International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Experimental Analysis for the Enhancement of Cooling Capacity of Cold Storage Plant through Artificial Draught

Nishant Raj, Kashiram Kadwe

Madhyanchal Proffesional University, Bhopal, M.P., India,

A B S T R A C T

This thesis represents the effect of air circulation on cold storage with the help of experimental analysis to improving performance of cold storage and food preservation quality. Air circulation can be possible better by experimental analysis with help of hot wire anemometer. In this paper presents air velocity and temperature distribution at different point of cold storage. Air flow model is based on Experimental analysis of air flow by evaporator arrangement at top, medium and bottom Thus result investigated from this arrangement based. A parametric analysis was performed by using the equivalent model with different result of blowing air velocity and locationof cooling units there was found a better cooling effectiveness and uniformity of temperature in cold store. And it is achieved by using higher blowing velocity and locating the cooling units lower and closer towards the array of the produce packages. In this research spatial distribution of air velocity was determined at ceiling medium floor for experimental cold storage and also temperature variation in different locationof cold storage.

Keywords: Cold storage; Frozen food; Air circulation analysis, Temperaturedistribution

INTRODUCTION

Cold storages are the facilities where perishable foodstuffs are stored under controlled temperatures with the purpose of maintaining quality. Preservation of food can be done under frozen or chilled temperatures. A cold storage is a place where the various items such as vegetables fruits, medicines etc. are stored to protect them from getting spoiled and to prolong their preservation period. This is done by storing the products at their preservation temperature and humidity etc. Preservation temperature is defined as the temperature at which its respiration rate in Cold storage will not be harm materials as long as the cooling and warming is done in a controlled manner, while keeping the moisture content of the components fixed. Moisture content is an intrinsic property that is influenced by the humidity present in the air, and second, by temperature.

1.1 Food Preservations:-

The food preservation is the technique by which the foods are stored in the cold area where the food can be withstand or protected for the long period. By this techniquethe food also controlled for getting damaged during the storage time or period. . It is also work for controlling the taste, color and their nutritive value. For an example in earlier days, ice was used to preserve the food in a very cold weather conditions. Thus, the very low temperature in the cold weather condition becomes an efficient method to prevent the items to get spoilt.

1.2 Principle of Food Preservation:-

Removal of micro-organisms: This is done by removing air, water (moisture), decreasing or increasing temperatures and it can also be done by increasing the concentration of salt or sugar or acid in food items. By this process the several types of food agents are preserved. For example the green leafy vegetables having the waterso that the water is extracted from the vegetables and then these are preserved.
Inactivating enzymes: -The enzymes that available in the food commodity and this can be in activated by the changing of the moisture and temperature conditions of the food agents. If you want to preserve the peas by using this method, the peas put in the vessel for the boiling then the enzyme inactivated and it safely preserved.

* *Corresponding author.* Tel.: +0-000-000-0000 ; fax: +0-000-000-0000.
E-mail address: author@institute.xxx

1.3 Following area unit listing the principles of food preservation:

Some of the factors affecting the growth of micro - organisms can be manipulated in different ways to prolong the life of the food product.
Temperature - Chilling or freezing the food to retard growth of micro-organisms and inhibit enzyme activity. Alternatively, heating the food to destroy micro-organisms and prevent enzyme activity.
Oxygen-Food kept in an airtight container will deprive micro-organisms of oxygen and prevent contamination.
Moisture- Reducing the moisture content of the food to make water, (which is essential for growth), unavailable to micro-organisms. Alternatively, placing food in asugary solution will make water unavailable for the growth of micro-organisms.
PH level -Placing food in an acidic or alkaline solution will inhibit the growth of micro-organisms.

1.4 Method of Food Preservation:-

1.4.1 Decreasing Temperature:-Decreasing temperature method is also one of the most important methods to save the foods. The enzyme and micro organism are in- activated of the food items by the decreasing the temperature of the preserving food agents. And then the foods are protected for the long time. This is the method that are used mostly in the home and as well as in the food preserving industries. The refrigerators are working on this method. Foods can be sealed at low temperature .the low temperature format is given below-

1. Refrigeration 40 C-70 C
2. Cold Storage 10 C-40 C
3. Freezing 180 C or below

1.4.2-Increasing Temperature: -This method is generally used in home to preserve the food stuff. By increasing the temperature of the food stuffs, the enzymes and micro organism get destroyed. There are various methods to preserve the food stuffs by use the increase the temperature But there are mainly two methods that used to preserve the food at high temperatures:-

1.4.2.1-Pasteurization:-Pasteurization is one of the methods of preservation of the foodstuff, where the food stuffs are heated up to the high temperature and then cooled suddenly. Due to sudden decrease in temperature harmful micro organism are not able to withstand the sudden changed in temperature and then it get destroyed to the micro organism.

1.4.2.2-Sterilization:-Meaning of sterilization is that the free from alive micro organism. This method are used at the high temperature, due to the high temperature of the food product, the all micro organism get destroyed of the preserving food.

