

Transportation

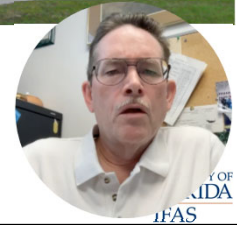


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Source of Information



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Transportation

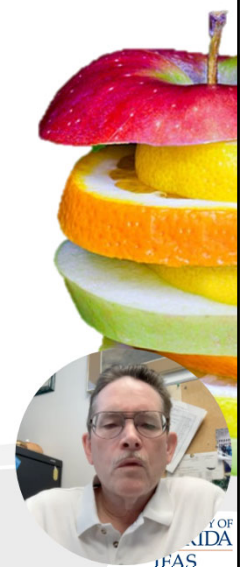
- Moving perishable commodities from the site of production to the site of consumption
 - Before the industrial revolution, these tended to be shorter distances (often local consumption)
 - Land – transport by humans and animals
 - Water – transport by ships
 - These means of transportation were slow



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Transportation

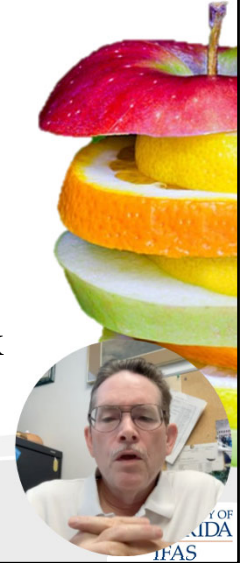
- Industrial revolution
 - Urbanization separated areas of production from areas of consumption
 - Development of faster forms of transportation
 - e.g., the steam engine and railroads
 - Better refrigeration



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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 (°F)	Temperate Commodities (Non-Chilling Sensitive)	Tropical/Subtropical Commodities (Chilling Sensitive)
122	Heat Injury Zone (TOO WARM)	Heat Injury Zone (TOO WARM)
113	Heat Injury Zone (TOO WARM)	Heat Injury Zone (TOO WARM)
104	Heat Injury Zone (TOO WARM)	Heat Injury Zone (TOO WARM)
95	Heat Injury Zone (TOO WARM)	Heat Injury Zone (TOO WARM)
86	Heat Injury Zone (TOO WARM)	Heat Injury Zone (TOO WARM)
77	Optimum Ripening Temperatures	Optimum Ripening Temperatures
68	Optimum Ripening Temperatures	Optimum Ripening Temperatures
59	Ideal Transit or Storage Temperatures	Ideal Transit or Storage Temperatures
50	Ideal Transit or Storage Temperatures	Ideal Transit or Storage Temperatures
41	Ideal Transit or Storage Temperatures	Chilling Injury Zone (TOO COLD)
32	Ideal Transit or Storage Temperatures	Chilling Injury Zone (TOO COLD)
< 32	Freezing Injury Zone	Freezing Injury Zone

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

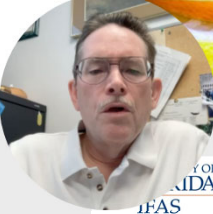


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Transportation Methods

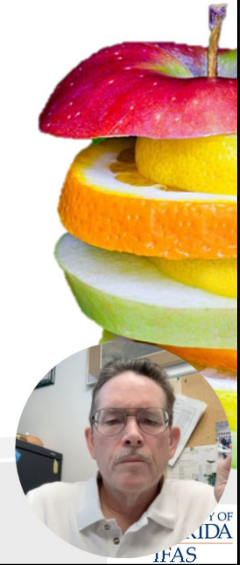
- Highway Trucks
- Marine Containers and Refrigerated Bulk Ships
- Rail Cars
- Air



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Transportation Equipment

- Truck trailers and marine containers
 - **Top-air or bottom-air delivery:** differ markedly in how the refrigerated air moves and how heat is removed
 - Refrigerated transport equipment is designed to maintain temperature
- Air transport containers
 - Usually no refrigeration unit
 - May use dry ice or eutectic mixtures
 - Minimal air circulation



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Road Transportation

- Types of vehicles:
 - Smaller refrigerated trucks
 - Large Tractor-trailers
 - Trailer on flat car (TOFC)
- **Over-the road transport used most commonly**



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Truck Trailers

- 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 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)

