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DESIGNING OF A VARIABLE VOLUME COLD STORE

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ABSTRACT

Cold stores do not work for all time as full loaded during storage period. There is always empty space when cold store is not fully loaded. Unnecessary energy is consumed because this empty volume must be cooled even there isn't any stored agricultural product. In this study a system was developed to adjust cold store volume according to the amount of stored agricultural product. Therefore, effective volume of the cold store where agricultural product stored will only be cooled and energy saving will be established. In addition, better cold air distribution will be established in the cold store and the quality of product will also be better preserved. Developed system is a moving wall-door system located inside of the cold store. It can be moved automatically. Sliding-wall door system can be moved by an electrical engine on a rail located at side walls. Leakage of cold air is prevented by a silicone seal balloon. The silicone seal balloon is located all-around of the sliding wall-door. The sliding wall change volume of cold store due to amount of stored product. Sliding wall-door system is a new approach for manufacturing of cold storage. This system will not be used only for new cold stores, but also can be used for old cold stores. Energy saving is expected by using developed system in cold stores. Submission of Petit patent for this developed system was approved by Turkish Patent Institute.

Key words: *cold store, energy saving, variable volume, sliding wall-door.*

INTRODUCTION

The main criteria for successful product storage are temperature and humidity, air movement within store, packaging and stacking in storage, as well as pre-storage applications (Eris, 2001). Cold storages are special structures designed for storing various agricultural products. They are manufactured in various types. The most important types are the large cold storages with commercial purpose. Products in cold storages are unloaded depending on market conditions. The cooling system refrigerates the same storage volume regardless of whether the store is full at 80, 50 or 30% (Figure 1). It is unnecessary to cool the empty volume without products. Cooling of empty volumes leads to energy waste. As less agricultural products are stored, the respiration heat spread by products will decrease depending on product amount.

During the establishment phase of the storage, pre-storage measures and in-store special applications enable proper calculation of cooling load and isolation, prevention of unnecessary energy consumption and reduction of product deterioration (Terzioglu, 1990). Certain tests were conducted by Patel and Patel (2012) to reduce energy consumption in cold storages, using different isolation materials, 3 different wall thicknesses and areas in consideration of compressor control parameters. Latest developments in cooling systems, electronic control systems are now used for energy saving through control of entire system instead of command on each individual device (Anonymous, 2009).

The objective of this study is to develop a sliding door system that enables reduction of cold storage volume for various loading conditions. In addition; study seeks developing a system that can be used in large commercial storages and containers.

MATERIALS AND METHODS

Cold storage with varying volume: The size of cold storage is 2.5 x 5.0 x 2.5 m (width x length x height) and volume will be 37.5 m^3.All walls and floors of cold store are made of prefabricated sandwich panels with polyurethane filling. Technical specifications of cooling system are given in Table 1.

Table 1. Technical specifications of cooling system

Evaporator/Condenser temperature :	-5/+40°C
C.O.P :	2,79
Cold Store temperature	+2°C
Capacity	4.876 Watt
Nominal Compressor Power	1,75 kW
Refrigeration	R 404A
Supply line	380 V - 50 Hz

Cooling system consists of an internal unit that transmits the cold air from rear wall to frontwards via evaporator, a condenser that condenses cold fluid circulating within the system, and an external unit that compresses the cooler to the system.

Moving door-wall system renders the cold store variable-volume for adjusting environmental conditions due to load amount. Various load rates of variable volume storage and the volumes of chests have been given in Figure 1.

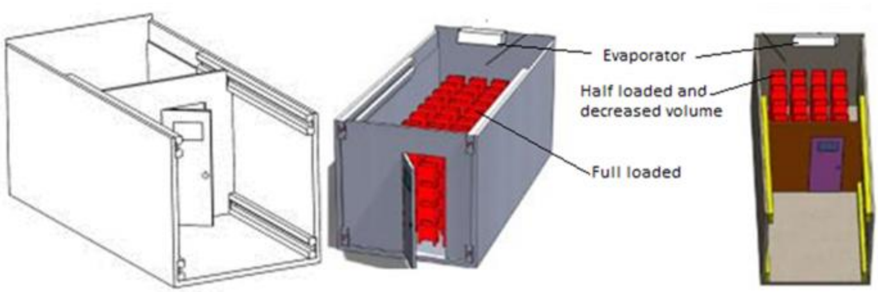


Figure 1. Moving door wall system and various load rates of variable volume storage

Size of the moving door-wall are 80 x 2500 x 2500 mm and made of the same material as cold room walls. The system is moved on the rail, placed behind the front door, by a mechanism to be operated by user, or via electric motor.
The door-wall mechanism reduced the cold storage volume depending on loading rate. The mechanism can be used in two different ways so as to ensure requested reduction.

