

Design, Operation and Maintain Of A Potato Cold Storage in Bangladesh

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Abstract

Potato is the third largest crop in Bangladesh. Its cultivation has been getting popular in Bangladesh over the last several years. For supplying potato in all the seasons' storage of potato is necessary. Many agricultural commodities, potato in particular, are being kept in commercial cold storages. For this reason many potato cold storages were built in Bangladesh. There are about 383 cold storages in Bangladesh. Since the design parameters are not well defined and the problems associated with these cold storages are also not properly addressed. Till now most of the cold storage are using so called old and traditional technologies. This paper deals with different aspects of cooling load estimation and its design. This paper also deals with operation & maintenance of a potato cold storage. This paper presents some ideas about possible efficiency improvement of existing cold storages.

Keywords: Cold Storage, Heat Transfer, Cooling Load.

1. Introduction

A cold Storage is a building or a group of buildings with thermal insulation and a refrigerating system in which perishable food products can be stored for various lengths of times in set conditions of temperature and humidity. Such storage under controlled conditions slows the deterioration and spoilage that would naturally occur in an uncontrolled natural environment. In addition to providing control of temperature and humidity, cold Storages can also be designed to deliver controlled atmospheres by maintaining the requisite concentration of various gases that aid in the preservation of food products.

The cultivation of potato increased considerably over the past years because of its various uses as food. For large scale commercial preservation of potatoes cold storages are used in Bangladesh. But the total number of cold storages in the country is much lower than that actually needed. There are altogether 383 cold storages of which some are out of operation due to various reasons. Average capacities of these cold storages are 2500 metric tons. To preserve the produced potatoes in Bangladesh, the number of cold storages should be increased by about 5 times the present number. Potatoes have to be stored after harvest for a shorter or longer period in order to maintain even supply to the market throughout the year for direct human consumption as well as for the processing industry. Seed potatoes have to be stored after harvest till the next planting time. In Bangladesh were found to be operated within the temperature range of 1.67 to 2.8⁰C and relative humidity was maintained within the range of 80 to 95 percent. Operating hours of the cold storage unit range from 10 to 18 hrs. The control system was either manual or automatic. Average capacity utilization ranged from 74.42 to 100 percent. The weight losses due to evaporation of moisture from potatoes in different cold storages range from 1.2 to 2.38 percent.

2. Cooling Load Calculation

To simplify the cooling load calculations, the total cooling load is divided into the number of individual loads according to the sources of heat supplying the load. The summation of these loads is the total cooling load on the equipment. The cooling load is consists of

- a. The transmission load(q1),
- b. Infiltration load(q2),
- c. Products load(q3),

- d. Respiration load(q_4),
- e. Other load sources (q_5) and
- f. Unknown and unexpected load(q_6)

a. Transmission heat load (q_1):

The calculation of the transmission heat created by walls, floor and ceiling requires information on thickness and type of isolation material used in construction of cold room, construction of building, physical specifications of the cold storage volume, inside and outside environment temperatures and the effect of sunshine. The wall gain load is a measure of heat flow rate by conduction through the walls of the refrigerated space from the outside.

$$\begin{aligned} q_1 &= U \times A \times (T_o - T_i) \times h \\ &= 1.1 \times 736.76 \times (40-2) \times 24 \\ &= 739117.63 \text{ KJ} \end{aligned}$$

When a wall is constructed for several layers of different layers of different materials, the total thermal resistance of the wall is the sum of the resistances of the individual materials in the wall construction.

$$\begin{aligned} 1/U &= \sum x_i / k_i \\ U &= 1.1 \text{ W/m}^2 \text{ K} \end{aligned}$$

b. Infiltration load (q_2):

The infiltration heat load is defined as the value obtained through the entrance of the air with a higher enthalpy to the cold storage. When the door of a refrigerated space is opened, warm outside air enters the space to replace the more dense cold air that is lost from the refrigerated space through the open door. The heat, which must be removed from this warm outside air to reduce its temperature and moisture content to the space design conditions, becomes a part of the total cooling load on the equipment.

