental materials, and the containers for such items, necessary for the operation and maintenance of the refrigeration system.

6.5 Open Flames and Equipment Surfaces Exceeding 800ºF.

6.5.1 Fuel-burning equipment shall be permitted in a machinery room where combustion air to the fuel-burning appliance is ducted from outside of the machinery room and sealed to prevent ammonia leakage from reaching the combustion chamber.

6.5.2 *Equipment with open flames or equipment with surface-temperatures exceeding 800°F (427°C) shall be permitted in a machinery room when an ammonia detection system is installed and operated in accordance with Section 6.13 and is designed to automatically shut down the equipment, or de-energize the source of ignition or heat, upon detection of ammonia at the concentration specified in Section 6.13.2.3.

6.5.3 Internal combustion engines powering compressors shall be permitted in a machinery room.

6.6 Piping

6.6.1 **Insulation.** Piping and fittings shall be insulated as required by Section 5.8.

6.6.2 **Pipe Penetrations.** Pipes penetrating the machinery room separation shall be sealed to the walls, ceiling, or floor through which they pass in accordance with Section 6.2.1. Where Section 6.2.1 requires that the separation have a fire rating, pipe penetrations shall be fire stopped in accordance with adopted codes and standards.

6.6.3 ***Connection of Ammonia Cylinders.** Ammonia cylinders shall not be connected to a refrigeration system unless ammonia is in the process of being transferred by authorized personnel.

6.7 Eyewash/Safety Shower

6.7.1 ***Inside Machinery Room.** A machinery room shall have a minimum of one eyewash/safety shower unit located inside the machinery room. Additional eyewash/safety shower units shall be installed inside the machinery room to ensure that the path of travel in the machinery room is no more than 55 ft. to an eyewash/safety shower unit.

6.7.1.1 The path of travel within the machinery room to at least one eyewash/safety shower unit shall be unobstructed and shall not include intervening doors.

6.7.1.2 An eyewash/safety shower is not required in a machinery room if all the following conditions are met:

6.7.1.2.1 The machinery room area is 1000 ft.2 or less;

6.7.1.2.2 The path of travel from any point in the machinery room to the permanently installed eyewash/safety shower required by 6.7.2 will not exceed 55 ft;

6.7.1.2.3 A temporary or portable means for the provision of quick drenching or flushing of the eyes and body is provided within the machinery room for immediate emergency use when maintenance occurs that involves the deliberate opening of a refrigerant circuit. Such means shall be indicated in the operating procedures and the requirements shall be posted on or adjacent to the primary machinery room door. Such means shall comply with the temperature, flow, and duration specifications of ANSI/ISEA Z358.1.

6.7.2 **Outside Machinery Room.** A minimum of one eyewash/safety shower unit shall be located outside the machinery room and shall be no further than 55 ft. from the outside of the machinery room door.

6.7.3 **Installation Standard.** Emergency eyewash/safety shower unit installations shall comply with the temperature, flow, and duration specifications of ANSI/ISEA Z358.1.

6.8 Electrical Safety

6.8.1 **Hazardous (Classified) Locations.** Machinery rooms are permitted to be designated as Unclassified Locations, as described in the electrical code, where the machinery room is provided with emergency ventilation in accordance with Section 6.14.7 and ammonia detection in accordance with Section 6.13.

A machinery room that does not have either continuously operating emergency ventilation or ammonia-detection-activated emergency ventilation shall be designated as not less than a Class I, Division 2, Group D Hazardous (Classified) Location, and electrical equipment installed in the machinery room shall be designed to comply with this classification.

EXCEPTION: Machinery rooms not provided with emergency ventilation but contain only refrigeration systems that are compliant with Section 6.14.7.1, Exception 1, are not required to be designated as a Class I, Division 2, Group D Hazardous (Classified) Location.

6.8.2 **Design Documents.** Electrical design documents shall indicate whether the machinery room is designated as an Unclassified Location or as a Hazardous (Classified) Location. Where the machinery room is designated as a Hazardous (Classified) Location, the Class, Division, and Group of the electrical classification, as required by the electrical code, shall be indicated in the documentation.

6.9 Drains

6.9.1 **General.** Floor drains shall be provided to dispose of wastewater.

6.9.2 **Contaminant Control.** Where a drainage system is not designed for handling oil, secondary coolants, or other liquids that might be spilled, a means shall be provided to prevent such substances from entering the drainage system.

6.9.3 ***Control of Ammonia Spills.** A means shall be provided to limit the spread of a liquid ammonia spill into the machinery room drainage system.

6.10 Entrances and Exits

6.10.1 **General.** Machinery rooms exceeding 1,000 ft^2 (93 m^2) in area shall not have fewer than two exit doors or exit-access doors. Where two doors are required, one door shall be permitted to be served by a stair, fixed ladder or an alternating tread device. Doors shall be separated by a horizontal distance equal to or greater than one-half of the maximum horizontal dimension of room. All portions of a machinery room shall be within 150 ft (45.7 m) of an exit-door or exit-access door, unless the building code permits an increased travel distance.

6.10.2 **Personnel Door Features.** Machinery room doors shall be self-closing and tight-fitting. Doors that are part of the means of egress shall be equipped with panic hardware and shall be side-hinged to swing in the direction of egress for occupants leaving the machinery room. Machinery room doors shall open with the use of only the panic hardware and shall not require the use of other hardware or switches to exit the room.

6.10.3 **Equipment Access Door Features.** Machinery room access doors for the removal or installation of equipment and supplies shall be designed to be tight fitting.

6.10.4 **Separation from Fire Escapes and Stairways.** Exit doors leading to the outdoors shall not be located beneath an open stairway that is designated as an emergency egress.

6.11 Lighting

6.11.1 **General.** Machinery rooms shall be equipped with light fixtures delivering a minimum of 30 foot-candles (320 lumens/m^2) at the working level, 36 in. (0.91 m) above a floor or platform.

6.11.2 **Light Control.** A manual control for the illumination source shall be provided. Occupancy sensors shall be permitted as an additional control for lighting, but not in lieu of a manual control.

6.12 *Emergency Control Switches

6.12.1 **Emergency Stop Switch.** A clearly identified emergency stop switch shall be located outside and adjacent to the designated principal machinery room door. The switch shall provide off-only control of refrigerant compressors, refrigerant pumps, and normally closed automatic refrigerant valves that are not part of an emergency control system, located in the machinery room. The function of the switch shall be clearly marked by signage near the controls. The switch shall be readily operable and protected from inadvertent operation and require manual reset.

6.12.2 **Emergency Ventilation Control Switch.** A clearly identified control switch for emergency ventilation that is not operated continuously shall be located outside the machinery room and adjacent to the designated principal machinery room door. The switch shall provide "ON/AUTO" override capability for emergency ventilation. The function of the switch shall be clearly marked by signage near the controls. The switch shall be readily operable.

6.13 Ammonia Detection and Alarm

6.13.1 **General.** Machinery rooms shall be provided with a minimum of two (2) ammonia detector(s) to initiate the alarm sequences for 25 ppm in accordance with Section 6.13.2.2 and 150 ppm in accordance with Section 6.13.2.3 and an alarm in accordance with Sections 17.2–17.6., and have the following features:

6.13.1.1 **Detection System Configuration.** The ammonia detection system shall comply with one of the following provisions:

1. The system shall use two or more detectors with at least two detectors having identical concentration sensing ranges, which shall initiate alarm sequences in accordance with Sections 6.13.2.2 and 6.13.2.3 and shall remain operable during failure or maintenance of any single detector.

2. The use of a single detector is permitted, if the failure or maintenance of the detector that causes the detection system to become inoperable, automatically initiates the alarm(s), notification(s), emergency ventilation, and equipment shutdown(s) described in Sections 6.13.2.2, 6.13.2.3, and 6.13.2.4, and shall persist until the detector or detection system is restored.

6.13.1.2 Audible and visual alarms shall be provided inside the room to warn that access to the room is restricted to authorized personnel and emergency responders when the alarm has activated. Additional audible and visual alarms shall be located outside of each entrance to the machinery room.

EXCEPTION:

The use of a single detector to initiate the alarm sequences in accordance with 6.13.2.2 and 6.13.2.3 is permitted if the failure or maintenance of the detector that causes the detection system to become inoperable automatically initiates the alarm(s), notification(s), emergency ventilation, and equipment shutdown(s) described in Sections 6.13.2.2, 6.13.2.3, and 6.13.2.4, and shall persist until the detector or detection system is restored.

6.13.2 **Alarm Response**

6.13.2.1 Detection of ammonia concentrations less than 25 ppm requires no alarm.

6.13.2.2 *Detection of ammonia concentrations equal to or exceeding 25 ppm shall activate visual indicators, audible alarms, provide a notice to a monitored location. Visual indicators and audible alarms shall be permitted to reset automatically if the ammonia concentration drops below 25 ppm.

6.13.2.3 *Detection of ammonia concentrations equal to or exceeding 150 ppm (1/2 IDLH) shall shutdown equipment with open flames or with surface temperatures exceeding 800ºF (427ºC) in accordance with Section 6.5.2 and activate emergency ventilation, where such is required in accordance with Section 6.14.7. Once activated, emergency ventilation, and visual indicators shall continue to operate until manually reset by a switch located in the machinery room. Audible alarms shall continue to operate until they are manually reset by a switch, located onsite. Equipment specifically identified in Section 6.5.2, shall remain de-energized until manually reset by the switch in the machinery room.

6.13.2.4 *Detection of ammonia concentrations that exceed a detector's upper detection limit or 40,000 ppm whichever is lower, shall automatically shut down the following equipment in the machinery room and shall remain shut down until being manually reset:

1. Refrigerant compressors,
2. Refrigerant pumps, and
3. Normally closed automatic refrigerant valves that are not part of an emergency control system.

If the detectors within the machinery room have more than one sensing range, the detector with the highest range of detection capability is permitted to be used to activate this alarm response. Once activated, emergency ventilation, and visual indicators shall continue to operate until being manually reset by a switch located in the machinery room. Audible alarms shall continue to operate until they are manually reset by a switch, located onsite.

6.14 Ventilation

6.14.1 ***Ventilation for Occupants.** During occupied conditions, outdoor air shall be provided at a rate of not less than 0.5 cfm/ft^2 (0.0025 $m^3/s \cdot m^2$) of machinery room area or 20 cfm (0.009 m^3/s) per occupant, whichever is greater.

6.14.2 **General Ventilation and Air Conditioning Equipment.** Machinery room ventilation fans and air conditioning equipment that do not meet all requirements set forth in 6.14.2 through 6.14.6 shall not be considered part of the machinery room's emergency ventilation system and shall be automatically de-energized upon detection of ammonia in accordance with 6.13.2.3. are not part of an emergency ventilation system shall be automatically de-energized and associated fan dampers, where provided, shall automatically close upon detection of ammonia in accordance with Section 6.13.2.3.

6.14.3 **Exhaust Ventilation.** Machinery rooms shall be vented to the outdoors by means of a mechanical exhaust ventilation system.

6.14.3.1 *Mechanical exhaust ventilation systems shall be designed to produce not less than the greater of (1) temperature control ventilation rate required by Section 6.14.6 or (2) the emergency exhaust ventilation rate required by Section 6.14.7.

6.14.3.2 Exhaust air ducts from the machinery room shall serve only the machinery room.

6.14.3.3 *Machinery room exhaust shall be to the outdoors not less than 20 ft (6 m) from a property line or openings into buildings.

EXCEPTION: Machinery room exhaust is permitted to be installed within 20 ft. (6m) of tight-fitting machinery room doors and roof hatches that are not designated for emergency egress and that have signage indicating they must be closed after passage.

6.14.3.4 Machinery room emergency exhaust shall discharge vertically upward with a minimum discharge velocity of 2,500 ft/min (762 m/min) at the required emergency ventilation flow rate.

6.14.3.5 *Emergency exhaust fans shall be constructed such that radial or axial displacement of the impeller or shaft will not permit two ferrous parts of the fan to rub or strike.

6.14.3.6 *Emergency exhaust fan motors located in the air stream or inside the machinery room shall be of the totally-enclosed type. Fan motors meeting this requirement are not required to be listed for use in hazardous (classified) locations.

6.14.4 **Fan Options.** Multiple fans or multispeed fans shall be permitted to provide both temperature control exhaust ventilation in accordance with Section 6.14.6 and emergency exhaust ventilation in accordance with Section 6.14.7. Fans used for both temperature control and emergency ventilation shall be controlled in a manner that provides equal to or greater than the emergency ventilation rate when emergency ventilation is activated.

6.14.5 **Inlet Air**

6.14.5.1 *Outdoor make-up air shall be provided to replace air being exhausted. The ventilation system(s) shall be designed to maintain negative pressure in the machinery room when exhaust fans are operating. The negative pressure shall not exceed 0.25 in. (6.4 mm) water column relative to the adjacent areas with a machinery room door, including the outdoors.

6.14.5.2 Make-up air supply locations in the machinery room shall be positioned to prevent short-circuiting of the make-up air directly to the exhaust.

6.14.5.3 Make-up air openings shall be covered with a corrosion-resistant screen of not less than ¼ in. mesh or equivalent protection.

EXCEPTION: A smaller screen mesh or air filters are permitted to be installed if engineering or administrative controls are in place to ensure that the maximum negative air pressure requirement in Section 6.14.5.1 and the air quantity requirements in Sections 6.14.1, 6.14.6 and 6.14.7 are met.

6.14.5.4 Intakes for make-up air to the machinery room shall serve only the machinery room.

6.14.5.5 *Where dampers are used for emergency ventilation systems, the system(s) shall be designed to prevent exceeding the negative pressure per Section 6.14.5.1.

6.14.5.6 Where direct openings or openings with ducts are not provided to supply make-up air, make-up air shall be provided by fans or fans with ducts.

6.14.6 **Temperature Control Ventilation**

6.14.6.1 *Temperature control mechanical ventilation design capacity shall be the volume required to limit the room dry-bulb temperature to 104°F (40°C), taking into account the ambient heating effect of equipment in the room and with the make-up air entering the room at the annual 1% design dry-bulb temperature. The emergency ventilation system shall be permitted to be used to supplement temperature control ventilation, and vice versa.

EXCEPTION: A reduced temperature control ventilation rate shall be permitted where a means of cooling is provided, or room electrical equipment and wiring is designed to accommodate temperatures exceeding a dry-bulb temperature of 104°F (40°C), in accordance with UL Listings and the electrical code.

6.14.6.2 Partial operation of a multiple-fan system or multispeed fans shall be permitted to deliver the temperature control ventilation design capacity.

6.14.6.3 Temperature control mechanical ventilation shall be continuous or shall be activated by both of the following:

1. A thermostat measuring space temperature; and
2. A manual control switch provided in accordance with Section 6.12.1, where temperature control ventilation is designed to contribute to emergency ventilation.

6.14.7 **Emergency Ventilation**

6.14.7.1 *Emergency mechanical ventilation systems shall provide not less than 30 air changes per hour based on the gross machinery room volume. The emergency ventilation system shall be permitted to include temperature control ventilation fans that meet the requirements of Section 6.14.3 and Section 6.14.6.3, Item 2.

EXCEPTIONS:

1. Where not prohibited by the AHJ, emergency mechanical ventilation shall not be required for a 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, based on the volume calculation determined in accordance with Section 5.2. The designer shall provide a copy of the calculations to be retained at the site.
2. A reduced emergency ventilation rate is permitted where an engineering analysis indicates that the reduced rate will prevent an ammonia concentration from exceeding 40,000 ppm in the machinery room following a release of the entire charge from the largest independent circuit in the room. The analysis must be documented and retained on-site.
3. *A reduced emergency ventilation rate, where justified by an engineering analysis and approved by the AHJ, shall be permitted. The analysis must be documented and retained on-site.

6.14.7.2 Operation of emergency ventilation that is not operated continuously shall be initiated by the ammonia detection system in accordance with Section 6.13.

6.14.7.3 Emergency ventilation that is not continuously operated shall also be operable manually by emergency control switches in accordance with Section 6.12.2.

6.14.7.4 Emergency ventilation shall be powered independently of the equipment within the machinery room and shall continue to operate regardless of whether emergency shutdown controls for the machinery room have been activated.

6.14.7.5 *Where an automatic means will be used to comply with monthly testing of the emergency ventilation system as required by ANSI/IIAR 6, Section 12.1, the automatic means shall be capable of sensing a change in air flow of 25% or more, either by direct airflow measurement or indirect sensor readings. Failure to prove airflow when the emergency ventilation fans are energized shall provide notice to a monitored location.

6.15 *Signage. Signage shall be provided in accordance with this section.

6.15.1 **NFPA 704 Placards.** A NFPA 704 placard shall be provided in accordance with Section 5.12.2 on or next to all doors through which a person can enter the machinery room.

6.15.2 **Alarm Signage.** Alarm signage shall be provided in accordance with Section 17.6.

6.15.3 **Restricted Access Signage.** Each machinery room entrance door shall be marked with a permanent sign to indicate that only authorized personnel are permitted to enter the room.

6.15.4 **Emergency Control Switch Signage.** Signage shall be provided near the emergency stop and emergency ventilation control switches as described in Section 6.12.

6.15.5 **Electrical Hazard Signage**. Where the machinery room is designated as a Hazardous (Classified) Location in accordance with Section 6.8.1, the Class, Division, and Group of the electrical classification shall be posted on a sign on or next to all doors through which a person can enter the machinery room.

Chapter 7. Refrigeration Equipment Located in Areas Other than Machinery Rooms

7.1 General. Industrial, public assembly, commercial, and large mercantile occupancies that are permitted by Section 4.2 to contain ammonia refrigeration systems or equipment in areas other than a machinery room shall comply with this chapter. Residential occupancies that are permitted by section 4.2.4 to contain ammonia refrigeration systems or equipment in areas other than a machinery room are not required to comply with this chapter but must comply with listing requirements and manufacturers' instructions.

7.2 Requirements for Non-machinery Room Spaces. Where an ammonia refrigeration system or equipment is installed indoors in areas other than a machinery room, the area containing the system or equipment shall comply with this section.

7.2.1 ***Separation.** The area shall be separated from other occupancy classifications in accordance with the building code, adopted codes and standards, and by tight construction with tight-fitting doors.

7.2.2 **Access.** Access to the refrigeration equipment shall be restricted to authorized personnel.

7.2.3 ***Detection and Alarms.** Level 1 detection and alarm shall be provided in accordance with Section 17.7.1. The detection and alarm system shall comply with Chapter 17.

EXCEPTIONS:

1. Unoccupied areas with continuous piping that has been joined by welding and does not include valves, valve assemblies, equipment, or equipment connections, do not require level 1 detection and alarm.
2. Where not prohibited by the AHJ, rooms or areas in industrial occupancies that are normally occupied 24 hours/day and are regularly patrolled when the rooms' functions are idled for scheduled downtime and are provided with an alternative to fixed detection and alarm equipment do not require level 1 detection and alarm. A means for emergency notification and initiation of alarm response in accordance with Section 17.7.1 shall be provided.
3. Where not prohibited by the AHJ, alternatives to fixed ammonia leak detectors shall be permitted for areas with high humidity or other harsh environmental conditions that are incompatible with detection devices. A means for emergency notification and initiation of alarm response in accordance with Section 17.7.1 shall be provided.

7.2.4 **Protection of Equipment from Physical Damage.** Where ammonia equipment is installed in a location subject to physical damage from powered vehicles normally operating in the area, guarding or barricading shall be provided.

7.2.5 **Environmental Compatibility.** Equipment shall be designed to operate in the environmental conditions of the area where it is to be installed.

7.2.6 **Illumination of Equipment Areas.** Illumination shall be in accordance with Section 5.14.4.

7.2.7 **Service Provisions.** Service provisions shall comply with Section 5.10.

7.2.8 **Penthouses.** Penthouses that are open to an interior space shall be regulated as part of the interior space. Penthouse that are automatically isolated from an interior space shall be regulated as an equipment enclosure in accordance with Section 5.13.1.

7.2.9 **Electrical Classification.** Areas in accordance with Sections 7.2.1 through 7.2.8 shall be designated as unclassified electrical locations as described in the electrical code, unless a different electrical classification is required in the space for reasons other than the presence of the ammonia refrigeration system.

7.2.10 ***Eyewash/Safety Shower/Supplemental Drenching/Flushing.** A permanent or portable means shall be provided for the provision of quick drenching or flushing of the eyes and body within or directly adjacent to the work area for immediate emergency use when maintenance occurs that involves the deliberate opening of an ammonia refrigeration system. Such means shall be indicated in the design documents, and shall comply with the temperature, flow and duration specifications of ANSI/ISEA Z358.1.

7.3 Ventilation

7.3.1 Refrigeration Systems with a Total Connected Compressor Drive Power Not Exceeding 100 HP (74.6 kW)

7.3.1.1 *Industrial occupancies containing ammonia systems with components other than those permitted in accordance with Sections 4.2.1.2.2, 4.2.1.2.3, and 4.2.1.2.4 with a total connected compressor drive power not exceeding 100 HP (74.6 kW) and located indoors in areas other than a machinery room in accordance with Section 4.2.1.2.1 shall comply with this section.

7.3.1.2 *Emergency mechanical ventilation shall be in accordance with this section.

7.3.1.2.1 Where the entire charge of ammonia released from the largest independent refrigerant circuit in a refrigeration system would yield an ammonia concentration exceeding 40,000 ppm in the room, space containing the equipment based on the volume calculation determined in accordance with Section 5.2~~5.2~~, emergency ventilation at a rate of 30 air changes per hour shall be provided.

Exception: Where approved, alternatives to emergency mechanical exhaust ventilation of the entire room that will maintain the concentration below 40,000 ppm shall be permitted.

7.3.1.2.2 When calculations performed in accordance with Section 5.2 are used as a basis for omitting emergency mechanical ventilation, the designer shall provide a copy of the calculations to be retained by the owner.

7.3.1.2.3 Where an emergency mechanical ventilation system is required, Level 3 ammonia detection and alarm in accordance with Section 17.7.2 shall be provided, and the system shall comply with Sections 6.14.7.2 through 6.14.7.6. The detection and alarm system shall comply with Chapter 17.

7.3.2 **Outdoor Systems.** Outdoor systems include those that comply with Sections 4.2.1.3, 4.2.2.4, 4.2.3.4, 4.2.4.4, 4.2.5.2, and 4.2.6.4. For outdoor systems, natural ventilation shall be provided in accordance with this section or mechanical ventilation shall be provided in accordance with Section 6.14 and Section 7.3 as applicable.

The free-aperture cross-section for natural ventilation shall not be less than

$$F = G^{0.5} \text{ (I-P)}$$
$$F = 0.138G^{0.5} \text{ (SI)}$$

where:

F = the free opening area, ft² (m²)
G = the mass of ammonia in the largest independent circuit, any part of which is located within the enclosure or structure, lbs. (kg)

7.3.3 **Equipment Pits Located Indoors**

7.3.3.1 Where refrigeration equipment containing ammonia is located in an indoor pit that is 5 ft (1.52 m) or more in depth, emergency ventilation at a rate of 30 air changes per hour shall be provided and Level 3 ammonia detection and alarm complying with Section 17.7.2 shall be provided. The emergency mechanical exhaust ventilation system shall comply with Sections 6.14.7.2 through 6.14.7.6.

7.3.3.2 Make-up air shall be supplied near the floor of the indoor pit. Air shall be directed toward the equipment and away from the pit exit.

7.3.3.3 Where pit ventilation is arranged to exhaust through a room that is open to the pit, the combined volume of the pit and the room shall serve as the basis for calculating emergency mechanical exhaust ventilation.

Part 3. Equipment

Chapter 8. Compressors

8.1 General. Ammonia refrigeration mechanical compressors shall comply with this chapter.

8.2 Design

8.2.1 **Design Pressure.** The minimum design pressure shall comply with Section 5.3.3.

8.2.2 ***Positive-Displacement Compressor Protection.** Where a stop valve is provided in the discharge connection, a positive-displacement compressor shall be equipped with a pressure relief device in accordance with Section 15.4.3.

8.2.3 **Pressure Relief Connections**

8.2.3.1 The minimum size compressor pressure relief connection shall be a ½” fitting or ¾” pipe and shall be in accordance with Section 15.8.1.

8.2.4 ***Limiting Devices.** Compressors shall be provided with high-discharge-temperature-, low-suction-pressure-, and high-discharge-pressure-limiting devices to shut down the compressors when the safe ranges are exceeded. Stop valves are not permitted between the high-discharge-pressure-limiting device and the pressure-imposing element. Compressors using forced feed oil lubrication shall be provided with an indicating-type lubrication failure control for low oil pressure shutdown. Except for booster compressors, high-pressure-limiting devices shall be of the manual-reset type.

8.2.4.1 The cutout setting of high-pressure-limiting devices shall not exceed the lower of

1. The compressor manufacturer’s recommendation, or
2. 90% of the set pressure of the pressure relief device on the discharge side of the compressor.

8.2.4.2 The cutout setting of low-pressure-limiting devices shall be the higher of

1. The system’s minimum design pressure to protect against damage, or
2. The compressor manufacturer’s recommendations.

8.2.5 **Guarding.** Protection from exposed rotating parts shall be in accordance with Section 5.14.1.

8.2.6 **Rotation Arrow.** A rotation arrow shall be cast in or permanently attached to the compressor.

8.2.7 **Ultimate Strength.** Ultimate strength requirements shall be in accordance with Section 5.11.2.

8.3 Procedures/Testing. Compressors shall be strength tested to a minimum of 1.5 times the design pressure, subsequently leak tested, and proven tight at a pressure not less than design pressure by the manufacturer.

8.4 Equipment Identification

8.4.1 **The following data shall be provided on nameplates or labels affixed to compressors:**

1. Manufacturer's name,
2. Manufacturer's serial number,
3. Manufacturer's model number,
4. Year manufactured (encoded with serial number is permissible),
5. Maximum allowable working pressure (MAWP),
6. Maximum rotation speed in rpm

8.4.2 A compressor without a nameplate per the requirements of Section 8.4.1 shall not be used unless the applicable compressor operating limitations have been verified through the identification of the manufacturer and the manufacturer's model number of the compressor from casting numbers or similar positive identification. Documentation of these operating limits shall be provided to the owner of the system.

8.5 Compressor Installation. Design for compressor installation shall comply with this section.

8.5.1 One or more valved connections shall be available to remove ammonia from compressors. Compressors that are packaged with other equipment shall be permitted to have pump-out connections located elsewhere in the package.

8.5.2 *Where system design or location results in the compressor or associated piping being exposed to temperatures below ammonia saturation conditions during operation or standby, a means shall be provided to prevent or remove ammonia condensation in those portions of the system.

8.5.3 At a minimum, designs shall include provisions for installing compressor foundations according to manufacturers' instructions, grouting, or for installing isolation from the floor or structure of the building, where required.

8.5.4 Where a variable frequency drive is used to operate a compressor, the manufacturer's instructions shall be followed and the compressor using the variable frequency drive shall be stable at all frequencies during its operation. If unstable frequencies encountering resonant harmonics are identified and cannot be isolated, they shall be permitted to be locked out.

8.5.5 The refrigeration compressor(s) shall be selected to operate within the design limitations specified by the compressor manufacturer.

8.5.6 *Compressors shall be provided with a discharge check valve, a suction check valve, or other means to avoid backflow of refrigerant, oil, or a refrigerant-oil mixture and the accumulation of liquid from the condensation of gas in the discharge piping when the compressor is shut down.

EXCEPTION: Packaged systems designed to equalize on shutdown shall not be required to have a suction or discharge check valve.

8.5.7 Before being applied in a new design, any previously used compressor shall be inspected for signs of alteration, modification, or physical repair that might affect the integrity of the compressor casing. Any compressor integrity issue shall be corrected and verified before operation.

8.5.7.1 Where a compressor casing has been altered, modified, or repaired, the casing shall be recertified prior to operation for pressure compliance by the manufacturer or insurance underwriter, and documentation of the recertification shall be maintained on site with the refrigeration management program.

8.5.8 Compressors shall be fitted with pressure- and temperature-indicating devices, including but not limited to gauges or readouts on a control display screen that allow an observer to determine visually the compressor's suction pressure, discharge pressure, oil pressure (if the compressor uses forced-feed lubrication), and discharge temperature.

8.5.9 ***High-Liquid-Level Shutdown.** Where the liquid level in a vessel may directly result in the carryover of liquid refrigerant to a compressor, the vessel shall incorporate a control to cause the associated compressors to shut down if a high liquid level is detected in the vessel.

Chapter 9. Refrigerant Pumps

9.1 General. Refrigerant pumps shall comply with this chapter.

EXCEPTION: Liquid ammonia transfer employing a high-pressure fluid to move a lower pressure liquid such as pumper drum systems. Such transfer systems that incorporate a pressure vessel shall comply with Chapter 12.

9.2 Design

9.2.1 Minimum design pressure shall be in accordance with Section 5.3.3, or greater where required by a specific application design requiring higher pressure.

9.2.2 *A means of protecting refrigerant pumps and connected piping from hydrostatic overpressure shall be provided.

9.2.3 Ultimate strength requirements shall be in accordance with Section 5.11.2.

9.2.4 Protection from exposed rotating parts shall be in accordance with Section 5.14.1.

9.2.5 Refrigerant pumps shall be suitable for the service in which they are being applied.

9.2.6 Refrigerant pumps shall be provided with isolation valves.

9.2.7 Refrigerant pump supports and foundations shall be installed in accordance with Section 5.9.

9.3 Procedures/Testing. Refrigerant pumps shall be strength tested to a minimum of 1.5 times the design pressure, subsequently leak tested, and proven tight at a pressure not less than design pressure by the manufacturer.

9.4 *Equipment Identification. Manufacturers producing refrigerant pumps shall permanently affix a nameplate to the pump providing not less than the following:

1. Manufacturer’s name;
2. Manufacturer’s serial number;
3. Manufacturer’s model number;
4. Year manufactured (encoded with serial number is permissible);
5. Maximum allowable working pressure (MAWP);
6. Maximum rotation speed in rpm; and
7. Direction of rotation, if it is not cast in or permanently attached to the pump.

9.5 Provision for Ammonia Removal. Pumps shall be equipped with a means for ammonia removal.

Chapter 10. Condensers

10.1 *General. Condensers shall comply with this chapter, and the provisions of Table 10.1.

Table 10.1 General Design Requirements for Condensers

Condenser Requirements[1,2]

	Design Pressure	Ultimate Strength[3]	Pressure Test, Leak Test[4,5]	Secondary Coolant Side Design Pressure	Protection of Isolatable Refrigerant Circuits	Protection of Isolatable Secondary Coolant Circuits[7]	Required Identification on a nameplate or label
Air-Cooled Condensers, Adiabatic Condensers, and Evaporative Condensers[6]	Comply with 5.3	Comply with 5.11.2	Test to a minimum of 110% of Design Pressure	-	Comply with 15.3.10	-	Manufacturer's name, model and serial number of the equipment, year of manufacture, design pressure, and, for air-cooled and evaporatively-cooled condensers, fan rotation direction, motor power (fan/pump), and electrical supply characteristics (volts, phase, frequency, and full-load amps)
Shell and Tube Condensers	Comply with 5.3	Comply with 5.11.2	Test to a minimum of 110% of Design Pressure	Comply with 5.11.2	Comply with 15.3.10	Comply with the mechanical code	Manufacturer's name, hot-side maximum allowable working pressure (MAWP) and corresponding maximum temperature, cold-side maximum allowable working pressure (MAWP) and corresponding maximum temperature, hot side minimum design metal temperature (MDMT), cold side minimum design metal temperature (MDMT), model number (if applicable), serial number, and year of manufacture.
Plate Condensers	Comply with 5.3	Comply with 5.11.2	Test to a minimum of 110% of Design Pressure	Comply with 5.11.2	Comply with 15.3.10	Comply with the mechanical code	
Double Pipe Condensers	Comply with 5.3	Comply with 5.11.2	Test to a minimum of 110% of Design Pressure	Comply with 5.11.2	Comply with 15.3.10	Comply with the mechanical code	

Normative notes:

1. Pressure Vessels incorporated into condensers shall comply with Chapter 12.

2. Condensers that are pressure vessels shall be protected in accordance with Section 15.3.

3. Requirements for ultimate strength apply to the refrigerant side and the secondary or process fluid side of condensers where applicable.
4. For equipment built in accordance with ASME B31.5, testing shall be done by the manufacturer in accordance with ASME B31.5, paragraph 538.
5. For equipment built in accordance with ASME B&PVC, testing shall be done by the manufacturer in accordance with ASME B&PV Code Sections UG-97 through UG 100 as applicable.
6. Nameplate data are not required on air-cooled desuperheaters that are integral with condensers.
7. If the secondary circuit includes an ASME stamp on the heat exchanger, that heat exchanger requires overpressure protection in accordance with the ASME B&PVC and Section 15.10.

10.2 Air-Cooled Condensers, Adiabatic Condensers, Air-Cooled Desuperheaters, and Evaporative Condensers. Tube-and-fin and micro-channel type air-cooled condensers and air-cooled desuperheaters shall comply with this section in addition to requirements in Section 10.1.

10.2.1 **Design**

10.2.1.1 Protection from exposed rotating parts shall be in accordance with Section 5.14.1.

10.2.1.2 Fan speeds shall not exceed the design speed limit recommended by the manufacturer.

10.2.2 ***Clearances.** Condensers shall be positioned to assure that necessary airflow requirements are met.

10.2.3 **Freeze Protection.** Where required to prevent damage, freeze protection shall be provided for water-containing portions of the condenser and condenser water piping.

10.2.4 **Drainage of Overflow and Wastewater.** Drainage of overflow and wastewater shall be provided to ensure that overflow and waste do not cause a nuisance or hazard.

Chapter 11. Evaporators

11.1 General. Evaporators shall comply with this chapter and the requirements of Table 11.1.

Table 11.1 General Design Requirements for Evaporators

Evaporator Requirements[1,2]	Design Pressure	Ultimate Strength[3]	Pressure Test, Leak Test[3,4]	Secondary Coolant Side Design Pressure	Protection of Isolatable Refrigerant Circuits	Protection of Isolatable Secondary Coolant or Process Fluid Circuits[6]	Required Identification on a nameplate or label
Forced-Air Evaporator Coils	Comply with 5.3	Comply with 5.11.2	Test to a minimum of 110% of Design Pressure	-	Comply with 15.3.10	-	Manufacturer's name, model and serial number of the equipment, year of manufacture, design pressure, and, for forced-air evaporator coils, fan rotation direction, fan motor power, electric defrost heater and drain pan heater ratings (as applicable), and electrical supply characteristics (volts, phase, frequency, and full-load amps).

Bare-tube evaporator and gravity evaporator coils.	Comply with 5.3	Comply with 5.11.2	Test to a minimum of 110% of Design Pressure	-	Comply with 15.3.10	-	Manufacturer's name, model and serial number of the equipment, year of manufacture, design pressure.
Shell and Tube Evaporators	Comply with 5.3	Comply with 5.11.2	Test to a minimum of 110% of Design Pressure	Comply with 5.11.2	Comply with 15.3.10	Comply with the mechanical code	Manufacturer's name, hot-side maximum allowable working pressure (MAWP) and corresponding maximum temperature, cold-side maximum allowable working pressure (MAWP) and corresponding maximum temperature, hot side minimum design metal temperature (MDMT), cold side minimum design metal temperature (MDMT), model number (if applicable), serial number, and year of manufacture.

Plate Heat Exchanger Evaporators	Comply with 5.3	Comply with 5.11.2	Test to a minimum of 110% of Design Pressure	Comply with 5.11.2	Comply with 15.3.10	Comply with the mechanical code	Manufacturer's name, hot-side maximum allowable working pressure (MAWP) and corresponding maximum temperature, cold-side maximum allowable working pressure (MAWP) and corresponding maximum temperature, model number (if applicable), serial number, and year of manufacture.
Double Pipe Evaporators	Comply with 5.3	Comply with 5.11.2	Test to a minimum of 110% of Design Pressure	Comply with 5.11.2	Comply with 15.3.10	Comply with the mechanical code	Manufacturer's name, hot-side maximum allowable working pressure (MAWP) and corresponding maximum temperature, cold-side maximum allowable working pressure (MAWP) and corresponding maximum temperature, model number (if applicable), serial number, and year of manufacture.
Scraped (Swept) Surface Heat Exchangers	Comply with 5.3	Comply with 5.11.2	Test to a minimum of 110% of Design Pressure	Comply with 5.11.2	Comply with 15.3.10	Comply with the mechanical code	Manufacturer's name, shell maximum allowable working pressure (MAWP) and corresponding maximum temperature, shell minimum design metal temperature (MDMT), model number (if applicable), serial number, and year of manufacture.

Jacketed Tanks	Comply with 5.3	Comply with 5.11.2	Test to a minimum of 110% of Design Pressure	Comply with 5.11.2	Comply with 15.3.10	Comply with the mechanical code	Manufacturer's name, maximum allowable working pressure (MAWP) and corresponding maximum temperature, model number (if applicable), serial number, and year of manufacture.

Normative notes:

1. Pressure Vessels incorporated into evaporators shall comply with Chapter 12.
2. Evaporators that are pressure vessels shall be protected in accordance with Section 15.3.
3. Requirements for ultimate strength apply to the refrigerant side and the secondary or process fluid side of evaporators, where applicable.
4. For evaporators built in accordance with ASME B31.5, testing shall be done by the manufacturer in accordance with ASME B31.5 paragraph 538.
5. For evaporators built in accordance with ASME B&PVC, testing shall be done by the manufacturer in accordance with ASME B&PVC Sections UG-97 through UG 100 as applicable.
6. If the secondary circuit includes an ASME stamp on the heat exchanger, that heat exchanger requires overpressure protection in accordance with the ASME B&PVC and Section 15.10.

11.2 *Fluid Freeze Protection. When heat exchangers are used to cool products or secondary coolants that are not intended to be frozen, the system shall be designed to prevent damage due to freezing of products or secondary coolants within the heat exchanger.

11.3 Design for Frozen Products. Evaporators or heat exchangers intended to freeze products by direct contact with the heat exchanger shall be designed to accommodate the frozen product without damaging the heat exchanger or associated refrigerant-containing equipment.

11.4 Forced-Air Evaporator Coils. Evaporator coils and micro-channel heat exchangers shall comply with this section in addition to the general requirements of Table 11.1.

11.4.1 **Design**

11.4.1.1 Protection from exposed rotating parts shall be in accordance with Section 5.14.1.

11.4.1.2 Fan speeds shall not exceed the design speed limit recommended by the manufacturer.

11.4.1.3 Pressure vessels coupled to evaporators shall comply with Chapter 12.

11.4.2 ***Installation Considerations**

11.4.2.1 *Forced-air evaporators shall be positioned to assure that necessary airflow requirements are met.

11.4.2.2 *A means for preventing freezing inside condensate drain lines shall be provided where lines are exposed to freezing temperatures.

11.4.2.3 A means shall be provided to prevent warm air from migrating through the condensate drain piping to the condensate drain pan connections.

11.5 Bare-Tube Evaporator Coils and Gravity Evaporator Coils. Bare-tube and gravity evaporator coils shall comply with this section in addition to the general requirements of Table 11.1.

11.5.1 **Design**

11.5.1.1 Pressure vessels coupled to evaporators shall comply with Chapter 12.

11.5.2 **Installation Considerations**

11.5.2.1 *Bare-tube and gravity coils shall be positioned to assure that necessary requirements for airflow or other secondary fluid flow are met.

