

# Transportation



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## 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)



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## 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)



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## Transportation

- Moving perishable commodities from the site of production to the site of consumption
  - Before the industrial revolution, these tended to be shorter distances (often local consumption)
    - Land – transport by humans and animals
    - Water – transport by ships
    - These means of transportation were slow



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## Transportation

- Industrial revolution
  - Urbanization separated areas of production from areas of consumption
  - Development of faster forms of transportation
    - E.g. the steam engine and railroads
  - Better refrigeration



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## Transportation

- Start with high quality produce
  - Packed correctly & precooled
- Match the perishability of the commodity with the transportation system
  - E.g. a product must be able to survive a 4 week journey by ship



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## Temperature, Temperature Temperature!

- All products are harmed by exposure to excessively high and low temperatures
- Temperate commodities should ideally be transported/stored at 32°F to 38°F (0°C-3°C)
- Tropical and subtropical products must be transported at higher temperatures to avoid chilling injury

Courtesy of Patrick Brecht and American President Lines

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## Maintain the Cold Chain

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

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## Transportation Methods

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



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## Road Transportation

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



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## ■ ■ ■ Road Transportation

- Trailers often:
  - 102 in (8.5 ft or 2.6 m) wide
  - 40 to **53 ft** (12.2 to 16.2 m) long
  - 2,500 to 3,500 ft<sup>3</sup> (70 to 100 m<sup>3</sup>) 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)

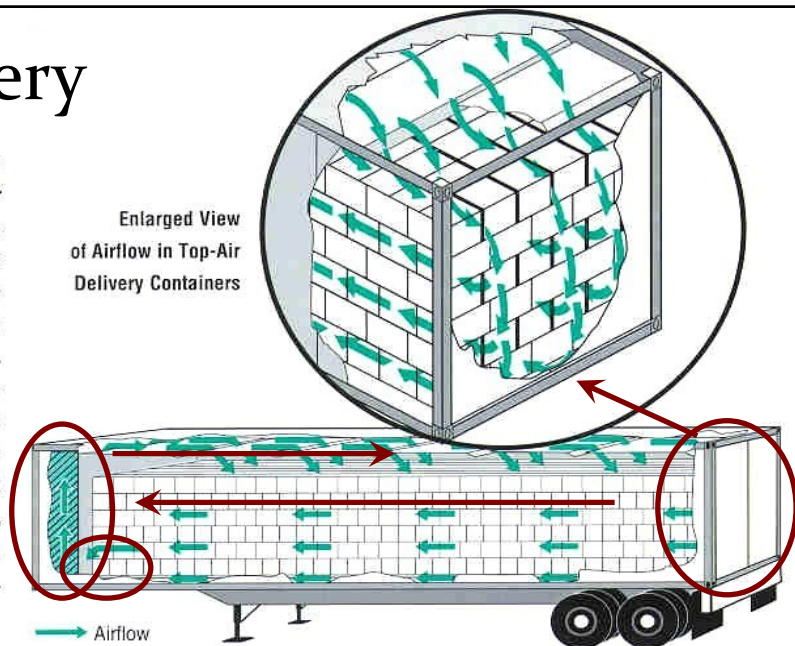


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## Top Air Delivery

In top-air delivery containers, air moves down the entire length of the load in channels created during the stowing process. Cartons must be strong enough to support the weight of offset cartons above, and be vented on all four sides.

Enlarged View of Airflow in Top-Air Delivery Containers



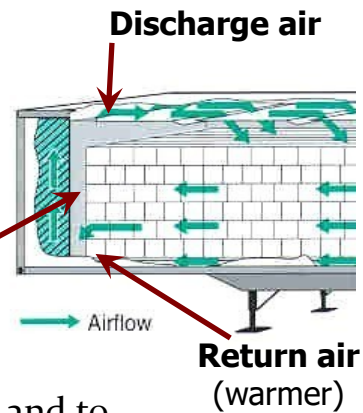
Courtesy of Patrick Brecht and American President Lines

