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Design of Refrigeration Systems for Cold Storage

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Module 1: Introduction

Learning Objectives

By the end of this section, you will be able to:

- **Identify** the primary and secondary consensus standards governing DOD cold storage refrigeration design.
- **Evaluate** project requirements to determine the prevailing authority in the event of conflicting safety or jurisdictional criteria.
- **Define** technical refrigeration terms essential for system selection and phase-change analysis.

Executive Summary: This chapter establishes the regulatory framework for DOD cold storage systems, adopting ASHRAE and IIAR standards as the technical baseline. It mandates a "most stringent" approach to safety conflicts and integrates sustainable design as a universal policy for all procurement methods.

Purpose and Scope

This UFC provides general **design criteria** for new refrigeration systems dedicated to cold storage. While primarily a guidance document for the **DOD**, these criteria serve as a standard for commercial firms engaged in the design and construction of DOD facilities.

⚠ Safety Constraint: This document is not a detailed technical design, maintenance, or operations manual. Its role is to identify appropriate **Non-Governmental Standards (NGS)** and specify the industry codes that incorporate Tri-service requirements.

Design Background

The fundamental objective of cold storage is to maintain or extend **product life**. Applications include food processing, manufacturing, warehousing, and biomedical storage.

- **Temperature Differentials:** Refrigerated systems operate at significantly lower temperatures than standard comfort air conditioning systems.
- **Technical Complexity:** The design and selection process is more intensive than comfort cooling, necessitating a specialized engineering approach.
- **Primary Use Case:** The refrigeration and freezing of food remain the largest application within the DOD.

Primary Voluntary Consensus Standard Reference


The Tri-services adopt the latest edition of the following as the **primary** standard for cold storage refrigeration:

- **ASHRAE Handbook Refrigeration**

Secondary Voluntary Consensus Standard References

The following standards serve as the **secondary** voluntary consensus references:

- **ASHRAE 15:** Safety Standard for Refrigeration Systems.
- **ASHRAE Handbooks:** Applications, Fundamentals, and HVAC Equipment and Systems.
- **ANSI/IIAR Standard 2:** Specifically for ammonia mechanical refrigeration systems.
- **IIAR Ammonia Refrigeration Piping Handbook.**

 **Design Tip:** Note that while ASHRAE standards cover both halocarbon and ammonia systems, IIAR standards apply **exclusively** to ammonia systems.

Resolution of Conflicts in Criteria

Navigating conflicting requirements is a critical responsibility for the Professional Engineer.

- **Safety Conflicts:** If a service's safety criteria conflict with **ASHRAE 15**, the most stringent requirement must prevail.
- **Jurisdictional Authority:** For facilities located off military-owned sites, local jurisdictional codes prevail if they are more stringent than the UFC.

Sustainable Design Policy

It is a mandatory policy to incorporate **sustainability concepts** into all infrastructure projects.

- **Applicability:** This applies to new construction, renovations, and alterations.
- **Funding & Procurement:** The policy holds regardless of funding source, project amount, or procurement method (including **design-build**).

Technical Definitions

Engineers must apply the following definitions when specifying system components:

- **Azeotropic:** A precise refrigerant mixture with properties differing from its individual constituents.
- **Design-Build:** A procurement method where the contractor furnishes both design and construction, typically from a performance specification.
- **Direct Expansion System:** A system where refrigerant enters an expansion valve and leaves the evaporator exclusively as vapor.
- **Glide:** The absolute difference between the starting and ending temperatures of a refrigerant's phase change process.



- **Halocarbon:** Hydrocarbon derivatives containing halogens such as bromine, chlorine, fluorine, or iodine.
- **Liquid Recycle System:** A system utilizing liquid refrigerant in the evaporator in volumes exceeding evaporation capacity to achieve higher heat transfer via wetted surfaces.
- **Plan and Specify:** An arrangement where an engineering firm provides the design for competitive bidding.
- **Owner:** The specific Tri-service arm responsible for operating and maintaining the facility.

Checkpoint Quiz

1. Which standard serves as the Primary Voluntary Consensus Standard for Tri-services cold storage design?

- a) ASHRAE 15
- b) IIAR Standard 2
- c) ASHRAE Handbook Refrigeration
- d) ASME B31.5

Answer: (c). This is specifically identified as the primary voluntary consensus standard reference.