Chapter 12. Pressure Vessels

12.1 General. Pressure vessels shall comply with this chapter.

12.2 Design

12.2.1 Minimum design pressure shall be in accordance with Section 5.3. Where ammonia liquid will be transferred from pressure vessels with pressurized ammonia gas, the pressure vessel design pressure shall accommodate the maximum possible transfer pressure and account for the lowest possible coincident metal temperature.

12.2.2 Pressure vessels exceeding 6 in. (15.24 cm) inside diameter shall comply with ASME B&PVC, Section VIII, Division 1, covering the requirements for design, fabrication, inspection, and testing during construction of unfired pressured vessels. Pressure vessels having inside diameters less than 6 in. (15.24 cm) shall require ultimate strength in accordance with Section 5.11.2.

12.2.3 Pressure vessels exceeding 6 in. (15.24 cm) inside diameter but less than 10 ft^3 (0.28 m^3) in internal volume, the pressure relief device connection shall not be less than NPS ¾ in. or a NPS ½ in. coupling. For pressure vessels with an internal volume of 10 ft^3 (0.28 m^3) or more, the pressure relief device connection shall not be less than NPS 1 in. pipe or a NPS ¾ in. coupling. Piping wall thickness shall be in accordance with 13.2.2. Coupling and fitting wall thickness shall be in accordance with 13.2.4.

12.2.4 *The heads of pressure vessels shall be hot formed or stress relieved after cold forming.

EXCEPTION: Pressure vessels primarily containing oil, including but not limited to oil separators, oil filters, oil coolers, and oil pots.

12.2.5 A pressure vessel shall be designed and stamped with a minimum design metal temperature no higher than its lowest expected operating temperature.

12.2.6 *In applications where vessels are subject to external corrosion as determined by the owner or owner's designated agent, suitable means shall be used to address vessel protection.

12.2.7 ***Pressure Vessels Used for System Pumpdown.** Pressure vessels that are intended to be used to hold refrigerant for pumpdown operations and subsequently isolated shall be designed such they will contain the intended liquid volume and sufficient vapor space to prevent hydrostatic overpressure.

12.3 *Procedures/Testing. Pressure vessels shall be tested in accordance with ASME B&PVC, Section VIII, Division 1 by the manufacturer.

12.4 *Equipment Identification

12.4.1 Manufacturers producing pressure vessels in accordance with ASME B&PVC, Section VIII, Division 1 shall provide data in accordance with the requirements of the relevant "UG" sections of ASME B&PVC, Section VIII, Division 1, but in any case, shall provide the following minimum data on a nameplate affixed to the equipment:

1. Manufacturer's name;
2. Maximum allowable working pressure (MAWP) _____ at _____ temperature;
3. Minimum design metal temperature (MDMT) _____ at _____ pressure;
4. Manufacturer's serial number or National Board number, as applicable;
5. Year of manufacture;
6. Manufacturer's model number, where applicable; and
7. The minimum operating temperature and corresponding pressure, if other than the MDMT at design pressure provided in Section 12.4.1.3, when designed in accordance with ASME B&PVC, Section VIII, Division 1, UCS-160.

12.4.2 Manufacturers producing vessels equal to or less than 6 in. diameter shall provide the following minimum data on a nameplate affixed to the equipment.

1. Manufacturer's name;
2. Maximum allowable working pressure (MAWP) _____ at _____ temperature;
3. Minimum design metal temperature (MDMT) _____ at _____ pressure;
4. Manufacturer's serial number;
5. Year of manufacture;
6. Manufacturer's model number, where applicable; and
7. Manufacturer's certification of listing or strength test.

12.5 Nameplate Mounting

12.5.1 Nameplates shall comply with Section 5.12.5.

12.5.2 *If any pressure vessel is insulated, the nameplate shall be mounted on an approved standoff, so it is not covered, or the insulation at the nameplate location on the pressure vessel shall be removable to allow for nameplate inspection. Alternatively, it is permitted to use a duplicate nameplate in accordance with Section 5.12.5.3.

12.6 Pressure Vessel Installation Considerations

12.6.1 Pressure vessel access shall be provided in accordance with Section 5.10.

12.6.2 Physical protection shall comply with Section 7.2.4.

12.6.3 Pressure vessel support shall be installed in accordance with Section 5.9.

Chapter 13. Piping and Hoses

13.1 *General. Piping and hoses shall comply with this chapter. The design, fabrication, examination, and testing of the piping, whether fabricated in a shop or as a field erection, shall comply with ASME B31.5, unless otherwise provided by this chapter.

13.2 *Pipe, Hose, Tubing, Fittings, and Flanges

13.2.1 ***Material.** Piping materials shall comply with ASME B31.5 except as specified in this section.

13.2.1.1 ASTM A53Type F pipe and cast iron or wrought iron pipe shall not be used for the pressure-containing side of closed-circuit ammonia refrigeration systems.

13.2.1.2 Zinc, copper, and copper alloys shall not be used in contact with or for containment of ammonia. Copper-containing anti-seize and/or lubricating compounds shall not be used in ammonia piping joints.

13.2.2 ***Minimum Pipe Wall Thickness.** Minimum pipe wall thickness shall be based on the properties of the selected pipe material and shall comply with the requirements of ASME B31.5.

EXCEPTIONS:

1. Where joined by threading, carbon or stainless-steel pipe shall be minimum Schedule 80 for pipe sizes larger than 1/2 in. and Schedule 160 for pipe sizes 1/2 in. and smaller.
2. Where joined by any method, carbon steel pipe 1-1⁄2 in. and smaller shall be minimum Schedule 80.
3. Where joined by methods other than threading, stainless steel pipe 1-1⁄2 in. and smaller shall be minimum Schedule 40.

13.2.3 ***Tubing**

13.2.3.1 Minimum tubing wall thickness shall be based on the properties of the selected material and the greater of the design working pressure or the requirement specified by the manufacturer of the compression ferrule used for the fitting connection.

13.2.3.1.1 *Carbon steel tubing is not permitted.

13.2.4 **Pipe Fittings**

13.2.4.1 Butt weld fittings shall match connected pipe schedules.

EXCEPTION: The schedule of butt weld fittings joining pipe at a wall thickness change shall match the schedule of the thicker wall pipe. The internal diameter of the end of the fitting connecting to the thinner wall pipe shall be machined or ground to match in accordance with ASME B31.5.

13.2.4.2 All forged and cast steel socket weld and screwed fittings shall be minimum Class 3000 in accordance with ASME B16.11.

13.2.4.3 Threaded joints shall not be used for refrigerant piping larger than 2 in.

EXCEPTION: Pressure relief devices and associated three-way valves.

13.2.5 ***Hoses and Corrugated Metal Hose Assemblies.** Hoses and corrugated metal hose assemblies used within closed-circuit refrigeration systems shall be designed, rated, or documented by the manufacturer as suitable for permanent installation in anhydrous ammonia refrigeration service and meet or exceed the temperature, pressure, marking, and manufacturing requirements of ISO 10380 or equivalent.

13.2.6 **Pipe Flanges**

13.2.6.1 Flanges not in accordance with the dimensional requirements of ANSI/ASME B16.5 shall comply with the requirements of ASME B31.5 and the flange class, or pressure and temperature rating, shall be based on the design working pressure and the maximum working temperature at the design working pressure.

13.2.6.2 Gaskets shall be correctly dimensioned for the flange set in accordance with ASME B16.20 or B16.21.

13.3 *Refrigerant Valves and Strainers. Valves used in ammonia-containing and lubricant-containing service shall comply with this section.

EXCEPTIONS:
1. Valves within the ammonia-containing envelope of other equipment, such as slide valves in screw compressors.
2. Pressure relief valves.

13.3.1 **Required Shut-Off Valve Locations.** A shut-off valve shall be installed in the refrigerant piping at each of the following locations:
1. At the inlet and outlet of a positive-displacement-type compressor, compressor unit, or condensing unit;
2. At the main feed inlets and outlets of individual refrigeration equipment loads; and
3. At the refrigerant inlet and outlet of a pressure vessel containing ammonia and having an internal gross volume exceeding 3 ft^3 (0.085 m^3).

EXCEPTIONS:
1. In lieu of providing shut-off valves at each piece of serviceable equipment, packaged systems and portions of built-up systems shall be permitted to have pump-down arrangements that permit the safe removal or isolation of ammonia for servicing one or more pieces of equipment.
2. Shut-off valves are not required between a refrigeration equipment load and a pressure vessel containing liquid ammonia where a single load is piped into a single pressure vessel, such as a surge-fed evaporator piped into a surge drum.

3. Packaged systems that incorporate subsystem isolation valves shall not require more than one shut-off valve on each ammonia-containing pipe connecting any two parts of a system.

13.3.2 Valves used for Equipment and System Design

13.3.2.1 *Where a valve is deliberately specified for use with the directional indicator marked by the manufacturer being opposite of the normal direction of flow, or the intended vertical, horizontal or rotational orientation is installed differently from the manufacturer's specification, the system design shall specify the intended installation direction and orientation provided that the alternative specification maintains effective and safe operation of the valves and the system.

13.3.2.2 Valve gasket materials shall be in accordance with the valve manufacturer's specifications and shall be of the thickness specified.

13.3.2.3 *Where a check valve is installed upstream of other automatic valves, pressure relief shall be provided. Provision for liquid removal to facilitate maintenance shall be located downstream of the check valve. Hydrostatic overpressure protection shall comply with Section 15.9.

13.3.2.4 Valve groups shall be fitted with a provision for ammonia removal to facilitate maintenance of strainers.

13.3.2.5 *Shut-off valves used to isolate equipment or devices from other portions of the system for the purpose of maintenance or repair shall be capable of being locked out by design or by an alternative method.

13.3.2.6 *Shut-off valves connecting ammonia-containing equipment or piping to atmosphere shall be capped, plugged, blanked, or locked closed during shipping, testing, operating, servicing, or standby conditions when they are not in use.

13.3.2.7 *Shut-off valves connecting ammonia-containing equipment or piping to atmosphere shall have a maximum operating pressure differential (MOPD) or a maximum seat sealing pressure differential (MSSPD) equal to or greater than the system design pressure.

13.3.2.8 Valves required for system emergency shutdown procedures shall be readily accessible and identified in accordance with Sections 5.10.5.2, 5.12.1, and 5.12.4. Other valves shall be accessible in accordance with Section 5.10.5.1.

13.4 *Piping, Hangers, Supports, and Isolation

13.4.1 *Piping hangers and supports shall carry the weight of the piping and any additional expected loads.

13.4.2 *Refrigerant piping shall be isolated and supported to prevent damage from vibration, stress, corrosion, and physical impact.

13.4.3 Anchors, their attachment points, and attachment methods shall be designed to support applied loads.

13.4.4 For insulated piping, supports shall be designed or the insulation shall be selected to avoid damage to the insulation from compression.

13.5 *Location of Refrigerant Piping

13.5.1 Refrigerant piping crossing walkway areas inside a building shall be not less than 7.25 ft (2.2 m) above the floor.

EXCEPTION: Where not prohibited by the AHJ, piping shall be permitted to be located less than 7.25 ft (2.2 m) above the floor provided that it is placed against the ceiling of such space. Any projection from the ceiling over a means of egress shall not reach a point less than 6 ft.-8 in. (2.0 m) from the floor.

13.5.2 Refrigerant piping shall not obstruct a means of egress.

13.5.3 Refrigerant piping shall not be placed in an elevator shaft, dumbwaiter shaft, or other shaft containing a moving object.

13.5.4 Refrigerant piping shall not be installed in a stair, landing, or means of egress, any of which is enclosed and is accessible to the public.

13.5.5 *Refrigerant piping is not prohibited from being buried underground provided that the piping is protected from corrosion.

13.5.6 Refrigerant piping installed in concrete floors shall be encased in pipe duct.

Chapter 14. Packaged Systems and Equipment

14.1 General

14.1.1 Packaged systems and equipment shall comply with this chapter. Such packages shall be permitted to be enclosed or unenclosed. Equipment enclosures shall comply with Section 5.13.

14.1.2 *Packaged systems and their internal equipment and devices shall be designed, constructed, and installed in accordance with the applicable provisions of Chapter 4 though Chapter 17

14.2 Design

14.2.1 The structure of the package shall be designed to support the operating weight of included equipment.

14.2.2 The structure of the package shall be designed to withstand the stresses caused by transporting and rigging. Temporary supports and bracing shall be permitted. Rigging instructions shall be provided to accommodate the installation of the structure.

14.2.3 The structure of the package shall be designed to withstand loads or stresses that will be imposed on the package after installation and startup, including environmental factors such as snow, ice, wind, and seismic forces, and imposed on the package during operation, including vibration.

14.2.4 Packaged equipment shall have valved pump-out connections for removal of ammonia.

14.2.5 Packages shall be designed for use in both the lowest- and highest-expected ambient temperatures in which they will operate.

14.2.6 *Access shall be provided for manually operated valves. Where manually operated valves are inaccessible from floor level, they shall comply with Section 5.10.5.1. Isolation valves identified as being part of system emergency shutdown procedures shall comply with Section 5.10.5.2 and valve tagging shall comply with Section 5.12.4.

14.2.7 Pipes shall be marked in accordance with Section 5.12.6.

14.2.8 Equipment shall be labeled in accordance with Section 5.12.3.

14.2.9 Packages shall be equipped with lighting, or the area with refrigeration equipment shall be equipped with light fixtures delivering a minimum of 30 foot-candles (320 lumens/m^2) at the working level, 36 in. (0.91 m) above a floor or platform.

14.2.10 Enclosed packages that require entrance for service, maintenance, inspection, or operation shall have lighting control located at entrances. Occupancy sensors shall be permitted as an additional control for lighting, but not in lieu of a manual control.

EXCEPTION: Where continuous lighting exists, the lighting control shall not be required to be located at the entrances.

14.3 Fabrication

14.3.1 Equipment shall be set on the package in accordance with the manufacturer's recommendations, including proper support and clearances.

14.3.2 Equipment and piping shall be supported to withstand transporting and rigging. Temporary supports and bracing shall be permitted.

14.3.3 Stationary or temporary rigging points shall be provided as required to position the package.

14.3.4 Piping shall be pressure-tested after fabrication, and leaks shall be repaired. The package shall be shipped with a holding charge of dry nitrogen or provided with another means approved by the manufacturer to allow validation that leakage has not occurred during shipping or subsequent storage prior to installation.

14.3.5 Electrical equipment and wiring shall be installed in accordance with the electrical code.

14.3.6 Gas fuel devices and equipment used with refrigeration systems in the package shall be installed in accordance with the mechanical code.

14.4 Alarms and Detection. Detection and alarms for packaged systems shall comply with the following:

1. Packaged systems that are required to be located in a machinery room as determined in Chapter 4 shall comply with Section 6.13.
2. Packaged systems located indoors and permitted to be located in areas other than a machinery room, in accordance with Sections 4.2.1 through 4.2.7, shall be provided with detection and alarms complying with Section 7.2.3 or 7.3.1.
3. Packaged systems located outdoors that comply with the free-aperture requirements of Section 7.3.2 shall not require ammonia detection or alarms.
4. Packaged systems located outdoors that do not comply with the free-aperture requirements of Section 7.3.2 shall be provided with detection and alarms complying with Section 6.13, or if permitted by Sections 4.2.1 through 4.2.7 shall be provided with detection and alarms complying with Section 7.3.1.

14.5 Ventilation. Ventilation for packaged systems shall comply with the following:

1. Packaged systems that are required to be located in a machinery room as determined in Chapter 4 shall comply with Section 6.14.
2. Packaged systems located indoors and permitted to be located in areas other than a machinery room in accordance with Section 4.2.1.2.1, shall comply with Section 7.3.1.
3. Packaged systems located outdoors shall comply with Section 7.3.2.

Chapter 15. Overpressure Protection

15.1 General Requirements. Pressure relief systems provided for the purpose of relieving excess pressure due to fire or other abnormal conditions causing pressures in excess of the design pressure shall comply with this chapter.

15.1.1 Refrigeration systems shall be protected by not less than one pressure relief device.

15.1.2 Liquid refrigerant, secondary fluids, or refrigerants other than ammonia shall not be vented into a common relief vent piping system used to convey ammonia vapor being discharged external to the closed-circuit refrigeration system.

15.1.3 *The overpressure relief of oil or ammonia-laden oil shall discharge back into the closed-circuit system or shall be relieved in such a way that the oil is captured, and any ammonia vapor is vented in accordance with Section 15.8.3.

15.1.4 *Where a gravity flooded heat exchanger or oil pot is protected by a vapor-rated pressure relief device configured to discharge to atmosphere, the set pressure of the relief device protecting the heat exchanger or oil pot shall not be less than the sum of the set pressure of the relief device protecting the supply vessel plus the maximum static head of liquid between the supply vessel and the connected heat exchanger or oil pot.

15.1.5 *Pressure relief devices configured to discharge internal to the closed-circuit system are prohibited for the following cases:

a. Where the design pressure of the component receiving the discharge fluid is equal to or less than the design pressure of the component being pressure protected.
b. Where the set pressure of the internal relief device would result in its actuation while the portion of the system receiving the relief valve discharge is within its normal operating pressure range.

15.2 *Pressure Vessel Requirements.

15.2.1 Pressure vessels less than 10 ft^3 (0.3 m^3) internal gross volume shall be protected by one or more pressure relief devices.

15.2.2 *Pressure vessels of 10 ft^3 (0.3 m^3) or more internal gross volume shall be protected by one or more of the following:

1. One or more dual pressure relief devices installed with a three-way valve to allow testing or repair, provided that all following conditions are met:

    a. Where dual relief devices are used, each device shall have the capacity required to pressure protect the vessel in accordance with the respective requirements set forth in Sections 15.8.2, 15.9.2, or 15.10.2. and

b. Where multiple dual relief device assemblies are used, the sum of the capacities of the pressure relief devices actively protecting the vessel equals or exceeds the respective requirements set forth in Sections 15.8.2, 15.9.2, or 15.10.2.

2. A single pressure relief device that discharges external to the closed-circuit refrigeration system is permitted provided that all following conditions are met:

   a. The vessel can be isolated and pumped out,
   b. The relief device is located on the low side of the system, and
   c. Other pressure vessels in the system are separately protected in accordance with the respective requirements set forth in Sections 15.8.2, 15.9.2, or 15.10.2.

15.3 Pressure Relief Devices

15.3.1 *Pressure relief device arrangements shall be configured to allow safe access for inspection, maintenance, and repair.

15.3.2 Pressure relief devices shall be direct-pressure actuated or pilot operated. Pilot-operated pressure relief valves shall be configured and set such that the main valve will automatically open at the set pressure or if the pilot fails.

15.3.3 Pressure relief devices shall not use cast iron seats or discs.

15.3.4 **Relieving Pressure.** Where required in this Standard, the *relieving pressure* of the pressure relief device shall be determined in accordance with this section.

15.3.4.1 *When the pressure relief device set pressure is configured to discharge to atmosphere, the relieving pressure shall be calculated using Equation 15-1.

$$P_r = (1.1 \cdot P_{set}) + P_{atm} \qquad \text{Equation 15-1}$$

where
P_r = relieving pressure, psia (kPa)
P_{set} = pressure relief device set pressure, psig (kPa)
P_{atm} = local atmospheric pressure, psia (kPa)

15.3.4.2 *When the pressure relief device is configured to discharge internally within the closed-circuit refrigeration system or externally to a treatment system, the relieving pressure shall be calculated using Equation 15-2.

$$P_r = (1.1 \cdot P_{set}) + P_{bp,s} + P_{atm} \qquad \text{Equation 15-2}$$

where
P_r = relieving pressure, psia (kPa)
P_{set} = pressure relief device set pressure which is less than the vessel's design pressure, psig (kPa)

$P_{bp,s}$ = superimposed back pressure standing at the outlet of the relief device which corresponds to the relieving pressure receiving the relief device discharge flow, psig (kPa)
P_{atm} = local atmospheric pressure, psia (kPa)

15.3.5 *Pressure relief devices shall have the design pressure for the portion of their body exposed to inlet pressure not less than the design pressure of the vessel being pressure protected. The design pressure for the portion of the body exposed to outlet pressure shall not be less than the pressure corresponding to maximum allowable back pressure as determined by Section 15.8.3.3 for relief valves discharging to atmosphere, Section 15.8.4.5 for vapor relief valves discharging internal to the system, and Section 15.9.3.7 for liquid service relief valves discharging internal to the system. For non-volatile liquid service relief valves discharging internal to the system, the design pressure of the outlet portion of the body shall not be less than the design pressure of the vessel connected to its outlet.

15.3.6 **Rupture Disks.**

15.3.6.1 Rupture disks are not permitted as the sole means of overpressure protection when discharging to atmosphere.

15.3.6.2 Rupture disks are permitted to be used in series with atmospheric pressure relief valves and in accordance with Section 15.8.

15.3.6.3 *Provision shall be made to prevent pressure build-up between the rupture disk member and the pressure relief device due to leakage through the upstream rupture disk.

15.3.7 Fusible plugs are not permitted for use as pressure relief devices.

15.3.8 **Pressure Relief Device Certification Requirements.**

15.3.8.1 **ASME-Stamped components.**

15.3.8.1.1 Pressure relief devices protecting ASME-stamped vessels and other ASME-stamped components shall be certified for compliance with ASME B&PVC, Section VIII, Division 1 and Section XIII.

15.3.8.1.2 Pressure relief devices used for vapor service shall be certified for vapor/gas service.

15.3.8.1.3 *Pressure relief devices used for liquid relief shall be certified for liquid service and comply with Section 15.9.

15.3.8.1.4 *The set pressure of a pressure relief device shall not be outside of the pressure range for which it is certified.

15.3.8.1.5 *Pressure relief device manufacturers shall specify their relief devices are suitable for the fluid (liquid or vapor) they are intended to relieve and accordingly certified for the state of the fluid being relieved.

15.3.8.2 **Non-ASME-Stamped components.**

15.3.8.2.1 ASME-certified pressure relief devices are permitted for overpressure protection of components that are not ASME-stamped. Relief devices other than ASME-certified pressure relief devices are permitted for overpressure protection of non-ASME-stamped components.

15.3.8.2.2 Tube-and-fin or microchannel evaporator and condenser coils that are located within 18 in (0.46 m) of a heating source and capable of being isolated shall be fitted with a pressure relief device that discharges according to the provisions of this chapter. The basis for sizing the pressure relief device shall be documented.

EXCEPTION: Pressure relief protection is not required on tube-and-fin or microchannel evaporator and condenser coils that have design pressure equal to or greater than 110% of ammonia's saturation pressure when exposed to the maximum heating source temperature.

15.3.9 ***Marking of Relief Devices.**

15.3.9.1 Pressure relief devices protecting ASME-stamped vessels and other ASME-stamped equipment shall be marked directly on the valve or on a corrosion-resistant plate securely fastened to the valve by the manufacturer with the data required in ASME B&PVC, Section VIII, Division 1.

15.3.9.2 The flow capacity of vapor/gas service pressure relief devices shall be marked in SCFM (m3/min) or lbm/min (kg/min) of air at 60°F (288.7 K).

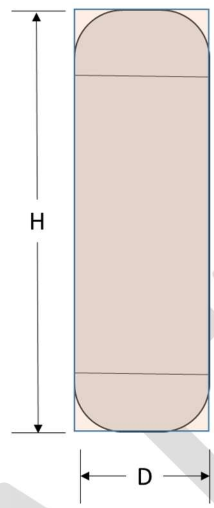
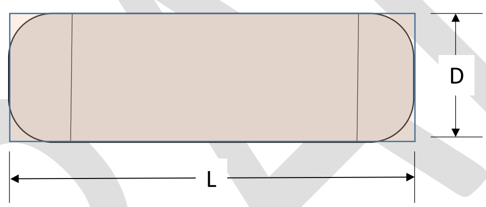
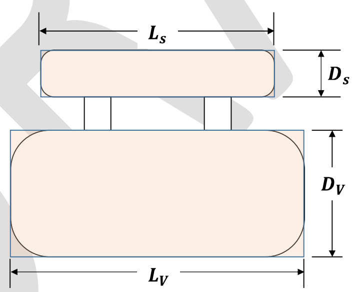
15.3.9.3 The flow capacity of liquid service pressure relief devices shall be marked in GPM (l/min) of water at 60°F (15.6°C).

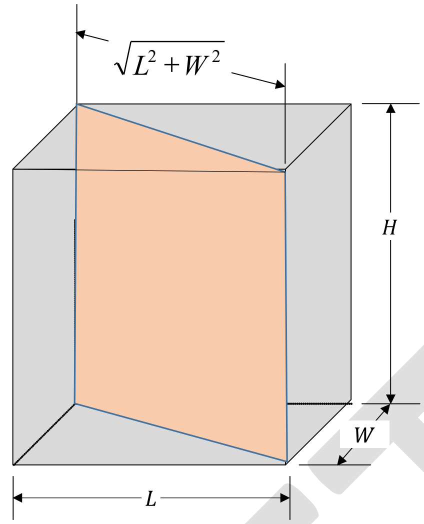
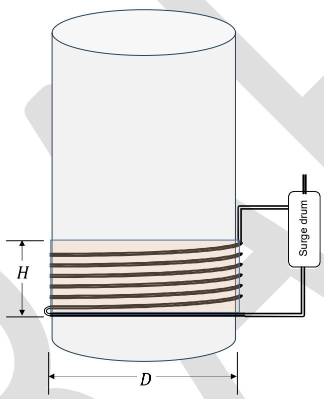
15.3.9.4 Rupture members for ammonia-containing pressure vessels shall be marked with the data required in ASME B&PVC, Section XIII.

15.4 *Sources Causing Overpressure. All applicable heat loads or energy sources capable of causing overpressure shall be analyzed to ensure the applied pressure relief device has sufficient capacity. The heat load or energy source that results in the largest pressure relief device capacity shall be used as the basis for relief device sizing. A reduced relief device capacity shall be permitted in cases where engineering controls are used to mitigate the effects of energy sources causing overpressure and designer documents the reduction. It is permissible to use manufacturer's data when determining relief requirements.

15.4.1 ***External Heat Sources.** The minimum required relief capacity shall be based on an external heat load from a fire radiating to the largest projected area of the protected component when viewed from any orientation. Examples of projected areas for many types of components are provided in Figure 15-1. In cases where combustible material are installed or intended to be stored within 20 ft (6.1 m) of the protected component, the factors used for determining the relief device capacity shall be multiplied by a factor of 2.5.

Figure 15-1: Examples of projected areas of components.

Component type	Illustration	Projected Area
Pressure vessel, vertical		$A = D \cdot H$
Pressure vessel, horizontal		$A = D \cdot L$
Heat exchanger, Shell-and-tube with surge drum		$A = (D_S \cdot L_S + D_V \cdot L_V)$

Heat exchanger, plate-type		$A = \left(\sqrt{L^2 + W^2}\right) \cdot H$
Heat exchanger, Fluid product silo		$A = D \cdot H$

15.4.2 ***Heat Addition due to Internal Loads.** Designers shall evaluate all sources of overpressure due to internal heat loads that can occur during operation, upset conditions, standby or other abnormal states. The applied pressure relief device shall have sufficient capacity to prevent overpressure of the equipment when subjected to the largest heat source.

15.4.3 ***Positive-Displacement Compressors.** Where a positive-displacement compressor is equipped with an intervening shut-off valve between the compressor discharge and the oil separator, the compressor shall be equipped with a pressure relief device having a capacity equal to or greater than the largest capacity determined by Section 15.4.3.1.

15.4.3.1 The pressure relief device shall be sized based on the compressor's mass flow rate at a suction pressure corresponding to 50°F (10°C) saturated temperature or at the design saturated suction temperature, whichever results in a larger capacity.

Exceptions:

1. Low-stage or booster compressors. For compressors capable of only discharging to the suction of a higher-stage compressor, flow shall be calculated at the saturation temperature equal to the highest intermediate temperature set point.

2. The pressure relief device for the compressor shall be permitted to be the minimum regulated flow rate of the compressor when all of the following conditions are met:

   a. The compressor is equipped with automatic capacity regulation.

   b. The capacity regulation actuates to minimum flow at not greater than 90% of the pressure relief device set pressure.

   c. A pressure-limiting device is installed and set in accordance with Section 8.2.4.

15.4.3.2 When the positive-displacement compressor is directly connected to a downstream oil separator with no intervening shut-off valve between the compressor and oil separator, the capacity required for a pressure relief device to protect both the oil separator and the compressor shall be the larger of the two values determined when calculated in accordance with both Sections 15.8.2 and Section 15.4.3.1.

15.4.4 **Positive-Displacement Liquid Pumps.** Where a positive-displacement liquid pump is capable of developing a discharge pressure greater than the design pressure of a portion of the system to which it discharges and the portion of the system receiving the liquid is intended to operate completely filled with liquid, the pressure relief device protecting the portion of the system receiving liquid shall be rated for liquid with volume flow capacity equal to or greater than the volumetric flow of the pump.

15.4.5 **Other Potential Overpressure Scenarios.** The designer shall evaluate other potential overpressure scenarios as applicable to the specific equipment being protected.

15.5 Relief Piping General Requirements. Piping connected to the inlet and outlet of pressure relief devices shall comply with this section.

15.5.1 Piping connected to the inlet of a pressure relief device and piping connected to the outlet of a relief device configured to discharge internally to the system shall comply with the design pressure requirements in Section 5.3.1.3.

15.5.2 The materials of construction for relief piping shall be the same as required for refrigerant piping within this standard.

15.5.3 *The cross-sectional area of piping, fittings, relief valve cartridge bodies, couplings, and any other piping components installed between the protected component and its pressure relief device shall be no less than the inlet cross-sectional area of the pressure relief device subject to the inlet pressure loss limitations in Sections 15.8.1.3 and 15.10.7.2 as applicable.

15.5.4 The cross-sectional area of the piping, fittings, relief valve cartridge bodies, couplings, shutoff valves, and any other piping components connected to the discharge side of a pressure relief device shall be no less than the cross-sectional area of the pressure relief device outlet subject to the pressure relief device's maximum allowable back pressure.

15.6 Shut-off valves.

15.6.1 *Installation of a shut-off valve located immediately downstream of a pressure relief device is permitted for the purpose of maintaining or replacing the relief device. The shut-off valve shall be capable of being locked or car-sealed open and the valve shall be locked or car-sealed open while the relief device is in service.

15.6.2 The effects of pressure drop through a shut-off valve installed downstream of a pressure relief valve shall be analyzed along with all connected downstream components in the path to the terminal discharge location. The analysis shall confirm the pressure drop through all piping, valves, and fittings does not exceed the maximum allowable back pressure for the relief valve type being used and that the relief valve operation will be stable during its operation. The results of the analysis shall be documented and included in the design basis for the relief system.

15.7 Relief System Configuration.

15.7.1 Safety relief devices providing overpressure protection for refrigeration system components shall comply with the preceding sections of this chapter and one of the following:

a. Vapor refrigerant relief devices discharging external to the system shall comply with Section 15.8.3.

b. Vapor refrigerant relief devices discharging internal to the system shall comply with Section 15.8.4.

c. Liquid refrigerant relief devices shall be configured to discharge internal to the system and comply with Section 15.9.

d. Non-volatile liquid relief discharging internal or external to the system shall comply with Section 15.10.

15.8 Vapor-Rated Refrigerant Relief Devices. This section establishes requirements for pressure relief devices certified for vapor as well as additional requirements for inlet piping applicable to vapor service pressure relief devices. For pressure relief devices certified for vapor that discharge external to the system, the requirements in Section 15.8.3 apply. For pressure relief devices certified for vapor that discharge internal to the system, the requirements in Section 15.8.4 apply.

15.8.1 **Additional Requirements for Inlet Piping to Vapor-rated Refrigerant Relief Devices.**

15.8.1.1 *The inlet piping to pressure relief devices certified for vapor service shall be connected above the highest anticipated liquid ammonia level in the vessel being pressure protected.

15.8.1.2 The use of a shut-off valve on the inlet to the pressure relief device is prohibited.

15.8.1.3 The pressure loss due to vapor flow through all piping, fittings, and three-way valves in the flow path from the protected component to the inlet of a vapor service pressure relief shall be analyzed in accordance with 15.8.1.4 to ensure both of the following requirements are met:

1. The reduction in relief device capacity due to the inlet pressure loss does not diminish the relief device capacity to less than the minimum required capacity determined in accordance Section 15.8.2.
2. The inlet pressure loss does not exceed the relief device blowdown as reported by the relief device manufacturer.

15.8.1.4 *The pressure loss to inlet of a pressure relief device shall be calculated using Equation 15-3 (IP units) or Equation 15-4 (SI units).

$$L = \frac{0.214 \cdot d^5 \cdot \left(P_{u,i}^2 - P_{d,i}^2\right)}{f \cdot C_r^2} - \frac{d \cdot ln\left(\frac{P_{u,i}}{P_{d,i}}\right)}{6 \cdot f} \qquad \text{Equation 15-3}$$

$$\left[L = \frac{7.4381 \times 10^{-15} \cdot d^5 \cdot \left(P_{ui,}^2 - P_{d,i}^2\right)}{f \cdot C_r^2} - \frac{d \cdot ln\left(\frac{P_{u,i}}{P_{d,i}}\right)}{500 \cdot f}\right] \qquad \text{Equation 15-4}$$

where
L = equivalent length of inlet piping including all non-recoverable form and fitting losses, ft (m).
C_r = the mass flow rate (air) of the connected relief device
f = Moody friction factor in fully turbulent flow.
d = inside diameter of pipe or tube, in (mm).
ln = natural logarithm
$P_{d,i}$ = the downstream pressure (absolute) of the inlet piping assembly, i.e. the inlet pressure to the relief device, psia (kPa).
$P_{u,i}$ = the upstream pressure (absolute) of the inlet piping being analyzed, i.e. vessel's relieving pressure, psia (kPa).

15.8.2 ***Relief Device Capacity Determination.** The capacity of pressure relief device(s) certified for vapor for overpressure protection of components shall be determined in accordance with the requirements of this section. The minimum capacity of a pressure relief device shall be determined using Section 15.8.2.1. In cases where engineering controls are used to mitigate the effects of energy sources causing overpressure per Section 15.4 and documented as part of the engineering design, lower-capacity pressure relief devices are permitted in accordance with the design. Where other energy sources capable of causing overpressure, as evaluated in accordance with Section 15.4 and the subsection that follows result in a larger capacity, the largest relief device capacity required shall be applied. When a single pressure relief device is used to protect more than one pressure vessel interconnected without intervening shut-off valves, the required capacity of the pressure relief device shall be the sum of the capacities required for each pressure vessel.

15.8.2.1 **Pressure Vessels Including ASME-Stamped Heat Exchangers.**

15.8.2.1.1 The minimum capacity of a pressure relief device certified for vapor protecting a pressure vessel shall be based on the heat addition from an external heat load as identified in 15.4.1. For ASME-stamped heat exchangers, both external and internal heat loads must be analyzed. The capacity of the pressure relief device for external heat load shall be determined using Equation 15-5 (mass flow) or Equation 15-6 (volumetric flow). The capacity of the pressure relief device for internal heat load shall be determined using Equation 15-7 (mass flow) or Equation 15-8 (volumetric flow). Values of the mass flow capacity factor, f, or volumetric flow capacity factor, g, are provided in Table based on the relieving pressure as determined by Section 15.3.4.

$$C_{\dot{m},e} = f \cdot K_{mat} \cdot A \qquad \text{Equation 15-5}$$

$$C_{\dot{V},e} = g \cdot K_{mat} \cdot A \qquad \text{Equation 15-6}$$

$$C_{\dot{m},i} = f_1 \cdot A \qquad \text{Equation 15-7}$$

$$C_{\dot{V},i} = g_1 \cdot A \qquad \text{Equation 15-8}$$

where

$C_{\dot{m},e}$ = required pressure relief device discharge capacity due to external heat addition expressed on a mass flow rate of standard air basis, lb_m/min.

$C_{\dot{V},e}$ = required pressure relief device discharge capacity due to external heat addition expressed on a volume flow of standard air basis, SCFM.

f = mass flow capacity factor for the relief device (air basis) for an external fire condition from Table 15-21, lb_m/min.

g = volume flow capacity factor for the relief device (air basis) Table 15-21, ft^3/min.

$C_{\dot{m},i}$ = required pressure relief device discharge capacity due to applicable internal heat addition expressed on a mass flow rate of standard air basis, lb_m/min.

$C_{\dot{V},i}$ = required pressure relief device discharge capacity due to applicable internal heat addition expressed on a volume flow of standard air basis, SCFM.

f_1 = modified pressure relief device discharge capacity due to internal heat load expressed on a mass flow rate of air basis determined in accordance with Section 15.8.2.1.2, lb_m/min.

g_1 = modified pressure relief device discharge capacity due to internal heat load expressed on a volume flow of air basis determined in accordance with Section 15.8.2.1.2, SCFM.

K_{mat} = 1.0 if no combustible materials are with 20 ft of the vessel or heat exchanger [-].

K_{mat} = 2.5 if combustible materials are within 20 ft of the vessel or heat exchanger [-].

A = largest projected area of component when viewed from any direction determined in accordance with Section 15.4.1, ft^2.

Table 15-1: **Relief device capacity factors for ammonia due to an external fire.*
(Note: Linear interpolation is permitted for set pressures that lie between values stated in the table).

<table>
<tr><th>P_{set}
[psig]</th><th>$P_{relieving}$
[psig]</th><th>f
[$lb_m/min\text{-}ft^2$]</th><th>g
[$SCFM/ft^2$]</th></tr>
<tr><td>250</td><td>275</td><td rowspan="4">0.50</td><td rowspan="4">6.54</td></tr>
<tr><td>300</td><td>330</td></tr>
<tr><td>400</td><td>440</td></tr>
<tr><td>500</td><td>550</td></tr>
<tr><td>600</td><td>660</td><td rowspan="2">0.55</td><td rowspan="2">7.20</td></tr>
<tr><td>700</td><td>770</td></tr>
<tr><td>800</td><td>880</td><td rowspan="2">0.60</td><td rowspan="2">7.85</td></tr>
<tr><td>900</td><td>990</td></tr>
<tr><td>1000</td><td>1100</td><td rowspan="2">0.70</td><td rowspan="2">9.16</td></tr>
<tr><td>1100</td><td>1210</td></tr>
<tr><td>1200</td><td>1320</td><td>0.80</td><td>10.47</td></tr>
</table>

15.8.2.1.2 Other energy sources, including internal heat loads, capable of causing overpressure shall be evaluated. Based on other energy sources applicable, the capacity of the vapor service pressure relief device is determined using Equation 15-5 (mass flow) or Equation 15-6 (volumetric flow) but using the modified mass flow capacity factor, f_1, or modified volumetric flow capacity factor, g_1, calculated by Equation 15-9 or Equation 15-10, respectively.

$$f_1 = \frac{\dot{Q}'_{max}}{150} \cdot f \qquad \text{Equation 15-9}$$

$$g_1 = \frac{\dot{Q}'_{max}}{150} \cdot g \qquad \text{Equation 15-10}$$

where

f_1 = modified pressure relief device discharge capacity due to external heat load expressed on a mass flow rate of air basis, lb_m/min.

g_1 = modified pressure relief device discharge capacity due to external heat load expressed on a volume flow of air basis, SCFM.