1.4.3-Freezing: - In this process the preservation of food at low temperature, due to the lowering of the temperature of the food commodity or environment the organism growth will be unstable and then the micro organism will not survive.

1.4.4-Dehydration:- Various types of items is preserved by the dehydration method. Dehydration means that the remove the moisture or water from the preserving food items. There is one of the most usable method in the society that is the drying the food items in the sun light. Now this method is elaborated in detailed the some food items are dried in the sun light such as Potatoes, grapes, onion, raw mangos and cauliflower etc.

1.4.5- Salting: - Salting is the processes of the preservation of the foods by which the moisture contain of the foods are extracted out. Due to the lack of moisture, the organism will die and hence the food will get the preserved for the long period.

1.4.6 -Sugaring: - Sugaring is the method that similar to the pickling method. Sugaring method is the process of drying a food first by dehydration then it is packingwith the sugar.

1.4.7-Pickling:- This is also food preservation method .The foods are dipping in the some chemical liquid that prevent to the growth of the micro organism. Peppers, cucumber and few vegetables are preserved by the pickling method. The liquids are used in which the foods are dipped for example- alcohol, brine and oils etc. the pickling can be done by two method chemical pickling and fermentation.

1.4.8-Smoking:-In this method the preserving food are exposed in the smoke. The smoke generated by the burning plant material such as wood. The smoke deposits on the foods in the form of paralysis.

1.5 Types of cold storage

The cold storage can be classified in following types:

i.Multipurpose Cold Stores: -These are designed for handling and storing a varietyof products simultaneously throughout the year. The products that can be stored inthis type of cold chamber are potato, fruits like mango, banana, dairy products etc.

ii. Bulk Cold Stores: -These type of cold storage facility store only single type ofcommodity for a long term duration such as storage of potato, apple etc.

ii. Small cold stores with precooking facilities:- These are used for storing contemporary fruits and vegetables, chiefly, for export oriented things like Grapes etc. The major portion of those units is in Maharashtra however the trendis currently reading in different states like state, Andhra and Gujarat etc

iii. Frozen food stores with or without process:- Frozen food stores with or without process and state change facility for meat, poultry, dairy merchandise, fish and processed fruits and vegetables.

1.7-Storage conditions for the preserving food commodity:

The few critical conditions for the designing of the cold storage are given below:-

(i)-Temperature range:-The temperature range of the cold storage should be depends on the storing food stuff and atmospheric condition. The cold storagetemperature should be close to the freezing points of the food items.

(ii)- CO2 level:- At the loading period of the product it should not be greater than 4000PPM and at holding period it should be 2000 PPM (source: industry).

(iii)-Humidity range:-For the fresh fruit the relative humidity are varies from the 90% to 98% (exp-cabbage, kiwi etc).For the fruit example onion and garlic therelative humidity varies in between 65-75%.

(iv)- Loading Rate:-The loading rate should be 4 to 5% of the total storage capacity in a day. For the loading period, the temperature should be 15˚C. The loading temperature should be get down to holding temperature at 2^0 to 3^0 C in a week.

(v)-Pulling-down time:-The time required at which the loading temperature cooled down to the holding temperature of the cold storage. In the 24 hours, the temperature pulls down to 15^0C, and this temperature pulls down to 2-3^0C at the holding temperature in a week. According to the CPRI the seed potatoes are cooled at 10^0C temperature in the 24 hours of the arrival time to the cold storage. The temperature further decreases from the pulling temperature to the holding temperature 3^0C.

(vi)- Air Circulation:-The circulation of air should be uniform and proper manner in the cold storage. The minimum air circulation in the storage should be 50 CFM/MT for the Potatoes.

(vii)- Ventilation needs in cold storage:-The ventilation is very important in the cold storage to maintain the CO2 level less than 4000 PPM. The recommended ventilation range is the 2 to 6 air changes per day. There are the options for the ventilation to use opening doors of cold storage and hatch windows and remove the CO2 which is assembled in cold storage.

(viii)- Dew point: - The dew point is the temperature at which the given humid air must be cooled and at the constant pressure for example- the water vapor condenses into the water and this condensed water is called dew. The dew point is associated with the relative humidity and saturation temperature. If the dew point is closer to the current air temperature than its indicate the relative humidity high. If the relative humidity 100% than it indicates the dew point temperature is equal to the current air temperature. And with the water, air is maximally saturated. When the dew point is constant and temperature increases than the relative humidity will decrease.

ix)- CIPC application:- The critical storage conditions are adopted in general for processing potatoes and for table potatoes. For slow pull down of temperature 0.5^0C per day, in this situation CPRI recommended that the high holding temperature is built-up and which is accelerated germination of potatoes immediately, after its dormancy period. So that the application of CIPC immediately is recommended after30 days to arrives the potatoes products in the cold storage.

(x)-Lighting Condition:-Dark

(xi)- Dew point: - The dew point is the temperature at which the given humid air must be cooled and at the constant pressure for example- the water vapor condenses into the water and this condensed water is called dew. The dew point is associated with the relative humidity and saturation temperature. If the dew point is closer to the current air temperature than it‟s indicate the relative humidity high.