$$\begin{aligned} q_2 &= c_p \times z \times V \times (T_o - T_i) \\ &= 1300 \times 8 \times 1225.7 \times (40-2) \\ &= 484396.64 \text{ KJ} \end{aligned}$$

c. Product load (q_3):

Product load is made up of the heat that must be removed from the refrigerated product in order to reduce the temperature of the product to the desired level. The term product used here is taken to mean any material whose temperature is reduced by the refrigerating equipment. In some instances, the product is frozen, in which case, the latent heat removed is also a part of the product load.

$$\begin{aligned} q_3 &= G \times C_1 \times (T_{out} - T_{in}) \\ &= 100000 \times 3.43 \times (40-2) \\ &= 13034000 \text{ KJ} \end{aligned}$$

d. Respiration Heat (q_4):

Fruits and vegetables are still alive after harvesting and continue to undergo changes while in storage. The more important of these changes are produced by respiration, a process during which oxygen from the air combines with the carbohydrates of the plant tissue and results in the release of carbon dioxide and heat. The heat released is called respiration heat and must be considered as a part of the product load where considerable quantities of fruit and /or vegetables are held in storage at a temperature above the freezing temperature.

$$\begin{aligned} q_4 &= G \times C_2 \\ &= 100 \times 122400 \\ &= 12240000 \text{ KJ} \end{aligned}$$

e. Other heat loads (q_5):

The miscellaneous load sometimes referred to as the supplementary load, takes into account all miscellaneous sources of heat. Chief among these are people working in or otherwise occupying the refrigerating space, along with the lights or other electrical equipment operating inside the space.

$$\begin{aligned} q_5 &= q_{51} + q_{52} \\ &= 32000 + 69120 \text{ KJ} \\ &= 101120 \text{ KJ} \\ q_{51} &= n \times c_i \times t_1 \\ &= 4 \times 1000 \times 8 \\ &= 32000 \text{ KJ} \\ q_{52} &= N_{ay} \times t_2 \\ &= 8640 \times 8 \\ &= 69120 \text{ KJ} \end{aligned}$$

f. Unknown and unforeseen heat loads (q_6):

It is common practice to add 5% to 10 % to the total cooling load as a safety factor. The percentage used depends on the reliability of the information used in the calculation of the total cooling load. As a general way, 10 % is used.

$$\begin{aligned} q_6 &= 0.1(q_1 + q_2 + q_3 + q_4 + q_5) \\ &= 0.1 \times 26598633.6 \\ &= 2659863.3 \text{ KJ} \end{aligned}$$

Total Cooling Load:

Total cooling load of the potato cold storage will be-

$$\begin{aligned} q &= q_1 + q_2 + q_3 + q_4 + q_5 + q_6 \\ &= 29258496.3 \text{ KJ/24h} \\ &= 1219104.01 \text{ KJ/h} \\ &= 96.3 \text{ Ton} \end{aligned}$$

3. Cold Storage Design Criteria

Some of the more important of these features are:

Space:

- a. For routine handling of scheduled deliveries to the plant relative to scheduled shipments from the plant
- b. For heavier than usual demands
- c. To allow for future expansion

Platforms:

- a. Convenient for the approach of trucks and/or railroad reefers
- b. Receiving platform above shipping dock to exploit gravity handling
- c. Large enough to avoid congestion and to facilitate rapid loading and unloading

Interior transportation facilities:

- a. Gravity conveyors for loading, unloading
- b. Incline conveyors (powered)
- c. Elevators, where more than one story

Construction details:

- a. Firm footings and foundation to prevent floor and wall cracking.
- b. Adequate and properly applied insulation throughout.
- c. Curtained walls to eliminate exposure of cold room walls to outside temperature.
- d. Maximum temperature rooms located next to walls exposed to outside temperature.
- e. Waterproof weather-exposed surfaces, especially roof.

