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Effect of Air Velocity on Temperature in Experimental Cold Store

Serap Akdemir and Selcuk Arin
Air Conditioning and Refrigeration Program, Tekirdag Vocational School,
Trakya University, 59030 Tekirdag, Turkey

Abstract: In this research, spatial distribution of air velocity was determined at ceiling, medium and floor for an experimental cold store. Mapping software used to create spatial distribution maps and descriptive statistics such as mean, maximum, minimum, standard deviation and coefficient of variation were also used to evaluate data. Determination of the spatial distribution of the storage factors such as air velocity for a cold storage is useful to apply best management techniques for storage of products.

Key words: Cold store, air velocity, temperature

INTRODUCTION

Temperature variation is minimized with adequate air circulation. Most stores are designed to provide airflow of 0.3 $m^3 min^{-1} ton^{-1}$ of product, based on the maximum amount of product that can be stored in the room. This is needed to cool product to storage temperature and also may be needed if the product has a high respiration rate. This high airflow rate can cause excessive weight loss from products and fans are a significant source of heat, so the system should be designed to reduce airflow to 0.06 to 0.12 $m^3 min^{-1} ton^{-1}$ of airflow. Motor speed control systems, such as variable rate-frequency control controllers for alternating current motors, are used to control fan speed at the lowest possible speed that will prevent unacceptably warm product in the storage[1].

Spatial distribution of the air velocity is important to protect agricultural product in a cold store. Aim of this study was to show spatial variability of the air velocity and ambient temperature in cold store. In this research an experimental cold store was used for this purpose. Cold air velocity and ambient temperature of different places in the experimental cold store were measured. Data were determined at ceiling, medium and floor level in the cold store. The results were evaluated by using descriptive statistics and data were also used to produce spatial distribution maps of air velocity and ambient temperature.

Air flow inside a cold store is investigated using computational fluid dynamics. The air flow model is based on the steady state incompressible, Reynolds-averaged Navier±Stokes equations. The turbulence is taken into account using a k¡ model. The standard as well as the renormalisation-group (RNG) version of the k¡ model is investigated. The forced-circulation air cooler unit is modelled with an appropriate body force and resistance, corresponding to the characteristics of the fan and the tube-bank evaporator[2].

The spatiotemporal temperature distribution in the imperfectly mixed airspace around plants has a considerable effect on the physiological plant processes. In a fully instrumented climate chamber, eight identification experiments were carried out to model the spatiodynamic temperature response around plants to variations in the supply air temperature and from the experimental data, a minimally parameterized, linear, discrete-time Transfer Function Matrix (TFM) model was identified, capturing the dominant model behavior of the dynamic process[3].

Chloro-Floro-Carbons (CFC) have been used approximately for 60 years because of its good cooling specifications. Poisonous value of CFC is low, flame resistance is high and anticorrosive specifications. It is used in many fields[4]. The composition of the R404A refrigerant as a percentage of weight is 44% HFC-125, 52% HFC 143a and 4% HFC 134a. R404A refrigerant classified as a high-pressure refrigerant can be used in commercial applications of medium and low temperature cooling systems instead of R502. Cooling per of the R404A refrigerant is too close to that of the R502. R404A can work at low compressor outlet temperature and this specification extends compressor life[5].

Corresponding Author: Serap Akdemir, Air Conditioning and Refrigeration Program, Tekirdag Vocational School, Trakya University, 59030 Tekirdag, Turkey
Tel: +90 282 2931438 (Ext: 168) Fax: +90 282 2931454 E-mail: serapakdemir@yahoo.com

MATERIALS AND METHODS

Cold store: Dimensions of cold store were (length×width×height) 4.52x1.90x2.22 m. The volume of the cold store was 19.07 m^3 (Fig. 1).

The cold store was made of reinforced concrete and isolated by using foam glass[4,5]. Foam glasses were placed on the walls using an adhesive material produced as variety of asphalt. Then a coverage material formed of steel rush was placed on the wall surface to cover the foam glass. The steel rush material was covered with plaster. Finally ceramics were used to cover the wall. Foam glass was put on the ceiling of the cold store and then both surfaces were covered with cement. The floor of the cold store was covered with foam glass and ceramics.

A compressor was located in the outside of the cold store. A condenser, a condenser ventilator, a fluid hopper and a drier were gathered as a group inside the compressor chassis. An evaporator was put on the ceiling of the cold storage with steel screws. Thermostatic expansion valve was fitted in the evaporator inlet and on the high-pressure side of the compressor. A control panel, which includes a thermometer-thermostat, a manometer and a humidity gauge, was placed on the front wall of the cold store. The refrigerant was R404A.