$\dot{Q}'_{max}$ = maximum internal or external heat load, normalized to the largest projected area of the component, Btu/min-ft^2.

150 = Reference heat load normalized to the largest projected area of the component, Btu/min-ft^2.

15.8.2.2 ***Positive-Displacement Compressors.**

15.8.2.2.1 The capacity of a pressure relief device certified for vapor used for protecting a positive-displacement compressor shall be provided by either the compressor manufacturer or by using either Equation 15-11 or Equation 15-12 based on the conditions and requirements set forth in Section 15.4.3.

$$C_{\dot{m},comp} = Q \cdot PL_{min} \cdot \eta_V \cdot \rho_v \cdot r_w \qquad \text{Equation 15-11}$$

$$C_{\dot{V},comp} = \frac{C_{\dot{m},comp}}{0.0764} \qquad \text{Equation 15-12}$$

where

$C_{\dot{m},comp}$ = required pressure relief device discharge capacity for a positive-displacement compressor on a mass flow rate of air basis, lb/min.

$C_{\dot{V},comp}$ = required pressure relief device discharge capacity for a positive-displacement compressor on a volume flow of air basis, SCFM.

0.0764 = density of air, lbm/ft^3.

Q = swept volume flow rate of the compressor, ft^3/min.

PL_{min} = fraction of compressor capacity at minimum regulated flow including the effects of a variable speed drive motor if equipped and controlled as part of the minimum regulated flow, [-].

ρ_v = density of ammonia vapor as determined based on conditions specified in Section 15.4.3.1, lbm/ft^3.

r_w = refrigerant-to-air conversion factor as determined by Equation 15-13.

$$r_w = 1.31 \cdot \frac{C_a}{C_r}\sqrt{\frac{T_r}{T_a}}$$ Equation 15-13

$$C_r = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$ Equation 15-14

where
C_a = constant for air = 356

$C_{r,}$ = constant for refrigerant as determined by Equation 15-14

T_a = absolute temperature of air = 520R

$T_{r,}$ = absolute temperature of refrigerant at the relieving condition or as specified in Section 15.4.3.1

k = ratio of ideal gas heat capacities for refrigerant vapor at the relieving condition or as specified in Section 15.4.3.1

15.8.3 **Relief Devices Discharging External to the System.** The following subsections provide additional requirements applicable to pressure relief devices certified on vapor that discharge external to the closed-circuit refrigeration system.

15.8.3.1 Piping connected to the outlet of a relief device configured to discharge external to the refrigeration system is not considered part of the closed-circuit refrigeration system.

15.8.3.2 Carbon steel piping from pressure relief devices discharging external to the closed-circuit system shall be steel pipe with a minimum Schedule 40 for pipe sizes up to 6 in. (DN 150) and minimum Schedule 20 for pipe sizes 8 in. (DN 200) and larger. Stainless-steel discharge piping shall be minimum Schedule 40 for pipe sizes 1-1/2 in. (DN 40) and smaller and minimum Schedule 10 for pipe sizes 2 in. (DN 50) and larger.

EXCEPTIONS:

1. Relief piping discharging external to the system shall be permitted to be galvanized or ungalvanized ASTM A53 Type F. Where these grades of ungalvanized pipe are used, the pipe shall be clearly identified using paint striping or another method or shall be segregated at a job site to prevent use in the closed-circuit system.
2. Malleable iron ASTM A197 fittings shall be permitted for relief piping discharging external to the system.
3. For relief devices having maximum allowable back pressures at or above 150

psig (1,034 kPa_g), the piping connected to the outlet shall comply with B31.5 for pipe schedule and fittings.

15.8.3.3 **Maximum Allowable Pressure Relief Device Back Pressure.**

15.8.3.3.1 Unless specified by the relief valve manufacturer, the maximum allowable back pressure, $P_{b,max}$, at the outlet of a pressure relief device during actuation shall not exceed the following:

a. For conventional relief devices, 15% of set pressure,
$$P_{b,max} = (0.15 \cdot P_{set}) + P_{atm}$$

b. For balanced relief devices, 25% of set pressure,
$$P_{b,max} = (0.25 \cdot P_{set}) + P_{atm}$$

c. For pilot operated relief devices, 50% of set pressure,
$$P_{b,max} = (0.50 \cdot P_{set}) + P_{atm}$$

15.8.3.3.2 When outlets of two or more relief devices, which are expected to operate simultaneously, are connected to a common discharge vent system, the common sections of the vent system shall be sized in accordance with Section 15.8.3.5.3 to prevent the pressure at the outlet of each operating relief device from exceeding its maximum allowable back pressure.

15.8.3.4 **Relief Device Discharge Terminal Locations.** Pressure relief devices configured to discharge external to the system are permitted to discharge directly to atmosphere, to a water diffusion tank, to a flaring/treatment system or other approved means in accordance with the respective requirements given in the subsections that follow.

15.8.3.4.1 **Relief Vapor Discharging Directly to Atmosphere.**

15.8.3.4.1.1 Where atmospheric relief devices are located within refrigerated spaces, precautions shall be taken to prevent moisture migration into the relief vent line or outlet body of the relief device.

15.8.3.4.1.2 The termination of discharge piping relieving to atmosphere shall be not less than 15 ft (4.6 m) above grade and not less than 20 ft (6.1 m) from windows, doors, and ventilation intakes.

15.8.3.4.1.3 The discharge termination from piping relieving to atmosphere shall not be less than 7.25 ft (2.2 m) above a roof. Where a higher adjacent roof level is within 20 ft (6.1 m) horizontal distance from the relief discharge, the discharge termination shall not be less than 7.25 ft (2.2 m) above the height of the higher adjacent roof.

15.8.3.4.1.4 Discharge piping shall terminate at not less than 7.25 ft (2.2 m) above platform surfaces, such as upper condenser catwalks, when the discharge is within 20 ft. (6.1 m) horizontal distance to the platform surface.

15.8.3.4.1.5 *The termination of the discharge piping shall be directed upward at an angle of 45° from the horizontal or greater and arranged to avoid spraying ammonia on persons in the vicinity.

15.8.3.4.1.6 Piping discharging to atmosphere shall have a provision to mitigate the entry of rain or snow into the discharge piping

15.8.3.4.1.7 Relief vent lines that terminate vertically upward and are subject to moisture entry shall be provided with a drip pocket having a minimum of 24 in. (0.6 m) in length and having the size of the vent discharge pipe. The drip pocket shall be installed to extend below the first change in vent pipe direction and shall be fitted with a valve or drain plug to permit removal of accumulated moisture.

15.8.3.4.2 **Relief Vapor Discharging to a Water Diffusion Tank.**

15.8.3.4.2.1 The water diffusion tank shall be sized to contain 1 gal of water for each lbm of ammonia vapor (8.3 l of water per kg of ammonia vapor) based on the quantity of ammonia that would be released from the single largest connected pressure relief device discharging for 1 hour.

15.8.3.4.2.2 The water diffusion tank shall be sized to accommodate the aggregate volume of water and discharged ammonia without overflowing but not less than required to contain a liquid volume of 1.1 times the required water volume for ammonia absorption.

15.8.3.4.2.3 Appropriate measures shall be taken to prevent water in the diffusion tank from freezing where sited in locations where the ambient temperature can be lower than 32°F (0°C).

15.8.3.4.2.4 The pressure relief discharge pipe shall distribute the vapor ammonia at the bottom of the tank but not more than 33 ft (10 m) below the maximum level of liquid in the tank.

15.8.3.4.2.5 The static head of the maximum water level in the tank shall be included as a component of built-up back pressure on the relief vent system in the sizing of the piping in accordance with 15.8.3.5.

15.8.3.4.2.6 The water diffusion tank shall be designed with a means to verify water level and a means to obtain a representative water sample.

15.8.3.4.3 **Relief Vapor Discharging to a Flaring/Treatment System.** If installed, a flaring/treatment system shall be tested to demonstrate compliance with the design.

15.8.3.4.4 **Other approved means.** Alternative pressure relief system discharge designs are permitted when approved by the Authority Having Jurisdiction.

15.8.3.5 **Discharge/Vent Pipe Sizing Requirements When Discharging External to the System.**

15.8.3.5.1 The individual branch vent lines and common sections of a headered relief vent system shall be sized to ensure the back pressure on each relief device does not exceed the maximum allowable back pressure as determined by Section 15.8.3.3.1 based on all scenarios identified where two or more pressure relief devices are expected to simultaneously discharge.

15.8.3.5.2 Each relief device in a headered relief vent system shall be included in at least one relief scenario.

15.8.3.5.3 For the purpose of sizing vent pipe sizing, the stamped capacity of a pressure relief device or a reduced capacity of a pressure relief device based on the effects of inlet pressure losses is permitted. Where a rupture disk may be used upstream of a pressure relief valve, the reduction in pressure relief valve capacity shall be adjusted in accordance with ASME B&PV Code Section XIII.

15.8.3.5.4 *The calculation of back pressure at the outlet of each pressure relief device due to the vent piping, fittings, and valves shall be determined using Equation 15-15 (IP units) or Equation 15-16 (SI units) applied systematically to each constant cross-section area of piping for a constant mass flow rate in that piping section.

$$L = \frac{0.214 \cdot d^5 \cdot (P_u^2 - P_d^2)}{f \cdot C_r^2} - \frac{d \cdot ln\left(\frac{P_u}{P_d}\right)}{6 \cdot f} \qquad \text{Equation 15-15}$$

$$\left[L = \frac{7.4381 \times 10^{-15} \cdot d^5 \cdot (P_u^2 - P_d^2)}{f \cdot C_r^2} - \frac{d \cdot ln\left(\frac{P_u}{P_d}\right)}{500 \cdot f}\right] \qquad \text{Equation 15-16}$$

where
L = equivalent length of discharge piping, fittings, and valves, ft (m).
C_r = the mass flow rate (air) in the piping segment being analyzed, in lb_m/min (kg/s) or as adjusted for reduced capacity due to inlet piping, fittings and valves.
f = Moody friction factor in fully turbulent flow.
d = inside diameter of pipe or tube, in (mm).
ln = natural logarithm.
P_d = the downstream pressure (absolute) of the discharge piping segment, psia (kPa). For discharge to atmosphere, P_d = P_{atm}. For discharging into a tank of water in accordance with Section 15.8.3.4.2, P_d = P_{atm} + P_{static}.
P_{atm} = atmospheric pressure at the nominal elevations of the installation.
P_{static} = static pressure due to hydrostatic head of water, psi (kPa).
P_u = the upstream pressure (absolute) of the piping segment being analyzed. For a single relief valve system with constant area vent piping, this would be the pressure at the outlet of pressure relief device, psia (kPa).

15.8.4 **Vapor service Pressure Relief Devices Discharging Internal to the System.**

15.8.4.1 Piping connected to the outlet of a pressure relief that discharges internal to the closed-circuit system is part of the closed-circuit refrigeration system and shall comply with the design pressure requirements of Section 5.3.1.3.

15.8.4.2 The relief device set pressure shall not be greater than the difference in design pressure of the component connected to the relief inlet and the set pressure of the relief device protecting the component connected to the relief outlet.

15.8.4.3 A shut-off valve located downstream of a pressure relief device that discharges internal to the closed-circuit system is permitted in accordance with Section 15.6.1.

15.8.4.4 Unless specified by the relief valve manufacturer, the maximum allowable back pressure ($P_{b,max}$) at the outlet of a pressure relief device discharging internally during actuation shall not exceed the following:

a. For conventional relief devices, 15% of aggregate of relief set pressure plus the downstream component's relieving pressure,

$$P_{b,max} = (0.15 \cdot P_{set}) + P_{r,downstream}$$

b. For balanced relief devices, 25% of relief set pressure plus the downstream component's relieving pressure,

$$P_{b,max} = (0.25 \cdot P_{set}) + P_{r,downstream}$$

c. For pilot operated relief devices, 50% of relief set pressure plus the downstream component's relieving pressure,

$$P_{b,max} = (0.50 \cdot P_{set}) + P_{r,downstream}$$

where

$P_{b,max}$ = is the maximum allowable back pressure at the outlet of a relief valve discharging internal to the system, psia, (kPa).

P_{set} = is the set pressure of the relief valve piped to discharge internal to the system, psig, (kPa_g).

$P_{r,downstream}$ = is the relieving pressure for the vessel receiving the refrigerant discharged by the internal relief valve, psia, (kPa).

15.8.4.5 The stamped capacity of a pressure relief device configured for internal relief shall be adjusted for operation at the elevated inlet and back pressures corresponding to the relieving conditions using information available from the valve manufacturer. If no information for relief device capacity adjustment is available from the manufacturer, the relief device capacity shall be corrected using the following.

$$C_{r,adj} = K_b \cdot C_r \qquad \text{Equation 15-17}$$

where

$C_{r,adj}$ = is the adjusted mass flow rate (air) of the relief device capacity intended for operating at higher inlet and back pressures, lbm/min, (kg/s).

C_r = the rated mass flow rate (air) of the relief device at the valve's actual relieving condition, lbm/min (kg/s) or as adjusted for reduced capacity due to inlet piping, fittings and valves.

K_b = is the capacity correction based on the set pressure of the internal relief device from Table 15-2.

Table 15-2: Relief device capacity correction factor.

P_{set} [psi]	K_b
50	0.6
100	0.7
150	0.8

15.8.4.6 The size of piping and fittings attached to the outlet of a pressure relief device shall ensure the back pressure at the outlet of an internal pressure relief device (superimposed and built-up) is less than the maximum allowable back pressure evaluated at the full capacity of the pressure relief device at its relieving condition.

15.8.4.7 *The calculation of back pressure due to the piping attached to the outlet of the pressure relief device shall be determined using Equation 15-18 (IP units) or Equation 15-19 (SI units).

$$L = \frac{0.214 \cdot d^5 \cdot (P'^2_u - P'^2_d)}{f \cdot C_r^2} - \frac{d \cdot ln\left(\frac{P'_u}{P'_d}\right)}{6 \cdot f} \qquad \text{Equation 15-18}$$

$$\left[L = \frac{7.4381 \times 10^{-15} \cdot d^5 \cdot (P'^2_u - P'^2_d)}{f \cdot C_r^2} - \frac{d \cdot ln\left(\frac{P'_u}{P'_d}\right)}{500 \cdot f}\right] \qquad \text{Equation 15-19}$$

where

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

C_r = the mass flow rate (air) in the piping, in lb_m/min (kg/s) or as adjusted for reduced capacity due to inlet piping, fittings and valves.

f = Moody friction factor in fully turbulent flow.

d = inside diameter of pipe or tube, in (mm).

ln = natural logarithm.

P'_d = the relieving pressure (absolute) for the component where the relief device discharge piping is connected, psia (kPa).

P'_u = the upstream pressure (absolute) of the piping segment. The upstream pressure shall not exceed the maximum allowable back pressure of the relief device, psia (kPa).

15.9 Refrigerant Pressure Relief Devices for Liquid Service. This section establishes requirements for pressure relief devices for liquid service and intended for overpressure protection of liquid refrigerant filled vessels. It specifies additional requirements for inlet piping applicable to pressure relief devices certified for liquid.

15.9.1 **Additional Requirements for Inlet Piping.**

15.9.1.1 The inlet to a pressure relief device certified for liquid shall be located below the lowest expected liquid level in the protected component.

15.9.2 **Relief Device Capacity Determination.** The capacity of pressure relief device certified for liquid shall be determined in accordance with the requirements of this section.

15.9.2.1 The capacity of the pressure relief device(s) certified for liquid shall be based on the relieving pressure as determined by Section 15.3.4 and the relevant sources of causes overpressure as determined by the requirements in Section 15.4. The liquid service capacity factor, g_l, in Table 15-3 shall correspond to the relieving pressure of the internal relief device.

Table 15-3: Volumetric flow capacity factors for pressure relief devices certified for liquid.

P_{set} [psig]	$P_{relieving}$ [psig]	g_l [GPM/ft^2]
250	275	42.7
300	330	44.2
400	440	47.0
500	550	49.6
600	660	52.3
700	770	55.1
800	880	58.1
900	990	61.4
1000	1100	65.2
1100	1210	70.0
1200	1320	76.3

15.9.2.2 The required minimum capacity of a pressure relief device certified for liquid for an external heat load shall be determined using Equation 15-20 and internal heat load shall be determined using Equation 15-21.

$$C_{l,e} = g_l \cdot K_{mat} \cdot A \qquad \text{Equation 15-20}$$

$$C_{l,i} = g_{l,1} \cdot A \qquad \text{Equation 15-21}$$

where

$C_{l,e}$ = required liquid service pressure relief device flow capacity (water) due to external heat addition, GPM/ft^2

g_l = volumetric flow (water) capacity factor for a liquid service pressure relief device from Table 15-3, GPM/ft^2

$C_{l,i}$ = required liquid service pressure relief device flow capacity due to applicable internal heat addition (water) GPM/ft^2

$g_{l,1}$ = modified volumetric flow capacity factor for liquid service pressure relief devices on a volume flow of water basis (water) as determined by Section 15.9.2.3, GPM

K_{mat} = 1.0 if no combustible materials are with 20 ft of the vessel or heat exchanger [-].

K_{mat} = 2.5 if combustible materials are within 20 ft of the vessel or heat exchanger [-].

A = largest projected area of pressure vessel when viewed from any determined in accordance with Section 15.4.1, ft^2

15.9.2.3 Other energy sources, including internal heat loads, capable of causing overpressure shall be evaluated. Based on other energy sources applicable, the modified volumetric flow capacity factor for the pressure relief device certified for liquid shall be determined using Equation 15-22 using the volumetric flow capacity factor, g_l.

$$g_{l,1} = \frac{\dot{Q}'_{max}}{150} \cdot g_l \qquad \text{Equation 15-22}$$

where

g_l = volumetric flow capacity factor for liquid service pressure relief device (water) from Table 15-3, GPM/ft^2

$g_{l,1}$ = modified volumetric flow capacity factor for liquid service pressure relief devices on a volume flow of water basis (water), GPM

$\dot{Q}'_{max}$ = maximum internal or external heat load, normalized to the largest projected area of the pressure vessel, Btu/min-ft^2

150 = Reference heat load normalized to the largest projected area of the pressure vessel, Btu/min-ft^2

15.9.3 Refrigerant Pressure Relief Device Certified for Liquid Discharge Terminal Location.

15.9.3.1 Pressure relief devices intended for liquid refrigerant pressure relief shall discharge internal to the system.

15.9.3.2 Piping affixed to the outlet of a pressure relief certified for liquid discharging internal to the closed-circuit system shall comply with the design pressure requirements in Section 5.3.1.3.

15.9.3.3 The relief device set pressure shall not be greater than the difference in design pressure of the pressure vessel connected to the relief device inlet and the set pressure of the relief device protecting the pressure vessel connected to the relief device outlet.

15.9.3.4 A shut-off valve located downstream of a pressure relief device certified for liquid that discharges internal to the closed-circuit system is permitted in accordance with Section 15.6.1.

15.9.3.5 The design pressure of the pressure relief device body for both the inlet and outlet shall be rated equal to or greater than at the design pressure of the higher-pressure component.

15.9.3.6 Unless specified by the relief valve manufacturer, the maximum allowable back pressure ($P_{b,max}$) at the outlet of a pressure relief device certified for liquid discharging internally during actuation shall not exceed the following:

a. For conventional relief devices, 15% of aggregate of relief set pressure plus the downstream vessel's relieving pressure,

$$P_{b,max} = 0.15(P_{set}) + P_{r,downstream}$$

b. For balanced relief devices, 25% of relief set pressure plus the downstream vessel's relieving pressure,

$$P_{b,max} = 0.25(P_{set}) + P_{r,downstream}$$

c. For pilot operated relief devices, 50% of relief set pressure plus the downstream vessel's relieving pressure,

$$P_{b,max} = 0.50(P_{set}) + P_{r,downstream}$$

15.9.3.7 The capacity of a pressure relief device certified for liquid configured for internal relief shall meet or exceed the minimum required capacity by the methods in Section 15.9.2 when evaluated at the relieving condition for the pressure relief device.

15.9.4 **Liquid Service Relief Discharge Piping Requirements.**

15.9.4.1 **Pipe Sizing.**

15.9.4.1.1 For the purpose of sizing piping connected to the outlet of a liquid service pressure relief device, the stamped capacity of a liquid service pressure relief device or a reduced capacity of a liquid service pressure relief device based on the effects of inlet pressure losses is permitted.

15.9.4.1.2 The size of piping, fittings and shut-off valve, where used, attached to the outlet of a liquid service pressure relief device shall be sufficient to prevent the maximum allowable back pressure determined in Section 15.9.3.6 from being exceeded when evaluated at the stamped capacity or adjusted capacity of the liquid service pressure relief device at its relieving condition. The calculation of back pressure due to the refrigerant flow through the piping at the outlet of the pressure relief device shall be determined using an analysis method that accounts for frictional losses due to two-phase flow as well as fitting (form) losses and the effects of static head of liquid in the discharge line to the point of connection to the receiving vessel based on its specific layout.

15.9.5 ***Non-ASME Equipment.** Where protection against overpressure due to thermal hydrostatic expansion of trapped liquid ammonia in a non-ASME-Stamped component is required, one or more of the following mitigation methods shall be used:

1. A hydrostatic relief device, or check valve, relieving to another part of the closed-circuit system;
2. An expansion compensation device;
3. A control valve with an internal design that will relieve downstream pressure to the upstream side of the control valve.

15.10 Non-Volatile Liquid Relief Discharging Internal or External to the System.

15.10.1 **Overpressure protection requirements.** Components intended to operate completely filled with a non-volatile liquid and connected to the ammonia refrigeration system shall comply with the additional overpressure protection requirements of this Section.

15.10.1.1 ASME-stamped components shall be protected by a pressure relief device certified for liquid service.

15.10.1.2 Vessels and equipment that are not ASME stamped shall be protected from overpressure by one of the following:

1. A hydrostatic relief device, or check valve, discharging to another part of the closed-circuit system;
2. An expansion compensation device.

15.10.2 **Relief Device Capacity Determination.** The capacity of pressure relief device(s) certified for liquid for overpressure protection of components containing non-volatile liquids shall be determined in accordance with the requirements of this section.

15.10.2.1 The capacity of the pressure relief device(s) shall be based on the relieving pressure as determined by Section 15.3.4 and the relevant sources of causes overpressure as determined by the requirements set forth in Section 15.4. The non-volatile liquid service capacity factors, g_{nvl}, given in Table 15-4 shall be used for the minimum relief device capacity determination.

Table 15-4: *Non-volatile liquid service relief capacity factors.*

Liquid	g_{nvl} [GPM/ft^2]
Oil	0.0150
Propylene glycol	0.0119
Water	0.00372

15.10.2.2 The required minimum capacity of a liquid service pressure relief device in non-volatile liquid service for an external heat load shall be determined using Equation 15-23 and for an internal heat load shall be determined using Equation 15-24.

$$C_{nvl,e} = g_{nvl} \cdot K_{mat} \cdot A \qquad \text{Equation 15-23}$$

$$C_{nvl,i} = g_{nvl,1} \cdot K_{mat} \cdot A \qquad \text{Equation 15-24}$$

where

$C_{nvl,e}$ = required non-volatile liquid service pressure relief device flow capacity (water) due to external heat addition, GPM/ft^2

g_{nvl} = volumetric flow capacity factor for non-volatile liquid service pressure relief devices (water) from Table 15-4, GPM/ft^2

$C_{nvl,i}$ = required non-volatile liquid service pressure relief device flow capacity (water) due to applicable internal heat addition, GPM/ft^2

$g_{nvl,1}$ = modified volumetric flow capacity factor for non-volatile liquid service pressure relief devices on a volume flow of water basis determined in accordance with Section 15.10.2.3, GPM

K_{mat} = 1.0 if no combustible materials are with 20 ft of the component [-]

K_{mat} = 2.5 if combustible materials are within 20 ft of the component [-]

A = largest projected area of pressure vessel when viewed from any determined in accordance with Section 15.4.1, ft^2

15.10.2.3 Other energy sources, including internal heat loads, capable of causing overpressure shall be evaluated. Based on other energy sources applicable, the capacity of the liquid service pressure relief device shall be determined using Equation 15-25 using the volumetric flow capacity factor, $g_{nvl,1}$.

$$g_{nvl,1} = \frac{\dot{Q}'_{max}}{150} \cdot g_{nvl} \qquad \text{Equation 15-25}$$

where

g_{nvl} = volumetric flow capacity factor for non-volatile liquid service pressure relief device from Table 15-4, GPM/ft^2 (water)

$g_{nvl,1}$ = modified volumetric flow capacity factor for non-volatile liquid service pressure relief devices on a volume flow of water basis due to internal heat load, GPM

$\dot{Q}'_{max}$ = maximum internal or external heat load, normalized to the largest projected area of the pressure vessel, Btu/min-ft^2

150 = Reference heat load normalized to the largest projected area of the pressure vessel, Btu/min-ft^2

15.10.3 **Shut-off valves.**

15.10.3.1 *When used for inspection, testing, maintenance, or repair of the pressure relieving device, discharge piping, or pressure protected component, shut-off valves are permitted to be installed upstream and downstream of a liquid service pressure relief device in non-volatile liquid service when all the following requirements are met:

1. The shut-off valves shall be capable of being locked or car-sealed in both the open and closed positions and the valves shall be locked or car-sealed open while in service and locked or car-sealed closed while out of service.
2. Administrative controls shall be developed and implemented to prevent unauthorized shut-off valve operation;
3. When isolation of the pressure protected component is intended for inspection, testing, repair, or replacement of the pressure relief device, administrative controls shall provide for an alternate means of pressure relief protection while the vessel or equipment is isolated from its normal pressure relief path;
4. When isolated for inspection, testing, repair or maintenance of the pressure protected component, administrative controls shall ensure the component is promptly depressurized and opened to atmosphere;
5. The pressure vessel or equipment shall only be isolated from its pressure relief path for the time required to test, repair, maintain and/or replace the pressure relief device or connected component.

15.10.4 **Additional Requirements for Inlet Piping.**

15.10.4.1 The inlet to the liquid service pressure relief device shall be located below the lowest expected non-volatile liquid level in the protected pressure vessel.

15.10.5 **Non-volatile Liquid Service Pressure Relief Device Discharging External to the System.**

15.10.5.1 Where discharging external to the system, the set pressure of the liquid service pressure relief device shall not exceed the design pressure of the vessel being pressure protected.

15.10.5.2 *The discharge of non-volatile fluid through a liquid service pressure relief shall not create a hazard external to the system.

15.10.5.3 Piping connected to the outlet of a liquid service pressure relief device discharging external to the system is not considered part of the closed-circuit refrigeration system.

15.10.5.4 The size of piping, fittings and shut-off valve, where used, attached to the outlet of a liquid service pressure relief device shall be sufficient to prevent the maximum allowable back pressure determined in Section 15.9.3.6 from being exceeded when evaluated at the stamped capacity or adjusted capacity of the liquid service pressure relief device at its relieving condition.

15.10.5.5 The calculation of back pressure due to the refrigerant flow through the piping at the outlet of the pressure relief device shall be determined using an analysis method that accounts for frictional losses due to two-phase flow as well as form losses and effects of static head of liquid in the discharge line to the point of connection to the receiving vessel based on its specific layout.

15.10.6 **Non-volatile Liquid Service Pressure Relief Device Discharging Internal to the System.**

15.10.6.1 The relief device set pressure shall not be greater than the difference in design pressure of the pressure vessel connected to the relief inlet and the set pressure of the relief device protecting the pressure vessel connected to the relief outlet.

15.10.6.2 The discharge of non-volatile fluid through a pressure relief device discharging internal to the closed-circuit refrigeration system shall not create a hazard to the closed-circuit refrigeration system.

15.10.6.3 Piping connected to the outlet of a liquid service pressure relief device discharging internal to the system shall be considered part of the closed-circuit refrigeration system.

15.10.7 **Pipe sizing.**

15.10.7.1 The piping connected to the inlet of a liquid service pressure relief shall not be less than the inlet connection size of the pressure relief device.

15.10.7.2 The inlet pressure loss to a liquid service pressure relief device relieving non-volatile liquid shall be calculated using fluid properties and calculations for liquid flow. The inlet pressure loss shall not diminish the liquid service pressure relief device capacity below the required capacity determined in Section 15.10.2.

15.10.7.3 For the purpose of sizing piping connected to the outlet of a liquid service pressure relief device, the stamped capacity of a liquid service pressure relief device or a reduced capacity of a liquid service pressure relief device based on the effects of inlet pressure losses is permitted.

15.10.7.4 The piping connected to the outlet of a liquid service pressure relief device shall not be less than the outlet connection size of the pressure relief device.

15.10.7.5 The piping connected to the outlet of a liquid service pressure relief device shall not serve any other pressure relief device.

15.10.7.6 The size of piping, fittings and shut-off valve, where used, attached to the outlet of a liquid service pressure relief device shall be sufficient to prevent the maximum allowable back pressure determined in Section 15.9.3.6 from being exceeded when evaluated at the stamped capacity or adjusted capacity of the liquid service pressure relief device at its relieving condition. The calculation of back pressure due to the refrigerant flow through the piping at the outlet of the pressure relief device shall be determined using an analysis method that accounts for frictional losses due to the non-volatile fluid flow, form losses, and effects of static head of non-volatile liquid that could accumulate in the discharge line to the point of connection to the receiving vessel based on its specific layout.

15.11 *Emergency Pressure Control System. Where required by the AHJ, refrigeration systems that are required by Section 4.2 to be in a machinery room and which have pressure relief valves that release directly to atmosphere shall comply with this section. The system shall be evaluated to determine whether a release of ammonia from pressure relief valves would result in an unacceptable public health consequence. If an unacceptable public health consequence is determined, the installation shall comply with one of the following:

1. An emergency pressure control system (EPCS) shall be installed. Use of an EPCS shall not eliminate overpressure-protection requirements of Section 15.4.
2. Pressure relief valves shall use a relief method, other than direct atmospheric venting, permitted by Section 15.8.3.

Chapter 16. Instrumentation and Controls

16.1 General

16.1.1 ***Operating Parameter Monitoring.** Instrumentation and controls shall be provided to indicate operating parameters of the refrigeration system and equipment and provide the ability to control the starting, stopping, and operation of the system or equipment manually or automatically. The instruments and controls shall provide notice to an owner's representative if the system's critical operating parameters, as determined by the owner or operator, have been exceeded. Monitoring of parameters is permitted to be automatic or manual or a combination of both methods.

16.1.2 **Documentation.** The function, sequence, and operating design parameters of each provided control shall be obtained or documented. The owner or operator shall maintain such documentation in a location that is accessible at the site.

16.1.3 ***Monitoring an Ammonia Release during a Power Failure** A means shall be provided for monitoring the concentration of an ammonia release in the event of a power failure where ammonia leak detection is required in accordance with this standard.

16.1.4 ***Restricted Access to Safety Settings.** Changing of safety settings shall be limited to authorized personnel only. Changing of system operational settings shall not permit or affect changes to safety settings.

16.1.5 **Electrical Control Systems.** Electrical control systems shall comply with the electrical code.

16.1.6 **MAWP.** The pressure-containing envelope maximum allowable working pressure of instruments and visual liquid level indicators shall be equal to or greater than the design pressure of the system or subsystem in which they are installed.

16.2 Visual Liquid Level Indicators:

Visual liquid level indicators, including but not limited to glass bull's eyes, flat "armored glass" linear sight glasses or sight columns, shall comply with this section.

16.2.1 **Design and Selection**

16.2.1.1 *Design of visual liquid level indicators shall be in accordance with one or more of the following:

1. Comply with the ultimate strength requirement in Section 5.11.2; or
2. Use a performance-based pressure-containment design substantiated by either proof tests as described in ASME B&PVC, Section VIII, Division 1, Section UG-101, or an experimental stress analysis.

16.2.1.2 The design pressure shall not be less than the pressure required by Section 5.3.

16.2.1.3 Sight glasses and linear liquid level indicators shall not be installed where a risk of hydraulic shock exists.

16.2.2 **Damage Protection.** Visual liquid level indicators used to observe ammonia level, such as in a vessel or heat exchanger, shall be designed and specified for installation in a manner that provides protection from physical damage.

16.2.3 ***Linear Liquid Level Indicators.** Linear liquid level indicators shall be fitted with internal check-type shut-off valves. Protection against accidental breakage of the glass tube from any direction shall be provided for the entire length of the tube.

EXCEPTION: Liquid level indicators using bull's eye type sight glasses.

16.2.4 **Bull's Eye Sight Glasses.** Bull's eye sight glass types shall be compatible for use with ammonia, and the thickness and diameter shall be sized for the intended application. Bull's eye sight glasses shall be provided with a traceable serial number or other form of identification that does not compromise the glass's structure or integrity.

16.3 *Electric and Pneumatic Sensor Controls.

Sensing devices that initiate control pulses or signals for refrigeration systems shall comply with this section.

16.3.1 **Design.** Sensing devices that initiate control pulses or signals shall have a design pressure that is not less than the design pressure required by Section 5.3. In addition, the sensing devices shall be in accordance with one or more of the following:

1. Complies with the ultimate strength requirement in Section 5.11.2;
2. Has a documented successful performance history for devices in comparable service conditions;
3. Uses a performance-based pressure-containment design substantiated by either proof tests as described in ASME B&PVC, Section VIII, Division 1, Section UG-101, or an experimental stress analysis; and/or
4. Is listed individually or as part of an assembly or a system.

16.3.2 **Equipment Identification.** Manufacturers producing electrical or pneumatic controls shall provide the following minimum nameplate data, noted either on the device or in the accompanying literature:

1. Manufacturer's name;

2. Manufacturer’s serial number, where applicable;
3. Manufacturer’s model number;
4. Electric supply: volts, full load amps, frequency (Hz), phase, where applicable;
5. Pneumatic system: control range: maximum supply air pressure, minimum supply air pressure, required ACFM, where applicable;
6. Flow direction, where applicable; and
7. Any additional characteristics designers and operators must be aware of to safely design, install, and/or utilize the device for its intended purpose.

16.4 Pressure Gauges. Pressure gauges used for visually determining system pressures shall comply with this section.

16.4.1 **Design and Selection.** Pressure gauges shall be designed or selected in accordance with one or more of the following:

1. Comply with the ultimate strength requirements in Section 5.11.2;
2. Have a documented successful performance history for devices in comparable service conditions;
3. Use a performance-based pressure-containment design substantiated by either proof tests as described in ASME B&PVC, Section VIII, Division 1, Section UG-101, or an experimental stress analysis; and
4. Be listed individually or as part of an assembly or a system.

16.4.2 **High Side Installation.** Where a pressure gauge is installed on the high side of the refrigeration system, the gauge shall be capable of measuring and displaying not less than 120% of the system design pressure.

Chapter 17. Ammonia Detection and Alarms

17.1 *Scope. Ammonia leak detection and alarms located in "Machinery Rooms" shall comply with Section 6.13 and Sections 17.2–17.6 of this chapter. Ammonia leak detection and alarms in "Areas Other than Machinery Rooms" shall comply with Section 7.2.3 or Section 7.3.1.2.3, as applicable, and this chapter. Ammonia leak detection and alarms for "Packaged Systems" shall comply with Section 14.4 and this chapter.

17.2 Installation Design Requirements.

17.2.1 ***Power Supply.** The power to the ammonia detection and alarm system shall be designed to accomplish each of the following:

17.2.1.1 Remain operational during emergency shutdown or routine stoppage of the refrigeration equipment;

17.2.1.2 Maintain power throughout expected refrigeration equipment maintenance procedures;

17.2.1.3 Send a trouble signal to a monitored location in the event of a loss of power to the ammonia detection and alarm system; and

17.2.1.4 *Where emergency ventilation is installed, initiate the sequence as outlined in section 6.13.2.3 in the event of a loss of power to the ammonia detection and alarm system.

17.2.2 **Wire Runs.** Detectors shall use supervised wire runs such that any faults in the wiring are reported to a monitored location.

17.2.3 **Communication.** Loss of communication between the detector and the control system(s) that enables response shall be reported to a monitored location.

17.2.4 **Monitoring Sensing Element(s).** Detectors shall actively monitor the primary sensing element(s) and report any trouble signal to a monitored location.

17.3 Design and Testing Standards. Ammonia detectors shall be designed and tested in accordance with UL-61010-1 "Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use" or ANSI/ISA 92.00.01 "Performance Requirements for Toxic Gas Detectors".

17.4 *Detector Placement. A leak detection sensor, or the inlet of a sampling tube that draws air to a leak detection sensor, shall be mounted in a position where it is expected to be the most effective. Leak detection sensors and sampling tube inlets shall be positioned where they can be accessed for maintenance and testing.

17.5 *Alarms. The audible alarms providing notification shall provide a sound pressure level of 15 decibels (dBA) above the average ambient sound level and 5 dBA above the maximum sound level of the area in which it is installed.

17.6 Signage. Ammonia leak detection alarms shall be identified by signage adjacent to visual and audible alarm devices.

17.7 *Detection and Alarm Levels. Where this standard specifies an ammonia detection and alarm concentration, the operational criteria shall be as specified in this section.

17.7.1 **Level 1 Ammonia Detection and Alarm.** Level 1 ammonia detection and alarm shall have the following features:

1. At least one ammonia detector shall be provided in the room or area, and
2. *The detector shall initiate notification to a monitored location so that corrective action is taken at an indicated concentration of 25 ppm or higher.

17.7.2 **Level 3 Ammonia Detection and Alarm.** Level 3 ammonia detection and alarm shall have the following features:

1. At least one ammonia detector shall be provided in the room or area.
2. The detector shall activate an alarm that reports to a monitored location so that corrective action can be taken at an indicated concentration of 25 ppm or higher.
3. Audible and visual alarms shall be provided inside the room to warn that, when the alarm has activated, access to the room is restricted to personnel authorized to respond to alarms and emergency responders.
4. Upon activation of the alarm, control valves feeding liquid and hot gas to equipment in the affected area shall be closed. Refrigerant pumps, nonemergency fans, or other motors that are part of the ammonia refrigeration equipment in the room shall be de-energized.
5. Upon activation of the alarm, emergency exhaust systems, where required, shall be activated.

Chapter 18. Absorption Systems

18.1 *General. Ammonia-based absorption refrigeration systems shall be designed in accordance with provisions of Chapters 4 through 17 as applicable, except that the provisions of this chapter shall prevail for the design of ammonia absorption systems.

18.2 Ammonia Purity Requirements. Anhydrous ammonia used for the initial and subsequent charging of ammonia-based absorption refrigeration systems shall meet the purity requirements shown in Table 18.2.1.

18.2.1 **Table 18.2.1**
Purity Requirements

Ammonia Content	99.5% minimum
Water (liquid-vapor systems)	unlimited
Water (solid-vapor systems)	5,000 ppm maximum
Oil	50 ppm maximum
Salt (calculated as NaCl)	None
Pyridine, hydrogen sulfide, naphthalene	None

18.3 Integration with Vapor-Compression Systems. Liquid-vapor ammonia absorption refrigeration system circuits shall be isolated from vapor compression system circuits. Solid-vapor ammonia absorption systems are permitted to be integrated with vapor compression system circuits. Indirect integration with vapor compression systems with the use of heat exchangers is permitted with either liquid-vapor or solid-vapor ammonia absorption systems.

