Interactions between Refrigerated Trailers and Product

This publication has been developed by United World Cargo to better educate Shippers, Customers, Carriers, and Receivers on how equipment performance and product characteristics influence fruit and vegetable products upon delivery. Discussed are reefer temperature settings, trailer load patterns, and product respiration data for a representative range of full load commodity products.

Continuous vs. Cycle Sentry

Continuous setting **must** be used for produce loads, as they need continuous air flow to handle the heat of product respiration. Continuous air flow allows for more consistent temperature throughout the trailer for the duration of transport. All reefer units have a 'Set Point'. For example, if you have a set point of 33°F, the temperature reading displayed by the set-point will stay constant on a smart reefer download. On continuous setting, the reefer has a set defrost cycle (definition: Defrost cycle – the process of removing ice or frost buildup from a coil). The intervals are factory set for every 6 hours, but the unit will auto defrost based on a temperature difference across the coil. The defrost cycle can be changed to compensate for produce that has higher heat respiration, for higher ambient temperature (definition: Ambient temperature - the certain temperature within an enclosed space), and for door openings. For example, if it is a humid day and the driver is doing a lot of door openings, you may need to have a more frequent number of defrost cycles. Although the reefer has this defrost cycle on continuous setting, it does not change the product temperature due to the fact that most reefers have a very high heating capacity (definition: Heating capacity – The amount of heat energy needed to raise the temperature of a given mass of a substance by one degree Celsius). The temperature in the air of the reefer will heat at a faster rate than the temperature of the product that is in the trailer. The time of a defrost cycle is not is significant enough to affect the product temperature.

Below is an example of a temperature recorder printout for a reefer in continuous mode (note spike at end of 41°F is at unloading point).[i]

Typical pattern with reefer in continuous mode.

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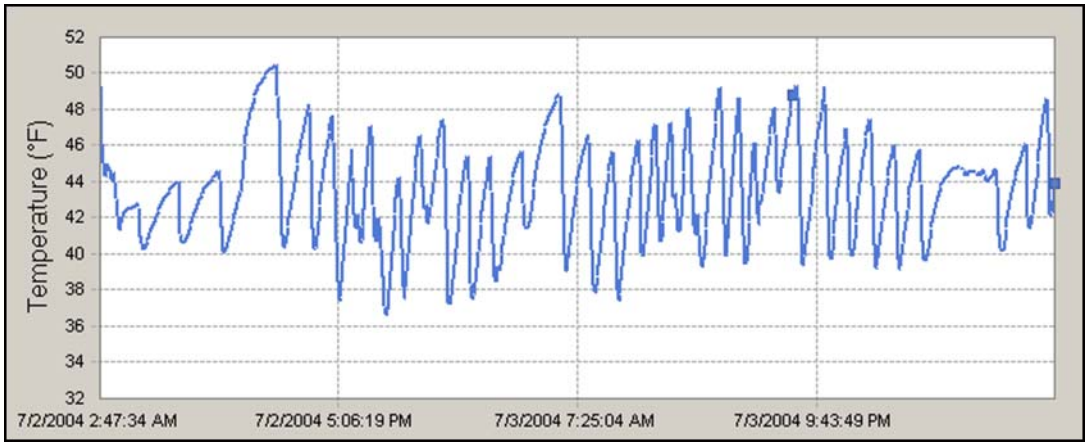
Cycle-Sentry setting should **only** be used for frozen loads, i.e. loads that are intended to ship colder than 24°F. Frozen loads can handle more significant temperature variances without causing damage to the product. On cycle-sentry, the load also has a 'Set Point.' For example, if you have a set point of 22°F, the set-point will also stay constant on the download, as it does on continuous setting. However, when the ambient temperature in the reefer drops to between .5 to 1 °F lower than the 'Set Point' (in this case that would be 21.5°F), it turns off. It then waits until temperature warms up 5°F past the set point (in this case, 27°F), and then turns itself back on. [ii]

Below is an example of a temperature recorder printout for a reefer in cycle-sentry mode:[iii]



