IMPROVING AIR DISTRIBUTION IN FRUIT STORAGE WAREHOUSES

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INTRODUCTION

Research has shown that uniformity of air distribution within each fruit storage room is profoundly affected by bin placement and stacking patterns. Hellickson and Baskins (2003) documented differences in air movement in a 1000 bin room equipped with one evaporator unit that provided air movement with four 30-inch diameter fans. Empty spaces and non-symmetrical bin placement caused major changes in airflow patterns.

Achieving the overall objective of providing the highest possible quality fruit to consumers requires careful attention to each phase of production, storage, transportation and distribution. One breakdown in this sequence can adversely impact product quality and profit. Establishment and maintenance of proper storage conditions is a vital link in this chain of events. Seemingly minor differences in room temperature, relative humidity, gas content and uniformity of air distribution can cause significant quality and quantity losses. The longer fruit are stored, e.g., long-term controlled atmosphere storage, the greater the impact these differences can have.

Information presented in this report was developed from visits to multiple fruit storage facilities located in Oregon and Washington, which provided data including precise inside dimensions of individual rooms, in addition to number, size, location, capacity and manufacturer of evaporator units present in storage rooms. Designated bin placement schemes and actual bin stacking patterns present at room closings were also documented.

ROOM SIZES AND CAPACITIES

Room sizes in regional storage facilities vary greatly in both width and depth. In this document, depth is measured in the same direction as air flow from an evaporator unit. Maximum and minimum room depths documented were 100 feet and 28 feet, respectively. Maximum and minimum room widths documented were 100 feet and 22 feet, respectively.

Room capacities listed by various storages ranged from the largest having an average bin count of 5000 and the smallest 810. Typically, these approximate capacities were reported for fruit stored in wooden bins that were spaced four to six inches between rows. Bin rows are defined as running perpendicular to room width. Some facilities differentiated listed room capacity depending upon whether apples or pears were to be stored.

EVAPORATOR MANUFACTURERS, CAPACITIES AND LOCATIONS

Evaporator units manufactured by the following companies were present in regional storerooms visited: Colmac, Frigid Coil, IMECO, Krack, Lewis, McCormack, Recold, and Wescold. Fan sizes varied from 18 inches to 42 inches in diameter. Fan motor horsepower varied from ½ HP to 5 HP. Cooling capacities ranged from 6.1 to 58 tons of refrigeration per unit. These capacities were typically determined based on a 12 ºF temperature difference across the cooling coil.

Air movement capacity (cubic feet per minute [cfm]) of evaporator fans is affected by blade diameter and configuration, motor speed (rpm), motor horsepower, number of evaporator fin rows present, space between fins (fins per inch [fpi]) and air density. Manufacturer reported values are typically for 32 ºF air temperature and zero static pressure.

Representatives from several of the coil manufacturers indicated that configuration and capacity information of each unit installed may be available from their records. Some companies have changed the identification nomenclature of more recent models. For example, Colmac has renamed their APC identified coils as now being in the ICH 18 group. Current catalogs reflect these newer designations.

BIN PLACEMENT IN ROOMS

Airflow from the evaporator units into the storage space creates the cooling environment necessary to maintain fruit quality. The more uniformly this cooled air is circulated over, under and through the stacked bins, the better. As in any fluid-flow system, airflow will be greatest in the path of least resistance. Research presented by Hellickson and Baskins (2000) documented real-time measurement of fruit cooling rates and efficiencies at 27 locations within regular-stacked and tight-stacked rooms filled with both wooden and plastic bins. Further research (Hellickson and Baskins, 2003) verified that nonsymmetrical bin stacking patterns and open spaces frequently left to allow egress of forklifts adversely affected airflow in the same rooms. Figure 1 illustrates a non-symmetrically stacked room that caused airflow patterns to be severely unbalanced within the room.

Unless wooden bins have two-way pallets, space required for forklift movement dictates that some bins must be cross-stacked. Cross-stacked bins are those that the pallet runner space is perpendicular to the majority of bins in a row of bins. Regional warehouses have developed various stacking plans for wooden bins. Some line up all runner spaces from the rear of the room to near the exit. Then, two or three rows of bin stacks are rotated 90 degrees and spaced approximately one foot from the previous stacks. As the stacking space directly in front of the exit door is filled, bin stacks are frequently angled such that the forklift can exit the room without damaging the door casing. Plastic bins are manufactured with two-way pallets which eliminates cross-stacking. However, forklift egress near doors is still challenging and drivers often angle the last few stacks of bins to more easily exit the room. Stacking height of bins placed directly in front of exit doors is typically limited to five bins high. Depending upon where the door is located in relation to the room, up to three stacks of bins may have this limitation. This creates a sizeable empty space that may both adversely affect uniformity of air distribution in the room, and increase unwanted air movement under evaporator units.