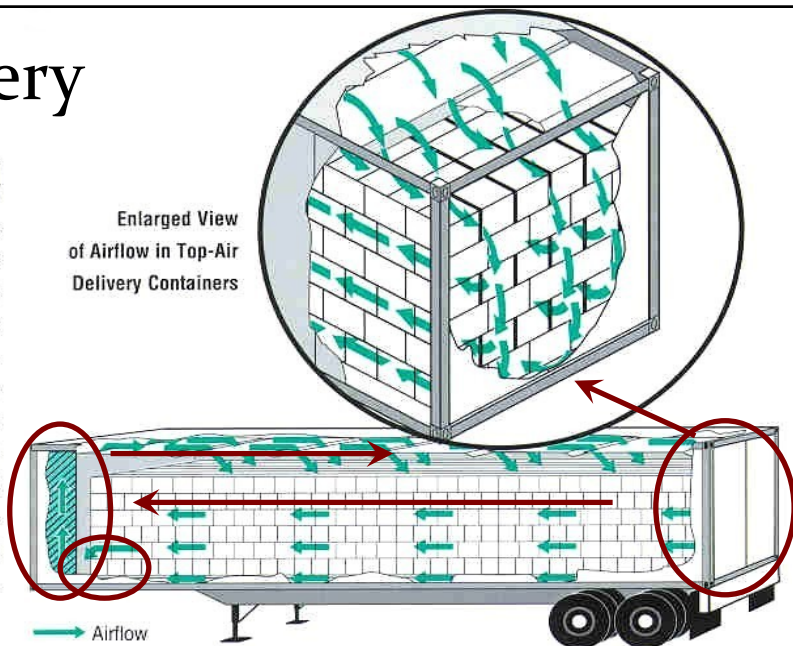


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Top Air Delivery

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



→ Airflow

Courtesy of Patrick Brecht and American President Lines

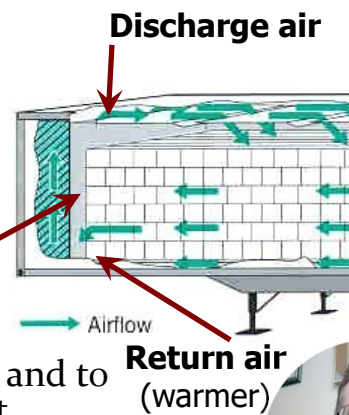
Airflow in Top-Air Delivery Containers



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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
 - Cartons should have at least **5% venting on side panels** (more about this in Cooling lecture)

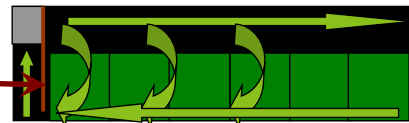


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Air Return

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

Refrigeration coils



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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 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)



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■ ■ ■ Air Return

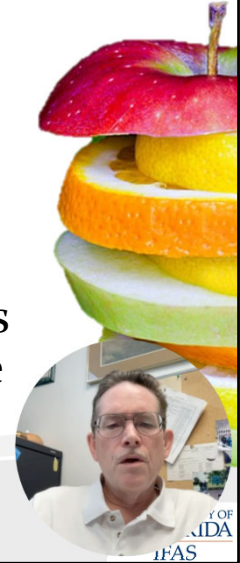
- **Corregated walls** hold cartons of fruit away from the wall better
 - Better cold air flow around the product
 - More easily damaged than flat walls



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Refrigeration Limits

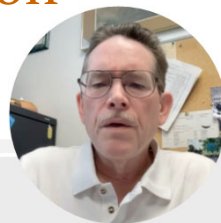
- Most heat removed by the refrigeration system conducts through the walls or is in air that leaks in
 - Product in contact with walls is warmer
- In most cases, the top air-delivery in trailers does not provide enough airflow to cool the product – *only maintains temperature*
 - Always cool product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



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Refrigeration Limits

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

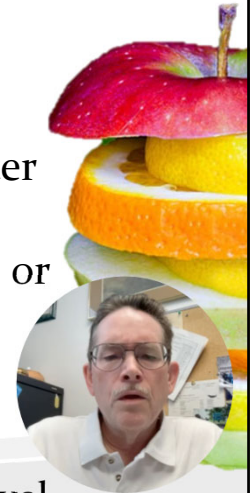


Rating	Min. Temp.
C65	65F (18C)
C35	35F (2C)
F	0F (-18C)
DF	-20F (-29C)

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Truck Trailers

- **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
- **Trailers are not air-tight enough to allow modified or controlled atmospheres**
 - MA can still be used at the pallet or package level



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Vibration Injury

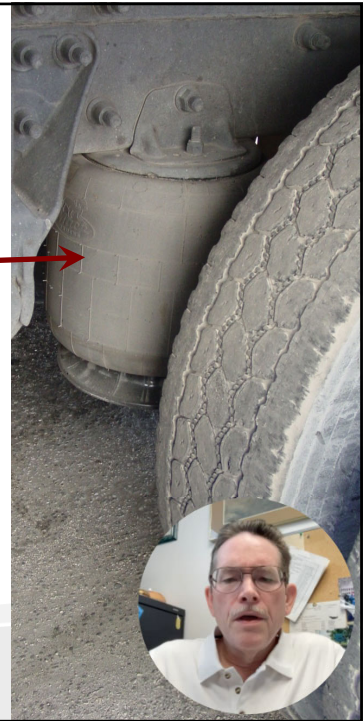
- The vibration within a trailer as it moves down the road can damage some produce
 - Product over the axels and at the top of a pallet receive the most vibration
 - Immobilizing product in packages can reduce this injury