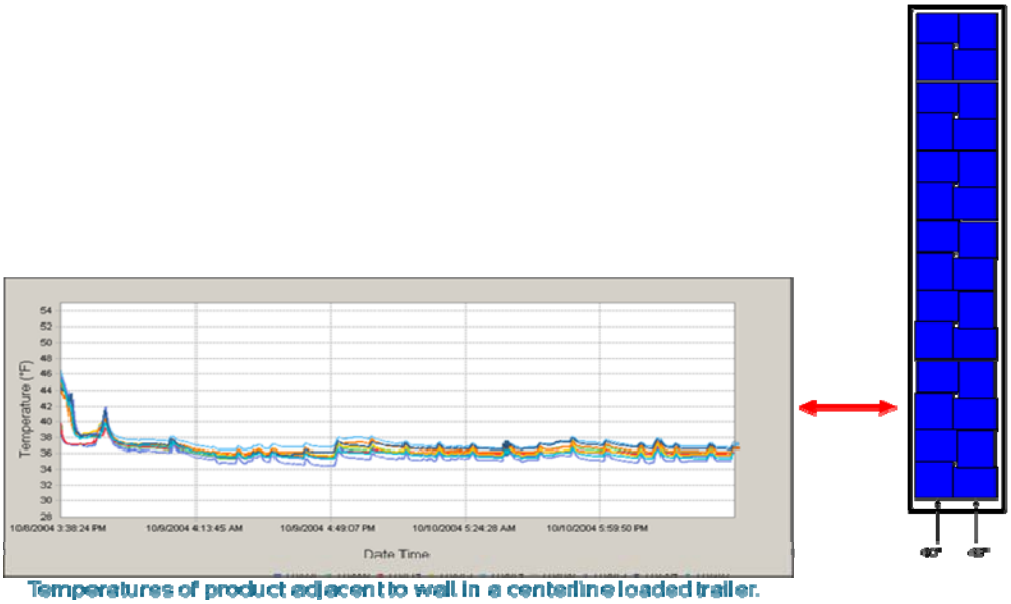
Typical pattern with reefer in cycle or fuel saver mode.

Produce loads **should not** be set on cycle-sentry, and the only benefit of operating on this setting is significant fuel savings. Because the temperature of a load on cycle-sentry can vary dramatically during the time of transport, this can cause freezing on top boxes or condensation in packaging.

Pallet Configuration in Reefer Units

This information illustrates how trailer pallet configuration and loading specifications can affect temptale recorder readings.

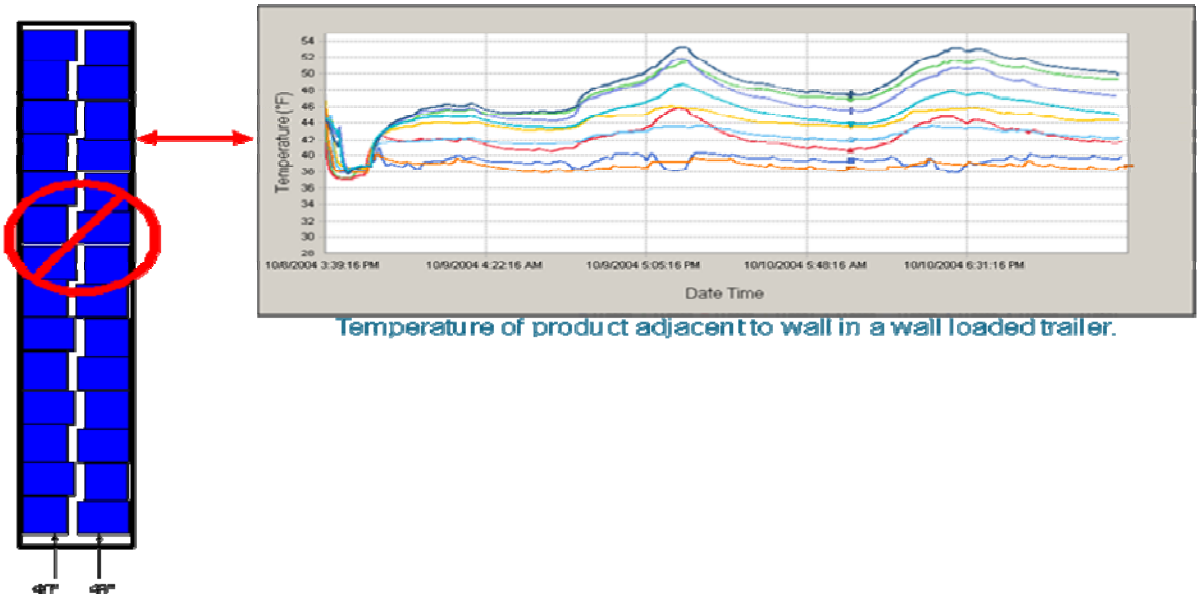
First, an example of a trailer that has been centerline loaded and the recorder reading this produces:[iv]



Temperatures of product adjacent to wall in a centerline loaded trailer.

