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FLOW ANALYSIS OF TWO DIFFERENT EVAPORATER ARRANGEMENTS IN A COLD STORAGE USING CFD

Prashant Jaiswal[1], Rohit Soni[2], Ravi Vishwakarma[3]

[1, 2] *Research Scholar, Professor, Shree Institute of Science and Technology,*
RGPV Bhopal, MP, (India)

ABSTRACT

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 using proper cooling system. Many cooling systems are used in cold storages; one of them is Evaporator coil located at the top of one of the wall of cold storage. We have analyzed this cooling system on CFD. Computational fluid dynamics (CFD) uses powerful computer and applied mathematics to model fluid Flow problems. In the recent years CFD has been applied in the food processing industry. Numerical modelling of airflow and temperature distribution in a cold store was performed using the Computational Fluid Dynamics (CFD). The aspects which were investigated include the influence of wind velocity. A mono-scale three-dimensional Computational Fluid Dynamic model was developed for estimating of airflow, heat and mass transfer. A computational Fluid Dynamics model was developed to estimate distribution of temperature and relative humidity.

Keyword: Evaporator, Cold Storage, CFD, Modelling.

I. 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. For many other products conditions other than temperature might be required. 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. In a packed container moisture percentage will not change.

Design of cold storage to be effective and economic is an important criterion in business as ineffective design may lead to financial loss and in some cases may lead to unsafe operation of the system. Beside from the loss of capital due to degradation of quality of the products, there is also power loss and in the country like India, it becomes of greater importance to save as much of power as possible.

The project emphasis has been given on cold storages preserving fruits and vegetables.

- Protective storage, as of foods or fruits, in a refrigerated place.
- The storage of things in an artificially cooled place for preservation.
- Informal a state of temporary suspension to put an idea into cold storage.
- The storage of food, furs, etc., in an artificially cooled place.

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 technique the food also controlled for getting damaged during the storage time or period. The food preservation is the important technique to save the food for future use. It is also work for controlling the taste, colour and their nutritive value.

1.1.2 Principal of Food Preservation

The food preservation is one of the best techniques to preserve the food commodities. And it prevented to the getting ruined and saves for the long period. Also, the food should not be damaged during the food preservation for all achieving to these conditions, certain basic methods were applied, and using the knowledge gained from the some observations of the effects of the natural conditions on different type of foods. 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.

There is the list of the principles of food preservation-

I. ***Removal of micro-organisms or inactivating them:*** - 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 water so that the water are extracted from the vegetables and then these are preserved. By the removing of water from the foods, the microorganism destroyed and then food can save for the long period.

II. ***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.

III. ***Insect's removal, worms and rats:*** - By storing to the food items in dry surroundings and air tight containers the insects, worms or rats are banned from demolished it.

1.2 Cold Storage Types

There are the some prescribed crops that required the pre cooling for pulling down and storage conditions. And for the fresh fruit and vegetables and some other horticulture products, the pre cooling are not needed.

The fresh potato tubers for following purposes:-

I. Early Crops (pre mature)

II. Seed Potatoes

III. Table Potatoes

IV. Process Potatoes

- French Fries
- Chipping

FRESH POTATOES	TEMPERATURE	STORAGE PERIOD	RELATIVE HUMIDITY
For Chipping	7.2-10°C	1 – 8 months	90 – 95%
For French Fries	7.2 - 10°C	1 – 10 months	90 – 95%
Seed Potato	3°C	1 – 10 months	90 – 95%
Early Crop	4 – 10°C	0 – 3 months	95%
Table Potato	4°C	5 – 10 months	90 – 95%

Table:-1-Temperatures, storage period and relative humidity etc-

1.3 Experimental Setup

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 horizontal and directly strikes on the products which generally kept in front of the cooling coil.

Fig.1 Evaporator located on the Top

In this type of arrangement the cooling coil is located either in center or on one side of the wall the cold storage. The cooling coil is kept at a certain height from the floor. The air throw is vertically downward and then strikes

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on the plate connected just below the cooling coil as shown in the picture. After striking on the plate air passes through stacks.