1.9-Design and operation of cooling component:-

The salient components of vapor compression refrigeration system used in Indian cold storage system are: evaporator, compressor, condenser and manually operated expansion valve. Since the refrigeration system is the major consumer of electrical energy in potato cold storage, an improvement in design and operation of the components leads to proportionate saving in energy A typical schematic diagram of the refrigeration system cut section model used in cold storage is shown below:

Compressor Condenser Expansion valve Evaporator Fan

2.1 LITERATURE REVIEW

A uniform cooling and cold storage of fresh produce are difficult to obtain in industrial cooling rooms because of an uneven distribution of the airflow .The airflow distribution is dependent on the produce the cooling medium the geometry and characteristic of the cooling room. The velocity distribution can be determined based on the conservation equations for mass and momentum. An analytical solution can be found only in simple cases. The variables can be examined experimentally but this isa tedious, costly, time-consuming method and furthermore, it is only applicable to existing storage rooms. With the increasing availability and power of computers together with ancient solution algorithms and processing facilities, the governing fluid own equations can now be solved numerically. This can be done by choosing such an arrangement of the evaporator among the available that is capable enough to cool down the product temperature as soon as possible. However, the following studies were useful in setting up proper air circulation in this research.

Son H.Ho,Luis Rosario, Muhammad M. Rahaman et.al [1]"Numerical simulation of temperature and velocity in refrigerated warehouses". In this paper numerical modeling can be used to predict fluid flow and heat transfer and to assess thermal uniformity in refrigerated warehouses. This paper also present the simulation of 3-D models and 2-D ones can be used tot o reducing computing cost. And it was found the result of high degree accuracy. A 3-D simulation model increased the velocity in cooling unit and hence the better cooling effectiveness and uniformity (lower maximum and mean temperatures and lower spatial standarddeviation) can be achieved.

Majid Sajadiye et, al. [2] A Multi scale 3-Dimensional CFD Model of a Full Loaded Cool Storage". In order to reduce the computational costs, the porous media parameters of the bed of the products inside the vented containers were extracted using a series of wind tunnel CFD simulations and then applied in the cool storage model. The model was validated against experiments by means of velocity, product temperature, and product weight loss measurements in cool storage.

M.K. Chourasia, et, al. [3]"CFD simulation of effects of operating parameters and product on heat transfer and moisture loss in the stack of bagged potatoes "In this paper a CFD simulation on effects of operating parameters and product on heat transfer and moisture loss in the stack of bagged potatoes. The heat and mass transfer within the stacked bags of potato depend on many parameters of both product and operating conditions. Most important factor are: rate of metabolic heat generation, porosity of the bulk medium, diameter of the product, resistance of the product ,skin preventing moisture loss, and temperature as well as RH of the storage air. Therefore, the effect of the parameters of the product and the operating conditions on heat and mass transfer in the stack of bagged potatoes during the transient cooling and at steady state were studied using the CFD modeling approach.

M.L.Hoang et,al.[4]" Analysis of the air flow in cold store by means of computational fluid dynamics" presented an analysis of air flow in a cold storage using CFD approach employing the Reynolds-averaged Naviour –Stokes equations with the k-ϵturbulence model .A comparison with experimental measurements showed an averaged difference of 26% between calculated and measured air velocities, it becomes only possible to have a qualitative insight into the air flow pattern for different product stacks, different fan rotation speeds and different room designs, without the need of experimental determination of boundary conditions for the velocity.

Ugwu et, al. [5] "Design and a cold storage on the basis of the country population, and the location of the country". Objective of this research was to determine atmospheric temperature and relative humidity distributions of two different cold stores which have two different cooling systems. One of the cold store which is called as Cold store-I, has classical cooling system such as compressor, condenser and evaporator. Second called Cold store-II, has air conditioning system for cooling, cold air ventilation and aspiration systems,and humidification system. Computational fluid dynamics was used for modeling and distribution of temperature and relative humidity of cold store walls. Storage temperature and relative humidity were assumed 2o C and 90%, respectively.

M.K. Chourasia, et, al. [6] "Simulation of Effect of Stack Dimensions and Stacking Arrangement on Cool down Characteristics of Potato in a Cold Store by Computational Fluid Dynamics."They Developed a Simulation of Effect of Stack Dimensions and Stacking Arrangement on cool down characteristics of Potato in a Cold Store by Computational Fluid Dynamics and validating the same with the existing prevailing situation. A satisfactory agreement was found between the experimental transient temperature data, as obtained in a commercial potato cold store, and simulated one, with an average temperature difference of 1.4+-0.98^{0}C.

Dr. M.K. Chourasia and Prof. Tridib Kumar Goswami et al [7] "Efficient design, operation, maintenance and management of cold storage "This paper deals with different aspects of design of cold storage and its improvement over the existing ones. Cold air flow being one of the key components in establishing the performance of a cold storage, a CFD analysis has been done and the results have been discussed in thispaper.

