BSR/IIAR CO2-20xx

Safety Standard for Closed-Circuit Carbon Dioxide Refrigeration Systems

Public Review #1 Draft

Following are supplementary instructions for submitting comments:

1) Provide all of the commenter's contact information [e.g. name, phone number(s), and e-mail].

2) Identify the specific Section (i.e. by its Chapter and Section number) that is the subject of each comment(s).

3) Provide specific wording changes or action that would resolve the commenter's concern(s). Additions to the text are shown by underlining and deletions by strikethrough, unless otherwise indicated. (i.e. Addition: include this, Removal: remove this).

4) Provide a brief substantiation statement that presents the rationale, justification, and supporting documentation; as well as any technical data and back up. Provide an abstract for lengthy substantiations. If supplementary documents are provided to support your comment(s), electronic files in word processed (MS Word preferred) or scanned form are preferred. Indicate whether attachments have been provided. Highlighting pens should not be used since highlighted text will not reproduce.

5) If you do not understand the material, proceed with doing the necessary homework to gain understanding of the material and/or call the IIAR to discuss before commenting. Do not submit comments as opinions or questions.

International Institute of Ammonia Refrigeration
1001 North Fairfax Street, Suite 503
Alexandria, VA 22314
Phone: (703) 312-4200
Fax: (703) 312-0065
www.iiar.org

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Notes on the Standard Text

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Informative Appendix A was added to provide explanatory material 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.”

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Foreword
(Informative)

This standard specifies minimum requirements for the safe design, safe installation, startup, and inspection, testing, and maintenance (ITM) of closed-circuit carbon dioxide refrigeration systems and any modifications or additions to an existing system. This standard reflects the consensus reached by the refrigeration industry representatives and is not a comprehensive task list for startup and should not be used in that manner.

For the purpose of this standard, it is assumed that the carbon dioxide refrigeration system and the modifications or additions to an existing system have been designed for the duty that it is to perform, that all piping and electrical equipment has been installed, and that adequate connections for the startup and test instruments have been provided. Since this document defines the minimum requirements for carbon dioxide refrigeration systems, it may not be sufficient to meet other standards and/or regulations that are applicable to each specific refrigeration system. Accordingly, precautions and additional requirements may be necessary because of particular circumstances, project specifications, or other jurisdictional considerations.

Informative Appendix A was included to provide explanatory information related to provisions in the standard. Sections of the standard with associated explanatory information are marked as an asterisk “*” after the section number, and the associated appendix information is located in Appendix A with a corresponding section number preceded by “A”.

At the time of publication of this new standard, the IIAR Standards Committee included the following members:

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Andy Campbell – Leo a Daly
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TITLE: Safety Standard for Closed-Circuit Carbon Dioxide Refrigeration Systems

Part 1.   General

Chapter 1.   Purpose, Scope, and Applicability

1.1  Purpose.

1.1.1  This standard specifies minimum requirements for the safe design of closed-circuit carbon dioxide refrigeration systems.

1.1.2  This standard specifies minimum requirements for the safe installation of closed-circuit carbon dioxide refrigeration systems.

1.1.3  This standard specifies minimum requirements for startup of closed-circuit carbon dioxide refrigeration systems.

1.1.4  This standard specifies minimum requirements for inspection, testing, and maintenance of new and existing closed-circuit carbon dioxide refrigeration systems.

1.2  Scope.

1.2.1  Stationary closed-circuit refrigeration systems utilizing carbon dioxide as the refrigerant shall comply with this standard.

1.2.2  This standard also applies to:

1.  Systems or parts of systems that function as heat pumps utilizing carbon dioxide as the refrigerating or heating medium.

2.  The part of refrigeration systems utilizing carbon dioxide as the low temperature refrigerant within a cascade system.

3.  The part of refrigeration systems utilizing carbon dioxide as a secondary fluid.

4.  Carbon dioxide refrigeration systems and heat pumps operating part-time or full-time with a transcritical cycle.

5.  *Additions or modifications to existing carbon dioxide refrigeration systems.
1.2.3 This standard does not apply to:

1. Replacements of refrigeration equipment or piping with functional equivalents.

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 buildings and facilities shall be maintained in accordance with the regulations that applied at the time of installation or construction.

3. Parts of a refrigeration system or heat pump that do not contain carbon dioxide as a refrigerant or secondary fluid.

4. Listed equipment or systems.

1.3 Applicability.

1.3.1 Conflicts. Where there is a conflict between this standard and an adopted building, fire, mechanical or electrical code, the requirements of the locally-adopted code shall take precedence unless otherwise stated in such code.

1.3.2 Alternative Materials and Methods. The Authority Having Jurisdiction (AHJ) is authorized to approve the use of devices, materials, or methods not prescribed by this standard as an alternative means of compliance, provided that any such alternative has been shown to be equivalent in quality, strength, effectiveness, durability and safety.

1.3.3 Installations in Locations Without an Authority Having Jurisdiction (AHJ). Where a system is installed in a jurisdiction without an Authority Having Jurisdiction (AHJ), the designer is authorized to specify an alternative, and the alternative shall be documented in the design documents.
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.

Alarm Message: A machine-to-person communication that is important or time sensitive.

Automatic Record Keeping: The collection of operating conditions without the use of a trained operator.

Cascade Refrigeration System: A refrigeration system having two or more refrigerant circuits, each with a pressure imposing element, a condenser, and an evaporator, where the evaporator of one circuit absorbs the heat rejected by another (lower temperature) circuit.

Crevice Corrosion: The localized attack on a metal surface at, or immediately adjacent to, the gap or crevice between two joining surfaces. The gap or crevice can be formed between two metals or a metal and non-metallic material.

Critical Point: The highest pressure and temperature for a pure gas at which the liquid and vapor phases can exist in equilibrium. For carbon dioxide, this occurs at a temperature of 87.9 °F (31.1 °C) and a pressure of 1070.6 psia (7381.8 kPa, abs).

Documentation: Material that provides details of information, facts, knowledge, official confirmation, evidence, or a combination thereof that is conveyed or represented by an arrangement or sequence and can serve as a record. It includes data that is accurate and timely, specific and organized for a purpose, presented in a context that gives it meaning and relevance, can lead to an increase in understanding and decrease in uncertainty, and is valuable because it can affect behavior, a decision, or an outcome.

Dry Nitrogen (Vapor): Minimum Grade “L” as defined by the Compressed Gas Association with a minimum nitrogen content of 99.998%, and a maximum of 4 ppmv moisture.

Emergency Shut-Off Valve: A shut-off valve that has been specifically identified for equipment or system emergency shutdown, mitigation, or both.

Frequency: The interval rate that inspections, testing, and maintenance (ITM) tasks are performed.

Gauge: A device for measuring the magnitude of pressure or temperature that provides a visual display indication of its measurement.
Heat Exchanger: Equipment that uses heat transfer surfaces such as coils constructed of pipes or tubes placed inside a shell or paired plates that are welded or brazed together or elastomerically sealed that may be placed inside a shell or stacked between pressure end-plates.

Inspection: The evaluation and assessment of equipment, a component, a system, or a portion of a system using human senses such as vision, hearing, touch, smell, or a combination thereof.

Installed: The condition under which a device, a component, or equipment is currently physically or wirelessly connected to any portion of the refrigeration system or an ancillary safety system.

Institutional Occupancy: A premise or that portion of a premise from which, because they are disabled, debilitated, or confined, occupants cannot readily leave without the assistance of others. Institutional occupancies include, among others, hospitals, nursing homes, asylums, and spaces containing locked cells.

ITM: Abbreviation of inspection, testing, and maintenance.

Maintenance: Work performed to keep equipment, components, and devices operating safely or to make repairs.

Manufacturer: An entity, enterprise, or organization that makes a product or products for sale through a process or processes involving raw materials, components, or assemblies, usually on a large scale.

MDMT (Minimum Design Metal Temperature): The lowest temperature the equipment can withstand with the chosen material and thickness.

Mixed Occupancy: Occurs where two or more occupancies are located within the same building. When each occupancy is isolated from the rest of the building by tight walls, floors, and ceilings and by self-closing doors, the requirements or each occupancy shall apply to its portion of the building. When the various occupancies are not so isolated, the occupancy having the most stringent requirements shall be the governing occupancy.

Nondestructive Testing (NDT): Test methods used to examine an object, material, or system without impairing its future usefulness.

Operating Limits: Defined upper or lower operating control limits which are the extent of the defined operating range within the safe design limits of the equipment or system.

Predictive Maintenance: Services performed to reduce the probability of unexpected equipment or component failure.
Qualified Inspector: A person who is experienced with closed-circuit CO2 refrigeration systems, has knowledge of the process, and has demonstrated proficiency and understanding to perform inspections.

Record Keeping: A record of periodic inspections, tests, servicing, and other operations and maintenance.

Residential Occupancy: A premise or that portion of a premise that provides the occupants with complete independent living facilities, including permanent provisions for living, sleeping, eating, cooking, and sanitation. Residential occupancies include, among others, dormitories, hotels, multiunit apartments, and private residences.

Self-Contained System: Unitary equipment consisting of a completely factory assembled and factory tested system whose refrigerant carrying components are all inboard of the unit; including compressor, condenser, evaporator and metering device. If any of the refrigerant containing components are remote, such as the condenser, the unit is not considered to be self-contained.

Stationary: A closed-circuit refrigeration system that operates in a fixed location.

Subcritical Cycle: A CO2 refrigeration cycle where evaporation occurs in the subcritical region and the thermal energy is rejected to a condenser operating at a pressure below the critical point.

Sudden Liquid Deceleration: The rapid decrease of liquid flow in a line or pipe, for example due to the sudden closing of a valve. This is also referred to as hydraulic shock or liquid hammer.

Supports: Any load bearing support that carries the expected static loads of the refrigeration equipment, such as the roof, ceiling, steel, concrete, anchor bolts, building structures, piping, insulation, and includes providing support and protection from the expected dynamic loads and movement (e.g. snow, rain, sleet, seismic, wind, moving parts).

Test: The operation of equipment, a component, or a device to verify that it is functioning correctly, or the measurement of a system characteristic to determine if it meets requirements.

Testing: A procedure used to determine the operational status of equipment, a component, a device, or a system by conducting periodic functional checks.

Transcritical Cycle: A vapor compression CO2 refrigeration cycle where evaporation occurs in the subcritical region and thermal energy is rejected to a gas cooler operating at or above the critical point.

Trapped Liquid: The complete filling of the internal volume of a container, such as a pressure vessel, pipe, or valve with liquid refrigerant subject to temperature rise. This is also referred to as hydraulic lockup.
**Triple Point**: The temperature and pressure at which a material exists simultaneously as a solid, liquid, and gas. For carbon dioxide the triple point is -69.9 °F (-56.6 °C) and 75.1 psia (518 kPa, abs).

**Vapor Propelled Liquid (Hydraulic Shock, Liquid Hammer, or Surge)**: The high-velocity movement of liquid refrigerant propelled by high-pressure vapor in hot gas or suction lines due to high or excessive differential pressure. This is also referred to as hydraulic shock, liquid hammer, or surge.

**Volatile Secondary Fluid**: Heat transfer medium that undergoes phase change at a constant pressure and temperature.
Chapter 3. Reference Standards

3.1 Air-Conditioning, Heating, & Refrigeration Institute (AHRI), standard as follows:
AHRI Standard 700 with Addendum 1 (2017), Specifications for Refrigerants.

3.2 American Society of Mechanical Engineers (ASME), standards as follows:
ASME B&PVC (2017), Boiler and Pressure Vessel Code, Pressure Vessels, Section VIII, Division 1.
ASME B16.21 (2016), Nonmetallic Flat Gaskets for Pipe Flanges.
ASME B16.22 (2018), Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings.
ASME B16.50 (2018), Wrought Copper and Copper Alloy Braze-Joint Pressure Fitting.

3.3 American Society of Testing and Materials (ASTM), standards as follows:

3.4 International Institute of Ammonia Refrigeration (IIAR), standards as follows:

3.5 National Fire Protection Association (NFPA), standards as follows:

3.6 Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, regulations as follows:
Part 2. Design Considerations Affecting Construction

Chapter 4. Location of Refrigeration Equipment

4.1 General. The location of carbon dioxide refrigeration equipment shall comply with this chapter.

4.1.1 Equipment Location. Refrigeration equipment located in a machinery room complying with Chapter 6 or located outdoors in accordance with Section 4.2.2 shall be permitted.

4.1.2 Multiple Refrigerants in Same Room. Where more than one refrigerant is contained in the same room, the requirements for all the refrigerants shall be considered and the most stringent requirements shall apply.

4.2 Permissible Equipment Locations. Refrigeration equipment shall be located in a machinery room complying with Chapter 6 unless otherwise permitted by this section.

4.2.1 Listed Equipment. Listed equipment constructed and installed in accordance with the listing and the manufacturer’s instructions shall be permitted in any occupancy without a machinery room.

4.2.2 Outdoor Installations. Refrigeration equipment shall be permitted to be installed outdoors. Refrigeration equipment, other than piping, installed outdoors shall be located not less than 20 ft from building openings, except for openings to a machinery room or openings to an industrial occupancy complying with Section 7.2. Equipment located outdoors within 20 ft of openings to other occupancies shall be in accordance with Section 4.2.4 or Section 4.2.5.

4.2.3 Industrial Occupancies and Refrigerated Rooms. The following refrigeration equipment shall be permitted to be installed outside of a machinery room indoors in industrial occupancies and refrigerated rooms complying with Chapter 7.

1. Evaporators, including their associated surge drums, used for refrigeration or dehumidification.

2. Heat reclaim heat exchangers used for heating the space in which they are located.

3. Low-probability pumps.
4. Valves, including but not limited to control and pressure-relief valves, and connecting piping, any of which are associated with Items 1, 2, and 3.

5. Refrigeration system or portions thereof with a total connected compressor drive power not exceeding 100 HP (74.6 kW).

4.2.4 *Public Assembly, Commercial, and Large Mercantile Occupancies.* Refrigeration equipment shall be permitted outside of a machinery room indoors in a public assembly occupancy, commercial occupancy, or large mercantile occupancy. The quantity of refrigerant shall be limited such that a complete discharge from any independent refrigerant circuit will not result in a carbon dioxide concentration exceeding 30,000 ppm in any room or area where equipment containing carbon dioxide is located. The calculation procedure for determining the concentration level shall comply with Section 5.3.

4.2.5 **Institutional and Residential Occupancies.** Refrigeration equipment shall be permitted outside of a machinery room indoors in an institutional occupancy, or residential occupancy. The quantity of refrigerant shall be limited such that a complete discharge from any independent refrigerant circuit will not result in a carbon dioxide concentration exceeding 15,000 ppm in any room or area where equipment containing carbon dioxide is located. The calculation procedure for determining the concentration level shall comply with Section 5.3.

4.2.6 **Use of Carbon Dioxide Refrigeration with Secondary Fluids.** Carbon dioxide refrigeration equipment located in a machinery room complying with Chapter 6 or outdoors in accordance with Section 4.2.2 shall be permitted to be used in conjunction with a secondary fluid that serves any occupancy, provided that the system is one of the following types and that use of the secondary fluid is in accordance with the Mechanical Code:

1. Indirect closed system.

2. Double-indirect open-spray system.
Chapter 5. General System Design Requirements

5.1 General. The design of closed-circuit carbon dioxide refrigeration systems shall comply with this chapter.

5.2 Refrigerant Specifications.

5.2.1 Carbon Dioxide. Refrigerant-grade carbon dioxide that meets or exceeds the minimum requirements noted in Table 5.2 shall be used for the initial charge and subsequent re-filling of the system to the operating inventory.

5.2.2 The supplier shall ensure that the purity of the carbon dioxide meets the requirements of the equipment manufacturer and at a minimum meet the requirements of Table 5.2.

5.2.2.1 The quality of the refrigerant shall be verified by standard practice in accordance with AHRI Standard 700.

Table 5.2 Purity Requirements

<table>
<thead>
<tr>
<th>Purity (by weight)</th>
<th>&gt; 99.9% (minimum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (water)</td>
<td>&lt; 10 ppm (by weight), -77 °F Dew Point</td>
</tr>
<tr>
<td>Air and Other Noncondensables (% by volume – vapor phase)</td>
<td>1.5% (maximum)</td>
</tr>
<tr>
<td>High Boiling Point Residue, Maximum (% by weight)</td>
<td>0.0005%</td>
</tr>
<tr>
<td>Particulates/Solids</td>
<td>Visually Clean</td>
</tr>
</tbody>
</table>

5.3 Volume Calculation for Determining Concentration of a refrigerant Release. For the purpose of applying Section 4.2.4, and Section 4.2.5, the volume used to calculate the potential refrigerant concentration in the event of a release shall comply with this section. The volume used to calculate the potential refrigerant concentration shall be the smallest gross volume of rooms or spaces in which the released refrigerant will accumulate.

5.3.1 *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 refrigerant 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.

5.3.2 **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.

5.3.3 **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.

5.3.4 **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 isolation 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.

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

5.5.1 **General**

5.5.1.1 **System Design Pressure**

1. The designer shall determine the system design pressures in accordance with 5.5.2 and 5.5.3.

2. Design pressure of refrigeration system components shall not be less than the system design pressures determined in accordance with Item 1.

3. Equipment and Piping Connected to a Pressure Vessel. Equipment and 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 set pressure of the pressure relief protection for the pressure vessel.

5.5.1.2 **Pressure-Limiting Devices.** In determining the design pressure, an
allowance shall be provided for setting pressure-limiting devices at not greater than 90% of the pressure-relief device settings to avoid equipment shutdown or loss of refrigerant during normal operation.

5.5.1.3 **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.

5.5.1.4 **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 permitted to equal the design pressure of the existing low-pressure side.

5.5.1.5 **Equipment and Piping Hydrostatic Overpressure Protection.** Provide overpressure protection in accordance with Section 11.8.

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

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

5.5.2.2 **Standby or Shutdown Conditions.** Where the design pressure calculated in Table 5.5.3 will be exceeded in the event of refrigerant warming to ambient temperature during normal standby or shutdown conditions, one of the following means shall be provided to maintain pressure at or below the design pressure:

1. A pressure relieving connection that will relieve excess pressure to a lower pressure part of the system.

2. A pressure relief valve in accordance with Chapter 11.

3. By other means as approved by the Authority Having Jurisdiction.

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

5.5.3 Minimum Permissible Design Pressure.

5.5.3.1 Components of refrigeration systems that utilize carbon dioxide as a heat transfer fluid shall comply with the minimum design pressure requirements in Table 5.5.3. The pressure at maximum operating conditions referenced by Table 5.5.3 shall be the highest pressure experienced during the following conditions:

1. Startup.

2. Full-load operation at the warmest heat rejection design condition.

3. Defrost, for systems designed with defrost capability.

5.5.3.2 Subcritical Systems and Minimum Permissible Design Pressure. The design pressure shall be as defined in Table 5.5.3.

5.5.3.3 Transcritical Systems and Minimum Permissible Design Pressure. The design pressure shall be as defined in Table 5.5.3.

Table 5.5.3 Minimum Design Pressures

<table>
<thead>
<tr>
<th>Type of System</th>
<th>Minimum Design Pressure</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Highside</td>
</tr>
<tr>
<td>Subcritical Refrigeration Systems - Cascade</td>
<td>Not less than 120% of the pressure developed by a pressure imposing element</td>
</tr>
<tr>
<td>Subcritical Refrigeration Systems - Circuits Without Compressor</td>
<td>Not less than 110% of the circuit pressure at maximum operating conditions</td>
</tr>
<tr>
<td>Transcritical Refrigeration Systems</td>
<td>Not less than 110% of the maximum pressure developed by a pressure imposing element</td>
</tr>
</tbody>
</table>
5.5.4  **Vacuum.** Refrigeration system components and equipment shall be designed for a vacuum of 29.0 in. (737 mm) of mercury.

5.6  **System Design Temperature.** The system 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 designer shall provide operating temperature limit information.

5.7  **Materials**

5.7.1  **General**

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

5.7.2  **Metallic Materials**

5.7.2.1  Metallic materials shall be permitted in accordance with ASME B31.5 or ASME B&PVC, Section VIII, Division 1. Metallic materials shall be permitted in accordance with Section 5.7.1 and Section 5.6.

5.7.3  **Nonmetallic Materials**

5.7.3.1  Nonmetallic materials shall be permitted in accordance with Section 5.7.1.

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

5.8  **Evacuation.** Means shall be provided to evacuate all portions of the closed-circuit refrigeration system including provisions to avoid trapping liquid in portions of the system.

5.9  **Lubrication Management**
5.9.1 **General.** Provisions shall be made in the system design to return refrigerant lubricant to the compressor(s).

5.9.2 **Compressors.** Compressor packages shall have a means to sample refrigerant lubricant for periodic analysis when required by the manufacturer’s recommendations or after a compressor motor failure.

5.10 **Insulation**

5.10.1 **Condensation and Frost Control.** Piping and equipment surfaces shall be insulated, treated, or otherwise protected to prevent condensation and excessive frost buildup from becoming a hazard or causing damage to the structure, electrical equipment, or refrigeration system.

**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.

5.11 **Supports and Foundations for Piping, Tubing, and Equipment**

5.11.1 **General.** Supports and anchorage for refrigeration equipment shall be designed in accordance with local jurisdictional codes.

5.11.2 **Combustibility.** Structural supports shall be noncombustible.

5.11.3 **Seismic Joints and Restraints.** Seismic joints and restraints shall be provided as required by local jurisdictional codes.

5.11.4 **Manufacturers’ Recommendations and Expected Loads.** Supports and foundations shall meet or exceed the manufacturers’ recommendations and shall be designed to carry expected loads.

5.11.5 **Vibration and Movement Resistance.** Supports and foundations shall be designed to prevent excessive vibration or movement of piping, tubing, and equipment.