Airflow in Top-Air Delivery Containers

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## Desirable Features For Temperature Management

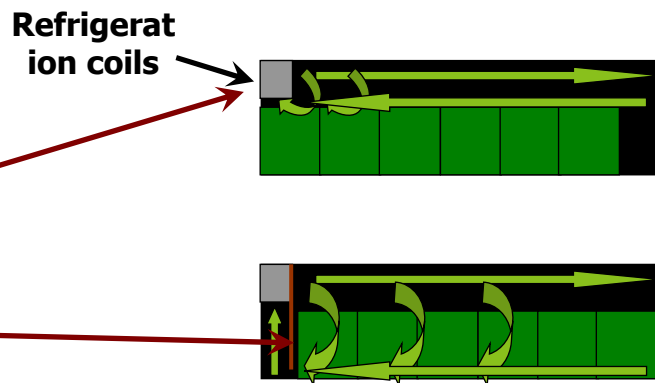
- High capacity fan
- Temperature monitored in discharge from refrigeration unit
- Unrestricted air return to the refrigeration coils
  - Solid front return-air bulkhead
  - Deep floor for air circulation
  - Air channels in walls for air circulation and to help isolate load from the environment



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## Air Return

- Air can “short circuit” back to the refrigeration unit if a bulkhead are not present to force the air to return via the floor.



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## ■ ■ ■ 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 in<sup>2</sup> of air channel, are much better common duct board floors
  - The common duct board floor has only ~47 in<sup>2</sup> of air channels (97” wide trailer)



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## ■ ■ ■ 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



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## 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



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## Refrigeration Limits

- Trailers are **rated** by the Refrigerated Transportation Foundation **based on their refrigeration capacity and insulation**

Rating	Min. Temp.
C65	65F (18C)
C35	35F (2C)
F	0F (-18C)
DF	-20F (-29C)

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## ■ ■ ■ 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 wear
  - Most long-haul tractors have air ride suspension. So load vibration sensitive produce near the front of the trailer



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## 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



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# Load Patterns



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## Water Transportation

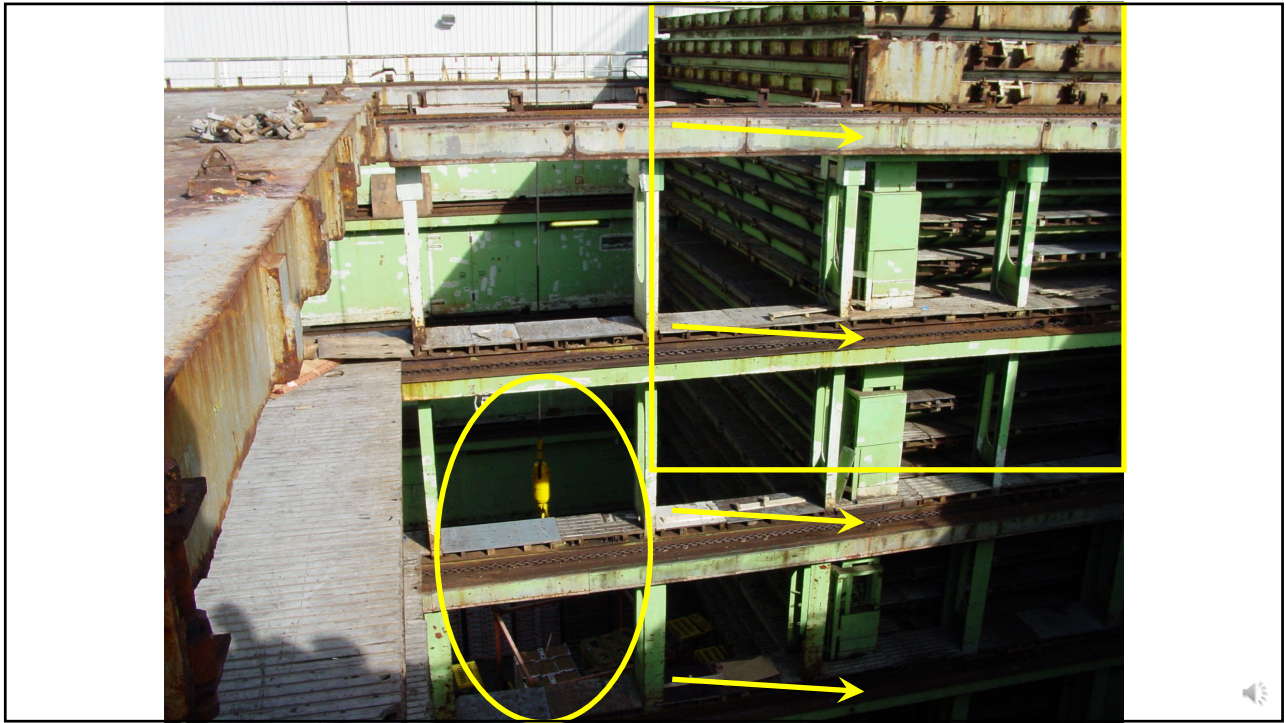
- More economical for long transport (e.g. 1 to 4 weeks)
- Types of shipping:
  - **Break Bulk** – produce loaded similar to how a cold storage facility might be loaded (only tighter)
  - **Containerized Shipping** – produce loaded onto containers that are then stacked on/in ships
- **MA or CA are possible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