M.K. Chourasia , et, al. [8] "Three dimensional modeling on airflow, heat and mass transfer in partially impermeable enclosure containing agricultural produce during natural convective cooling" A three dimensional model was developed to simulate the transport phenomena in heat and mass generating porous medium cooled under natural convective environment. Unlike the previous works on this aspect, the present model was aimed for bulk stored agricultural produce contained in a permeable package placed on a hard surface. This situation made the bottom of the package impermeable to fluid flow as well as moisture transfer and adiabatic to heat transfer.

S.Duret, H.M.Hoang and D.Flick et.al [9] "Experimental characterization of air flow, heat and mass transfer in a cold room filled with food products". This research presents the Experimental investigation was performed in cold room filled with four apple pallets. Based on the experimental air velocity field, a simplified air flow was proposed. The understanding of heat and mass transfer of cold storage was performed by the interpreting the measured value of air velocity, temperatures (air and products), convective heat transfer coefficient and weight loss.

Tapsobaand, and Denis Flick et .al [10] "Airflow patterns in an enclosure loaded with slotted pallets". In this study, experimental and numerical simulations with the fluent CFD code were carried out in order to characterize velocities and air flow pattern through out a vehicle enclosure loaded with two rows of slotted pallets. A satisfactory agreement is found between numerical and experimental data concerning the jet decay and velocity profiles above and inside the slotted pallets. To analyze the uniformity and ventilation a numerical approach is performed to separately calculate the local ventilation efficiency and the fresh air renewal within the palates.

3.1 PROBLEM DETAIL

Based on the air circulation and its effect it is observed that the design and mounting of cooling coils play an important role to achieve the fast cooling

Evaporator arrangement: In this type of arrangement the cooling coil is located at the top of one of the wall of the cold storage. The air throw is horizontaland directly strikes on the products which generally kept in front of cooling coil

Fig.3.1 Evaporator located on the Top

3.1.2. Duct & its position: ducts are used to create artificial draught in chamber so that air throw from evaporator fan can be reached end part of chamber. Here induce draught is used in experiment. Duct is placed at farthest end of chamber opposite to evaporator position. Duct is fitted with axial blower fan which create low pressure area at inlet of duct so that induce draught create for air which throw from evaporator horizontally. Two types of ducts considered for experiment as uniform distribution is core objective of current work. First type duct has flat wall without any slot while other has equally -spaced slots on room facing side.

4.1 RESEARCH OBJECTIVE

The basic objective of the present study is to see theperformance analysis of cold storage for the different slot opening arrangement of our duct in cold storage analysis with help of slotted duct and induced duct.

5.METHODOLOGY

EXPERIMENTAL SETUP FOR FLOW ANALYSIS

Test is conducted on scaled model for the following three conditions

1. General configuration (without duct arrangement)
2. With induce duct arrangement
3. With induce duct having equip-spaced slots

General configuration deals with only closed chamber equipped with evaporator and measuring arrangements, no other system is applied inside the chamber. It is similar to empty cold storage plant. In this case flow velocity in chamber is measured along the vertical central plane at different locations which are marked along the length and height of vertical plane. As shown in figure 5.1 Velocity profile for this condition is shown in figure 5.2 Velocity measured through hot wire anemometer at mention location in figure 5.3 Velocity was also measured in reverse direction from mid height of vertical plane as flow it has been observed during experiment that flow thrust from evaporator is get back to evaporator from its bottom and direction of flow is toward evaporator in bottom section of chamber.

Results shows that flow velocity is dropping drastically almost around mid-section of the chamber it indicate that flow become highly turbulent near the evaporator coils. Because of this turbulent region flow is loss its momentum and causes restriction in flow in farthest parts of chamber from the evaporator. Results shows that velocity of flow is maximum just in front of evaporator drop their after lengthwise and velocity is lowest near the wall opposite to evaporator. Figure 5.4 indicates that reverse flow also pickup velocity just below evaporator can define as evaporator create a induce draught. It sucks mass from its bottom and back and throw it axially in positive X distraction. In this work we are observed the data on cold storage air distribution in empty room as well as loaded room data was observed in period of May –June 2022.

Method and used material on cold storage: Dimension of cold store were calculated these are: Length=1.5m, width 1m, height1m and the volume of the cold storage are 1.5 m^3 shown in fig. 5.1.

