Principles of Mechanical Refrigeration
Level 1: Introduction
Technical Development Programs (TDP) are modules of technical training on HVAC theory, system design, equipment selection and application topics. They are targeted at engineers and designers who wish to develop their knowledge in this field to effectively design, specify, sell or apply HVAC equipment in commercial applications.

Although TDP topics have been developed as stand-alone modules, there are logical groupings of topics. The modules within each group begin at an introductory level and progress to advanced levels. The breadth of this offering allows for customization into a complete HVAC curriculum – from a complete HVAC design course at an introductory-level or to an advanced-level design course. Advanced-level modules assume prerequisite knowledge and do not review basic concepts.

Air conditioning is all about moving heat energy, either by adding or removing it from one place and moving it to another. This module deals with the way heat is moved from a place of lower temperature to a place of higher temperature in a process called mechanical refrigeration. This process is used in preserving the food we eat and for comfort air conditioning. Much of the equipment discussed in other TDP modules dealing with equipment uses the principles discussed in this TDP. A designer needs a thorough understanding of the concepts of mechanical refrigeration to create the best performing and cost effective projects. The Principles of Mechanical Refrigeration is divided into two modules, Level 1: Introduction, and Level 2: Analysis. Before proceeding to the equipment TDPs, the information in the Level 1: Introduction, should be understood. Level 2: Analysis, will provide a better understanding of how to evaluate unit performance and select refrigeration components.

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Introduction

The process of mechanical refrigeration has changed our daily lives. Thanks to mechanical refrigeration the variety, quality, and safety of the foods we eat has improved; and the buildings where we live and work are more comfortable and productive. The mechanical refrigeration cycle is the process of how heat is moved. This module will explain the process.

This book is the first of two modules on the topic of mechanical refrigeration. The first step is to understand the terminology used in mechanical refrigeration, and understand how four basic principles are applied to cause the movement of heat. These principles can then be applied to the refrigeration process that uses four basic components to accomplish moving heat – the evaporator, the compressor, the condenser, and the metering device. The process also requires a fluid, called a refrigerant, to move heat through the system. This module describes what constitutes a good refrigerant and how to determine its properties anywhere in the refrigeration cycle.

The second module of Principles of Mechanical Refrigeration deals with analyzing the refrigeration cycle. The pressure-enthalpy diagram (p-h) is a useful tool used by system designers. The construction of this diagram will be explained and the function of each refrigeration system component is explained using the p-h diagram. Finally, this second module will use the p-h diagram to evaluate several system variations and evaluate their performance.

It is important for a designer to understand the operation of a refrigeration system. While the designer may not actually design the refrigeration system, as is typical with packaged units, proper selection and application depends on a working knowledge of mechanical refrigeration. This module will develop an understanding of the mechanical refrigeration system and demonstrate how to analyze system performance.

Definition

Heat is a form of energy, and energy is simply the potential to do work. The first law of thermodynamics states that energy can neither be created nor destroyed, we only transferred heat energy from one place to another. The total heat energy into a system must therefore always equal the heat energy out. The second law of thermodynamics says that energy can only flow from a level of higher potential to a level of lower potential. Therefore, heat transfer is the movement of heat energy from a higher temperature substance to a lower temperature substance.

The refrigeration process becomes the process of providing a substance at a lower temperature to which heat can flow from a higher temperature substance.
History of Refrigeration

The earliest use of a cold substance for taking away heat was using ice or snow. The Chinese were among the first to learn that ice made drinks cooler and tastier. Early Greek and Roman slaves were used to carry snow from mountaintops to be stored in pits for later use in creating frozen delicacies. In France during the 16th century, ice and snow were used to cool beverages, and frozen dishes became popular.

In 1626, Francis Bacon was the first to experiment with refrigeration for preserving foods. He experimented with a chicken stuffed with snow to see if it would preserve it; but it was not until the discovery of the microscope in 1683 that tangible results were obtained. With the microscope, scientists learned about bacteria, enzymes, and molds. They discovered that these microscopic organisms multiply with heat, but below 50º F they seem to hibernate.

Lower temperature does not kill these organisms, but it does control their growth. Food could now be maintained in its fresh state by the use of cold instead of preserving it through drying, smoking, or salting. The use of cold, or refrigeration for food preservation grew to the worldwide business it is today.

For nearly a hundred years, all refrigeration for foods was provided by nature through the use of ice or snow. It was not until 1775 that experiments were made to create lower temperatures artificially, but these first experiments never got beyond the laboratory. In 1834 the first patent was granted on a mechanical refrigeration machine. This was a British patent, and a quotation from it is of interest because in principle it describes the mechanical refrigeration cycle as it is used today:

> What I claim is an arrangement whereby I am enabled to use volatile fluids for the purpose of producing the cooling or freezing of fluids, and yet at the same time constantly condensing such volatile fluids and bringing them again and again into operation without waste.

In 1855, the first mechanical refrigeration machine was put to use in the United States, in Cleveland, Ohio, where it was used for the artificial making of ice. About 1900, electricity began to enter homes, and with the development of the small electric motor, the “ice plant” was brought into the home.

It was recognized that the same cooling used to preserve foods could be used to cool the air and improve comfort. Over the next 100 years the use of mechanical refrigeration for comfort and food preservation grew dramatically to the point it became universally accepted. Now refrigeration machines are made in sizes up to hundreds of horsepower, and multiple machines are used for systems totaling several thousands of horsepower in a single installation – all with the same principle as described in that original patent.
The mechanical refrigeration cycle can be classified into two broad categories, comfort cooling and process cooling. Both involve the process of removing heat energy from a place where it is not wanted and rejecting it to a place where it is not objectionable.

In general, the concepts presented here apply equally well to either comfort or process applications. There are some differences however.

Systems used for comfort, often referred to as air conditioning, operate at higher refrigeration system temperatures than most process or refrigeration applications like food storage. In this module reference to refrigeration means the mechanical process of refrigeration not necessarily lower temperature mechanical refrigeration in food or process application. The TDP text will clearly distinguish between comfort applications and low-temperature or process applications.

Basic Principles

To understand the way mechanical refrigeration works, we must first understand how heat moves. The process can then be explained by four fundamental principles. Heat transfer must first be understood so the four principles of refrigeration can be explained.

Heat Transfer

Heat energy can move by one of three methods of heat transfer.

Conduction is heat transfer from one molecule to another either in the same material or two materials in contact with each other. We have most likely experienced this when we grabbed a spoon that has been in a hot pan of food on the stove. First, the spoon got hot from the contact with the hot food (conduction), then the spoon handle got hot as heat energy moved up the spoon (conduction), and finally, our hand got hot when we touched the spoon (also conduction). This principle is used extensively in refrigeration, for example the refrigerant in the tubes is in contact with the tubes and heat transfer takes place from the refrigerant to the tube to the fluid that surrounds the tube.