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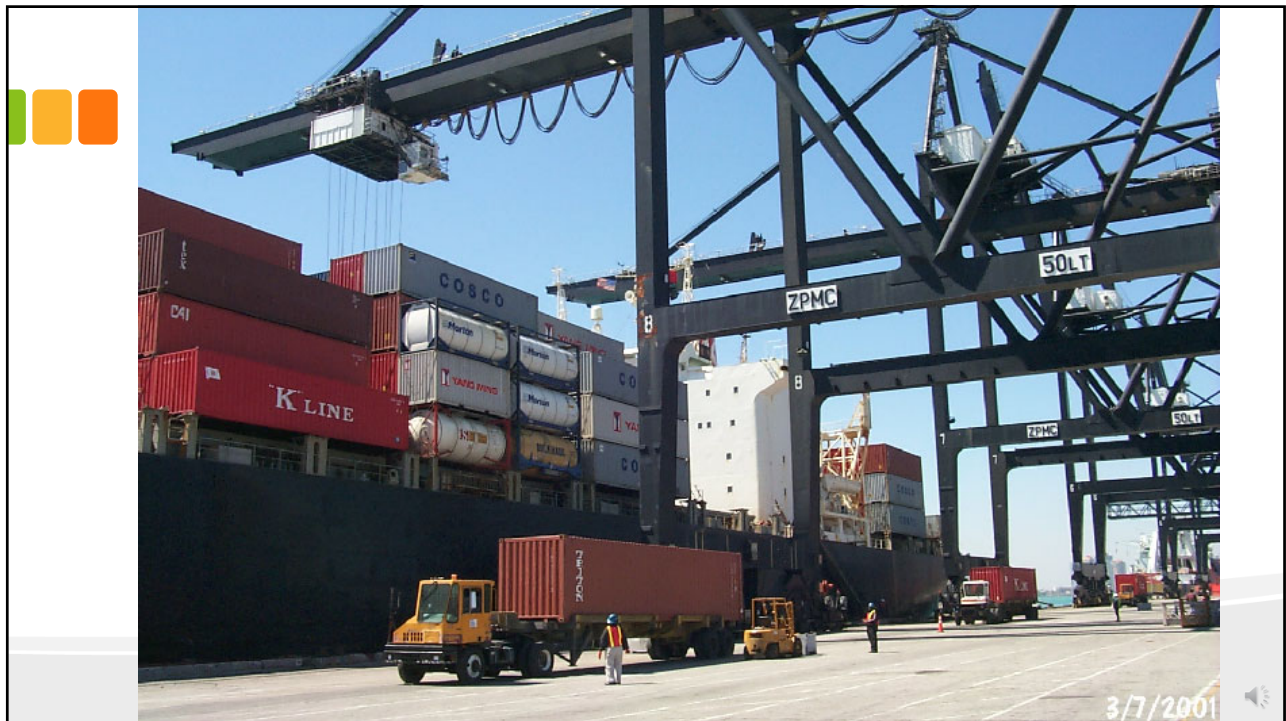