The compressor was a hermetic type and its capacity was 10460 kJ h^{-1}. An electrical motor of 1.49 kW powered the compressor. The condenser was cooled by air. It consists of copper pipes, aluminium plates and an axial type ventilator. Its capacity was 12540 kJ h^{-1}.

The evaporator was made of copper pipes and outside surface covered with aluminium plates. An axial ventilator was located on the back of the evaporator to distribute the cooled air into the cold store. An electrical heater was used to defrost. The capacity of evaporator was 10460 kJ h^{-1}. The fan speed was 1375 rpm. The ventilator has four vanes.

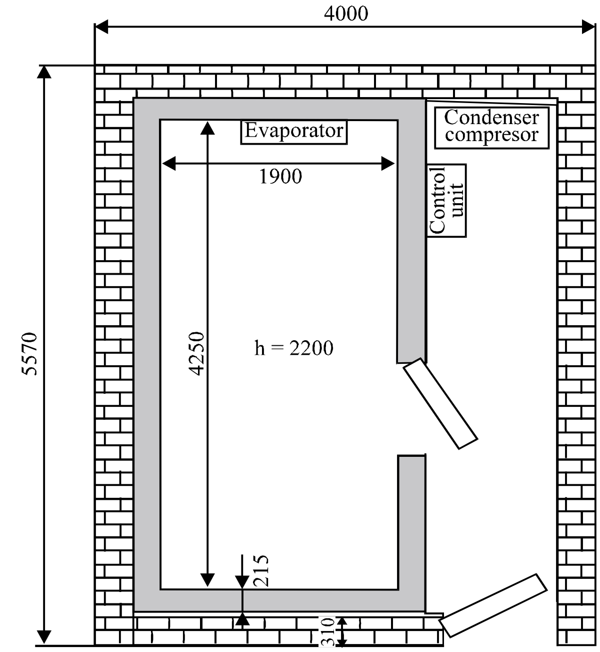

Fig. 1: Schematic view of the experimental cold store (dimensions in mm)

Sensors: Measurement limits of the temperature sensors were between-20 and +100°C. Accuracy of the temperature sensors was ±1%.

Velocity measurement device was vane type. Measurement limits of the air velocity sensors ranged between 0 and 20 m s^{-1}. Accuracy of this sensor was ±1%. Cold store was empty during the experiments.

Storage temperature of the cold store was set as 3°C. Cooling system was worked. A special framework was made of iron to replace sensors on it. Four temperature sensors were used to determine ambient temperature. A vane type air velocity measurement device was used in this research.

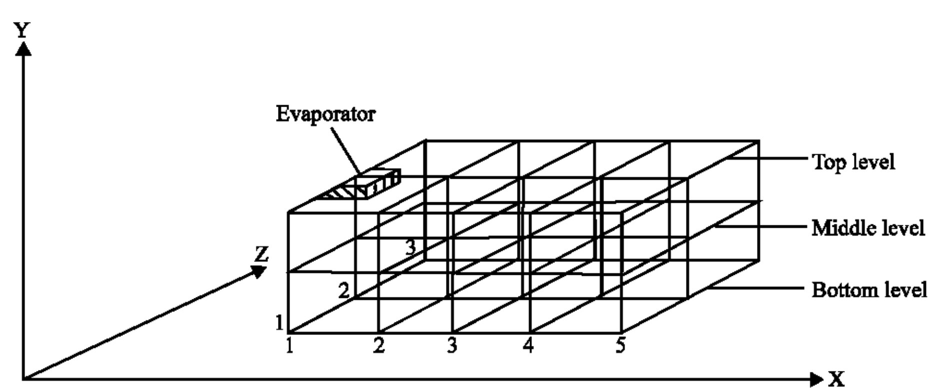

Fig. 2: Measurement points in cold store

First of all, cold air velocities were measured for determined point in the cold store. Then the ambient temperatures of the cold store for a determined storage temperature (in this research 3°C) were measured for the same points. Measurements were realized in top, medium and bottom level of the cold store (Fig. 2).

Mean, maximum, minimum, standard deviation and coefficient of variation were calculated for these data[6]. The results were used to produce spatial distribution maps of air velocity. Surfer Graphic Program was used to create maps. Measured data arranged in a file to use by Surfer Program. Grid data files were created by using original data files. Then these grid data files were used to create contour maps by using Surfer Graphic Programme[7].