Manual Controlled Moving Door Wall System:

Linear bearing (rail-slide) and Tube ball car :3500 mm long 2 linear bearings (rail-slides) TSX45E-G2-3500 mm and 4 tube ball cars INA RWU45EH-G2-V0 of -45 are used as support between bearings. Additionally, a metal profile is used in order to connect the bearings on the underside.
Support shaft and moving bearing set: In order to prevent overturn and twist of the 2.5 m high wall, 2 support shafts of 3500 mm length, and 4 moving bearing sets IN 40 KGBO40-PP-AS, which move on these shafts (IN 40 TSWWA40-3500 mm), are installed on the left and right side of the movable wall (Figure 2). Therefore the door-wall system can be moved back and forth in a parallel and smooth manner.

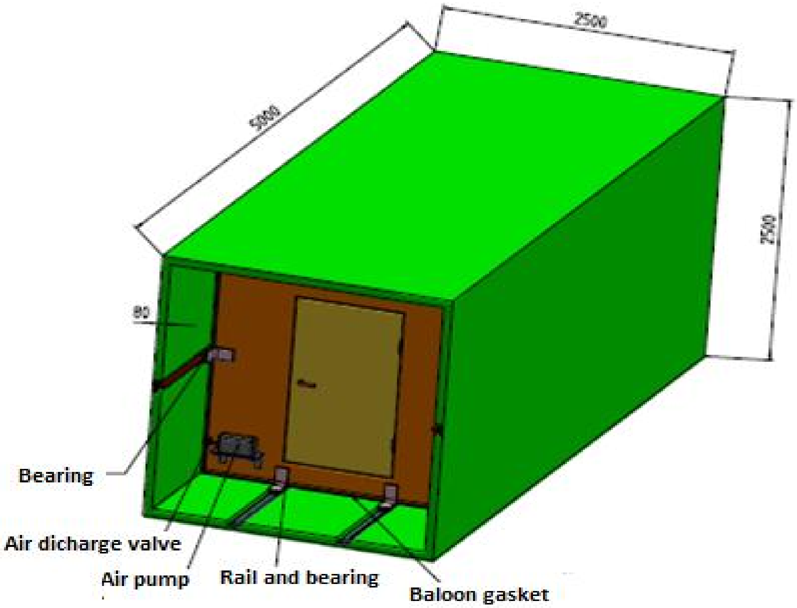
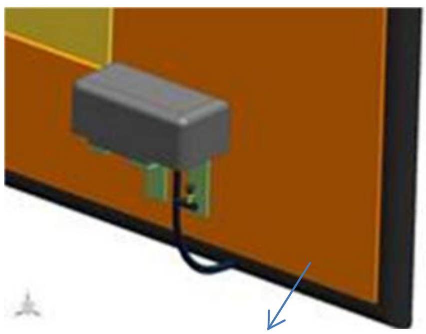


Figure 2. Moving wall elements of cold store with rail

Air relief valve:Itensures that the air within balloon gasket is released for moving door-wall mechanism (Figure 3a).
Balloon gasket: The balloon gasket, essentially made of silicone, is encircling the entire moving wall for sealing (Figure 3b). Part of the gasket, which run into moving wall corners, are welded to establish perpendicular corner. The gasket will be formed as a rectangular closed hose. The gasket has a wall thickness of 3 mm, made of a transparent material with a density of 2.33 g/cm3; once inflated, it attains 80 mm in diameter. A sensitive sealing sponge of 3-5 mm is adhered to the gasket parts that run into surrounding walls in order to prevent possible slight leakages.

(a)



(b)

Figure 3a. Air relief valve Figure 3b. Balloon gasket

Rubber gaskets: The thickness of rubber gaskets used in centring and bearing sections is 10-15 mm. (Figure 3-b). Hardness of rubber sealing elements will be chosen as 20-25 Shore. The rubber sealing elements will be connected to moving bearings, cars on bottom linear bearings and side centring bearings. These materials, which serve as special gasket, are connected on 4 tube ball cars and moving bearing sets.As is seen on Figure 3b, the gasket, placed in its specific housing on four sides of the wall, will be inflated by an air pressure of 10-15 bars. As the moving wall is drawn to the required spot, the gasket will be deflated; thus, the moving wall will be separated from exterior walls. Consequently, the wall can be easily pushed to desired point without significant friction or resistance. Once the wall reaches the prescribed point, electric air pump will inflate the balloon gasket via related valve; thus, the gasket will adhere to side walls and ensure both sealing and fixation of the wall.

Automatic Controlled Moving Door Wall System:

Electric air pump: Electric air pump is used to inflate the balloon gasket by an air pressure of 10-15 bars to enlarge its diameter up to 80 mm (Figure 4).