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## Bulk vs. Containers

- 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



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## 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 ft<sup>3</sup> (56.6 to 65.1 m<sup>3</sup>) interior volume
  - 2.4 to 2.9 ton (8.4 to 10.2 kW) refrigeration capacity. Can also provide heat



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## 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

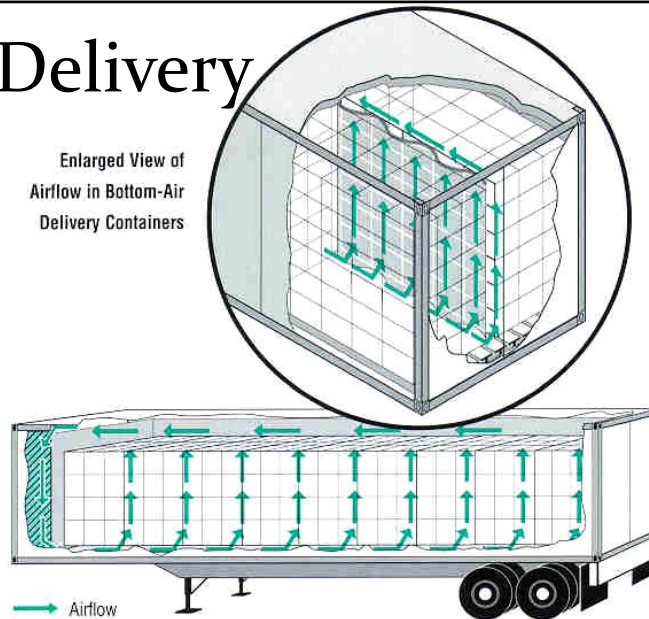


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# Bottom Air Delivery

Enlarged View of  
Airflow in Bottom-Air  
Delivery Containers



In bottom-air delivery containers, air is forced through the floor space under the load and up through the cargo. This type of airflow provides the most even temperature management for chilled cargo.