Extra equipment's:

- a. Provide adequate standby equipment for emergencies.
- b. Install humidifiers such as spray heads in chill compartments for moisture control.
- c. Install temperature alarms (maximum or minimum in critical rooms).

Utilities:

- a. Ensure adequate and cheap supply of condenser cooling water or install appropriate cooling towers.
- b. Ensure adequate source of power to operate compressor, fans, pumps, etc.
- c. Provide good lighting in all parts of the plant and the warehouse.
- d. Provide weighing scales.

Control:

- a. Ample office space for carrying on the normal business transactions of warehouse and the refrigerant plant.
- b. Checking points established at appropriate locations to control and record deliveries and shipments.
- c. Fire extinguishers strategically located and ready for use.

4. Design

The design is for 100 Ton of potato storage capacity. Potato capacity per bag is 80kg. So, total 1250 bags of potato should be stored. The standard dimensions of bag is length 0.4572 meter, width 0.4572 meter and height

0.762 meter. For structure and other spaces another 0.4572 meter is necessary in both width and height. So, each bag will need $0.762 \times 0.762 \times 1.0668 = 0.619$ cubic meter. For, total 1250 bags the volume required is 774.3 cubic meter. For evaporator, other accessories, ducts, chillers, freezers, docking station another 450 cubic meter is required.

After visiting different cold storage in Dhaka city and from the above calculation the design criteria of a 100 ton potato cold storage are given below.

Storage Capacity	100,000 kg
Storage Size	18.3×9.15×7.32 m
Total Surface Area	736.76 m ²
Volume	1225.7 m ³
Insulation	3.5 cm of Styrofoam
Outside Temperature	40 °C
Inside Temperature	2 °C
Humidity	90%
Specific heat of potato	3.43 kJ/Kg-K
Miscellaneous heat loads	4 workers, 1000 kJ per h for each person
	Lighting load 8640 kJ

5. Construction Feature of Cold Storage

The design of cold storage includes the drawing up of specifications, sketching of a site plan and a general plan, the setting of the dimensions of the cold rooms (which depends on stacking arrangement), the calculation of heat balances and refrigeration capacity and the insulation thickness, selection of refrigeration system components, their installation and testing and finally performance evaluation. Any deviation from this procedure results in defective cold storage construction, increasing in cost of storage of the product due to increased operational and maintenance cost.

Storage building:

The building ideally should have a floor perimeter in the shape of a square. A rectangular configuration has more wall area per unit volume of the cold storage, resulting in higher construction cost and higher heat in-leak compared to square shape. The orientation of walls should be such that they receive minimum solar radiation. A dark, flat roof can be 42 °C warmer than that of the outside air temperature. Painting a south facing wall with a light color can reduce the effective wall temperature by 11 °C compared with a dark colored wall.

Insulation material:

Thermal insulation of a cold storage is necessary for proper control of storage conditions. A lower capital investment with an inferior quality and thinner insulation leads to a larger heat in-leak. A larger compressor with more power consumption is required to make good for the additional cooling load. Therefore, quality and quantity of insulation material has a direct relation with the power consumption. The optimum insulation quality and its thickness, of course, is a function of the energy cost and hence a function of the instant of time. It is however not so in practice and reality. In Bangladesh usually Styrofoam or rice husk is used for insulation.

Vapor barrier:

It plays a big role in determining the insulation quality with passage of time that ultimately affects the electrical energy consumption in cold storage. In the absence of vapor barrier, the insulation material may absorb the water vapor and after condensation therein, the energy consumption increases dramatically as the thermal conductivity of wet insulation increases by about 32 times.

6. Selection of Components of Cold Storage

Generally methods of refrigeration can be classified as non-cyclic and cyclic. Other methods are Gas Cycle, Thermoelectric refrigeration, Magnetic refrigeration, Air cycle, Vortex tube, Thermo acoustic refrigeration etc.

