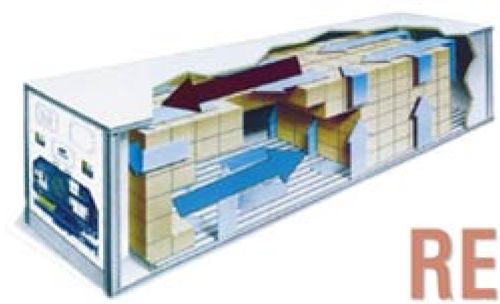
AIR CONDITIONING AND REFRIGERATION
Journal
The magazine of the Indian Society of Heating, Refrigerating and Air Conditioning Engineers

Issue : January-March 2005



CONTAINER REFRIGERATION
(Part 2)

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In this issue, we will examine the various types of refrigerated cargo and the implications of the different types on the performance and operation of container refrigeration machinery.

Question : What are the various types of cargo that can be carried in a refrigerated container?

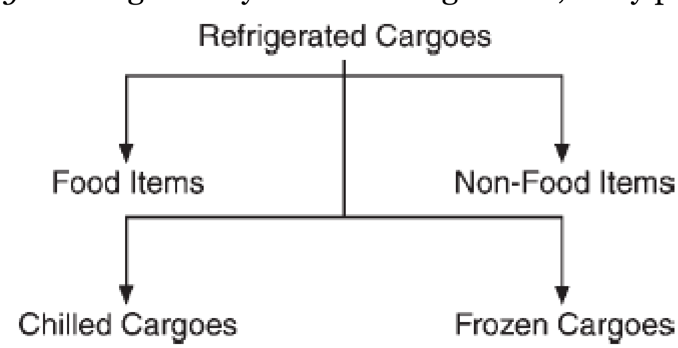
A. Refrigerated cargo carried in reefer containers can be classified as food items and non-food items. Examples of food items are fruits, vegetables, meat, fish, beverages, dairy products, ice cream, etc. Examples of non-food items are chemicals, explosives, leather, photo films, medicines, vaccines etc.

More importantly, refrigerated cargoes can be classified as *chilled cargoes* and *frozen cargoes*.

Chilled cargoes are those cargoes which are stored above –10°C. They are live cargoes with chemical reactions and processes going on within the product due to respiration, with continuous liberation of gases and heat. Chilled cargoes are also known as "perishable cargoes" in refrigeration parlance.

Frozen cargoes are those cargoes which are stored below –10°C. They are dead cargo, with no chemical processes or reactions taking place within the product and no liberation of gases or heat.

Chilled cargoes are temperature sensitive cargoes. The heat generated by the chemical reactions has to be led outside the cargo space faster than it is liberated to prevent any accumulation of heat and rise of temperature. Similarly, gases which are liberated as products of the chemical reactions have also to be drawn out of the cargo space, if found unsuitable for the cargo. Otherwise the cargo might deteriorate and get damaged. *Chilled cargoes* are generally fruits and vegetables, dairy products, chilled meat, beverages etc.

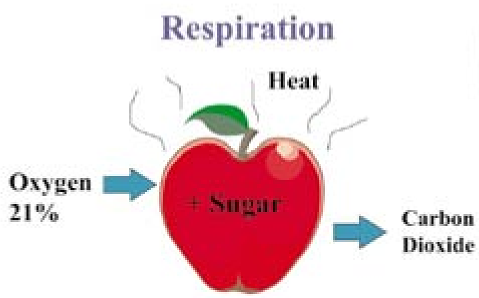


The temperature of *chilled cargo* needs to be maintained within a very narrow band of ± 0.5°C around the set point. Variation of temperature beyond this may enhance chance of cargo deterioration.

Myth: For all refrigerated cargoes, the lower the temperature, the better it is for the preservation of cargo.

Reality: For *chilled cargoes*, temperature must be maintained very close to the set point. If the temperature is allowed to fall lower than the set point, cargo damage may occur because of overcooling of cargo. *Frozen cargoes* do not get damaged even if temperature goes below the set point for prolonged periods of time. Instead of –20°C, if we maintain the temperature of ice cream at –25°C, it does not cause any damage or deterioration to the cargo. For frozen cargo, as there is no evolution of heat from the cargo, it is much easier to maintain the temperature.