Centerline loading prevents heat conduction between wall and product as it creates a gap between the wall and the product where air can flow to remove heat that penetrates the wall.

Second, an example of a trailer that has been wall-loaded and the subsequent temptale recorder reading:[v]



Temperature of product adjacent to wall in a wall loaded trailer.

Wall loading permits heat to be conducted through the walls and into the product. Therefore, produce loads **should not** be wall-loaded.

Temperature Recorder Placement

Temperature recorders are also commonly referred to as TempTales or Ryan recorders. According to Sensitech, the correct location of the TempTale is on the back right pallet facing the doors. If the TempTale is placed before the last pickup, the Temptale should still be placed on the last pallet for that pickup.

Below is an image of TempTale Placement:[vi]

Incorrect TempTale Placement

Correct TempTale Placement

Product Respiration

A reefer is **not** designed in any way to cool product; it is designed **only** to maintain the load temperature of product. Even state of the art technology in refrigeration can only "chill" product 2 degrees °F every 24 hours. Further, if the trailer is set to a very low temperature in an attempt to cool product at a faster rate than mentioned above, the unit can "freeze up" and inhibit the ability to maintain the desired temperatures after the product is loaded on the trailer. Or if a shipper loads "hot product" on the trailer, the moisture created can cause the unit to not cycle properly. [vii]

There are two sources of load based (or product based) heat: Sensible heat and vital heat. Sensible heat is also referred to as retained heat and is the amount of heat above the desired transit temperature in products and packages. Vital heat is generated by the respiratory activity of products like fruit, vegetables, and flowers.

Find below the product facts, and recommendations for avocadoes, mangoes, watermelons, tomatoes, apples, pears, and strawberries. These illustrate examples of the different product respiration rates, characteristics, and recommendations that are present in all fruits, vegetables, and flowers. Resources are from the UC Davis Post Harvest Technology Research and Information Center Produce Facts website, http://postharvest.ucdavis.edu/Produce/Producefacts/index.shtml. [viii]

Avocadoes [ix]

Optimum temperature: 41-55F for mature-green avocadoes, depending on cultivar and duration; 36-40F for ripe avocadoes.

Optimum relative humidity: 90-95%.

Rates of respiration:

Temperature	5°C (41°F)	10°C (50°F)	20° (68°F)
ml CO_2/ kg·hr	10-25	25-80	40-150*

*In layman's terms, this describes the rate that CO_2 will respirate depending on the temperature of the product.

Mangoes [x]

Optimum Temperature: 55F for mature-green mangos; 50F for partially-ripe and ripe mangoes.

Optimum relative humidity: 90-95%

Rates of respiration:

Temperature	10°C(50°F)	13°C(55°F)	15°C(59°F)	20°C(68°F)
ml CO_2/kg·hr	12-16	15-22	19-28	35-80

Watermelons [xi]

Optimum Temperature: 50-59°F. Storage life is typically 14 days at 59F with up to 21 days attainable at 45-50°F. For short-term storage or transit to distant markets (> 7 days), most recommendations use 45°F and 85-90% Relative Humidity as the acceptable handling conditions. Watermelons, are however, prone to chilling injury at this temperature. Extended holding at this temperature will induce chilling injury, rapidly evident after transfer to typical retail display temperatures. Many watermelons are still shipped without pre-cooling or refrigeration during transit. These fruit must be utilized for prompt market sales as quality declines rapidly under these conditions.

Optimum relative humidity: 85-90%; high relative humidity is generally advisable to reduce desiccation and loss of glossiness.

