Comparative Analysis of Cold Storage Filled with Fresh Potatoes

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Abstract— A well-established cold storage has been considered in present work which was used for storage of potatoes, so as to protect them from getting spoiled and to prolong their preservation period. The theoretical analysis has been conducted to evaluate coefficient of performance (COP), relative humidity and power consumption of the above mentioned cold storage. Further, the change in level of refrigerant i.e. NH3 on that cold storage with respect to the change in load has been noticed and reported. All the above analysis was repeated by changing the number of times, the door was opened. Also, the results were reported from no load to full load condition i.e. when the storage is empty to when the storage is half filled. On the basis of theoretical outcome and observe reading of the above mentioned process, it was found that COP and relative humidity decreases with increasing the number of door opening, whereas, power consumption increases with increasing the number of door opening. It has been seen that all the above mentioned trends decreases the overall efficiency of the cold storage. In that respect, corrective action has been suggested in the present work on the basis of theoretical analysis so that, the output of the complete system will enhance without incorporating much changes in the already installed unit.

Key words: Cold Storage, Coefficient of Performance, Relative Humidity, Power Consumption, Refrigerant

I. Introduction

Cold storage or refrigerated warehouses are facilities where perishable foodstuffs are handled and stores under Controlled temperatures with the aim of maintaining quality. Preservation of food can occur under frozen or chilled temperatures. For some products other conditions other than temperature might be require. A cold storage is place where the various items such as vegetables fruits, medicines and meat etc. are stored so as to protect them from getting spoiled and to prolong their preservation period. This task is accomplished by their storing the products at their preservation temperature and humidity etc. preservation temperature for fruits can be defined as the temperature at which its respiration rate is Cold storage will not be harm materials as long as the cooling and warming is done in a controlled manner, with the moisture content of the components held stable. Moisture content is an intrinsic property that is influenced by the humidity in the surrounding air and secondarily, by temperature. In this project, emphasis has been given on cold storages

A. Critical Storage Conditions and Grouping of Products

– Pre-cooling- Pre-cooling requirements vary based on produce and method of cooling such as room cool, hydro cool, forced air cooling, evaporative forced air cooling and ice packaging. However, forced air cooling within 4-6 hours is adoptable to a wider range of commodities than any other pre-cooling method and may suffice for most of the produce and therefore, it is taken for recommending general technical standards for pre-cooling system.
– Quality of product – Product should be mature with required firmness and free from bruises and other external damages. Therefore, for good keeping quality, fresh produce should be carefully handled in all operations including picking, grading and packaging.
– Commodity Storage Conditions: - For designing a cold storage, product storage conditions must be defined in terms of critical storage conditions of temperature, relative humidity, presence of NH_3, ethylene, air circulation, light etc. In absence of research data for Indian conditions, it is recommended to adopt commodity storage conditions as prescribed by Commodity Storage Manual of WFLO in absence of research data from Indian Institutions. Example - Design conditions for Irish Potatoes which are adopted, in absence of data for Indian potatoes are as given below.

Fresh Potato	Temp. °C	Storage Period in month	RH %
Early Crop	4 – 10	0 – 3	95
Seed Potato	3	5 – 10	90 – 95
Table Potato	4	5 – 10	90 – 95
For French Fries	7.2 - 10	1 – 10	90 – 95
For Chipping	7.2-10	1 – 8	90 – 95

Table 1: The temperature, storage condition and relative humidity of potatoes

Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India, vide its communication No. 22011/5/2007-M-II dated 16 June 2009 constituted a Technical Standards Committee. The TSC has classified cold storages for fruits and vegetables in following three main categories as listed below,

– Cold storages for storage of fresh horticulture products which do not require pre-cooling.
– Multi-commodity Cold storages for short term and long-term storage of fresh horticulture. Products, which require pre-cooling and varying storage requirements.
– Control Atmosphere (CA) Storages.