Whenever there is a power breakdown or a planned and purposeful shutdown, it must be remembered that *chilled cargoes* are more vulnerable for damage and deterioration due to heat generation and accumulation inside the container resulting in temperature rise. *Frozen cargoes* do not get damaged because the temperature rise is very slow as there is not heat generation from the cargo. So, whenever possible, all *chilled cargo* reefer containers should be clustered together and connected to one power source or circuit breaker. Power should be restored as soon as possible for *chilled cargo* containers. Power to the *frozen cargo* containers can be restored later after all the chilled cargo containers have been activated.



Question : Does the reefer machinery perform in the same way for both the chilled and frozen types of cargoes?

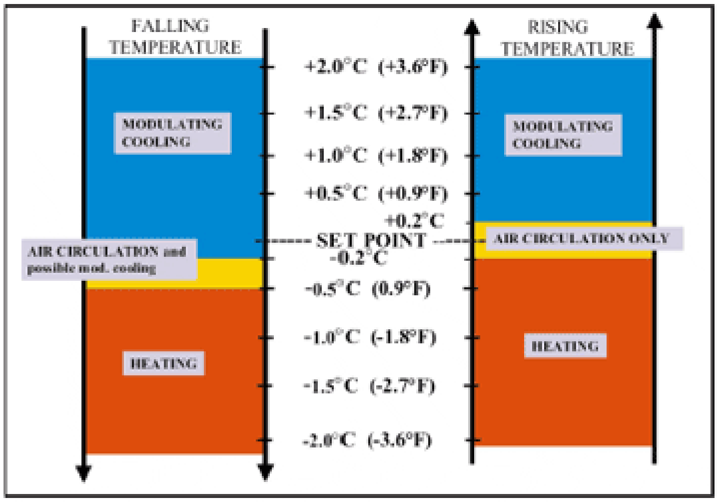
A. Obviously not. The refrigeration machinery behaves differently for chilled and frozen types of cargo.

Chilled Cargoes. When the set point temperature desired for the cargo is set to above –10°C, and the machinery connected and started, modulated cooling takes place, i.e., as the temperature inside the cargo chamber gets closer to the set point, the amount of refrigerant passing through the refrigeration circuit gets reduced, the additional refrigerant which is not under circulation gets stored in the receiver. When the temperature inside the cargo space reaches 0.2°C below the set point, the cooling is stopped. This is achieved by stopping the condensor fan and the compressor with a signal from the controller when a difference of 0.2°C is sensed between the set point and the actual temperature measured inside the container. This is a proactive step by the controller to prevent the temperature from falling far too much below the set point as chilled cargo will get damaged at temperatures much below the set point. The evaporator fans continue to run without the cooling circuit, circulating the same uncooled air and help in stabilizing the temperature closer to the set point due to heat generation from the cargo.

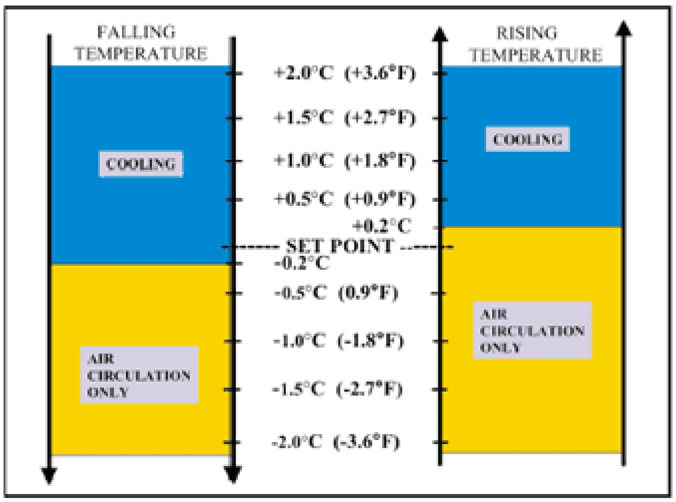
In case, the temperature of the cargo continues to fall further because of the momentum of the cooling cycle and the time taken for the temperature to stabilize along the entire length of the container, when the temperature reaches 0.5°C below the set point, the controller decides that the temperature must be prevented from falling any further, as a proactive step it activates the electric heaters. This is done by closing a heater relay inside the controller circuit, which energises a heater contactor and allows high voltage to flow through the heater coils. Since the evaporator fans are already running, hot air will be circulated through the cargo space inside the container.