18.4 Minimum Lowside Design Pressure. The minimum design pressure for the low side of liquid-vapor absorption systems shall be 200 psig (1,379 kPa).

18.5 Highside Design Pressure. For packaged absorption units listed and manufactured in accordance with other ANSI standards with refrigerant quantities not exceeding 22 lbs. (10 kg), the highside design pressure shall be equal to or greater than the maximum pressure that could occur during operating, standby, or shipping conditions. The manufacturer shall provide operating pressure limit information.

18.6 Materials. All components of liquid-vapor ammonia absorption systems shall be compatible with water-saturated ammonia. All components of solid-vapor systems shall be compatible with strontium chloride, manganese chloride, activated carbon, metallic salt, or any other absorbent material specified by the design to absorb ammonia vapor.

18.7 Oil Free Components. All components of ammonia absorption systems shall be rendered oil free before construction.

18.8 Oil Management Systems. Oil management systems are not required for ammonia absorption systems.

18.9 Service. Packaged absorption units with refrigerant quantities not exceeding 22 lbs. (10 kg) are exempt from the requirements of Sections 5.10.3 and 5.10.6.

18.10 Nameplates and Marking. Packaged absorption units with refrigerant quantities not exceeding 22 lbs. (10 kg) are exempt from the requirements of Sections 5.12.5.2, 5.12.5.3, and 5.12.6.

18.11 Emergency Shutdown Documentation. Packaged absorption units with refrigerant quantities not exceeding 22 lbs. (10 kg) are exempt from the requirements of Section 5.12.

18.12 Illumination. Packaged absorption units with refrigerant quantities not exceeding 22 lbs. (10 kg) are exempt from the requirements of Section 5.14.

18.13 Piping. Packaged absorption units with refrigerant quantities not exceeding 22 lbs. (10 kg) are exempt from the requirements of Section 5.14.7.

18.14 Solution Pumps. Solution pumps for packaged liquid-vapor absorption units with refrigerant quantities not exceeding 22 lbs. (10 kg), designed to pump a water-ammonia mixture, are exempt from the requirements of Sections 9.2.6, 9.2.7, 9.4, and 9.5.

18.15 Condensers. Packaged absorption units with refrigerant quantities not exceeding 22 lbs. (10 kg) are exempt from the equipment identification requirements of Section 10.1.

18.16 Evaporators. Packaged absorption units with refrigerant quantities not exceeding 22 lbs. (10 kg) are exempt from the equipment identification requirements of Section 11.1.

18.17 Pressure Vessels. Packaged absorption units listed and manufactured in accordance with other ANSI standards with refrigerant quantities not exceeding 22 lbs. (10 kg) are exempt from the requirements of Sections 12.2.5, 12.2.6, 12.3, 12.4, 12.5, and 12.6.

18.18 Piping. Tubing complying with Section 18.6, with minimum wall thickness based on the properties of the selected material and the design working pressure, are permitted to be used in packaged liquid-vapor absorption units. Packaged absorption units listed and manufactured in accordance with other ANSI standards with refrigerant quantities not exceeding 22 lbs. (10 kg) are exempt from the requirements of Section 13.2.4.2.

18.19 Valves. Packaged absorption units with refrigerant quantities not exceeding 22 lbs. (10 kg) are exempt from the requirements of Sections 13.3.1 and 13.3.2.6.

18.20 Design. Packaged absorption units with refrigerant quantities not exceeding 22 lbs. (10 kg) are exempt from the requirements of Sections 14.2.7, 14.2.8, 14.2.9, 14.2.10, 14.3.3, 14.3.4, 14.4, and 14.5.

18.21 Discharge from Relief Valves. Packaged absorption units listed and manufactured in accordance with other ANSI standards with refrigerant quantities not exceeding 22 lbs. (10 kg) may discharge directly to the atmosphere within the unit enclosure. The termination of the relief valve(s) shall be directed to avoid spraying ammonia on persons in the vicinity or servicing the unit while the unit is operating.

18.22 Instrumentation and Controls. Packaged absorption units with refrigerant quantities not exceeding 22 lbs. (10 kg) are exempt from the requirements of Sections 16.1.2 and 16.1.4.

18.23 Operating Parameter Monitoring. Instrumentation and controls shall be provided to indicate operating parameters of the refrigeration system and equipment and provide the ability to control the starting, stopping, and operation of the system or equipment manually or automatically. The instruments and controls shall provide notice if the system's critical operating parameters have been exceeded. Monitoring of parameters is permitted to be automatic or manual or a combination of both methods.

18.24 Ammonia Detection and Alarms. Packaged absorption units installed outdoors with refrigerant quantities not exceeding 22 lbs. (10 kg) are exempt from requirements of Chapter 17. Packaged absorption units installed indoors with refrigerant quantities not exceeding 6.6 lbs. (3 kg) are exempt from the requirements of Chapter 17.

Part 4. Appendices

Appendix A. (Informative) Explanatory Material

This informative appendix is not a part of the standard. It provides explanatory information related to provisions in the standard. Sections of the standard with associated explanatory information in this appendix are marked with an asterisk "*" after the section number, and the associated appendix information is located in a corresponding section number preceded by "A." If options presented within this appendix are implemented, they must comply with the normative provisions of this standard.

A.1.1 This standard is created to address specific safety and design topics related to using ammonia as the refrigerant in vapor compression and absorption systems. These topics can be addressed when the direct and ancillary systems, and the buildings in which these systems are located, are designed to the requirements listed in this standard.

A.1.2 This standard does not apply retroactively to existing buildings or facilities that contain ammonia refrigeration systems. This standard only applies to cases where ammonia refrigeration systems or equipment are newly installed, not including replacement in-kind, as defined in ANSI/IIAR 1, or repair of existing equipment. Deviation from any of these factors would require a safety review and might initiate a management of change procedure. When the manufacturer or model for a replacement differs from the original, it is recommended that a documented review of the materials of construction, capacities, function, and maintenance procedures be examined to determine if it is a replacement in-kind.

A.2.1 ANSI/IIAR 1 provides a unified set of definitions for use in IIAR standards and is a companion for other IIAR standards. Definitions are introduced and approved through the public review process in the standard where they are originally used and subsequently incorporated into ANSI/IIAR 1 and removed from the originating standard. When a new edition of an originating standard is published, it may revise definitions that would apply to that new edition and be effective as of its legal publication or adoption date. When a new edition of ANSI/IIAR 1 is published, it will reflect those definition changes.

A.4.2 See ANSI/IIAR 1 for *occupancy classifications.* Commercial occupancies include office, work, and storage areas that do not qualify as industrial occupancies. Examples of public assembly occupancies include, but are not limited to, auditoriums, stadiums, arenas, ballrooms, classrooms, passenger depots, restaurants, and theaters.

A.4.2.1 ANSI/IIAR 2, ANSI/ASHRAE 15 and model mechanical codes include a long-standing allowance to install evaporators in industrial occupancies outside of a machinery room. While the concept of low-probability pumps can be applied to pumps conveying any liquid, provisions for low-probability pumps in ANSI/IIAR 2 only pertain to pumps conveying liquid ammonia.

Pressure vessels that are integral to the operation of an evaporator are often known as surge drums. A surge drum that is used for circulation and liquid/vapor separation in gravity-fed evaporators, and dedicated solely to the operation of the evaporators, is considered part of the evaporators, and thus is permitted. A surge drum must not be used as a storage, distribution, or transfer vessel for other portions of the refrigeration system. Surge drums that are incorporated into evaporator designs must nonetheless be designed and maintained according to IIAR standards related to ASME and Non-ASME vessels.

A.4.2.1.3 This section's reference to industrial occupancies regulated by Section 7.2 is intended to exempt any area that is allowed to contain ammonia equipment from the 20-ft separation requirement. For example, no separation is required between a rooftop air-handling unit that uses ammonia and any openings to industrial process or storage areas that are permitted to contain ammonia equipment. Logically, ammonia equipment located outdoors within 20 ft of an opening to an industrial process or storage area is no greater hazard than simply placing the equipment inside the space, which would be permitted.

A.4.2.2.2 The purpose of Section 4.2.2.2 is to establish a maximum refrigerant concentration level (RCL) for nonindustrial occupancies. The RCL is a term defined by ANSI/ASHRAE 15 as "the refrigeration concentration limit, in air, determined in accordance with ANSI/ASHRAE Standard 34 and intended to reduce the risks of acute toxicity, asphyxiation, and flammability hazards in normally occupied, enclosed spaces." The intent of Section 4.2.2.2 is to define the RCL in the same manner as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). For the purpose of the ANSI/IIAR 2 standard, the RCL established is 300 ppm. ASHRAE uses an RCL of 320 ppm for ammonia.

A.4.2.3.2.1 The purpose of Section 4.2.3.2.1 is to establish a maximum refrigerant concentration level (RCL) for nonindustrial occupancies. The RCL is a term defined by ANSI/ASHRAE 15 as "the refrigeration concentration limit, in air, determined in accordance with ANSI/ASHRAE Standard 34 and intended to reduce the risks of acute toxicity, asphyxiation, and flammability hazards in normally occupied, enclosed spaces." The intent of Section 4.2.3.2.1 is to define the RCL in the same manner as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). For the purpose of the ANSI/IIAR 2 standard, the RCL established is 300 ppm. ASHRAE uses an RCL of 320 ppm for ammonia.

A.5.1 See Appendix B (Informative) for additional information regarding the characteristics and properties of ammonia.

A.5.1.1 ANSI/IIAR 6, Chapter 15, Maintenance Task a) Section A.15.1, and Appendix B, describes the effects of water contamination in a refrigeration system, how water may enter a system, and how to detect water contamination in a system. ANSI/IIAR 2, Appendix P contains information and design suggestions for testing water content and removal of water from a refrigeration system. ANSI/IIAR 5, Chapter 4, Section A.4.1.1 describes mitigation of stress corrosion cracking (SCC) in carbon steel vessels.

A.5.2 The provisions in this section are generally based on ANSI/ASHRAE 15 however, they are different in that ANSI/ASHRAE 15 includes refrigerants that are typically heavier than air. Ammonia is a lighter-than-air gas, and ANSI/IIAR 2 provisions address this difference.

A.5.2.1 For the purpose of determining how to treat interconnected spaces, as separate or singular, ANSI/ASHRAE 15 recognizes permanent wall openings that might include doors, passages, and conveyor openings. In the design phase, it may be relevant to consider whether or not any physical opening that is determined to create interconnected spaces is able to remain reliably unobstructed through the life of the building.

In addition, where the calculation procedure is being performed for the purpose of determining whether emergency ventilation is needed to reduce the risk of a flammable concentration, in accordance with Section 7.3.1.2, it is important to be very conservative in determining interconnected spaces. The threshold for requiring emergency ventilation is based on a calculated average concentration in the space of 40,000 ppm, which is approximately 25% of the lower flammable limit, and this average concentration could be associated with higher concentrations in local areas. Given that ignition sources such as fueled heaters and ordinary light fixtures would be permitted at the ceiling level in these areas, it is important that the calculation provides a high level of confidence that an ignitable concentration will not exist in any location where ignition sources might be present.

A.5.2.3 Using the smallest volume space for a release event provides a worst-case scenario analysis.

A.5.2.4 Fire dampers, smoke dampers, and dampers that provide both functions are normally open and will only close in a fire event, not an ammonia release event, and it is not the intent of this section to require a design that assumes an ammonia release that is simultaneous with a fire.

A.5.3 It should be noted that ANSI/ASHRAE 15 includes a requirement that the design pressure of refrigeration systems need not exceed the critical pressure for a refrigerant unless higher pressure is anticipated during operating, standby, or shipping conditions. In the case of ammonia, the critical pressure is 1,636 psi, which far exceeds any system design pressure; therefore, this provision is not relevant in ANSI/IIAR 2 and was not included.

A.5.3.1.5 See Section 5.14.3 for requirements regarding the installation of used equipment.

A.5.3.2.2 Examples of standby conditions that would be considered in applying this section include maintenance, shutdown, and power failure.

A.5.3.3 **Item (6):** The pressure differential requirement is for design purposes, and it is not the intent of this standard to require testing for this condition. See ANSI/IIAR 5, Section 5.5 for pressure tests, leak tests, and evacuation. Additional information on designing for full vacuum conditions can be found in the IIAR technical paper, “Designing Industrial Refrigeration Systems for Full Vacuum – Considerations”, M. Timm, 2021.

A.5.5.1.2 Air and water are examples of expected contaminants. Nevertheless, in trace amounts that might ordinarily be present in an ammonia refrigeration system, significant deterioration of materials, such as steel piping or vessels, is not expected.

A.5.7.3 A nipple and cap rather than a plug is the preferred method for isolating end-of-line threaded valves. If a plug is over-tightened, it can cause the valve to split. Locked-closed stop valves with one side of the valve opening to atmosphere should only be considered for temporary isolation of service valves. When a cap or blank is used, a procedure for venting pressure before opening the system should be considered. See ANSI/IIAR 7 for "Equipment and Line Opening Procedures".

A.5.8.1 Insulation can also be provided for energy conservation purposes, as required by the owner or local energy conservation requirements. For additional information on insulation of piping, see the *IIAR Piping Handbook and the IIAR Guideline for Insulation Installation.*

A.5.9.1 Structural supports and anchorages are designed by structural engineers and the requirements vary between different jurisdictions. Local requirements may account for area classifications and maximum forces and acceleration levels for the equipment under consideration. Equipment manufacturers may provide additional requirements that should be considered by the designer.

A.5.10.1 See Chapter 3 of the *Uniform Mechanical Code* and Chapter 3 of the *International Mechanical Code,* which provide requirements for access to all types of mechanical equipment, including ammonia refrigeration systems.

This section requires equipment to be designed and installed with serviceability in mind, including clearances for service tools and similar serviceability provisions. Also see OSHA 29 CFR 1910.25 for information on providing fixed stairs for access to serviceable equipment.

Access for maintenance is different from replacement and/or overhaul of equipment. Access for replacement and/or overhaul is not mandated by codes. Designers may wish to consider providing clearance or other means to periodically replace equipment or components of equipment. For example, shell and tube chillers can be arranged with the tube pull area into an aisle, or a removable wall panel could be used to accomplish the same.

A.5.10.3 Examples of equipment that might require maintenance or functional control testing include liquid level indicators, float switches, and high-pressure cutout switches. ANSI/IIAR 6 provides the minimum-required functional control tests that should be considered in the design of systems. Designs should facilitate functional testing with minimal disassembly of the ammonia-containing parts of the system.

A.5.10.4 The designer should use judgement regarding location and number of valves needed to perform service. Improper placement of hand isolation valves could hinder the function of control valves.

A.5.10.5.1 See OSHA 29 CFR 1910.23 for information regarding ladder access.

A.5.11.2.2 This requirement is consistent with ANSI/ASHRAE 15, which regulates the secondary coolant.

A.5.12.1 Normally the person in charge of the premises, or that person's designee, on which the refrigeration system is installed, would provide directions for the emergency shutdown of the system at a location that is readily accessible to trained refrigeration system staff and trained emergency responders.

A.5.12.2 NFPA 704 is a standard that governs warning placards that are placed on and around facilities that produce, use, or store hazardous materials to warn emergency responders of potential hazards. These four-color diamonds include numeric "degree of hazard" rankings for health, flammability, and instability risks ranging from "0" for no hazard to "4" for extreme hazards.

In the case of anhydrous ammonia, the principal hazards are corrosivity and flammability. NFPA 704 designates a hazard ranking of "3" for corrosive liquids. The hazard ranking for anhydrous ammonia flammability is more subjective. Because ammonia is difficult to ignite in unconfined outdoor locations, model fire and mechanical codes have supported a hazard ranking of "1" for outdoor locations. For indoor locations, ignition risk is ordinarily controlled by adequate ventilation, but in the remote chance that ventilation might not perform as intended, a flammable environment could exist. Therefore, it is considered prudent to assign a hazard ranking of "3" for ammonia refrigeration located indoors to ensure that emergency responders are suitably warned of the worst-case risk that may be faced with an indoor ammonia release.

NFPA 704 normative requirements for the location of signage is impractical for most ammonia refrigeration facilities, where entire facilities with multiple rooms and areas containing ammonia refrigeration equipment are often present. However, the standard provides informative language that explains the intention of its normative section on location. The following is excerpted from NFPA 704:

> "A.4.3. The quantity and location of NFPA 704 placards are based on factors such as fire department response and access: fire department operations; location, configuration, size, and arrangement of storage areas; location configuration of the buildings; and other factors. The authority having jurisdiction should be consulted regarding the placement of identification in response to incidents at the location."

A.5.12.3 IIAR publishes, "*Guidelines for the Identification of Ammonia Refrigeration Piping and Equipment*" which can be used as a resource to meet equipment labeling requirements.

A.5.12.4 Refrigeration management programs require that the valve diagram be reviewed and updated, as necessary, when changes are made that affect valve operation during emergency shutdown procedures.

Examples of unique identification include valve tags and signs.

A.5.12.5.3 Appendix D (Informative) provides further information on duplicate nameplates.

A.5.12.6 IIAR publishes, "*Guidelines for the Identification of Ammonia Refrigeration Piping and Equipment*" which can be used as a resource to meet pipe labeling requirements.

A.5.13.1 Equipment intended for outdoor installation, but that is not intended to be entered, may be provided with enclosures to protect the equipment from the environmental conditions (e.g., wind, sun, rain, sleet, hail, snow, sanitation, etc.).

Indoor enclosures may be provided to protect the equipment and isolate it from general areas. For example, it might be desirable to enclose pump packages or compressor packages or heat exchange packages in areas other than a machinery room, where permitted. This could be to protect equipment from wash down, reduce noise, prevent tampering or other reasons.

A.5.13.2 Installed equipment may be arranged to provide space to perform tasks for operation, inspection, maintenance, repair, and component or equipment removal without fixed obstructions from adjacent equipment or building features. For example, horizontal shell-and-tube heat exchangers are commonly installed with sufficient clearance to pull and reinstall tubes. Where tube removal is limited by a nearby wall, a removable wall access panel can be used to provide the needed opening. The space beyond the access panel is also typically kept clear to allow tube extraction and replacement. Similarly, packaged equipment is often arranged so motors, compressors, and other serviceable components can be removed and replaced without fixed interference.

A.5.13.3 The method for determining if enclosures have the potential to reach a concentration of 40,000 ppm in the event of a release can be found in Section 5.2.

A.5.14.1 Examples of moving parts that might require protection include shafts, belts, pulleys, flywheels, and couplings.

A.5.14.3 Further information on structural load requirements can be found in the building code and the mechanical code. Also see Section 5.9.

A.5.14.4 For additional information, see OSHA 29 CFR 1926.56.

A.5.14.5 The building code provides comprehensive regulations for means of egress, but of particular concern in ammonia refrigeration facilities is the required minimum clear height and width for access to equipment in areas that contain piping or equipment. The designer is cautioned to ensure that the minimum clear height and width provisions in the building code for aisles are maintained in the design. See 2018 *International Building Code* Section 1018.5, Exception, and Sections 1003.2 and 1003.3.

A.6.2.1 See Section 6.10 for requirements related to doors and Section 6.6.2 for pipe penetrations. Also see the definitions of *tight construction* and *tight-fitting door* in ANSI/IIAR 1.

A.6.4 Combustible materials are any materials that can ignite and burn. Typical combustible solids in refrigerated manufacturing or storage facilities can include spare pallets and packaging.

Flammable liquids are those that have a flash point lower than 100 deg F (37.8 deg C), which generate sufficient flammable vapors for ignition under most ambient conditions.

Combustible liquids are those that have a flash point of 100 deg F (37.8 deg C) or greater, meaning that additional heat input would be needed under most ambient conditions to generate sufficient vapors for ignition and sustained flame.

Refrigeration oils meeting these requirements can be stored in machinery rooms outside of fire rated cabinets so long as the designated location of the containers or barrels does not impede nor obstruct the pathways to eyewash & safety showers and emergency egress routes.

A.6.5.2 The concentration specified in Section 6.13.2.3 is not a flammability threshold. It is the earliest required machinery-room ammonia detection response level that is a latched condition and requires manual reset. Using that same alarm level to de-energize open flames and equipment with surfaces exceeding 800°F, including electric heaters and other non-combustion devices, is a conservative ignition-source control intended to reduce conflagration risk before an ammonia release can escalate.

A.6.6.3 Ammonia charging cylinders are not considered part of the closed-circuit refrigeration system. Facility designers are nonetheless urged to consider where and how charging cylinders might be stored. The Compressed Gas Association document CGA-G-2.1 *Requirements for the Storage and Handling of Anhydrous Ammonia* provides guidance on the topic of storage. The International Fire Code, Section 5003, addresses building requirements for storage of hazardous materials. Closed-circuit refrigeration systems are not subject to the IFC, Section 5003 requirements.

A.6.7.1 Section 6.7.1 is intended to ensure that eyewash/safety shower units be available for immediate use per ANSI/ISEA Z358 1-2014, which uses time rather than distance to establish eyewash/safety shower placement. It is recognized that the average person covers a distance of approximately 55 ft. (16.8 m) in 10 seconds when walking at a normal pace.

Section 6.7.1 is intended to ensure that suitable eyewash/safety shower units are available for quick drenching and flushing of the eyes and body inside the machinery room for immediate emergency use. In some scenarios, personnel may need to exit the machinery room after the initial use of the units installed inside the machinery room due to an on-going emergency situation. To account for these scenarios, Section 6.7.2 specifies that at least one eyewash/safety shower unit be installed outside a machinery room door. Additional eyewash/safety showers might be required based on a process hazard analysis and/or hazard review.

A.6.9.3 Examples of methods that could be used for limiting the spread of a liquid ammonia spill into a machinery room drainage system may be the use of curbing at doors, drain plugs, drain mats, absorption pads, an in-ground drainage pit, or other equivalent means which might involve administrative or engineering controls.

A.6.12 An example means to protect switches from inadvertent operation is a cover that provides unhindered access to the switches yet protects them from being bumped or otherwise accidentally activated.

A.6.13.2.2 Visual indicators can be provided by strobes or other distinctive visual signaling devices.

A.6.13.2.3 The threshold for initiating emergency ventilation was changed in the 2014 edition of ANSI/IIAR 2. Some previous editions and model mechanical codes specify that emergency ventilation is to be activated at an ammonia concentration not exceeding 1,000 ppm. The 1,000 ppm value had been based on concerns that serious damage to equipment might occur if a large volume of frigid outdoor air unnecessarily flooded a machinery room in a cold climate zone because a leak detector sensed a small leak or a small maintenance-related release.

A.6.13.2.4 An additional detector with a higher range can be used to de-energize refrigeration equipment at a concentration not greater than 40,000 ppm (which is approximately 25% of published LFL). This may be desirable so that refrigeration equipment can continue to operate at concentrations below 40,000 ppm but above the range of detectors that activate emergency ventilation systems at 150 ppm.

A.6.14.1 This requirement correlates with the minimum ventilation for occupants consistent with current requirements in model mechanical codes for machinery rooms.

A.6.14.3.1 If a single exhaust system is used for both temperature control and emergency exhaust, it is not necessary to sum the required flow rates for temperature control and emergency ventilation.

A.6.14.3.3 When selecting a location for exhaust discharge to the atmosphere, it is preferable to select a location that will minimize the risk of creating a nuisance or hazard in the event of an ammonia release. Consideration should be given to the natural airflow around the building, prevailing winds, and surrounding structures.

A.6.14.3.5 Fans in a machinery room are not required to be suitable for installation in Class I, Division 2, atmospheres because the electrical code does not require hazardous location electrical equipment in areas containing ammonia with adequate mechanical ventilation. Nevertheless, this standard requires an extra level of protection for the construction of emergency exhaust fans in a machinery room. Emergency exhaust fans are not required to meet any standard rating for spark resistant construction. However, fans combining a ferrous shroud (housing) and ferrous blade (propeller or impeller) will not meet the intent of the standard. Radial or axial shifts of the fan might be caused by bearing wear or fan imbalance.

A.6.14.3.6 Fans in a machinery room are not required to be suitable for installation in Class I, Division 2, atmospheres because the electrical code does not require hazardous location electrical equipment in areas containing ammonia with adequate mechanical ventilation. Nevertheless, in an abundance of caution, this standard requires an extra level of protection for fan motors in machinery rooms.

A.6.14.5.1 It is not ideal to locate outside make-up air intakes where they might draw in air that is contaminated with dust, truck exhaust, cottonwood seeds, pollen, feathers, and similar contaminants.

A.6.14.5.5 When motorized dampers or louvers are used in climates that could cause damage because of cold air infiltration, designers may wish to specify an alarm system to indicate that the motorized dampers or louvers have opened when the outdoor conditions could cause damage to the refrigeration or building systems.

Although not required, systems may be designed to include independent-power backup for damper actuator(s), fail-open positioning for damper actuator(s), gravity dampers, or other means that prevent exceeding the permissible negative pressure.

Gravity dampers function independently of electrical controls, and when used, can open and close automatically in response to airflow direction and pressure differences.

A.6.14.6.1 See *ASHRAE Handbook,* Fundamentals, Chapter 14, Climate Design Information, for determination of dry-bulb temperature.

A.6.14.7.1 The 30 air-change requirement established by this section is based in part on a study documented in IIAR Technical Paper 5-2005, "Machinery Room Ventilation for Industrial Refrigeration Systems: A Rational Engineering Analysis," which was followed by a full-scale release event at Ford Ord, California in 2008. The release event replicated a complete break involving a 1/2 in. liquid pipe sourced at 90 psig. This and other information was reviewed by a special IIAR task group that accepted 30 air changes per hour as an appropriate prescriptive design basis for ammonia machinery room emergency ventilation. The 30 air changes per hour requirement was approved by American National Standards Institute in August 2010 as part of Addendum A to the 2008 edition of ANSI/IIAR 2. It should be recognized that the 30 air changes per hour requirement is a prescriptive value intended as adequate to limit the average room concentration of ammonia resulting from a plausible release event to 40,000 ppm. That value is approximately 25% of the lower flammability limit for ammonia. The inclusion of this prescriptive value in ANSI/IIAR 2 should not be regarded as precluding the option for a design engineer to calculate an alternative basis for machinery room ventilation based on an engineering analysis of a specific facility. Such alternatives are permitted by Section 1.3.2.

Appendix K (Informative) provides example calculations for determining emergency ventilation rates.

Research and experience have indicated that high velocity discharge from emergency exhaust systems poses minimal risk to either onsite personnel or offsite receptors. However, AHJs or facility owners may require ammonia vapors to be (temporarily) contained or reduced. Operational containment or exhaust scrubbing systems can be used to mitigate concerns about off -site receptors. See Appendix M for guidance on the design features and the control sequence for operational containment.

Exhaust scrubbing systems have been used to reduce the concentration of ammonia in emergency exhaust systems and may be useful to avoid annoyance of a facility's neighbors. Some local jurisdictions require them. Scrubbing systems route the discharge of emergency exhaust fans through a water mist, which absorbs ammonia. The resulting aqueous ammonia solution must then be treated and disposed of by an approved method. Designs of these systems vary, and their effectiveness will vary depending on the magnitude and duration of a leak. IIAR published a technical paper, "Ammonia Refrigeration Machinery Exhaust Treatment", Snowden, 36th Annual IIAR Conference, 2014, examining various aspects of scrubbing and dilution systems.

A.6.14.7.1 **Exception (3):** The analysis should identify the criteria used to determine the level of safety, and the technical basis and acceptance criteria for the release scenario used to establish the reduced rate.

The release scenario may include relevant factors such as release location, release phase(s), rate, and duration, as well as machinery room volume, ventilation effectiveness, room mixing, and any mitigation actions considered in the analysis, including detection, alarm, and refrigerant release isolation methods. Where mitigation actions are included in the analysis, it may be useful to document the associated assumptions, such as activation setpoints, response times, and sequence of operation.

A.6.14.7.6 It is not intended to require automatic means for testing of the emergency ventilation system when it is anticipated that inspections will be performed manually. The intent of Section 6.14.7.6 is to recognize that, where such periodic testing is performed automatically, the means to prove emergency airflow is in place.

Devices that can be used to prove emergency airflow include but are not limited to: 1) pressure differential switches 2) sail switches 3) current monitors.

Where automated means of testing is used, there is not an expectation that accurate flow measurement be made on a continuous or repetitive basis. Fluctuations of airflow in the range of +/- 25% can be common and are not of significant concern. Thus, detection of such fluctuations is not required. The detection required is for indicating significant problems with ventilation systems that would cause a reduction of greater than 25% of the design airflow. Examples of such problems are the failure of motors, belts, fan blades, and the severe reduction of makeup air flow.

A.6.15 See also Appendix J for further information regarding machinery room signs.

Additional signage may be required by Federal, State, or local agencies that are not directly related to the refrigeration system. For example, signage indicating requirements for hearing and eye protection is common for machinery rooms.

A.7.2.1 The reference to separation from other occupancies in this section is intended to correlate with occupancies defined by the mechanical code, which are different from those listed in the building code. Specifically, process and storage areas in the mechanical code and ANSI/IIAR 2 are considered "industrial" occupancies, and the separation specified by this section would, for example, require that administrative offices be separated from process and storage areas by tight construction and tight-fitting doors. Ordinarily, the responsibility for compliance with this requirement will fall on a general contractor rather than the refrigeration contractor.

A.7.2.3 Exception 1: The term “unoccupied area” is intended to apply to portions of premises that are accessible only to authorized personnel performing inspection or maintenance.

Exception 2: Because ammonia is self-alarming, with a pungent odor that alerts occupants of ammonia’s presence well before the concentration reaches a level that is acutely hazardous, leaks are readily apparent when someone is in the area. An emergency action plan for handling an ammonia release may rely on occupants to detect and respond to a leak in lieu of a fixed detection system. If interruptions to 24 hour per day occupancy are expected, the facility should have a procedure for monitoring the area when occupants are not present.

Where applicable, OSHA’s Process Safety Management (PSM) Standard requires that the employer establish and implement an emergency action plan for the entire plant in accordance with the provisions of 29 CFR 1910.38(a). In addition, the emergency action plan should include procedures for handling small releases. Employers covered under this standard may also be subject to the hazardous waste and emergency response provisions contained in 29 CFR 1910.120(a), (p), and (q).

For additional information, facilities with more than the 10,000-lbs. threshold quantity of ammonia or facilities with a more restrictive threshold specified by a state regulatory agency can refer to IIAR’s Process Safety Management & Risk Management Program Guidelines Volume I & II. Facilities with less than 10,000 lbs. of ammonia or facilities with less than a more restrictive threshold that is specified by a state regulatory agency can refer to IIAR’s *Ammonia Refrigeration Management Program (ARM).*

In jurisdictions where a model mechanical code has been adopted, use of an alternative to fixed detection might require approval of the AHJ because the mechanical codes specifically require leak detection for these applications unless an alternative is approved. In jurisdictions where a mechanical code has not been adopted, the approach to detection will be determined by the designer, as provided in Section 1.3.3, based on an assessment of the area to be protected.

A.7.2.10 Examples of maintenance that involves the deliberate opening of a system include oil draining, equipment replacement, and valve or piping maintenance. Quick drenching or flushing can be accomplished using eyewash/safety shower units installed within 55 ft. of the work area, drench hoses connected to a tepid water supply, portable eyewash/safety shower units or other supplemental equipment that is suitable for the purpose. The use of supplemental equipment such as drench hoses and personal wash units is intended to provide immediate flushing to support permanently plumbed or self-contained emergency eyewash and shower equipment, but not replace them. A facility with a machinery room will have eyewash and safety shower equipment at the machinery room. But facilities without machinery rooms still need at least one permanently plumbed or self-contained emergency eyewash/safety shower on site even if supplemental quick drenching or flushing is provided.

A.7.3.1.1 By referencing Section 4.2.1.2.1, it is specifically intended that this section, and the associated provisions for ventilation, not apply for equipment that is permitted in indoor locations other than a machinery room by Sections 4.2.1.2.2 - 4.2.1.2.4.

A.7.3.1.2 If an area includes multiple refrigeration systems, each system is permitted to be considered individually when calculating release concentration. In some cases, an enclosure might be provided for equipment containing ammonia, and local ventilation within the enclosure might be used to meet the emergency ventilation provisions in lieu of ventilating the entire room or area. See Section 5.13 for additional information regarding enclosures and see Appendix K for information regarding alternative ventilation calculation methods. Alternatives to ventilation might include systems that employ a water mist system or a CO_2 fogging system, where approved by the AHJ.

A.8.2.2 This section requires a positive displacement compressor with a stop valve in the discharge line to have a relief device sized for compressor flow. Under this section, the valve is to be sized at a minimum of 50°F saturated suction temperature at the compressor inlet. This section assumes an event in which a compressor has the discharge valve inadvertently closed, the suction valve open, the high-pressure cut-out either not functioning, or the motor starter contactors welded shut, so that the compressor cannot be shut down in response to raising discharge pressure above the high pressure cutout. It also assumes adequate refrigerant is available at the compressor suction to reach a saturated suction temperature of 50°F or design saturated suction temperature, whichever is higher. Note that ammonia heat pumps could have a design suction temperature above 50°F. This would put a higher density of gas at the compressor suction and would require the relief device to be sized for the higher mass flow associated with a higher suction pressure.

Appendix E (Informative) describes an acceptable method of calculating the discharge capacity of positive-displacement compressor pressure relief devices.

A.8.2.4 The referenced safety controls are commonly referred to as a low-pressure cutout and a high-pressure cutout. An indicating-type lubrication failure control is commonly referred to as a low-oil-pressure cutout.

A.8.5.2 Examples of preventing condensation include but are not limited to controlling cooling water supply to stop cooling water from flowing through a reciprocating compressor; for outdoor applications, controlling an automatic shut-off valve in the economizer suction, such as in the horizontal line at the top of the header, or installing electrical heaters and/or insulation to maintain temperatures above saturation. An alternative to condensation prevention may include developing and implementing administrative or engineering controls to verify and remove condensed liquid for compressor protection prior to restarting.

A.8.5.6 Compressor designs vary. Sometimes installing a discharge check valve is sufficient to avoid liquid accumulation and backflow. For example, some designs that use high-pressure ammonia for oil cooling will also require a suction check valve. Other means, such as automatic shut-off valves, are not often used but can be effective in lieu of check valves.

A.8.5.9 The requirements in this section are intended to protect compressors from liquid carryover. Designers sometimes choose to provide a high-level liquid alarm that activates prior to an automatic high-liquid level shutdown to allow operator intervention.

A.9.2.2 Permissible means of protection should include, but not be limited to, either

1. A hydrostatic or differential pressure relief device, or
2. A vent pipe containing a normally open isolation valve.

The inlet connection for the relief device or vent pipe should be located on the pump casing or piping between the stop valves or stop check valves at the pump inlet and outlet, except that when a check valve is located between the pump and its outlet stop valve, the relief device or vent pipe inlet should be connected to the pipe between the discharge check valve and stop valve. The discharge of this relief or vent pipe should connect either to the pump suction line upstream of the pump suction stop valve or to the vessel to which the pump suction is connected. This pressure relief device or vent pipe should be external to the pump housing.

A.9.4 Process safety information provided by the manufacturer can include the following:

1. "Ammonia" compatible;
2. Operating condition data;
3. Performance data;
4. Construction data, including maximum allowable pressure at operating temperature, test pressure, bearing type, and impeller data;
5. Head: differential pressure (ft, m, or psi);
6. Impeller identification (diameter size);
7. Rpm (speed): rpm for fixed-speed pumps and minimum, maximum, and operating rpms for adjustable speed pumps;
8. Capacity (maximum rated GPM or liters/min) with identified impeller;
9. Materials: metals and gaskets;
10. Motor (drive) information;
11. Electric motor ratings if applicable: volts, full load amps (FLA), frequency (Hz), phase, output (HP and/or kW);
12. Electric heater ratings if applicable: volts, amps, phase, output (kW);
13. Insulation classification;
14. Piping size and connections schematic;
15. Pump operating procedure description;
16. Inspections and tests verification: performance and pressure test;
17. Minimum circuit amps (MCA) and maximum overcurrent protection (MOCP), if applicable;
18. Weight; and
19. Directional arrow on the unit for the direction of rotation.

A.10.1 The location of a condenser relative to the receiver should be arranged to provide sufficient refrigerant head for the ammonia to drain properly. Refer to the *IIAR Refrigeration Piping Handbook*.

A.10.2.2 Manufacturers normally recommend minimum clearances for positioning of condensers and their respective air inlets and air outlets to avoid short-circuiting and to ensure unobstructed air flow. When these clearances cannot be achieved, the expected capacity of the condenser should be adjusted and documented, or changes should be made to the design of the equipment to maintain the rated capacity.

A.11.2 It is not expected that heat exchangers themselves be designed and constructed to withstand freezing of products or secondary coolants. The properties of the product or secondary coolant are integral to the system design. When the method of preventing freezing inside the heat exchanger relies on the physical properties of the cooled fluid, it might be necessary to periodically test the fluid to ensure its freeze point, often driven by the concentration of anti-freeze additives, has not substantially changed. Such tests should be integrated into inspection, testing and maintenance programs.

A.11.4.2 The prevention of moisture migration to coils can be accomplished by the use of P-traps. Use of a P-trap at each unit is the surest way to prevent moisture from migrating from a unit that is in defrost to a unit that is in cooling mode. Other means, such as automatic valves, could also be used.

A.11.4.2.1 Manufacturers normally recommend minimum clearances for positioning of forced-air evaporators and their respective air inlets and air outlets to avoid short-circuiting and to ensure unobstructed air flow. When these clearances cannot be achieved, the expected capacity of the evaporators should be adjusted and documented, or changes should be made to the design of the equipment to maintain the rated capacity.

A.11.4.2.2 Some means for preventing freezing of condensation drain lines may include: sloping the lines to drains, heat tracing, insulation, and clean-outs.

A.11.5.2.1 Manufacturers typically provide recommend minimum clearances for positioning of bare-tube and gravity coils and their respective air inlets and air outlets to avoid short-circuiting and to ensure unobstructed air flow. When these clearances cannot be achieved, the expected capacity of the equipment should be adjusted and documented, or changes should be made to the design of the equipment to maintain the rated capacity.

A.12.2.4 See Appendix H (Informative) for information regarding the mitigation of stress corrosion cracking.

A.12.2.6 Carbon steel pressure vessels used in closed-circuit ammonia refrigeration systems may be subject to external corrosion. Corrosion is more likely in applications where the surface temperature of an uninsulated vessel periodically cycles or operates continuously below the dewpoint temperature in the area where it is installed, when the vessel is inadequately insulated, or when installed outdoors and unprotected from the weather (e.g., receivers, accumulators, recirculators, oil pots, transfer vessels).

Accordingly, the user or his or her designated agent who knows how the vessel will be applied, should consider corrosion-preventive measures where necessary when specifying new vessels. Preventive measures include painting, insulation, cathodic protection, corrosion control gel, or similar products. The addition of a corrosion allowance may be required to meet the life expectancy of a particular pressure vessel installation.