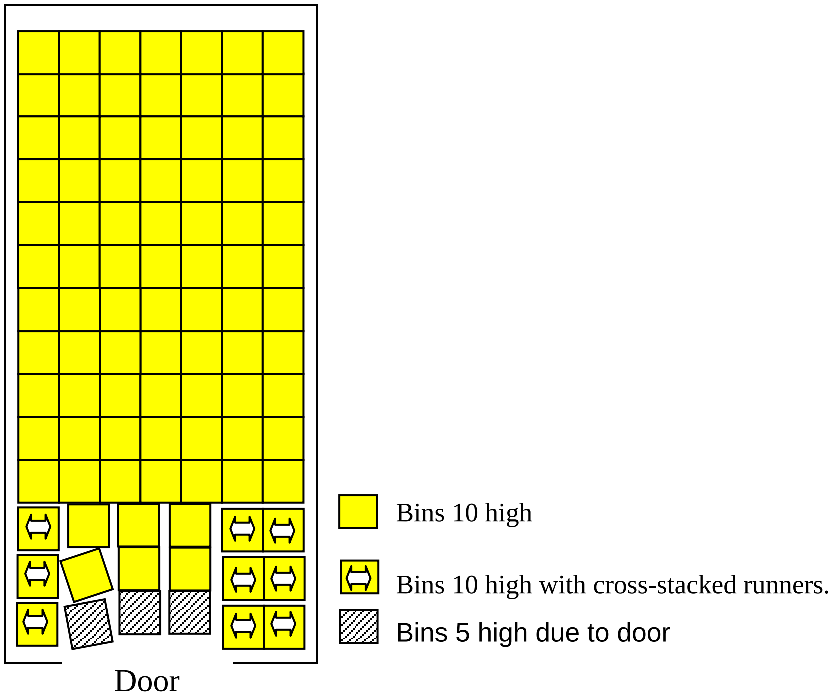

Figure 1. Illustration of a non-symmetrical bin stacking pattern that adversely affected airflow uniformity.

TIGHT-STACKING BINS

Conventional stacking of fruit bins attempts to maintain an open space of approximately six inches between rows to facilitate airflow past the containers and presumably improve fruit cooling. Maintaining this space between rows of wooden bins is seldom accomplished due to wood deflections. Additionally, most wooden bins do not have ventilation slots in their vertical sides. Therefore, the amount of heat transferred from the fruit through the solid sides of a bin is minor compared to cooling induced by air passing over the fruit through the runner space.

A formula to determine if tight-stacking bins in a room is possible is:

$$N = (\text{Room width in feet} - 1 \text{ foot}) / \text{bin width}$$

This formula requires that actual inside width of the room is measured and that six inches of space is maintained between bin stacks and sidewalls. (This is the term "-1 foot" in the above equation.) Placing stacks of bins tight against the walls is not recommended. Wooden bins typically measure 4 feet. Model 28 MacroBin bins measure 4.0725 feet.

The following example illustrates use of the above formula.

- Actual inside dimensions are 42' – 0" wide by 61' – 0" deep
- Normal stacking (with spaced stacks) = 9 rows of stacks wide by 14 stacks deep
- Room to be filled with Model 28 MacroBin bins
- N = (42 feet – 1 foot) /4.0725 feet
- N = 10.0675 bins

Since the value of N, above, is equal to, or in this case, greater than 10, one additional row of stacked bins can be added to this room.

Research presented by Hellickson and Baskins (2000) showed that equal cooling rates were achieved when fruit were tight-stacked or conventionally stacked. A symmetrical pattern of tight-stacked bins eliminates space between rows of bins and results in increased airflow through runner spaces where the majority of fruit cooling is accomplished. Research presented by Hellickson and Baskins (2003) also documented that nonsymmetrical bin placement caused airflow in some areas of the room to short circuit and return to the evaporator unit before reaching the opposite end of the room. Another positive consequence of tight-stacking a room is that additional fruit may be stored in the same space.

Providing sufficient open space at end walls is also critical to achieving uniform air movement throughout the room. (End walls are defined as the walls opposite the evaporator units.) Likewise, sufficient open space must be maintained so the air returning to evaporator units is not restricted. If either or both of these spaces are less than approximately two feet, resistance to airflow will be increased. Restricting open space at end walls will reduce the quantity and velocity of air movement in that area of the room. Restricting open space between the wall and bins stacked under evaporator units will reduce cooling efficiency and delivery volume.

Space between the top of bins stacked directly under an evaporator unit is also very important to system performance. Air moving away from evaporator units does so at a high rate of speed (face velocity). The same principle of physics that causes lift on an airplane wing applies in this area of the room. Air traveling over the curved top side of an airplane wing goes faster than the air traveling under the flat underside of the wing. The faster moving air decreases the pressure on the top side of the wing relative to that on the bottom side. Thus, lift is created. Likewise, the fast moving air in front of evaporator units creates a low pressure area in that vicinity. The greater the space between the top of the bins and the bottom of the evaporator unit, the more air will flow under the coil and mix with the fast moving air. Thus, less air is circulated through the evaporator unit and overall cooling efficiency is reduced.

RECOMMENDATIONS

A symmetrical pattern of tight-stacked bins, either wooden or plastic, provides the best possibility for creating uniform air movement throughout the entire room. Minimizing the number of cross-stacked bins in any one stack is preferred.

Before tight-stacking a room, verify that evaporator capacity is adequate to cool and maintain the additional fruit to be placed in the room. Industry currently recommends 1.8 cfm/box or 45 cfm/bin.

Maintain 4” to 6” of space between bins and sidewalls. Provide 24” of space between bins and both back walls and front walls.

Document interior dimensions of every room. Provide forklift drivers with a precise plan for bin placement.

Develop a bin-stacking protocol for each room that minimizes unwanted open spaces.

Measure distance from floor to bottom edge of evaporator units. Minimize the open space between bin tops and underside of evaporators.

REFERENCES:

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