AN AIR-FLOW PATTERN FOR TRUCK SHIPMENTS OF CITRUS PACKED IN THE 4/5-BUSHEL CORRUGATED CARTON

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One phase of the marketing research program of the Agricultural Marketing Service to improve the marketing of agricultural products is the development of more satisfactory loading patterns for packaged agricultural commodities. This problem has become more acute and complicated in recent years with the introduction of new transportation services and equipment and many new types and sizes of containers.

Loading patterns not only affect the amount of commodity and container damage sustained during transit, but also the effectiveness with which the available refrigeration in the vehicle can be used. They also influence the design of containers used and many cost factors in handling and loading.

Sainsbury and Schomer (1) reported stacking patterns had a marked effect on the rate of cooling pears packaged in corrugated cartons. Atrops (2) showed improved rates of cooling in truck shipments of citrus when loaded in an air stack pattern while Harvey and coworkers (3) found the same to be true in railcars.

One of the popular containers now used by the Florida citrus industry is the 4/5-bushel corrugated fiberboard carton. However, there was no satisfactory loading pattern in use before the research reported here was undertaken about three years ago. Winston and Cubbedge (4) reported the loading pattern for corrugated fiberboard citrus cartons had been modified several times during the past 10 years.

The purpose of the research described in this paper was to design a new and improved loading pattern for the 4/5-bushel corrugated citrus carton for ventilated and refrigerated truck and rail piggyback shipments.

MATERIALS AND METHODS

The basic component of this pattern is the bonded-block stack shown in fig. 1. Containers are placed alternately lengthwise and crosswise, with a 2-3-inch wide air channel between the lengthwise cartons. Thus in each bonded-block stack there are 5 air channels and 6 rows of lengthwise containers. There are channels for air circulation between the containers in the outside edges of the load and sidewalks of the vehicles. When these stacks are placed so that the bottom boxes along the sidewalks are in the

Fig. 1. Basic air-flow loading patterns.
sequence of 2 lengthwise, 2 crosswise, 2 lengthwise, etc., there is a network of connecting air channels as is shown in fig. 2. These channels provide for air circulation to each container in the load to facilitate rapid cooling and maintenance of uniform temperatures.

With slight modification, this basic pattern can be adapted for use in ventilated or refrigerated shipments in vehicles having vertical or horizontal air circulation systems. Various modifications of this pattern are now used by truckers to meet special needs for their particular equipment. For example, some truckers prefer a solid top layer when the shipment moves under ventilation. This forces a large percentage of the front-to-rear air movement through the channels in the body rather than across the top of the load. In refrigerated loads the top layer is generally open-stacked (i.e. openings are left between some of the top-layer boxes to permit the cooled air discharged from the ceiling duct to reach the channels in the lower part of the load). Unless openings are provided between boxes in the top layer in refrigerated shipments in trailers equipped with vertical or diagonal sidewall striping or ribbing, much of the refrigerated air discharged from the ceiling duct will by-pass the main body of the load by going down the sidewall openings on its return to the refrigeration unit. However, some carriers prefer to place an

(a) VENTILATED LOAD
(tight top layer - blower off - vent doors open)

(b) REFRIGERATED LOAD
(open top layer - blower on - vent doors closed)

Fig. 2. Air channels and circulation patterns in ventilated and refrigerated loads.
extra box in the top layer of the last two stacks for added tightness and stability required at this critical point in the load.

Most trailers used for fresh produce are equipped with 2 to 3 inches of insulation and have a loading width of about 90 inches in which the basic pattern will fit quite well. For trucks with thicker insulation and loading space less than 90 inches, the basic pattern must be changed to 6 lengthwise and 4 crosswise cartons.

Variations in the length of loading space can be accommodated by utilizing one or two single lengthwise stacks shown in figures 1 and 2. They are so placed that the air channels between them match the air channels in the adjacent bonded stacks. These single lengthwise stacks may be used anywhere in the load except at the rear where more stability is provided by a bonded-block stack.

RESULTS AND DISCUSSION

During a two-year period over 30 shipping tests were conducted in the development and refinement of this loading pattern. Air circulation, temperature maintenance, and commodity and container damage were studied.

Air circulation in ventilated loads moves from front to rear through the load as shown in fig. 2A. Air velocity measurements taken in all channels at 50 miles per hour road speed at the rear stack average 250 ft./min. (feet per minute).

Air circulation in the refrigerated loads is from the blower across the top of the load (fig. 2B). Some air enters the channels at the rear of the load and some through the open-stacked top layer. All of the air returns to the blower from rear to front through the network of channels provided by the pattern. Air velocities in refrigerated loads vary according to the capacity of the blower fan, bulkhead design, and sidewall stripping or ribbing. Air movement through the load channels averaged about 175 ft./min.