ASME B&PVC, Section VIII, Division 1 permits the use of plate material with under-tolerance that is the smaller of 0.01 in. (0.3 mm) or 6% of the nominal material thickness. Vessels constructed in accordance with the rules of ASME B&PVC, Section VIII, Division 1 using plate materials that have under-tolerance within the allowed ranges are compliant even though the plate material thickness could be less than the nominal wall thickness or the calculated minimum wall thickness and may be used at full design pressure. In these cases, pitting or surface corrosion can reduce life expectancy. Determination of suitability for continued service should be based on vessel inspection requirements in Section 10.1 of ANSI/IIAR 6. When pitting or surface damage exceeds these guidelines, vessel derating, wall repair by an ASME R stamp holder, or vessel replacement is required.

A.12.2.7 The designed system pump down strategy may be to pump the entire charge into one pressure vessel, multiple pressure vessels, or into a temporary and separate storage pressure vessel(s) such as an ammonia tanker truck(s). The maximum volume of liquid in vessels has traditionally been considered 90% at a temperature of 60ºF-90°F. Calculations can be done to determine other levels and worst-case temperatures. Refer to CGA-G-2.1 (2023).

If liquid pressure relief is used to protect against overpressure due to hydraulic expansion, the requirement for atmospheric relief is not eliminated if it is required elsewhere in this standard.

A.12.3 Where ASME B&PVC is not adopted, at a minimum, pressure vessels should be strength tested hydrostatically to a minimum of 1.3 times the design pressure or air tested to a minimum of 1.1 times the design pressure, subsequently leak tested, and proven tight at a pressure not less than design pressure by the manufacturer.

A.12.4 The data described by Item 7 in the list of nameplate requirements is commonly referred to as “dual stamping” and is a requirement for vessels that are intended to operate at temperatures below the minimum design metal temperature (MDMT) at design pressure, which is described in Item 3. Provisions in ASME B&PVC permit the operation of vessels at lower temperatures, and coincident pressures under the conditions described therein. Vessels should be evaluated or designed for this type of service and stamped accordingly.

A.12.5.2 Removal of insulation for nameplate inspection is not preferred. See Appendix D for additional information on duplicate nameplates for vessels.

A.13.1 See ANSI/IIAR 1 for the definition of piping. The requirement to comply with ASME B31.5 applies to both shop-fabricated and field-erected piping.

A.13.2 It is recommended to minimize lengths of NPS 1/2 in. and smaller pipe due to risk of physical damage.

A.13.2.1 In addition to materials that are specifically mentioned therein, ASME B31.5 Section 523.1.2 also allows the use of other materials, which can be accepted as compliant with ANSI/IIAR 2 where approved by the AHJ based on the submittal of documentation that demonstrates the suitability of the pipe for the intended application. See also Appendix L (Informative) for additional information on pipe materials.

A.13.2.2 ASME B31.5 sets requirements for pipe stresses based on various forces acting on the pipe. This includes but may not be limited to internal pressure, dead loads, live loads, and thermal expansion or contraction.

A.13.2.3 Tubing is used for compressor lubrication lines, small bore pressure-sensing lines, hydrostatic relief lines, etc.

A.13.2.3.1.1 Carbon steel tubing is not permitted per ASME B31.5-2022, part III, Section 505.1.1

A.13.2.5 Common hose constructions used in ammonia service include nylon-braided hoses, stainless-steel-braided hoses, PTFE-lined hoses, and corrugated stainless-steel hose assemblies. Hoses and corrugated metal hose assemblies should be reviewed to confirm suitability for permanent installation in anhydrous ammonia service. The selection criteria should be based on the applicable service conditions, which may include but may not be limited to operating temperature, pressure, vibration, repetitive movement, and compatibility with refrigerant oil; for example, some EPDM hose constructions might not be suitable for permanent installation where oil exposure can deteriorate the hose. Always refer to the manufacturers' recommendations for suitability.

For information regarding temporary-use hoses, such as those used for charging, transfer, maintenance, or service operations, refer to ANSI/IIAR 5 and ANSI/IIAR 6.

A.13.3 Refer to ANSI/IIAR 3 for the manufacturing, design, and performance requirements of ammonia refrigeration valves and strainers.

A.13.3.2.1 This section provides for situations where a designer chooses to install a directional valve in a backwards orientation, which is a method that is sometimes used to provide a high level of resistance to backflow.

A.13.3.2.3 This valve arrangement has the potential to trap liquid.

A.13.3.2.5 Shut-off valves are also referred to as stop valves. Control valves and other valves without a manually operable and lockable actuating element intended to stop flow for isolation purposes, such as solenoid valves and check valves, are not classified as shut-off or stop valves.

A.13.3.2.6 A nipple and cap rather than a plug is the preferred method for isolating end-of-line threaded valves. If a plug is over-tightened, it can cause the valve to split. Locked-closed stop valves with one side of the valve opening to atmosphere should only be considered for temporary isolation of service valves.

When a cap or blank is used, a procedure for venting pressure before opening the system should be considered. See ANSI/IIAR 7 for “Equipment and Line Opening Procedures”.

A.13.3.2.7 Shut-off valves are often installed for draining purposes, gage access, evacuation, charging and future expansion planning. Even though valves must be capped or plugged during normal operations, the downstream side will eventually be opened to atmosphere and must hold the system’s pressure when plugs or caps are removed. Valves that have an MOPD or MSSPD less than system design pressure should be marked “not suitable for end-of-line service”. See ANSI/IIAR 1 and ANSI/IIAR 3 for additional information regarding MOPD and MSSPD.

A.13.4 ASME B31.5 provides guidance for certain pipe support and hanger components, protective coatings, etc. See also Appendix F (Informative) for additional information.

A.13.4.1 Examples of loads include ammonia weight, insulation, frost, ice, seismic, wind, and thermal.

A.13.4.2 Supports for piping should not be welded directly to piping unless the piping and supports are specifically designed for such an installation and the assembly conforms with ASME B31.5.

Methods of isolation and support to prevent corrosion can include insulating supports where there is a chance for condensation due to temperature differences, routing the piping and supports where water will not drip on them (e.g. condenser piping that might be subjected to overspray and chemical treatment), and avoiding the pipe routing in places where snow or rain can accumulate.

A.13.5 See Section A.5.10 for additional information related to clearances required by the building bode.

A.13.5.5 Piping that is buried underground is likely to be problematic to inspect. It is likely better to install piping overhead, in a plate covered trench, or in an accessible shaft or tunnel. To protect against corrosion when pipe is directly buried, reactive gel, insulation, vapor barriers and heavy jacketing could be a suitable means.

A.14.1.2 The designer should first refer to Chapter 4 to determine if a machinery room is required. Should a machinery room be needed, the requirements of Chapter 6 apply. Should the package be permitted to be located in areas other than a machinery room, the requirements of Chapter 7 apply.

A.14.2.6 The intent of requiring emergency valves to be directly operable is to have the valve available for rapid operation in the event of an emergency. Accordingly, a valve operating wheel needs to be permanently installed on manual emergency valves that are not chain operated, and access to operate valves cannot require use of a ladder, stool, or similar assistive device.

A.15.1.3 The discharge from a pressure relief device used to overpressure protect an oil filled component such as an oil cooling heat exchanger is permitted to discharge external to the system; however, an atmospheric vented collection receptacle or other treatment system is essential to prevent environmental damage or other hazards that may arise from oil discharge.

A.15.1.4 With components like oil pots or gravity flooded heat exchangers located below vessels supplying liquid, the pressure of the oil pot or heat exchanger will be higher than the parent vessel due to the static head of liquid present in the parent vessel. This means at a standstill condition when the pressure of the parent vessel approaches its design pressure, the relief device protecting the oil pot or heat exchanger will actuate before the relief valve protecting the parent vessel. To prevent this unwanted situation, the connected oil pot or heat exchanger must have a higher design pressure as well as a higher pressure relief device set pressure when configured to discharge external to the system.

A.15.1.5 In the case where both components have equal design pressures, there is no pressure differential to enable an internal relief to properly function. For item “a.” in the list, the vessel receiving relief from another component could, in theory, be equipped with a lower set pressure relief device to enable a pressure difference to be established between the pressure protected component and the downstream vessel receive fluid discharge. This arrangement presents unnecessary and added risks of an unwanted release. In terms of item “b.”, there may be situations where a component fitted with internal relief is isolated from the system and because the receiving vessel’s operating pressure may be low, the internal relief valve would actuate at a pressure substantially below its design pressure. For example, consider an oil pot with a 300 psig design pressure connected to a low temperature recirculator with a 250 psig design pressure. A pressure relief device with a set pressure of 50 psig is fitted to the oil pot. If the recirculator normally operates at 25 psig, the oil pot relief valve would actuate if it was isolated and the oil pot’s pressure increased to 75 psig just due to ambient heat gain to the pot.

A.15.2 In Section 2.2, a “pressure vessel” is defined as: “Any refrigerant containing vessel in a closed-circuit refrigeration system designed, manufactured, and stamped in accordance with ASME Section VIII, Division 1, Boiler and Pressure Vessel Code (B&PVC). See also receiver: receiver and controlled-pressure receiver, in ANSI/IIAR 1”. Keep in mind that a “pressure vessel” can include pressure containing components that are not the familiar “tank” such as heat exchangers, filter housings, etc. ASME allows these components to classified as “pressure vessels” and bear the ASME stamp. Once stamped, those pressure containing components must meet all of the ASME division requirements, including the use of certified pressure relief devices.

A.15.2.2 Three-way valves used for dual relief devices are not considered shutoff valves since both relief ports are not capable of being simultaneously isolated. Three-way valves should be set to a fully seated position to enable only one pressure relief device to be active during operation.

A.15.3.1 Designers need to consider how maintenance staff will undertake the task of relief valve changeout safely. Consideration must be given to enable personnel to access the valves safely and to avoid any unnecessary risks that may involve a fall or personnel exposure.

A.15.3.4.1 The local atmospheric pressure, P_{atm}, is taken as a function of the site elevation. The following can be used for the given location with the elevation rounded to the nearest increment included in the table.

Atmospheric Pressure at Nominal Installation Elevation (P_{atm})

Elevation Above Sea Level (ft)	Pressure (psia)	Elevation Above Sea Level (m)	Pressure (kPa)
0	14.7	0	101
500	14.4	150	99.5
1,000	14.2	300	97.8
1,500	13.9	450	96.0
2,000	13.7	600	94.3
2,500	13.4	750	92.6
3,000	13.2	900	91.0
3,500	12.9	1,050	89.3
4,000	12.7	1,200	87.7
4,500	12.5	1,350	86.1
5,000	12.2	1,500	84.6
6,000	11.8	1,800	81.5
7,000	11.3	2,100	78.5
8,000	10.9	2,400	75.6
9,000	10.5	2,700	72.8
10,000	10.1	3,000	70.1
15,000	8.296	4,500	57.7
20,000	6.578	6,100	46.5
30,000	4.371	9,100	30.3

Source: ASHRAE Handbook of Fundamentals

A.15.3.4.2 The superimposed back pressure for a relief device configured to discharge internally to the system would be the relieving pressure (gauge) of the vessel receiving the discharge vapor from the internal relief. For a treatment system, the designer needs to identify the maximum pressure (gauge) imposed by the treatment system and apply that pressure as the superimposed back pressure.

A.15.3.5 For pressure relief devices that discharge to atmosphere, the design pressure is typically evaluated on the basis of the back pressure that can occur during relief device actuation.

Where pressure relief devices discharge internally to another pressure-retaining portion of the system, the outlet portion of the relief device body should be evaluated in the context of the applicable internal-discharge arrangement. Depending on the relief service, the relevant basis may be associated with allowable back pressure or, for non-volatile liquid service relief valves, the design pressure of the vessel connected to the relief device outlet.

A.15.3.6.3 Rupture members used in series with a downstream pressure relief device are susceptible to built up of pressure between the rupture member and the pressure relief device. Any pressure increase in this interstitial space will function to increase the "opening pressure" of the rupture member. The use of a device such as an excess flow valve with a rapid shut-off function or other means is intended to prevent this type of operational deviation.

A.15.3.8.1.3 The term "liquid service" relief device refers to a pressure relief device that is certified for liquid service. The liquid relief being referred to in this requirement is applicable to non-volatile or "non-flashing" liquid since the National Board does not certify liquid service relief valves under flashing flow. In this standard, those terms are used interchangeability.

A.15.3.8.1.4 For example, a 100 psig set pressure relief device configured for internal relief to protect a 400 psig vessel while discharging to a 300 psig pressure vessel would have its certified pressure range to at least 400 psig.

A.15.3.8.1.5 Pressure relief devices intended for relieving vapor phase refrigerant are commonly referred to as "gas service" relief devices. Pressure relief devices intended to protect ASME-stamped components and relieve liquid are referred to as "liquid-service" relief devices and certified for liquid service.

A.15.3.9 The marking of certified pressure relief devices is specifically intended for those applied to ASME-stamped equipment.

A.15.4 Manufacturer's data can be used when determining pressure relief capacity.

For details on overpressure protection by system design, see ASME Section VIII Division 1 UG-154(e) and ASME Section XIII Part 13.

A.15.4.1 The presence of combustible materials "installed" within 20 ft of a pressure vessel refers to the presence of building materials near pressure vessels. The case where combustible materials are intended to be "stored" near pressure vessels refers to purpose-built storage. For example, packaging materials that are intended to be stored within 20 ft of a vessel shall apply the 2.5 multiplier on the capacity factor. This multiplier is not intend for de minimis combustible materials that may intermittently stored near a pressure vessel such as a pallet.

A.15.4.2 Designers often evaluate internal heat loads to determine if the internal loads have sufficient temperature to drive pressures within a heat exchanger beyond the component's design pressure. In those cases, the designer would then identify the largest internal load capable of causing overpressure and evaluate the relief capacity requirements to compare with external heat loads and size the relief device for the largest anticipated heat load.

See Appendix C (Informative), for more information related to Methods for Calculating Relief Valve Capacity for Heat Exchanger Internal Loads for more information.

A.15.4.3 See Appendix E (Informative), for more information related to Methods for Calculating Discharge Capacity of a Positive-Displacement Compressor Pressure Relief Device.

A.15.5.3 This provision is a carryover from the ASME B&PV Code Section VIII Div. 1 and Section XIII. It is important to realize that meeting this area criteria can still lead to an inlet pressure loss that diminishes the relief valve's capacity below what is required for protecting the component it is serving. As such, the area criteria alone is insufficient to ensure a safe and compliant relief system, whereas meeting the applicable criteria set forth in Sections 15.8.1.3 or 15.10.7.2 are essential.

A.15.6.1 The shut-off valve is evaluated for more than its cross-sectional area. This requirement necessitates that its pressure loss be accounted for in the downstream piping system to ensure the maximum allowable back pressure on the valve is not exceeded. In cases where shut-off valves are installed on pressure relief devices as part of a dual relief assembly, both shut-off valves would be locked open unless one of the valves is being serviced or replaced.

A.15.8.1.1 This provision should be read in the context of the fluid state in the protected component when the relief valve will actuate.

A.15.8.1.4 Typical Moody friction factors (f) for fully turbulent flow are provided in Tables A.15.8.1.4(1) and A.15.8.1.4(2). If the material being used is not exhibited in the tables below, different resources of determining friction factors should be consulted.

		Table A.15.8.1.4(1) **Typical Moody Friction Factors** **Carbon Steel Pipe** (e=0.00015 ft)					
Pipe Size		**Sch 40**		**Sch 80**		**Sch 160**	
NPS (in)	**DN**	**ID (in)**	***f***	**ID (in)**	***f***	**ID (in)**	***f***
½	15	0.622	0.0259	0.546	0.0269	0.466	0.0269
¾	20	0.824	0.0240	0.742	0.0247	0.614	0.0260
1	25	1.049	0.0225	0.957	0.0230	0.815	0.0241
1 ¼	32	1.38	0.0210	1.278	0.0214	1.16	0.0219
1 ½	40	1.61	0.0202	1.5	0.0205	1.337	0.0211
2	50	2.067	0.0190	1.939	0.0193	1.687	0.0199
2 ½	65	2.469	0.0182	2.323	0.0185	2.125	0.0189

3	80	3.068	0.0173		
4	100	4.026	0.0163		
5	125	5.047	0.0155		
6	150	6.065	0.0149		
8	200	7.981	0.0141		
10	250	10.02	0.0134		
12	300	11.94	0.0130		

Table A.15.8.1.4(2)
Typical Moody Friction Factors
Stainless Steel Pipe (e=0.0001 ft)

Pipe Size		Sch 80		Sch 160	
NPS	**DN**	**ID**	***f***	**ID**	***f***
½	15S	0.546	0.0240	0.466	0.0251
¾	20S	0.742	0.0222	0.612	0.0233
1	25S	0.957	0.0208	0.815	0.0216
1 ¼	32S	1.278	0.0193	1.16	0.0198
1 ½	40S	1.5	0.0186	1.338	0.0191
2	50S	1.939	0.0175	1.687	0.0181
2 ½	65S	2.323	0.0168	2.125	0.0172

A.15.8.2 Pressure relief devices are intended to have sufficient net flow–carrying capacity in order to limit the pressure rise in protected equipment to prevent their catastrophic failure. As such, the minimum relief capacity would depend on the equipment being protected and the scenarios under which overpressure is being created. The minimum capacity of a pressure relief device based on the largest of the relevant sources of overpressure would then be determined by the subsections referenced in Section 15.8.2.

A.Table 15-1 The relief device capacity factors in this table are based on a refrigerant mass flow rate derived from the applied external heat load to pressure vessel the divided by the heat of vaporization of ammonia evaluated at the relieving pressure but accounting for the portion of the vapor produced during evaporation remaining within the vessel occupying the volume previously filled by liquid evaporated.

A.15.8.2.2 See Appendix E (Informative), for examples and more information related to Methods for Calculating Discharge Capacity of a Positive-Displacement Compressor Pressure Relief Device.

A.15.8.3.4.1.5 The 45° angle is measured relative to horizontal. The purpose for this requirement is to discharge the venting vapor at an upward angle to promote mixing into the atmosphere and minimize hazard of personnel exposure in the area around the relief vent discharge and further downwind.

A.15.8.3.5.4 See A.15.8.1.4 for typical Moody friction factors (f) for fully turbulent flow.

Although Equations 15-5 and 15-6 are expressed in terms of equivalent length, they are used to calculate the pressure into (or out of) constant sections of piping and fittings that have defined lengths (or equivalent lengths) for a given mass flow rate. In the simple limiting case of a single vent line connected from the outlet of a pressure relief device to atmosphere, Equation 15-5 and 15-6 would be applied from a location of known pressure – the vent outlet at atmospheric pressure (Pd). The mass flow used corresponds to the relief valve's stamped or adjusted capacity per Section 15.8.3.5.3. The upstream pressure (Pu) is found by iteratively solving the equation given values of the pipe size, length, and friction factor. The calculated upstream pressure at the inlet to the vent piping would be identical to the outlet or back pressure at the relief device.

In the general case of a headered relief systems, this equation is applied systematically to vent pipe segments that have a constant cross-sectional area and mass flow rate. In common sections of a headered vent system downstream of branch pipe connections, each section further downstream would be analyzed if mass flow is added at a branch connection. Whether or not a branch connection is presumed to have mass flow contributing to the common portion of a header will depend on the scenarios identified by the designer in accordance with the requirements set forth in Sections 15.8.3.5.1-15.8.3.5.2.

A.15.8.4.7 See A.15.8.1.4 for typical Moody friction factors (f) for fully turbulent flow.

A.15.9.5 This section is primarily aimed at protecting equipment, such as condensers, that are often classified as "piping" and not ASME-stamped.

A.15.10.3.1 A locked or car-sealed open shut-off valve downstream of a pressure relief device that relieves internal to a different part of the system that provides overpressure protection, would not be considered an obstruction when used in relief discharge piping.

A.15.10.5.2 To avoid creating a hazard when discharging a non-volatile liquid, such as oil, external to the system, a design that utilizes an atmospheric vented tank to collect oil is one option. The tank would then be sized to accommodate the maximum quantity of oil that could be discharged.

A.15.11 The function of and design guidance for emergency pressure control systems (EPCS) are described in Appendix I (Informative). Release modeling programs are available to aid in evaluating off-site consequences. In determining the possible use of an EPCS system, the designer should consider conducting a process hazard analysis and/or hazard review to ensure that the EPCS will not create any unintended hazardous conditions.

A.16.1.1 For refrigeration systems with automatic monitoring, the monitoring system should automatically report critical alarms to a monitored location. Examples of critical alarms may include: discharge pressure greater than the compressor high-pressure cutout setting; ammonia concentration greater than 150 ppm within an enclosed area; or other criteria that indicate a refrigerant release has occurred. Automatic monitoring systems for critical operating parameters should acquire and store data in a manner and for a time period that is compatible with the owner's intended inspection methods.

A.16.1.3 One possible means of monitoring ammonia concentration resulting from a leak during a power failure is a portable ammonia monitoring device.

A.16.1.4 Examples of systems that might be inadvertently affected by unauthorized personnel include emergency exhaust and equipment shutdown controls. For these systems and others, an unauthorized individual might mistakenly change the set points for normal system operation related to temperature, pressure, flow, or vessel levels, and unintentionally affect alarm or emergency control settings.

A.16.2.1.1 The basis of a performance-based design could be an analysis that is consistent with the general design philosophy embodied in ASME B31.5.

A.16.2.3 Linear liquid level indicators are sometimes referred to as sight columns. It is recommended that linear liquid level indicators be of the flat "armored glass" type in preference to the tubular glass type.

A.16.3 This section does not address relay switches, contactors, and starters.

A.17.1 A facility's response plan will usually require that facility personnel, once they have investigated and evaluated the ammonia detection notification, to determine if the release is hazardous and warrants evacuation or sheltering in place. Safety systems or features that are automatically engaged because of detection should not be delayed because an investigation or evaluation is pending.

A.17.2.1 This section is intended to address power specific to the ammonia detection and alarm system and does not address plant-wide nor system-wide power loss events. A process hazard analysis (PHA), including review of historical power loss frequency and outage duration, may suggest additional power continuity provisions for ammonia detection and alarm system operation during extended loss-of-power events.

A.17.2.1 (4) In facilities where emergency ventilation is installed and controlled by the ammonia detection and alarm system, the ventilation control circuit should be designed to operate even if the ammonia detection and alarm system loses power. This could be accomplished by wiring the emergency ventilation start circuit through a normally closed (fail-safe) relay contact, arranged such that loss of power to the ammonia detection and alarm system causes the relay contact to change state and automatically initiate emergency ventilation.

A.17.4 There is no standardized method to determine the most effective placement of ammonia sensors. The most effective placement should be a result of considering room layout, room temperature, equipment location, maintenance and other considerations. Ammonia detector manufacturers might provide suggestions on detector placement based on experience. Another resource to aid in considering detector placement is the IIAR technical paper “CFD Simulation of NH3 Release and Detection in Refrigerated Spaces”, Greulich et. al., written as a result of an ARF funded research project.

A.17.5 The minimum audibility required for fire alarm signaling devices is normally a sound pressure level of 15 decibels (dBA) above the average ambient sound level and 5 dBA above the maximum sound level in the area where the device is installed. This was determined to be a suitable level for ammonia detection alarms to ensure adequate audibility. The intent of including a specific sound pressure level in dBA is to provide a measurable basis for alarm design and to determine adequacy of the audibility where someone might question if an alarm is reasonably loud when the alarm is commissioned. A difference of opinion in this regard could be resolved by using a sound meter.

A.17.7 The normative parts of this standard currently require only level 1 and level 3 ammonia detection and alarm levels. Information regarding level 2 is retained here for reference. Designers or end users may wish to use level 2 in lieu of level 1.

Level 2 Ammonia Detection and Alarm. If level 2 ammonia detection and alarm are implemented, it would have the following features:

1. At least one ammonia detector would be provided in the room or area.
2. The detector would activate an alarm that reports to a monitored location so that corrective action can be taken at an indicated concentration of 25 ppm or higher.
3. Audible and visual alarms would be provided inside the room to warn that when the alarm has activated access to the room is restricted to authorized personnel and emergency responders.

A.17.7.1 **Item (2):** Notification to a monitored location is intended to inform personnel responsible for corrective action. This should be read separate from other provisions in this standard that address audible and visual alarm notification.

A.18.1 See Appendix N (Informative) for more information on ammonia absorption refrigeration.

Appendix B. (Informative) Ammonia Characteristics and Properties

This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the American National Standards Institute requirements for a standard and may contain material that has not been subject to public review or a consensus process. If options presented within this appendix are implemented, they must comply with the normative provisions of this standard.

B.1 Ammonia Characteristics

The term ammonia, as used in this standard, refers to the compound formed by combination of nitrogen and hydrogen, having the chemical formula NH_3. It is not to be confused with aqua ammonia, which is a solution of ammonia gas in water. Whenever the term ammonia appears in this standard, it means refrigerant-grade anhydrous ammonia.

Experience has shown that ammonia is difficult to ignite and, under normal conditions, is a very stable compound. It requires temperatures of 840–930°F (450–500°C) (723.2–773.2K) to cause it to dissociate slightly at atmospheric pressure. The flammable limits at atmospheric pressure are 15.5% to 27% by volume of ammonia in air. An ammonia-air mixture in an iron flask does not ignite below 1,204°F (651.1°C) (925.3K).

Because ammonia is self-alarming, it serves as its own warning agent so that a person is not likely to remain voluntarily in concentrations that are hazardous.

B.2 Physical Properties of Ammonia

Physical Property	**Inch-Pound**	**Common Metric**	**SI**
Molecular symbol	NH_3	NH_3	NH_3
Molecular weight	17.031 lb/lb-mol	17.031 g/mol	17.031 g/mol
Boiling point at one atmosphere*	-27.99°F	-33.33°C	239.82K
Freezing point at one atmosphere*	-107.78°F	-77.66°C	195.5K
Critical temperature	269.99°F	132.22°C	405.37K
Critical pressure	1,644 psig	115.6 kg/cm^2 (gauge)	11.34 MPa (gauge)

Latent heat at -28°F (-33°C)(240.15K) and one atmosphere	588.8 Btu/lb	327.1 cal/g	1.369 MJ/kg
Relative density of vapor compared with dry air at 32°F (0°C)(273.15K) and one atmosphere	0.5967	0.5967	0.5967
Vapor density at -28°F (-33°C)(240.15K) and one atmosphere	0.05554 lb/ft^3	0.8896 kg/m^3	0.8896 kg/m^3
Specific gravity of liquid at -28°F (-33°C)(240.15K) compared with water at 39.4°F (4.0°C) (277.1K)	0.6816	0.6816	0.6816
Liquid density at -28°F (-33°C)(240.15K) and one atmosphere*	42.55 lb/ft^3	681.6 kg/m^3	681.6 kg/m^3
Specific volume of vapor at 32°F (0°C)(273.15K) and one atmosphere*	20.80 ft^3/lb	1.299 m^3/kg	1.299 m^3/kg
Flammable limits by volume in air at atmospheric pressure	15.5% to 27%	15.5% to 27%	15.5% to 27%
Ignition temperature	1,204°F	651.1°C	924.13K
Specific heat, gas at 59°F (15°C)(288.15K) and one atmosphere*			
At constant pressure (c_p) At constant volume (c_v)	0.5184 Btu/lb°F 0.3928 Btu/lb°F	0.5184 cal/g°C 0.3928 cal/g°C	2.1706 kJ/kg K 1.6444 kJ/kg K
Ratio of specific heat k(c_p/c_v) at 50°F (15°C)(288.15K) and one atmosphere*	1.320	1.320	1.320

NOTE: *One standard atmosphere = 14.696 psia (1.0333 kg/cm^2 absolute) (101.33 kPa absolute)

Appendix C. (Informative) Methods for Calculating Relief Valve Capacity for Heat Exchanger Internal Loads

This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the American National Standards Institute requirements for a standard and may contain material that has not been subject to public review or a consensus process. If options presented within this appendix are implemented, they must comply with the normative provisions of this standard.

Introduction

This informative appendix presents approaches for determining the capacity of relief valves for overpressure scenarios not explicitly covered in Chapter 15. This information can be used to document a basis for relief device capacity determination for heat exchangers that may be subject to overpressure due to internal heat loads or blocked valves that can lead to high refrigerant pressures. Pressure relief devices need to have sufficient mass-flow carrying capability (capacity) to limit the pressure rise in protected equipment to prevent catastrophic failure. The minimum required relief device capacity will depend on the specific equipment being protected and the scenarios under which overpressure is being created. The maximum relief device capacity is not limited by codes and standards. However, oversizing relief valves should be avoided to prevent unstable relief device operation.

Although the methods presented in this informative appendix are intended to apply across a wide range of refrigeration equipment and operating conditions, it is not possible to prescribe relief device sizing and selection criteria that covers all situations. The approach presented here is intended to be illustrative of the process that can be followed in establishing pressure relief requirements for specific situations. As such, the use of sound engineering principles and the application of engineering judgment are expected.

It is important to emphasize that for all of the cases considered, the rate of refrigerant vapor production needs to be converted to an air mass flow because all relief devices are rated on an air basis. In the sections that follow are methods for relief capacity determination for different types of heat exchangers based on internal heat addition.

Nomenclature

$c_{p,fluid}$ = secondary fluid heat capacity (Btu/lb-°F).

$cp_{fluid,CIP}$ = clean-in-place fluid heat capacity (Btu/lb-ºF).

C_r = minimum required discharge capacity of the relief device for a vessel (lb/min of air).

$C_{r,plate\ HX}$ = minimum required relief device capacity for plate heat exchanger (lb/min of air).

$C_{r,OS}$ = minimum required discharge capacity of the relief device protecting an oil separator (lb/min of air).

$C_{r,tank}$ = minimum required discharge capacity of the relief device protecting a product tank heat exchanger (lb/min of air).

D = outside diameter of vessel or product tank (ft).

D_s = outside diameter of surge drum (ft).

D_v = outside diameter of the main vessel portion of the shell-and-tube heat exchanger (ft).

f = relief device capacity factor that depends on refrigerant type and whether combustible materials are in close proximity to equipment. For ammonia this value is 0.5 in normal circumstances. It is 1.25 when combustible material is stored or installed within 20 ft. of the equipment.

H = height of the plate pack or tank heat exchanger (ft).

$h_{vapor,sat}$ = saturated vapor refrigerant enthalpy at the fully accumulated relief device set pressure (Btu/lb).

$h_{liquid,sat}$ = saturated liquid refrigerant enthalpy at fully accumulated relief device set pressure (Btu/lb).

L = length of the vessel or plate pack (ft).

$LMTD$ = Log mean temperature difference (°F).

L_s = length of surge drum (ft).

L_v = length of the main vessel portion of the shell-and-tube heat exchanger (ft).

$\dot{m}_{brine}$ = secondary fluid mass flow rate (lb/min).

$\dot{m}_{fluid,CIP}$ = clean-in-place fluid mass flow rate (lb/min).

$\dot{m}_{refrigerant}$ = refrigerant vapor generation rate (lb/min).

$\dot{m}_{refrigerant,OC}$ = mass flow rate of refrigerant vapor generated by the oil cooler (lb/min).

$\dot{m}_{refrigerant,tank}$ = mass flow rate of refrigerant vapor generated in a tank heat exchanger (lb/min).

Pr = Prandtl number for fluid used to establish the nominal UA (-).

Pr' = Prandtl number for fluid used to establish the modified UA' (-).

Q = heat exchanger heat flux (Btu/min).

Q_{OC} = oil-cooling heat exchanger heat load (Btu/min).

$T_{fluid,CIP,supply}$ = maximum fluid supply temperature during clean in place (CIP) (ºF).

$T_{refrigerant}$ = refrigerant saturation temperature (°F).

$T_{ref,sat}$ = refrigerant's saturation temperature at the relief valve set pressure (ºF).

T_{return} = load-side heat exchanger secondary fluid return temperature (°F).

T_{supply} = load-side heat exchanger secondary fluid supply temperature (°F).

UA = overall heat transfer coefficient-area product (Btu/min-°F).

UA' = modified overall heat transfer coefficient-area product (Btu/min-°F).

W = width of the plate pack (ft).

ε = refrigerant-to-product tank effectiveness (estimated as 0.2 for bulk tanks).

Application

If a heat exchanger is built to the requirements of ASME B&PVC, Section VIII, Division 1, and is physically stamped as such, it requires pressure relief protection per ASME B&PVC, Section VIII, Division 1, Section UG-125. In cases where conventional pressure relief protection is not required, it is often desirable to size a suitable "process" relief that will prevent over-pressurizing the heat exchanger during abnormal operation. The first step in determining the minimum required mass flow for relief protection is defining the scenarios likely to cause the overpressure situation. Heat exchangers are susceptible to overpressure by internal heat loads from either product or other secondary fluid flow streams (e.g., clean-in-place systems). In either situation, the key consideration for relief device sizing is determining the rate of refrigerant vapor production by evaporation, which will be dependent on the heat load and the refrigerant properties (saturation pressure-temperature relationship and heat of vaporization).

Shell-and-Tube, Plate and Frame, and Scraped (Swept) Surface Heat Exchangers

Most scenarios involve alternate means of thermal energy input to the heat exchanger when the refrigerant side of the chiller has been isolated from the refrigeration system, but the secondary fluid side remains active. Examples of thermal loads that could generate excessive pressure in a shell-and-tube or plate-and-frame heat exchanger may include, but are not limited to, product loads and clean-in-place (CIP) loads.

Of primary concern are thermal energy sources whose temperatures exceed the saturation temperature corresponding to the heat exchanger's maximum allowable working pressure (MAWP) or pressure relief device set pressure. If the maximum fluid-side supply temperature is less than the saturation temperature corresponding to the heat exchanger's MAWP, the pressure relief capacity can be determined by ANSI/IIAR 2, Section 15.3. If the maximum fluid-side temperature is greater than the saturation temperature corresponding to the heat exchanger's MAWP, vapor generation rates based on the "internal loads" should be estimated to determine if a larger relief device capacity requirement results.

The first step in considering an internal heat load scenario that could generate an overpressure situation is to evaluate the normal capacity of the heat exchanger. The next step is to estimate the heat exchanger's capacity under the adverse load condition and determine the corresponding rate of refrigerant vapor generation. Lastly, the predicted rate of refrigerant vapor generation is converted to an equivalent air mass flow rate to allow relief device selection.

Determining the rate of refrigerant vapor production can be accomplished by solving a system of equations that characterize the equipment heat transfer performance, as given by Equation (1), and the balance of both refrigerant-side and fluid-side energy flows as given by Equations (3) and (4), respectively. The system of governing equations is as follows:

$$Q = UA \cdot LMTD \tag{1}$$

$$LMTD = \frac{\left(T_{return} - T_{supply}\right)}{\ln\left[\frac{\left(T_{return} - T_{refrigerant}\right)}{\left(T_{supply} - T_{refrigerant}\right)}\right]} \tag{2}$$

$$Q = \dot{m}_{fluid} \cdot c_{p,fluid} \cdot \left(T_{return} - T_{supply}\right) \tag{3}$$

$$Q = \dot{m}_{refrigerant} \cdot \left(h_{vapor,sat} - h_{liquid,sat}\right) \tag{4}$$

Where

Q	=	heat exchanger heat flux (Btu/min).
UA	=	overall heat transfer coefficient-area product (Btu/min-°F).
$LMTD$	=	Log mean temperature difference (°F).
T_{return}	=	load-side heat exchanger secondary fluid return temperature (°F).
T_{supply}	=	load-side heat exchanger secondary fluid supply temperature (°F).
$T_{refrigerant}$	=	refrigerant saturation temperature (°F).
$\dot{m}_{fluid}$	=	secondary fluid mass flow rate (lb/min).
$c_{p,fluid}$	=	secondary fluid heat capacity (Btu/lb-°F).
$\dot{m}_{refrigerant}$	=	refrigerant vapor generation rate (lb/min).
$h_{vapor,sat}$	=	saturated vapor refrigerant enthalpy at the fully accumulated relief device set pressure (Btu/lb).
$h_{liquid,sat}$	=	saturated liquid refrigerant enthalpy at fully accumulated relief device set pressure (Btu/lb).

In a liquid-containing heat exchanger, the refrigerant temperature ($T_{refrigerant}$) is assumed to be the saturation temperature corresponding to the pressure relief device set (opening) pressure. The enthalpy of vaporization ($h_{vapor,sat} - h_{liquid,sat}$) for the refrigerant-side energy balance is evaluated at the pressure relief device set pressure as well. The return fluid temperature to the heat exchanger (T_{return}) is estimated based on the load that is a function of the fluid flow rate and return fluid from process, CIP set temperature, etc. The mass flow rate of fluid on the load side of the heat exchanger ($\dot{m}_{fluid}$) is required as is the load-side fluid heat capacity ($c_{p,\,fluid}$).

The nominal value of the heat exchanger's overall heat transfer area product (UA) is based on design operating conditions. Equation (1) is used to estimate a nominal or design UA. Once a nominal or design UA is established, it can be adjusted or corrected for use in estimating the refrigerant vapor production rate arising in an overpressure situation. For example, if the fluid-side flow rate would be expected to vary from the design condition, the following relationship based on the Dittus–Boelter turbulent heat transfer correlation could be used to predict a modified UA based on an alternative fluid-side flow rate.

$$UA' = UA \cdot \left(\frac{\dot{m}'_{fluid}}{\dot{m}_{fluid}} \right)^{0.8} \cdot \left(\frac{\mathrm{Pr}'}{\mathrm{Pr}} \right)^{0.4} \tag{5}$$

Where

UA = nominal overall heat transfer coefficient-area product (Btu/min-°F).

UA' = modified overall heat transfer coefficient-area product (Btu/min-°F).

Pr = Prandtl number for fluid used to establish the nominal UA (-).

Pr' = Prandtl number for fluid used to establish the modified UA' (-).

In addition, Equation (5) accommodates changes in working fluids when transitioning from a design load condition to a different working fluid that may arise and create an overpressure situation (e.g., changing from a beverage fluid during load conditions to a CIP solution during clean-up) that forms the basis for sizing pressure relief protection for the heat exchanger.

The above-mentioned known information ($T_{refrigerant}$, $h_{vapor,sat}$, $h_{liquid,sat}$, T_{return}, $\dot{m}_{fluid}$, $c_{p,fluid}$, and UA) can be used to simultaneously solve Equations (1), (3), and (4) to find the remaining three unknown variables: $\dot{m}_{refrigerant}$, T_{supply}, and Q. The quantity of interest is the refrigerant vapor flow rate, $\dot{m}_{refrigerant}$, which represents the mass flow of vapor generated during the overpressure scenario. Once obtained, the resulting refrigerant mass flow rate should then be converted to an equivalent mass flow rate for air using the following relationship (ANSI/ASHRAE 15 2007 Appendix F):

$$C_r = \dot{m}_{refrigerant} \cdot \frac{C_{air}}{C_{refrigerant}} \cdot \sqrt{\frac{T_{refrigerant}}{T_{air}}} \cdot \sqrt{\frac{M_{air}}{M_{refrigerant}}} \tag{6}$$

Appendix C of ANSI/ASHRAE 15 (2013) assumes a refrigerant temperature of 510°R (283 K) and an air temperature of 520°R (289 K). Appendix C of ANSI/ASHRAE 15 lists values of the constants, C_{air} and $C_{refrigerant}$, for several different refrigerants. The calculated air mass flow based on the estimated refrigerant vapor mass flow represents the minimum *required* relief capacity for the *internal* load scenario.