Fig.2 Evaporator located on the Bottom

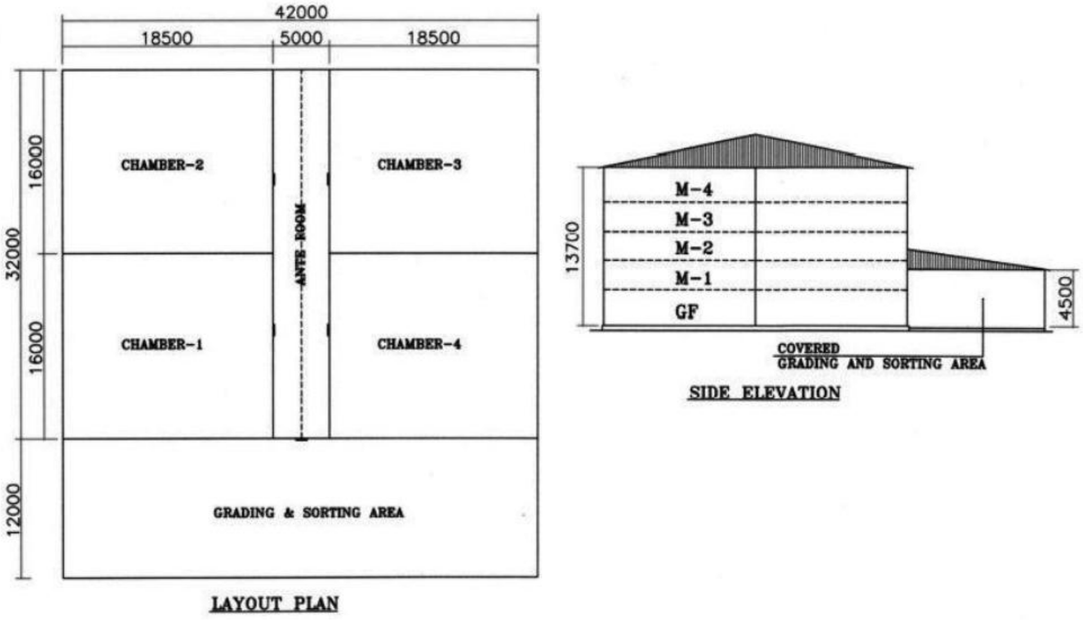

Fig.3 Option-A Layout pre-cooling not required

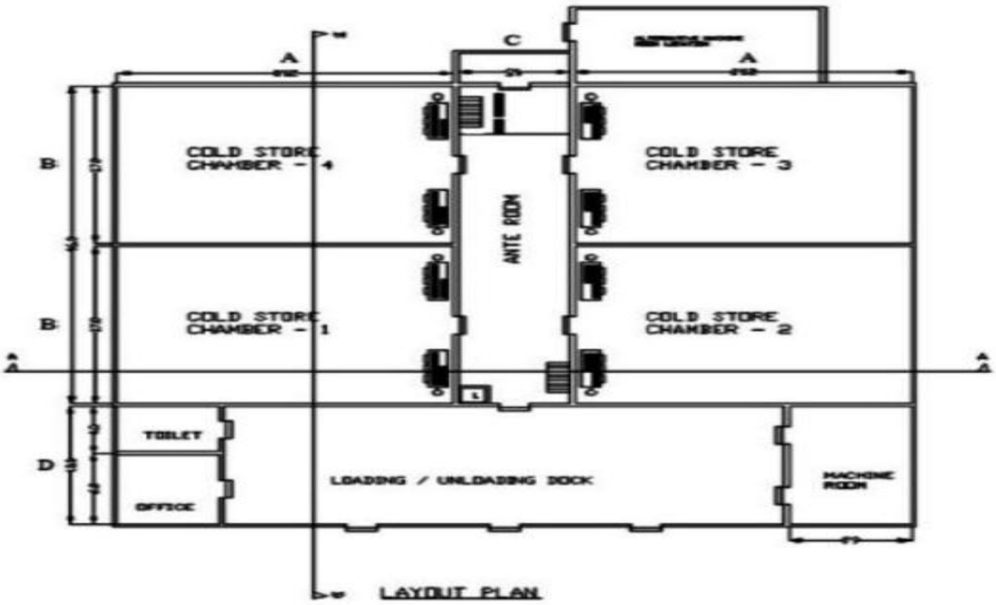

Fig.4 Option-b Layout pre-cooling not required

II. PROBLEM FORMULATION ANALYSIS

Cold storage or refrigerated warehouses are facilitated where fresh foodstuffs are handled and stores under controlled temperatures for maintaining the quality of the foodstuffs. Preservation of food can occur under frozen or chilled condition of the temperatures. For some products other conditions are required other than temperature. A cold storage is an area where the different type of commodities are stored such as vegetables, fruits, medicines and meat etc. for protecting to them from getting spoiled and to make longer their preservation period. This task is completed by their storing the products at their preserving temperature and humidity etc. The preservation temperature for storing items 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 the main property of the air that is influenced by the humidity in the surrounding air, and secondary, by the temperature. The moisture contain will not be changed in a sealed container. Effective and economic design of cold storage and their cooling components such as evaporator, compressor, fan etc are an important requisite for the business as ineffective design of the cold storage may lead to financial loss and in some cases may lead to unsafe operations of the system. The project emphasis has been given on cold storages preserving fruits and vegetables.

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Estimated Motor rating	Configured in kW, Input AC power supply, RPM, and type of insulation.
The capacity of the cooling system at critical operating conditions.	Configured in kW
Type	For ammonia refrigerant, the reciprocating and multi cylinder compressors.
Quantity	In pre-cooling, one compressor is used in each chamber.

Table:-2- Refrigeration Compressors & Motors

Unit casing	With removable G.S sheet panels & inspection windows etc
Other provisions	Air inlet grilles, Water spray arrangement and eliminators for suitable design
Suggested Standard	ARI Std. 490
Estimation of Heat rejection capacity	Configured in KW