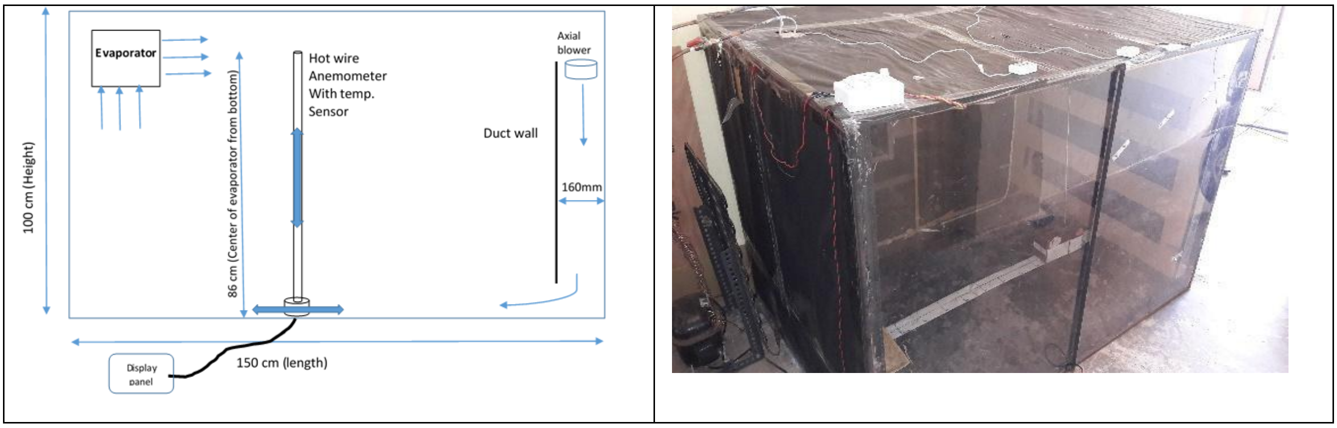


Fig 5.1 Line diagram and actual picture of experimental setup

The experimental cold storage made up of acrylic sheet and transparent glasses placed on wall side using on adhesive material. The four evaporative fans was setup in upper part of the cold storage these rating of the cooling fan was2450m^3/h and upper side one door is placed for keeping products for cooling purpose. The floor of cold storage was covered with foam glass and ceramics. A compressor was setup in the outside of the cold storage. In compressor chassis we were include condenser, ventilator fluid hoppers etc. An evaporator was put on the ceiling of the cold storage and tightened with steel screw. View of experimental cold storage is shown in fig 5.2 below-.

Fig-5.2 Air Velocity Measurement during Experiment

Sensor: For the measurements of air velocity at different locations in model chamber hot wire anemometer is used. Detailed specifications of instrument is as under
Name of instrument: HTC AVM -08 Hot Wire Anemometer
Air velocity measuring range: 0.1 to 25 m/s (± 5%) with 0.01m/s resolution
Temperature measuring range: 0˚C to 50˚C (± 1˚C) with 0.1˚C resolution)

Velocity measurement:

Velocity measurement was performed to describe the air flow in the entire cold room in terms of magnitude and direction (the identification of the turbulence intensity was out of the objective) .A Hot wire anemometer was used because of its good balance between cost accuracy and convenience. Velocity magnitude was calculated by using formula

$$V = \sqrt{V_x^2 + V_y^2 + V_z^2} \text{ measurements.}$$

Where Vx, Vy, Vz is the velocity component measurement in along the x, y, z direction figure 5.2 and 5.3 shows the velocity of x component of the air flow in cold storage in side view and as well as front view.

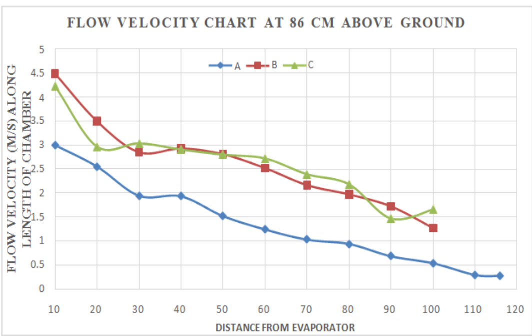
Digital Temperature measuring sensor: In cold storage outer side digital temperature measuring sensor is used for temperature measurement in cold storage at different point of view. The schematic view of digital sensor is shown in fig7.1 below

Fig-5.6 Digital Temperature Measuring Sensor

6.1 RESULT AND ANALYSIS

Results: During the measurement of velocity inside the cold storage chamber following flow velocity chart observed at 86 cm above ground distance from evaporator shown in fig- 6.1

- At 86 cm above ground air circulation in chamber at for this part from the evaporator is better if induced duct are used fig 6.1 shows at 100cm away from the evaporator velocity of air flow is around 1.5m/s with duct and 0.5 m/s without duct condition it shows that proper air distribution happen if duct is used.



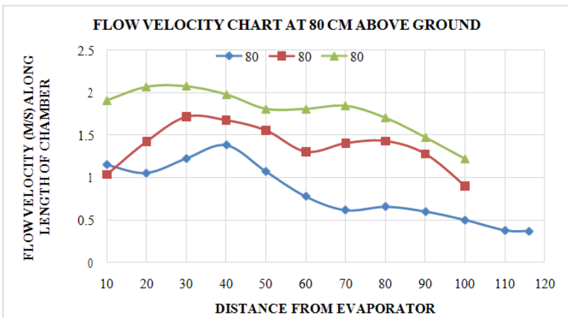


Fig-6.1 flow velocity chart at 86cm above ground

Fig-6.2 Flow velocity chart at 80 cm above ground

- Fig 6.1 shows that air velocity improves along length increasing at different point of state. And red line show velocity performance with duct including in cold storage chamber and green line show the result with slotted duct including in chamber blue line indicate without duct performance curve.
- At 80 cm above the base duct produce better result. But if slots occurred on duct then velocity profile improved.