Rates of respiration:

Temperature °C	(°F)	ml CO_2 / kg·hr
0	32	NR
5	41	3-4
10	50	6-9
15	59	NA
20	68	17-25
25	77	NA

NR = not recommended due to chilling injury
NA = not available

Tomatoes[xii]

Optimum temperature: Mature Green 55-60°F, Light red (USDA Color stage 5) 50-55°F, Firm-ripe (USDA color stage 6) 44-50°F for 3-5 days. Mature green tomatoes can be stored up to 14 days prior to ripening at 55°F without significant reduction of sensory quality and color development. Decay is likely to increase following storage beyond two weeks, at this temperature. Typically 8-10 days of shelf life is attainable if the product is kept within the optimum temperature range after reaching the firm-ripe stage. Short term storage or transit temperatures below this range are used by some in the trade but will result in chilling injury after several days. Extended storage with controlled atmosphere has been demonstrated.

Ripening Temperatures: 65-70°F; 90-95% relative humidity for standard ripening, 57-61°F for slow ripening (i.e., in transit).

Optimum Relative Humidity: 90-95%; high relative humidity is essential to maximize post harvest quality and prevent water loss (desiccation). Extended periods of higher humidity or condensation may encourage the growth of stem-scar and surface molds.

Rates of respiration:

Temperature	ml CO_2/ kg·hr Mature-green Ripening
5°C (41°F)	3-4[NR]
10°C (50°F)	6-9 7-8
15°C (59°F)	8-14 12-15
20°C (68°F)	14-20 12-22
25°C (77°F)	18-26 15-26

Responses to ethylene: Tomatoes are sensitive to exogenous ethylene and exposure of mature-green fruit to ethylene will initiate ripening. Ripening tomatoes produce ethylene at a moderate rate and co-storage or shipment with sensitive commodities, such as lettuce and cucumbers, should be avoided.

Ripening: Faster ripening results from higher temperatures between 12.5 -25°C (55-77°F); 90-95% R.H.; 100 ppm ethylene. Good air circulation must be maintained to ensure temperature uniformity within the ripening room and to prevent the accumulation of CO_2. CO_2 (above 1%) retards the action of ethylene in stimulating ripening. The optimum ripening temperature to ensure sensory and nutritive quality is 20°C (68°F). Color development is optimal and retention of vitamin C content is highest at this ripening temperature. Tomatoes allowed to ripen off-the-vine above 25°C (77°F) will develop a more yellow and less red color and will be softer. Ethylene treatment typically extends ripening for 24-72 hours. A second treatment period may follow repacking if immature green fruit were included in the harvest.

Apples (Golden Delicious)[xiii]

Optimum Temperature: 32°F ± 2°F; Freezing temperature 29°F.

Optimum relative humidity: 90-95%

Rates of respiration:

Temperature	0°C (32°F)	5°C (41°F)	10°C (50°F)	20°C (68°F)
ml CO_2/ kg·hr	3-6	4-8	7-12	15-30

[1] Higher rates for riper apples.

Apples (Red Delicious)[xiv]

Optimum temperature: 32°F ± 2°F; Freezing temperature: 29°F.

Optimum relative humidity: 90-95%

Rates of respiration:

Temperature	0°C (32°F)	5°C (41°F)	10°C (50°F)	20°C (68°F)
ml CO_2/ kg·hr	2-5	3-7	5-10	12-25

Pears (Anjou, Bosc & Comice)[xv]

Optimum temperature: 30 to 32°F; freezing temperatures are 29 to 28°F.

Optimum relative humidity: 90-95%

Rates of respiration:

Temperature	0°C(32°F)	5°C(41°F)	10°C(50°F)	20°C(68°F)
ml CO_2/kg·hr*	1 - 3	3 - 6	5 - 10	15 - 30

*Low end for 'Anjou' and high end for 'Bosc' and 'Comice' pears.

Strawberries[xvi]
Optimum Temperature: 32 ± 1°F

Optimum Relative Humidity: 90 to 95%

Rates of Respiration:

Temperature	0°C (32°F)	10°C (50°F)	20°C (68°F)
ml CO_2/kg·hr	6 - 10	25 - 50	50 - 100

Conclusion

This document has demonstrated the various factors that are at work in each and every produce load. All of these factors must be taken into account when loading product, and when evaluating product upon delivery.

If the product pulps hot or cold upon loading, it must be noted that this will affect the ambient temperature inside the trailer and that this will also be reflected in the temptale recorder reading. It must be noted that temptale recorders are not designed to indicate set point or running temp of the reefer; their primary function is to record the ambient temperature inside a reefer.

With a better understanding of equipment performance and product characteristics, receivers are able to better evaluate the products they receive and ensure future success in deliveries.

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