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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, vibration-sensitive produce should be loaded 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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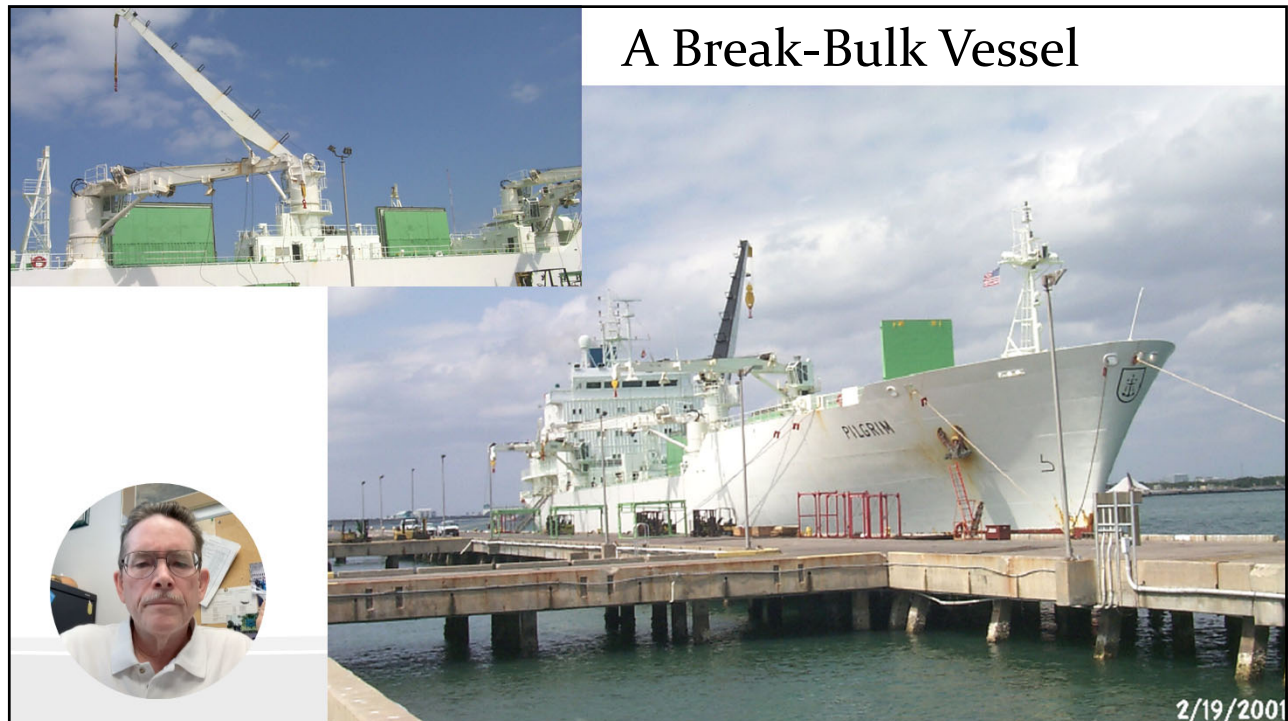
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Water Transportation

- 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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Refrigerated Cargo Holds