RESULTS AND DISCUSSION

According to the results big differences were determined in the cold store between measurement levels. For example mean of air velocity was changed between 0.00 and 2.93 m s^{-1}. General CV was 161.69% (Table 1).

In addition, there were also differences for the same levels of the cold store. Coefficient of variation was 136.76 and 124.17% for the top and bottom level, respectively. Changing of the air velocity was small for the medium level of the cold store but velocities of the cold air was also small.

Distribution of the air velocity in the experimental cold store is shown in Fig. 3. The evaporator was mounted on the ceiling of the cold store. In front of the evaporator, velocity of the air was higher than that left and right areas of the evaporator for the top level in the cold store.

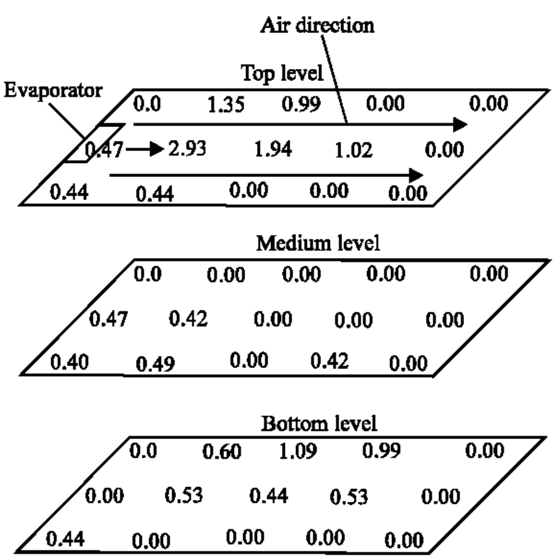

Fig. 3: Air velocities in the cold store

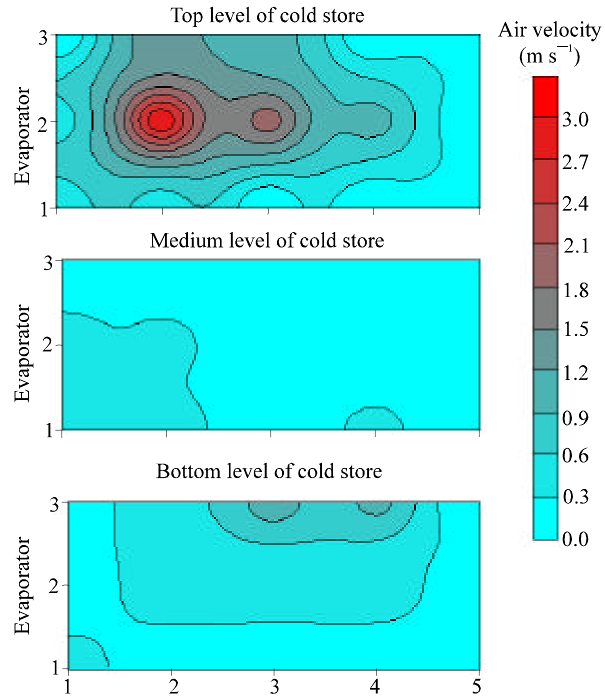

Fig. 4: Distribution of air velocity in the experimental cold store

Table 1: Descriptive statistics of air velocity distribution

	Level of cold store			
Air velocity (m s^{-1})	Top	Middle	Bottom	General
Number	15.00	15.00	15.00	45.00
Mean	0.64	1.08	0.31	0.36
Maximum	2.93	0.49	1.08	2.93
Minimum	0.00	0.00	0.00	0.00
Standard deviation	0.87	0.22	0.38	0.59
Coefficient of variation (%)	136.76	20.06	124.17	161.69

Table 2: Descriptive statistics for ambient temperature at 3°C storage temperature

	Level of cold store			
Temperature (°C)	Top	Middle	Bottom	General
Number	15.00	15.00	15.00	45.00
Mean	4.51	5.41	4.83	4.70
Maximum	5.30	5.50	5.70	5.70
Minimum	3.60	3.70	3.50	3.50
Standard deviation	0.48	0.51	0.59	0.54
Coefficient of variation (%)	10.66	9.45	12.26	11.42

Velocity was decreased in the mid level of the cold store. There is no big difference between middle and bottom level of the cold store. The results of the air velocity were not good for these levels because of the evaporator. These explanations can also be seen on the spatial distribution maps (Fig. 4).