II. Literature Review

M K Chourasia and T K Goswami, comes out to be the model predicted values of air velocity, product temperature and moisture loss from the potato in the stack were found to be in good Agreement with experimental values. There is no doubt that the temperature of the product is one of the most signification factors that govern the extent of storage losses and hence, the economic visibility of then storage system. Moisture loss is an equally important parameter as product.it was found that in some of the stack where the air distribution was comparatively poor, the relative humidity at steady state condition dropped by about 7% compared with the surrounding air.

Y H Yau (2010), Analyses for heat recovery ventilation systems and concluded the heat wheel system was the best system as it has the highest total energy saving, shortest payback period and providing the most stable indoor air conditions.

M.K. Chourasia T.K.Goswami: Theoretical analysis and experimental validation: Liquid nitrogen (LN_2) is a colorless, odorless, low boiling cryogenic liquid. Due to its inertness and high expansion ratio (646 between liquid and gaseous N_2 at 0 ºC), it is an excellent material for rapid purging of the initial O2 gas from the space of the controlled atmosphere (CA) storage. The present study establishes a relationship for predicting the amount of LN_2 required for reducing O2 concentration in the CA storage. The simulation results were validated using the laboratory scale CA storage system having a storage capacity that could hold 10 kg of apples.

C. Zamfirescu: In this research they are explores the application of constructed design to tree-shaped Networks for cold storage. The objective is the maximization of ice production per unit volume, for specified operating conditions (temperature difference, pressure drop, storage time, construction material). Constructed design starts from the smallest Scale (elemental volume) and proceeds toward larger and more complex assemblies of elements. At the next larger scale, the ice production was maximized on arrays of tubes assembled as ‘Z-shaped registers’.

Dr. Sharad Chaudhary- The principal of refrigeration is method of successful storage of vegetable and fruits to maintain their flavour and freshness, for post-harvest product deterioration start with time and temperature so it need to be maintain desirable temperature and relative humidity for post-harvest product that is for potato. This paper deal with all standard refrigeration principles and different aspect of design of cold storage and this design is hypothetically intended to serve as a guide for future fabrication and erection.

Ricardo Badia-Melis - In this paper they discussed about millions of tons of temperature-sensitive goods are produced, transported, stored or distributed worldwide, thus making their temperature and humidity control essential. Quality control and monitoring of goods during the cold chain is an increasing concern for producers, suppliers, logistic decision makers and consumers. In this paper they present the results of a combination of RFID and WSN devices in a set of studies performed in three commercial wholesale chambers of 1848 m3 with different set points and products. Up to 90 semi-passive RFID temperature loggers were installed simultaneously together with seven motes, during one week in each chamber.

Darshan Gajdhar -In this research they observed cold room is a refrigerated enclosure intended for the storage of chilled and/or frozen foodstuff or other perishable items. Cold room is the storage facility where large quantities of products could be stored for longer duration at lower temperature. The current scenario reveals that there is a tremendous scope for the development of cold chain facilities and Cold Rooms form the heart of the cold chain. The Vapour compression refrigeration is widely used for air conditioning of buildings and automobiles. It is also used in domestic and commercial refrigerators, large-scale warehouses for chilled or frozen storage of foods and meats, refrigerated trucks and railroad cars, and a host of other commercial and industrial services

N. Mukhopadhyay-They are observed in this energy crisis is one of the most important problems the world is facing now-a-days. With the increase of cost of electrical energy operating cost of cold storage storing is increasing which forces the increased cost price of the commodities that are kept. In this paper they are proposed a modified theoretical heat transfer model of convective heat transfer in the evaporator space and heat enter in the cold store due to infiltration through cold room doors using Taguchi L9 orthogonal array

Amit M. Patel -They observed in this the demand for refrigeration and Air conditioning has been increased during the last decade, the cold storage system can be used to the economic advantage over conventional plants. Energy conservation is required in the cold storage system so The Design of Experiment is used to Optimization of different parameters of cold storage on the bases of performance experiments. Objective of this paper is Optimize different parameters in the cold storage. The various tools of DOE are used for analyze the final results of the experiment with the help of Graphs.