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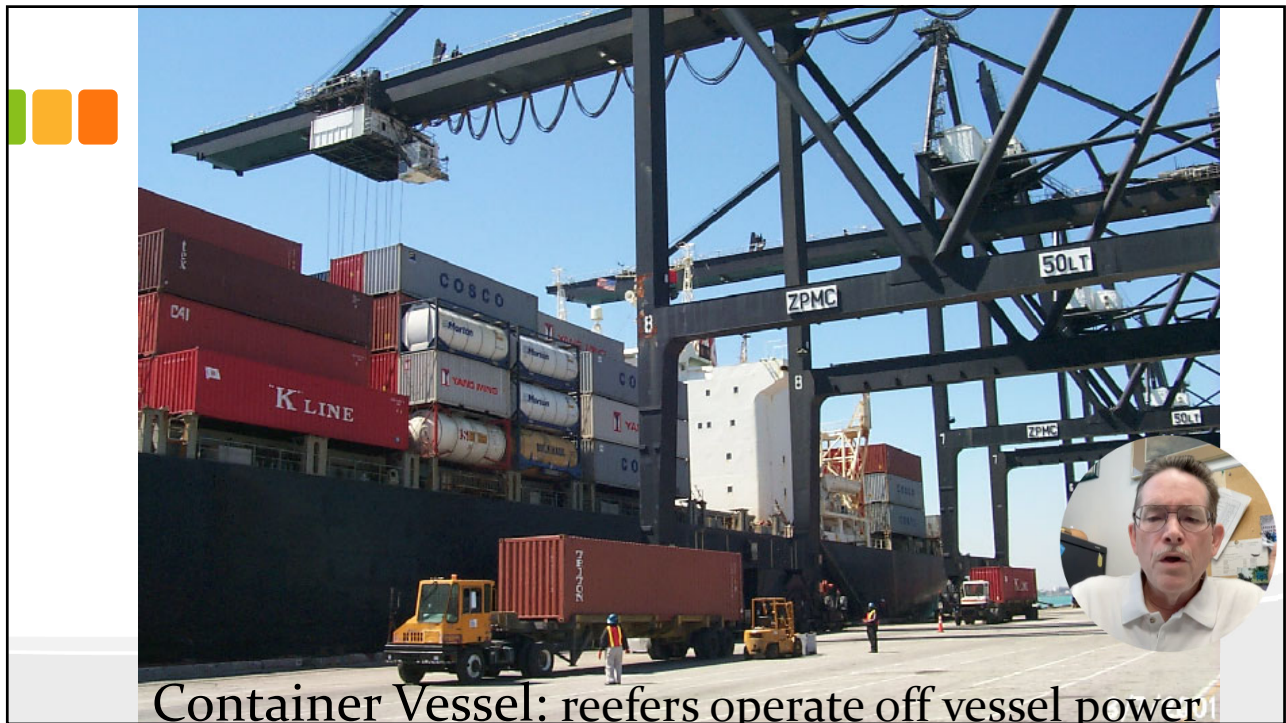
LoLo - Lift-On/Lift-Off



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Bulk vs. Containers

- Holding capacity:
 - Bulk: ~ 350,000 packages total (e.g., 40-lb banana cartons)
 - Containers: ~1,000 to 1,500 packages per container times up to 24,000 containers (24-36,000,000 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 is not broken



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Marine Containers

- 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



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Marine Containers

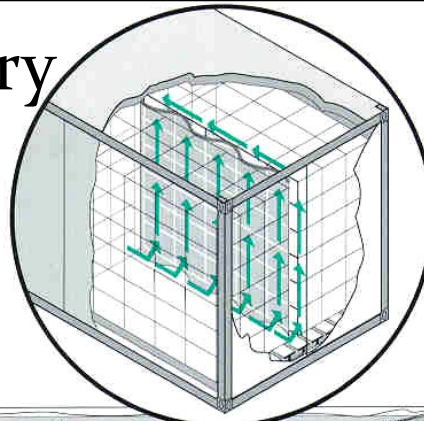
- Road weight limits still apply:
 - 80,000 lb (36,288 kg) gross weight max. & each axle has its own weight restriction
 - 40,000 to 48,000 lb (18,100 to 21,700 kg) load capacity



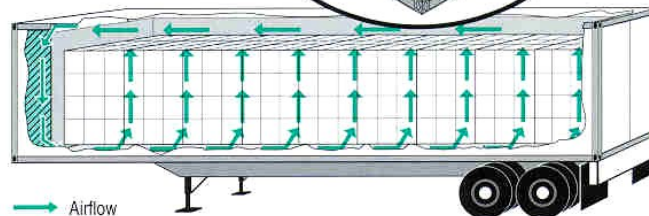
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Bottom Air Delivery

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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Marine Containers

- 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 when cross-stacked.
 - Internal packaging should not block air flow



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Incorrect Stowage

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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MA Controller

Fresh-air Exchange

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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 ft³ (113 m³) interior volume. Can haul >100,000 lbs (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. Unintended MA if the drains clog



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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!**
- Generally poor temperature control
 - Often no refrigeration & little air flow
 - Handling delays while waiting to be loaded
 - MA difficult even at the package level due to the poor temperature control
- Very low humidity



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Ice
bunker



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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 $\sim 1^{\circ}\text{F}$ (0.5°C) around the set point
 - Older systems with return air sensing should be set at least 2°F (1°C) above the set point



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Microprocessor Control = Good Insurance

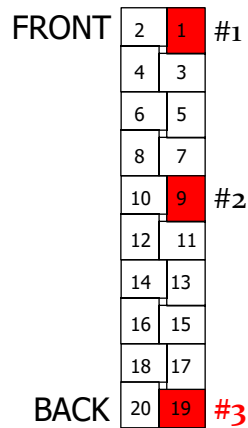
- Measures and controls discharge & return air temperatures
- Documents refrigeration unit performance.
- Optional features
 - Cargo temperature recording
 - Upper/lower set-point limits
 - Atmosphere management (CA & humidity)



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Placement of Temperature

Recorders



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.



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Quality In:Quality Out



- Pre-transit handling and preparation of the products, and the choice of transportation equipment & how it is used dictate the quality, safety, and shelf life after transport



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