Example: Scraped (Swept) Surface Heat Exchanger

Heat exchanger characteristics for one manufacturer's scraped (swept) surface heat exchanger:

- $U \cong 300 \frac{\text{Btu}}{\text{hr}} \cdot \text{ft}^2 \cdot \text{°F}$
- $6 \text{ ft}^2 \leq A \leq 14.5 \text{ ft}^2$
- $150 \text{ psig} \leq MAWP \leq 250 \text{ psig}$

Heat load assumption

- Internal load is created by 160°F CIP fluid
- $Q = UA \cdot LMTD \cong U \cdot A \cdot (T_{CIP} - T_{sat,ref})$
- $Q = \dot{m}_{refrigerant} \cdot \left(h_{vapor,sat} - h_{liquid,sat}\right)$
- $\dot{m}_{ref} = \dfrac{U \cdot A \cdot \left(T_{CIP} - T_{sat,ref}\right)}{\left(h_{vapor} - h_{liquid}\right) \cdot 60 \dfrac{\text{min}}{\text{hr}}}$

Heat exchanger characteristics

- U = 300 Btu/hr-ft^2-°F
- A = 14.5 ft^2
- $MAWP$ = **150** psig (Δh = 488 Btu/lb, $T_{sat,ref}$ = 89.6°F)
- T_{CIP} = 160°F

$$\dot{m}_{ref} = \frac{300 \dfrac{\text{Btu}}{\text{hr-ft}^2\text{-°F}} \cdot 14.5 \text{ ft}^2 \cdot (160 - 89.6) \text{ °F}}{(488) \dfrac{\text{Btu}}{\text{lbm}} \cdot 60 \dfrac{\text{min}}{\text{hr}}}$$

$$= 10.5 \frac{\text{lbm}}{\text{min}} \text{(ammonia)}$$

$$\dot{m}_{air} = 1.314 \cdot 10.5 = 13.8 \left(\frac{\text{lbm}}{\text{min}}\right)_{air}$$

Heat exchanger characteristics

- U = 300 Btu/hr-ft^2-°F
- A = 14.5 ft^2
- $MAWP$ = 250 psig (Δh = 453 Btu/lb, $T_{sat,ref}$ = 120.8°F)
- T_{CIP} = 160°F

$$\dot{m}_{ref} = \frac{300\dfrac{\text{Btu}}{\text{hr-ft}^2\text{-°F}}\cdot 14.5\ \text{ft}^2 \cdot (160-120.8)\ \text{°F}}{(453)\dfrac{\text{Btu}}{\text{lbm}}\cdot 60\dfrac{\text{min}}{\text{hr}}}$$

$$= 6.3\frac{\text{lbm}}{\text{min}}\ \text{(ammonia)}$$

$$\dot{m}_{air} = 1.324\cdot 6.3 = 8.3\left(\frac{\text{lbm}}{\text{min}}\right)_{air}$$

Oil-Cooling Heat Exchangers

Over-pressurization can occur when a thermosiphon oil-cooled screw compressor package is started while the refrigerant side of the oil cooler is isolated (valved out). In this case, the compressor will operate and reject heat to the oil cooler, resulting in increasing oil temperature back to the compressor over time. As the compressor continues to operate and reject a portion of its heat of compression through its oil to the oil-cooling heat exchanger, a point will be reached when the onboard compressor safeties shut down the unit on high oil temperature. A typical screw compressor package high oil temperature cutout is approximately 205°F (96°C). The saturation pressure corresponding to a refrigerant temperature equal to the oil at its high temperature cutout of 205°F (96°C) is 825 psig for ammonia. Because this pressure is significantly greater than the oil-cooling heat exchanger's maximum allowable working pressure, the oil cooler will be subject to overpressure under this scenario.

The mass flow rate of refrigerant vapor generated on the refrigerant side of an oil cooler in an overpressure situation is given by

$$\dot{m}_{refrigerant,OC} = \frac{Q_{oc}}{\left(h_{vapor,sat} - h_{liquid,sat}\right)} \tag{7}$$

Where

Q_{OC} = oil-cooling heat load generated by the compressor operating at design suction pressure and discharge pressures with a corresponding supply oil temperature at the compressor high-temperature cutout limit (Btu/min).

$\dot{m}_{refrigerant,OC}$ = mass flow rate of refrigerant vapor generated by the oil cooler (lb/min).

$h_{vapor,sat}$ = saturated vapor refrigerant enthalpy at the fully accumulated relief device opening pressure (Btu/lb).

$h_{liquid,sat}$ = saturated liquid refrigerant enthalpy at the fully accumulated relief device opening pressure (Btu/lb).

The best source for determining the overpressure condition oil-cooling loads, Q_{OC}, is by information provided from the compressor manufacturers. Some compressor manufacturers' computerized selection programs provide this information based on users inputting the design suction and discharge pressures along with oil-supply temperatures. The programs return the resulting oil-cooling load under the modified (high oil supply temperature) conditions. The oil-cooling load imposed on the oil coolers can be evaluated at these modified conditions or alternatively, the full oil-cooling load can be taken for sizing the relief device.

The resulting oil-cooling load at the elevated operating condition (Q_{oc}) can then be used to estimate the refrigerant mass flow rate using Equation (7). The refrigerant mass flow rate is then converted to an air basis using Equation (6), thereby permitting the selection of a relief device.

Product Storage Tanks

The scenario for refrigerant vapor generation in the heat exchanger due to internal loads arises during clean-in-place. The rate of refrigerant vapor generation during clean-in-place can be estimated as follows:

$$\dot{m}_{refrigerant,tank} = \frac{\varepsilon \cdot \dot{m}_{fluid,CIP} \cdot cp_{fluid,CIP} \cdot \left(T_{fluid,CIP,supply} - T_{ref,sat}\right)}{\left(h_{vapor,sat} - h_{liquid,sat}\right)} \tag{8}$$

Where

$\dot{m}_{refrigerant,tank}$ = mass flow rate of refrigerant vapor generated in the heat exchanger (lb/min).

ε = refrigerant-to-product tank effectiveness (estimated as 0.2).

$\dot{m}_{fluid,CIP}$ = CIP fluid mass flow rate (lb/min).

$cp_{fluid,CIP}$ = CIP fluid heat capacity (approximated as 1 Btu/lb-ºF).

$T_{fluid,CIP,supply}$ = maximum fluid supply temperature during CIP (ºF).

$T_{ref,sat}$ = refrigerant's saturation temperature at the relief valve set pressure (ºF).

$h_{vapor,sat}$ = saturated vapor refrigerant enthalpy at fully accumulated relief device set pressure (Btu/lb).

$h_{liquid,sat}$ = saturated liquid refrigerant enthalpy at fully accumulated relief device set pressure (Btu/lb).

After determining the refrigerant mass flow rate, the relief device capacity (on an air-equivalent basis) is found by using Equation (6). The greater of these two capacities forms the basis for relief device selection for a product tank.

Appendix D. (Informative) Duplicate Nameplates on Pressure Vessels

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Duplicate Nameplates on Pressure Vessels

ASME B&PVC, Section VIII, Division 1, permits duplicate (or secondary) nameplates on pressure vessels. Duplicate nameplates may be desirable in certain circumstances, especially where the original nameplate may be obscured by insulation.

Experience has shown that attempting to access the original nameplate for inspection through windows, removable insulation sections, stanchion mounting, etc., tends to compromise the integrity of the insulation system. Moisture ingress into the insulation system follows, with possible damage to the pressure vessel. The use of duplicate nameplates helps prevent vessel damage from inspection ports and other deliberate damage to insulation.

Unfortunately, using duplicate nameplates creates the possibility that the wrong (duplicate) nameplate will be applied to a vessel. ASME B&PVC, Section VIII, Division 1, specifies that the vessel manufacturer must ensure that the duplicate nameplate is properly applied. While the easiest way to accomplish this is for the manufacturer to weld the nameplate to a support or other permanent vessel appurtenance that will not be insulated, field installation is also permitted. (Some inspection authorities consider the insulation jacket as a permanent attachment to the vessel, and therefore the duplicate nameplate may be applied to the jacket.) The manufacturer's procedures for ensuring a proper match of duplicate to original should be rigorously followed. It is advisable to record the location of the original nameplate should inspection be necessary.

Various inspection authorities such as state vessel inspectors may demand to inspect and/or approve the duplicate and original nameplates before insulation is applied. While many inspection bodies will accept a duplicate nameplate as evidence of ASME B&PVC, Section VIII, Division 1, compliance for an insulated vessel, authorized inspectors may always demand to inspect the original vessel, including its nameplate. In particular, when the inspector is concerned about the physical condition of the vessel or questions the provenance of the duplicate nameplate, he or she may require the entire insulation system or any part to be removed to permit inspection. Damage to the insulation system should be promptly and professionally repaired, and due allowance should be made for the shorter service life of the repaired insulation system.

Appendix E. (Informative) Method for Calculating Discharge Capacity of a Positive-Displacement Compressor Pressure Relief Device

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The following calculation method provides the required discharge capacity of the compressor pressure relief device in Section 8.2.2.

$$W_r = \frac{Q \cdot PL \cdot \eta_v}{v_g} \qquad \text{(E.1)}$$

Where

W_r = mass flow of refrigerant, lb/min (kg/s)

Q = swept volume flow rate of compressor, ft^3/min (m^3/s)

PL = fraction of compressor capacity at minimum regulated flow

η_v = volumetric efficiency (assume 0.9 unless actual volumetric efficiency at relieving pressure is known)

v_g = specific volume of refrigerant vapor (rated at 50°F [10°C] saturated suction temperature), ft^3/lb (m^3/kg)

Next, find the relieving capacity in mass flow of air, W_a, for an ASME B&PVC-rated pressure relief device:

$$W_a = W_r r_w \qquad \text{(E.2)}$$

$$r_w = \frac{c_{air}}{c_{refrigerant}} \cdot \sqrt{\frac{T_{refrigerant\cdot}}{T_{air\cdot}}} \cdot \sqrt{\frac{M_{air}}{M_{refrigerant}}} \qquad \text{(E.3)}$$

Where

r_w = refrigerant-to-standard-air-mass-flow conversion factor

$M_{refrigerant}$ = molar mass of refrigerant (17.0 for ammonia)

M_{air} = molar mass of air = 28.97

T_{air} = absolute temperature of the air = 520°R (289K)

c_{air} = constant for air = 356

$c_{refrigerant}$ = constant for refrigerant (as determined from Equation E.4)

$T_{refrigerant}$ = absolute temperature of refrigerant = 510°R (283K)

$$C_{refrigerant} = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \qquad \text{(E.4)}$$

Where

k = ratio of specific heats c_p/c_v

c_p = constant-pressure specific heat of refrigerant at a refrigerant quality of 1 at 50°F (10°C)

c_v = constant-volume specific heat of refrigerant at a refrigerant quality of 1 at 50°F (10°C)

Constants for ammonia are listed below:

k = 1.422

$M_{refrigerant}$ = 17.0

$c_{refrigerant}$ = 358.0

r_w = 1.28

EXAMPLE:

Determine the flow capacity of a relief device for an ammonia screw compressor with a swept volume, Q, of 1665 ft^3/min (0.7858 m^3/s). The compressor is equipped with capacity control that is actuated at 90% of the pressure relief device set pressure to its minimum regulated flow of 10%.

$$Q = 1665 \text{ ft}^3\text{/min } (0.7858 \text{ m}^3\text{/s})$$
$$\eta_v = 0.90 \text{ (assumed)}$$
$$PL = 0.1$$
$$v_g = 3.2997 \text{ ft}^3\text{/lb } (0.206 \text{ m}^3\text{/kg})$$

$$W_r = \frac{1665\,\frac{\text{ft}^3}{\text{min}}\cdot 0.1\cdot 0.9}{3.2997\,\frac{\text{ft}^3}{\text{lb}_\text{m}}} = 45.4\,\frac{\text{lb}_\text{m}}{\text{min}}$$

$$\left(W_r = \frac{0.7858\,\frac{\text{m}^3}{\text{s}}\cdot 0.1\cdot 0.9}{0.206\,\frac{\text{m}^3}{\text{kg}}} = 0.343\,\frac{\text{kg}}{\text{s}}\right)$$

$$W_a = W_r \cdot r_w = 45.4\cdot 1.28 = 58.1\,\frac{\text{lb}_\text{m}}{\text{min}}\text{ air}$$

$$\left(W_a = W_r \cdot r_w = 0.343\cdot 1.28 = 0.439\,\frac{\text{kg}}{\text{s}}\text{ air}\right)$$

Converting to standard ft^3/min (SCFM), where V_a= specific volume of air = 13.1 ft^3/lb (0.818 m^3/kg) for dry air at 60°F (15.6°C),

$$\text{SCFM} = 13.1(58.1) = 761 \text{ ft}^3\text{/min}$$

$$(\text{SCFM} = 0.818(0.439) = 0.359 \text{ m}^3\text{/s})$$

Appendix F. (Informative) Pipe Hanger Spacing, Hanger Rod Sizing, and Loading

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F.1 Recommended maximum spacing of hangers and minimum hanger rod size for steel pipe are set forth in Table F.1. Spacing does not apply where span calculations are made or where concentrated loads such as flanges, valves, specialties, etc., are placed between supports. These tables, adapted from MSS SP-58-2018, do not account for seismic, thermal, or other dynamic load considerations. Spacing beyond twelve (12) foot spans for piping of Nominal Pipe Size (in) of 4" or larger should be confirmed accounting for concentrated loads and seismic, thermal, or other dynamic load considerations. Note that ASME B31.5 requires wind load calculations, which could affect spacing of hangers and rod sizes. Local mechanical codes should be reviewed for specific requirements.

Table F.1 Recommended Maximum Spacing of Hangers and Minimum Rod Size

Nominal Pipe Size (in.)	**Maximum Span (ft)**	**Minimum Rod Diameter (in.)**
Up to 1	7	3⁄8
1 1⁄4–1 1⁄2	9	3⁄8
2	10	3⁄8
2 1⁄2	11	1⁄2
3	12	1⁄2
4	14	5⁄8

5	16	5⁄8
6	17	3⁄4
8	19	7⁄8
10	22	7⁄8
12	23	7⁄8
14	25	1
16	27	1
18	28	1 1⁄4
20	30	1 1⁄4

F.2 The maximum recommended hanger rod loading based on threaded hot-rolled steel is shown in Table F.2.

Table F.2 Maximum Hanger Rod Loading

Rod Diameter (in.)	**Maximum Load (lb)**	**Rod Diameter (in.)**	**Maximum Load (lb)**
3⁄8	610	1 1⁄2	11,630
1⁄2	1,130	1 3⁄4	15,700
5⁄8	1,810	2	20,700

3⁄4	2,710	2 1⁄4	27,200
7⁄8	3,770	2 1⁄2	33,500
1	4,960	2 3⁄4	41,600
1 1⁄8	6,230	3	50,600
1 1⁄4	8,000	3 1⁄4	60,500

Appendix G. (Informative) Hydrostatic and Liquid Overpressure Relief

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NOTE:
This appendix is presented entirely in the inch-pound (I-P) engineering unit system.

G.1 Background

Incompressible liquids such as oil, secondary coolants, and subcooled primary refrigerants create risk in situations where they become trapped within a fixed volume within a closed-circuit ammonia refrigeration system and subjected to a temperature rise due to heat addition. Trapped liquid that experiences an increase in temperature will result in a rise in pressure due to the volume expansion characteristics unique for each specific liquid. Because liquids are nearly incompressible, their increase in pressure when trapped can be very rapid; however, the corresponding rates of volume increase of the liquids are relatively low. As a result, the required capacity of pressure relief devices installed enable the expanding liquid volume to escape the system during overpressure events are significantly lower when compared to the capacity of pressure relief valves used in vapor service.

G.2 Overview of Protection Options for Liquid Overpressure

There are two situations that arise when addressing the engineering controls for protecting refrigeration system components from failure due to liquid overpressure: *liquid pressure relief* and *hydrostatic relief*. For the purposes of this appendix, the term "*liquid pressure relief*" refers to pressure relief required for ASME-stamped equipment. The term "*hydrostatic relief*" refers to pressure relief required for non-ASME liquid-filled components. When a pressure vessel or any other ASME-stamped piece of equipment is expected to operate completely filled with liquid, it must be equipped with certified pressure relief devices designed for *liquid pressure relief* per the ASME B&PV Code [UG-125(f)]. The National Board of Boiler and Pressure Vessel inspectors certifies relief devices and maintains a listing of approved *liquid pressure* relief devices along with vapor-service relief devices in its publication NB-18. The fluid used when rating pressure relief devices for *liquid pressure relief* is water. For consistency, the calculations for *liquid pressure relief* and *hydrostatic relief* shown in this appendix are converted to a water-equivalent basis. This approach is analogous to the use of an air basis for vapor service pressure relief valves.

Hydrostatic relief refers to the application of overpressure protection for liquid-filled components that are not ASME-stamped. In this case, the requirements set forth in Section 15.9.5 of this standard apply and exceed the requirements set forth in Section 501.4.2 of ASME piping code - B31.5. Unlike ASME-stamped vessels, overpressure protection for *hydrostatic relief* situations does not require a certified *liquid pressure* relief including the methods described in Section 15.9.5 of this standard. The designer must ensure the device intended for overpressure protection has sufficient volume holding or flow rate capability (capacity). In the case where the designer installs an "expansion compensation device" (item 2 in Section 15.9.5), a sufficiently sized accumulator to receive the expanded volume of liquid from the pressure-protected part of the system is essential. In the case where the designer installs a relief device, the relief device and downstream piping need to be sized to convey liquid from the portion of the system being pressure protected at a rate equal to or greater than the anticipated rate of liquid volume expansion to another part of the refrigeration system or to an external treatment system.

G.3 Determining Required Liquid Flow Rate

The following equation provides a method for determining the minimum required liquid volume flow rate so a suitable relief device can be selected.

$$GPM_{liquid} = \frac{\beta \cdot H}{500 \cdot SG \cdot C} \qquad \textit{Eq. G-1}$$

where:

GPM_{liquid} = the minimum required flow rate for trapped liquid relief, gal/min of water

β = cubical expansion coefficient corresponding to the trapped liquid at the expected relieving temperature, ft^3/ ft^3-°F

H = rate of heat addition into the trapped liquid at the relieving condition, Btu/hr

SG = specific gravity of the trapped liquid at the relieving condition

C = specific heat of the trapped liquid at the relieving condition, Btu/lb_m-°F.

Note: β for liquid ammonia = 0.00164 ft^3/ ft^3/°F, propylene glycol = 0.00073 ft^3/ ft^3/°F, oil = 0.00039 ft^3/ ft^3/°F

Equation G-2 provides a simplified approach to Equation G-1 in order to calculate the required liquid volume flow for liquid overpressure situations. The *hydrostatic/liquid pressure* relief device capacity factor, f_{HS}, used in Equation G-2 is based on the properties of liquid and it incorporates the same rate of heat addition for capacity determination of vapor service relief devices.

$$GPM_{liquid,w} = f_{HS} \cdot A_p \qquad \textit{Eq. G-2}$$

where:

$GPM_{liquid,w}$ = minimum required volume flow rate for trapped liquid relief, gal/min of water

f_{HS} = *hydrostatic/liquid pressure* relief capacity factor, 0.0433 for ammonia, 0.0133 for propylene glycol, 0.0178 for oil

A_p = projected area of component with trapped liquid exposed to an external heat load of 9,000 Btu/hr, ft^2

Note: if combustible materials are present, multiply f_{HS} by 2.5, similar to the requirements for vapor relief capacity determination

G.4 *Liquid Pressure* Relief for ASME-Stamped Pressure Vessels

The two most common *liquid pressure* relief situations that arise in industrial ammonia refrigeration systems includes the oil-side of an ASME-stamped oil cooling heat exchanger on a screw compressor package and the "load side" of a liquid refrigerant subcooler. Nearly always, both the oil-side and refrigerant-side of these heat exchangers will be covered by ASME B&PVC, Section VIII, Division 1, as evidenced by the U-stamped or ASME-stamped data tag affixed to the heat exchangers. As a result, the heat exchanger is required to meet the overpressure protection requirements set forth in Section VIII Division1.

As noted above in Section G.2, ASME pressure vessels that operate completely filled with liquid, the following requirements for *liquid pressure* relief apply:

a. Vessels that are to operate completely filled with liquid shall be equipped with pressure relief devices designed for *liquid pressure*, unless otherwise protected against overpressure. (UG-125)

b. *Liquid pressure* relief valves protecting ASME pressure vessels must be rated for liquid pressure relief duty and bear the ASME UV Code Symbol Stamp. (UG-129-UG-131) The standard fluid used for rating *liquid pressure* relief valves is water.

c. Any *liquid pressure* relief valve used should have at least NPS ½" connections. (UG-128).

d. The opening through all pipe, fittings, and non-reclosing pressure relief devices (if installed) between a pressure vessel and its relief valve shall be at least the area of the pressure relief valve inlet. In this upstream system, the pressure drop must not reduce the relieving capacity below that required or adversely affect the proper operation of the pressure relief valve. [UG-135(b)(1)]

e. The size of the discharge lines leaving a hydrostatic overpressure relief valve must be sufficient so as not to reduce the relieving capacity of the pressure relief valve below that required to properly protect the vessel. [UG-135(f)]

In virtually all cases, the oil-side of these stamped heat exchangers is expected to be completely filled with liquid and, as such, is subject to the provisions of *liquid pressure* relief. The same is true for the secondary fluid side of water-cooled or glycol-cooled oil coolers. In contrast, the refrigerant-side of thermosiphon oil coolers is not expected to operate completely filled with liquid. The designer needs to consider and design for the situations where overpressure conditions may occur on the refrigerant-side of these heat exchangers. Commonly, the design scenario for the refrigerant-side of these heat exchangers is a case where the heat exchanger is isolated and pumped-out with some remaining residual liquid refrigerant remaining in the heat exchanger. Subsequently, the compressor package is started without provision for oil cooling and heat from the oil becomes an internal load on the refrigerant-side of the heat exchanger creating the overpressure condition. In this case, the provision set forth in Section 15.4.2 of this standard applies and is usually the controlling (maximum) factor for relief capacity requirement. The designer needs to verify by comparing the relief capacity from an external heat load as prescribed by Section 15.4.2 in this standard.

Equation G-2 can be used to determine the minimum required liquid flow rate for *liquid pressure* overpressure protection. This equation expresses the liquid flow rate on a water-equivalent basis which enables designers to select certified *liquid pressure* relief devices as they are rated with water as the working fluid.

G.5 *Hydrostatic relief* for liquid piping and other non-ASME stamped equipment

The most common situation where trapping liquid in non-ASME stamped equipment occurs in a piping system. Two categories of overpressure arise: subcooled liquid refrigerant and non-volatile liquids such as oils, glycols, and water or other liquid products. In this case, other types of devices, such as a reseating pressure relief regulator, are permitted for overpressure protection. The designer must ensure the device selected for pressure relief has sufficient liquid flow rate capability to accommodate the rate of trapped liquid expansion.

If the designer chooses to determine the flow rate requirement on the actual working fluid's basis, Equation G-1 can be used with SG=1. Alternatively, Equation G-1 or Equation G-2 can be used, and the calculated liquid flow rate will be expressed on a water-equivalent basis.

G.6 Outlet Piping and Discharge Location

Liquid refrigerants must not be relieved directly to atmosphere. Rather, the discharge of refrigerants from a *liquid pressure* or *hydrostatic* relief device must be piped either internally to another portion of the refrigeration system or to an appropriate external treatment system. It is important for the designer to consider the differential pressure available between the portion of the system being pressure-protected (upstream) and the portion of the system receiving the refrigerant (downstream).

Designers should also consider and plan for the state of the relieved liquid downstream of the relief device. Two separate cases apply: single-phase flow (liquid-only) and two-phase flow (flashing liquid). Single-phase flow is common for relief of non-volatile liquids including oil and secondary coolants. Secondary coolants including chilled water and water mixed with glycol, calcium chloride, sodium chloride, or other additives. Two-phase flow will occur when the upstream liquid is a volatile fluid such as ammonia and its temperature is above the saturation temperature corresponding to the downstream pressure.

The pressure drop due to the flow of a single-phase fluid in the inlet or outlet piping is given by the following equation.

$$h = f \frac{L_{eq}}{D} \frac{V^2}{2g_c} \qquad \textit{Eq. G-3}$$

Where

h = pressure (head) loss due to single-phase liquid flow in piping, ft

f = friction factor, -

L_{eq} = Equivalent length of piping and fittings, ft

D = inside diameter of the piping, ft

V = average velocity of liquid flowing in the piping, ft/s

g_c = gravitational constant, 32.2 lbm-ft/s2-lbf

The friction factor, *f*, can be calculated using the Colebrook equation:

$$\frac{1}{\sqrt{f}} = -2.0 \cdot log\left(\frac{\varepsilon}{3.7 \cdot D} + \frac{2.51}{Re\sqrt{f}}\right) \qquad \textit{Eq. G-5}$$

Where

ε = is the pipe roughness, ft

D = inside diameter of pipe, ft

Re = Reynolds number for liquid flowing in the pipe, -

Because Equation G-5 is implicit in the friction factor, a more conservative estimate of the friction factor can be determined by using the fully rough formulation:

$$\frac{1}{\sqrt{f}} = -2.0 \cdot log\left(\frac{\varepsilon}{3.7 \cdot D}\right) \qquad \textit{Eq. G-5}$$

Equation G-3 can be recast in a form that calculates the pressure drop in psi, rather than ft of head, and uses more readily available information expressed as follows:

$$\Delta P = \frac{SG \cdot f}{72.3} \frac{L_{eq}}{d^5} (GPM)^2 \qquad \textit{Eq. G-6}$$

Where

ΔP = pressure drop due to single-phase liquid flow in piping, psi

SG = specific gravity of the single-phase liquid flowing in piping, -

f = friction factor, -

L_{eq} = Equivalent length of piping and fittings, ft

d = inside diameter of the piping, in

GPM = volume flow of single-phase liquid flowing in the piping, gal/min

G.7 Example: *Hydrostatic* relief

Hydrostatic overpressure protection is required for a 25 ft section of 2-1/2" schedule 40 piping rated at 250 psig is designed to convey a 25% (wt) solution of propylene glycol-water. The 2-1/2" schedule 40 pipe has an outside diameter of 2.875 inches and an inside diameter of 2.47 inches.

Determine the minimum required liquid flow rate for an internal relief that utilizes 8 ft (equivalent length) of piping in outlet connection size for a relief regulator.

In this case, the liquid is non-flashing. The projected area of 25 ft of 2-1/2" schedule 40 piping is:

$$A_p = L \cdot D = 25 \cdot 2.875/12 = 6\ ft^2$$

The minimum required volume flow rate can be determined using Equation G-2 with f_{HS}=0.0133.

$$GPM_{liquid,w} = f_{HS} \cdot A_p = 0.0133 \cdot 6 = 0.08 \text{ gpm}$$

Once the required liquid flow rate has been established by the heat addition scenario, a suitable device to provide overpressure protection needs to be selected. Because the section of piping subject to overpressure is not ASME-stamped, we have flexibility in selecting a device to accomplish the overpressure protection.

In this case, we will evaluate a relief regulator with a set pressure of 250 psig. The flow rate capability of this regulator can be determined based on the device's flow coefficient, *Cv*. The flow rate is a function of the valve's *Cv*, pressure difference available across the regulator, and the fluid's specific gravity.

The ASME B&PV Code Section VIII Division 1 allows a 10% overpressure above the MAWP of the protected equipment for a certified relief device to fully actuate and deliver its rated flow. There is not an analogous provision for non-stamped equipment but applying an identical requirement in this case establishes a conservative requirement.

For a *hydrostatic relief* situation where the downstream portion of the system receiving the liquid has an identical design pressure to the upstream portion, the available pressure difference for the relief device and piping to accommodate is simply 1.1 times the design pressure. The available pressure difference across the regulator in this case is:

$$\Delta P = \left(1.1 \cdot P_{design}\right) - P_{design} = (1.1 \cdot 250) - 250 = 25\,psi$$

The definition of the flow coefficient, *Cv* is given as

$$Cv = \frac{GPM}{\sqrt{\Delta P/SG}} \qquad \textit{Eq. G-7}$$

Rearranging Equation G-7 to solve for the flow rate through the regulator for a given pressure differential across the regulator becomes

$$GPM = Cv\sqrt{\Delta P/SG} \qquad \textit{Eq. G-8}$$

The liquid flow through the regulator with the manufacturer-specified flow coefficient of 1.14 on a differential pressure of 25 psig for a water basis becomes

$$GPM = 1.14\sqrt{25/1.0} = 5.7\,gpm$$

The regulator flow rate is well above the minimum required of 0.08 gpm.

The liquid flow characteristic in the downstream piping needs to be evaluated to ensure the resulting pressure drop will not diminish the regulator's flow to a level below the minimum required. The pressure drop is evaluated based on a water basis for the regulator's actual flow rate (not the calculated minimum flow rate required) through the 8 ft (equivalent length) of outlet connection size piping which is ½" schedule 80 (i.d. = 0.55"). The pipe has a friction factor of 0.014 and the pressure drop in the outlet piping section becomes:

$$\Delta P = \frac{1 \cdot 0.014}{72.3}\frac{8}{0.55^5}(2.5)^2 = 0.2\,psi$$

This pressure drop, effectively, reduces the pressure difference across the regulator from 25 psig to 24.8 psig which does not diminish the flow capacity below the minimum required so this selection would be adequate.

G.8 Example: *Liquid pressure* relief

An ASME-stamped liquid ammonia subcooling heat exchanger requires the application of a certified pressure relief device to protect the subcooled liquid portion of the heat exchanger. The largest projected area of the plate-and-shell heat exchanger is 1.5 ft^2. The design pressure of the heat exchanger is 300 psig and it is relieving to the highside of the refrigeration system with a corresponding design pressure of 50 psig.

Using Eq G-2, the liquid flow rate required to protect this stamped component is:

$$GPM_{liquid,w} = f_{HS} \cdot A_p = 0.0433 \cdot 1.5 = 0.065\ gpm$$

A candidate *liquid pressure* relief valve is selected. The liquid rated capacity of this ½ x ¾ relief valve with a 50 psi set pressure is 8.8 gpm and is thus adequate. The saturation temperature of ammonia at the upstream design pressure of 300 psig is 126.5ºF and the saturation temperature of ammonia at the downstream design pressure of 250 psig is 114.6ºF. In cases where overpressure of the liquid ammonia occurs at a temperature below the saturation temperature corresponding to the downstream pressure, no flashing of the liquid ammonia will occur; however, if the upstream liquid temperature is higher than the saturation temperature for the downstream pressure, the flow in the downstream piping will be flashing two-phase flow. Calculation of the pressure drop in the downstream piping for non-flashing flow is identical to method used in Section G.7. For flashing liquid flow, refer to the IIAR Piping Handbook for pressure drop calculations.

Appendix H. (Informative) Stress Corrosion Cracking

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H.1 Introduction

Stress corrosion cracking (SCC) is a generic term describing the initiation and propagation of cracks that can occur in metals when subjected to stress in the presence of an enabling chemical environment. The stress can originate from an externally applied force, thermal stress, or residual stress from welding or forming.

H.2 Background

Carbon steel, stainless steel, and aluminum are susceptible to SCC when stressed in the presence of ammonia and oxygen. Studies have shown that the following factors work to enable SCC:

- Material yield strength greater than 50 ksi,
- Presence of oxygen within the system,
- Residual or applied stress, and
- Water content less than 0.2% (2000 ppm).

Although SCC has been identified as a potential metallurgical risk in agricultural and transport industries for many years (due to the frequent presence of non-condensable gas that commonly occurs in these applications), it is a comparatively low risk in closed-circuit ammonia refrigeration systems.

H.3 SCC in Ammonia Refrigeration Systems

SCC in closed-circuit ammonia refrigeration systems is less common, but there have been isolated reports of SCC in vessels and piping. Pressure vessels may be more susceptible to SCC because of their higher material yield strengths and higher residual stress present after fabrication. High-pressure receivers are somewhat more vulnerable due to the greater likelihood of oxygen being present because of the potential accumulation of non-condensable gases, higher operating pressures, and lower water content, but SCC has occurred in lowside pressure vessels. Section H.5 provides recommendations to further reduce risks of SCC occurring in the vessels used in closed-circuit ammonia refrigeration systems.

The fabrication of a pressure vessel involves processes that mechanically deform the parent material. For example, the shell of a pressure vessel is created by roll-forming flat plate stock into a cylinder. The dished heads of the pressure vessel are die-struck from flat plate stock in either a cold-formed or a hot-formed (recommended) process. The interior of a pressure vessel will have surface cracks and other subsurface discontinuities that, in the presence of a favorable chemical environment and stress, tend to slowly propagate. As the cracks propagate from the interior surface toward the external surface of the vessel, they relieve stress. In most situations, the cracks self-arrest before reaching the exterior shell of the pressure vessel. In the rare occurrence when these cracks do reach the exterior shell of the vessel, a "pinhole leak" results. Although the repair of an individual pinhole leak can be performed, the vessel is susceptible to such leaks occurring from other cracks that may be similarly propagating.

H.4 Inspections

Surveillance inspections for SCC are not recommended for closed-circuit ammonia refrigeration systems. First, the frequency of SCC occurrence in closed-circuit ammonia refrigeration systems is quite low. Second, the best means for inspection of SCC indications is the use of wet magnetic fluorescent particle inspection, a manual procedure that requires access to the interior of a pressure vessel. Practically speaking, this cannot be done in closed-circuit ammonia refrigeration systems because such access is not available. Furthermore, adding such access capability in future vessels would increase the probability of leaks occurring at the access point. Third, field experience has shown that steps noted in Section H.5 have proven to be quite effective at further reducing the likelihood of an already low-probability event.

H.5 Recommendations to Inhibit SCC in Ammonia Refrigeration Systems

The following recommendations are intended to further minimize the likelihood of SCC for vessels constructed from carbon steel for use in closed-circuit ammonia refrigeration systems.

- **Purge non-condensable gases:** The presence of non-condensable gases (specifically, oxygen) increases the probability of SCC. As such, purging of air from the system during both initial startup and during operation and maintenance is important. Purging is also used to help maintain system performance and energy consumption. As a result, it is used almost universally on closed-circuit ammonia refrigeration systems for reasons other than safety.
- **Reduce residual stresses:** Post-weld heat treat (PWHT) all high-temperature vessels, especially vessels such as high-pressure receivers and intermediate and low-temperature water chillers, intercoolers, and economizers to relieve the residual stress that occurs as a result of the fabrication processes (welding and forming) of a pressure vessel. In some cases, such as specialized vessels that contain internal gaskets etc. (specialty chillers), PWHT may not be possible. In those situations, it is important to fabricate the component using hot-formed heads. In other situations, such as oil separators and oil pots, the film of oil on the interior surface of the pressure vessel provides a barrier layer to prevent the presence of oxygen from reaching the internal surface to enable SCC. In these cases, PWHT can still be specified but provides a higher cost/benefit ratio.

NOTE: Because PWHT may produce significant scale, which could cause operating problems in the system, specifying the use of a purge gas during PWHT can minimize scaling.

Appendix I. (Informative) Emergency Pressure Control Systems

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Emergency Pressure Control System Design and Installation Guidelines

I.1 General

I.1.1 Purpose. This technical guideline describes requirements for emergency pressure control systems (EPCS), which provide a means of internally mitigating an overpressure event in a refrigeration system that is independent of other required safety features and functions prior to operation of a pressure relief device.

I.1.2 Scope. Emergency pressure control systems used as a means to mitigate an overpressure event involving an ammonia refrigeration system should comply with this technical guideline.

I.1.3 Limitations. An EPCS does not reduce or eliminate requirements for pressure relief devices set forth in other codes and standards.

I.2 Definitions

Crossover valve is a valve that allows interconnection of two different portions of a refrigeration system that normally operate at different pressures.

Emergency pressure control system (EPCS) is a system 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.

Header is a pipe to which other pipes or tubes are connected.

High side consists of those portions of a mechanical refrigeration system that are subjected to approximate condenser pressure.

Low side consists of those portions of a mechanical refrigeration system that are subjected to approximate evaporator pressure.

Pressure sensor is a mechanical or electronic device that measures ammonia pressure.

Seep is a nuisance loss of refrigerant from a relief valve that can occur when the vessel pressure approaches the relief pressure setting, or a nuisance loss of refrigerant from a relief valve that can occur after the valve discharges if the valve does not fully reseat.

Zone is a general term used to identify a pressure level or temperature level of a refrigeration system. A zone will be associated with a compressor or group of compressors and the associated vessels serving a common pressure level. The term does not pertain to individual temperature-controlled areas or rooms served by one or more compressor.

I.3 Referenced Standards

I.3.1 International Fire Code (IFC), Section 606.10.

I.4 EPCS Recommended. Each zone should be provided with an EPCS. Each EPCS, other than the lowest-pressure zone, should include a crossover valve to allow an abnormally high pressure to be discharged to a lower-pressure zone.

I.4.1 Design and Installation Recommendations

I.4.2 Crossover Valve Connections

I.4.2.1 Crossover valves should be connected to locations that will allow pressure in each high-pressure zone to discharge to a lower-pressure zone. Connections between pressure zones should continue in the previously described manner until all major pressure zones in a system are connected with the EPCS, always with the intended flow traveling from a high pressure to a lower pressure.

I.4.2.2 Where multiple low-pressure zones are present, low-pressure zones with the highest pressure should be connected to the next lowest pressure zone.

I.4.2.3 Crossover valve connections should not be to pipes or tubes conveying liquid refrigerant.

I.4.2.4 High-pressure crossover valve connections should come from the top of a dry suction header, compressor discharge header, or other main gas header.

I.4.2.5 Low-pressure crossover valve connections should discharge to the vapor space in a receiving vessel or to a common vapor header serving multiple receiving vessels.

I.4.2.6 The designer of a refrigeration system should consider the ability of the low-pressure portion of the system to receive the high-pressure discharge from the EPCS crossover valve. Operation of the crossover valve should not cause a release of refrigerant from pressure relief devices on the low-pressure portion of the system.

I.4.2.7 Crossover valves and connecting piping and valves should have a minimum nominal size of 1 in.

I.4.2.8 Piping and tubing associated with a crossover valve should be independent of any other connections. The connection should not be in the same pipe or tube where a pressure relief device is connected.

I.4.3 Crossover Valve Type and Status Monitoring. The crossover valve should be of a type that fully opens when activated. Where the status of power to the valve cannot be readily verified, an indicator light is recommended to show whether power is supplied to the valve.

I.4.4 Isolation Valves

I.4.4.1 Each crossover valve should be provided with a stop valve on either side to allow isolation of the crossover valve for maintenance.

I.4.4.2 Isolation valves should be locked in the open position during normal operations.

I.4.5 System Operation

I.4.5.1 The EPCS should be arranged for automatic operation.

I.4.5.2 Where required by the fire department, the EPCS should be provided with a remote switch for manual activation.

I.4.5.3 An EPCS should be arranged to activate at a pressure not greater than 90% of the pressure relief device setting or 95% of the pressure relief device setting when a rupture disc is installed upstream of the relief device.

I.4.5.4 A dedicated, independent mechanical pressure switch or pressure sensing transducer should be provided to activate each EPCS.

I.4.5.5 Pressure-sensing equipment should continuously monitor pressure in the refrigeration system adjacent to each crossover valve.