Ryan Anderson - In this research paper they were observed the thermal energy storage in packed beds is receiving increased attention as a necessary component for efficient implementation of concentrated solar power plants. A simplified, one-equation thermal model for the behavior of a packed bed is presented for a-alumina as solid storage material and air as the heat transfer fluid. The model successfully predicts the thermocline behavior over time. Two flow rates during storage are presented for alumina in a cylindrical packed bed. Temperature-dependent thermo-physical properties are utilized to accurately model the systems. An additional study of air and alumina at high temperature is presented to further highlight the importance of variable thermo-physical properties in real models

Antonio G.N. Novaes -In this research they are observed the temperature of refrigerated products along the distribution process must be kept within close limits to ensure optimum food safety levels and high product quality. They also discussed about variation of refrigerated vehicle distributing food material and their optimum utilization. The thermal quality of routing alternatives is evaluated in this analysis with Process Capability Indices (PCI). Since temperature does not vary linearly with time, a Simulated Annealing algorithm was developed to get the optimal solution in which the minimum vehicle traveling distance is searched, but respecting the quality level expressed by a required minimum PCI value.

III. EXPERIMENTAL SETUP

A. Compressor

A refrigerant compressor is a component of a refrigerator which is designed to compress the refrigerant used to cool the refrigerator.

- Compressor: 3 stage reciprocating compressor (Kirloskar make, KC-6, open type 6 cylinder)
- Outside pressure: 304.58 PSI (21 bar)

- Speed of the compressor: 1000 RPM
- Stroke: 110 mm.
- Bore: 160 mm.
- Isentropic efficiency: 81%

B. Evaporator

The process of heat removal from the substance to be cooled or refrigerated is done in the evaporator.

1) Evaporator/cooling chamber

- Total length of tubes: 1700 feet (515.1m)
- Total no. of rows: 12
- Inner diameter of tube : 1" (25.4mm)
- Thickness of tube: 1.3 mm
- Tube material: ASTM-A179 cold drawn low carbon steel pipe.

S. No.	Particular	Specification
1	Basis of design	ESP-150mm external walls and ceiling, 75mm internal walls and 125mm floors
2	Size of cold storage room	2.89m × 2.89m × 2.73m
3	Cold storage capacity of potatoes	3 tones
4	Outside condition	DW- 42° C, WB- 30° C
5	Inside condition	7 °C
6	Loading period	One Weak
7	Specific heat of potatoes	3.433KJ/Kg°k
8	Ventilation air	2-6 m^3 air charge/day
9	Occupancy	Two people working for 8 hours per day

Table 1: Particular & Specification

IV. Calculation

A. Heat Load without Potato

- Specific Heat of Ammonia (Cp) =4.606KJ/Kg-K,
- Latent Heat of Ammonia (h_{fg}) =1150.19KJ/Kg-K
- Mass of Ammonia (m) =5kg,
- W = 9 KW, T_1=7°C, T_2=36°C, Δ T=29°C
- Q = m (Cp+h_{fg}) (T_2-T_1)
- Q = 5 Kg × (4.606KJ/Kg-K +1150.19KJ/Kg-K) × 29°C
- Q=167445.42 KJ
- COP=Q/W
- COP=167445.42KJ /9× 3600
- COP=5.168

B. Heat Load without Potato

- Specific heat of potato (Cp) =3.433KJ/Kg °C,
- Mass of potato (m) =200Kg, W = 9KW
- T_1=7°C, T_2=36 °C, ΔT=29°C
- Q= mxCp (T_2-T_1)
- Q_2= 200Kg × 3.433 KJ/Kg x29°C
- Q_2=19911.42 KJ
- Q=Q_1+Q_2
- Q=167445.42 KJ + 19911.4 KJ
- Q=187356.82KJ
- COP=Q/W
- COP=187356.82 KJ/9 × 3600
- COP = 5.79

C. Observation-Tables with Potatoes

S.N	Energy Meter Reading	Outside Temp.	Inside Temp.	RH %	NH_3 Level ppm	COP
1	9 KW	28°C	7 °C	85%	2300	5.79

