ICE-CREAM & FROZEN DESSERTS

B. Tech. (Dairy Technology) ► DT-3 ► Resources ► Lecture 15. CALCULATING REFRIGERATION LOAD,REFRIGERATION CONTROL AND RELATED INSTRUMENTATION

Module 5. Thermodynamics of freezing and refrigeration load

Lesson 15
CALCULATING REFRIGERATION LOAD,REFRIGERATION CONTROL AND RELATED INSTRUMENTATION

15.1 Introduction

Refrigeration systems are widely used for cooling, freezing, and refrigerated storage of food and other products. Refrigeration units used for these applications must be sized to overcome heat gain through the walls of the system and also perform the desired functional operation. For example, freezing a food product may be considered as a three-step operation: (1) the product is cooled to its freezing point, (2) it is frozen at constant temperature, and (3) the frozen product is further cooled to the desired final temperature. The energy required to do this can be computed as:

$$Q = mc_P(t_1 - t_f) + mh_{sf} + mc'_P(t_f - t_2)$$

where,

c_p, c'_p = specific heat values above and below freezing,respectively, kJ/(kg°K)

h_{sf} =the latent heat of fusion, kJ/kg

m =the mass of product being frozen, kg

Q =the total energy removed in the cooling operation, (kJ) and

t_1, t_2, t_f =the initial, final and freezing point temperatures, respectively, °C or °K.

K = degree kelvin

Freezing foods involves the removal of energy from the food. The energy removed to freeze foods is partially the sensible cooling required lowering the temperature to the freezing point, but the primary energy removed is the latent energy for phase change. The latent heat of freezing for water, 335 kJ/kg, is many times larger than the sensible energy removed to lower the temperature by one degree. Latent heat values are used to compute the amount of energy removed for freezing. The thermal conductivity of water and food
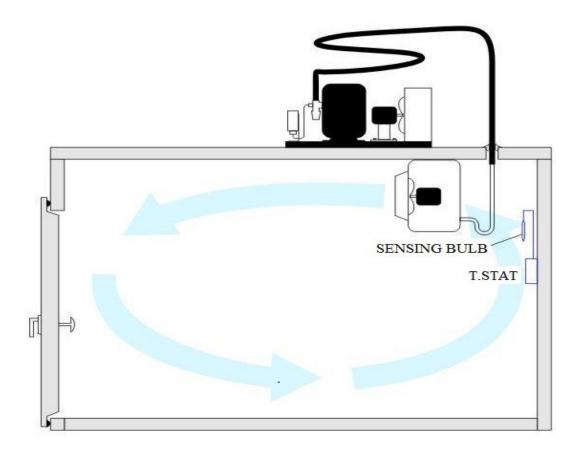
materials increases greatly at below freezing temperatures; the increase is 4-fold for water. Other thermal properties change, but to a lesser degree, during freezing.

15.2 Refrigeration Control and Related Instruments

Previously, the refrigeration system was manually controlled, resulting in inefficient operation. Refrigeration systems require operating controls so they can cycle on and off to maintain a certain temperature. They also require safety controls to stop operation if unsafe conditions occur. There are many varieties of controls. Different types respond to temperature, pressure, humidity, liquid levels, other controls, manual intervention and other things.

15.3 Thermostatic Controls

Some thermostatic controls are designed with a capillary line temperature sensor which is intended to be inserted between the evaporator fins on units that have a tendency to ice up. A commercial cooler in a hot environment which is constantly being accessed would tend to ice up. A *Constant Cut In Control,* also known as a beverage cooler control forces an off cycle defrost at the end of each run cycle. The control will remain open until the evaporator has reached a temperature which indicates that any frost accumulated during the previous run cycle has been melted. Adjusting the knob on this type of control changes only the Cut Out setting, the Cut In setting remains fixed.

SENSING BULB

T.STAT

Fig. 15.1 Thermostatic control

The sensing bulb of the control should be mounted so that it senses the evaporator inlet air. During the off cycle the constant fan recirculates the air in the box. The temperature of the air becomes an average of the product temperature, the wall temperature, any infiltrated air and any other loads such as caused by a person entering the box. When the air temperature reaches the cut in point of the control it brings on refrigeration.

15.4 Pressure Control System

A Pressure control can also be used as an operating control. The Refrigeration control system improved refrigeration system efficiency via the following mechanisms: 1) Compressors are turned off as the refrigeration load decreases to maximize the loading and efficiency on the remaining operating-units; 2) Higher efficiency units are preferentially operated to meet the required cooling load; 3) Compressor suction pressure is allowed to increase (if the evaporating temperature can be raised) to reduce compressor head and power consumption; 4) Compressor discharge pressure is allowed to decrease (if lower outside temperatures facilitate heat rejection at the condensers) to reduce compressor head and power consumption;5) Evaporator fans are turned off as allowable (if adequate cooling can be maintained) to directly reduce fan power and fan motor waste heat that must be removed by evaporators; 6) The evaporator defrost cycle is terminated as soon as ice is removed from the coils to minimize waste heat that must be removed by evaporators; 7) Liquid ammonia flow to the evaporators is controlled to minimize frost build-up; 8) The condenser spray pumps and fans are turned off if adequate heat rejection is possible without these auxiliary units running; 9) System equipment is monitored to identify problems quickly and reduce time operating at non-optimum conditions.

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DT-3