I.4.5.6 When a pressure sensor reaches the EPCS activation pressure, all of the following should occur:

1) All compressors supplying the pressure zone that is in an overpressure condition should be stopped by a means that is independent of the high pressure safety controls provided on the compressors.

2) Associated crossover valves should open.

3) Condenser fans and pumps should be stopped if the system pressure falls below 90 psig.

I.4.5.7 A means should be provided to signal personnel responsible for refrigeration system maintenance that an EPCS has been activated.

I.4.5.8 Once an EPCS has been activated, it should remain active until manually reset.

I.4.6 Inspection and Maintenance. EPCS crossover valves and isolation valves should be inspected and tested on an annual basis to verify proper operation.

I.4.7 Written Procedures. Written procedures should be in place to describe the operation of the EPCS. Procedures should address the importance of maintaining isolation valves in the fully open position unless maintenance is being performed on the crossover valve.

Considerations for Pressure Set Points

Seep through a relief valve is nuisance refrigerant loss due to pressure differential conditions across the valve or dirt and debris located at the seat. Seep is measured in bubbles per minute and can vary by manufacturer, design, type of seat material, pressure differential across relief, amount of dirt that is trapped after a relief discharges, and age of the relief valve. Relief valves are set with a tolerance of +/- 3%, but when these reliefs are stored or left in operation for a long period of time, the reliefs can begin to seep at larger tolerances. In some cases, seep has occurred when pressure increases to within 10% of relief set pressure.

One method to prevent seep is to maintain a pressure on the relief valve of 90% or less of the rated relief valve pressure setting. When pressures higher than 90% of rated relief valve pressure setting are anticipated, it is possible to select soft seats that are bubble tight at higher pressures. Rupture disks in combination with a relief valve will result in tighter tolerances.

Tables I.1 and I.2 show examples of typical tolerances and pressures associated with relief valves and the EPCS.

Table I.1

Typical Set Point Values and Tolerances for a 300 psig System

Relief full open (+10%)	330 psig
+3% tolerance	309 psig
Relief valve set point	300 psig
-3% tolerance	291 psig
Potential seep point (-10%)	270 psig
EPCS set point (EPCS set point is equal to or below the seep point)	250–270 psig
Design system operating pressure (-25%) (System operating pressure should be 25% lower than the relief valve setting when selecting relief valves)	225 psig

Compressor offset point	225 psig

Table I.2

Typical Set Point Values and Tolerances for a 250 psig System

Relief full open (+10%)	275 psig
+3% tolerance	257.5 psig
Relief valve set point	250 psig
-3% tolerance	242.5 psig
Potential seep point (-10%)	225 psig
(EPCS set point is equal to or below the seep point)	
EPCS set point	210 psig to 225 psig
Design system operating pressure (-25%)	200 psig
(System operating pressure should be 25% lower than the relief valve setting when selecting relief valves)	
Compressor offset point	200 psig

Appendix J. (Informative) Machinery Room Signs

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For caution and warning signs, refer to ANSI/ISEA Z535.2.

Key to door signage:

J.1 Refrigeration Machinery Room—Authorized Personnel Only

Color: Black text, yellow background

Location: All entrances to machinery room

J.2 Caution—Ammonia R-717

Color: Black text, yellow background

Location: All entrances to machinery room

J.3 Caution—Eye and Ear Protection Must Be Worn in This Area

Color: Black text, yellow background

Location: All entrances to machinery room

J.4 Warning—When Alarms Are Activated, Ammonia Has Been Detected

1. Leave room immediately when alarms are activated.
2. Do not enter except by emergency trained personnel only.
3. Do not enter without personal protective equipment.

Location: All entrances to machinery room

J.5 Refrigeration Machinery Shutdown, Emergency Use Only

Color: Black text, orange background

Location: Designated principal exterior machinery room door.

J.6 Refrigeration Machinery Room: Refrigeration Ventilation, Emergency Use Only

Color: Black text, orange background

Location: Designated principal exterior machinery room door, also can be used for remote ON / AUTO ventilation switch

J.7. NFPA 704Ammonia Fire Diamond

Color: Black text, white, blue, red, and yellow background

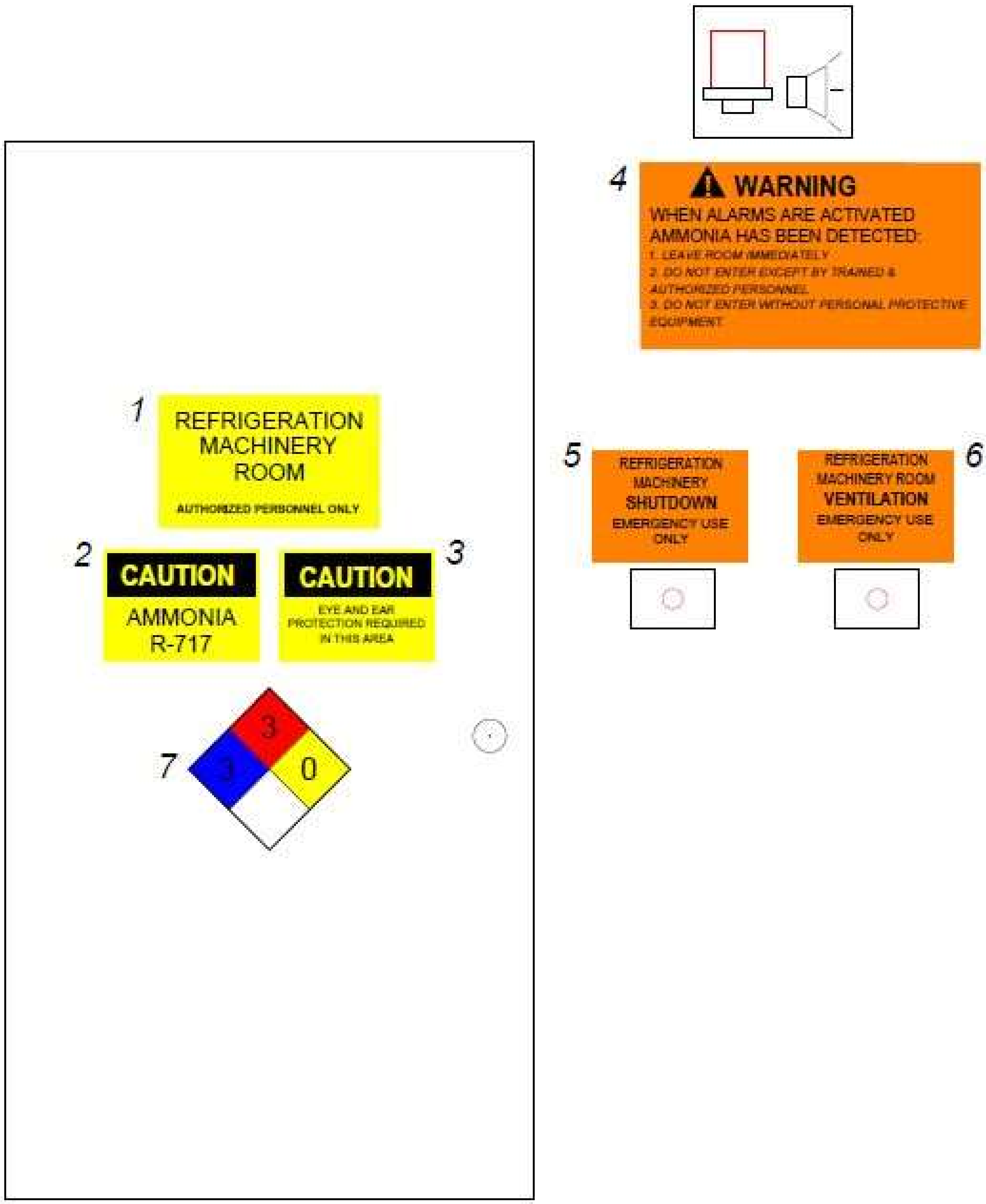
1. Warning for indoor ammonia refrigeration equipment: **3-3-0**

This includes all entrances to a machinery room.

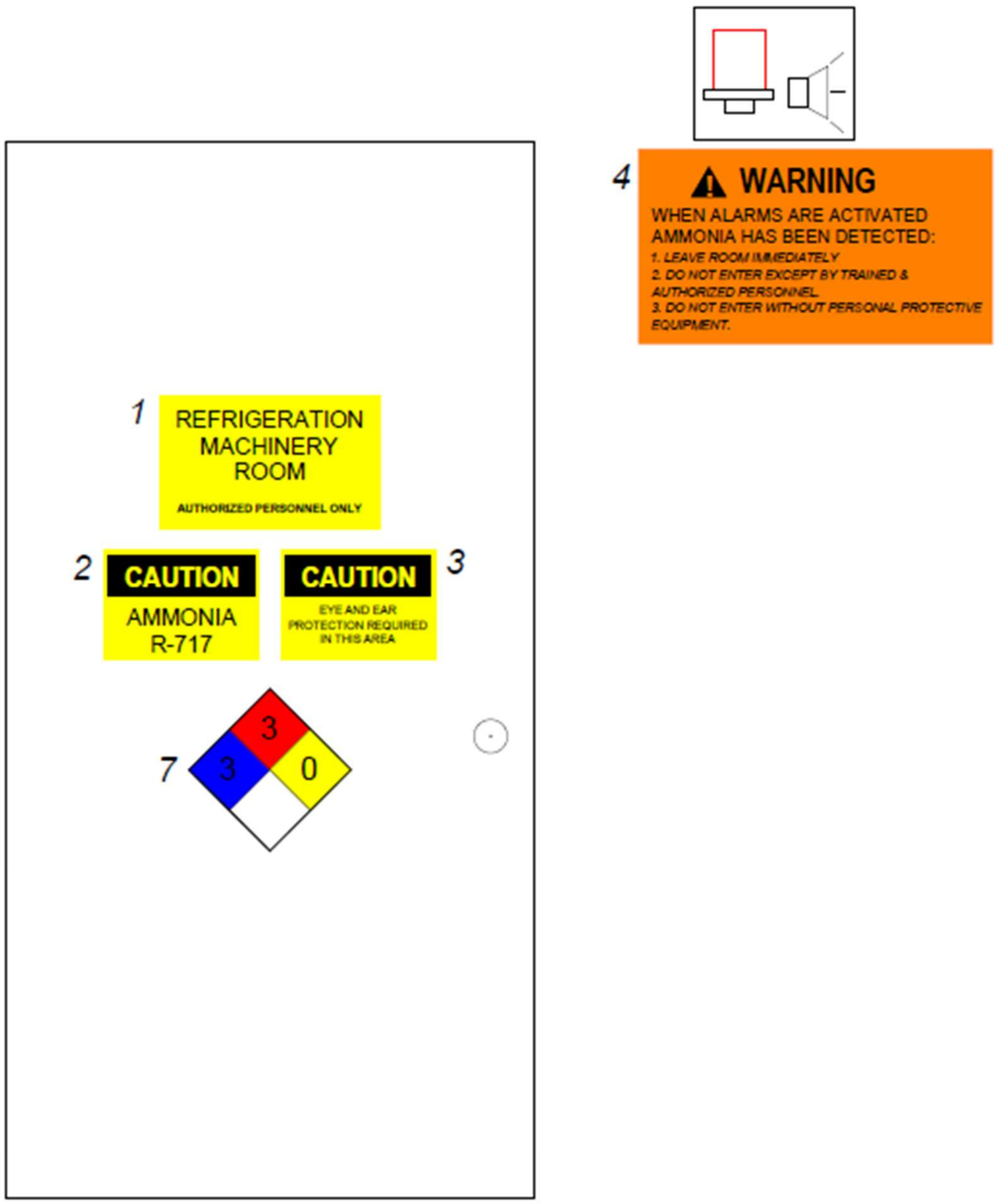
2. Warning for outdoor ammonia refrigeration equipment: **3-1-0**

This is for equipment located entirely outdoors.

The following example of the principal and auxiliary machinery room doors are provided for reference only.



Principle Machinery Room Door



Auxiliary Machinery Room Door

Appendix K. (Informative) Alternative Ventilation Calculation Methods

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K.1 General

The exception to Section 6.14.7 describes alternative ventilation methods that are available for ammonia (NH_3) refrigeration systems. This appendix (informative) contains sample calculations for the design of alternative ventilation methods.

K.2 Sample calculation: 30 air changes per hour (ACH) for emergency ventilation rate

K.2.1 Design the ventilation system for an ammonia refrigeration skid package that contains 450 lb of anhydrous ammonia (G) and is located in a machinery room that has a volume (V) of 100,000 ft^3.

K.2.2 The emergency ventilation rate equation (30 ACH = 0.5 air changes/minute):

$Q = V \times 0.5$ (changes/min)

Where

Q = airflow in ft^3/min.

V = room volume in ft^3.

For this example,

$Q = (100{,}000 \text{ ft}^3) \times 0.5 \text{ (changes/min)} = 50{,}000 \text{ ft}^3\text{/min}$

K.3 Sample calculations: Demonstrate that ammonia concentrations will never exceed 40,000 ppm [approximately 25% of the lower flammability limit (LFL)]

K.3.1 Demonstrate that the ammonia concentrations would never exceed 40,000 ppm if 100 lb of anhydrous ammonia (G) were released from an ammonia refrigeration skid package located in a machinery room that has a volume (V) of 100,000 ft^3.

K.3.2 The following equation can be used to demonstrate that the ammonia concentrations would never exceed 40,000 ppm:

$C = G \times \text{(vapor sp. vol.)} \times (100\%) / V$

Where

C = volumetric concentration of ammonia in %,

G = amount of ammonia released in the room in lb. For the purposes of these calculations it is assumed that the entire ammonia inventory is released and vaporized inside the machinery room.

Vapor sp. vol. = the vapor specific volume for anhydrous ammonia in ft^3/lb.

V = room volume in ft^3.

Vapor-Specific Volumes @ 15 psia

Temperature (°F)	Specific Volume (ft^3/lb)
40	20.6880
60	21.5641
80	22.4338
100	23.2985

For this example:

C = (100 lb) × (22.4338 ft^3/lb at 80ºF) × (100%) / (100,000 ft^3) = 2.24%

The LFL% for anhydrous ammonia is typically considered to be 16% (160,000 ppm). Twenty-five percent of the LFL% is 4% (40,000 ppm). Thus, under steady-state conditions, the ammonia concentration inside the machinery room (2.24%) would not exceed 40,000 ppm, even if the entire ammonia charge were released and vaporized within the machinery room.

K.3.3 Even though the calculations demonstrate that under steady-state conditions the ammonia concentrations would never exceed 40,000 ppm, it is recommended that an emergency ventilation system be provided in the machinery room in this example. The emergency ventilation rate used would be at the discretion of the designer(s).

K.4 Sample calculations: Provide localized (spot) ventilation designed to maintain ammonia concentrations below 40,000 ppm

K.4.1 Design a localized (spot) ventilation system for an ammonia refrigeration skid package that contains 250 lb. of anhydrous ammonia (*G*) and is located in a machinery room that has a volume (*V*) of 100,000 ft^3 that will maintain the ammonia concentrations below 40,000 ppm. Assume the temperature to be 60°F.

K.4.2 The following equation can be used to calculate the ventilation rate for a localized (spot) ventilation system that will maintain the ammonia concentrations below 40,000 ppm. The derivation of this equation and an explanation of its use can be found in Chapter 4, Section 4.5 (General Industrial Ventilation) from ACGIH, *Industrial Ventilation: A Manual of Recommended Practice for Design, 30th Edition.* This equation has been modified to be specific for anhydrous ammonia at approximately 60°F and a maximum allowable vapor concentration of approximately 25% of the LFL (40,000 ppm).

$Q = 570 \times ER$

Where

Q = airflow in ft^3/min

ER = evaporation rate of liquid in lbs./min.

Example:

For the purposes of these calculations, it is assumed that the entire ammonia inventory is released and vaporized inside the machinery room over a 10-minute period, i.e., 250 pounds over a 10-minute period (25 lb./min).

$Q = 570 \times 25$ lbs./min.

$Q = 14{,}250$ ft^3/min

K.4.3 Chapter 4 of *Industrial Ventilation: A Manual of Recommended Practice for Design* provides guidance on dilution ventilation principles that should be followed when designing localized (spot) ventilation systems. These principles include the following.

K.4.3.1 Locate the exhaust openings near the sources of contamination, if possible, to obtain the benefit of "spot ventilation."

K.4.3.2 Locate the air supply and exhaust outlets such that the air passes through the zone of contamination. The operator should remain between the air supply and the sources of the contaminant.

K.4.3.3 Replace the exhausted air by use of a replacement air system.

K.4.3.4 Avoid re-entry of the exhausted air by discharging the exhaust high above the roof line and by ensuring that no window, outdoor air intakes, or other such openings are located near the exhaust discharge.

K.5 Determine leak rates based on analyzed scenarios. Subsequently, design a ventilation system based on the amount of air needed to limit concentration to 40,000 ppm.

K.5.1 For each automatically isolatable section of a system with ammonia piping in the machinery room under study, estimate:

a. Leak rate from liquid line whose combination of diameter and pressure results in largest potential leak rate of liquid
    - Assume full bore hole for line sizes up to ½”
    - For line sizes larger than ½”, use the larger of
        - ½” full bore hole size,
        - hole size with cross section equivalent to 20% cross section area of the pipe

b. Leak rate from vapor line whose combination of diameter and pressure results in largest potential leak rate of vapor
    - Assume full bore hole for line sizes up to ½”
    - For line sizes larger than ½”, use the larger of
        - ½” full bore hole size,
        - hole size with cross section equivalent to 20% cross section area of the pipe

c. Allow leak rate calculation to be adjusted based on existence of safeguards that are independent, effective, and auditable. An adjustment of the leak flow rate could be justified if the source of the ammonia is from a vessel outside the machinery room, such that the flow is through a pipe that is subject to flow restriction from flashing and/or pressure drop.

d. Refrigerant inventory (charge).

K.5.2 After analyzing all isolatable sections, pick the worst case(s) leak rate(s) into the machinery room, and estimate the peak ammonia concentration possible in the room taking into account:

e. Room volume
f. Room emergency ventilation rate

K.5.3 Determine if a desired criterion has been satisfied, such as not exceeding some percentage of ammonia LFL. At a minimum, 40,000 ppm (approximately 25% of the LFL) should not be exceeded.

K.5.4 If the optional method does not yield an attractive alternative, the designer should use the prescribed method in the standard.

K.5.5 The method above allows the designer some latitude to adjust their design if a desired criterion for the optional method is not met. A designer could consider additional release mitigation methods such as:

- Use smaller line sizes, perhaps sacrificing some energy efficiency
- Reduce head pressure through use of more efficient/larger condensers
- Revise the design to reduce the refrigerant charge
- Add more automatic isolation valves where feasible
- Increase the emergency ventilation rate
- Move ammonia inventory into automatically isolatable vessels outside the machinery room (preferably outdoors)

- Add safeguards that limit the leak flow rate; safeguards should be independent, effective, and auditable

Appendix L. (Informative) Pipe, Fittings, Flanges, and Bolting

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The following criteria for materials have historically been commonly used in the ammonia refrigeration industry for ammonia pipe, fittings, flanges, and bolting. See Appendix OR for cited references.

L.1 Pipe

Carbon steel: ASTM A53 Grade A or B, Type E or S.

Carbon steel: ASTM A106 Grade A or B.

Stainless steel: ASTM A312 Type 304, 304L, 316, or 316L, Type E or S.

Carbon steel (below -20°F): ASTM A333 Grade 1 or 6, Type E or S.

Carbon steel pipe: ASTM A53 Type E or S; or ASTM A106 is permitted to be used below -20°F provided it meets the limitations on materials in accordance with ASME B31.5. The application of finite element analysis is an acceptable alternative method for determining stress analysis for carbon steel piping that is used for low-temperature applications.

The use of ½" and smaller pipe is not recommended. Where the use of ½" and smaller pipe is required in the engineering design, it should be adequately supported and/or protected to prevent damage.

L.2 Fittings

Carbon steel: ASTM A105

Carbon steel: ASTM A234

Stainless steel: ASTM A403

Carbon steel (below -20°F): ASTM A420.

L.3 Flanges

Carbon steel: ASTM A105

Carbon steel: ASTM A181

Stainless steel: ASTM A403

Carbon steel (below -20°F): ASTM A707

L.4 Bolting

Cast iron flanges when used with ring gaskets or when coupled to a raised-face flange: ASTM A307 Grade B.

Carbon or stainless steel flanges down to -55°F: ASTM A193 Grade B7.

Low-temperature applications (-55°F to -150°F): ASTM A320 Grade L7.

Nuts for aforementioned materials: ASTM A194, in accordance with the bolting material requirements listed in the previously referenced standards.

NOTE: The aforementioned materials refer to common materials in joining piping flanges only. These materials or other commonly used qualifying materials selected for a safe design are permitted for bolts and studs for equipment closures, valve bonnet-body connection, etc.

Appendix M. (Informative) Operational Containment

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Operational containment is defined as an optional control sequence wherein all ventilation for a room is de-energized so that ammonia vapor is retained in the room.

Operational containment is a rare strategy as an alternative ventilation method where sensitive off-site receptors are present, such as densely populated areas, nursing homes, or schools. The design should be handled on a case-by-case basis for definition of appropriate criteria for application and design as a variance to the standard practices defined in ANSI/IIAR 2.

An ammonia detection system meeting the requirements of Chapter 17 and a ventilation system meeting the requirements of Section 6.14.7 should be provided, at a minimum.

Operational containment initiates at a detection level determined by the site refrigeration management designee, emergency responders, and/or owner. A predetermined procedure should be developed to ensure that personnel are not located within the machinery room before operational containment is initiated. The procedure should include the following at a minimum:

1. Provide an "ON / OFF / AUTO" override for emergency ventilation at a secured remote location that can be used for operational containment shutdown of the ventilation system.
2. Automatically de-energize all unclassified electrical equipment at the detection of ammonia vapor concentrations that exceed the detector's upper detection limit or 40,000 ppm (approximately 25% LFL), whichever is lower, or upon stopping ventilation using manual controls.
3. Equipment or controls that should remain energized for monitoring or controlling equipment should be designed for operation in a hazardous location.
4. Airflow dampers on fans, air inlets, and air outlets should close when operational containment is actuated.

Appendix N. (Informative) Ammonia Absorption Refrigeration

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Ammonia absorption refrigeration (AAR) systems are usually configured as liquid-vapor systems. Less commonly they are configured as solid-vapor systems. The working fluid pair most commonly used in liquid-vapor ammonia absorption refrigeration (LVAAR) is ammonia with water as the sorbent.

Solid-vapor ammonia absorption systems (SVAAR) are a more recently developed technology and accordingly less common. The fluid pairs are coordinative complex compounds comprising a solid metal inorganic salt, activated carbon, or other compatible materials, that serve as the sorbent and ammonia as the refrigerant.

Absorption systems use heat energy to compress the ammonia gas and thus create the conditions necessary for a complete refrigeration system. Common components include an evaporator, condenser, an expansion valve, one or more receivers, valves, a refrigerant pump, and piping. The compression of the ammonia refrigerant, accomplished with a motor- or engine-driven compressor in mechanical vapor compression refrigeration (MVCR) systems, is replaced by a thermally activated compressor (TAC). A TAC comprises a thermal source such as a fuel-fired heater or a waste-heat or steam-heat exchanger and a sorption component that absorbs the heat, often referred to as the generator or desorber.

Occupancy restrictions are similar to MVCR systems. This standard only covers liquid-vapor and solid-vapor ammonia absorption systems.

The three primary differences between AAR and MVCR systems are as follows:

(1) Compressor:

AAR systems use a heat activation process compressor also known as a TAC. For an LVAAR the TAC comprises an absorber, a desorber, a solution pump, a heat recovery solution heat exchanger, and a rectifier. The low-pressure (LP) ammonia vapor to be compressed enters the TAC at the absorber, where the vapor is exothermically absorbed into an ammonia-water solution and heat is rejected. The solution pump recirculates the absorbing solution between the LP absorber to the high-pressure (HP) desorber. Driven by input heat, HP vapor exits the desorber.

For the LVAAR compressor to function properly, a rectifier and a solution receiver are required. The desorbed ammonia vapor contains excess water vapor (typically 3–10%). A rectifier is provided to reduce the water vapor to the typical max concentration of 1%. A solution heat exchanger provides regenerative heating and cooling of the recirculating absorbing solution. A solution receiver is provided for temporary storage of the solution.

To achieve a close approach to ideal thermodynamic performance in the solution compressor, additional components are needed. Examples include a solution cooled rectifier and a solution heat exchanger.

For an SVAAR, the TAC comprises two or more sorbers containing the solid sorbent complex compound functioning as the absorber and desorber. The cycle does not require a solution pump and operates in a batch mode in which the functions of the two sorbers are switched from absorber to desorber and vice versa by valves and connecting piping. The LP ammonia vapor to be compressed enters the TAC at the absorber, where the LP vapor is exothermically absorbed into the solid complex compound matrix and heat is rejected until the solid bed is saturated. Driven by input heat, HP vapor exits from the desorber until the solid bed is depleted. Upon saturation and depletion of the absorber and generator beds the functions are reversed. For the SVAAR compressor, a rectifier is normally not required as the ammonia purity is near 100%. A heat transfer loop connecting the two-complex compound sorbers is recommended to recover heat during the switching process in which the absorber is heated and the desorber is cooled. A solution receiver is also not required for the SVAAR compressor. The unique thermodynamic nature of the refrigerant bond in coordinative complex compounds (monovariancy) allows for the systems to be operated as thermal energy storage systems without a need for additional tanks or reservoirs.

(2) Working Fluids

The working fluid refrigerant for MVCR systems is ammonia, which is often circulated with oil needed for the mechanical compressors.

The working fluid in LVAAR systems is ammonia saturated with water. Ammonia is completely miscible with water. The ammonia is the fluid being absorbed in the LVAAR system. MVCR systems in practice function well with up to 2% water. The working fluid water content in AAR will operate as high as 50–90% in the TAC.

The working fluid in SVAAR systems is ammonia bonded to a coordinative complex compound sorbent. For systems operating at or above 10°F a ratio of 1 mole of strontium chloride per 1–8 moles of ammonia is typically used; and for systems operating between –50°F and 10°F, a ratio of 1 mole of manganese chloride per 2–6 moles of ammonia is typically used. Activated carbon and metallic salts are also used as absorbents. Depending on the absorbent used, the nature of the coordinative bond between the ammonia and the solid complex compound tolerates the presence of oil, thus allowing SVAAR systems to operate in parallel with MVCR systems using the same refrigerant piping. SVAAR systems, like MVCR systems, can function well with up to 2% water.

(3) Refrigerant Heat Exchanger (RHX)

The RHX recuperates thermal energy from cold ammonia vapor exiting the evaporator to the warm liquid ammonia exiting the condenser, functioning similarly to a liquid/suction line heat exchanger in an MVCR. It provides some efficiency improvement to the MVCR. It is also beneficial in MVCR systems to reduce wear caused by vapor impingement on thermal expansion valves, which commonly causes wear known as wire drawing. The RHX improves LVAAR system efficiency to a larger degree, so it is almost always present. For SVAAR systems, the benefits are similar to MVCR systems.

Appendix O. (Informative) Designing to Avoid Component Failure Caused by Abnormal Pressure or Shock

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O.1. Sudden Liquid Deceleration

Sudden liquid deceleration is caused by the rapid closing of a valve in a pipe carrying flowing liquid. When the flow of liquid stops suddenly, a spike of pressure within the valve body and connected piping occurs.

If there is a sudden liquid deceleration problem with an existing system, it can be prevented by using a solenoid valve that has a delay in closing of about one second. Valves that have a built-in dash pot provide this slight delay.

The high-pressure liquid feed to either a low-pressure vessel or a direct expansion evaporator should have a solenoid valve installed as close as possible to the metering device. Otherwise, when the solenoid is closed, the liquid in the downstream line will evaporate (i.e. will be “pumped out”), and when reopened, high pressure liquid will rapidly fill the line causing a sudden liquid deceleration shock at the metering device.

O.2. Vapor-Propelled Liquid Slugging and Condensation-Induced Shock

Vapor-propelled liquid slugging is caused by high-pressure vapor flowing in a line partially filled with liquid that entrains a sufficient volume of liquid to fill the pipe circumference, thereby creating a liquid “slug”. These liquid “slugs” move rapidly until they encounter an obstruction such as a valve or pipe end-cap. Momentum from the flowing liquid is imparted to the obstructing component resulting in a rapid rise in pressure or hydraulic shock.

Condensation-induced shock is caused when high pressure refrigerant vapor rapidly condenses in pipelines containing both liquid and vapor. As ammonia vapor condenses, it undergoes a large decrease in volume. This large reduction in volume causes liquid to accelerate. When the accelerated liquid encounters adjacent obstructions, such as valves, pipe end-caps, or even equipment, it attempts to move and damage the obstruction.

A sudden change in pressure is the basic cause of most of the vapor propelled liquid problems that are part of the hot got defrost cycle. It is important that pressure be introduced gradually to an evaporator at the initiation of defrost and that it be gradually bled away at the termination of defrost.

The use of a slow, gradual, or stepped opening valve or a group of valves to introduce hot gas pressure into an evaporator to be defrosted may be an advisable modification where the risk of hydraulic shock exists. Provisions can be made to gradually bleed down the pressure from the evaporator before opening the main suction valve. This can usually be done with the addition of a small valve that bypasses the main suction valve.

Sloping of headers toward receivers, liquid drainers, or other equipment to avoid trapping or pooling of liquid within piping helps to mitigate against condensation induced hydraulic shock.

O.2.1. Liquid in Hot Gas Lines

The following are recommendations for mitigating problems from liquid in hot gas lines:

1. Consider insulating all hot gas lines to minimize condensation. This is especially important for hot gas lines passing through unheated, refrigerated, or outdoor spaces. Unless the inner surface of the hot gas line is kept at a temperature above the saturation temperature of the hot gas, condensation of liquid refrigerant will take place in the pipe line.

2. Consider installing liquid drains at any low points in the hot gas main which cannot be avoided. Even insulated, some condensation will take place because there is intermittent flow in the lines. Unless steps have been taken to eliminate the liquid from the hot gas line, it will collect in the low points of the line. These liquid drains can be used to transfer the liquid back to the low side of the system.

3. The addition of a solenoid hot gas "King" valve in the machinery room that opens only when there is a downstream need for hot gas could help mitigate condensation in headers. This could be a slow opening valve, one that will take three (3) to five (5) minutes to fully open. By increasing pressure in the hot gas main gradually, formation and acceleration of liquid slugs or plugs by the hot discharge gas can be avoided. Furthermore, only the hot gas left in the pipeline when the valve is closed can condense into liquid that would fill less than 5% of the total pipe volume.

   Caution: Ambient temperature may reduce the hot gas main pressure to below the suction pressure of the evaporator. In a freezer, the main may reach pressures as low as, or lower than, 9.0 psig (-10°F saturated). If this same main supplies evaporators with 20 psig or higher suction pressures, gas and liquid will backflow through the local hot gas solenoid valve and fill the lower pressure hot gas main. Check valves may be installed in the hot gas entrance of each coil and between a hot gas heated drain pan and the main coil to prevent back flow when "King" hot gas valves are used.

4. The replacement of a solenoid valve with an outlet-pressure regulator with a pilot electric shut-off to regulate downstream hot gas pressure can reduce the risk of condensation. However, these regulators are not slow opening devices. Their purpose is to control maximum hot gas feed pressure to a defrosting evaporator and to help stabilize the defrost times which would otherwise vary with fluctuating head pressure.

Outlet pressure setting for these regulators range from 90 to 110 psig (630 to 770 kPa) for ammonia when the regulator is located near the coil(s) to be defrosted. It is not recommended that the setting be less than 30 psig (210 kPa) above the setting of the defrost relief regulator.

5. Reconfiguring the hot gas supply to an evaporator to avoid feeding hot gas through suction lines containing liquid, such as liquid overfeed systems, may mitigate vapor propelled liquid slugs.

Occasionally, hot gas is introduced into the evaporator through suction lines. When the hot gas enters a suction line, the pipe entrance may be moved as close to the evaporator as possible to minimize the risk of a slug. Sloping of headers toward receivers, liquid drainers, or other equipment to avoid trapping or pooling of liquid within piping helps to mitigate against condensation induced hydraulic shock.

O.2.2. Initiation of Hot Gas Defrost

It is essential to pumpout a low temperature evaporator before introducing hot gas during its defrost cycle. The time needed to pumpout will probably be ten (10) to fifteen (15) minutes but can be longer. The pumpout should be done by closing the liquid solenoid valve and allowing the fan(s) to continue running with the suction valve open.

The evaporator most vulnerable to vapor propelled liquid is a liquid overfed, low temperature unit that has not been allowed to evaporate residual liquid (i.e. “pumped out”), is full of liquid and is supplied by a hot gas line from which the liquid has not been removed. Some of the reasons for this vulnerability are as follows:

1. The difference between suction and head pressure is greater in a low temperature system creating a greater driving force behind any vapor propelled liquid. This is true at the onset and termination of the defrost cycle.

2. Pipe and evaporators are larger and colder. More hot gas is needed for defrost resulting in larger control valves and supply piping. Greater forces result from the high mass flow rates of refrigerant involved.

3. Liquid overfeed can completely fill an evaporator with liquid during light load or heavy frost conditions.

4. Hot gas piping is located in a colder space enhancing condensation even though the line is insulated.

5. Location of the hot gas injection on the evaporator or piping may be below the liquid level if the coil is allowed to fill. A possible liquid slug in the hot gas line will transmit its force through the non-compressible cold liquid to the containment.

To mitigate shock in large blast freezers operating on a booster compressor suction their defrost relief vent may be relocated to an intermediate suction pressure [e.g. 20 to 40 psig (140 to 280 kPa)] through a dedicated defrost relief line rather than to the evaporators own suction level. If there is more than one coil or coil section feeding condensate to a common relief regulator or drain, consider a check valve at each coil refrigerant condensate out. If there is one coil feeding through one regulator or drain, the check valve can be at the outlet of whichever device is used.

If blast freezers operating on a booster compressor suction line have their defrost relief vented into the booster suction line, and the total amount of booster load defrosted at one time exceeds 30% of the booster capacity adjustments should be considered. Under these conditions there is a risk that the booster suction pressure will rise to a point above that of the operating (i.e. non-defrosting) evaporator’s return air conditions and cause them to fill with overfed or flooded liquid. These coils will not have any load and no refrigerant will evaporate. Under these circumstances, it is essential to not initiate a defrost cycle on these liquids filled coils until normal conditions have existed for a period of time after the termination of the defrost cycle.

O.2.3. Termination of Hot Gas Defrost

Large, low temperature evaporators should be bled down slowly before the main suction line automatic isolation valve is opened. This function is vital. To ensure that evaporators are completely bled down, the installation of a bleed down solenoid bypassing the suction shut-off valve is recommended to mitigate shock.

An adequately sized bleed down solenoid valve will bleed the evaporator to suction pressure in three (3) to four (4) minutes.

If a multi-stage refrigeration system is involved, the defrost relief may modified to vent into an intermediate pressure with a check valve at the outlet of the relief device to prevent reverse flow during refrigeration. However, a complete bleed down of the evaporator cannot be accomplished by bleeding into an intermediate pressure and a bleed down solenoid valve should be considered.

In liquid overfeed systems, liquid will tend to be trapped in any low point of the suction line. If defrost pressure is suddenly released into the suction line, the liquid will be picked up by the high velocity vapor and pushed ahead of it as a liquid slug resulting in a tremendous force at its stopping point. For example, floor standing blast freezer coil suction lines that are trapped may result in this condition. Low temperature refrigeration systems have low pressure suction lines filled with light density vapor which offers little resistance to accelerating vapor propelled liquid.

O.2.4. Light and No-Load Conditions

The following are recommendations for preventing such shocks:

1. An evaporator that is full of liquid should not be defrosted.

2. Provide an adequate pumpout before initiating a defrost cycle.

3. Shut off the liquid feed to the evaporator whenever the fan(s) are off, where fan cycling is used.

4. A check valve installed by itself in the liquid feed to an evaporator may cause a risk of incomplete pump down. The use of a solenoid valve with the check valve is recommended. A check valve should be installed at the outlet of the solenoid valve if a defrost is needed for an evaporator in a liquid overfeed system.

5. Consider the installation of a room thermostat, preferably sensing air temperature returning to the evaporator, to identify light or no-load conditions and to turn off the liquid line solenoid valve. For blast freezers, where thermostats are not practical, the liquid line solenoid

may be controlled manually or tied into some other event that occurs only in times of a light load, such as a conveyor drive motor

O.3. Thermal Expansion of Trapped Liquid Ammonia

The following are some suggestions for reducing the risk of component failure due to thermal expansion of trapped liquid ammonia:

1. Liquid line check valves installed on the upstream, inlet side of a solenoid valve will trap liquid when the solenoid valve is de-energized. It is recommended that check valves be installed on the outlet side of solenoid valves.

2. Pump discharge check valves installed without relief protection between them and pump shut off valves present a risk of trapped liquid. Where this type of installation is found it is advisable to install a pressure relief valve or inlet pressure regulator on a liquid pump discharge line and relieve pressure to the pump suction. Additionally, it is recommended that a relief valve or regulator be installed downstream of the discharge check valve to prevent trapping of liquid when all evaporator liquid solenoid valves are closed. Any hand valves in this relief line should be locked open and tagged with a warning against closing. Finally, this section of pipe could also be equipped with a pressure gauge and gauge valve as indicators of possible overpressure conditions.

3. Existing evaporator coil automatic hot gas defrost control valve groups should be reviewed to ensure that abnormal liquid pressure will be relieved during defrost cycles or power failures. A pressure relieving device discharging to the suction or an intermediate pressure is suggested. If defrost relief is to an intermediate pressure, a check valve installed downstream of the pressure relieving device may be advisable. Relieving to liquid-filled or hot gas supply lines by using back-flowing hot gas solenoid valves or hot gas outlet pressure regulators is not a recommended practice and should be considered for mitigation. When defrosting two or more evaporator coils at the same time with a single defrost relief regulator, check valves are recommended at each coil to prevent regulator backflow when its outlet pressure is higher than the evaporation pressures.

Appendix P (Informative) Removal of Water from a Refrigeration System

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Although the presence of water in an ammonia refrigeration system does not represent a significant safety concern, water content of 2% or more can cause measurable energy penalties. Lubrication oil can also become contaminated and therefore become less effective. Systems that operate at less than atmospheric pressure are more susceptible to the absorption of water into ammonia refrigerant. Systems that use heat exchangers to cool a process fluid or a secondary coolant are also at risk of water contamination if the heat exchangers fail. It may be prudent for designers to consider planning for the connection of a distilling unit in these types of systems. ANSI/IIAR 6, Appendix C, provides additional information on water contamination and the means of testing and removal.

The removal of water from a refrigeration system is best accomplished by using a distilling process which typically operates as a batching system verses a continuous operation. A distilling unit may also be referred to as a regenerator or an anhydrator, depending on the manufacturer of the unit.

A regenerator may rotate between two distilling vessels keeping the distillation process online continuously. While one vessel is in the distilling process, the other vessel permits the batch draining of the accumulated water contamination.