Table 1: One Time Door Opening per Day

1	8.0 KW	30°C	7 °C	83%	2500	6.51
2	10.5KW	34 °C	7 °C	85%	2200	4.96

Table 2: Two Time Door Opening Per Day

1	7.5 KW	29 °C	7 °C	84%	2800	6.94
2	9.9 KW	31°C	7 °C	85%	2400	5.29
3	12.6 KW	35°C	7 °C	87%	2300	4.14

Table 3: Two Time Door Opening Per Day

1	7.0 KW	27 °C	7 °C	84%	3000	7.44
2	8.8 KW	29°C	7 °C	85%	2800	5.92
3	11.2 KW	32°C	7 °C	86%	2500	4.65
4	14.2 KW	36°C	7 °C	87%	2100	3.67

Table 4: Four Times Door Opening Per Day

1	8.0 KW	29 °C	7 °C	80%	3400	6.51
2	9.8 KW	31°C	7 °C	82%	3100	5.32
3	12.4 KW	33°C	7 °C	84%	2900	4.2
4	15.2 KW	37°C	7 °C	83%	2600	3.43
5	18.2 KW	39°C	7 °C	86%	2200	2.86

Table 5: Five Times Door Opening Per Day

1	7.5 KW	30°C	7 °C	74%	3500	6.94
2	9.6 KW	32°C	7 °C	77%	3000	5.43
3	12.3 KW	35°C	7 °C	80%	2700	4.24
4	15.3 KW	38°C	7 °C	83%	2300	3.41
5	18.9 KW	40°C	7 °C	86%	2100	2.76
6	22.8 KW	42°C	7 °C	88.50%	2000	2.79

Table 6: Six Time Door Opening Per Day

V. Results

A. Comparative Results

The comparative results will shows the with potatoes under the condition of normal working of plant and scientific rectification technique. Here the we can consider following parameters for comparative result i.e. Coefficient of performance, Relative humidity, Power consumption and Refrigerant level.

B. Coefficient of Performance

The variation of COP as a function number of door opening per day is shown in figure 6.9 COP versus number of door opening. It observed the COP is decreases with increases in number of door opening per day; this may be due to the fact that as we open the door and the fresh air will enter inside the cold storage chamber which increases the cooling load. In order to reduce the temperature of the cold storage up to the require temperature compressor has to more work and therefore the work input to the system will increases which reduce the COP of the system.

The maximum value of COP is observed as figure 6.9 for single opening of the door when as its minimum value is observed 2.05 for six numbers of door opening per day of the cold storage system. In case of condition space is loaded with potatoes the maximum value of COP is observed as 6.94 for single opening of the door when as its minimum value is observed 2.29 for six number of door opening per day of the cold storage system.

At the analyzing of the values of COP at with loading condition at without rectification techniques and including rectification techniques the following result will be shows.

Scientific technique for improving performance of plant:

– It may be suggested that the frequency of door opening should be less at the experimented value and the door will be equipped with flex therm insulated curtain or insulated industrial strip door to restrict the ambient air in the conditioned space. As well as mechanized air curtain would be placed on the main entrance of the cold storage.

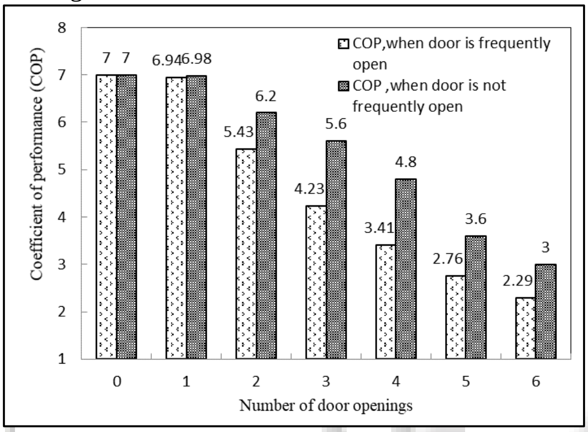

Fig. 1: Comparison of COP versus number of door opening.