5.12 **Service Provisions**
5.12.1  *General*. Equipment shall be accessible for maintenance, as required by the local jurisdictional codes.

5.12.2  **Charging Connection Security**. Refrigeration system charging connections shall be capped. When located outdoors, they shall be locked or otherwise restricted to access by only authorized personnel.

5.12.3  *Maintenance and Functional Testing*. Design provisions for maintenance and functional testing of safety controls shall be provided. Such provisions shall not disable primary safety elements such as high-pressure safety switches.

5.12.4  **Pressure Gauges**. Where a pressure gauge is installed on the refrigeration system, the gauge shall be capable of measuring and displaying not less than 120% of the applied system design pressure.

5.12.5  *Service Isolation Valves*. Serviceable equipment 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 hand 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 refrigerant for servicing one or more devices in lieu of isolation valves.

5.12.5.1  Where a risk of trapping liquid refrigerant between isolation valves or components during system operations exists, hydrostatic overpressure protection devices shall be installed.

5.12.6  **Pressure and Temperature Indicating Devices**. The system shall be fitted with pressure and temperature indicating devices, including but not limited to gauges or readouts that allow an observer to visually determine the operating conditions of the system’s primary refrigerant suction and discharge piping and other components as necessary for maintenance and operation of the system as determined by the system designer.

**EXCEPTION:** Packaged systems and portions of built-up systems shall be permitted to have an arranged means for indication as determined appropriate for the application.

5.13  **Testing and Ultimate Strength**

5.13.1  **Strength Testing**. Items making up the pressure containing envelope of equipment
containing refrigerant shall be strength tested, by the Manufacturer, to the minimum pressure exceeding the design pressure specified in Section 5.5.

5.13.1.1 Refrigeration equipment shall be strength 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.

5.13.1.2 Compressors and refrigerant pumps shall be to strength tested by the manufacturer to 1.5 times the design pressure.

EXCEPTION: For hermetic, dual containment low-probability pumps, the secondary containment pressure test shall be at a minimum of 1.25 times the design pressure.

5.13.2 Ultimate Strength. Items making up the pressure containing envelope of refrigeration equipment shall comply with Sections 5.13.2.1 and 5.13.2.2.

EXCEPTION: The following shall be permitted to comply with Section 5.13.2.3 in lieu of complying with this section:

1. Pressure vessels.

2. Provided that they are not part of a pressure vessel: piping including valves; evaporators; condensers; and heating coils with refrigerant as the working fluid.

3. Pressure gauges.

4. Refrigerant pumps.

5. Control mechanisms.

5.13.2.1 *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, and assembled to have an ultimate strength sufficient to withstand three (3) times the design pressure for which it is rated.

5. Designed in accordance with ASME B&PVC, Section VIII, Division 1.
5.13.2.2  *Secondary fluid* 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 (1724 kPa gauge) or two times the design pressure for which they are rated.

**EXCEPTION:** Equipment with carbon dioxide as the secondary coolant shall be in accordance with 5.13.2.1.

5.13.2.3  Equipment designed based on the Exception to Section 5.13.2 shall be required to comply with additional requirements in Chapter 8 and ASME B31.5, as applicable.

5.14  Signage, Labels, Pipe Marking

5.14.1  **Installation Identification.** Each refrigeration system erected on the premises shall be provided with a legible permanent sign, securely attached and easily accessible, indicating:

1. The name of and address of the installer,
2. The refrigerant number and amount of refrigerant.
3. The lubricant identity and amount.
4. The field test pressure(s) applied.

5.14.2  Equipment **Labels.** Refrigeration equipment shall be provided with identification labels.

5.14.3  **Emergency Shutdown Valve Identification and Tagging.** Valves required for emergency shutdown of the system shall be clearly and uniquely identified at the valve itself and in the system schematic drawings.

5.14.4  **Nameplates**

5.14.4.1  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.

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

5.14.4.3  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(e).
5.14.5 **Pipe Marking.** Refrigerant piping mains, headers, and branches shall be identified with labels stating the following information:

1. “CARBON DIOXIDE”, corresponding to the contained refrigerant type.
2. Pipe service, which shall be permitted to be abbreviated.

5.14.5.1 Piping labels shall include the following descriptive information:

1. Physical state of the refrigerant.
2. Relative pressure level of refrigerant, being low or high as applicable.
3. Direction of flow.

**EXCEPTION:** In lieu of the above items the marking system shall either be one established by a recognized model code or standard or one described and documented by the facility owner.

5.15 **Emergency Shutdown Documentation.** It shall be the duty of the owner or owner’s designated representative in charge of the premises at which the carbon dioxide refrigeration system, containing more than 55 lb. (25 kg) of refrigerant, is installed to provide directions for the emergency shutdown of the system at a location that is readily accessible to the trained refrigeration system technician and trained emergency responders. Schematic drawings or signage shall include the following:

1. Instructions with details and steps for shutting down the system in an emergency.
2. The name and telephone numbers of the refrigeration operating, maintenance, and management staff, emergency responders, and safety personnel.
3. Quantity of refrigerant in the system.
4. Type and quantity of refrigerant lubricant in the system.
5. Field test pressures applied.

5.16 **Equipment Enclosures**

5.16.1 **General.** Enclosures for refrigeration or heat pump equipment shall be suitable for the installation location and shall be provided with protection from physical and environmental damage as required by the authoritative jurisdictional codes.

5.16.2 **Egress.** Operational and maintenance service egress shall be provided by access panels or doors, or the design shall provide for remote service by removal of the
enclosure or the contents from the installed location.

5.17 General Safety Requirements

5.17.1 Protection from Physical Damage. Where refrigerant-containing equipment is installed in a location subject to physical damage from vehicular traffic guards or barricades shall be provided.


5.17.3 Carbon Dioxide Storage. Carbon dioxide refrigerant shall be stored in cylinders or vessels designed for carbon dioxide refrigerant containment and access restricted to authorized personnel.

5.17.4 *Used Equipment. Used equipment to be installed as a replacement for equipment in 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 or an expansion to an existing system shall meet the requirements of this standard.

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

5.17.6 *Illumination of Equipment Areas. Illumination shall be available for refrigeration equipment work areas.

5.17.7 *Means of Egress. Means of egress shall comply with the Building Code.

5.17.8 Refrigeration Piping. Refrigerant piping with 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 located adjacent to passageways, aisles, walkover stairs, or landings, shall be provided with one of the following: 1. caution signs, 2. insulation, or 3. guards to prevent contact.
Chapter 6.  Machinery Rooms

6.1  General. Where a machinery room is required by Chapter 4 to contain refrigeration equipment, the machinery room shall comply with this chapter.

6.2  Construction. Machinery rooms shall be constructed in accordance with the building code 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. Doors shall comply with Section 6.6.

6.2.2  Piping Supports. Where piping is supported by the floor, roof, or ceiling structure, the structure or foundation supporting the piping shall be designed to support the expected static and dynamic loads, including seismic loads. Foundations and supports shall be in accordance with the building code.

6.2.3  Equipment Supports. Foundations, floor slabs, and supports for compressor units and other equipment located within the machinery room shall be of noncombustible construction and capable of supporting the expected static and dynamic loads imposed by such units, including seismic loads. Foundations and supports shall be in accordance with the building code.

6.2.3.1 A compressor or condenser supported from the ground shall rest on a concrete pad or base or shall be furnished with a support base for setting directly on and anchoring to the foundation.

6.2.4  Vibration Control. Equipment shall be mounted in a manner that prevents excessive vibration from being transmitted to the building structure or connected equipment. Isolation materials shall be permitted between the foundation and equipment.

6.2.5  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 refrigerant leakage in the machinery room 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, as required by Section 5.17.7, 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 5.12.1.

6.3.3 **Access to Valves**

6.3.3.1 *Manually operated valves that are inaccessible from floor level shall be operable from portable platforms, fixed platforms, ladders, or shall be chain operated.

6.3.3.2 Manually operated isolation valves identified as being part of the system emergency shutdown procedure shall be directly operable from the floor or chain operated from a permanent work surface. Emergency valve identification shall comply with Section 5.14.3.

6.3.4 **Restricted Access.** Access to a machinery room shall be restricted to authorized personnel. Signage on machinery room doors shall comply with Section 6.11.

6.4 **Piping**

6.4.1 **Insulation.** Piping and fittings shall be insulated as required by Section 5.10.

6.4.2 **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.

6.4.3 **Pipe Marking.** Piping shall be marked as required by Section 5.14.5.

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

6.5 **Drains**

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

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

6.6 **Entrances and Exits**

6.6.1 **General.** Machinery rooms exceeding 1,000 ft² (93 m²) 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 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.

6.6.2 **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. Doors to the outdoors shall be fire rated where required by the Building Code based on the fire rating required for exterior wall openings.

### 6.7 Lighting

6.7.1 **General.** Machinery rooms shall be equipped with light fixtures delivering a minimum of 30 foot-candles (320 lumens/m2) at the working level, 36 in. (0.91 m) above a floor or platform.

6.7.2 **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.

### 6.8 Emergency Control Switches

6.8.1 **Emergency Stop Switch.** A clearly identified emergency shut-off switch with a tamper resistant cover 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 located in the machinery room. The function of the switch shall be clearly marked by signage near the controls.

6.8.2 **Emergency Ventilation Control Switch.** A clearly identified control switch for emergency ventilation with a tamper-resistant cover 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.

### 6.9 Refrigerant Detection and Alarm

6.9.1 **General.** Machinery rooms shall be provided with refrigerant detection and alarm in accordance with Sections 13.3–13.6 and the following features:

1. At least one detector shall be provided for each refrigerant contained in the room or area.
2. The refrigerant detector shall activate an alarm that reports to a monitored location so that corrective action can be taken at an indicated carbon dioxide concentration of 5,000 or higher.

3. 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 is activated. Additional audible and visual alarms shall be located outside of each entrance to the machinery room.

4. Audible and visual alarms shall be labeled.

5. The power supply for the refrigerant detectors and alarms shall be a dedicated branch circuit.

6. In the event of a loss of power on other circuits or an emergency shutdown of refrigeration equipment, the refrigerant detection and alarm system shall remain on.

7. In the event of a loss of power to the refrigerant detection and alarm system, a power failure trouble signal shall be sent to a monitored location.

6.9.2 *Alarm Response

6.9.2.1 Detection of Carbon Dioxide

6.9.2.1.1 Detection of carbon dioxide concentrations less than 5,000 ppm requires no alarm.

6.9.2.1.2 *Detection of carbon dioxide concentrations equal to or exceeding 5,000 ppm shall activate visual indicators and audible alarms as specified in Section 6.9.1. The visual indicator and audible alarm shall be permitted to automatically reset if the carbon dioxide concentration drops below 5,000 ppm.

6.9.2.1.3 Detection of carbon dioxide concentrations equal to or exceeding 15,000 ppm (1/2 IDLH) shall activate visual indicators and an audible alarm per Section 6.9.2.1.2 and shall also activate emergency ventilation, where required, in accordance with Section 6.10.7. Once activated, emergency ventilation shall continue to operate until manually reset by a switch located in the machinery room.

6.10 Ventilation

Mechanical ventilation shall be provided for machinery rooms and shall be sized to exhaust the minimum quantity of air during normal operating and emergency conditions.
6.10.1 **Ventilation for Occupants.** In occupied conditions, outdoor air shall be provided at a rate of not less than 0.5 cfm/ft\(^2\) (0.0025 m\(^3\)/s • m\(^2\)) of machinery room area or 20 cfm (0.009 m\(^3\)/s) per occupant, whichever is greater.

6.10.2 **General Exhaust and Air Conditioning Equipment.** Machinery room exhaust fans and air conditioning equipment that is not intended for exhausting refrigerant vapor shall be de-energized, and fan dampers, where provided, shall close upon detection of refrigerant in accordance with Section 6.9.2.1.2.

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

   6.10.3.1 Mechanical exhaust ventilation systems shall be automatically activated by refrigerant leak detection in accordance with Section 6.9 or temperature sensors and shall be manually operable.

   6.10.3.2 Mechanical exhaust ventilation systems shall be designed to produce not less than the temperature control ventilation rate required by Section 6.10.6 and the emergency exhaust ventilation rate required by Section 6.10.7.

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

   6.10.3.4 *Machinery room exhaust shall vent to the outdoors no fewer than 20 ft (6 m) from a property line or openings into buildings.

   6.10.3.5 Machinery room exhaust shall discharge vertically upward in such a manner as not to cause a nuisance or danger.

6.10.4 **Fan Options.** Multiple fans or multispeed fans shall be permitted to provide both temperature control exhaust ventilation in accordance with Section 6.10.6 and emergency exhaust ventilation in accordance with Section 6.10.7. 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.

6.10.5 **Inlet Air.**

   6.10.5.1 Outdoor make-up air shall be provided to replace air being exhausted and shall maintain negative pressure in the machinery room, not to exceed 0.25 in. (6.4 mm) water column relative to the adjacent areas with a machinery room door, including the outdoors.
6.10.5.2 Make-up air supply locations in the machinery room shall be positioned to:

1. Prevent short-circuiting of the make-up air directly to the exhaust.

2. Ventilate the room by taking into account the density of the refrigerant(s) relative to air.

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

6.10.5.4 Intakes for make-up air shall be positioned to draw uncontaminated outdoor air.

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

6.10.5.6 Motorized louvers or dampers, where utilized, shall fail to the open position upon loss of power.

6.10.5.7 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.

6.10.6 Temperature Control Ventilation

6.10.6.1 *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 a 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.

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

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

1. A thermostat measuring space temperature.
2. A manual control switch provided in accordance with Section 6.8.2, where temperature control ventilation is designed to contribute to emergency ventilation.

6.10.7 Emergency Ventilation

6.10.7.1 Emergency mechanical ventilation systems shall provide airflow not less than the quantity obtained by the following equation or 15 air changes per hour based on the gross machinery room volume, whichever is greater.

\[ Q = 100 \sqrt{G} \]

Where

- \( Q \)  Airflow rate (ft\(^3\)/min)
- \( G \)  Mass of refrigerant charge (lbs.) in the largest independent refrigeration circuit of the system, any part of which is in the machinery room.

The emergency ventilation system shall be permitted to include temperature control ventilation fans that meet the requirements of Section 6.10.6.3, Item 2.

**EXCEPTION:** Where approved, emergency mechanical ventilation shall not be required for a refrigeration system that will not yield a carbon dioxide concentration exceeding 15,000 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 5.3. The designer shall provide a copy of the calculations to be retained at the site.

6.10.7.2 Emergency mechanical ventilation shall be activated by both of the following:

1. Refrigerant leak detection complying with Section 6.9.
2. A manual control switch provided in accordance with Section 6.8.2.

6.10.7.3 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.
6.10.7.4 A monitored location shall be notified upon loss of power to or failure of the emergency mechanical ventilation system.

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

6.11.1 **NFPA 704 Placards.** Refrigeration units or systems having a refrigerant circuit containing more than 220 pounds (100 kg) of carbon dioxide shall be provided with placards in accordance with NFPA 704 and the Mechanical Code.

6.11.2 **Alarm Signage.** Alarm signage shall be provided in accordance with Section 13.6.

6.11.3 **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.
Chapter 7. Refrigeration Equipment Located in Areas Other Than Machinery Rooms

7.1 General. Refrigeration systems or equipment that are permitted by Section 4.2 in areas other than a machinery room shall comply with this chapter.

7.2 Requirements for Nonmachinery Room Spaces. Where a carbon dioxide 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.

EXCEPTION: Equipment which will not exceed the RCL in accordance with Section 4.2.

7.2.1 *Separation. The area shall be separated from other occupancy classifications 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 13.6. The detection and alarm system shall comply with Chapter 13.

EXCEPTION: Unoccupied areas with continuous piping that does not include valves, valve assemblies, equipment, or equipment connections.

7.2.4 *Physical Protection. Where equipment containing refrigerant is located in an area with heavy vehicular traffic during normal operations and a risk of impact exists, vehicle barriers or alternative protection shall be provided by posts or other physical barriers.

7.2.5 Temperature Control Ventilation. The area where heat generating equipment is located shall have temperature control ventilation in accordance with Section 6.10.6.

7.2.6 Environmental Compatibility. Equipment shall be designed to operate in the environmental conditions of the area where it will be installed.

7.2.7 Illumination of Equipment Areas. See Section 5.17.6.

7.2.8 Service Provisions. Service provisions shall comply with Section 5.12.

7.2.9 Penthouses. Penthouses that are open to an interior space shall be regulated as part of the interior space. Penthouses that are isolated from an interior space shall be regulated as an equipment enclosure in accordance with Section 5.16.

7.2.10 The floor area per occupant is not less than 100 ft² (9.3 m²).
EXCEPTION: The minimum floor area shall not apply where the space is provided with egress directly to the outdoors or into approved building exits.

7.3 Ventilation.

7.3.1 Outdoor Systems. Outdoor systems include those that comply with Section 4.2.2 and comply with the natural ventilation requirements of this section. For outdoor systems, natural ventilation shall be provided in accordance with this Section. For systems installed outdoors that do not comply with the natural ventilation requirements of this section, Level 1 detection and alarm shall be provided in accordance with Section 13.6.1. The detection and alarm system shall comply with Chapter 13.

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

\[
F = G^{0.5} (I-P) \\
F = 0.138G^{0.5} (SI)
\]

Where

\(F\) = the free opening area, \(ft^2\) (\(m^2\)).

\(G\) = the mass of carbon dioxide in the largest independent circuit, any part of which is located within the enclosure or structure, \(lb\) (\(kg\)).

7.3.2 Equipment Located in Confined Spaces

7.3.2.1 Where refrigeration equipment containing carbon dioxide is located in a space which requires a confined space permit, emergency ventilation at a rate of 15 air changes per hour shall be provided and refrigerant detection and alarm complying with Section 6.9 shall be provided. The emergency mechanical exhaust ventilation system shall comply with Sections 6.10.7.3 and 6.10.7.4.

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

7.3.2.3 Where ventilation is arranged to exhaust through a room that is open to the confined space, the combined volume of the confined space and the room shall serve as the basis for calculating emergency mechanical exhaust ventilation.
Chapter 8. Carbon Dioxide Refrigeration Equipment

8.0 General. Refrigeration Equipment shall comply with this chapter.

8.1 Compressors

8.1.1 Requirements.

8.1.1.1 Any compressor selected for a carbon dioxide refrigeration system shall be specifically designed for use with carbon dioxide and the system’s application.

8.1.2 Design Pressure.

8.1.2.1 The minimum design pressure shall comply with Table 5.5.3.

8.1.3 Compressor Protection.

8.1.3.1 Compressors shall be protected from fracture by a pressure relief mechanism.

8.1.3.2 The pressure relief valve shall be sized to allow full mass flow under all conditions.

8.1.3.2.1 *The relief device shall be sized based on compressor flow at a minimum of 50°F (10°C) saturated suction temperature at the compressor suction or at design saturated suction temperature, whichever is greater.

EXCEPTIONS:

1. Low-Stage or Booster Compressors: For compressors capable of operating only when discharging to the suction of a higher-stage compressor, flow shall be calculated at the saturated suction temperature that is equal to the design operating intermediate temperature.

2. The discharge capacity of the relief device 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 the minimum flow at not greater than 90% of the pressure-relief device setting.
   c. A pressure-limiting device is installed and set in accordance with
the manufacturer instructions.

8.1.3.3 If a discharge stop valve is fitted the pressure relief valve shall be fitted between the compressor and the stop valve.

8.1.3.4 All compressors shall be fitted with manual reset high pressure cut out switch.

8.1.3.5 High pressure cut out switches shall always be set at least 10% below the pressure relief valve setting.

8.1.3.6 Compressors shall be fitted with crankcase heaters to prevent the condensation of refrigerant.

8.1.3.7 The crankcase heaters shall be controlled to avoid over pressurizing the compressor.

8.1.4 Equipment Identification.

8.1.4.1 See Table 8.1 Nameplate requirements.

8.2 Refrigerant Pumps

8.2.1 Requirements.

8.2.1.1 Only pumps specifically designed for use with carbon dioxide shall be selected for use in carbon dioxide systems.

8.2.1.2 If a pump is isolatable, a means of hydrostatic pressure relief shall be provided to avoid over pressure.

8.2.1.3 Where positive displacement pumps are utilized, protection shall be provided by a hydrostatic pressure relief device from the discharge side of the pump to the lowside of the system.

8.2.2 Design Pressure.

8.2.2.1 The minimum design pressure shall comply with Table 5.5.3.

8.2.3 Equipment Identification.

8.2.3.1 See Table 8.1 Nameplate requirements.
8.3  Air-Cooled Condensers and Gas Coolers

8.3.1  Requirements.

8.3.1.1  Where the heat exchanger is isolatable either automatically or manually, provision shall be made to relieve over pressure.

8.3.1.2  All heat exchangers shall be specifically designed for carbon dioxide and the particular system’s application.

8.3.2  Design Pressure.

8.3.2.1  The minimum design pressure shall comply with Table 5.5.3.

8.3.3  Equipment Identification.

8.3.3.1  See Table 8.1 Nameplate requirements.

8.4  Evaporators

8.4.1  Requirements.

8.4.1.1  All evaporators shall be specifically designed for carbon dioxide and the particular application.

8.4.1.2  Where the evaporator is isolatable either automatically or manually, provision shall be made to relieve over pressure in accordance with Section 11.8.

8.4.2  Design Pressure.

8.4.2.1  The minimum design pressure shall comply with Table 5.5.3.

8.4.3  Equipment Identification.

8.4.3.1  See Table 8.1 Nameplate requirements.

8.5  Heat Exchangers Other Than Air Exchangers

8.5.1  Requirements.

8.5.1.1  Heat exchangers selected for a carbon dioxide refrigeration system shall be specifically designed for use with carbon dioxide and the system’s application.