At 100 cm from evaporator velocity is 0.5 m/s for without duct condition 0.8 m/s forwith duct condition and 1.3 m/s for duct with slot condition.

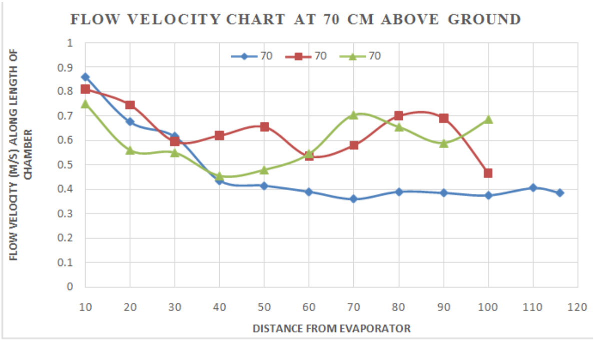


Fig-6.3 Flow velocity chart at 70 cm above ground

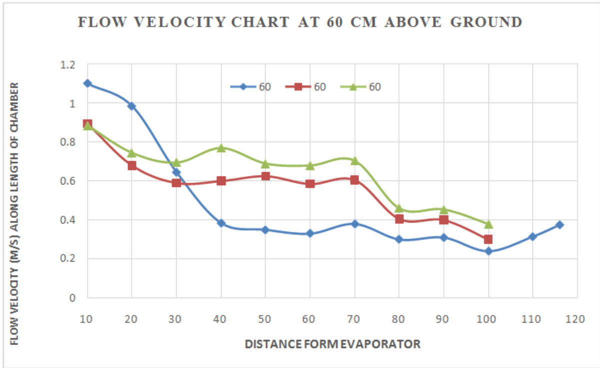
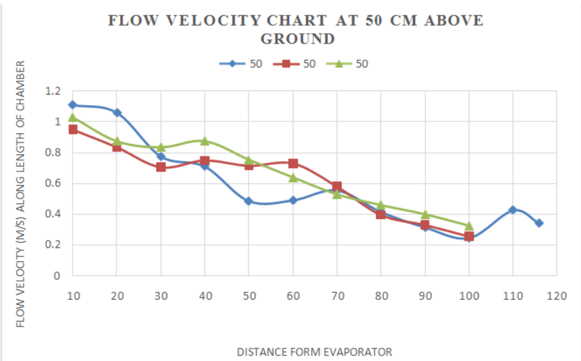


Fig 6.3 flow velocity chart at 70cm above ground

Fig 6.4 flow velocity chart at 60cm above ground

By 6.4 shows result for slotted duct condition are preferably better than other it is alsofound at mid section there is tendency of flow towards evaporator direction.



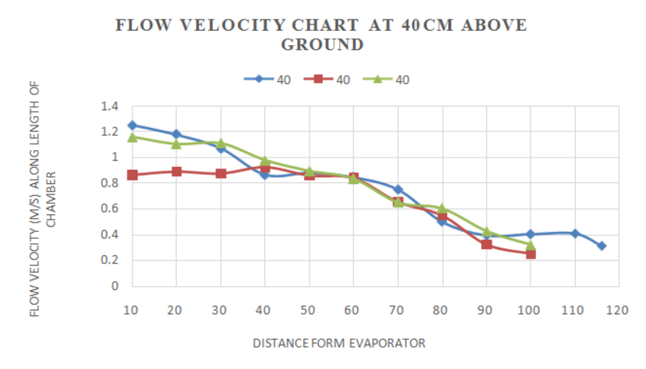
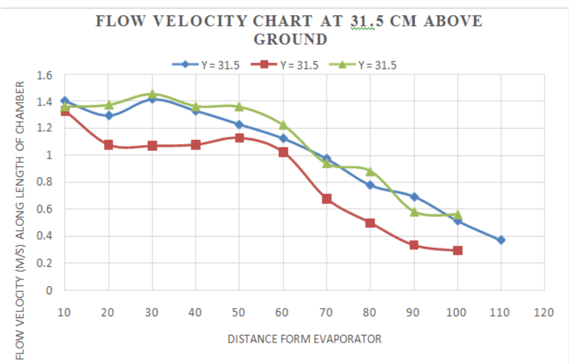


Fig-6.5 Flow velocity chart at 50 cm above ground

Fig-6.6 Flow velocity chart at 40 cm above ground

At mid section of chamber in terms of both height wise and length wise slottedduct is best choice. Fig 6.6 and fig 6.7 both show that slotted duct improve flow in bottom section as compare to duct without slot.