Variation of the ambient temperature of the cold store at 3°C changed between 3.5 and 5.7°C. Coefficient of

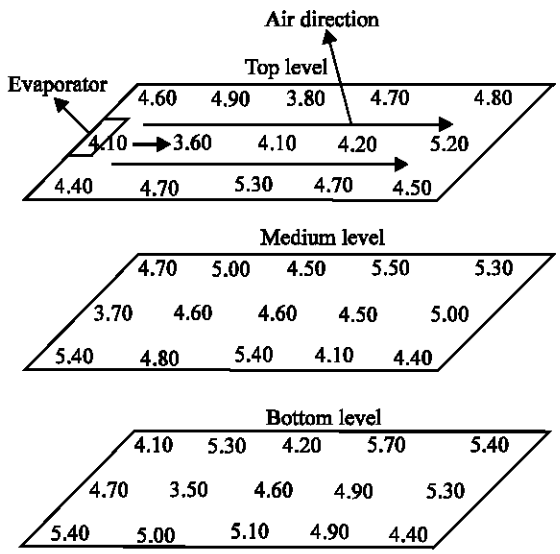

Fig. 5: Ambient temperature distribution in the experimental cold store

variations of top, middle and bottom level at the cold store were 10.66, 9.45 and 12.26%, respectively (Table 2). According to the results general mean of the storage temperature set as 3°C was 4.7°C. Coefficient of variation for all data was 11.42%.

Smallest temperature in this experiment was measured around the evaporator. Temperatures of the other areas were higher than these values. Air circulation produced by evaporator was caused for these results (Fig. 5).

When investigated spatial distribution of the ambient temperature;

- on the top level of the cold store, temperature is close to set value of the cooling store,
- temperature of close area to the evaporator for the middle and bottom level in the cold store was good than other area (Fig. 6).

Reason of bad spatial distribution of air velocity is evaporator fan. Evaporator fan is not enough to circulate air inside cold store and to create homogenize air distribution. Evaporator was selected for this experimental cold store according to the calculations. Additional fan or fans may be used to improve distribution of the air velocity for this cold store.

Bad air distribution affects spatial distribution of the ambient temperature. Ambient temperature differences may be arranged by good air distribution. There are some cheap solutions such as using additional fans and/or changing evaporator's fan to increase air velocity in cold stores.

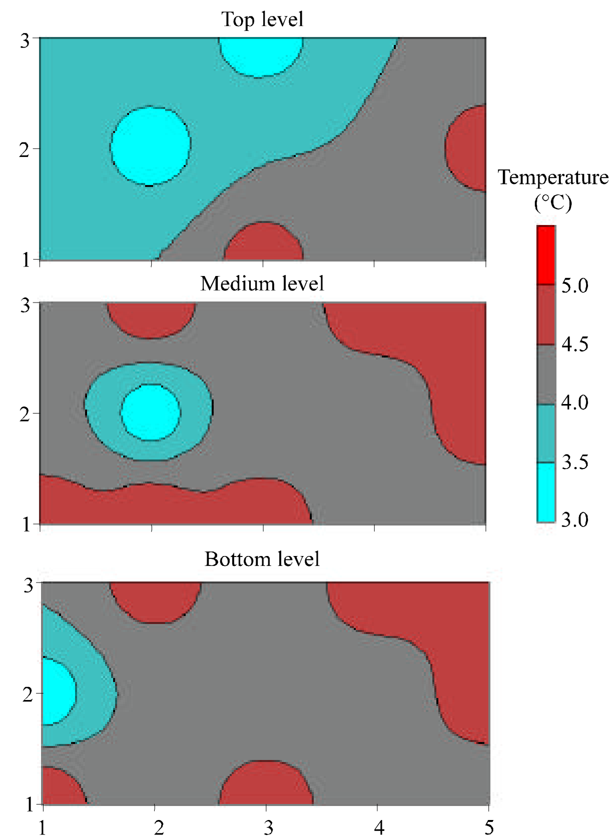

Fig. 6: Spatial distribution of temperature for 3°C storage temperature

Mapping software can also be used to show spatial distribution of the storage factors such as air velocity for a cold storage to apply best management techniques. Bad distribution area for air velocity can be determined by using these maps. If it is required, ventilation of the air can be directed to the bad distribution area or added new ventilation units to correct bad distributions of these factors in a cold store.

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