8.5.1.2  Where the heat exchanger is isolatable automatically, provision shall be
made to relieve over pressure in accordance with Section 11.8.

8.5.2 Design Pressure.

8.5.2.1 The minimum design pressure shall comply with Table 5.5.3.

8.5.3 Equipment Identification.

8.5.3.1 See Table 8.1 Nameplate requirements.

8.6 Pressure Vessels

8.6.1 Requirements.

8.6.1.1 Any vessel selected for a carbon dioxide refrigeration system shall be specifically designed for use with carbon dioxide and the system’s application.

8.6.1.2 Where the vessel is isolatable automatically, provision shall be made to relieve over pressure in accordance with Section 11.8.

8.6.2 Design Pressure.

8.6.2.1 The minimum design pressure shall comply with Table 5.5.3.

8.6.3 Equipment Identification.

8.6.3.1 See Table 8.1 Nameplate requirements.
# Table 8.1
Nameplate(s) Requirements

<table>
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<tr>
<th>Manufacturer’s Name</th>
<th>Compressor</th>
<th>Refrigerant Type</th>
<th>Condenser / Gas Cooler</th>
<th>Forced Air Evaporator</th>
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Chapter 9. Piping

9.1 General. Piping 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.

9.2 Pipe, Tubing, Fittings, and Flanges

9.2.1 Material. Piping materials shall comply with ASME B31.5 and as specified in this section. CO₂ piping systems can and may use carbon steel, stainless steel, copper, and aluminum with the following considerations.

9.2.1.1 ASTM A53-Type F pipe and cast iron or wrought iron pipe shall not be used for the pressure-containing side of closed-circuit carbon dioxide refrigeration systems.

9.2.1.2 ASTM 333 Grade 6 carbon steel pipe requires additional considerations for operating conditions below -50 °F (-45.6 °C).

9.2.1.3 ASTM A53 and A106 carbon steel pipe require additional considerations for operating conditions below -20 °F (-28.9 °C).

9.2.1.4 ASTM B280 Type ACR B seamless (nitrogenized) copper tube is permitted for sub-critical CO₂.

9.2.1.5 *ANS C119400 XHP 120 high pressure copper (ASTM rating number pending) is permitted for both subcritical and trans-critical systems when listed by an approved nationally recognized testing laboratory. MAWP shall be at least 1885 psig (130 Bar).

9.2.1.6 ASTM A-312 Grade 304, 304L, 316, 316L stainless steel are permitted.

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

9.2.3 Tubing

9.2.3.1 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.
9.2.3.1.1 Carbon steel tubing and carbon steel compression fittings shall be limited to valve sensing pilots, compressors, compressor packages, and packaged systems.

9.2.4 Fittings

General. Brazed, welded, or soldered copper fittings require the use of annealed pressure ratings.

Flared fittings are not permitted at locations where the system operating temperature is less than 40 °F (4.4 °C).

9.2.4.1 Steel

9.2.4.1.1 Butt weld fittings shall match 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.

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

9.2.4.2 Copper and Copper Alloys

9.2.4.2.1 Brazed:

9.2.4.2.1.1 ASTM B280 Type ACR B seamless (nitrogenized) copper tube is permitted for sub-critical CO₂. Pressure ratings are to be verified.

9.2.4.2.1.2 ANSI C119400 XHP 120 high pressure copper is permitted for transcritical applications.

9.2.4.2.1.3 Fittings: Wrought copper in accordance with ASME B16.22.

9.2.4.2.1.4 Joints: Silver solder, 45% Ag - 80% Cu - 5% P using non-corrosive flux for copper to steel or brass; 15% Ag for copper to copper.

9.2.4.2.2 Flanged:

9.2.4.2.2.1 Bronze or brass in accordance with ASME B16.24, Class to match duty.
9.2.4.2.2  Bronze or brass in accordance with ASME B16.26.

9.2.5  **Stainless Steel**

9.2.5.1  ASTM A182M-F, 304, 304L, 316, 316L are permitted.

9.2.6  **Threaded Pipe, Fittings, and Joints**

9.2.6.1  Pipe, fittings, and joints with threaded connections shall conform with pressure and other design requirements in accordance with Chapter 5.

9.2.7  **Flanges**

9.2.7.1  Flanges

9.2.7.1.1  Flanges in accordance with ASME B16.5 shall comply with the requirements of ASME B31.5, and the flange class shall be based on the design working pressure and corresponding maximum working temperature.

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

9.3  **Valves in Equipment and System Design**

See Chapter 10 Valves for valve general information, performance criteria, valve requirements, materials of construction, pressure envelope requirements, design validation, and marking requirements.

9.3.1  Where the manufacturer’s specifications indicate that a particular vertical, horizontal, or rotational orientation is required for proper operation of a valve, the system design shall indicate the required orientation.

**EXCEPTION:** Where the system design accommodates an installation not in accordance with the manufacturer’s specification.

9.3.2  Where a valve is deliberately specified for use with the directional indicator marked by the manufacturer being opposite of the normal direction of flow, the system design shall specify the intended installation direction.

9.3.3  Where valve gaskets are permitted, valve gasket materials shall be in accordance with the valve manufacturer’s specifications and shall be of the thickness specified.

9.3.4  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 11.6.

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

9.3.6 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.

9.3.7 Shut-off valves connecting refrigerant-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.

9.3.8 Shut-off valves required for system emergency shutdown procedures shall be readily accessible and identified in accordance with Sections 5.14.3 and 6.3.3.2. Other valves shall be accessible in accordance with Section 6.3.3.1 if installed in a machinery room.

9.3.9 Shut-off valves shall be installed at 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.

3. At the refrigerant inlet and outlet of a pressure vessel containing liquid refrigerant and having an internal gross volume exceeding 3 ft³ (0.085 m³).

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 refrigerant 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 refrigerant 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 refrigerant-containing pipe connecting any two parts of a system.
9.4 Piping, Hangers, Supports, and Isolation

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

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

9.4.3 Threaded hot-rolled steel hanger rods shall be permitted.

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

9.4.5 Mechanically expanded concrete anchor bodies shall not be adjusted or axially spun after being set.

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

9.4.7 Location of Refrigerant Piping

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

**EXCEPTION:** Where approved, 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.

9.4.7.2 Refrigerant piping shall not obstruct a means of egress.

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

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

9.4.7.5 Refrigerant piping shall be permitted to be installed underground provided that the piping is protected from corrosion.

9.4.7.6 Refrigerant piping installed in concrete floors shall be encased in pipe duct.
Chapter 10. Valves

10.1 General. Valves used in closed-circuit refrigeration systems utilizing carbon dioxide as the refrigerant shall comply with this chapter.

For Valves in Equipment and System Design, See Chapter 9 Piping, Section 9.3.

10.1.1 Valves include shut-off valves, control valves, check valves, ball valves, gauge valves, and strainers designed and manufactured for use in closed-circuit refrigeration systems utilizing carbon dioxide as the refrigerant.

10.1.2 This chapter includes criteria for materials of construction, pressure-containing envelope, seat leakage, quality assurance, marking, and production testing applicable to finished products as delivered by the original manufacturer.

10.1.3 Compliance with this chapter shall not be required for products manufactured prior to the publication date of this standard.

10.1.4 This chapter shall not apply to the following:

10.1.4.1 Valves wholly contained within the pressure-containing envelope of other equipment, such as slide valves in screw compressor casings.

10.1.4.2 Strainer baskets wholly contained within the pressure-containing envelope of other equipment, such as strainers in compressor casings.

10.1.4.3 Safety relief valves within the scope of Section VIII of the ASME Boiler and Pressure Code.

10.1.4.4 Float switches.

10.1.4.5 Liquid level transmitters.

10.2 Performance Criteria.

10.2.1 Valves intended for carbon dioxide refrigeration service shall meet the design requirements of ASME B31.5.

10.2.2 The performance criteria in this chapter applies to actuator elements that form a part of the pressure-containing envelope on valves.

10.2.3 The performance criteria applies to valves incorporating a mechanical actuating float or other mechanism exposed to the refrigerant.
10.3 Valve Requirements.

10.3.1 A valve shall perform its designated function over the range specified by the manufacturer for the system design conditions as required by Chapter 5.

10.3.2 All shut-off valves shall incorporate a backseat feature such that the stem (spindle) seal can be serviced with the valve under pressure.

**EXCEPTION:** Quarter-turn ball and butterfly valves, gate valves, and uni-body valves.

10.3.3 Flow Direction

10.3.3.1 The manufacturer shall mark the direction of flow on a valve intended to flow in only one direction, such as a check valve, by placing a directional arrow on the valve body. The manufacturer’s literature shall identify valves designed to also permit fluid flow opposite to the directional arrow on the valve body.

10.3.3.2 Where a manually seated valve will tolerate a maximum seat sealing pressure differential (MSSPD) that exceeds the pressure differential against which the actuator mechanism will support opening of the valve, the manufacturer shall specify the maximum permissible opening pressure differential. The manufacturer shall mark the valve to indicate the direction of pressure difference for which the actuator will support opening of the valve at or above the MSSPD.

10.3.4 Control valve maximum operating pressure differential (MOPD) and reverse-flow MSSPD shall be specified by the manufacturer. The MOPD is permitted to be less than the maximum allowable working pressure (MAWP) if the valve is marked accordingly.

10.3.5 Multi-function valves shall comply with the requirements of each incorporated valve type’s functions.

10.3.6 Valve-actuating attachments shall be designed and installed in accordance with the valve manufacturer’s requirements.

10.3.7 Valve internal configurations that may incidentally capture fluid within an internal cavity as a function of actuation, such as ball valves, shall incorporate a method for equalizing to prevent hydrostatic pressure increase within the cavity.

10.3.8 The applicable assembly and installation procedures for the valve bonnet, flanges, and other pressure-containing attachments to the valve shall be specified by the
manufacturer and made available on request.

10.3.9 Valve design and construction shall prevent unintentional extraction of the valve stem (spindle), loosening or removal of the bonnet, or both through actuation of the valve.

10.3.10 The permissible seat leakage for control valves that are not designed to functionally stop flow shall be made available by the manufacturer on request.

10.3.11 Seal Caps

10.3.11.1 Seal caps shall be designed such that the attachment mechanism permits gradual removal of the cap, such as screw threads, enabling venting of any pressure contained within the cap before the cap is disengaged from the valve.

10.3.11.2 Where seal caps are specified as pressure-containing, they shall have the same MAWP as the valve and be identified in the manufacturer’s literature and by marking the cap.

10.3.12 The manufacturer’s product documentation shall be made available upon request and shall include the relevant specifications, performance information, and marking information required by this standard.

10.4 Materials of Construction.

10.4.1 All valves and strainers shall be manufactured using only those materials that comply with the requirements of ASME B31.5.

10.4.2 Mating or companion flanges and flange hardware used on flange-mounted valves and strainers shall meet or exceed the manufacturer’s specified pressure and temperature range of the valve.

10.4.2.1 Mating or companion flanges intended for installation by welding shall be manufactured from carbon steel or stainless steel material compatible with the material specification of the pipe to which the flange is welded.

**EXCEPTION**: Aluminum flanges welded to aluminum connections on manufactured equipment are permitted.

10.4.2.2 Mating or companion flanges intended for installation on the pipe by screw thread joint shall be manufactured from carbon steel, stainless steel, or ductile iron material.
10.5 Pressure Envelope Requirements.

10.5.1 Pressure/Temperature Range. The design of the valve-pressure envelope shall meet minimum criteria in accordance with Chapter 5.

10.5.2 Flange mounted valves shall have the flange faces of the valve and mating flange(s) limited to captive gasket style or raised face style to ensure retention of the sealing gaskets between the mating faces.

10.6 Design Validation.

The manufacturer shall retain a permanent record of each proof test procedure and results.

The manufacturer shall provide design validation test results upon request.

Test apparatus or restraints applied to the shut-off valve, control valve, or strainer to perform the proof test(s) shall not adversely influence test validity.

The valve design shall be validated through the applicable proof test(s) on a production sample(s) as follows:

10.6.1 Pressure Envelope. Shut-off valves, control valves, and strainers, including field-mounted control valve sub-assemblies and pressure-containing seal cap(s) where applicable:

   a. PRESSURE ENVELOPE PROOF TEST: At room temperature [60 °F (15.6 °C) to 100 °F (37.8 °C)]:
      
      i) sustain 2.2 times MAWP for one minute without visible leakage, and
      
      ii) withstand 3 times MAWP for one minute without bursting.

   b. VACUUM LEAK TEST: Exhibit not more than 150 microns pressure increase over 24 hours at room temperature after evacuation to a maximum pressure of 1,500 microns absolute and isolation from the vacuum source.

      These tests shall separately validate the stem (spindle) packing and, where applicable, the pressure-containing seal cap(s).

10.6.2 Shut-Off Valves.

   a. DESTRUCTIVE STEM (SPINDLE) TORQUE TEST(S): At room temperature [60 °F (15.6 °C) to 100 °F (37.8 °C)] the valve assembly, as delivered by the original manufacturer, shall be tested under conditions of stem (spindle) failure to verify the integrity of
i) pressure containment at room temperature MAWP;

ii) the disc, seat, and back seat mechanisms against failure; and

iii) MSSPD containment on top of the seat at full forward (in) stem (spindle) position.

Tests i) and ii) shall be conducted at stem (spindle) positions of full forward (in) and full backward (out).

b. SEAT SEAL TEST AT THE SPECIFIED UPPER- AND LOWER-TEMPERATURE LIMIT MAWP: The valve assembly, as delivered by the original manufacturer, shall be tested to validate that the seat maintains a bubble-tight seal to atmosphere for 60 minutes

i) in both directions of flow; OR

ii) only in the designated direction of flow when the valve is so marked, provided the reverse-flow MSSPD is also specified and documented by the manufacturer.

c. SEAT OPENING TEST AT ROOM TEMPERATURE [60 °F (15.6 °C) to 100 °F (37.8 °C)]: The valve assembly, as delivered by the original manufacturer, shall be tested at the pressure difference between room temperature MAWP and atmosphere to validate that the valve can be opened

i) with the pressure respectively under and above the seat, OR

ii) with the pressure only in the designated direction of flow when so specified by the manufacturer and marked on the valve.

EXCEPTION: A lower MSSPD may be used for this test provided this value is specified by the manufacturer and marked on the valve.

10.6.3 Control Valves. Control valves shall be proof tested for maximum seat leakage as a percentage of rated Cv (Kv) at the MAWP applied as a pressure difference (ANSI/FCI-70-2).

Control valves additionally designed to functionally stop flow with zero seat leakage:

a. SEAT SEAL TEST AT THE SPECIFIED UPPER- AND LOWER-TEMPERATURE LIMIT MAWP: The valve assembly, as delivered by the original manufacturer, shall be tested to validate that the seat maintains a bubble-tight seal to atmosphere for 60 minutes
i) in both directions of flow, OR

ii) only in the designated direction of flow when so specified by the manufacturer and marked on the valve.

10.6.4 **Stem Sealing System.** All valves equipped with stem (spindle) sealing system:

a. PACKING TIGHTNESS TEST AT ROOM-TEMPERATURE MAWP [60 °F (15.6 °C) to 100 °F (37.8 °C)]: The valve assembly, as delivered by the original manufacturer, shall be tested to validate that the packing maintains a bubble-tight seal to atmosphere for 60 minutes at room temperature in the following stem (spindle) positions:

   i) full forward (in),

   ii) full backward (out), and

   iii) mid stroke.

b. PACKING TIGHTNESS TEST AT THE SPECIFIED UPPER- AND LOWER-TEMPERATURE LIMIT MAWP: The valve assembly, as delivered by the original manufacturer, shall be tested to validate that the packing maintains a bubble-tight seal to atmosphere for 60 minutes in the following stem (spindle) positions:

   i) full forward (in),

   ii) full backward (out), and

   iii) mid stroke.

10.6.5 Life-cycle rating claims shall be validated through testing.

10.7 **Marking.** Marking shall not be obscured by paint or other finish applied by the manufacturer.

10.7.1 **Shut-Off Valves.** All shut-off valves shall carry the following markings:

   a. Manufacturer’s name or unique symbol permanently marked on the body;

   b. Specific direction of flow if the valve is so designed;

   c. Model number;

   d. Size, nominal; and
e. The application range or limits of the shut-off valve shall be identifiable through the model number or other unique marking.
Chapter 11. Overpressure Protection Devices

11.1 General. Pressure relief devices provided for the purpose of relieving excess pressure due to fire or other abnormal conditions shall comply with this chapter.

11.2 Pressure Relief Devices.

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

11.2.2 Pressure relief devices provided for vessels constructed in accordance with ASME B&PVC, Section VIII, Division 1, shall comply with that code and other applicable requirements of this standard.

11.2.3 Relief device arrangements shall be configured to allow access for inspection, maintenance, and repair.

11.2.4 Pressure relief devices intended for vapor service shall be connected above the highest anticipated liquid carbon dioxide level.

11.2.5 Where relief devices are located in refrigerated spaces, precautions shall be taken to prevent moisture migration into the valve body or relief vent line.

11.2.6 Setting of Pressure Relief Devices

11.2.6.1 The set pressure for a pressure relief device shall not exceed the design pressure of equipment protected by the device.

11.2.6.2 The set pressure of a rupture member if used in series with a relief device shall not exceed the design pressure of the equipment protected by the rupture member.

11.2.6.3 Provision shall be made to detect pressure build-up between the rupture member and the relief device, with which it is installed in series, due to leakage through the upstream relief device.

11.2.7 Marking of Relief Devices

11.2.7.1 Pressure relief devices for carbon dioxide-containing equipment shall be set and sealed by the manufacturer. Pressure relief devices shall be marked by the manufacturer with the data required in ASME B&PVC, Section VIII, Division 1.

11.2.7.1.1 Resetting of a pressure relief device shall be performed by the manufacturer or a company holding a valid testing certificate for this
11.2.7.2 The capacity in SCFM (m³/s) or in lb air/min (kg air/min) at 60°F shall be stamped on devices or available on request.

11.2.7.3 Rupture members for carbon dioxide-containing pressure vessels shall be marked with the data required in ASME B&PVC, Section VIII, Division 1.

11.3 Pressure Relief Protection.

11.3.1 Pressure vessels and other types of equipment built and stamped in accordance with ASME B&PVC, Section VIII, Division 1, shall be provided with certified pressure relief protection.

11.3.2 Pressure vessels intended to operate completely filled with liquid carbon dioxide and capable of being isolated by stop valves from other portions of a refrigeration system shall be protected with a certified hydrostatic service relief device as required by ASME B&PVC Section VIII, Division 1. Hydrostatic overpressure relief shall comply with Section 11.6.

11.3.3 Pressure relief devices shall be sized in accordance with Section 11.3.7.

11.3.4 Pressure vessels less than 10 ft³ (0.3 m³) internal gross volume shall be protected by one or more pressure relief devices.

11.3.4.1 Fusible plugs shall not be used.

11.3.5 Pressure vessels of 10 ft³ (0.3 m³) 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
   a. Where dual relief devices are used, each device shall comply with Section 11.3.7.
   b. Three-way valves used for dual relief devices shall be set to a fully seated position (i.e. with one side open and one side closed).
   c. 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 requirements set forth in Section 11.3.7.

2. A single pressure relief device, provided that
a. The vessel can be isolated and pumped out.

b. The relief device is located on the low side of the system.

c. Other pressure vessels in the system are separately protected in accordance with Section 11.3.7.

11.3.6 Where pressure relief devices discharge into other portions of the refrigeration system, the portion of the system receiving the internal discharge shall be equipped with pressure relief devices capable of discharging the increased capacity in accordance with Section 11.3.7, and the pressure relief devices discharging into the system shall be with one of the following types:

1. A pressure relief device not appreciably affected by backpressure.

2. A pressure relief device affected by backpressure, in which case the valve’s set pressure added to the set pressure of the relief device protecting the downstream portion of the system shall not exceed the maximum allowable working pressure of any equipment being protected and shall comply with the following:

   a. The pressure relief device that protects the higher pressure vessel shall be selected to deliver capacity in accordance with Section 11.3.7 without exceeding the minimum design pressure of the higher pressure vessel accounting for the change in mass flow capacity due to the elevated backpressure.

   b. The capacity of the pressure relief device protecting the part of the system receiving a discharge from a pressure relief device protecting a higher pressure vessel shall be at least the sum of the capacity required in Section 11.3.7 plus the mass flow capacity of the pressure relief device discharging into that part of the system.

   c. The design pressure of the body of the relief device used on the higher pressure vessel shall be rated for operation at the design pressure of the higher pressure vessel in both pressure-containing areas of the valve.

**EXCEPTION:** Where hydrostatic overpressure protection relief devices are discharged into other portions of a refrigeration system that are protected by pressure relief devices designed to relieve vapor in accordance with Section 11.3, the capacity of the hydrostatic overpressure protection relief devices shall not be required to be summed with the vapor capacity required in Section 11.3.7
11.3.7 Pressure Relief Device Capacity Determination

11.3.7.1 Pressure relief devices shall have sufficient mass flow carrying capacity to limit the pressure rise in protected equipment to prevent catastrophic failure. The minimum required relief capacity shall depend on the equipment being protected, the effects of inlet pressure losses, and the scenarios under which overpressure is being created. This relief capacity protection includes heat loads from cleaning operations and process loads.

11.3.7.2 The following sources of heat loads that can lead to overpressure shall be considered when determining the pressure relief device capacity for refrigerant-containing equipment. It is permissible to use manufacturer’s data when determining relief requirements. All applicable heat loads capable of causing overpressure shall be considered, and the capacity of the pressure relief device shall be based on the scenario with the largest capacity requirements:

11.3.7.2.1 Overpressure Due to External Fire

i. Pressure Vessels

The required discharge capacity of a pressure relief device for each pressure vessel shall be determined by the following equation:

\[ C = f \cdot D \cdot L \text{ (lb/min)} \]

\[ [C = f \cdot D \cdot L \text{ (kg/s)}] \]

Where

- \( C \) = required discharge capacity of the relief device, lb air/min (kg/s)
- \( f \) = capacity factor of the relief device:
- For Carbon Dioxide \( f = 1.0 \) (0.082)

\[ [1.0 \text{ is in inch-pounds (IP), 0.082 is in International System of Units (SI)}] \]

- \( D \) = outside diameter of vessel, ft (m)
- \( L \) = length of vessel, ft (m).