Coil section	Hot dip galvanized M.S. pipes. And aluminium tube and aluminium fins.
Water sump tank	S.S.304 or M.S. Epoxy coated with necessary connections
Fan section	With 2 / 3 Axial Flow Fans with Cast Aluminium OR S.S impellers, complete with the TEFC Squire cage motors and Class F insulation & IP-55 protection

Table:-3- Evaporative Condenser for Ammonia cooling system

III. METHODOLOGY

After studying the basic steps in CFD to be followed to analyze the flow inside a chamber. Now we can start the analysis of the cold storage with actual data. Following three steps are required to run the simulation.

1. CAD Modeling: 2. Meshing: 3. Type of Solver:

4. Physical model 5. Material Property. 6. Boundary Condition.

Three-dimensional Model Description

A 3-dimensional model of a room in the shape of a rectangular prism is developed for Type 1 & Type 2 evaporator arrangements. The physical dimensions set to be 14 m length, 7 m width, and 8 m height. The model geometry will be created using pre-processor ANSYS DESIGN MODELER. On the basis of this data, two geometry and mesh as per project is discussed.

- A cool storage is modeled in CFD with the dimensions of 14m length, 7m width, and 8m height.
- The cooling unit was located at the top centre of the storage and consisted axial fans for air circulation and a finned tube heat exchanger.
- Apples were packed in the containers with a capacity of 436 kg/container.
- The pallets or container's wall were made of high-density polyethylene (HDPE) and modeled as conducting walls. Containers of apples were modeled as a porous media.
- The enclosure was loaded with 600 containers with in-line array with the dimensions of 1.2 m length, 1m width, and 0.75m height.
- Four containers stacked with a small vertical gap of 0.06 m and there were four stacks along Z-direction with 0.06 m horizontal gap.
- Six columns of containers positioned alongside X-direction (width) with 0.1 m horizontal gap in between. All the gaps between the container and room's side walls were 0.25 m.
- The distance between pallets and roof, back, and front walls of room considered as 0.5, 0.1, and 1m, respectively.
- These distances were considered according to guidelines of settings in a refrigerated warehouse (Vipul cold chain & food processing pvt. limited.- Raisen(M.P.).