Compressors

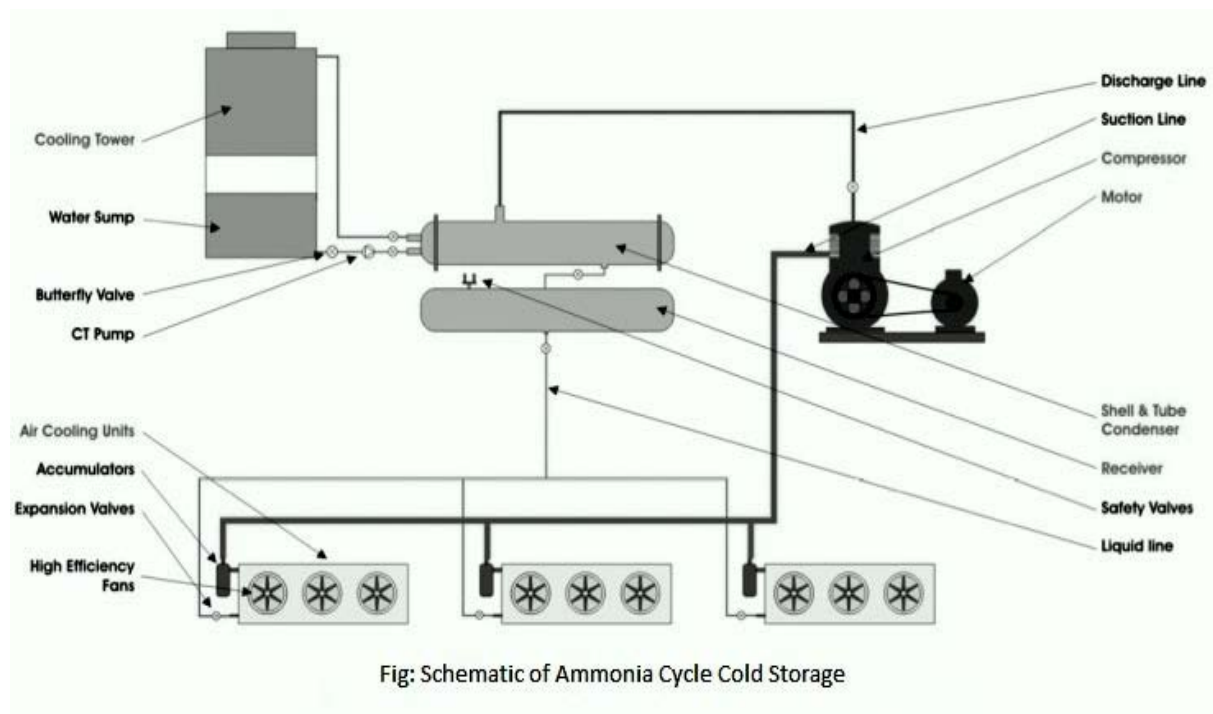
At the heart of the vapor compression cycle is the mechanical compressor. There are generally three types of compressors that are used in vapor compression systems. These are: Reciprocating, Rotary, and Centrifugal. There are also scroll and screw compressors but not widely used. But in the cold storages mostly reciprocating compressor are used.

Evaporator

Evaporators are heat exchangers in which a refrigerant is evaporated at low temperature and pressure for the purpose of removing heat from the refrigerated space or material. There are different type of evaporator like dry expansion evaporator, air-cooling evaporator, flooded type evaporator, liquid cooling evaporator etc. In Bangladesh mainly air-cooling evaporator is used in most of the cases.

Condenser

The condenser is the component in the refrigeration cycle where heat is removed and rejected. There are mainly three type of condenser air cooled, water cooled and evaporative condenser. For cold storage water cooled condenser is used.



Expansion devices

The expansion device is just opposite of compressor. The expansion devices are different types. They are thermostatic expansion valve, automatic expansion valve, and capillary tube etc. Dx type expansion valve is mainly used in cold storage.