When one pressure relief device is used to protect more than one
pressure vessel, the required capacity shall be the sum of the capacities required for each pressure vessel.

ii. **Oil Separators**

The required discharge capacity of a pressure relief device for each oil separator shall be determined by the following equation:

\[ C = f \cdot D \cdot L \text{ (lb/min)} \]

\[ [C = f \cdot D \cdot L \text{ (kg/s)}] \]

Where

\( C \) = required discharge capacity of the relief device, lb air/min (kg/s)

\( f \) = capacity factor of the relief device:

For Carbon Dioxide \( f = 1.0 \ (0.082) \)

[1.0 is in inch-pounds (IP), 0.082 is in International System of Units (SI)]

\( D \) = outside diameter of vessel, ft (m)

\( L \) = length of vessel, ft (m).

iii. **Plate Heat Exchangers**

The capacity of the pressure relief device for plate heat exchangers shall be based on the largest projected area of the exchanger using the following equation:

\[ C_{r,plate\ HX} = f \cdot \sqrt{L^2 + W^2} \cdot H \text{ (lb/min)} \]

\[ [C_{r,plate\ HX} = f \cdot \sqrt{L^2 + W^2} \cdot H \text{ (kg/s)}] \]

Where

\( C_{r,plate\ HX} \) = minimum required relief device capacity for plate heat exchanger (lb/min of air) [kg/s].

\( f \) = capacity factor of the relief device:

For Carbon Dioxide \( f = 1.0 \ (0.082) \)
Shell and Tube Heat Exchangers

The capacity of the pressure relief device for shell and tube heat exchangers shall be based on the sum of the capacities required for the heat exchanger and the surge drum, if provided, as follows:

\[ C = f \cdot (D_v \cdot L_v + D_s \cdot L_s) \text{ (lb/min)} \]

Where

- \( C \) = required discharge capacity of the relief device, lb air/min (kg/s).
- \( f \) = capacity factor of the relief device:

For Carbon Dioxide \( f = 1.0 \) (0.082)

Product Storage

Tanks For product storage tanks with cooling jackets, the capacity of the pressure relief device shall be based on the diameter of the storage tank and the height of the cooling jacket as follows:

\[ C_{r,tank} = f \cdot D \cdot H \text{ (lb/min)} \]
Where $C_{\text{r,tank}} = f \cdot D \cdot H \ (\text{kg/s})$

- $C_{\text{r,tank}}$ = required discharge capacity of the relief device, lb air/min (kg/s).
- $f$ = capacity factor of the relief device:
  - For Carbon Dioxide $f = 1.0 \ (0.082)$
    - $1.0$ is in inch-pounds (IP), $0.082$ is in International System of Units (SI)
- $D$ = outside diameter of the tank, ft (m).
- $H$ = height of the active portion of the heat exchanger (distance between the refrigerant supply and return) ft (m).

11.3.7.2.2 Scenarios for Potential Overpressure Conditions During Isolation

- i. **Positive Displacement Compressor Protection.** Pressure relief protection for positive displacement compressors shall comply with Chapter 8, Section 8.1.3.

- ii. **Oil Cooling Heat Exchangers.** The designer shall evaluate potential overpressure scenarios.

- iii. **Hydrostatic Overpressure Relief Protection.** Hydrostatic overpressure relief shall comply with Section 11.6.

11.3.7.2.3 Potential for Overpressure Due to Internal Heat Load. The designer shall evaluate potential overpressure scenarios due to internal heat loads.

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

11.3.8 Where combustible material is stored within 20 ft (6.1 m) of a pressure vessel that is outside of a machinery room, the relief device capacity factor, $f$, in the formulas shall be increased by a factor of 2.5, for Carbon Dioxide $f = 2.5 \ (0.205)$.

11.3.9 The rated discharge capacity of a pressure relief device shall be determined in accordance with ASME B&PVC, Section VIII, Division 1. The marking of relief devices
shall be in accordance with Section 11.2.7.

11.3.10 The rated discharge capacity of a rupture member discharging under critical flow conditions shall be determined by the following equations:

\[
C = 0.64 \, P_1 \, d^2 \text{ (lb/min)}
\]

\[
d = 1.25 \left( \frac{C}{P_1} \right)^{0.5} \text{ (in.)}
\]

\[
[C = 1.1 \cdot 10^6 \, P_1 \, d^2 \text{ (kg/s)}]
\]

\[
[d = 959 \left( \frac{C}{P_1} \right)^{0.5} \text{ (mm)}]
\]

Where

\( C = \) rated discharge capacity in lb/min (kg/s) of air.

\( d = \) smallest of the internal diameter of the inlet pipe, retaining flanges or rupture member in in. (mm).

\( P_1 = \) rated pressure (psig) \( \cdot 1.1 + 14.7 \) psi. [\( P_1 = \) rated pressure (kPa gauge) \( \cdot 1.1 + 101.3 \) kPa].

Provisions shall prevent plugging the piping in the event the rupture member relieves.

11.4 Pressure Relief Device Piping. Piping for relief of vapor shall comply with this section.

11.4.1 Stop valves shall not be installed in the inlet piping of pressure relief devices. Where installed in the outlet piping of pressure relief devices, the pressure drop effects of full area stop valves shall be taken into account in the engineering of the relief vent piping system. Where used, stop valves installed in the downstream piping of a relief device shall be locked open, including each stop valve installed on a dual relief from a three-way valve.

11.4.2 The area of the opening through pipe, fittings, and pressure relief devices, where installed, including three-way valves, between a pressure vessel connection and its pressure relief device shall be no less than the area of the pressure relief device inlet. This upstream system shall be such that the pressure drop will not reduce the relieving capacity below that required.

11.4.3 Discharge piping from pressure relief devices shall use the same materials of construction as required for refrigerant piping within this standard.
11.4.4 The size of the discharge pipe from a pressure relief device shall be no less than the outlet size of the pressure relief device. The minimum size and total equivalent length of common discharge piping downstream from each of two or more relief devices shall be determined based on the sum of the discharge capacities of all relief devices that are expected to discharge simultaneously, with due allowance for the pressure drop in each downstream section.

11.4.5 Where piping in the system and other equipment required to comply with this section could contain liquid carbon dioxide that can be isolated from the system during operation or service, the installation shall comply with Section 11.6 for protection against overpressure due to thermal hydrostatic expansion.

11.4.6 Discharge piping shall be supported in accordance with Section 6.2.2 and Section 9.4.

11.4.7 Discharge piping is not permitted on pressure relief devices that could relieve liquid directly to atmosphere. The relief device shall be located at the end of the relief pipe and vent only vapor to atmosphere with no discharge piping to avoid clogging. Relief piping shall not be used to relieve discharge from hydrostatic overpressure relief devices or any other fluid discharges, such as a secondary coolant or oil.

11.5 Discharge From Pressure Relief Devices.

11.5.1 Atmospheric Discharge. Pressure relief devices designed to relieve CO₂ vapor shall comply with this section. Pressure relief systems designed to relieve liquid internally to another part of the closed-circuit shall comply with Section 11.7. Different refrigerants shall not be vented into a common relief piping system.

11.5.2 The maximum length of the discharge piping installed on the outlet of pressure relief devices designed to relieve to atmosphere shall be determined in accordance with this section.

11.5.2.1 The design backpressure in the discharge piping at the outlet of the pressure relief devices designed to relieve to atmosphere through a single relief device, shall be limited by the allowable equivalent length of piping determined by equation 11.5.2.1.1 or 11.5.2.1.2.

11.5.2.1.1 Allowable relief discharge piping length, English units.

\[ L = \frac{0.2146d^2(P_o^2 - P_2^2)}{C_{tr}^2} - \frac{dx\ln(P_o/P_2)}{6f} \]

11.5.2.1.2 Allowable relief discharge piping length, SI units.
L = \frac{7.4381 \times 10^{-15} d^5 (P_o^2 - P_a^2)}{fC_r^2} - \frac{\text{d} \ln \left( \frac{P_o}{P_2} \right)}{500f}

Where

L = \text{equivalent length of discharge piping, ft (m)}.

Cr = \text{rated capacity as stamped on the relief device in lb/min (kg/s), or in SCFM multiplied by 0.0764, for a rupture member, or as adjusted for reduced capacity due to piping as estimated by an approved method.}

f = \text{Moody friction factor in fully turbulent flow [see Tables A.11.5.2.1 (1) and (2)].}

d = \text{inside diameter of pipe or tube, in. (mm).}

ln = \text{natural logarithm.}

P_2 = \text{absolute pressure at outlet of discharge piping, psi (kPa).}

P_o = \text{allowed backpressure at outlet of discharge piping, psi (kPa).}

Unless the maximum allowable backpressure (P_o) is specified by the relief valve manufacturer, the following maximum allowable backpressure values shall be used for P_o, where P is the set pressure and P_a is the atmospheric pressure at the nominal elevation of the installation. (See Table A.11.5.2.1 (3)).

a. For conventional relief devices, 15% of set pressure, \( P_o = (0.15*P) + P_a \)
b. For balanced relief devices, 25% of set pressure, \( P_o = (0.25*P) + P_a \)
c. For rupture members and pilot-operated relief devices, 50% or set pressure, \( P_o = (0.5*P) + P_a \)

11.5.3 Discharging Location Exterior to Building. Pressure relief devices designed to discharge external to the refrigeration system shall be arranged to discharge outside of a building and comply with all of the following:

11.5.3.1 Outdoor systems containing carbon dioxide refrigerant shall be permitted to discharge at any elevation where the point of discharge is located in an access controlled area restricted to authorized personnel only.
11.5.3.2 The pressure relief device outlet shall be located not less than 15 ft (4.6 m) above grade and not less than 20 ft (6.1 m) from windows, building ventilation openings, pedestrian walkways, or building exits.

11.5.4 The termination outlet from a pressure relief device relieving to atmosphere shall be not less than 7.25 ft (2.2 m) above a roof that is occupied solely during service and inspection. Where a higher adjacent roof level is within 20 ft (6.1 m) horizontal distance from the relief discharge, the discharge termination shall be greater than 7.25 ft (2.2 m) above the height of the higher adjacent roof.

11.5.5 The pressure relief device outlet directly relieving to atmosphere shall be located not less than 20 ft (6.1 m) horizontally from below-grade walkways, entrances, pits, or ramps if a release of the entire system charge into such a space would yield a concentration of carbon dioxide refrigerant in excess of 30,000 ppm. The direct discharge of a relief vent into enclosed outdoor spaces, such as a courtyard with walls on all sides, shall not be permitted if a release of the entire system charge into such a space would yield a concentration of carbon dioxide refrigerant in excess of 30,000 ppm. The volume for the carbon dioxide refrigerant concentration calculation shall be determined using the gross area of the space and a height of 8.2 ft (2.5m), regardless of the actual height of the enclosed space.

11.5.6 The pressure relief device outlet shall be directed to avoid spraying carbon dioxide directly on persons in the vicinity.

11.5.7 The termination outlet of vent discharge lines shall be designed in a manner that prevents foreign material or debris from entering the discharge piping.

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

11.6 Discharging Location Interior to Building. Pressure relief devices serving carbon dioxide refrigeration systems shall be permitted to discharge to the interior of a building only when all of the following apply:

1. The system contains less than 110 lb (50 kg) of carbon dioxide refrigerant.
2. The system to be installed as required by Chapter 4.

Refrigeration systems that do not meet the above requirements shall meet the requirements of Sections 11.5.2 or Section 11.5.3.
11.7 Pressure Relief Devices Discharging to Another Part of the System. Internal Relief.

11.7.1 Pressure relief devices designed to discharge from a higher-pressure vessel into a lower-pressure vessel internal to the system shall comply with all of the following:

11.7.1.1 The pressure relief device that protects the higher-pressure vessel shall be selected to deliver capacity in accordance with Section 11.3.7 without exceeding the maximum allowable working pressure of the higher-pressure vessel accounting for the change in mass flow capacity due to the elevated backpressure.

11.7.1.2 The capacity of the pressure relief device protecting the part of the system receiving a discharge from a pressure relief device protecting a higher-pressure vessel shall be at least the sum of the capacity required in Section 11.3.7 plus the mass flow capacity of the pressure relief device discharging into that part of the system.

11.7.1.3 The design pressure of the body of the relief device used on the higher-pressure vessel shall be rated for operation at the design pressure of the higher-pressure vessel in both pressure containing areas of the device.

11.8 Equipment and Piping Hydrostatic Overpressure Protection

11.8.1 Protection Required. Protection against overpressure due to thermal hydrostatic expansion of trapped liquid carbon dioxide shall be provided for equipment and piping sections that can be isolated and can trap liquid carbon dioxide in an isolated section in any of the following situations:

1. Automatically during normal operation.
2. Automatically during shutdown by any means, including alarm or power failure.
3. During planned isolation for standby or seasonal conditions.
4. Due to an equipment or device fault.

**EXCEPTION:** If trapping of liquid with subsequent thermal hydrostatic expansion is only possible during maintenance or service operations, engineering or administrative controls, or both, shall be permitted as the means of relieving or preventing overpressure.

11.8.2 Protection Method. Where protection against overpressure due to thermal hydrostatic expansion of trapped liquid carbon dioxide is required, one or both of the
following mitigation methods shall be used:

1. Provide a static relief device or check valve relieving to another part of the closed-circuit system.

2. Provide an expansion compensation device.

11.8.3 **Hydrostatic Expansion.** Pressure rise resulting from hydrostatic expansion due to temperature rise of liquid refrigerant trapped in or between closed valves shall be addressed by the following:

11.8.3.1 If trapping of liquid with subsequent hydrostatic expansion can occur automatically during normal operation or during standby, shipping, or power failure, engineering controls shall be used that are capable of preventing the pressure from exceeding the design pressure. Acceptable engineering controls include but are not limited to:

a. Pressure relief device to relieve hydrostatic pressure to another part of the system.

b. Reseating pressure relief valve to relieve the hydrostatic pressure by discharge to an approved location.

11.8.3.2 If trapping of liquid with subsequent *thermal* hydrostatic expansion can occur only during maintenance—i.e., when personnel are performing maintenance tasks—either engineering or administrative controls shall be used to relieve or prevent the hydrostatic overpressure.
Chapter 12. Instrumentation and Controls

12.1 General. Instrumentation and controls shall comply with this chapter.

12.1.1 Operating Parameter Monitoring. Instruments and controls shall be provided to indicate operating parameters of the refrigeration system and equipment and provide the ability to manually or automatically control the starting, stopping, and operation of the system or equipment. The instruments and controls shall provide notice if the system’s critical operating parameters, as determined by the owner or operator, have been exceeded.

12.1.2 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.

12.1.3 *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.

12.1.4 Ultimate Strength. The pressure-containing envelope of instruments and visual liquid level indicators shall be in accordance with Section 5.13.2.

12.2 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 and pressure gauges, shall comply with this section.

12.2.1 Design and Selection.

12.2.1.1 *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 12.1.6.

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.

12.2.1.2 The design pressure shall not be less than the pressure required by Section 5.5.

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

12.2.2 Damage Protection. Visual liquid level indicators used to observe refrigerant 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.

12.2.3 *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.

12.2.4 Sight Glasses. Sight glass types shall be compatible for use with refrigerant, and the thickness and diameter shall be sized for the intended application. Sight glasses shall be provided with a traceable serial number or other form of identification that does not compromise the glass structure or integrity.

12.3 *Electric and Pneumatic Sensor Controls.* Sensing devices that initiate control pulses or signals for refrigeration systems shall comply with this section.

12.3.1 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 5.5. 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 12.1.6.

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.

4. Is listed individually or as part of an assembly or a system.

12.3.2 Equipment Identification. Manufacturers producing electrical or pneumatic controls shall provide the following minimum nameplate data:

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.

7. Any special characteristics of a control device shall be noted either on the name tag or in the accompanying literature.
Chapter 13. Refrigerant Detection and Alarms

13.1 General. Refrigerant leak detection and alarms located in “Machinery Rooms” shall comply with Section 6.9 and Sections 13.2–13.6 of this chapter. Refrigerant leak detection and alarms in “Areas Other Than Machinery Rooms” shall comply with Section 7.2.3, and this chapter.

13.2 Power for Detectors and Alarms. The power supply for the refrigerant detectors and alarms shall be a dedicated branch circuit.

13.3 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 refrigerant from a leak is expected to accumulate. In rooms equipped with continuous exhaust ventilation, the location of leak detection sensors and sampling tubes shall take into account the air movement toward the inlet of the ventilation system. Leak detection sensors and sampling tube inlets shall be positioned where they can be accessed for maintenance and testing.

13.4 *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.

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

13.6 Detection and Alarm Levels. Where this standard specifies a refrigerant detection and alarm concentration, the operational criteria shall be as specified in this section.

**EXCEPTION:** Where approved, alternatives to fixed refrigerant leak detectors shall be permitted for areas with high humidity or other harsh environmental conditions that are incompatible with detection devices.

13.6.1 Level 1 Carbon Dioxide Detection and Alarm. Level 1 carbon dioxide detection and alarm shall have the following features:

1. At least one carbon dioxide 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:

   a. **Carbon Dioxide** at 5,000 ppm or lower.
Part 3. Installation

General. Chapters 14 - 18 apply to field installation of equipment and systems.

Chapter 14. Supervision of Installation

14.1 Installation shall be executed by individuals, who through experience and appropriate training have been verified that they have been taught the skills necessary to safely receive, transport, and install refrigeration equipment, piping, and components in a manner so as to assemble a complete refrigeration system and not harm themselves, others, or the structure in which the equipment is to be installed.

14.1.1 Individuals who are in training or others who do not have these skills may participate in the installation provided they are closely supervised by qualified and experience individuals.
Chapter 15. Equipment Installation

15.1 Compressors.

General. This section applies to compressors which are utilized in closed-circuit carbon dioxide refrigeration systems.

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

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

15.1.2 Where a compressor is located in an area with a low ambient temperature, a means shall be provided to prevent condensation of refrigerant in the compressor package or piping during operation or standby.

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

15.1.4 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.

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

15.1.6 Compressors shall be provided with a discharge check valve, a suction check valve, or other means to avoid backflow of refrigerant, lubricant, or a refrigerant-lubricant 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.

15.1.7 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.
15.1.7.1 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.

15.1.8 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 visually determine the compressor’s suction pressure, discharge pressure, oil pressure (if the compressor uses forced-feed lubrication), and discharge temperature.

**EXCEPTION:** Compressors that are part of a factory assembled packaged system.

### 15.2 Condensers.

**General.** This section applies to refrigerant condensers applied to closed-circuit refrigeration systems.

15.2.1 **Clearances.** Condensers shall be installed with manufacturer-recommended minimum clearances for position of the units and their respective air inlets and air outlets to avoid short-circuiting and to ensure unobstructed air flow.

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

15.2.3 **Drainage of Overflow and Waste Water.** Drainage of overflow and waste water shall be provided to ensure that overflow and waste do not cause a nuisance or hazard.

15.2.4 **Shell-and-Tube Condenser Installation Considerations.** Where design permits servicing of condenser tubes at its installed location, clearance shall be provided to accommodate maintenance or replacement.

### 15.3 Evaporators.

**General.** This section applies to evaporators which are applied to closed-circuit carbon dioxide refrigeration systems.

15.3.1 **Installation Considerations.**

15.3.1.1 Manufacturer’s recommended clearances for unobstructed airflow at the
inlet and outlet of the forced-air evaporator shall be provided.

15.3.1.2 A means for preventing freezing inside condensate drain lines, such as but not limited to slope to drain, heat tracing, insulation, or clean-outs, shall be provided where lines are exposed to freezing temperatures.

15.3.1.3 To prevent warm air from migrating to the condensate drain pan connections and creating frost, P-traps on the condensate drain are required for each evaporator.

15.3.1.4 Where design permits servicing of evaporator tubes at their installed location, clearance shall be provided as necessary to accommodate maintenance and replacement.

15.4 Pressure Vessels.

General. This section applies to pressure vessels which are applied for use in closed-circuit carbon dioxide refrigeration systems.

15.4.1 Access, Protection, and Supports.

15.4.1.1 Pressure vessel access shall be provided in accordance with Section 5.12.

15.4.1.2 Physical protection shall comply with Section 7.2.4.

15.4.1.3 Pressure vessel support shall be installed in accordance with Section 5.11.

15.5 Refrigerant Pumps.

General. This section applies to refrigerant pumps applied for use in closed-circuit carbon dioxide refrigeration systems.

15.5.1 Protection, Isolation Valves, Supports, and Foundations.

15.5.1.1 A means of protecting refrigerant pumps and connected piping from hydrostatic overpressure shall be provided in accordance with Section 11.8.

15.5.1.2 Protection from exposed rotating parts shall be in accordance with Section 5.17.2.

15.5.1.3 Refrigerant pumps shall be provided with isolation valves.

15.5.1.4 Refrigerant pump supports, and foundations shall be installed in accordance with Section 5.11.
15.5.2 **Provision for Carbon dioxide Removal.** Pumps shall be equipped with a means for carbon dioxide removal.

15.6 **Components and Controls.**

**General.** Install components and controls in accordance with manufacturer’s instructions and Section 15.6.

15.6.1 **Visual Liquid Level Indicators constructed using sight glass type indicator(s)**

15.6.1.1 All visual liquid level indicators shall be inspected prior to installation. Any indicator found to have a scratch, chip or any defect shall be discarded.