Case 1:-The cooling unit is located at the top centre of the storage and consisted axial fans for air circulation and a finned tube heat exchanger at a height of 6.5 m from bottom wall or floor and 0.1 m from back wall. The inlet was given to the front of the fan and the outlet was given to the bottom of the heat exchanger as shown in figure further.

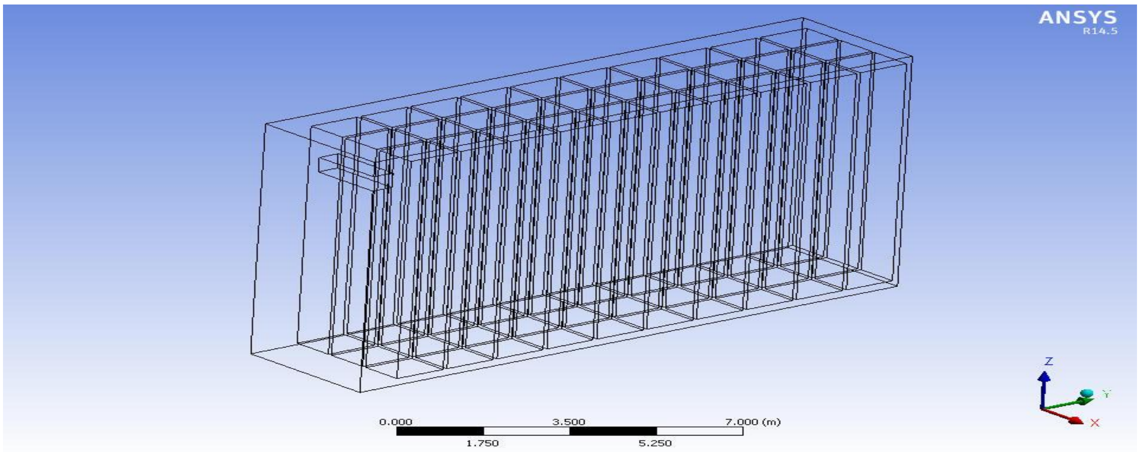

Fig.5-3D model of the case 1 arrangement

Case 2:-The cooling unit with same capacity is located at a height of 4 ft from the floor and 0.1 m from back wall and consisted axial fans for air circulation and a finned tube heat exchanger. The inlet was given at the bottom of the fan and the outlet was given on the top of the heat exchanger as shown in figure below.

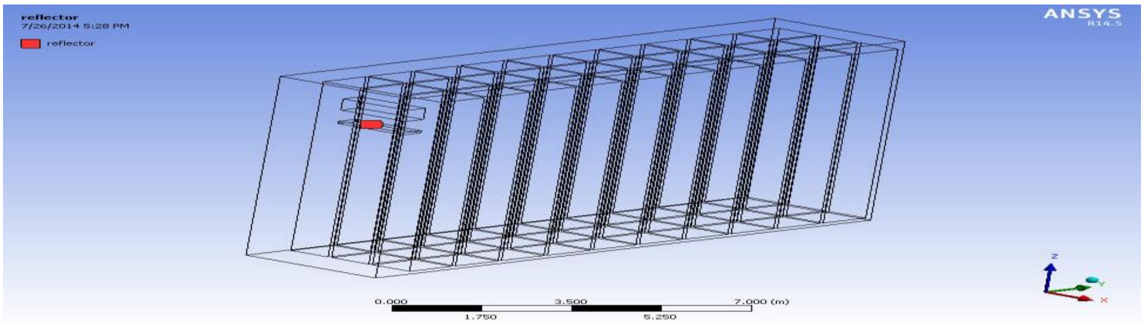

Fig.6-3D model of the case iind arrangement

IV.RESULT AND DISCUSSION

The predicted airflow velocity, pressure and temperature profiles during forced-air cooling of produce in different airflow patterns in a cool storage which were considered in this research work. The predicted temperature profiles were compared with experimental data for model validation.