Courtesy of Patrick Brecht and  
American President Lines

Airflow in Bottom-Air Delivery Containers

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## Water Transportation

- 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

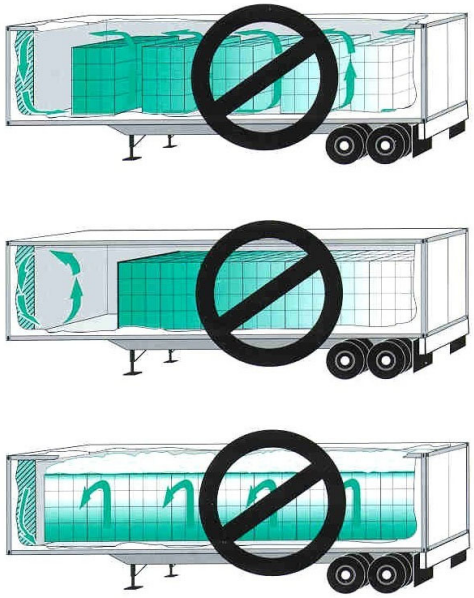


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### Incorrect Storage

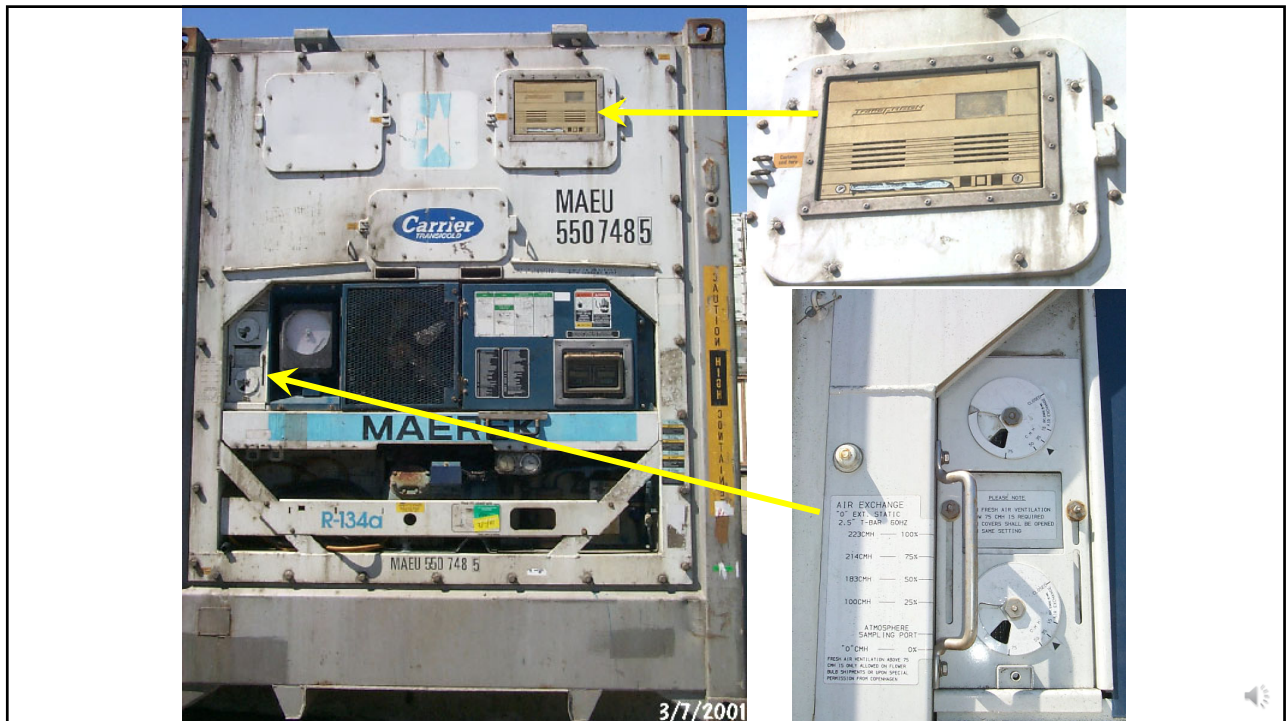


Examples of stowage patterns that cause **short cycling** of air through the load and result in less effective temperature management

Courtesy of Patrick Brecht and American President Lines



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## 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



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## ■ ■ ■ Rail Transportation

- Rail cars often have:
  - >4,000 ft<sup>3</sup> (113 m<sup>3</sup>) 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



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## ■ ■ ■ 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



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## Thermostats

- Thermostats should be calibrated regularly
- Supply air temperature sensor vs. return air temperature sensors or both
  - How would loading warm product affect this?
- Ideally, set temperature just above freezing or chilling temperature
  - Newer units with supply air control vary only ~1F (0.5C) around the set point
  - Older systems with return air sensing should be set at least 2F (1C) above the set point



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## Microprocessor Control = Good Insurance

- Measures and controls discharge & return air temperatures
- Documents refrigeration unit performance.
- Optional features
  - Cargo temperature recording
  - Upper/lower set-point limits
  - Atmosphere management (CA & humidity)



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## Placement of Temperature Recorders

FRONT	2	1
	4	3
	6	5
	8	7
	10	9
	12	11
	14	13
	16	15
	18	17
	BACK	20

Three temperature monitors:

1. Inside the first pallet **near the front bulkhead** of the reefer unit to detect any occurrences of short cycling of refrigerated air
2. Inside a pallet **near the center of the load** (position 9, 10, 11, or 12) where product heating is most likely to occur
3. On **the outside rear face of the last pallet** at eye level to record air temperature at the farthest point from the reefer unit. *If only one temperature recorder is used, place it here.*

Do not place temperature recorders directly on trailer walls. This may result in elevated readings that do not accurately reflect the air temperature in the load space.