Design of Refrigeration Systems for Cold Storage

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PDH: 2

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CHAPTER 1

INTRODUCTION

1-1 **PURPOSE AND SCOPE**. This course provides general criteria for the design of new refrigeration systems for cold storage. This document, and all references contained herein, provides guidance to engineers commercial firms engaged in the design and construction of refrigeration systems for cold storage for commercial and industrial facilities.

Note that this document does not constitute a detailed technical design, maintenance or operations manual. Rather, its purpose is to identify and utilize the most appropriate Non-Governmental Standards (NGS) by specifying the refrigeration industry codes and standards that best apply.

1-2 **BACKGROUND**. The purpose of refrigerated systems for cold storage is to maintain or extend product life. Refrigeration systems for cold storage are applied to processing, manufacturing, and warehousing food, biomedical materials, ice manufacture, and other uses; but the largest application is for the refrigeration and freezing of foods. Refrigerated systems provide much lower temperatures than comfort air conditioning systems. The design, selection, and construction of a refrigeration system is different and can be more intensive than that for a comfort air conditioning system. For this reason, the refrigeration industry has evolved into a separate and distinct industry.

1-3 **PRIMARY VOLUNTARY CONSENSUS STANDARD REFERENCE**. This course adopts the latest edition of American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc. (ASHRAE) Publications listed below as the primary voluntary consensus standard for the Tri-services refrigeration systems for cold storage.

- *ASHRAE Handbook Refrigeration*

1-4 **SECONDARY VOLUNTARY CONSENSUS STANDARD REFERENCES**. This course adopts the latest edition of the standards listed below as the secondary voluntary consensus standard for the Tri-services refrigeration systems for cold storage. ASHRAE Standards encompass halocarbon and ammonia refrigeration systems.
International Institute of Ammonia Refrigeration (IIAR) refers to ammonia systems exclusively.

- *ASHRAE 15*
- *ASHRAE Handbook Applications*
- *ASHRAE Handbook Fundamentals*
- *ASHRAE Handbook HVAC Equipment and Systems*

- *ANSI/IIAR STANDARD 2*
- *IIAR Ammonia Refrigeration Piping Handbook*

1-5 **CONFLICTS IN CRITERIA**. If any conflicts arise between the service's safety criteria and *ASHRAE 15,* the most stringent requirement shall prevail. If a facility is located off of military owned sites, where local jurisdictional authority has control and code requirements that are more stringent than those herein, the local jurisdictional authority will prevail.

1-6 **SUSTAINABLE DESIGN**. It is the policy of the tri-services to incorporate sustainability concepts in the design of all facilities and infrastructure projects to the fullest extent possible, consistent with budget constraints and customer requirements. This policy applies to renovations and alteration projects as well as new construction; applies to projects regardless of funding source or amount; applies to projects for all customers; and applies to design associated with all procurement methods, including design/build. For further information, see NAVFAC Planning and Design policy Statements PDP 98-01, 98-02, 98-03 on the Construction Criteria Base (CCB) at http://www.ccb.org, and *Sustainable Design* at http://www.efdlant.navfac.navy.mil/lantops_04/designguides.htm. Also see Corps of Engineers ETL 1110-3-491, *Sustainable design for military facilities, at* http://www.ccb.org/.

1-7 **REFERENCES**. Refer to Appendix A for references applicable to this document.

1-8 DEFINITIONS

Azeotropic – A precise refrigerant mixture or blend of substances that has properties differing from either of the two constituents.

Design-Build – Contractor furnishes a designed and constructed facility, usually from a performance specification.

Direct Expansion System –- A refrigerant system that has the refrigerant entering an expansion valve and only vapor leaves the evaporator.

Glide – The absolute value of the difference between the starting and ending temperatures of a phase change process by a refrigerant.

Halocarbon – Refrigerant that is a hydrocarbon derivative that contain one or more of the halogens bromine, chlorine, fluorine, or iodine; hydrogen may also be present.

Liquid Recycle System – A refrigerant system that has liquid refrigerant in the evaporator in amounts larger than can be evaporated and obtains higher efficiencies due to higher heat transfer of wetted surfaces.

Plan and Specify – Engineering firm furnishes a design, then the design is competitively bid.

CHAPTER 2

REFRIGERATION SYSTEM DESIGN REQUIREMENTS

2-1 **GENERAL**. Design refrigerated systems for cold storage to provide safety, economy, and reliability. Refrigeration design is a specialized field. The design of cold storage refrigerated systems should be performed by an experienced refrigeration design engineer. A "plan and specify" or a "design-build" arrangement can perform the refrigeration design. Design-build has been the trend of the refrigeration industry.

In many cases, equipment manufacturers have significantly supported the refrigeration design.

2-2 **SAFETY**. Safety is paramount. Safety is critical in the design, construction and operation of refrigeration systems for cold storage, especially with ammonia systems. Refrigeration system's safety standards must meet *ASHRAE 15*. *ASHRAE 15* specifies safe design, construction, installation, and operation of refrigeration systems by establishing safeguards for life, limb, heath and property and prescribing safety standards. This includes, but is not limited to, occupancy classification, restriction on refrigeration use, installation restrictions, design and construction of equipment and systems, and operation and testing.

Consider equipment selection and its placement for safe accessible maintenance. A safety review of the engineered design and equipment layout is recommended with participation from the owner's site operations and maintenance (O&M) entities.