15.6.1.2 Indicators shall be installed according to manufacturer’s recommendations.

15.6.1.3 Gaskets shall be new, clean and smooth.

15.6.1.4 Gaskets used shall be those recommended by the manufacturer of the visual liquid level indicator.

15.6.1.5 The retaining ring shall be installed according to specifications provided by the manufacturer.
Chapter 16. Pipe and Valve Installation

16.1 General. This section applies to pipe, fittings and valves for use in closed-circuit carbon dioxide refrigeration systems and associated overpressure protection relief piping systems.

16.1.1 Valves shall be installed according to the manufacturer’s recommendations. Piping shall not be forced by prying, jacking, or other distortions to facilitate valve installation.

16.1.2 Hot Tap tie-ins are not prohibited when connecting new piping to existing refrigeration piping.

16.1.3 Hot Taps shall comply with ASME B31.5 Section 538 and Section 504.3.

16.1.4 When utilized, Hot Tapping shall follow hot tap equipment manufacturers’ procedures and site specific safe work practices.

16.2 The piping materials used for closed-circuit mechanical refrigeration systems, whether fabricated in a shop or as a field erection, shall comply with Chapter 9.

16.3 Pipe.

16.3.1 Pipe shall be new, clean and free of rust, scale, sand and dirt, both internally and externally.

16.4 Refrigerant Valves.

General. This section applies to the valves as defined in Chapter 10.

EXCEPTIONS:

1. Valves within the refrigerant-containing envelope of other equipment such as slide valves in screw compressors;

2. Safety relief valves.

16.4.1 Valves shall be oriented in accordance with the respective manufacturer’s instructions or as shown on the drawings.

16.4.2 Valve gasket materials shall match valve manufacturer’s specifications, be compatible with carbon dioxide and of the dimensions specified. Flange bolts shall be tightened in accordance with 10.5.2.

16.4.3 Valves with specialized tightening requirements shall be installed according to manufacturer’s instructions.
16.4.4 Shut-off (Stop) valves used to isolate equipment, control valves, controls or other components from other parts of the system for the purpose of maintenance or repair shall be capable of being locked out or secured per the facility’s “Lock Out / Tag Out” procedure (ref.4.2.1.2).

16.4.5 Shut-off (Stop) valves shall be installed in the refrigerant piping of a refrigeration system to meet minimum safe design requirements.

16.4.6 Shut-off (Stop) valves connecting refrigerant-containing parts to atmosphere shall be capped, plugged, blanked, or locked closed during shipping, testing, operating, servicing, or standby conditions if they are not used.

16.5 Piping Fabrication and Assembly.

Valves (or flange sets) shall be installed in accordance with manufacturer’s instructions.

16.5.1 Piping joints shall be supported and in alignment such that the joint assembly is not distorted or stressed during assembly and installation.

16.5.2 Flanges.

16.5.2.1 The mating surfaces of the gasketed joints shall be parallel, aligned and perpendicular to the pipe axis, in good condition and free of debris and corrosion.

16.5.2.2 Gaskets shall be correctly dimensioned for the flange set.

16.5.2.3 Nuts, bolts, cap screws and washers shall meet manufacturer’s requirements for application. Bolt threads shall extend completely through the mating nut.

16.5.2.4 The fasteners shall be progressively tightened in a diametrically staggered (crisscross or star) pattern.

16.5.2.5 Flange sets with specialized tightening requirements shall be installed according to manufacturer’s instructions.

16.5.3 Threaded Joints.

16.5.3.1 Thread compound used in threaded joints shall be suitable for service in a refrigeration system.

16.5.3.2 Threaded joints that require seal welding shall be made up without any thread compound.

16.5.4 Welded and Brazed Joints.

16.5.5 The inside of the piping system shall be kept clean and free of debris during fabrication and assembly.
Chapter 17. Insulation

General. This section applies to insulation used for closed-circuit carbon dioxide refrigeration systems.

17.1 Refrigeration piping or components shall be insulated in accordance with Section 5.10.

17.1.1 All exterior refrigerant lines which require insulation shall have an insulation thickness selected to minimize condensation and minimize heat gain into the refrigerant within the piping.

17.2 Newly installed refrigerant piping and joints shall be exposed to allow for visual inspection and acceptance by the authority having jurisdiction prior to being covered and enclosed.
Chapter 18. Testing of Installation

General. This section applies to testing prior to startup of a closed-circuit carbon dioxide refrigeration system.

18.1 Field Testing.

18.1.1 Upon complete installation of or revision to a closed-circuit carbon dioxide refrigeration system, the system or affected part shall be tested for leaks before charging. This field leak testing program for closed-circuit refrigeration systems is designed to ensure a tight system which will operate without any appreciable loss of refrigerant.

18.1.2 Carbon dioxide refrigeration systems are vulnerable to corrosion in the presence of free water. For this reason, oxygen free, dry nitrogen is the only gas recommended for pressure testing. Compressed air must NOT be used as a test gas, even though it is allowed per ASME B31.5.

18.1.3 Preparation for Testing.

All joints shall remain unpainted and un-insulated until field testing has been completed.

Prior to testing, the following preparations shall be made:

18.1.3.1 Valve off and isolate from any test pressures all refrigeration compressors, non-hermetic liquid pumps, pressure switches and pressure transducers.

18.1.3.2 Remove all safety pressure relief devices and cap or plug the openings.

18.1.3.3 Open all solenoid, pressure-regulating, check or other control devices by means of their manual lifting stems.

18.1.3.4 Open all other valves except those leading to the atmosphere.

18.1.3.5 Cap, plug, or lock shut all valves and devices leading to the atmosphere.

18.1.4 Pressure Testing.

Pressure test shall be in accordance with Section 538 of ASME B31.5, Refrigeration Piping and Heat Transfer Components.

18.1.5 Leak Testing.

Upon completion of installation, the carbon dioxide refrigeration system shall be field tested for tightness and evacuated in accordance with Chapter 19. All parts of the system, including factory tested equipment, shall be exposed to field test pressures equal to those minimum design pressures listed in Chapter 5 or as specified in the engineering design. A pre-test
inspection shall be made to verify that all components in the section of piping under examination have a pressure rating which meets or exceeds the specified field test pressure. All leaks shall have been repaired and defective material shall have been replaced and retested.

18.1.5.1 After the pressure and leak tests have been performed, passed and documented, the pressure should be bled off in 10-15 psi (~1 bar) increments from the low points of the system to help expel any residual water.

18.1.6 *Evacuation.*

18.1.6.1 The refrigeration system shall be evacuated to a 500-micron vacuum.

18.1.6.2 Break the vacuum with refrigeration grade carbon dioxide vapor in accordance with Section 5.2.

18.1.6.3 Refer to Chapter 20 for Charging.
Part 4. Startup of New Systems and Additions or Modifications to Existing Systems

Chapter 19. Pre-Charging Activities and Requirements

General. This section applies to pre-charging closed-circuit carbon dioxide refrigeration systems.

19.1 Startup Team.

19.1.1 A startup team shall be organized to perform the startup.

19.1.1.1 *At a minimum, the startup team shall include:

1. Owner.
2. Qualified contractor(s), where applicable.
3. Operating and maintenance personnel.

19.1.1.2 The startup team shall define and follow an agreed upon startup plan.

19.2 Design Documentation and Installation Records.

19.2.1 All system documentation from the planning, design, and installation phases of the project shall be assembled and readily available. This includes:

1. Design documentation.
2. Equipment and component documentation.
3. Test reports.

EXCEPTION: Unitary systems with listed equipment.

19.3 Pressure Tests, Leak Tests, and Evacuation.

19.3.1 General.

19.3.1.1 *Upon completion of installation, the carbon dioxide refrigeration system shall be pressure tested, subsequently leak tested for tightness, and evacuated per Chapter 18.

19.4 Mechanical System Checkout.

19.4.1 The entire refrigeration system and associated safety systems shall be visually inspected to ensure they comply with the system design documentation.
19.4.2 The machinery room and any other spaces containing portions of the refrigeration system and associated safety systems shall be visually inspected to ensure they comply with the system design documentation, IIAR, and the adopted Building Codes.

19.4.3 Manufacturer’s instructions shall be observed to prepare equipment for operation.

19.4.4 Ensure all valves or piping connecting pressure-envelope portions of the refrigeration system to atmosphere are capped, plugged, blanked, or locked closed.

19.4.5 Ensure that all machine guarding is secured in place.

19.4.6 Ensure that the area is free from portable equipment and obstructions that could impede egress.

19.4.7 Pre-charging and pre-startup checklists shall be filed.

19.5 Electrical Systems Checkout.

19.5.1 Electrical checkout requirements shall apply to the refrigeration system and the associated safety systems.

19.5.2 Electrical power and electrical control systems shall be visually inspected to ensure they comply with the system design documentation.

19.5.3 The continuity of all electrical power, control wiring, and connections shall be tested and confirmed as safe circuitry before any electrical supply is connected.

19.5.4 All electronic controls shall be functionally checked out.

19.5.5 Drive motors shall be checked for correct direction of rotation and operation and the overloads shall be set to the nameplate values.

19.5.6 Control setpoints shall be set to the values specified in the design documentation or according to the manufacture instruction requirements.

19.5.7 Testing results, including a list of the initial setpoint values, shall be recorded.

19.6 Safety Systems Checkout and Activation.

19.6.1 The following shall be checked out, tested, proven to function as designed, and put into operation by trained startup personnel prior to charging the system with carbon dioxide refrigerant:

   I. Ventilation system - temperature control and emergency.
2. Refrigerant detection and alarms.
3. Emergency shutdown and ventilation controls.

19.6.2 Continuous emergency ventilation is permitted where the refrigerant detection is not operational.

19.6.3 Startup personnel shall be trained on the use of personal protective equipment (PPE).

19.6.4 PPE and required First Aid equipment shall be readily available in a clearly identified location.

19.6.5 Offsite emergency response authorities and the authority having jurisdiction (AHJ) shall be advised of the charging plan.

19.6.6 All site personnel shall be advised of the time, date, and location of the refrigeration system charging activities.

19.7 Water and Secondary Coolant System Checkout.

19.7.1 Systems were water is used for condensing or compressor oil cooling shall be checked, tested, and put into operation prior to charging the refrigeration system with refrigerant.

19.7.2 Where secondary systems are employed, they shall be checked out, tested, and made operational prior to charging the system with refrigerant.
Chapter 20. Charging

General. This section applies to charging closed-circuit carbon dioxide refrigeration systems.

20.1 Pre-Charging Review.

20.1.1 The completion of all pre-charging requirements and activities shall be confirmed prior to charging the refrigeration system with carbon dioxide refrigerant.

20.2 Refrigerant Delivery, Transfer Hose(s), and Charging Location.

20.2.1 Carbon dioxide refrigerant shall be in accordance with Chapter 5, Section 5.2. Carbon dioxide refrigerant delivery shall be provided by cylinder(s) or by bulk truck(s) connected to the closed-circuit carbon dioxide refrigeration system with a carbon dioxide transfer hose(s).

20.2.2 *Carbon dioxide transfer hose(s) used for charging shall be:

1. Certified for carbon dioxide service.
2. Rated for design with a minimum working pressure of 1740 psig and a minimum burst pressure of 5200 psig.
3. Visually inspected for damage or defects.
4. Within the manufacturer’s service date stamped on the transfer hose.
5. Connected with an inline shut-off valve and a check valve.

20.2.3 *Carbon dioxide transfer hose(s) used for charging shall be connected to the refrigeration system at a location that will not result in liquid carbon dioxide entering a compressor.

20.3 Precautions.

20.3.1 Site personnel shall be notified of the charging activity.

20.3.2 PPE and required First Aid equipment shall be readily available and utilized by personnel performing charging activities.

20.3.3 The charging area shall have restricted access.

20.3.4 All operating refrigeration equipment and associated operating components shall be monitored.

20.3.5 The charging or transfer process shall be attended at all times.
20.4 Charging Activities.

20.4.1 Charging standard operating procedure (SOP) shall be utilized for compliance.

20.4.2 Carbon dioxide vapor shall be introduced into the closed-circuit refrigeration system that has been held in a vacuum to reach, at a minimum, 100 Psig.

20.4.3 *A final leak check shall be conducted using carbon dioxide vapor.

20.4.4 All identified leaks shall be repaired and retested.

20.4.5 After successful completion of the final leak test, the closed-circuit carbon dioxide refrigeration system shall be charged with carbon dioxide vapor to 100 psig before the introduction of liquid carbon dioxide refrigerant.

20.4.6 The carbon dioxide charged shall be weighed and the quantity recorded.

20.4.7 Once the closed-circuit carbon dioxide refrigeration system is charged, all previously adjusted valves shall be returned to their normal operating position.
Chapter 21. Startup Process

General. This section applies to startup of closed-circuit carbon dioxide refrigeration systems.

21.1 Equipment/System Startups.

21.1.1 The new equipment/system shall be made operational in accordance with:

1. The requirements of this Chapter.
2. Manufacturer’s instruction(s).

21.2 Testing of Protection Devices.

21.2.1 All protection devices shall be tested to prove correct functionality. Testing shall be done by a trained startup technician having the training and experience that qualify that individual to startup verify the designated closed-circuit carbon dioxide refrigeration with which he or she has already become familiar.

21.2.2 *The protection devices to be tested for verification include, but are not limited to:

1. Compressor High Discharge Pressure Cutout.
2. Compressor Low Suction Pressure Cutout.
3. Compressor High Discharge Temperature Cutout.
4. Compressor Oil Differential Pressure Cutout, where applicable.
5. Refrigerant Level Protection Devices, where applicable.
6. Compressor Oil Level Protection Device, where applicable.

21.3 Inspection of Operating System.

21.3.1 *When operating the closed-circuit carbon dioxide refrigeration system at design temperatures, the closed-circuit carbon dioxide refrigeration system shall be inspected for leaks and abnormalities.

21.4 Verification.

21.4.1 *The closed-circuit carbon dioxide refrigeration system shall be checked to verify functional performance and to confirm it operates as intended by the design.

21.4.2 *The system shall be operated to demonstrate correct functionality, during verification:

1. Pressures and temperatures shall be recorded.
2. Liquid level controls shall be checked.
21.4.3 *The manufacturer’s instructions on oil and filter changes during startup shall be observed.

21.5 Issue Resolution.

21.5.1 *Issues identified during the verification phase shall be resolved or an acceptable plan shall be developed to resolve identified issues in a safe and timely manner.

21.5.2 Issue resolution shall be documented.

21.6 System Monitoring.

21.6.1 *After completion of the functional performance testing and the resolution of all identified issues, the system shall be monitored for a period of time long enough to verify long term performance, safe operations, integrity, and reliability.

21.6.2 Once training is complete and there has been a period of continuous and fault-free operation, the system shall be turned over to the owner.

21.7 Startup Documentation.

21.7.1 Startup documentation shall be provided to the owner.

21.7.2 Startup documentation, at a minimum, shall include applicable:

1. Startup checklists.
2. Pressure testing records.
3. System baseline data.
4. Updated design documents.
5. Issue resolution documentation.
Part 5. Inspection, Testing, and Maintenance

Chapter 22. Inspection, Testing, and Maintenance

General. This Chapter of the standard does not apply to self-contained refrigeration systems using carbon dioxide as a refrigerant and whose compressor is less than 5 horsepower.

22.1 ITM Program Requirements.

The owner or owner’s designated representative shall ensure an inspection, testing, and maintenance program is developed to reduce the probability of system failure. This program shall comply with manufacturer recommendations, equipment and system operating and maintenance history, and the minimum safe requirements of this standard.

When performing ITM tasks, safe work practices shall be used.

All workers and observers must wear proper PPE.

22.1.1 Inspection and Testing. Inspections and tests shall be performed on the carbon dioxide refrigeration system(s), connected equipment, and installed devices.

22.1.1.1 The frequency of inspection and testing shall be consistent with applicable manufacturers’ recommendations and operating history.

22.1.1.2 Each inspection and test performed shall be documented and include the following information:

1. Date of the inspection or test.
2. Name of the individual or individuals that performed the inspection or test.
3. Serial number or other identifier of the equipment on which the inspection or test was performed.
4. Description of the inspection or test performed.
5. Recommended corrective action(s) for each deficiency identified.
6. Description of corrective action(s) for each deficiency identified.
7. Identification of each designated responsible person assigned and authorized to remedy each deficiency identified.
8. Results as found of the inspection or test, including instrumentation.
9. Expected activation set points (+/-) including a functional description of the control logic.
10. Results as left of the inspection or test, including instrumentation.
11. Expected completion date(s).
12. Actual Completion date(s).

22.1.1.3 Deficiencies identified during inspection and testing be documented along with any related action items to ensure safe operations.

22.1.2 **Equipment Deficiencies.** Equipment identified as operating outside of the operating limits shall be corrected before further use or in a safe and timely manner when necessary means are taken to ensure safe operation.

22.1.2.1 Equipment shall not be set to operate outside of upper and lower safe operating limits.

22.1.3 **Maintenance.** Equipment shall be maintained to operate within operating limits.

22.1.3.1 Maintenance frequencies shall be in accordance with this standard or OEM requirements whichever is more stringent.

22.1.4 **Materials and Replacement Parts.** Maintenance materials and replacement parts shall be suitable for the system application for which they will be used.

22.1.5 **Risk-Based ITM.** Risk-Based ITM strategies for performing inspection, testing, and maintenance tasks and evaluating frequencies are permitted.

22.2 **Frequency.**

Where inspection, testing, and maintenance is performed on a Calendar Basis in lieu of a Runtime Basis, the Calendar Basis frequencies shall be as outlined in Table 22.2.

22.2.1

*Where a history of deficiencies has been recorded, the (ITM) task frequencies shall be increased. Where a history of fault-free operation has been recorded, the (ITM) task frequencies are permitted to be decreased. In either case, a determined change in a (ITM) task frequency and its technical justification shall be documented.*

22.3 **Record Keeping Requirements.**

The owner or owner’s designated representative shall ensure a record keeping system is established and maintained to provide evidence that the provisions of this standard have been implemented and to address identified deficiencies.

22.3.1 *The owner or owner’s designated representative shall perform the record keeping activities. An automatic record keeping system that meets these requirements is
permitted. Automatic recorded items shall be reviewed whenever the technician is on site but not less than once per month to identify safety alarms, shutdowns, system functioning outside operating limits, or a combination thereof. Corrective action for identified safety items shall be developed and implemented.

22.3.2 *Inspection, testing and maintenance records shall be readily accessible, whether filed at the facility, offsite, or electronically.

22.3.3 *The current system documentation records shall be readily accessible and include the following:

1. Refrigeration flow drawings.
2. Defined operating limits.
4. Relief valve list with set pressure and rated capacity.
5. Ventilation system functional description.
6. Installation, operation, and maintenance manuals.
7. Manufacturer data reports for all pressure vessels.
8. Equipment list.

22.3.4 Monitored Control.

Where a monitored control is utilized, operating parameters being acquired automatically as the system is being used in lieu of performed rounds shall be verified and alarm messages shall be tested per this standard’s frequencies to ensure notifications are sent and received.

22.3.5 Lack of functional instrumentation does not reduce record keeping requirements.

22.3.6 Refrigeration System Records.

The following refrigeration system records shall be maintained:

22.3.6.1 *A means of record keeping, such as a log, to document and transfer pertinent operational, maintenance, and ongoing duty information between operators shall be implemented.

22.3.6.2 Secondary coolant records shall include the type of fluid, equipment identification, equipment location, quantity added or removed, and the date. Other fluid information necessary for the process shall also be included, such as pH or the solution composition.

22.3.6.2.1 For secondary coolants which contain a component with a freezing point equal to or greater than the saturation temperature of the
corresponding refrigeration system, the freeze point or specific gravity of each independent secondary coolant circuit shall be measured and recorded prior to charging and after charging to determine if the secondary coolant concentration is within the operating limits.

22.3.6.3 *Refrigeration oil records for documenting the type of oil, the total estimated amount of oil in the system, the quantity added or removed, the location where the oil was added or removed, and the date.

22.3.6.4 Pressure relief valve records shall include the pressure relief device identification, equipment identification that it is installed on, the set pressure, the rated capacity, and the date of installation.

22.3.7 Retention of Records.

Records shall be retained in accordance with Table 22.3.7 or per a facility’s requirements that take precedence to sustain processing, jurisdictional regulatory requirements, or both, such as for food safety.

<table>
<thead>
<tr>
<th>Type of Record</th>
<th>Retention Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly Inspection Records</td>
<td>Most current 12 months.</td>
</tr>
<tr>
<td>Monthly Testing Records</td>
<td>Most current 12 months.</td>
</tr>
<tr>
<td>Monthly Maintenance Records</td>
<td>Most current 12 months.</td>
</tr>
<tr>
<td>Quarterly Inspection Records</td>
<td>Most current 12 months.</td>
</tr>
<tr>
<td>Quarterly Testing Records</td>
<td>Most current 12 months.</td>
</tr>
<tr>
<td>Quarterly Maintenance Records</td>
<td>Most current 12 months.</td>
</tr>
<tr>
<td>Annual Inspection Records</td>
<td>Most current 5 years.</td>
</tr>
<tr>
<td>Annual Testing Records</td>
<td>Most current 5 years.</td>
</tr>
<tr>
<td>Annual Maintenance Records</td>
<td>Most current 5 years.</td>
</tr>
<tr>
<td>Five Year Inspection Records</td>
<td>Two (2) most current.</td>
</tr>
<tr>
<td>Five Year Testing Records</td>
<td>Two (2) most current.</td>
</tr>
<tr>
<td>Five Year Maintenance Records</td>
<td>Two (2) most current.</td>
</tr>
<tr>
<td>Ten Year Maintenance Records</td>
<td>Two (2) most current.</td>
</tr>
<tr>
<td>Engineering design documentation</td>
<td>Life of the process.</td>
</tr>
<tr>
<td>Pressure vessel U1, U-1A, U-3, UM reports</td>
<td>Equipment life.</td>
</tr>
<tr>
<td>Log (Operator Transfer of Information)</td>
<td>Most current 12 months.</td>
</tr>
<tr>
<td>Secondary Coolant Records</td>
<td>Most current 12 months.</td>
</tr>
</tbody>
</table>
### CO2 Refrigerant Records
- Most current 5 years.