– Automation: The automation technique will be used for the improving the performance of the plant, Here we can suggest that the stacking of potato would not be loose or in bulk type, it would be stack in the form of bagged of 25 kg/50kg or 100 kg. The bagged system is easy for the automation technique to loading unloading and stacking of the baggage. i.e. baggage handling system of airports. There is a growing of automated point solution that can drastically reduce escalating operational costs. In some way automation can reduced the 50% of energy consumption and labour as much as 70%.
– Occupancy: The human body radiated the 4.7 W/m^{2}per K with normal working condition if there will be more than one person and they are work continually 8 hours in the day then the radiation is considerable decline the performance of plant so, here we can suggest that the occupancy of workers as possible as less in the working plant.

C. Relative Humidity

The variation of relative humidity as a function number of door opening per day is shown in figure 6.10 of RH versus number of door opening at the bases of without loading and with loading of potatoes .It observed the relative humidity is increases with increases in number of door opening per day. this may be due to the fact that as we open the door fresh air will enter inside the cold storage chamber which increases the cooling load.

In order to reduce the temperature of the cold storage up to the require temperature compressor has to more work and therefore the work input to the system will increases which increase the Relative Humidity of the system.

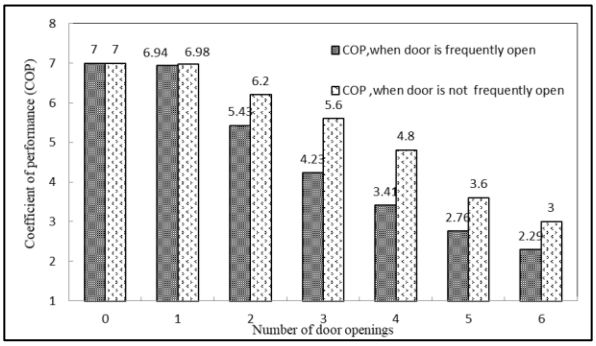

Fig. 2: Comparison chart of relative humidity versus number of door opening

The maximum value of relative humidity is observed as 71% for single opening of the door at without loading condition, when as its minimum value is observed 81% for six n of door opening per day of the cold storage system. The maximum value of relative humidity is observed as 74% for single opening of the door at with loading condition, when as its minimum value is observed 88.5% for six numbers of door opening per day of the cold storage system.

Humidity Affects both Thermal Comfort and Indoor Air Quality.

1) Facilitates the growth of fungi (mould) and bacteria that can cause respiratory problems and/or allergic reactions
2) Results in odors in poorly ventilated spaces because of fungal growth.

Reasons for High Humidity,

1) Water leakage through the building envelope
2) Damp ground conditions under suspended timber floors Retained construction moisture, i.e. moist
3) The building materials such as timber framing, concrete floors and plaster, after installation.
4) Plumbing leaks.

How to Controlling Humidity the internal humidity can be controlled by:

D. Passive ventilation by opening windows for cross ventilation

1) Raising indoor temperatures by heating or insulating, since warmer temperatures imply lower relative humidifies.
2) Occupants not drying clothes on racks inside.

E. Preventing Moisture

– Ensure there is good ventilation under suspended timber floors – clear openings of 3500 mm^2 per square meter of floor area must be provided.
– Cover the ground with a Vapour barrier such as polyethylene sheet where there is high ground water content under the building or where sufficient under floor ventilation cannot be provided. (Even with a vapour barrier, minimum subfloor ventilation openings of 700 mm2 per square meter of floor area must still be provided.)
– The most effective passive ventilation to remove internal moisture is simply to open windows. These should preferably be on opposite sides of the building to maintain a good cross air flow.
– Vents in window frames allow air movement while maintaining security when the house is closed up. The

recommended minimum vent area is 4000 mm^2 of air opening per room space for an average size room. This can be achieved by a 600 mm long vent in a window frame.

F. Power Consumption

The variation of power consumption as a function number of door opening per day is shown in figure 6.11 of power consumption versus door opening .it observed the power consumption is increases with increases in number of door opening per day. This may be due to the fact that as we open for the door fresh air will enter inside the cold storage chambers which increase the cooling load.