Control System

Controls are necessary to maintain optimum operating conditions commensurate with varying load situations. Automatic control makes the plant independent of skilled supervision. It also achieves a higher degree of accuracy in maintaining the required temperature, pressure and humidity. Though cold storage load does not fluctuate as frequently as it does in air conditioning systems every cold Storage is equipped with automatic control mechanisms that ensures smooth running. In most of the cold storages self-actuated control system is used.

7. Conclusion

In order to reduce the post-harvest deterioration, potatoes are kept in cold Storage for long-term storage. The stored potatoes are subjected to heat and mass transfer during the extensive storage period of about 8 months. Uniform cooling in bulk of potatoes within commercial cold Storage is difficult to attain, owing to existence of an uneven distribution of the airflow, which results in considerable temperature and humidity difference within the stored product. The variability of the cooling rate and resultant spatial variation in temperature of the product inside a cold Storage causes the product quality to deteriorate through either increased respiration at

higher temperature or by chilling injury at lower temperature. The poor airflow distribution through stacks of bagged potatoes could also result in non-uniform humidity, which might lead to condensation of moisture wherein relative humidity reaches at saturation or excessive dehydration wherein the relative humidity remains very low. The prevailing situations in the potato cold Storage lead to storage losses even up to 10 % against the prescribed maximum limit of 5% during the storage period of 8 months. Therefore, one of the main aims in designing storage system is to ensure a uniform targeted temperature and humidity in the bulk of stored product. In Bangladesh, the storage losses in potato cold stores account for 5–10% of the stored product in the form of rotting, cold injury, weight loss, sprouting, nutritive value degradation, etc. However, the potato losses may increase up to 40 – 45 % due to poor storage management and operations.

Possible causes behind higher energy consumption beyond permissible limit:

There are many factors affecting the energy consumption and storage losses in a potato cold Storage. Some important of them are listed below-

- Irregular loading pattern.
- Overloading of the storage chamber.
- Defect in the design and operation of the refrigeration system of cold storage.
- Poor airflow distribution in the storage chamber and within the stack mass.
- Prevalent stack size and stacking arrangement.
- Overlooking or completely elimination of curing process before loading the potatoes in cold storage chamber.

Scientific approaches to reduce the problems:

The problems of higher energy consumption and storage losses in the potato cold storage industry have been known since decades and efforts were also made by the cold storage owners, operators and other concerned personals to overcome these defects.

• Data collection on airflow, temperature in the cold storage chamber:

To get an insight view of the problems of energy consumption and storage losses, a thorough knowledge of airflow, temperature and relative humidity distribution in the cold storage chamber is necessary. The required knowledge can be obtained either through experimentation or mathematical simulation. Due to the availability of faster computers at reasonable prices, the detailed information on airflow, temperature distribution and moisture loss in the cold storage chamber could be obtained economically in short time thorough mathematical analysis.

• Analysis of collected data to identify the defects in the existing cold storage:

Once an insight view of cold storage in terms of temperature, relative humidity and airflow distribution is available, the probable zones such as hot and cold spots, dead area, moisture condensation, etc. could easily be located. The product in the stack would suffer severe moisture loss, if the relative humidity in the stack dropped below 80% and moisture might also condensed on cold surfaces of the potatoes when the relative humidity in the surrounding air approaches near 100%.

8. Recommendation

There are unlimited capabilities of this technique in the processing industries. The following are some of the areas wherein this technique could be used for the improvement of performance of the cold storage.

- To investigate the effect of air velocity, storage air temperature and relative humidity and hence optimization of storage air conditions.
- To check the initial quality of potatoes, like maturity, variety, size, shape, etc.
- To study the effect of stacking arrangement and gaps between the stacks.
- To Determine the gaseous composition of storage environment and hence, the required frequency for charging the fresh air into the cold storage chamber.
- To modify the arrangement of cooling coils and ceiling fans to improve the air circulation.
- To regulate the reducing sugar in the potato during the long-term storage as required for potato processing industries.

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