Sources of Information

- Patrick Brecht - PEB Commodities
- Postharvest Technology of Horticulture Crops (UC ANR Pub. 331)
- Maintaining Optimum Perishable Product Temperatures in Truck Shipments (UCD Postharvest Horticulture Series #12)
- Marine Container-Transport of Chilled Perishable Produce (UC ANR Pub. #21595)

Maintain the Cold Chain

- Load from an Enclosed, Refrigerated Dock
- Pre-cool the trailer or container before loading

Transportation Methods

- Highway Trucks
- Marine Containers and Refrigerated Ships
- Rail Cars
- Air

Road Transportation

- Types of vehicles:
  - Smaller refrigerated truck
  - Large Tractor-trailers
  - Trailer on flat car (TOFC)
- Used most commonly

Sources of Information

- USDA Handbooks
  - #593 Export Handbook for US Agric. Products
  - #668 Tropical Products Transport Handbook
  - #700 Agric. Export Transportation Handbook
  - A Business of Details—Exporting High Value U.S. Agricultural Products (video & handbook)
Road Transportation

- Trailers often:
  - 102 in (8.5 ft or 2.6 m) wide
  - 40 to 51 ft (12.2 to 16.2 m) long
  - 2,500 to 3,500 ft³ (70 to 100 m³) interior volume
  - 80,000 lb (36,288 kg) gross weight max.
  - Each axle has its own weight restriction
  - 40,000 to 45,000 lb (18,100 to 20,400 kg) load capacity
  - 3.5 to 4.7 ton (12.3 to 16.4 kW) refrigeration capacity can also provide heat

Desirable Features For Temperature Management

- High capacity fan
- Temperature monitored in discharge from refrigeration unit
- Unrestricted air return to the refrigeration coils
  - Solid front return-air bulkhead
  - Deep floor for air circulation
  - Air channels in walls for air circulation and to help isolate load from the environment

Air Return

- Air returning to the refrigeration coils can easily be blocked
  - Placing produce on pallets greatly enhances the volume of space for air to return
  - “T-beam” floors, at ~200 in² of air channel, are much better common duct board floors
  - The common duct board floor has only ~47 in² of air channels (97” wide trailer)

Air Return

- Corregated walls hold cartons of fruit away from the wall better
  - Better cold air flow around the product
  - More easily damaged than flat walls
Refrigeration Limits

- Most heat removed by the refrigeration system conducts through the walls or is in air that leaks in
  - Product in contact with walls is warmer
- In most cases, the top air-deliver in trailers does not provide enough airflow to cool the product
  - Always cool product before loading

Road Transportation

- Relative humidity is usually not controlled
  - Added water may weaken fiberboard cartons
  - Compromise between carton strength and water loss during transit
  - Water loss can be retarded using liners, wraps, or packages
- Road trailers are not air-tight enough to allow modified or controlled atmospheres
  - MA can still be used at the pallet or package level

Vibration Injury

- The vibration within a trailer as it moves down the road can damage some produce
  - Product over the axels and at the top of a pallet receive the most vibration
  - Immobilizing product in packages can reduce this injury

Vibration Injury

- Vibration can be greatly reduced using air ride suspension
  - More expensive, but also improve driver comfort and reduce tire ware
  - Most long-haul tractors have air ride suspension. So load vibration sensitive produce near the front of the trailer

Mixed Loads

- Compatibilities??
  - Temperature
  - Ethylene production vs. sensitivity
  - Ethylene scrubbers may reduce injury
  - Moisture Compatibility
    - Dry produce (e.g. onions) vs. other produce needing high RH
    - Odor producers vs. odor absorbers

Load Patterns
Condition of Vehicles??

Water Transportation

- More economical for long transport (e.g. 1 to 4 weeks)
- Types of shipping:
  - Break Bulk – produced loaded similar to how a cold storage facility might be loaded (only tighter)
  - Containerized Shipping – produce loaded onto containers that are then stacked on/in ships
- MA or CA are possible for both
**Bulk vs. Containers**

- **Holding capacity:**
  - Bulk = ~350,000 packages
  - Containers = ~1,000 to 1,500 packages
- Bulk shipping is generally less expensive than containers
  - Bulk containers have large insulated holds with central refrigeration systems
  - Containers = large # of individual refrigeration units
- Containers are easily transported between packinghouse & distribution loading docs
  - Fewer transfer steps. Cold chain no broken

**Water Transportation**

- Containers are often:
  - 96 in (8’ or 2.4 m) wide
  - 40 ft (12.2 m) long, 8.5 to 9.5’ (2.6 to 2.9 m) high
  - 2,000 to 2,300 ft³ (56.6 to 65.1 m³) interior volume
  - 2.4 to 2.9 ton (8.4 to 10.2 kW) refrigeration capacity. Can also provide heat
Water Transportation

- Road weight limits still apply:
  - 80,000 lb (36,288 kg) gross weight max. & each axle has its own weight restriction
  - 40,000 to 48,000 lb (18,100 to 21,700 kg) load capacity

Bottom Air Delivery

- With proper loading, so that air is forced through the packages, slow cooling (2 to 4 days) can be achieved
  - All open floor space needs to be covered.
  - Block open pallet edges
  - Cartons should have at least 3% venting on top and bottom panels
  - Vents should align even if cross-stacked.
  - Internal packaging should not block air flow

Examples of stowage patterns that cause short cycling of air through the load and result in less effective temperature management
Rail Transportation
- Used mostly for less perishable products (e.g. potatoes, onions, carrots) for long distant transport in North America
- Each car usually contains a single commodity

Rail Transportation
- Rail cars often have:
  - >4,000 ft³ (113 m³) interior volume. Can haul >100,000 lb (45 metric tons) of product
  - Top air delivery
  - Adequate refrigeration capacity and airflow to slowly cool provided the product is not packed too tightly
  - Fairly air-tight. Untended MA if the drains get clogged

Air Transportation
- Provides rapid transport of perishable products
  - E.g. cut flowers, early season cherries, strawberries, and some tropical fruits
- EXPENSIVE!
- Very poor temperature control
  - Often no refrigeration & little air flow
  - Handling delays waiting to be loaded
  - MA difficult even at the package level
- Very low humidity