In order to reduce the temperature of the cold storage up to the require temperature compressor has to more work and therefore the work input to the system will increases which increase the Power consumption of the system.

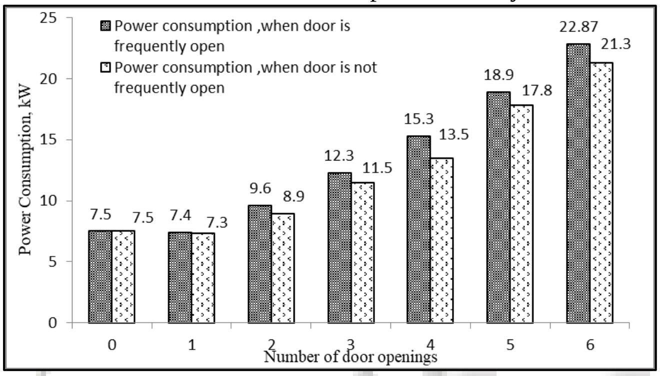

Fig. 3: Comparison chart of power consumption versus Number of door opening.

For unloaded condition of potatoes, the maximum value of power consumption is observed as 6 kWh for single opening of the door when as its minimum value is observed 21 kWh for six numbers of door opening per day of the cold storage system.

For loaded condition of potatoes, the maximum value of power consumption is observed as 7.5 kWh for single opening of the door when as its minimum value is observed 22.8 kWh for six numbers of door opening per day of the cold storage system. Some of the measures implemented to limit infiltration of outside air and loss of refrigerated air in the newer buildings, and slowly retrofitted to the older ones.

The rectification technique to the reduced the power consumption of plants they are,

- Airlocks on all personal access (PA) doors
- Interlocking inflatable airbag operation to dock doors
- Airlocks on forklift ramps
- Insulated finger-dock (enables unloading from the side inside an enclosed area) to unload tray trucks and taut liners
- Strict maintenance on door seals, door self-closers and air bags.

G. Refrigerant Level (NH_3 Level)

The variation of NH_3 Level as a function number of door opening per day is shown in figure 5.4 NH_3 level versus number of door opening at without loaded potatoes and with loaded potatoes Figure 4 .It observed the nh_3 level is decreases with increases in number of door opening per day. This may be due to the fact that as we open the door fresh air will enter inside the cold storage chambers which increase the cooling load. in order to reduce the temperature of the cold storage up to the require temperature compressor has to more work and therefore the work input to the system will increases which reduce the NH_3 level of the system.

The maximum value of NH_3 level at without load condition, is observed as 3100 ppm for single opening of the door when as its minimum value is observed 2000 ppm for six no of door opening per day of the cold storage system, The maximum value of NH_3 Level at with load condition, is observed as 3500 ppm for single opening of the door when as its minimum value is observed 2000 ppm for six no of door opening per day of the cold storage system.

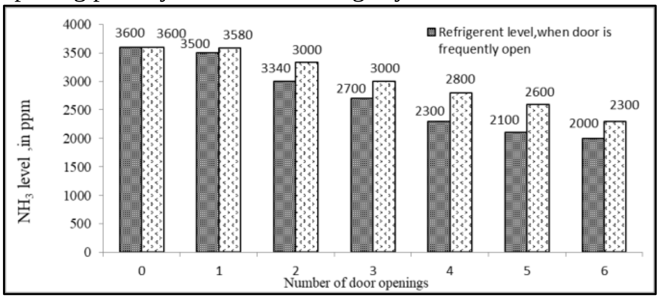

Fig. 4: Comparison chart of refrigerant level versus number of door opening.

Here we analyzing of the values of NH_3 level at with loading and without loading condition, it may be suggested that the frequency of door opening should be less at the experimented value and the door will be equipped with flex therm insulated curtain or insulated industrial strip door to restrict the ambient air in the conditioned space. As well as mechanized air curtain would be placed on the main entrance of the cold storage.

The figure shows that the level of refrigerant is directly with contact of coefficient of performance of the plant, if the coefficient of performance go down the controlling unit release refrigerant in high intensity and the evaporation of refrigerant is increased.

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