The designer is required to perform a system safety plan and hazard analysis. Personnel safety measures are required as part of the facility design. Refer to http://www.efdlant.navfac.navy.mil/lantops_04/designguides.htm. Hazardous substances requiring consideration may include, but are not limited, to the following:

- Ozone depleting gases
- Greenhouse gases
- Ammonia
- Pressurized gases
- Flammable gases
- Hazardous gases
- Hot gases and equipment
- Electrical power

2-3 **OPERATION AND MAINTENANCE**. Tri-service facilities do not perform the maintenance typical of commercial and industrial facilities. Participation of the site operations and maintenance entities in the design process is critical to a safely operated and maintained facility, plus helps to ensure a successful project. O&M entities will be interviewed up front in the "Charrette" stage of a refrigeration design project. Design charrettes are a key component in the initial stages of any project and should be required. The mechanical designers (specifically the lead mechanical engineer) involved in the refrigeration design should participate in the design charrette.

2-4 **ECONOMY**. Design systems to provide the lowest life-cycle cost with maximum energy efficiency and give special consideration to safety and low maintenance. As noted in Section 2-3, the maintaining of Tri-services facilities is not indicative of commercial and industrial facilities. Actual maintenance costs can be hidden and high. Therefore, a simple, high reliability design can be weighed greater than efficiency.
Consider this in the life cycle analysis. Also, consider the impact of refrigerant phase-out and replacement costs, and OSHA Regulations (refer to Section 2-6.3.2) to the life cycle analysis of the refrigeration system.

2-5 **REFRIGERANT PHASE-OUT AND REPLACEMENT.** The phase-out schedule of refrigerants is briefly defined in the refrigerants chapter of the *ASHRAE Handbook Fundamentals.* This information can also be found at the United States Environmental Protection Agency's web site http://www.epa.gov/spdpublc/title6/phaseout/.
Summarizing, the international treaty, Montreal Protocol, and its subsequent revisions control the ozone depleting substances including refrigerants. This treaty dictated complete cessation of the production of chlorofluorocarbons (CFC) in 1996 and halons in 1994. The treaty also dictated the phase-out of hydrochlorofluorocarbons (HCFC), including R-22, by reducing production of HCFC over the next 30 years, with production reduced to 10% by 2015 of 1996 reference production level, and complete cessation of HCFC production by 2030. HFC (including R-134a) are not regulated by the Montreal Protocol. Below are some of the primary phased out refrigerants that have replacements.

- R-12 (CFC) has been phased out and the designated replacement is 134a
- R-502 (contains CFC-115) has been phased out and the designated replacement is R-404a
- R-22 (HCFC) does not have a replacement at this writing and competes with ammonia (R-717). But with a 90% production decrease by the year 2015, R-22 can become cost prohibitive during its phase-out, similar to R-12.

2-6 **SYSTEM DESIGN AND SELECTION**. This section addresses the general requirements for the design and selection of a refrigerated system for cold storage. ASHRAE Standards are the basis for refrigeration system design, selection, installation, testing, and operating. For ammonia systems, the standards of the International Institute of Ammonia Refrigerators (IIAR) will apply, and if more stringent than ASHRAE Standards, IIAR will prevail.

2-6.1 **Facility Design**. Design new refrigerated facilities to meet the considerations for building design that are provided in the refrigerated facility design chapter of *ASHRAE Handbook Refrigeration.* Cold storage facilities held below freezing can cause under floor ice formation, resulting in floor upheaval. Design sub-floor freeze protection for facilities that are held below freezing, such as air duct systems, electrical heating systems, or heated pipe grids. These systems are detailed in the above-mentioned chapter. Comply with *ASHRAE 15* criteria, including equipment placement, ventilation design, door and passageway restrictions, refrigerant monitoring, open flame devices, pressure relief and purge piping, refrigerant piping, signs, self-contained breathing apparatus (SCBA), and miscellaneous installation restrictions.

2-6.2 **Refrigeration Load**. Determine the refrigeration loads by the calculations in the Refrigeration Load chapter of *ASHRAE Handbook Refrigeration.*

2-6.3 **Refrigeration System Selection**. The primary selection of a refrigeration system, such as halocarbon or ammonia refrigerant, direct expansion or liquid recirculation, should be determined by life cycle cost analysis. Should a system be selected for a design because of other issues, such as safety, reliability, simplicity, the preference of the owner, and the recommendations of the design engineer, then the designer must clearly justify their selection in the project's design analysis, and include concurrence from the user and the funding agency.

Perform the design of the entire system, including pipe sizes and layout/slopes, based on guidance from ASHRAE. On the drawings, indicate that it will be the Contractor's responsibility to coordinate the pipe sizes and layout/slopes with the equipment and piping configurations to be provided. For small systems (systems with 1 or 2 compressors and 1 or 2 coolers; 1 compressor for each cooler), the designer may elect to show only the individual components and their relative layout or schematic with no pipe sizes or slopes. For these types of systems, it will be the Contractor's responsibility to submit shop drawings and calculations to completely define the entire system based on the equipment to be provided.

Refer to the *ASHRAE Handbook Refrigeration,* in the following chapters:

- Liquid Overfeed Systems
- System Practices of Halocarbon Refrigerants
- System Practices for Ammonia Refrigerant
- Secondary Coolants in Refrigeration Systems

2-6.3.1 **Refrigerants**. The selection of a refrigerant impacts the project economics and safety. The selection, design, construction, and operation of a refrigeration system must meet *ASHRAE 15*. Occupancy, and restrictions on refrigerant quantity and usage are also detailed on the drawings. Product, occupancy, or other criteria might require a" low-probability system" for the refrigeration system. Low-probability systems are designed so that if a leak occurred, the refrigerant cannot enter the occupied space. Most indirect systems are considered "low-probability systems".