Electric Engine and Reductor:For automatic movement of moving wall via electric engine, a standard engine of 2.2 kW and 1400 rpm, as well as a reductor for revolution adjustment, are installed on the system. The reductor output speed will be 20 rpm .

Two wheel connected via Shaft:The 2 wheels connected via shaft will be attached by means of gear and chain system on the electric motor, which enables automatic positioning of the system. The wheels have diameter of Ø 230 mm, and are covered with polyurethane. The shaft will be supported with cast bearings.

Gear and chain system: The system will employ double-row chain. The shaft will be supported by cast bearings.

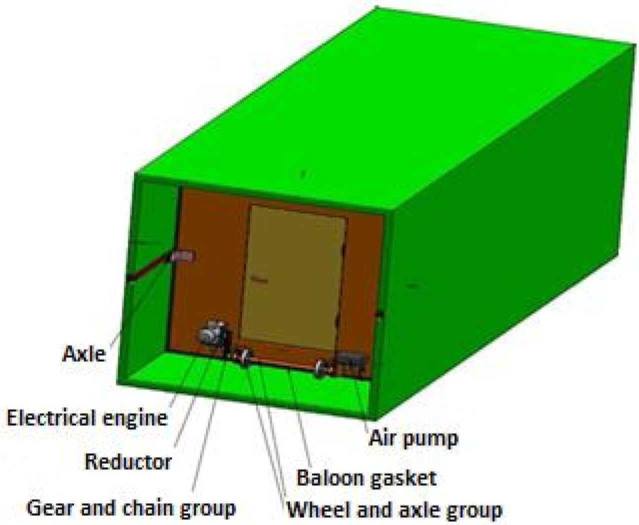


Figure 4. Automatic mowing wall-door elements

Automatic stopping and fixing at requested spot via electric motor: the moving wall operates with 2 wheels, connected to one another via a shaft, as well as with electric motor that revolves these wheels and shaft, in addition to the reducer, gear and chain system (Figure 4). Motor and reducer are mounted on moving wall. The torque from reducer is transmitted by means of a chain to the shafts and gears to which wheels are connected. Wheels and shaft will be supported with bearings on two ends, and the motor and reducer group will be placed on a small platform that will have the wall in between. Motor and reducer system will provide wheels with a speed of 4-6 m/min. Therefore, since the movement is very slow, the motor can be stopped any time by means of a button.

CONCLUSION

In current cold stores, the entire volume is cooled regardless of the loading rate (full, ¾ full or ¼ full). The cooling of vacant volume brings along redundant energy consumption depending on storage volume. Both domestic and imported cold storages are of constant volume. In other words, the cooled volume remains constant even if the amount of agricultural products decreases after delivery from cold store. Indeed, incoming orders may lead to whole or partial sale of products. In cases where the store is not completely full, any reduction in storage volume will abolish the necessity for refrigeration of the entire empty section. As a result, energy consumption, which constitutes the most significant part of operating costs in cold stores, will be reduced. Hereby study develops a moving wall-door system that can be adapted to both future and currently running cold stores. Moreover, the system can be applied in containers for situations where the products, carried to various countries in containers, decrease in the course of time. The system will reduce storage volume depending on the amount of products stored in cold room.

In the stores using this new system, the cooling will be carried out for only the required volume; therefore, notable saving will be obtained regarding energy consumption. Energy saving depends on storage volume and the power of cooling system to cool it. This system will decrease especially the operating costs of cold stores. Vegetable cultivation increased by 2.5% compared to previous year, and attained 28.5 million tonnes; while fruit production rose by 1.2% to 18.2 million tonnes. Apple enjoyed a production rise of 8.3% in 2013 and 8.3% in 2015, (TUIK, 2016). The production amounts of fruits and vegetables are sufficient to put forth the potential with respect to cold storage in Turkey. This fact underlines the importance of hereby study in regard to national economy. Energy saving is not the only advantage of the system. As storage volume decreases, the loss of quality and quantity in agricultural products will decrease. Consequently, agricultural products will be sold at more favourable prices. Moreover, the proper distribution of cold air in cold store is another influential factor on agricultural products. In a cold room with varying fullness level, the distribution of air within the room varies as well. Thus, agricultural products are cooled under varying storage conditions in cold rooms. The new system eliminates any cooled empty volume; therefore, agricultural products will be stored under better conditions. According to Bayboz *et* *al.* , (2004), the maintenance of same temperature at every section of cold room air would influence reduction in frosting; indeed, simple cooling units or packet coolers may ensure temperature homogeneity within cold room air for small volume stores. Nevertheless, they indicate that in large volume cold stores, separate and specific air duct systems should be added to cooling units or packet coolers in order to ensure temperature homogeneity. As our present study provides cooling as per loading rate, no additional costs will be in question for large volume stores.

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