As the temperature inside the container starts rising, when the temperature reaches 0.2°C below the set point, the heaters are stopped and only the evaporator fans are kept running. As the temperature continues to rise further, due to the heat generation from the cargo, once the temperature inside the container reaches 0.2°C above the set point, the cooling circuit gets activated through closing of the appropriate relays in the controller circuit, and the compressor and the condensor fan start running. The idea is to initiate proactive steps to keep the temperature of the cargo inside the container as close to the set point as possible, 0.2°C and 0.5°C being the limiting values.

Frozen cargoes. When the set point temperature desired for the cargo is set to below –10°C, and the machinery connected to power and started, nonmodulated cooling of the space takes place with the refrigerant flow kept fully (100%) in circulation through the refrigerant circuit. When the temperature reaches 0.2°C below the setpoint, as in the case of *chilled cargoes*, the cooling circuit gets switched off with the signal from the controller stopping the compressor and condenser fan. Only the evaporator fans continue to run. The evaporator fans continue to run until the temperature starts rising and reaches 0.2°C above the set point, when the cooling circuit gets activated again. In frozen mode, the heater coils do not get energized at all. The logic for this is that even if it takes longer time for the temperature to come closer to the set point or even if the cargo temperature falls below the set point for a prolonged period of time, cargo does not get damaged. So, the heater circuit need not be energized, thus achieving a saving in power.



Controller Set Point ABOVE -10°C (+14°F), or -5°C (+23°F) optionally
Perishable (Chill) Range Operation.



Controller Set Point at or BELOW -10°C (+14°F), or -5°C (+23°F) optionally
Frozen Range Operation.

Frozen cargoes run on non-modulated cooling so that the temperature can be brought down to the set point as soon as possible and saving power by cutting off the cooling circuit. It does not damage the cargo even if the temperature is lower than the set point for prolonged periods of time.

Evaporator Fans

Generally, there are two evaporator fans for a reefer container. Both of them are dual speed fans. Both of them run either at low speed or at high speed. (It is not possible to run one of the evaporator fans at low speed and the other at high speed). The running of the evaporator fans is controlled by two contactors with each contactor allowing power to be sent to both the fans either to low speed coils or to the high speed coils of both the evaporator fan motors.

Question : Is this cut-off temperature of –10°C between chilled cargoes and frozen cargoes sacrosanct? There may be some cargoes which are stored at more than –10°C and yet behave like frozen cargoes. How does the equipment treat and handle such cargoes – chilled or frozen?

A. Yes, there may be such cargoes which may be stored at more than –10°C, yet they may be frozen cargoes. The distinction point of –10°C is set as default by most of the manufacturers of reefer container machinery to control the operating logic of the various components. However, there is an option provided to change this setting from –10°C to –5°C. That means certain cargoes which are stored above –10°C, but below –5°C can be treated as frozen cargoes and the machinery will apply the logic of frozen cargoes.

Question : Why are two speeds required for the evaporator fans and when are the two different speeds used?

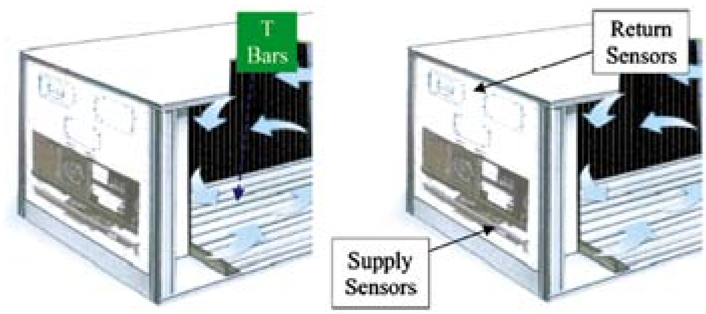
A. When carrying *chilled cargo*, both the evaporator fans run at high speed and when carrying frozen cargo, they run at slow speed.

Since *chilled cargoes* are temperature sensitive cargoes, as we need to maintain the temperatures within a very narrow range of ± 0.5°C, and as they are live cargo generating heat continuously, unless the heat generated is drawn away from the cargo space faster than it is generated, there will be heat accumulation and consequent cargo damage. To facilitate faster removal of the evolved heat, evaporator fans run at a higher speed.