### Refrigeration Oil Records
- Most current 5 years.

### Pressure Relief Valve (PRV) Records
- PRV life.

### Current System Records listed in Section 22.3.3
- Life of the process.

### Instrument and device testing and calibration
- Most current 5 years.

#### 22.4 Inspection Requirements.

The owner or owner’s designated representative shall ensure an inspection program is developed and maintained to meet the requirements of Sections 22.1 – 22.3 and this section.

22.4.1 *When a deficiency is identified, the owner or owner’s designated representative shall ensure a timely evaluation is arranged to determine the appropriate corrective action(s) and the time frame to execute each task.*

#### 22.5 Testing Requirements.

The owner or owner’s designated representative shall ensure a testing program is established and maintained to meet the requirements of Sections 22.1 – 22.3 and this section.

22.5.1 Testing instruments, testing devices, and testing gauges used for testing refrigeration system protection devices shall be calibrated in accordance with manufacturers’ instructions.

22.5.2 Testing and calibration of protection devices that are integral to the function of shutting down equipment or a system where the devices are designed and installed for such and within design limits shall be in accordance with manufacturers’ instructions unless a different frequency is justified in accordance with Section 22.2.1.

22.5.3 Portions of the system opened to the atmosphere for inspection testing and maintenance shall be checked for leaks after applicable ITM tasks are complete and prior to resuming normal operations.

22.5.4 Where standby power sources are installed for emergency systems, these power sources shall be tested per the manufacturers’ instructions not less than once per year.

22.5.5 Test frequencies shall be in accordance with manufacturers’ recommendations, historical ITM data, predictive maintenance reports, and other adopted RAGAGEP.

#### 22.6 Maintenance Requirements.

The owner or owner’s designated representative shall ensure a maintenance program is
developed and maintained to meet the requirements of Sections 22.1 – 22.3 and this section.

22.6.1 *Procedures shall be developed for maintenance tasks and used where applicable. Applicable procedures include safe work practices.

22.6.2 A non-routine maintenance task shall require a safe procedure be developed prior to the task being performed.

22.6.3 Maintenance frequencies shall be in accordance with the maintenance tasks located in the equipment chapter ITM task tables, based from manufacturers’ recommendations, historical ITM data, predictive maintenance reports, or a combination thereof.

22.6.4 When any component is lubricated (i.e. service valves) where the lubricant could come in contact with the refrigerant or system lubricant, the lubricant used for maintenance must be compatible with the lubricant in the system.

22.6.5 If system alarms will activate during controlled maintenance tasks or inspections, disabling alarms through engineering or administrative controls, or both, shall be permitted as a means of controlling and preventing nuisance alarms. The affected alarms shall be functionally tested after the controlled maintenance tasks or inspections are complete.

22.6.6 *Equipment and piping shall be kept free from excessive ice buildup.

22.6.6.1 Ice buildup shall not interfere with timely operation of critical isolation valves.

22.6.6.2 Ice accumulation shall not be permitted to stress or bend pipes, displace components, or negatively impact the system’s structural integrity.

22.7 Compressors.

22.7.1 *Inspection, Testing, and Maintenance Tasks. Inspection, testing, and maintenance tasks shall be performed on the different compressor types at the indicated frequencies, set forth in Table 22.7.1 or per manufacturers’ instructions, unless a different frequency is justified in accordance with Section 22.2.1.

<table>
<thead>
<tr>
<th>ITM Task Description</th>
<th>Screw</th>
<th>Reciprocating</th>
<th>Rotary Vane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 22.7.1
Compressors Inspection, Testing, and Maintenance Tasks
<table>
<thead>
<tr>
<th>a) Discharge pressure</th>
<th>M</th>
<th>M</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>b) Oil pressure</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>c) Oil temperature</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>d) Discharge temperature</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>e) Verify oil levels are adequate</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>f) Oil filter differential pressure</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>g) Refrigerant/Oil leaks</td>
<td>Q</td>
<td>Q</td>
<td>Q</td>
</tr>
<tr>
<td>h) Determine shaft seal leak rate (if open compressors are used)</td>
<td>Q</td>
<td>Q</td>
<td>Q</td>
</tr>
<tr>
<td>i) Motor amperage (current)</td>
<td>Q</td>
<td>Q</td>
<td>Q</td>
</tr>
<tr>
<td>j) Recorded Alarms and Shutdowns</td>
<td>Q</td>
<td>Q</td>
<td>Q</td>
</tr>
<tr>
<td>k) Free from abnormal sounds and excessive vibration</td>
<td>Q</td>
<td>Q</td>
<td>Q</td>
</tr>
</tbody>
</table>

**Testing**

| a) Low suction pressure cutout (LPCO) | A | A | A |
| b) High discharge pressure cutout (HPCO) | A | A | A |
| c) High discharge temperature cutout | A | A | A |
| d) Low oil pressure cutout | A | A | A |
| e) High liquid level cutout | A | A | A |

**Maintenance**

| a) Add Oil | As Needed | As Needed | As needed |
| b) Change oil filter | As indicated by oil filter ΔP 2 psi max. | As indicated by oil filter ΔP 2 psi max. | As indicated by oil filter ΔP 2 psi max. |
| c) Clean internal oil pump suction strainer | As needed - A | As needed - A | As needed - A |
| d) Oil Analysis - Take oil sample and obtain oil analysis results from qualified testing if motor burnout has occurred | Motor burnout | Motor burnout | Motor burnout |
or oil has foul smell

| f) Calibrate pressure and temperature cutout devices (found in the Testing Section above) | 2 | 2 | 2 |
| g) Check electrical wiring and connections for hot spots | A | A | A |
| h) Calibrate motor current transducer/transformer | A | A | A |

**Frequencies:**  M - Monthly, Q - Quarterly, A - Annual, 2 - Two years, Others as noted.

22.7.1.1 *The function of the high discharge pressure shutdown safety device shall be tested by one of the following methods based on the type of device being used:

22.7.1.1.1 **Electromechanical Switch.** Functional testing of an electromechanical switch as a high-pressure limiting device requires proof of the three following characteristics:

1. Function of the device to shut down an operating compressor.  
2. Function test setpoint shall be no more than 90% of the relief valve setting.  
3. Calibration of the device to show it functions within an accuracy of +/- 2.5% at the setpoint when compared to a pressure standard or master gauge.

22.7.1.1.1.1 **Permitted test methods:**

1. Manipulation of discharge pressure to the cutout set point.  
2. Using a check valve, a bleed valve, and an external pressure source.

22.7.1.1.2 **Pressure Transducer or Transmitter Connected to an Electronic Controller.** Functional testing of a pressure transducer or transmitter connected to an electronic controller as a pressure-limiting device requires proof of the three following characteristics:

1. Function of the device to shut down an operating compressor after sensors are calibrated.  
2. Setpoint shall be no more than 90% of the relief valve setting.  
3. Calibration of the device to show it reads pressure within an accuracy of +/- 2.5% at the set point or at two pressures...
chosen to verify the accuracy of the calibration curve
programmed into the controls, when compared to a pressure
standard or master gauge.

22.7.1.1.2.1 Permitted test methods:

1. Manipulation of discharge pressure to the cutout set point.
2. Reduce the cutout set point and raise the discharge pressure until
   shutdown occurs.
3. Using a check valve, a bleed valve, and an external pressure source.

22.8 Refrigerant Pumps.

22.8.1 Inspection, Testing, and Maintenance Tasks. Inspection, testing, and maintenance
tasks shall be performed on refrigerant pumps at the indicated frequencies, set forth
in Table 22.8.1 or per manufacturers’ instructions.

<table>
<thead>
<tr>
<th>ITM Task Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>a) Listen and visually check for abnormal sounds</td>
<td>Q</td>
</tr>
<tr>
<td>b) Verify oil level in reservoir is acceptable</td>
<td>Q</td>
</tr>
<tr>
<td>c) Visually inspect pump assembly for oil leaks and connective tubing for integrity</td>
<td>Q</td>
</tr>
<tr>
<td>d) Verify base frame anchors are in place</td>
<td>Q</td>
</tr>
</tbody>
</table>

**Frequencies:** Q - Quarterly.

22.9 Condensers

22.9.1 *Inspection, Testing, and Maintenance Tasks. Inspection, testing, and maintenance
tasks shall be performed on condensers at the indicated frequencies, set forth in
Table 8.1. This includes highside heat exchangers. For heat exchangers that are
pressure vessels, see Chapter 22.11 or per manufacturers’ instructions.

<table>
<thead>
<tr>
<th>ITM Task Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>Evaporative</td>
<td></td>
</tr>
<tr>
<td>Shell and Tube</td>
<td></td>
</tr>
<tr>
<td>Plate-Heat Exchanger</td>
<td></td>
</tr>
<tr>
<td>Air-Cooled</td>
<td></td>
</tr>
</tbody>
</table>
### 22.10 Evaporators

#### 22.10.1 *Inspection, Testing, and Maintenance Tasks*

Inspection, testing, and maintenance tasks shall be performed on evaporators at the indicated frequencies, set forth in Table 22.10.1. This includes lowside heat exchangers. For heat exchangers that are pressure vessels, see Chapter 22.11 or per manufacturers’ instructions.

**TABLE 22.10.1**

**Evaporators Inspection, Testing, and Maintenance Tasks**

<table>
<thead>
<tr>
<th>ITM Task Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inspection</strong></td>
<td></td>
</tr>
<tr>
<td>a) Observe and listen to all rotating parts for abnormal sounds and vibrations.</td>
<td>Q</td>
</tr>
<tr>
<td>b) Visually inspect the supports, fasteners, and mounting bolts for cracking,</td>
<td>A</td>
</tr>
<tr>
<td>warping, stretching, bending, and looseness</td>
<td>A</td>
</tr>
</tbody>
</table>

### Frequencies:
- Q - Quarterly
- A - Annual
- NA - Not Applicable
c) Verify evaporator is free from ice buildup.

<table>
<thead>
<tr>
<th>ITM Task Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>Q</td>
</tr>
</tbody>
</table>

d) Verify secondary coolant is circulating

<table>
<thead>
<tr>
<th>ITM Task Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>Q</td>
</tr>
</tbody>
</table>

e) Observe function of defrost cycle

<table>
<thead>
<tr>
<th>ITM Task Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>WA-A</td>
<td>WA-A</td>
</tr>
</tbody>
</table>

**Frequencies:** Q - Quarterly, A - Annual, WA - Where Applicable.

### 22.11 Pressure Vessels

#### 22.11.1 *Inspection, Testing, and Maintenance Tasks*

Inspection, testing, and maintenance tasks shall be performed on carbon steel pressure vessels at the indicated frequencies, set forth in Table 22.11.1 or per manufacturers’ instructions.

#### TABLE 22.11.1

<table>
<thead>
<tr>
<th>Pressure Vessels Inspection, Testing, and Maintenance Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITM Task Description</td>
</tr>
<tr>
<td>---------------------------------------</td>
</tr>
<tr>
<td>Inspection</td>
</tr>
<tr>
<td>a) Visually inspect for damage and/or moisture in insulation or degradation of materials (i.e. dampness, condensation, frost, ice buildup)</td>
</tr>
<tr>
<td>b) Visually inspect structural supports and mounting bolts are in place</td>
</tr>
<tr>
<td>c) Visually inspect for excessive vibration or movement when liquid is being supplied</td>
</tr>
<tr>
<td>d) Visually inspect nameplate legibility and attachment</td>
</tr>
<tr>
<td>e) Test and calibrate liquid level indicator sensor and controls</td>
</tr>
<tr>
<td>f) Test liquid level float switch sensor and controls</td>
</tr>
</tbody>
</table>

**Frequencies:** A - Annual, S - Semiannual, WA - Where Applicable.

22.11.1.1 Where pitting or surface damage has not materially reduced the vessel wall thickness beyond its permitted corrosion allowance, the pressure vessel metal surface shall be cleaned and recoated to arrest further deterioration.

1. For line or crevice corrosion, the depth of the corrosion shall not exceed 25% of the original wall thickness.

2. Isolated pits may be disregarded provided their depth is not more than 50% of the required wall thickness of the pressure vessel (exclusive of any corrosion allowance), provided the total.
22.11.2 Where general corrosion is found that does not exceed the limits identified by Section 22.11.1, the pressure vessel metal surface shall be cleaned and recoated to arrest further deterioration.

22.11.3 For insulated pressure vessels, where insulation is removed, partly or completely, for visual inspection or remaining wall thickness measurement(s), a protective coating shall be applied to the exposed metal surface and the insulation shall be replaced in accordance with the manufacturer’s installation instructions after arresting any identified exposed pressure vessel metal corrosion.

22.12 Piping

22.12.1 *Inspection, Testing, and Maintenance Tasks. Inspection, testing, and maintenance tasks shall be performed on copper, carbon steel and stainless steel piping at the indicated frequencies, set forth in Table 22.1 or per manufacturers’ instructions.

<table>
<thead>
<tr>
<th>ITM Task Description</th>
<th>Insulated Frequency</th>
<th>Non-Insulated Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Visually inspect metal surfaces for pitting or surface damage</td>
<td>NA NA NA</td>
<td>NA A A</td>
</tr>
<tr>
<td>b) Visually inspect for damage or moisture incursion in insulation (i.e. dampness, frost, condensation, ice buildup)</td>
<td>A A A</td>
<td>NA NA NA</td>
</tr>
<tr>
<td>d) Visually inspect supports for cracks and degradation</td>
<td>A A A</td>
<td>A A A</td>
</tr>
<tr>
<td>f) Visually inspect piping for indications of movement</td>
<td>A A A</td>
<td>A A A</td>
</tr>
<tr>
<td>a) Replace missing or broken hangers, hanger rods, and pipe support</td>
<td>A A A</td>
<td>A A A</td>
</tr>
</tbody>
</table>

**Frequencies:** A - Annual, NA - Not Applicable.

22.12.1.1 Where pitting or surface damage is visually observed on a metal surface of the piping, deficient areas shall be further evaluated.

22.12.1.2 For insulated piping, where insulation is removed, partly or completely, for
visual inspection or remaining wall thickness measurement(s), a protective coating shall be applied to the exposed metal surface and the insulation shall be replaced in accordance with the manufacturer’s installation instructions after arresting any identified exposed piping metal surface corrosion.

22.13 Safety Systems

22.13.1 Inspection, Testing, and Maintenance Tasks. Inspection, testing, and maintenance tasks shall be performed on Safety Systems for Emergency Ventilation, Carbon Dioxide Detection and Alarms, and Computer Controls, at the indicated frequencies, set forth in Tables 22.13.1 – 22.13.3 or per manufacturers’ instructions.

TABLE 22.13.1
Emergency Ventilation Systems Inspection, Testing, and Maintenance Tasks

<table>
<thead>
<tr>
<th>ITM Task Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>a) Verify automatic function of Temperature Control Ventilation</td>
<td>WA-A</td>
</tr>
<tr>
<td>b) Listen for abnormal sounds and observe for excessive vibration</td>
<td>S</td>
</tr>
<tr>
<td>c) Visually inspect emergency ventilation override switch for damage or degradation</td>
<td>S</td>
</tr>
<tr>
<td>Testing</td>
<td></td>
</tr>
<tr>
<td>a) Functionally test audible and visual annunciators</td>
<td>A</td>
</tr>
<tr>
<td>b) Functionally test manual override of Emergency Ventilation</td>
<td>A</td>
</tr>
<tr>
<td>c) Expose carbon dioxide detector(s) to calibration test gas and verify function of ventilation equipment</td>
<td>A</td>
</tr>
<tr>
<td>d) Test sail switches, air flow sensors, or other means to verify function of emergency exhaust equipment</td>
<td>A</td>
</tr>
<tr>
<td>e) Test function of intake louvers</td>
<td>A</td>
</tr>
<tr>
<td>f) Functionally test notification to a monitored location for the loss of power to or failure of the emergency ventilation system</td>
<td>A</td>
</tr>
</tbody>
</table>


TABLE 22.13.2
Carbon Dioxide Detection and Alarm Systems Inspection, Testing, and Maintenance Tasks

<table>
<thead>
<tr>
<th>ITM Task Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>a) Visually inspect for proper installation of signage</td>
<td>S</td>
</tr>
<tr>
<td>b) Visually inspect electrical enclosures for covers to be in place or panel doors to</td>
<td>S</td>
</tr>
</tbody>
</table>
be closed

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>c) Verify sensor(s) are mounted in place</td>
<td>A</td>
</tr>
<tr>
<td>d) Verify panel(s) are mounted in place</td>
<td>A</td>
</tr>
</tbody>
</table>

**Testing**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Calibrate all carbon dioxide detector sensors</td>
<td>S</td>
</tr>
<tr>
<td>b) Expose the carbon dioxide detector to calibration test gas and verify refrigeration equipment shuts down at specified concentration levels</td>
<td>A</td>
</tr>
<tr>
<td>c) Expose the carbon dioxide detector to calibration test gas to automatically activate the emergency ventilation system</td>
<td>A</td>
</tr>
<tr>
<td>d) Functionally test alarms – audio and visual</td>
<td>A</td>
</tr>
<tr>
<td>e) Functionally test the power failure trouble signal to a monitored location for a power loss to the carbon dioxide detection system</td>
<td>A</td>
</tr>
<tr>
<td>f) Measure audio alarm output level to have a minimum of 15 decibels (dBA) above average ambient sound level</td>
<td>A</td>
</tr>
<tr>
<td>g) Measure audio alarm output level of 5 decibels (dBA) above maximum sound level</td>
<td>A</td>
</tr>
</tbody>
</table>

**Maintenance**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Replace detector sensor cells that do not calibrate</td>
<td>S</td>
</tr>
</tbody>
</table>

**Frequencies:** S - Semiannual, A – Annual.

---

**TABLE 22.13.3**

**Emergency Ventilation Systems Inspection, Testing, and Maintenance Tasks**

<table>
<thead>
<tr>
<th>ITM Task Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inspection</strong></td>
<td></td>
</tr>
<tr>
<td>a) Visually inspect for exposed control wiring or damage</td>
<td>WA-A</td>
</tr>
<tr>
<td><strong>Testing</strong></td>
<td></td>
</tr>
<tr>
<td>a) Calibrate all sensors</td>
<td>A</td>
</tr>
<tr>
<td>b) Functionally test safety alarm indicators</td>
<td>A</td>
</tr>
<tr>
<td>c) Functionally test safety system software</td>
<td>A</td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td></td>
</tr>
<tr>
<td>a) Replace batteries integral to the control systems</td>
<td>WA-5</td>
</tr>
</tbody>
</table>

**Frequencies:** A - Annual, 5 - Five Years, WA - Where Applicable.

---

**22.14 Overpressure Protection Devices**

**22.14.1 Inspection, Testing, and Maintenance Tasks.** Inspection, testing, and maintenance tasks shall be performed on overpressure protection devices at the indicated frequencies, set forth in Table 14.1 or per manufacturers’ instructions.

**TABLE 22.14.1**

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Emergency Ventilation Systems Inspection, Testing, and Maintenance Tasks

<table>
<thead>
<tr>
<th>ITM Task Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>a) Visually inspect for unbroken ASME seal</td>
<td>A</td>
</tr>
<tr>
<td>b) Verify legible nameplate/tag</td>
<td>A</td>
</tr>
<tr>
<td>c) Confirm “Installation Date” is less than 5 years’ old</td>
<td>A</td>
</tr>
<tr>
<td>d) Verify discharge outlet piping supports are not missing or broken</td>
<td>A</td>
</tr>
<tr>
<td>e) Verify discharge outlet piping has no obstructions (nests, insects, debris)</td>
<td>A</td>
</tr>
<tr>
<td>f) Inspect rupture disc or discharge relief indicators</td>
<td>WA-W</td>
</tr>
</tbody>
</table>

**Frequencies:** W – Weekly, A - Annual, WA - Where Applicable.

22.15 Secondary Coolants

22.15.1 Inspection, Testing, and Maintenance Tasks. Inspection, testing, and maintenance tasks pertaining to the secondary coolants shall be performed at the indicated frequencies, set forth in Table 22.15.1 or per manufacturers’ instructions. This only applies to secondary fluids other than carbon dioxide.

**TABLE 22.15.1**

Secondary Coolants Inspection, Testing, and Maintenance Tasks

<table>
<thead>
<tr>
<th>ITM Task Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>a) Secondary Coolant freeze point</td>
<td>WA-A</td>
</tr>
<tr>
<td>b) Secondary Coolant corrosion inhibitor</td>
<td>WA-A</td>
</tr>
<tr>
<td>c) Secondary Coolant pH</td>
<td>WA-A</td>
</tr>
<tr>
<td>d) Concentration correction to proper specific gravity (SG)</td>
<td>WA-A</td>
</tr>
<tr>
<td>e) Corrosion inhibitor correction</td>
<td>WA-A</td>
</tr>
<tr>
<td>f) pH balance correction</td>
<td>WA-A</td>
</tr>
</tbody>
</table>

**Frequencies:** A - Annual, WA - Where Applicable.
Part 6. Appendices (Informative)

Appendix A. Explanatory Material (Informative)

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.”

A.1.2.2, Item 5: Additions and Modifications are defined as:

1. Any new attachment to an existing operating system, or system which has been in operation, which did not exist prior to the attachment.
2. Any reconfiguration of any portion of an existing operating system, or system which has been in operation, to service a new or converted area which does not function in the same manner as before the conversion.
3. Any activity which requires pipe to be replaced due to non-wear and tear issues, pipe cut to fit, pipe welded, or pipe threaded to reconnect sections of a closed-circuit ammonia refrigeration system.