A distiller requires a heat source to drive the distillation process. A portable or stationary distilling unit's heat source may be provided by the following:

1. A hot gas connection from the facility's refrigeration system that flows through an internal coil in the distiller vessel that condenses the refrigerant and returns it back into the system.
2. A high side connection from the facility's refrigeration system that provides hot/warm liquid or a liquid/vapor mixture that flows through an internal coil in the distiller vessel and returns all refrigerant back into the system, including any vapor which condenses.
3. Hot gas circulated through an external surface panel/plate on the upper portion of the distiller vessel that condenses and returns the refrigerant back into the system.
4. A low/suction side connection of the facility's refrigeration system to a portable unit that has its own compressor that provides hot gas, hot/warm liquid, or a liquid/vapor mixture as the heat source that returns all refrigerant back into the system, including any vapor which condenses.
5. An electric band wrapped around the lower portion of the distiller vessel.
6. Hot or warm water circulated through an internal coil in the distiller vessel.
7. Hot or warm water circulated through an external surface panel/plate on the upper surface of the distiller vessel.

The need to remove water from an ammonia refrigeration system has not characteristically been considered an integral part of system design. As a result, many systems typically lack the means to remove water. Designers should consider the means for sample collections and connections for distillers (e.g., connections for the source of heat and the supply and return of ammonia to the system.) It may also be prudent to consider the connection of a distiller's relief piping into system relief piping headers, or plan to route them separately. Designers should review the installation requirements of commercially available distillers and plan accordingly.

It is crucial that qualified personnel, whether from inhouse, a hired contractor service, or both who develop and perform the water removal procedure have safe work practices in place for performing the entire process.

Water contamination is different than the contamination of non-condensable gases. Water contamination needs to be removed by a distilling process while the contamination of non-condensable gases needs to be removed by a purging process. The distiller heats the contaminated liquid ammonia refrigerant to boil it off and return to the system while separating it from the water. The isolated water is then removed. A purging device used to remove non-condensable gases typically does not remove water contamination, other than an extreme small amount that is removed with the non-condensable gases when purged out of the system.

Appendix Q. (Informative) Application Examples for Internal Overpressure Relief Protection

This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the American National Standards Institute requirements for a standard and may contain material that has not been subject to public review or a consensus process. If options presented within this appendix are implemented, they must comply with the normative provisions of this standard.

Historically, Chapter 15 of ANSI/IIAR 2 established requirements for the application of overpressure protection for ammonia refrigeration systems that, preferably, discharge directly to atmosphere. This includes providing means and methods to quantify pressure drop due to vapor flow through vent piping to ensure the piping is properly sized to comply with stated back pressure limits on pressure relief valves as prescribed in the Standard. These means and methods, along with other requirements for overpressure protection, allow designers to demonstrate and document that their designs are in compliance with the standard.

The recently revised Chapter 15 provides more comprehensive coverage for overpressure protection configurations that discharge internally to the closed-circuit refrigeration system. This includes a methodology for evaluating pressure drop in the piping downstream of a vapor service internal relief valve while determining pressure losses downstream of an internal relief of liquid refrigerant is substantially more difficult due to the presence of two-phase flow. The updated chapter also includes prescribed limits to the maximum allowable back pressure (built-up) on the pressure relief device discharging internally to the system. These additions now enable designers to determine how best to engineer the overpressure protection in accordance with the requirements in the standard and provide end-users with a coherent design and design basis that both complies with RAGAGEP and maintaining system safety.

This informative Appendix provides demonstrates the use of the newly added requirements for internal relief for two of the most common configurations: oil pot connected to a low-side vessel and for a thermosiphon oil cooling heat exchanger.

ANSI/IIAR 2 Requirements

Recall that ANSI/IIAR 2 requirements for internal relief parallel those for atmospheric relief, that is, applying a relief valve in excess of the required capacity, accounting for inlet losses, and calculating pressure drop in the downstream piping.

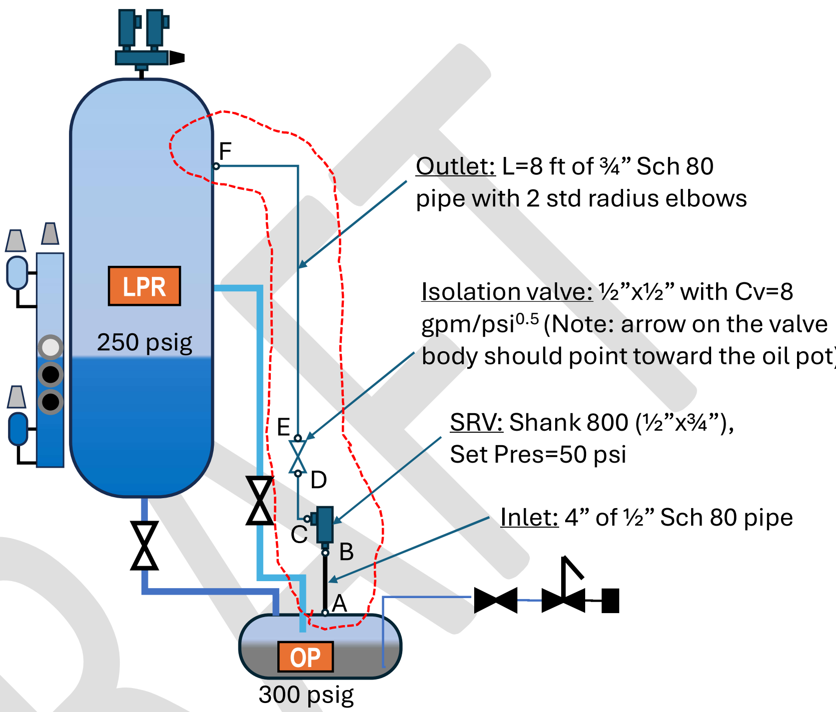
Example 1: OIL POT RELIEVING INTERNALLY TO AN LPR

This example demonstrates the application of ANSI/IIAR 2 Chapter 15 requirements for an oil pot with a 300 psig MAWP configured to relieve internally to an LPR with a 250 psig MAWP using a relief (single) device with a 50 psi set pressure. The specific requirements in Chapter 15 that apply to this configuration are found in Section 15.8.4.

Summary of the Pressure Relief Arrangement:

Atmospheric pressure:	14.32 psia (725' elevation)
OIL POT Dimensions:	6-5/8" DIA, 36" L
OIL POT MAWP:	300 psig
LPR MAWP:	250 psig
LPR Operating range:	20-40 psig

The pressure relief device is configured as internal with 4" of ½" NPS SCH 80 piping on the inlet. The relief valve is a Cyrus Shank 800 (½"x¾") with a set pressure of 50 psi. The valve is certified for gas (vapor) service by the National Board of Boiler and Pressure Vessel Inspectors. A vapor service relief device is selected for this particular installation arrangement because (1) the inlet to the pressure relief device located at the top of the oil pot where a vapor space exists in normal operation due to the vent pipe being stubbed into the pot and/or (2) the valve will only function when the pot is fully isolated and ammonia vapor is present at the top of the pot. (NOTE: There is no other relief valve widely used in the industrial ammonia refrigeration industry that is rated to 50 psi that would be appropriate for this application.) If a liquid-rated relief valve were to be installed, the ASME B&PV Code requires the inlet connection for the relief valve to be at or near the bottom of the oil pot. This would be accomplished by (1) the use of a dip tube that extends fully to where liquid (oil in this case) would always be present or (2) adding a connection at the bottom of the oil pot.



The piping connected to the outlet of the relief valve comprises a total of 8 ft (lineal) of ¾" NPS SCH 80 piping and includes two (2) standard radius elbows (1.2 ft equivalent length for each elbow) as well as a straight pattern isolation valve with a C_v of 8 gpm/psi$^{0.5}$ (10.57 ft equivalent length) for a total equivalent length piping between the relief valve outlet and the LPR of L=20.97 ft.

Relief Scenarios:

In general, all relief scenarios considered for this configuration have the oil pot isolated (valved-out) from the LPR with the oil pot experiencing an overpressure condition. Three distinct relief scenarios could be considered for evaluation and nominal design scenario (Scenario #1) is based on the design external heat load to the oil pot consistent with that of the sizing basis for the relief device - a fire condition.

1. Oil pot is isolated from the LPR and both the oil pot and LPR receive external heat addition causing overpressure triggering both the LPR and oil pot to relieve. In this case, the inlet pressure to the relief valve on the oil pot is assumed to be the oil pot relief valve's relieving pressure in accordance with Section 15.3.4.2 where the variable names have been slightly to apply to the equipment in this case, $P_{r,OP} = 1.1 \cdot (P_{set} + P_{bp,s}) + P_{atm}$, where $P_{bp,s}$ = 275 psig is the relieving pressure of the LPR is the superimposed back pressure at the outlet of the relief device. The outlet of the discharge piping connected to the oil pot relief valve is assumed to be the LPR's relieving pressure $1.1 \cdot P_{set,LPR} + P_{atm}$. The maximum allowable backpressure is evaluated in accordance with Section 15.8.4.4 or $P_{b,max} = 0.15 \cdot P_{set} + P_{r,downstream} + P_{atm} = 0.15 \cdot 50 + 275 + 14.32 = 296.82\ psia$.
2. Another possible relief condition arises when the oil pot is valved out from the LPR and the LPR is at its highest expected operating pressure, 40 psig. In this case, the oil pot relief will actuate when its inlet pressure reaches 90 psig (set pressure plus the 40 psig operating back pressure) or 104.32 psia which corresponds to a saturation temperature of 58°F. This operating temperature results in a heat load substantially less than a fire condition; therefore, this scenario does not present any risk for over-pressuring the oil pot. It does, however, raise a risk of an unwanted actuation of an internal relief valve if the oil pot is valved out and dwells in an environment where the ambient temperature is above 58°F.
3. In this case, the oil pot is valved out from the LPR and the LPR is at its lowest expected operating pressure, 20 psig. In this case, the oil pot relief will begin to actuate at 70 psig (set pressure plus 20 psig operating back pressure) or 84.32 psia which corresponds to a saturation temperature of 47°F. Similar Scenario 2, Scenario 3 is at even greater risk of the oil pot relief valve actuating if the oil pot is valved out and dwells in an environment where the ambient temperature is above 47°F.

DESIGN SCENARIO: Both Oil Pot and LPR are at their Respective Relieving Pressures

The relieving pressure for the LPR discharging to atmosphere is determined in accordance with 15.3.4.1 and Equation 15-1:

$$P_r = (1.1 \cdot P_{set}) + P_{atm} \qquad \text{Equation 15-1}$$

where:
P_r = relieving pressure, psia (kPa)
P_{set} = pressure relief device set pressure (equal to the vessel's design pressure), psig (kPa)
P_{atm} = local atmospheric pressure, psia (kPa)
The relieving pressure for the LPR then becomes:
$P_{r,LPR} = (1.1 \cdot 250) + 14.32\ psia = 289.32\ psia\ (275\ psig)$

In this scenario, the superimposed back pressure on the oil pot relief valve is the LPR relieving pressure, 275 psig. The relieving pressure for the oil pot discharging internally to the LPR is determined in accordance with 15.3.4.2and Equation 15-2:

$$P_r = (1.1 \cdot P_{set}) + P_{bp,s} + P_{atm} \qquad \text{Equation 18-1}$$

where:
P_r = relieving pressure, psia (kPa)
P_{set} = pressure relief device set pressure which is less than the vessel's design pressure, psig (kPa)
$P_{bp,s}$ = superimposed back pressure standing at the outlet of the relief device, psig (kPa)

NOTE: The superimposed back pressure is different based on the method of discharge:

- *For discharge to another part of the system (internal relief), this would be the maximum pressure downstream of the internal relief device.*
- *For discharge to a diffusion tank this would be the maximum static head of water in the tank.*
- *For discharge to a treatment system, this would be the maximum static pressure of the treatment system.*

P_{atm} = local atmospheric pressure, psia (kPa)
The oil pot's relieving pressure for this scenario then becomes:
$P_{r,OP} = 1.1 \cdot 50 + 275\,psig + \ 14.32\,psia = 344.32\,psia$

The required relief capacity for the oil pot is based on the requirement set forth in 15.8.2.1.1 for an external heat load using Equation 15-3

$$C_{\dot{m},e} = f \cdot K_{mat} \cdot A \qquad \text{Equation 15-3}$$

where:
$C_{\dot{m},e}$ = required pressure relief device discharge capacity due to external heat addition expressed on a mass flow rate of standard air basis, lb_m/min.
f = mass flow capacity factor for the relief device (air basis), lb_m/min
K_{mat} = 1.0 if no combustible materials are with 20 ft of the vessel [-]
K_{mat} = 2.5 if combustible materials are within 20 ft of the vessel [-]
A = largest projected area of component when viewed from any determined in accordance with Section 15.4.1, ft^2

The capacity factor, $f = 0.5$, is taken from Table 15-2 and the required capacity for the oil pot then becomes

$$C_{\dot{m},OP} = 0.5 \cdot 1.0 \cdot \frac{6.625\text{ in}}{12\,\frac{\text{in}}{\text{ft}}} \cdot 3\text{ ft} = 0.83\text{ lb}_\text{m}\text{/min (air)}$$

With an inlet pressure of 344.32 psia and configured to discharge to atmosphere, the capacity of a Cyrus Shank 800 would be 11.05 lb_m/min (air) based on the National Board's certified coefficient for this valve (0.420 SCFM/psia). Because this relief valve is configured to discharge internally when the coincident pressure at the relief valve outlet is significantly higher than near-atmospheric pressure which would be typical of a relief to atmosphere. In the case of an internal relief arrangement, the capacity of the SRV will be affected by the higher inlet pressure and higher coincident superimposed backpressure.

As indicated in Section 15.8.4.5, the designer should first seek information on the impact of these higher inlet & outlet pressures on the valve's capacity from the relief valve manufacturer. In the absence of manufacturer-specific information, a correction factor due to the presence of elevated backpressure can be estimated using Equation 15-17 which is based on a method documented in *Emerson's Pressure Relief Engineering Handbook* (2012) and generalized in the 2024 Jekel & Reindl IIAR paper (TP#7). In this case, the relief device capacity adjustment factor, K_b, is estimated to be $K_b = 0.592$ using Table 15-3 and Equation 15-17 results in an adjusted relief valve capacity for the oil pot of:

$$C_{\dot{m},OP,adj} = C_{\dot{m},OP} \cdot K_b = 11.05 \cdot 0.592 = 6.54\text{ lb}_\text{m}\text{/min (air)}$$

PRV required capacity: 0.83 lb_m/min AIR (fDL with no combustibles within 20')

Adjusted PRV capacity 1: 6.54 lb_m/min AIR (adjusted due to elevated inlet and back pressures resulting in a 59.2% derate of the valve's stamped capacity at 330 psig)

The inlet piping pressure loss is calculated based on the requirement set forth in 15.8.1.4 using Equation 15-3.

$$L = \frac{0.214 \cdot d^5 \cdot \left(P_{u,i}^2 - P_{d,i}^2\right)}{f \cdot C_r^2} - \frac{d \cdot ln\left(\frac{P_{u,i}}{P_{d,i}}\right)}{6 \cdot f} \qquad \text{Equation 15-3}$$

where:

$\boldsymbol{L = 1.26}$ **ft** [equivalent length of inlet piping including all non-recoverable form and fitting losses]

$\boldsymbol{C_r = 6.54}$ **lb$_m$/min (air)** [the mass flow rate (air) of the connected relief device]

$\boldsymbol{f = 0.02687}$ [Moody friction factor in fully turbulent flow, See Section A.15.8.1.4]

$\boldsymbol{d = 0.546}$ **in** [inside diameter of pipe or tube]

$P_{d,i}$ = unknown [downstream pressure (absolute) of the inlet piping assembly, i.e. the inlet pressure to the relief device, psia]

$\boldsymbol{P_{u,i} = 344.32}$ **psia** [the upstream pressure (absolute) of the inlet piping being analyzed, i.e. vessel's relieving pressure]

Solving Equation 15-3 iteratively for the unknown pressure in the downstream portion of the inlet piping (pressure at the inlet to the relief device), $P_{d,i} = 344.12$ psia or the inlet pressure drop is 0.2 psi (0.41% of the PRV set pressure, 0.2 psi / 50 psi).

Adjusted PRV capacity 2: 6.51 lb$_m$/min AIR (adjusted due to elevated inlet and back pressures resulting in a 59.2% derate of the valve's stamped capacity at 330 psig)

As noted above, the piping connected to the outlet of the relief valve comprises a total of 8 ft (lineal) of ¾" NPS SCH 80 piping and includes two (2) standard radius elbows as well as a straight pattern isolation valve with

The pressure loss in the piping downstream of the relief device is determined in accordance with Equation 15-18 as prescribed by Section 15.8.4.7.

$$L = \frac{0.214 \cdot d^5 \cdot \left({P'}_u^2 - {P'}_d^2\right)}{f \cdot C_r^2} - \frac{d \cdot ln\left(\frac{P'_u}{P'_d}\right)}{6 \cdot f} \qquad \text{Equation 15-18}$$

where:

$\boldsymbol{L = 20.97}$ **ft** [equivalent length of discharge piping]

$\boldsymbol{C_r = 6.54}$ **lb$_m$/min air** [the mass flow rate (air) into the discharge piping not derated for inlet pressure loss]

$\boldsymbol{f = 0.02467}$ [Moody friction factor in fully turbulent flow, See Section A.15.8.1.4]

$\boldsymbol{d = 0.742}$ **in** [inside diameter of pipe or tube]

$\boldsymbol{P'_d = 289.32}$ **psia** [the design pressure (absolute) of the LPR where the relief device discharge piping is connected]

$\boldsymbol{P'_u}$ **= unknown** [the upstream pressure (absolute) of the piping segment. The upstream pressure shall not exceed the maximum allowable back pressure of the relief device.]

Solving Equation 15-18 for the upstream pressure in the discharge piping, which is equal to the relief device outlet pressure or back pressure, yields $P'_u = 290.11\ psia$ for a pressure loss of 0.79 psi (or 1.6%= 0.79 psi/50 psi). The maximum back pressure at the outlet of the relief device cannot exceed 15% of the valve's set pressure in accordance with 15.8.4.4 and calculated as:

$$P_{b,max} = (0.15 \cdot P_{set}) + P_{r,downstream} + P_{atm} = (0.15 \cdot 50) + 275 + 14.32 = 296.82 \text{ psia}$$

Because the calculated back pressure, $P'_u = 290.11$ psia is less than the maximum allowable back pressure, $P_{b,max} = 296.82$ psia, the outlet pipe size along with the associated fittings are adequately sized.

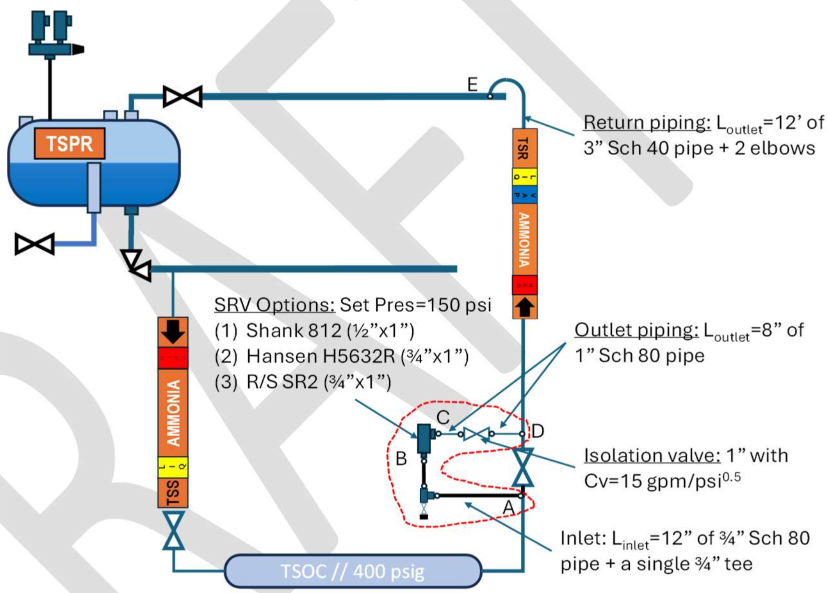
Two other scenarios were considered to confirm Scenario #1 is the case that defines the SRV sizing while ensuring the inlet and outlet piping are appropriately sized. The SRV with a 50 psi set pressure will open whenever the oil pot is isolated and the pressure in the oil pot is 50 psi greater than the pressure at the outlet of the relief valve - the LPR pressure. When the LPR pressure is within its range for normal operation, the capacity of the relief valve may be lower than the required capacity; however, this is not a necessarily compliance issue because the oil pot pressure would be able to rise to the MAWP (or MAWP plus the allowed overpressure) which would effectively increase the SRV's capacity.

Example 2: THERMOSIPHON OIL COOLER

This example demonstrates the application of ANSI/IIAR 2 Chapter 15 requirements to provide overpressure protection for the refrigerant-side of an oil cooling heat exchanger with a 400 psig MAWP configured to relieve internally to a thermosiphon pilot receiver (TSPR) with a 250 psig MAWP using a relief (single) device with a 150 psi set pressure.

Summary of the Pressure Relief Arrangement:

Atmospheric pressure:	14.32 psia (725' elevation)
Dimensions:	10" DIA, 10' L
Oil Cooling HR"	568.8 kBtu/hr
MAWP:	400 psig
TSPR MAWP:	250 psig
TSPR Operating range:	115-200 psig



The relief valve is configured as internal and certified for gas duty based on the assumption that (1) the relief device will be "active" when the oil cooling heat exchanger is valved out from the high-side of the system and becomes subject to overpressure and (2) the refrigerant-side of the oil cooling heat exchanger would be pumped out as a normal course of its isolation from the system. Because there are multiple relief valves with a set pressure of 150 psi to choose from, three options are included in this example. The installation has 12" (lineal) of SCH 80 ¾" NPS piping on the inlet and one (1) branch tee fitting with a connection for pump out. The piping on the outlet side of the pressure relief device comprises 8" (lineal) of SCH 80 1" NPS piping and a straight pattern isolation valve with a C_v of 15 gpm/psi$^{0.5}$. The example will also include pressure loss analysis for vapor flowing out of the relief branch piping to through TSR piping to the TS main which comprises 12' (lineal) of SCH 40 3" NPS with and two (2) standard radius elbows. No additional pressure loss is included in the TSR main piping to the thermosiphon pilot receiver.

DESIGN SCENARIO: Both Thermosiphon Oil Cooler and Pilot Receiver Relief Valves at their Respective Relieving Pressures

The relief scenario considered for this internal relief arrangement assumes the oil cooling heat exchanger is isolated (valved-out) from the high-side of the system. The further assumption is that operating personnel would have "pumped-out" refrigerant within the refrigerant-side of the oil cooler to avoid trapping liquid refrigeration in the heat exchanger during isolation as a normal practice for any equipment in an ammonia refrigeration system.

In this case, the refrigerant-side of the thermosiphon oil cooling heat exchanger is isolated from the high-side of the system and both the thermosiphon oil cooling (TSOC) heat exchanger and the thermosiphon pilot receiver (TSPR) receive external heat addition causing overpressure triggering both the TSOC heat exchanger and TSPR relief valves to relieve. In this case, the inlet pressure to the relief valve on the TSOC heat exchanger is assumed to be the TSOC relief valve's relieving pressure in accordance with Section 15.3.4.2, $P_{r,OC} = (1.1 \cdot P_{set}) + P_{bp,s} + P_{atm}$, where $P_{bp,s}$ = 275 psig (relieving pressure of the TSPR) as the superimposed back pressure at the outlet of the relief device. The oil cooler relief valve's relieving pressure then becomes $P_{r,OC} = (1.1 \cdot 150) + 275 + 14.32 = 454.32\ psia$. The outlet of the discharge piping connected to the TSOC relief valve is assumed to be the TSPR's relieving pressure $\left(1.1 \cdot P_{set,TSPR}\right) + P_{atm}$. The maximum allowable backpressure is evaluated in accordance with Section 15.8.4.6 or $P_{b,max} = 0.15 \cdot P_{set} + P_{r,downstream} + P_{atm} = (0.15 \cdot 150) + 275 + 14.32 = 311.82\ psia$ for a conventional relief valve.

The relief device capacity for heat exchangers is determined in accordance with Section 15.8.2.1. This section requires the minimum capacity due to external heat addition be determined using Equation 15-5 in Section 15.8.2.1.1. In addition, other sources of overpressure, including internal heat loads, must be evaluated in accordance with 15.8.2.1.2. The required capacity of the relief valve would be the larger of the sources of relevant sources of overpressure.

External Heat Load: Per Section 15.8.2.1.2 using a capacity factor, $f = 0.5$, from Table 15-2 and $K_{mat} = 1.0$) because no combustible materials are within 20 ft of the vessel. The capacity factor due to external heat load then becomes

$$C_{\dot{m},e} = f \cdot K_{mat} \cdot A \qquad \text{Equation 15-5}$$

$$C_{\dot{m},e,OC} = 0.5 \cdot 1 \cdot \frac{10\ in}{12 \frac{in}{ft}} \cdot 10\ ft = 4.2\ lb/\min(air) \qquad \text{Equation 15-5}$$

External Heat Load: Per Section 15.8.2.1.2, a modified capacity factor, f_1 is determined using the maximum internal heat load from the compressor oil of 568.8 kBtu/hr) using Equation 15-9

$$f_1 = \frac{\dot{Q}'_{max}}{150} \cdot f \qquad \text{Equation 15-9}$$

$\dot{Q}'_{max}$ is the maximum internal (or external) heat load, normalized to the largest projected area of the component, Btu/min-ft^2. For the oil cooling heat exchanger, it becomes:

$$\dot{Q}'_{max} = \frac{568{,}800\ Btu/hr}{60\ min/hr} \frac{\frac{568{,}800\ Btu/hr}{60\ min/hr}}{\frac{10\ in}{12\ in/ft} \cdot 10\ ft} = 1{,}137.6 \frac{Btu}{min-ft^2}$$

$$f_{1,OC} = \frac{1{,}137.6}{150} \cdot 0.5 = 3.792$$

The modified capacity factor is then used in Equation 15-7 as required by Section 15.8.2.1.2 to determine the required relief capacity based on the internal heat load.

$$C_{m,int} = f_1 \cdot K_{mat} \cdot A \qquad \text{Equation 15-7}$$

$$C_{\dot{m},OC,int} = 3.792 \cdot 1 \cdot \frac{10\ in}{12 \frac{in}{ft}} \cdot 10\ ft = 31.6\ lb/\min(air)$$

Because the internal heat load condition yields the largest required relief valve capacity, that becomes the basis for valve selection and further relief system analysis.

SRV Option (1): Cyrus Shank 812 (½"x1")

If the oil cooling heat exchanger was configured to discharge to atmosphere, the capacity of a Cyrus Shank 800 would be 46.5 lb_m/min (air) based on a relieving pressure of 454.32 psia and the National Board's certified coefficient for this valve of 1.339 SCFM/psia. Because this Shank 812 relief valve is configured to discharge internally with the pressure at the relief valve outlet significantly higher than near-atmospheric pressure, its relieving capacity will be affected by the higher inlet pressure (as opposed to the set pressure). As noted in the cases for the oil pot, a relief device capacity adjustment factor, K_b, is estimated to be $K_b = 0.82$ (from Table 15-3) resulting in a relief valve capacity for the oil cooling heat exchanger:

$$C_{\dot{m},OC,BP} = C_{\dot{m},OC} \cdot K_b = 46.5 \cdot 0.82 = 38.1 \text{ lb}_\text{m}\text{/min (air)}$$

However, this adjusted capacity does not account for inlet pressure losses to the relief valve - only the effects of higher inlet and outlet pressure.

The inlet piping pressure loss is calculated based on the requirements set forth in 15.8.1.4 using Equation 15-3.

$$L = \frac{0.214 \cdot d^5 \cdot \left(P_{u,i}^2 - P_{d,i}^2\right)}{f \cdot C_r^2} - \frac{d \cdot ln\left(\frac{P_{u,i}}{P_{d,i}}\right)}{6 \cdot f} \qquad \text{Equation 15-3}$$

where

- $\boldsymbol{L = 3.76\ ft}$ [1 ft length of inlet piping including 2.4 equivalent length due to flow turning through the tee which imposes a non-recoverable fitting loss, and the fitting loss of 0.36 ft due to the reduction from ¾" piping to the ½" relief device inlet]
- $\boldsymbol{C_r = 38.1}$ **lb_m/min** [the mass flow rate (air) of the connected relief device]
- $\boldsymbol{f = 0.02467}$ [Moody friction factor in fully turbulent flow, See Section A.15.8.1.4]
- $\boldsymbol{d = 0.742}$ **in** [inside diameter of the inlet piping]
- $\boldsymbol{P_{d,i}}$ **= unknown** [downstream pressure (absolute) of the inlet piping assembly, i.e. the inlet pressure to the relief device – noted as point B in the above schematic]
- $\boldsymbol{P_{u,i} = 454.32}$ **psia** [the upstream pressure (absolute) of the inlet piping being analyzed, i.e. vessel's relieving pressure – noted as point A in the above schematic]

Solving Equation 15-3 iteratively for the unknown pressure in the downstream portion of the inlet piping (which equals the pressure at the inlet to the relief device), $P_{d,i} = 452.18$ psia or the inlet pressure drop is 2.14 psi (1.4% of the PRV set pressure, 2.14 psi / 150 psi). In this case, the relief valve capacity adjusted for inlet pressure losses and elevated inlet and back pressure decreases to **37.9 lb_m/min** (air basis) which is still greater than the required capacity of 31.6 lb_m/min (air basis). This satisfies the capacity requirement of the relief valve for serving the design overpressure condition – internal heat load on the oil cooling heat exchanger. We now have to determine the back pressure on the relief valve and whether it is in excess of the maximum allowable back pressure.

There are two distinct segments of piping connected to the outlet of the relief device that will be evaluated as part of the discharge stream of the relief valve outlet

(1) twelve (12) lineal feet of 3" sch 40 pipe having an i.d. of 3.068" with two (2) elbows @5.8 equivalent feet per elbow for a total of 11.6 equivalent and

(2) eight (8) inches of 1" sch 80 pipe having an i.d. of 0.957", an isolation valve with a Cv=15 gpm/psi$^{0.5}$ @11.5 equivalent feet, and a non-recoverable loss for the expansion from 1" branch to the 3" thermosiphon return piping @2.8 equivalent feed for a total of 15 feet equivalent of the 1" sch 80 pipe.

Initially, we will assume the thermosiphon main pressure is equal to the relieving pressure for the pilot receiver at 275 psig + 14.32 = 289.32 psia. This known pressure at point E becomes the "outlet pressure" in the 3" thermosiphon return pipe segment being evaluated to point D. Equation 15-18 in Section 15.8.4.7 is used to calculate the pressure at point D.

$$L = \frac{0.214 \cdot d^5 \cdot (P'^2_u - P'^2_d)}{f \cdot C_r^2} - \frac{d \cdot ln\left(\frac{P'_u}{P'_d}\right)}{6 \cdot f} \qquad \text{Equation 15-18}$$

where

- $\boldsymbol{L}$ **= 11.6 ft** [equivalent length of 3" piping between points E and D in the above schematic]
- $\boldsymbol{C_r = C_{\dot{m},OC,BP}}$ **= 37.9 lb$_m$/min** [the mass flow rate (air) from the relief valve adjusted for inlet pressure loss and elevated pressure operation]
- f $= \mathbf{0.01731}$ [Moody friction factor in fully turbulent flow through 3" pipe, See Section A.15.8.1.4]
- $\boldsymbol{d = 3.068}$" [inside diameter of pipe segment]
- $\boldsymbol{P'_d = 289.32\ psia}$ [pressure in the downstream pipe segment at point E]
- $\boldsymbol{P'_u = unknown}$ [upstream pressure (absolute) in the piping segment at point D]

The calculated upstream pressure is 289.33 psia so the loss in the entire 3" segment of piping is only 0.01 psia which supports ignoring the pressure loss within the event larger piping from point E to the pilot receiver.

Now we use this known pressure at point D to calculate the pressure loss in the branch piping connected to the outlet of the relief valve to determine the pressure at point C which is the back pressure on the relief valve. As noted above, the piping connected to the outlet of the relief valve comprises a total of 8 in (lineal) of 1" NPS SCH 80 piping and a 1" isolation valve with a Cv=15 gpm/psi$^{0.5}$, and the expansion from 1" to 3" for a total equivalent length of 1" piping of 15 ft. Equation 15-16 is used to calculate the upstream pressure in that segment to point C.

$$L = \frac{0.214 \cdot d^5 \cdot (P'^2_u - P'^2_d)}{f \cdot C_r^2} - \frac{d \cdot ln\left(\frac{P'_u}{P'_d}\right)}{6 \cdot f} \qquad \text{Equation 15-18}$$

where

- $\boldsymbol{L\ =\ 15.0}$ **ft** [total equivalent length of discharge piping including 0.7 lineal ft + 11.5 equivalent ft for the isolation valve, and 2.8 equivalent ft for the expansion from the 1" branch piping to the 3" thermosiphon return piping.]
- $\boldsymbol{C_r\ =\ 37.9}$ **lb$_m$/min air** [the mass flow rate (air) from the relief device adjusted for inlet pressure losses to the relief valve and elevated operating pressure].
- $\boldsymbol{f\ =\ 0.02304}$ [Moody friction factor in fully turbulent flow for 1" pipe, See Section A.15.8.1.4]
- $\boldsymbol{d\ =\ 0.957}$ **in** [inside diameter of pipe or tube]
- $\boldsymbol{P'_d = 289.32}$ **psia** [the design pressure (absolute) of the LPR where the relief device discharge piping is connected]

P'_u = unknown [the upstream pressure of the piping segment to point C]

Solving Equation 15-18 for the upstream pressure in the 1" branch pipe connected to the outlet of the relief valve yields $P'_u = 294.4\ psia$ for a pressure loss of 5.07 psi (or 3.4%= 5.07 psi/150 psi). The maximum back pressure at the outlet of the relief device cannot exceed 15% of the valve's set pressure in accordance with 15.8.4.4 and calculated as:

$$P_{b,max} = (0.15 \cdot P_{set}) + P_{r,downstream} + P_{atm} = (0.15 \cdot 150) + 275 + 14.32 = 311.82 \text{ psia}$$

Because the calculated back pressure, $P'_u = 294.4$ psia is less than the maximum allowable back pressure, $P_{b,max} = 311.82$ psia, the outlet pipe size along with the associated fittings are adequately sized.

SRV Option (1):

PRV required capacity:	31.6 lb_m/min – air basis (internal heat load)
Adjusted PRV capacity:	38.1 lb_m/min – air basis (adjusted for elevated operating pressure)
Inlet pressure loss:	2.14 psi (1.4%)
Adjusted PRV capacity: and inlet pressure loss	37.9 lb_m/min – air basis (adjusted for elevated operating pressure
Built-up back pressure:	5.07 psi (3.3% which is less than 15% max allowable)
Pressure loss in the TSR:	0.01 psi

SRV Option (2): Hansen Technologies H5632R (¾"x1")

Using the same analysis approach as shown above, the results for SRV Option (2) are:

Adjusted PRV capacity:	46.4 lb_m/min AIR (82% of rated capacity at 452.9 psia)
Inlet pressure loss:	2.93%
Adjusted PRV capacity: and inlet pressure loss)	45.8 lb_m/min – air basis (adjusted for elevated operating pressure
Built-up back pressure:	7.3 psi (4.9%)
Pressure loss in the TSR:	0.02 psi

Because this relief valve has a greater nominal capacity, the inlet pressure loss increases as well as the back pressure on the relief valve. The relief valve selection along with the inlet and outlet piping & fittings yield a compliant option.

SRV Option (3): R/S SR2 (¾"x1")

Using the same analysis approach as shown above, the results for SRV Option (3) are:

Adjusted PRV capacity:	38.9 lbm/min – air basis (82% of rated capacity at 452.9 psig)
Inlet pressure loss:	2.21%
Adjusted PRV capacity: and inlet pressure loss)	38.6 lb_m/min – air basis (adjusted for elevated operating pressure
Built-up back pressure:	5.2 psi (3.5%)
Pressure loss in the TSR:	0.02 psi

This SRV option also is compliant with SRV's relieving capacity between the Shank 812 and the Hansen H5632R. Because the Shank 812 had the lowest relieving capacity that was compliant, the decision is to specify this SRV as the candidate relief valve for further evaluation/consideration with the R/S SR2 as an alternate option.

Conclusion

These examples were intended to demonstrate how the newly crafted requirements for internal relief as-proposed for Chapter 15 can be applied for internal relief. The two most common cases of internal relief were shown: oil pot relieving to its parent vessel and the refrigerant-side of a thermosiphon oil cooling heat exchanger.

Appendix R. (Informative) References and Sources of References

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R.2 Sources of References (Informative)

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1330 Kemper Meadow Drive, Suite 600
Cincinnati, OH 45240
www.acgih.org

R.2.2 American National Standards Institute (ANSI)
25 West 43rd Street, 4th Floor
New York, NY 10036
www.ansi.org

R.2.3 ASHRAE
180 Technology Parkway
Peachtree Corners, GA 30092
www.ashrae.org

R.2.4 American Society of Mechanical Engineers (ASME)
ASME International
Two Park Avenue
New York, NY 10016-5990
www.asme.org

R.2.5 ASTM International
100 Barr Harbor Drive
P.O. Box C700
West Conshohocken, PA 19428-2959
www.astm.org

R.2.6 Environmental Protection Agency (EPA)
1200 Pennsylvania Avenue, N.W.
Washington, DC 20004
www.epa.gov

R.2.7 European Committee for Standardization (EN)
CEN-CENELEC Management Centre
Rue de la Science 23
B - 1040 Brussels, Belgium
www.cencenelec.eu

R.2.8 International Association of Plumbing and Mechanical Officials (IAPMO)
4755 E. Philadelphia St.
Ontario, CA 91761
www.iapmo.org

R.2.9 International Code Council (ICC)
500 New Jersey Ave. NW, 6th Floor
Washington, DC 20001
www.iccsafe.org

R.2.10 IIAR
1001 North Fairfax Street, Suite 503
Alexandria, VA 22314
www.iiar.org

R.2.11 Manufacturers Standardization Society (MSS)
127 Park St. NE
Vienna, VA 22180
www.msshq.org

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1 Batterymarch Park
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www.nfpa.org

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Publications Department
200 Constitution Avenue, NW, Room N3626
Washington, DC 20210
www.osha.gov

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Research and Special Programs Administration
Office of Hazardous Materials Safety
1200 New Jersey Avenue, S.E.
Washington, DC 20590
www.dot.gov

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7321 Shadeland Station Way, Suite 285
Indianapolis, IN 46256
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R.2.16 FM Global
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R.2.17 International Organization for Standardization (ISO)
ISO Central Secretariat
Chemin de Blandonnet 8
CP 401 - 1214 Vernier, Geneva, Switzerland
www.iso.org

R.2.18 UL LLC
UL Headquarters
333Pfingsten Road
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www.ul.org

R.2.19 National Institute of Standards and Technology (NIST)
100 Bureau Drive
Gaithersburg, MD 20899
www.nist.gov

R.2.20 The International Society of Automation (ISA)
67 T. W. Alexander Drive
PO Box 12277
Research Triangle Park, NC 27709
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R.2.21. International Safety Equipment Association (ISEA)
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Arlington, VA 22209-1762
www.safetyequipment.org

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8484 Westpark Drive
Suite 220
McLean, VA 22102
www.cganet.com