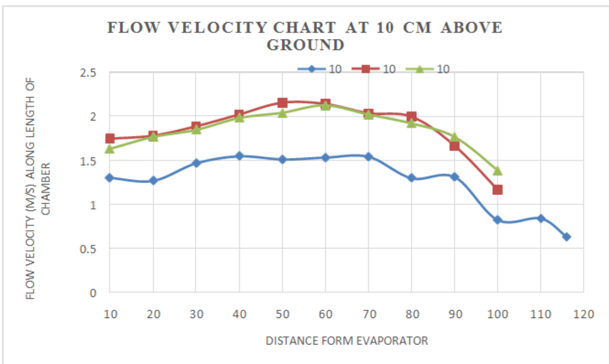


Fig-6.7 Flow velocity chart at 31.5 cm above ground

Fig-6.8 Flow velocity chart at 10 cm above ground

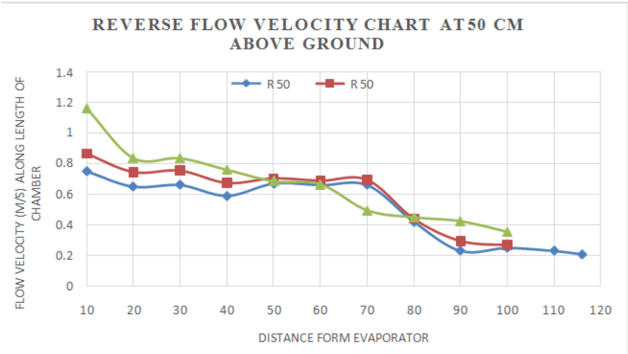


Fig-6.9 Reverse flow velocity chart at 50 cm above ground

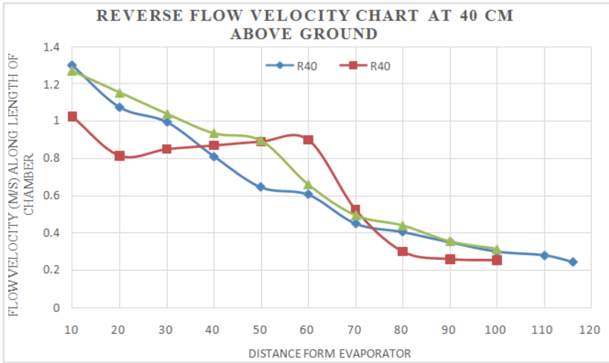


Fig-6.10 Reverse flow velocity chart at 40 cm above ground

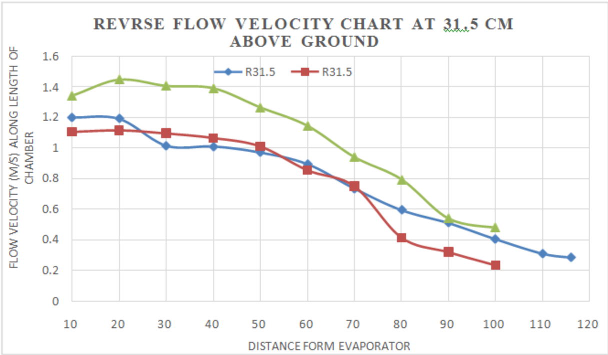


Fig-6.11 Reverse flow velocity chart at 31.5 cm above ground

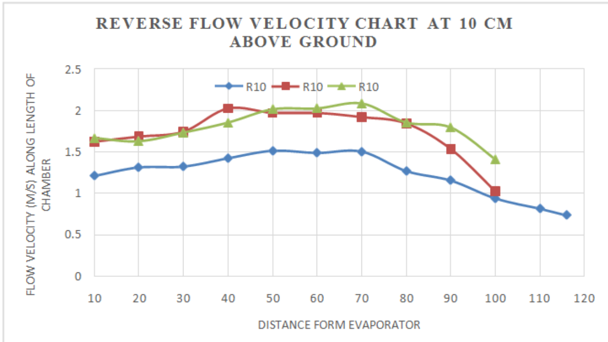


Fig-6.12 Reverse flow velocity chart at 10 cm above ground

Fig 6.9, 6.10, 6.11, 6.12 reconfirm that slotted duct improve the circulation and shift the turbulence zone around mid section a little ahead of this chamber as a result better flow distribution is setup.

7.1 CONCLUSION AND FUTURE SCOPE

CONCLUSION: From the present work results for the airflow and temperature distribution in a cold store, different conclusions have been pointed out:

From the analysis of the variation of the air velocity at the middle and bottom of the cold store, it was found that the variation is less than the top level of cold store because the evaporator was placed at the top level of cold store.

The four fans operate in normal conditions and therefore, the flow pattern is symmetrical inside the cold store.

At 86 cm above ground air circulation in chamber at for this part from the evaporator is better if induced duct are used fig 6.1 shows at 100cm away from the evaporator velocity of air flow is around 1.5m/s with duct and 0.5 m/s without duct condition it shows that proper air distribution happen if duct is used.