2. A project is being designed for a site located off military property. The local municipal code requires a higher safety factor for pressure vessels than the UFC. Which requirement takes precedence?

- a) The UFC, as it is a federal DOD document.
- b) The local jurisdictional authority, because it is more stringent.
- c) The ASHRAE 15 standard exclusively.
- d) An average of the two requirements.

Answer: (b). If a facility is off-site and local requirements are more stringent than the UFC, the local authority prevails.

3. In the context of phase change, what does the term "Glide" represent?

- a) The speed of refrigerant through a liquid recycle system.
- b) The absolute value of the temperature difference between the start and end of a phase change.
- c) The pressure drops across a direct expansion valve.
- d) The ratio of liquid to vapor in an evaporator.

Answer: (b). This is a critical factor when dealing with non-azeotropic refrigerant blends.

Module 2: Refrigeration System Design Requirements

Learning Objectives

By the end of this section, you will be able to:

- **Select** appropriate refrigerants and system types based on life-cycle cost, safety, and temperature requirements.
- **Evaluate** the impact of refrigerant phase-out schedules and OSHA thresholds on long-term system maintenance and compliance.
- **Specify** critical design features for cold storage, including sub-floor freeze protection, specialized materials, and control system logic.

Executive Summary: Successful refrigeration design for DOD facilities requires a specialized engineering approach that balances paramount safety (ASHRAE 15 compliance) with high-reliability, low-maintenance configurations. While ammonia systems offer superior efficiency for large applications, engineers must carefully navigate the "10,000-pound" OSHA compliance threshold and select system types (Direct Expansion vs. Liquid Recirculation) that align with specific site O&M capabilities.

Design Fundamentals

Design refrigerated systems for cold storage to provide **safety, economy, and reliability**. Because refrigeration is a specialized field, design should be performed by an experienced **refrigeration design engineer**.

- **Procurement Trends:** Design may be performed via "plan and specify" or "design-build" arrangements; however, **design-build** has become the industry trend.
- **Manufacturer Support:** Equipment manufacturers frequently provide significant support during the design phase.

Safety Requirements

Safety is critical, particularly for **ammonia systems**. All systems **must meet ASHRAE 15**, which prescribes safe design, construction, installation, and operation.

- **Maintenance Access:** Select and place equipment to ensure safe and accessible maintenance.
- **Safety Reviews:** Conduct reviews of the engineered design and layout with the owner's site **Operations and Maintenance (O&M)** entities.
- **Hazard Analysis:** The designer must perform a system safety plan and hazard analysis.

⚠ Safety Constraint: Designers must consider hazardous substances including ozone-depleting gases, greenhouse gases, ammonia, pressurized/flammable gases, and electrical power.



Operation and Maintenance (O&M)

Tri-service facilities have unique maintenance profiles compared to commercial facilities.

- **Charrette Participation:** O&M entities must be interviewed during the **Charrette stage**.
- **Lead Engineer Role:** The lead mechanical engineer should participate in these project-initialization charrettes.

Design Economy

Engineers should target the **lowest life-cycle cost** with maximum energy efficiency.

Design Tip: Because Tri-service maintenance costs are often high and hidden, a **simple, high-reliability design** may be weighted more heavily than pure energy efficiency in the life-cycle analysis.

Refrigerant Phase-Out and Replacement

The **Montreal Protocol** dictates the phase-out of ozone-depleting substances.

- **CFCs/Halons:** Production ceased in the 1990s.
- **HCFCs (e.g., R-22):** Production reduced to 10% by 2015, with complete cessation by **2030**.
- **HFCs (e.g., R-134a):** Currently not regulated by the Montreal Protocol

Phased-Out Refrigerant	Designated Replacement
R-12 (CFC)	134a
R-502 (CFC-115)	R-404a
R-22 (HCFC)	Ammonia (R-717) / No direct HFC replacement listed

System Design and Selection

ASHRAE Standards are the baseline for design; for **ammonia systems**, **IIAR standards** apply and prevail if more stringent than ASHRAE.

Facility Design

- **Sub-floor Freeze Protection:** Facilities held below freezing can cause **floor upheaval** due to under-floor ice formation.
- **Required Systems:** Design air duct systems, electrical heating, or heated pipe grids to protect the sub-floor.

Refrigeration Load

Calculate loads per the **ASHRAE Handbook Refrigeration**.



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the technical materials.