The data collected using ANSYS FLUENT 14.5 included the temperature data, pressure data and airflow velocity at the monitor point and the temperature distribution , pressure distribution and airflow velocity at all node points in the model room.

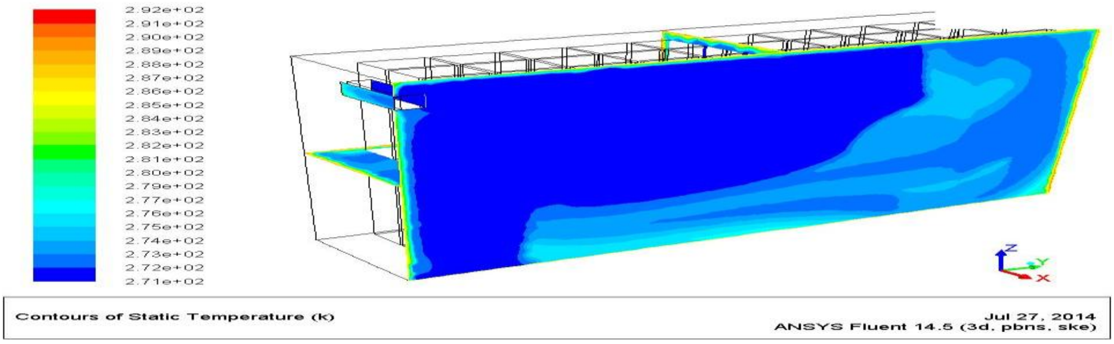

Fig.7- Temperature distribution of case 1 arrangement i.e. evaporator located at the Top.

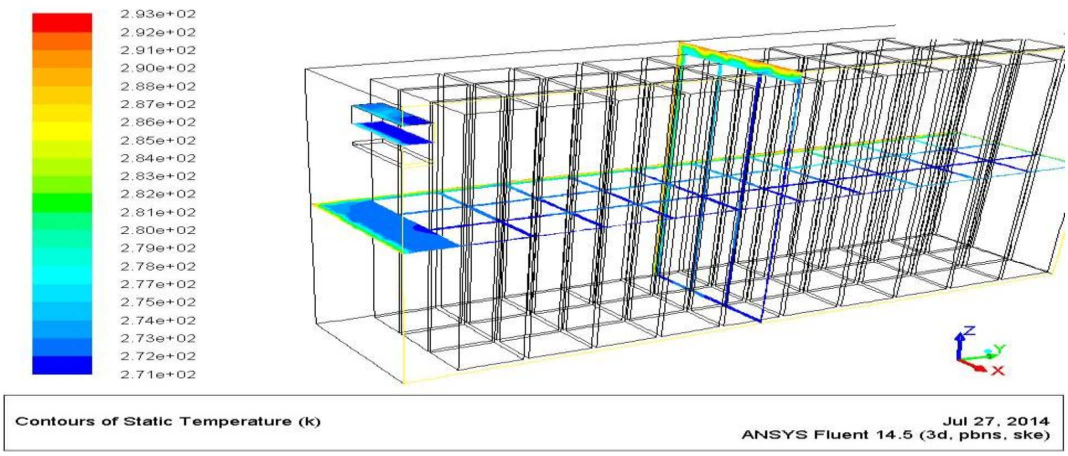

Fig.8- Temperature distribution of case 1 evaporator Arrangement at the middle section of the cold chamber