FUTURE SCOPE: Future scope of air circulation analysis of cold storage: in India is a growing food industry for improving the product quality broadly used cold storage. Due to large amount of storage of food and beverage the air circulation analysis is required in cold storage for large amount of product storage due to large need of cold storage

REFERENCES

[1]. **Son H. Ho, Luis Rosario,Muhammad M. Rahaman*** Numerical simulation of temperature and velocity in refrigerated warehouse IJR33(2010)1015-1025 DOME University of South Florida,4202 E.Fowler Avenue,ENB 118,Tampa,FL33620,USA

[2]. **Seyed Majid Sajadiye*, Hojjat Ahmadi, Maryam Zolfaghari, Seyed Saeid Mohtasebi, Younes Mostofi, and Amir Raja**--A Multi-Scale Three-Dimensional CFD Model of a Full Loaded Cool Storage.doi 10.1515/ijfe- 2012-0015 International Journal of Food Engineering 2013

[3]. **M.K. Chourasia and T.K. Goswami** -CFD simulation of effects of operatingparameters and product on heat transfer and moisture loss in thestack of bagged potatoes-Journal of Food Engineering 80 (2007) 947–960

[4]. **M.L.Hoang *,Pvervoven, j. De Baerdemaeker ,B.M.Nicolai, "** Analysis of the air flow in a cold store by means of CFD" International journal of refrigeration23 (2000)127-140

[5]. **Environs Ugwu, Hyginus Ubabuike*, Ogbonnaya, Ezenwa Alfred,** Design and Adaptation of a Commercial Cold Storage Room for Umudike Community ,IOSR Journal of Engineering May. 2012, Vol. 2(5) pp: 1234- 1250

[6]. **M.K. Chourasia; T.K. Goswami,** Simulation of Effect of Stack Dimensions andStacking Arrangement on Cooldown Characteristics of Potato in a Cold Store by Computational Fluid Dynamics. Bios stems Engineering (2007) 96 (4), 503–515

[7]. **M.K. Chourasia,1, T.K. Goswami,***"Steady state CFD modeling of airflow, heat transfer and moisture loss in a commercial potato cold store"***,**International Journal of Refrigeration 30 (2007) pp.672-689.

[8]. **M.K. Chourasia a, T.K. Goswami,***"Three dimensional modeling on airflow, heat and mass transfer in partially impermeable enclosure containing agricultural produce during natural convective Cooling*"**,**Energy Conversion and management 48 (2007) 2136-2148.

[9]. **S.Duret, H.M.Hoang and D.Flick,O.Laguerre***"Experimental characterization of air flow, heat and mass transfer in a cold room filled with food products* ".IJR 46 (2014)17-25 accepted 12 July 2014 Irstea,UR GPAN,1 rue Pierre-Gilles de Gennes, 92761 Antony, France

[10]. **MitoubkietaTapsoba Jean Moureh and Denis Flick** *"Airflow patterns in anenclosure loaded with slotted pallets".*International journal of refrigeration 29 (2006) pp 899-910 Cemagref, BP.44, 92163 Antony Cedex, France.

[11]. **Margeirsson and Sigurjon***"Numerical modeling of airflow and temperature distribution in a cold store"* ", Ph.D. Thesis, University of Iceland, 2008.

[12]. **H.B. Nahor, M.L. Hoang, P. Verboven**,"*CFD model of the airflow, heat and mass transfer in cool stores", International Journal of Refrigeration*, Vol. 28, Issue 3, pp. 368–380, 2005.

[13]. **Serap Akdemir And Selcuk Arin**,*"Spatial Variabilty of Ambient Temperature, Relative Humidity and Air velocity in a Cold Store",* Journal of Central European Agriculture, vol. 7, No.1, pp. 101-110, 2006.

[14]. **Baired,C.D, and Gaffney,J.J,1976.***A numerical procedure for calculating heat transfer in bulk loads of fruits or vegetables.*ASHRAE Transactions94(1), pp 1434-1454

[15]. **Nicouline, CV, Jacob,P.C., Tory S.** *Computer modeling of commercial refrigerated ware house facilities*" .in proceeding of the 1988 ACEEESummerstudy on energy efficiency in industry,pp.15-27

[16]. **Smale , N.J,Moureh,J., Cortella,G,2006.**"*A review of numerical model of air flow in refrigerated food applications*."International journal ofRefrigeration29(6) pp 911-930

[17]. M.K. Chourasia, T.K.Goswami(2001) Losses of potatoes in cold storage vis-à- vis types, mechanism and influential factors, Journal Food Science Technology 38 (2001) 301-313.

[18]. M.K.Chourasia, T.K.Goswami, K.Chowdhury (1999).Temperature profile during cold storage of bagged potatoes, Effects of geometric and operating parameters. Transactions of the ASAE, 42(5), 1345–1351.

[19]. G.G.Maidment,G.T. Prosser(1998) Investigation into the Viability of CHP in Cold Storage Facilities, in: International Institute of Refrigeration Conference, Refrigerated Transport, Storage and Display Conference, Cambridge, 29 March, 1998.

[20]. M.A. Al-Nim, M. Abu-Qudais, M. Mashaqi(1996).Dynamic behavior of a packed bed energy storage system, Energy Conversion and Management 37 (1) (1996) 23