One of the most important advantages of the new pattern is the improved product refrigeration made possible through better air circulation. The rate of initial cooling and effective temperature maintenance in a given load depends on the temperature and volume of the air moving through the channels. In ventilated loads, the air temperature is controlled by the outside temperature. The air volume is controlled by the speed of the vehicle and size of the front and rear ventilation openings. In refrigerated loads, the air temperature and volume are controlled by the capacity of the mechanical unit or the ice bunker blower, and by the size and design of the air distribution system.

Commodity and air temperatures were taken in both ventilated and refrigerated shipments in which the new pattern was used. Representative temperatures in some tests were taken with thermocouples and in others some pulp temperatures of the fruits were taken with stick thermometers at shipping point and destination. The data shown in table 1 are from comparable test shipments in which adequate temperature measurements were made.

In one ventilated shipment the average pulp

Table 1.—Commodity temperature reduction in motortruck shipments of Florida citrus in the 4/5-bushel corrugated fiberboard cartons loaded in "air-flow loading pattern" 1/

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<td>53</td>
<td>69</td>
<td>67-73</td>
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<td>70</td>
<td>36</td>
<td>65</td>
<td>59-73</td>
<td>25</td>
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<tr>
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<td>71-78</td>
<td>62</td>
<td>84</td>
<td>42</td>
<td>41-45</td>
<td>33</td>
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1/ Three test shipments from Florida to New York, New York.
temperature at loading time was 80° F. After 53 hours this had been reduced to 69°. During this period the ambient temperature averaged 62°.

In one load an ice bunker and blower supplied the refrigeration. The average commodity temperature at loading time was 90° and after 36 hours of travel the commodity temperatures had been reduced to 65°. During this period the outside air temperatures averaged 70°.

Another load moving under mechanical refrigeration via piggyback was loaded with fruit averaging 75°. After 84 hours in transit, the average commodity temperatures had been reduced to 43°. During this period the outside air temperatures averaged 62°.

Commodity and container damage as affected by the loading pattern were insignificant during these tests. The bonded-block pattern provides more stability and reduces load shifting which helps keep physical damage to a minimum.

**Summary**

The modified bonded-block “air-flow” loading pattern for the 4/5 bushel corrugated fiberboard carton provides a system of connected air channels for improved air circulation and temperature control in truck and rail piggy-back shipments of fresh citrus.

In the 1961-62 Florida citrus season there was widespread use of this pattern under commercial conditions. Reports from packinghouses, truckers, and receivers indicate its adoption has resulted in better overall arrival condition of Florida citrus in terminal markets.

**LITERATURE CITED**


**DECAY AND RIND BREAKDOWN OF ORANGES IN FIBERBOARD CARTONS AND WIREBOUND BOXES**

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Since the use of fiberboard cartons for the shipment of fresh fruit to market became commercially practical, many have thought that more decay would develop in citrus fruits packed in cartons than in wirebound wood boxes. There was thought to be less aeration in cartons, allowing the accumulation of products of respiration such as carbon dioxide about the fruit with a decrease in oxygen. Loucks and Hopkins (4) have shown that oranges held in a tightly closed steel drum developed 54 per cent stem-end rot after three weeks storage as compared with 10 per cent in a similar drum containing alkaline permanganate to absorb carbon dioxide and ethylene or 12 per cent in ordinary storage in wood crates. However, fiberboard cartons, even the closed type, are not “air tight”; they appear to allow considerable exchange of respiratory gases. The ventilated cartons now generally used result in still more aeration of the fruit.

Pintov, et al., (5) report results of several shipping tests from Israel to European ports using wooden cases and non-ventilated cartons. Their observations throughout the season showed no significant differences in spoilage between oranges packed in cartons or in wooden cases. Winston, et al., (6) in refrigerated shipments from Florida to the New York market, found no significant differences in decay between fruit packed in wire-bound crates and telescope cartons with slots or vent openings on all surfaces.

During the last ten years there has been a revolution in shipping containers for fresh Florida citrus. A comparison of the number of containers used in 1951-52 with the 1961-62 season shows a definite trend toward fiberboard cartons (Annual Citrus and Vegetable Inspection Division Reports). In the 1951-52 season 75 per cent of all Florida citrus was shipped in wire-bound boxes. Ten years later this percentage has dropped to 54 per cent. Only 3 per cent of Florida citrus was shipped in fiberboard cartons in 1951-52; ten years later 32.5 per cent was