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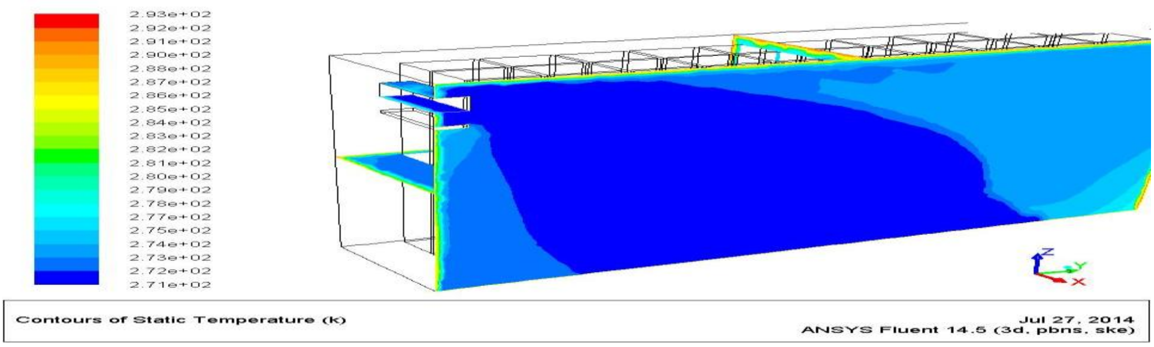

Fig.9- Temperature distribution of case 1 evaporator Arrangement at the Bottom section of the cold chamber

V. CONCLUSION

- A three-dimensional CFD simulation was developed to compare airflow and heat transfer models in different airflow patterns in a fully loaded cool storage Dynamic behavior of the fan, and heat exchanger were considered in the model. In this project work two different evaporator arrangements compared and analyzed.
- The calculation domains were discredited with a tetrahedral meshing for the entire domain was selected. Using ANSYS FLUENT 14.5 software a finite volume code was used for the numerical implementation of the models.
- Standard k - ε turbulence model was enabled based on the previous studies (Nahor, et al., 2008).
- The overall accuracy of the model was selected as second order upwind. The pressure–velocity coupling was ensured using SIMPLE algorithm; the model was solved for velocity field. Initial conditions i.e. inlet air temperature, room temperature, cooling capacity were kept same for all the three cases.

After getting all the results based on CFD and analyzing them now we can conclude that the **Case 1** i.e. evaporator located at the top center and air flowing horizontally is a better arrangement than **Case 2** type i.e. evaporator with air flowing vertically downward on the basis of following points.

1) In case 2 the suction temperature is lower i.e. 271.434 K which indicates that the air coming out from the evaporator at 271.15 K is being sucked by the evaporator without circulating properly inside the chamber. The cold air is not coming properly in contact with products hence it is not exchanging heat with the products and hence its temperature is not increasing at the suction point.

Whereas in case 1 the suction temperature is higher i.e. 273.271 K which indicates that air is reaching to the evaporator after circulating properly throughout the chamber.

2) The temperature of air while travelling from top to bottom (i.e. along the height) of the chamber is also less i.e. 287.35 K in case 1 while the temperature of air in case 2 is 291.064 K. this indicates that there is more heat exchange taking place between cold air and the products in case 1 as compared to case 2.

3) The temperature of air while travelling along length of the chamber is again less in case 1 as compared to case 2. The end temperatures are 272.87 K in case 1 and 274.165 K. this is again an indication of proper heat exchange between cold air and products.

4) All the readings regarding pressure distribution shows that pressure drop is more in case 1 as compared to case 2. This is may be due to the fact that in case 1 the air coming out from the evaporator is circulating properly throughout the chamber therefore the pressure drop is more whereas in case 2 the air coming out from the evaporator is not reaching to all the corners of the chamber hence the pressure drop is less compared to case 1.

5) It is seen from table no. 7.6 that in case 1 the velocity of cooling air is nearly 0.242491 m/s at a distance of about 13m along the length from the evaporator whereas in case 2 the velocity of cooling air at the same distance seems nearly 0.105537 m/s which indicates that in case 1 the cooling air is reaching to the farthest point of the chamber whereas in case 2 it is not reaching properly to the farthest point. Hence in this (case 2) arrangement cooling of the product will be less as compared to case 1 because air circulation velocities is low in case 2.

Thus considering the above points we can conclude that case 1 evaporator arrangement is better than the case 2 evaporator arrangement.

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