An in-kind replacement of a component for maintenance reasons, such as a solenoid valve, is not an Addition or Modification to a closed-circuit ammonia refrigeration system.

When an Addition or Modification occurs to an existing operating system, or system which has been in operation, only the Addition or Modification itself shall be subject to the requirements of this document.

A.2.2 See IIAR 1 for definition of Occupancy Classifications.

Commercial Occupancy: Commercial occupancies include office, work, and storage areas that do not qualify as industrial occupancies.

Public Assembly Occupancy: Examples of public assembly occupancies include, but are not limited to, auditoriums, stadiums, arenas, ballrooms, classrooms, passenger depots, restaurants, and theaters.

A.4.2.2 This section’s reference to industrial occupancies regulated by Section 7.2 is intended to exempt any area that is allowed to contain carbon dioxide equipment from the 20-ft separation requirement. For example, no separation is required between a rooftop air handling unit that uses carbon dioxide and any openings to areas that are permitted to contain carbon dioxide equipment.

A.4.2.3 While the concept of low-probability pumps can be applied to pumps conveying any liquid,
provisions for low-probability pumps in this standard only pertain to pumps conveying liquid carbon dioxide.

A.4.2.4 The purpose of Section 4.2.4 is to establish a maximum refrigerant concentration level (RCL) for nonindustrial occupancies. The RCL is a term defined by 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 4.2.4 is to define RCL in the same manner as ASHRAE. For the purpose of this standard, the RCL established is 30,000 ppm (which corresponds to 3.4 lbs. per 1000 ft³). ASHRAE uses an RCL of 30,000 ppm for carbon dioxide.

A.5.3 The provisions in this section are generally based on ASHRAE 15.

A.5.3.1 For the purpose of determining how to treat interconnected spaces, as separate or singular, 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 reliably remain unobstructed throughout the life of the building.

A.5.3.3 Using the smallest volume space for a release event provides a worst-case scenario analysis.

A.5.3.4 Where a damper might be expected to stop airflow between two rooms or spaces, those spaces should not be considered as connected for purposes of evaluating a worst-case scenario of a carbon dioxide release into the smallest exposed space. Fire dampers, smoke dampers, and dampers that provide both functions are normally open and will only close in a fire event, not a carbon dioxide release event, and it is not the intent of this section to require a design that assumes a carbon dioxide release that is simultaneous with a fire.

A.5.5.1.1 The intent of this requirement is to avoid nuisance shutdowns or nuisance releases caused by the lack of a buffer between normal operational pressure levels and pressure levels associated with abnormal or emergency conditions that lead to a shutdown or a release.

A method to avoid a pressure relief valve from lifting during an extended power failure would be to install a refrigeration system that operates by a standalone generator to keep the refrigerant temperature below the refrigerant boiling point in the liquid/vapor separator (flash tank).

A.5.8 Proper evacuation of moisture, air and other noncondensable gases is very important to the operation of carbon dioxide refrigeration systems. Adequate means to allow removal these contaminants from the system prior to initial system charge and during subsequent maintenance activities should be considered in the design of all refrigerant containing portions of systems.

A.5.10.1 Insulation can also be provided for energy conservation purposes, as required by the owner or local energy conservation requirement.
Energy codes, including the IECC and CEC require specific insulation thicknesses based on temperature and pipe size.

**A.5.12.1** 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 refrigeration systems. In addition, Chapter 11 of the Uniform Mechanical Code includes special access provisions for refrigeration equipment. This section requires equipment to be designed and installed with serviceability in mind, including clearances for service tools and similar serviceability provisions.

See OSHA 29 CFR 1910.24 for information on providing fixed stairs for access to serviceable equipment.

**A.5.12.3** Examples of equipment that might require maintenance or functional control testing include liquid level indicators, float switches, and high-pressure cut-out switches.

**A.5.12.5** 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.

Access ports or service valves to relieve system pressure prior to servicing should be considered and installed downstream of an isolation valve.

**A.5.13.2.1** This requirement is consistent with ASHRAE 15.

**A.5.13.2.2** This requirement is consistent with ASHRAE 15, which regulates the secondary fluid. See ASHRAE 15, Section 9.11.1.

**A.5.17.2** Examples of moving parts that might require protection include shafts, belts, pulleys, flywheels, and couplings.

**A.5.17.4** Used equipment includes equipment that is relocated or purchased after previous use.

**A.5.17.5** Further information on structural load requirements can be found in the Building Code and the Mechanical Code. Also see Section 5.11.

**A.5.17.6** For additional information, see OSHA 29 CFR 1926.56.

**A.5.17.7** The Building Code provides comprehensive regulations for means of egress, but of particular concern in 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 2015 International Building Code Section 1018.5, Exception, and Sections 1003.2 and 1003.3.

A.6.2.1 See Section 6.7 for requirements related to doors and Section 6.4.2 for pipe penetrations.

A.6.3.3.1 See 29 CFR 1910.27 for information regarding ladder access.

A.6.9.2 For CO2 Concentration Levels and Expected Effects on Human Health, see Appendix B.

A.6.9.2.1.2 Visual alarms can be provided by strobes or other distinctive visual signaling devices.

A.6.10.1 This requirement correlates with the minimum ventilation for occupants consistent with current requirements in model mechanical codes for machinery rooms, but has been expanded here to permit the use of natural ventilation where natural ventilation can be demonstrated as meeting the minimum air exchange requirements.

A.6.10.6.1 See ASHRAE Handbook, Fundamentals, Chapter 14, Climate Design Information, for determination of dry bulb temperature.

A.6.11.1 This requirement correlates with the minimum ventilation for occupants consistent with current requirements in model mechanical codes for machinery rooms, but has been expanded here to permit the use of natural ventilation where natural ventilation can be demonstrated as meeting the minimum air exchange requirements.

A.6.11.3.4 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 a refrigerant release. Consideration should be given to the natural airflow around the building, prevailing winds, and surrounding structures.

A.6.11.6.1 See ASHRAE Handbook Fundamentals, Climate Design Information, for determination of dry bulb temperature.

A.6.11.8 The IFC (Chapter 6) defines 220 pounds (100 Kg) as the quantity, for A1 refrigerants, above which systems require fire department access, testing of emergency devices, and emergency signage. A reduced frequency for testing may be established if enough test data already exist or after enough test data have been accumulated to support the reliability of the ventilation equipment with less frequent testing.

A.6.12.1 International Mechanical Code (IMC) Table 1103.1 establishes the degree of severity designations to be provided on the NFPA 704 placard, which differs for indoor and outdoor locations based on the risk of ignition. The NFPA designates health, fire, and reactivity respectively as 3-0-0 for carbon dioxide. The IFC (Chapter 6) defines 220 pounds (100 Kg) as the quantity, for A1
refrigerants, above which systems require fire department access, testing of emergency devices, and emergency signage.

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 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, as opposed to the refrigeration contractor.

A.7.2.3, EXCEPTION 1: The term “unoccupied area” applies to portions of premises that are accessible only to authorized personnel performing inspection or maintenance.

A.7.2.4 Physical barrier impact protection can include posts or other barriers. There are specific requirements in the Fire Code (IFC 312) which may be used as a guideline.

A.7.3.1.1 By referencing Section 4.2.3 Item 5, it is specifically intended that this section, and the associated provisions for ventilation, not apply to equipment that is permitted outside of a machinery room by Section 4.2.3 Items 1–3.

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 carbon dioxide, 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 Appendix K.

A.8.1.3.2.1 The exceptions to 8.1.3.2.1 allow booster compressors to be sized based on the saturated intermediate temperature at the compressor suction and also allow the minimum regulated flow of the compressor to be used in the valve sizing as long as the specified requirements are met.

A.9.2.1.5 High pressure copper pipe has been developed that is made from alloy C19400 (aka. Copper-iron, CuFe2P, etc.) The tube is made to meet the dimensional (OD), mechanical, cleanness, and eddy current testing requirements of the applicable specification of ASTM B280 (Seamless Copper Tube for Refrigeration Field Service). Similarly, the fittings are made to meet the dimensional requirements and other applicable specifications of ASME B16.22 (WROUGHT Copper and copper alloy…Pressure Fittings). The tubing is third party recognized for refrigeration applications with continuous operating pressures of up to 1885 psig (130 Bar) at up to 250 °F (120 °C).
A.11.5.2.1 Typical Moody friction factors \( f \) for fully turbulent flow are provided in Tables A.11.5.2.1(1) and A.11.5.2.1(2).

**Table A.11.5.2.1(1) - Typical Moody Friction Factors, Steel Tubing**

<table>
<thead>
<tr>
<th>Tubing OD (in.)</th>
<th>DN</th>
<th>ID (in.)</th>
<th>( f )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{3}{8} )</td>
<td>8</td>
<td>0.315</td>
<td>0.0136</td>
</tr>
<tr>
<td>( \frac{1}{2} )</td>
<td>10</td>
<td>0.430</td>
<td>0.0128</td>
</tr>
<tr>
<td>( \frac{5}{8} )</td>
<td>13</td>
<td>0.545</td>
<td>0.0122</td>
</tr>
<tr>
<td>( \frac{3}{4} )</td>
<td>16</td>
<td>0.666</td>
<td>0.0117</td>
</tr>
<tr>
<td>( \frac{7}{8} )</td>
<td>20</td>
<td>0.785</td>
<td>0.0114</td>
</tr>
<tr>
<td>( 1\frac{1}{8} )</td>
<td>25</td>
<td>1.025</td>
<td>0.0108</td>
</tr>
<tr>
<td>( 1\frac{3}{8} )</td>
<td>32</td>
<td>1.265</td>
<td>0.0104</td>
</tr>
<tr>
<td>( 1\frac{5}{8} )</td>
<td>40</td>
<td>1.505</td>
<td>0.0101</td>
</tr>
</tbody>
</table>

**Table A.11.5.2.1(2) – Typical Moody Friction Factors, Steel Piping**

<table>
<thead>
<tr>
<th>Piping NPS</th>
<th>DN</th>
<th>ID (in.)</th>
<th>( f )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{3}{8} )</td>
<td>15</td>
<td>0.622</td>
<td>0.0259</td>
</tr>
<tr>
<td>( \frac{3}{4} )</td>
<td>20</td>
<td>0.824</td>
<td>0.0240</td>
</tr>
<tr>
<td>1</td>
<td>25</td>
<td>1.049</td>
<td>0.0225</td>
</tr>
<tr>
<td>( 1\frac{1}{4} )</td>
<td>32</td>
<td>1.380</td>
<td>0.0209</td>
</tr>
<tr>
<td>( 1\frac{3}{4} )</td>
<td>40</td>
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<td>2.469</td>
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<td>6</td>
<td>150</td>
<td>6.065</td>
<td>0.0149</td>
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</table>

Table A.11.5.2.1(3) Atmospheric Pressure at Nominal Installation Elevation (Pa)

<table>
<thead>
<tr>
<th>Elevation above Sea Level (ft)</th>
<th>$P_a$ (psia)</th>
<th>Elevation above Sea Level (m)</th>
<th>$P_a$ (kPa)</th>
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<tbody>
<tr>
<td>0</td>
<td>14.7</td>
<td>0</td>
<td>101</td>
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<td>500</td>
<td>14.4</td>
<td>150</td>
<td>99.5</td>
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<td>1500</td>
<td>13.9</td>
<td>450</td>
<td>96.0</td>
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<tr>
<td>2000</td>
<td>13.7</td>
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<td>94.3</td>
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<td>1050</td>
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<td>4500</td>
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<td>1350</td>
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<td>12.2</td>
<td>1500</td>
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<td>11.8</td>
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<tr>
<td>10000</td>
<td>10.1</td>
<td>3000</td>
<td>70.1</td>
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</table>
A.12.1.4 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, but unintentionally affect alarm or emergency control settings.

A.12.2.1.1 The basis of a performance-based design could be an analysis that is consistent with the general philosophy embodied in ASME B31.5.

A.12.2.3 Linear liquid level indicators are sometimes referred to as sight columns. It is recommended that linear liquid indicators be of the flat “armored glass” type in preference to the tubular glass type.

A.12.3 This section does not address relay switches, contactors, and starters.

A.13.4 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 for carbon dioxide detection alarms to ensure adequate audibility. The intent of including specific sound pressure level in dBA is to provide 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.13.6 Level 2 detection is not required in the normative section of the standard, for reference, should Level 2 be considered, the following criteria are recommended:

1. At least one carbon dioxide 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:
   a. Carbon Dioxide at 15,000 ppm or lower for Industrial Occupancies.
   b. Carbon Dioxide at 5,000 ppm or lower for other Occupancies.

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 authorized personnel and emergency responders.
A.18.1.6 Starting with a dry refrigeration system is paramount due to that carbon dioxide is very sensitive to water in the system.

Suggested Evacuation Criteria (May be modified as appropriate for particular system conditions):
The refrigeration system is initially pulled down to a 5,000-micron vacuum which is slightly above freezing. The vacuum is then broken using dry nitrogen vapor, which absorbs more of the system water vapor. Pressure should rise back to atmospheric 760 mm hg (760,000 microns).

The refrigeration system is then pulled down to a 5,000 micron vacuum a second time. If the pressure drop slows or “hangs” between 10,000 and 5,000 microns, then there is still water in the system and a third evacuation is recommended. The vacuum is then broken using dry nitrogen vapor and system pressure should again rise to about 760,000 microns.

A third and final vacuum is then performed. The refrigeration system is then evacuated to a 500-micron vacuum and held for 24 hours. At the end of 24 hours, the vacuum pumps are shut down and isolated, and system pressure is monitored. System pressure should not increase above 650-micron after 3 hours. If required, break vacuum with dry nitrogen vapor and repeat the above steps.

If the refrigeration system vacuum holds, at or less than 650 microns after 3 hours, break this vacuum with refrigeration grade carbon dioxide vapor (See Section 5.2). NEVER BREAK VACUUM WITH LIQUID CARBON DIOXIDE as it will immediately form dry ice.

Continue to add CO2 vapor until the system pressure reaches 100 psig (6.9 Bar). If the system is to be left in this state for a prolonged period of time, then the system pressure should be logged along with ambient temperatures until the final system charge is taken.

A.19.1.1.1 The system overview training should provide a system description to develop understanding of the carbon dioxide refrigeration system, equipment, and components and their function(s). In addition, the operator should be trained on the use of the control system and operation manuals. Awareness training and emergency action training should be provided for the designers, engineers, and contractors.

A.21.2.2 The Compressor High Discharge Cutout is also known as a compressor High Pressure Cutout (HPCO). Compressor High Discharge Pressure Cutouts are a special case and require a specific testing method. Refer to Chapter 22 for permitted functional testing methods of a Compressor High Discharge Pressure Cutout.

A.21.3.1 The reduction in temperature will cause materials to contract and shrink perhaps resulting in a refrigerant leak. Items such as valve stem packing nuts or flanges may require tightening to compensate.
Abnormalities may include piping movement or vibration that may require identifying the source and rectifying the root cause. This may require installing support modifications or adjustments.

A.21.4.1 Verification does not necessarily require full performance operation. During verification, the system should be operated with the available heat load.

A.21.4.2 Verification is functional performance testing. Verify that the following are operating safely, correctly, and as intended by design, where applicable:

1. Refrigeration system equipment, components, and devices.
2. Control set point adjustments for area space temperatures, process fluid temperatures, discharge pressures, suction pressures, refrigerant liquid levels, and refrigerant oil liquid levels.
3. Sequence of operation for compressor staging, discharge pressure control, evaporator defrosting, ventilation control, and pro-active detection and alarm systems.
4. All operator interface(s).

A.21.5.1 Issues could include vibration, wiring, software/programming, defective components and devices, poor sensing location, valves that leak through, or components that do not perform to design specifications.

A.21.6.1 The duration of this monitoring period should be determined by the startup team. This monitoring will allow performance verification under a wider range of operating conditions and demands. It will also provide time to confirm component integrity.

A.22.1.4 The facility may store additional maintenance materials, spare parts, and equipment that are suitable for the system application for which they will be used. This is typically done for materials, spare parts, and/or equipment that have long lead times.

A.22.1.5 A risk-based ITM strategy includes the study and risk ranking of equipment and system failures based on probability (likelihood) and consequence (severity). The risk-based assessment learnings are used as criteria to further enhance the development of ITM tasks for the equipment and systems for planning, implementing, and optimizing results. See Appendix E - Risk-Based Inspection, Testing, and Maintenance.

A.22.2 Occasional record keeping interruptions may occur from being reviewed once per day on weekends, and/or during holidays. This is when coverage by refrigeration personnel is not normally scheduled. During the next scheduled service or maintenance shift when a trained technician is back on duty, the assigned record keeping activities should resume and be analyzed for comparison and current operating conditions.
A.22.2.1 A history of abnormalities consists where repeated abnormalities have occurred during five consecutive frequency (ITM) tasks as presently planned and scheduled that should be addressed in order to prevent a risk of operating outside of operating limits. Due to risk on a case-by-case basis, an owner may choose to address consecutively identified abnormalities sooner.

Predictive maintenance technologies applied to equipment are permitted to result in justifying, analyzing, and decreasing or extending time between major maintenance activities. Examples of predictive maintenance technologies are oil analysis, vibration analysis, thermography, and shaft alignment.

A Computer Maintenance Management System (CMMS) that is used by the facility that provides reliable record keeping for inspection, testing, maintenance, and logs and the documented information is readily accessible is permitted.

A.22.3.1 The owner or owner’s designated representative ensures the record keeping activities are performed. The owner or owner’s designated representative may perform the record keeping activities. The designated representative is the person responsible for performing the record keeping activities. This person should a working knowledge of the system.

A.22.3.2 The original manufacturers’ design, operations, and maintenance documentation for each instrumentation device, including those ancillary devices used to fabricate an assembly or subassembly, should be obtained and filed. Where the original technical information and documentation cannot be found or no longer exists, such information can be developed in conjunction with a process hazard analysis in sufficient detail to support the analysis.

A.22.3.3 The relief valve list with set pressure and minimum rated capacity should have readily accessible information of the calculations for common discharge headers to show that they have adequately sized piping to prevent excessive backpressure on relief valves,

The ventilation system functional description should have readily accessible information of the capacity calculations.

The “current” system is what is presently in operation as the refrigeration system of which the minimum documentation records listed in Section 22.3.3 should be readily accessible.

A.22.3.6.1 The means of record keeping, such as a log, to document and transfer pertinent operational, maintenance, and ongoing duty information between operators could include shift change notes, explanatory for equipment ITM tasks at hand (inspection, testing, and/or maintenance logs), nuisance reports or details at hand (leaks, intermittent issues or circumstances), incidents and incident investigations, round reports and explanatory field information, forthcoming
tasks, safe work practices (hot work, lockout/tagout, confined space, line breaking, working at heights, ground disturbance, etc.) occurring and requiring transfer, etc.

A.22.3.6.3 Oil Consumption should be verified and analyzed to determine if excessive amounts of oil are being consumed and carried over into the refrigeration system. Where excess oil is being added, an investigation can be put into place to determine which particular machine or equipment is causing the increased usage. Increased requirements in oil draining is another indicator that should be verified and analyzed.

A.22.4.1 The evaluation of an identified deficiency may include a ranking method to determine the severity and likelihood of what could result if the deficiency is not resolved and determine a time frame to assign a corrective action(s) to resolve the deficiency. The evaluation and corrective action determination may be simply addressed by the qualified assigned responsible person, require the arrangement and involvement of additional qualified individuals who are familiar with the specific refrigeration system or others who have expertise in engineering, operations, and/or maintenance of refrigeration systems.

A facility may utilize a contractor service providing operators, technicians, or both for performing inspections while searching, hiring, and training replacement employees that are no longer employed at the facility, while employees are offsite for training, vacation, or leave of absence events, or both. Some locations may have identified that utilizing a contractor service for its coverage works better for the facility.

Each component or device installed on equipment, such as an oil pump on a compressor, should be inspected in accordance with the component or device manufacturers’ recommendations. The manufacturers should provide the component or device manufacturers’ recommendations used on equipment they manufacture. The owner or owner’s designated purchaser should request and verify they obtained the component or device manufacturers’ recommendations that are used on equipment from the manufacturer of such equipment.

A.22.6.1 Original equipment manufacturer procedures may be used as long as they are stored in the same place as the written procedures and are readily available.

A.22.6.6 The owner is permitted to develop and incorporate defrost operational procedures, ice removal procedures using mechanical tools, or both, with determined frequencies to safely remove ice often enough to avoid excess accumulation.

A.22.7.1 Any time a maintenance or service technician is on site and working on the covered unit, a recommendation is that, at a minimum, inspection tasks (e), (j), and (k) should be inspected.
If oil is found to be leaking, it should be assumed that refrigerant is leaking. In order for the leak to be repaired, that portion of the system should be isolated and repaired without pressure in the system. In addition, the isolated area should be subjected to a 500 micron vacuum prior to opening it back to the system.

The amperage of the oil heater circuit may be measured and compared to normal ranges as part of the evaluation of operation.

A.22.7.1.1 A compressor’s high discharge pressure cutout, otherwise known as the high-pressure cutout (HPCO), is a pressure limiting device. This pressure limiting device is required to be tested during the initial startup and commissioning of the compressor.

A.22.9.1 Highside heat exchangers on the refrigeration system can apply the inspection, testing, and maintenance (ITM) tasks included in Table 8.1. Heat exchangers on the highside of a refrigeration system may include water cooled shell-and-tube, oil coolers, heat recovery units, and liquid sub-coolers. The plate types may be gasketed plate and-frame, welded plate-pair, or other. Liquid sub-coolers may be a shell-and-tube type, shell-and-coil type, or a shell-and-plate type.

