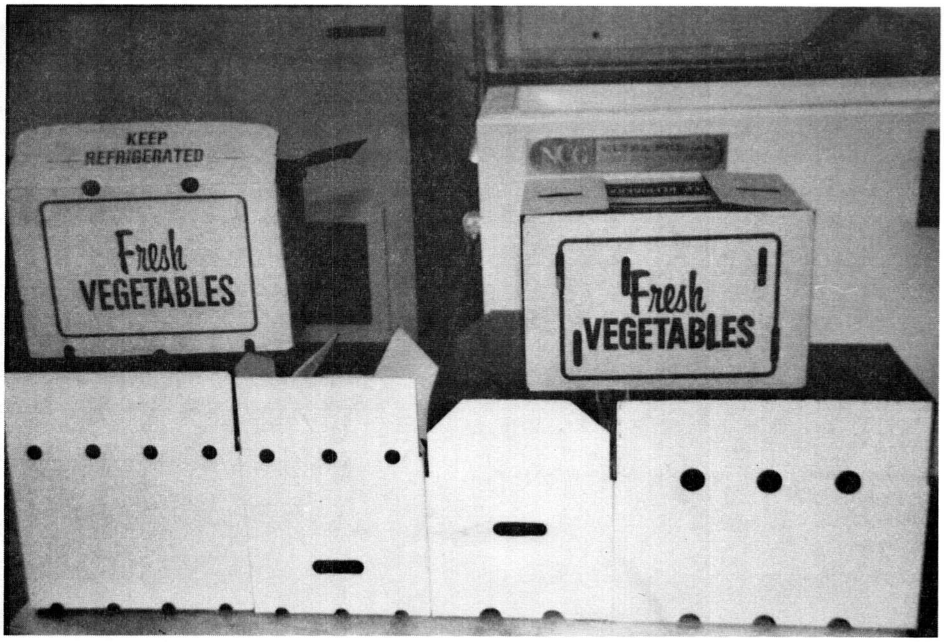

Figure 7. Several currently used and experimental containers with vents of various sizes, shapes, and locations.

carton venting is circular or round-ended slots, which are combinations of rectangles and semicircle ends. The total vent area should then be divided by the total face area of that surface (length times height) and finally multiplied by 100.

For many packinghouse operations, cartons are placed such that the side vents align with the side vents of the adjacent carton or the end vents align with the end vents of the adjacent carton, for example standard 1-1/9 bushel containers stacked eight containers per layer (Figures 3 and 8). In other applications, such as 40 x 30 MUM (Modularization, Unitization, and Metrification) containers stacked ten per layer, the stacking patterns require ends of cartons to align with the sides of adjacent cartons and the carton vent locations must be designed accordingly (Figures 9 and 10). If the vent holes on adjacent cartons do not align, a major disruption of air flow occurs and should be avoided. For produce cartons with slender vertical slots commonly used on the ends and sides, offset of the carton by as little as 0.6 cm (1/4 in) results in vent hole misalignment. This is another reason for selecting large rather than small vent holes, because the larger holes would allow partial vent alignment even when the cartons are not aligned correctly. However, wide holes can be partially blocked by the product more so than narrow slots. Also, more corrugate flutes are cut with a wider hole, which reduces the strength of the carton.

Pallet configurations

Pallet placement

In one type of forced-air cooler, two rows of pallets are placed end to end to form each side of a cooling tunnel (Figures 1 and 3). It is important that the pallets are placed such that very little gap exists between the cartons of adjacent pallets. Otherwise another path is created for the cooling air to bypass the cartons. Velocity measurements [9] indicated significant air flow through such gaps, particularly when plastic was installed to seal the side openings of the pallets. For example, a 4.5 cm (2 in) by 1.2 m (4 ft) gap was noted between the two pallets during a test at a packinghouse with plastic installed. The measured velocity through the gap was 5 m/s (970 fpm) and the calculated flow rate was 0.3 m^3/s (650 cfm). The total flow through an adjacent carton was 0.01 m^3/s (26 cfm). At another packinghouse, a 4.5 cm (2 in) by 28 cm (11 in) gap was noted between the two pallets with plastic installed. The measured velocity through the gap was 3.5 m/s (680 fpm) and the calculated flow rate was 0.05 m^3/s (104 cfm). The total flow through an adjacent carton was 0.006 m^3/s (12 cfm).

This study [9] suggests that additional studies should be conducted to determine how varying the number of pallets, height of the cartons on the pallets, tunnel width (distance between rows of pallets), and similar factors affect the performance of the air handling and cooling systems. Limited data indicates that reducing the number of pallets in the cooling tunnel from 10 to 6 reduced the half cooling time for the last pallet (without plastic) from 1.9 to 0.7 hours. Therefore, it might be possible to cool 36 pallets (3 groups of 12 pallets cooled) with tunnels 6 pallets long in the same length of time as 20 pallets (1 group of 20 pallets cooled) with tunnels 10 pallets long, if sufficient refrigeration capacity is available (Figure 11).

In addition to the side openings in the two-way pallet, the bottom layer of cartons at times does not always completely cover the surface of the pallet. This leaves openings between boards on the top of the pallet, thus allowing air to bypass the product. Significant air bypass was noted through these open pallet surfaces [9]. Normally the cartons are stacked flush with one side of the pallet, while the other side exposes the surface of the pallet.