Typical industry standard is to follow manufacturers’ recommendations and run to failure. During annual inspection, it is recommended to inspect for carbon dioxide leaks using a handheld CO₂ detector with the water shut off on evaporative condensers. Also, with shell-and-tube, as well as, plate-heat exchanger type condensers that use water as a medium, it may be beneficial to inspect for CO2 leaks with a handheld CO2 detector with the water shut off on these types of condensers as well. Air-cooled condenser types, which do not typically use water, can be inspected for CO2 leaks using a handheld CO2 detector. Some owners install a separate water spray mist on air-cooled condensers to give it the evaporative cooling effect. In this situation, the water spray mist on an air-cooled condenser is recommended to be shut off during inspections.

Condensers using fans can unfortunately have their fan guarding blocked by plastic wrap, pieces of cardboard, papers, spill prevention materials, etc. which causes the space behind the obstruction to see a rapid change in pressure causing the fan blades to flex. This flexing due to an obstruction can result in vibrations, cracking, and separations of the fan blades, and damage to fan hubs, if the material causing the obstruction is not removed.

Breakage of fan blades can result in the separated material being launched as shrapnel projectiles causing property damage, possible equipment leakage due to penetrating a refrigerant coil tube, and/or possible personnel injury.

A.22.10.1 Other types of equipment used for cooling or chilling on the lowside of a refrigeration system can apply the inspection, testing, and maintenance (ITM) tasks as needed that are included in Table 9.1, where applicable. These other types of heat exchangers on the lowside of a refrigeration system may include liquid chillers, falling-film chillers, plate-or-tube ice makers, or
orbital-rod evaporators. The plate types may be gasketed plate and-frame, welded plate-pair, or shell-and-plate, or other.

Frost accumulation on evaporator coils and surfaces is normal. Heavy ice accumulation is abnormal and should be addressed. The owner is permitted to develop and incorporate defrost operational procedures, ice removal procedures using mechanical tools, or both, with determined frequencies to safely remove ice often enough to avoid excess accumulation.

Typical industry practice is to follow manufacturers’ recommendations or to run to failure (until a refrigerant odor becomes present).

Forced-Air evaporators can unfortunately have their fan guarding blocked by plastic wrap, pieces of cardboard, papers, spill prevention materials, etc. which causes the space behind the obstruction to see a rapid change in pressure causing the fan blades to flex. This flexing due to an obstruction can result in vibrations, cracking, and separations of the fan blades, and damage to fan hubs, if the material causing the obstruction is not removed. Breakage of fan blades can result in the separated material being launched as shrapnel projectiles causing property damage, possible equipment leakage due to penetrating a refrigerant coil tube, and/or possible personnel injury.

A.22.11.1 Refrigeration system pressure vessels should be listened to for abnormal sounds. Abnormal sounds may be indications of hydraulic shock occurring, such as sudden liquid deceleration, vapor-propelled liquid, and/or condensate-induced shock and should be evaluated and addressed in a timely manner. See informative Appendix E: Avoiding Component Failure in Industrial Refrigeration Systems Caused by Abnormal Pressure or Shock.

Different types of visual liquid level indicators using glass as a “sight glass” are bull’s eyes, tubular, or flat “armored” plate. The sight glass visual inspection should include the glass, retaining ring or other type fasteners, the gasket or gasket edges (if visible) and the housing for pitting, surface damage, and or misalignment. On the glass, look for nicks, cracks, chips, or other imperfections using illumination to provide black or oblique lighting. Verify adequacy and condition of guards, for example, visually inspect the entire length and 360-degree protection coverage for tubular sight glasses.

A.22.11.1.2 Pitting implies corrosion. Pitting corrosion is the formation of holes in an otherwise relatively unattached surface. Pitting is usually a slow process causing isolated, scattered pits over a small area that does not substantially weaken the vessel. It could, however, eventually cause a leak. Pitting can be measured with a pit gauge or other qualifying technique.

Pressure vessel shells can be made of pipe and are very common up to 24 inches in diameter and, in some possible cases, may even be larger. A corrosion allowance on pipe provides additional wall thickness material which adds to the permissible wall loss.
Where the owner does not have record of the pressure vessel’s required wall thickness, the owner should request this information from the pressure vessel manufacturer. Where the pressure vessel manufacturer or information is no longer available, an engineering assessment should be performed to establish required wall thickness values for the pressure vessel section(s) in question. See ASME Boiler and Pressure Vessel Code, Pressure Vessel, Section VIII, Division 1.

**Inspection Records** - The following items should accompany any formal inspection report:

1) Facility Name  
2) Vessel Name or number  
3) National Board number (if available)  
4) Name of inspection company and inspector  
5) Date(s) inspection data was acquired  
6) Condition of the vessel when inspected  
7) Inspection results

“Where Applicable – Annual” (WA-A) for testing to determine the remaining wall thickness of the pressure vessel is to be performed on the locations where pitting or surface damage were visually observed. Where no pitting or surface damage is visually observed, testing to determine the remaining wall thickness of the pressure vessel does not need to occur. The pressure vessel is considered at its original thickness or at its remaining wall thickness from the most recent test result.

Where pressure vessels are insulated and operate at temperatures below 25°F with ice accumulation around the full circumference of the pressure vessel and the ice accumulation is maintained below freezing (i.e. below 32°F) during temporary operational shutdowns, the pressure vessel is expected to be preserved and sustained to the similar conditions of previous inspection results. If damage were to occur to the pressure vessel insulation and/or vapor barrier, the owner should proceed with repairing and/or replacing the damaged pressure vessel insulation and/or vapor barrier in a timely manner. Due to the below freezing temperatures being maintained by the system operations and the timely replacement and/or repair of any damaged insulation and/or vapor barrier, the preserved pressure vessel should not have been subject to pitting or surface damage.

**A.22.12.1** Refrigeration system piping should be listened to for abnormal sounds. Abnormal sounds may be indications of hydraulic shock occurring, such as sudden liquid deceleration, vapor-propelled liquid, and/or condensate induced shock and should be evaluated and addressed in a timely manner. If hydraulic shock has occurred, the pipe may have indications of movement. See informative Appendix E: *Avoiding Component Failure in Industrial Refrigeration Systems Caused by Abnormal Pressure or Shock.*
Indications of movement may include shifting, bending, broken, or missing pipe hangers, scratches and rub marks on the piping, saddles, or insulation jacketing surfaces from hangers that have moved, or cracked or failed welds at supports.
### Appendix B. CO2 Concentration Levels and Expected Effects on Human Health (Informative)

#### CO2 Concentration Levels and Expected Effects on Human Health

<table>
<thead>
<tr>
<th>PPM</th>
<th>Health Effects</th>
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<tbody>
<tr>
<td>350</td>
<td>Normal Value in Atmosphere</td>
</tr>
<tr>
<td>1,000&lt;sup&gt;(5)&lt;/sup&gt;</td>
<td>Human Comfort Limit</td>
</tr>
<tr>
<td>5,000&lt;sup&gt;(1)&lt;/sup&gt; (0.5%)</td>
<td>Threshold Limit valve (TLV) – time weighted average (TWA) &lt;sup&gt;(2)&lt;/sup&gt;</td>
</tr>
<tr>
<td>10,000 (1.0%)</td>
<td>Continuous exposure at this level will cause drowsiness</td>
</tr>
<tr>
<td>15,000 (1.5%)</td>
<td>Mild respiratory stimulation for some people</td>
</tr>
<tr>
<td>30,000&lt;sup&gt;(3)&lt;/sup&gt; (3.0 %)</td>
<td>Breathing rate doubles after short time exposure</td>
</tr>
<tr>
<td>40,000 (4.0 %)</td>
<td>IDLH value&lt;sup&gt;(4)&lt;/sup&gt;</td>
</tr>
<tr>
<td>100,000</td>
<td>Lowest Lethal concentration, few minutes of exposure could produce unconsciousness</td>
</tr>
<tr>
<td>200,000</td>
<td>Death Accidents have been reported</td>
</tr>
<tr>
<td>300,000</td>
<td>Quickly results in unconsciousness and convulsions</td>
</tr>
</tbody>
</table>

(1) – OSHA revised Permissible Exposure Limit (PEL): Time-Weighted Average (TWA) concentration that must not be exceeded during any 8 hour per day, 40 hour per week.

(2) - Threshold Limit Value (TLV): TWA concentration to which one may be repeatedly exposed for 8 hours per day, 40 hours per week without adverse effect.

(3) – Short Term Exposure Limit (STEL): a 15-minute TWA exposure that should not be exceeded at any time during the workday. Refrigerant Concentration Limit (RCL); ASHRAE 34.

(4) - Immediately Dangerous to Life or Health (IDLH) value: maximum level for which one could escape within 30 minutes without any escape-impairing symptoms or any irreversible health effects.

(5) Position statement from ASHRAE “Summary of ASHRAE’s position on Carbon Dioxide Levels in Spaces” by Stephen Petty, PE, CIH.
Appendix C. Avoiding Component Failure in Refrigeration Systems Caused by Abnormal Pressure or Shock (Informative)

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 ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process.

The information contained in this appendix has been obtained from sources believed to be reliable. However, it should not be assumed that all acceptable methods or procedures are contained in this appendix or that additional measures may not be required under certain circumstances or conditions.

The IIAR makes no warranty or representation, and assumes no liability or responsibility, regarding any information contained in this appendix.

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C.I. Preface

Refrigeration system component designs incorporate safety factors well above normal system working pressures. However, all systems are subject to conditions created by design, operation, or service that can result in excessive pressures within the closed-circuit refrigeration system. These pressures release static and kinetic energy that may damage evaporators, valves, pressure vessels, or piping causing a release of refrigerant that could lead to possible product loss or personal injury.

The scope of this informative appendix is to provide voluntary guidelines and recommendations for avoiding component failure in industrial refrigeration systems that may be caused by abnormal pressure or shock, also known as hydraulic shock. For safety, it is crucial that all refrigeration systems be on alert and are routinely checked for onset indications of abnormal pressures and hydraulic shock. Indications identified at the onset can address the root cause situations and avoid component failure that could otherwise lead to risks of injury, equipment damage, or both. The recommendations contained in this informative appendix are intended for systems using CO2 as the refrigerant. However, the principles involve may apply to industrial refrigeration systems using other refrigerants.

C.II. Hydraulic Shock

Hydraulic shock is a sudden localized spike in pressure that can occur in piping or equipment when there is a rapid change in velocity of a flowing liquid. This is often referred to as “liquid hammer”. 
Hydraulic shock in refrigeration systems can generate extreme high pressures with the potential to cause the catastrophic failure of piping, valves, and other equipment. The highest pressures often occur when vapor and liquid refrigerant are present in a single pipeline and are disturbed by a sudden change in volume.

Moderate hydraulic shocks can generate pressures that are evidenced by indicating knocking sounds emanating from piping and valves that are trying to release kinetic energy (i.e. liquid hammer). These hydraulic shocks will actually try to move the piping, valves, or equipment. Visual indications may be seen when pipe hangers have tried to shift, bend, or the piping shows scratches and marks from the hangers rubbing on the piping themselves.

Three (3) common disturbance mechanisms can cause hydraulic shock in refrigeration systems which are as follows:

1) Sudden Liquid Deceleration – 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.

2) Vapor-Propelled Liquid Slug – 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.

3) Condensation-Induced Shock – Caused when high pressure refrigerant vapor rapidly condenses in pipe lines containing both liquid and vapor. As CO2 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.

Damaging hydraulic shock events are typically the condensation-induced type and frequently can occur in low temperature refrigeration systems. These events are often associated with the transition from high temperature and pressure to low temperature and pressure during and after the defrosting of evaporators with hot gaseous refrigerant.

A combination of both condensation-induced shock and vapor-propelled liquid often occur during a hydraulic shock. Damaged system components could be evaporators, associated valves, suction piping and suction header mains downstream of the evaporators, including the pipe end-caps. Undesirable transient events can occur in piping that are conveying both liquid and vapor.

C.III. Trapped Liquid
Although not a hydraulic shock, which is a kinetic energy risk where the refrigerant as a vapor, liquid or both is moving, a hydrostatic lockup is a static energy risk that can occur when liquid refrigerant is trapped and not moving. Trapped liquid is the complete filling of the internal volume of a containment envelope, such as a pressure vessel or pipe, with liquid refrigerant. As temperature and pressure proportionately change, rising temperatures lead to increases in internal component pressure. The increasing internal pressure of the trapped liquid places its rising force against all the internal surfaces of the pressure containing envelope causing the containment area to increase in volume.

Failures of the pressure containing envelope can occur when the rising force thermally expands the component beyond its designed material strength until it ruptures.

Trapped liquid is most frequently caused by the improper closing of hand valves that trap liquid in confined space. This typically can occur during an isolation procedure while servicing a component in a liquid line.

Examples of this include trapping of liquid between two hand valves or between a check valve and a downstream hand valve.

Before servicing a control valve or other components in a liquid line, the liquid from both sides of the device(s) should be removed. A hand valve on the inlet side should be closed first and the liquid removed (i.e. evacuated or pumped out) from the component and its downstream side. Only then should the downstream side or suction be closed off, thereby isolating the component from the closed-circuit system.

An evaporator that is full of liquid refrigerant should not be isolated. If isolation is necessary, the evaporator must be pumped out first. An evaporator located in a cold area may take several hours for a total pump out.

C.IV. SUDDEN LIQUID DECELERATION

Sudden liquid deceleration is similar to liquid hammer (i.e. water hammer) in a water distribution system that does not have shock absorbing air pockets in the piping at the location of each shut-off valve. Simple vapor pockets in a liquid refrigerant system cannot be relied upon to provide the same protection because the refrigerant vapor will tend to condense, filling the pockets with liquid.

Sudden liquid deceleration can be caused by flow in a liquid line that is suddenly stopped by a snap acting solenoid valve. However, the design flow velocities and pressures in the liquid lines of overfed systems are normally too low to produce shocks of any significance.

C.V. VAPOR-PROPELLED LIQUID SLUG and CONDENSATION-INDUCED SHOCK

Nearly all industrial refrigeration systems are safe and function, under normal circumstances, without problems resulting from high velocity liquid propelled by high-pressure vapor. However, abnormal
and unusual conditions can cause trouble in a system where neither the design nor operating procedures have anticipated these problems.

Most reported vapor propelled liquid problems occur in low temperature systems with components operating a 20°F (-29°F) or colder refrigerant, employing liquid overfeed and using hot gas defrost. Air, electric, and secondary coolant (i.e. glycol, brine) sprayed defrosting techniques tend to be less stressful than hot gas defrosts on low temperature evaporators.

Vapor propelled liquid can be caused by the sudden release of a high-pressure vapor, such as hot gas, into a line that is partially filled with liquid.

Condensation-induced shock can be caused when high pressure refrigerant vapor rapidly condenses in piping containing both liquid and vapor. As the CO2 vapor condenses, it undergoes a large decrease in volume. This large reduction in volume causes liquid to accelerate. When the accelerated liquid suddenly encounters adjacent obstructions, such as valves, pipe end caps, or even equipment, it attempts to move and damage the obstruction from the increased pressure.

A combination of both condensation-induced shock and a vapor propelled liquid slug often occur during a “Hydraulic Shock” event.

Following are examples of where a combination can develop and result as a hydraulic shock:

a. A hot gas line containing some condensed liquid, that is intended to defrost one or more evaporators, is introduced with hot gas.

b. The sudden release of both pressurized liquid and vapor from a defrosted evaporator into a trapped or incorrectly sloped wet suction line. Because sudden gas releases can reach velocities of 100 ft/s (30 m/s), the resulting impact pressure produced by a liquid slug can exceed 3,000 psig (21,000 kPa).

Abnormal shocks to a system caused by vapor propelled liquid are accompanied by external symptoms. These include abnormal load sounds (e.g. such as bangs and thumps), moving pipes, and moving evaporators. Pressure gauge needles may also be pinned beyond their stop. Insulation may come loose, and refrigerant leaks may start. If the first shock does not cause a leak or rupture, repeated shocks can eventually lead to a failure.

C.V.1. Liquid in Hot Gas Lines

The most common way to defrost industrial refrigeration evaporators is with the use of hot gas. Mismanagement of hot gas usage can cause vapor propelled liquid problems and possible system failures. The most significant problem is the condensation of liquid inside a hot gas line. This condensation itself can result as a condensation-induced shock or set the stage to become a combination event with vapor-propelled liquid resulting as a slug.
When defrosting occurs, a hot gas valve opens and high-pressure vapor rapidly moves through the pipe line. The high velocity flow of this vapor will pick up any liquid lying in its path and push it ahead of the vapor until it is stopped.

When using hot gas for defrosting, it is important that the condensed liquid be removed from the hot gas line. All condensation in hot gas lines cannot be prevented, but where condensation may occur, adjustments could be made to minimize the condensation.

C.V.2. Initiation of Hot Gas Defrost

The potential for shock is strong at the initiation of hot gas defrost when an evaporator is suddenly changed into a condenser. Abnormal pressure or shock can be eliminated if the change in pressure is applied in a gradual manner. This is particularly important if there is excessive liquid in the evaporator or it is completely full of liquid.

If the incoming hot gas contains liquid which was condensed in the hot gas line and was not removed, the shock effect from vapor propelled liquid can be very destructive to the evaporator coil. The header pipe-end caps could blow off or headers and return bends could split.

C.V.3. Termination of Hot Gas Defrost

As with hot gas defrost initiation, the potential for shock is also high at the termination of hot gas defrost, when a condenser is suddenly changed into an evaporator. The change in pressure must be gradual because liquid is present in the coil and in liquid overfeed suction lines.

The gradual release of defrost pressure into the suction line is equally important for flooded or liquid overfeed evaporators. For flooded systems, a defrost reseating relief regulator with an electric full-opening feature can be used to bleed down the evaporator by energizing the full-opening pilot solenoid valve.

C.V.4. Light and No-Load Conditions

Evaporators that have a constant load are rare. Variations in production rates, stopping of conveyor lines, changes in outdoor temperatures, cycling of evaporator fans, and changes in suction pressures are common events that will change the load on an evaporator.

If an evaporator defrost is incomplete, each subsequent defrost will leave additional ice on the coil. The capacity of the evaporator will continue to drop because of the insulating effect of the ice. Thus, it is impossible for an evaporator to become completely filled with liquid while operating under light and no-load conditions.

If hot gas defrosting is initiated on a liquid overfeed evaporator that has been operating under very light load conditions for an extended period of time, the evaporator will be very vulnerable to shock due to vapor propelled liquid.
C.V.5. Operating System’s Emanating Sounds - Normal or Abnormal?

It is not always easy to duplicate an abnormal pressure or shock situation during “normal” operating conditions because these incidents frequently occur during light load periods such as nighttime, weekends, or holidays.

However, the emanating sounds an operating refrigeration system makes are often an important factor in determining if the system is operating properly. A qualified operator who has become familiar with an operating refrigeration system(s) can recognize the difference between normal and abnormal emanating sounds.

For example, the emanating sounds an evaporator makes as it sequences through a hot gas defrost cycle should be minimal. Loud emanating sounds such as thumps, bumps, slams, thuds, and clunks, are not normal and the qualified operator should recognize these abnormal sounds and take steps to eliminate the causes.

The extremely high-pressure spikes created by sudden liquid deceleration or vapor propelled liquid are so brief that a relief valve or regulator cannot respond quickly enough to make any difference. However, pressure gauge needles do move and get jammed beyond their stop and will stay in that position. Jammed gauge needles may indicate the presence of unusually high pressure at the location of the gauge. Flange bolts that repeatedly require tightening may also be indicators of excessive pressures.

Caution must be taken to ensure proper defrost procedures and the correct handling of valves to prevent abnormal pressure of shock failures. Whenever abnormal emanating sounds are heard or piping is moving, the qualified operator must be suspicious of a condition that may exist that will lead to component failure.

Inspection of pressures and a check for abnormal emanating sounds at all the evaporators during a defrost cycle should be a regular part of the maintenance routine requirements.
Appendix D. Risk-based Inspection, Testing, and Maintenance (Informative)

The overall objective of inspection, testing, and maintenance (ITM) practices are to sustain reliability to increase the profitability of the operation and optimize the total life cycle cost without compromising safety or environmental issues.

Risk assessment integrates reliability with safety and environmental practices and can be used as a decision tool for predictive and preventive maintenance planning strategies.

Unexpected failures usually have adverse effects that can lead to an unsafe or environmental hazard. There is a close relationship between ITM practices and the resulting reliability of equipment and systems. To maximize equipment and system availability and efficiency, to control equipment and system deterioration, to ensure a safe and environmentally friendly operation, and to minimize the total cost of the operation, a strategy with ITM practices should be implemented. ITM management techniques that adopt a structured risk-based ITM strategy can further provide optimization. A risk-based ITM strategy can be cost effective for operations and minimize or prevent hazards, both to humans and the environment, caused by unexpected equipment or system failures.

A risk-based ITM strategy includes the study and risk ranking of equipment and system failures based on probability (likelihood) and consequence (severity). The risk-based assessment learnings are used as criteria to further enhance the development of ITM tasks for the equipment and systems for planning, implementing, and optimizing results. The risk-based assessment is a technique for identifying, characterizing, quantifying, and evaluating loss from an event. It integrates probability and consequence analysis at various stages of the assessment. In this context, risk can be defined for a particular failure scenario as the following:

$$\text{Risk} = \text{Probability of failure} \times \text{Consequence of the failure}$$

At a minimum, the risk assessment, which can be qualitative or quantitative, should have its methodology include the following:

1) A risk determination, which consists of risk identification and estimation.
2) A risk evaluation, which consists of risk aversion and risk acceptable analysis.
3) ITM task planning considering risk factors.

Reducing the level of risk or eliminating the risk is the objective of the risk-based ITM developed practices. The risk ranking is used to optimize ITM task intervals and to plan predictive and preventive practices based on site acceptable risk levels and operating limits, while mitigating risks as appropriate.