Since *frozen cargoes* do not generate heat being dead cargoes, and cargo does not get damaged or deteriorated in spite of storage at temperatures much below the set point for prolonged periods of time, evaporator fans are run at lower speed, saving some power in the bargain.

Question : Where is the temperature measured inside the cargo space? Is there any difference in measuring points for the two different types of cargo?

A. The temperature sensors are located before the evaporator fans and are called "return air (temperature) sensors" and the ones after the evaporator coil are known as "supply air (temperature) sensors". Usually, with a normal running container machinery, there exists a temperature difference of 2-3°C between the supply temperature and the return temperature, the supply being always cooler than the return as it is after the cooling effect of the evaporator. The circulation of the cold air from the evaporator coil is through the bottom of the container. The hot air from the cargo being lighter tends to rise to the top of the container. The suction to the evaporator fans is from the top. The evaporator fans force the air downwards through the evaporator coil, cooling the air and the cold air and passes eventually through the bottom of the container. To facilitate the flow of cold air across the entire length of 20 ft. or 40 ft. of the container, the evaporator fans are designed to provide sufficient air throw. Further facilitation of the same is provided by the T bars in the floor. Cold air passes through the spaces between the T bars and travels right till the end of the container. Cargo is placed on top of the T bar floor and even spacing of the cargo allows cold air to pass through the cargo and cool the cargo. It is important to keep the spaces between the T bars clear, otherwise there will be obstruction to the flow of cold air. Dunnage, paper, plastic and other packing material may block the passage between the T bars.



When carrying *chilled cargo*, the supply air temperature sensor acts as a controlling probe and when carrying *frozen cargo*, the return air temperature sensor acts as a controlling probe. This implies that in chilled mode, the temperature at the supply sensor acts as the controlling point to initiate cooling circuit, heating circuit or to run only the evaporator fans. Since at no point of time, any part of *chilled cargo* should be exposed to cold air at a temperature lower than the set point, the temperature at the supply side is the limiting factor. For *frozen cargo*, return temperature sensor is the controlling probe because the temperature of the cargo can be brought down below the set point without causing damage to the cargo. Hence temperature of the cargo will be brought to the set point and maintained with lesser running of the cooling circuit achieving significant saving in power.

Question : What about the packages of chilled and frozen cargoes? Can they both be both identical?

A. No. For *chilled cargoes*, each piece of the cargo (fruit or vegetable) has to be cooled by exposing it to the cooled air. Each piece of the cargo should be wrapped in material which can allow cold air to pass through. Generally, each piece of cargo is carried in plastic net or thin porous paper. Chilled cargo pieces should not be wrapped in completely enclosed plastic wrapper as plastic is an insulator. A totally sealed plastic wrapper does not allow the cargo piece to breathe. After a short passage of time, there will be a deficiency of oxygen and an excess of carbon-dioxide and accumulation of heat and gases like ethylene being liberated from the cargo because of ripening. If plastic is used as a wrapping material, it must have sufficient holes to allow the cold air to touch the cargo piece, and to allow breathing of each individual piece of cargo.

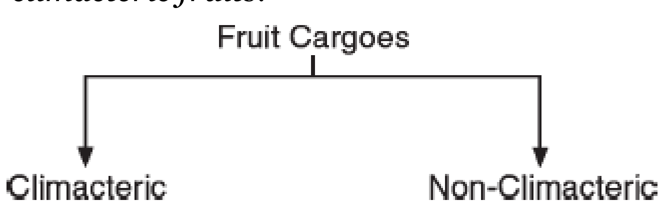
The cardboard or wooden boxes in which each individual piece of cargo is packed should not be air tight and a fully sealed container. They should have sufficient air holes all around the sides to allow cold air to pass through and cool each individual piece of cargo.

The same logic holds good for *frozen cargo*. The cold air should be allowed to touch the individual pieces of cargo. However, since *frozen cargo* does not generate heat nor gases as it is not a live cargo, the individual pieces of cargo may be packed in fully sealed air tight wooden or cardboard boxes.

Question : What are ethylene sensitive cargoes?

A. Ethylene is the sweet smelling gas which is evolved when fruits ripen. It is one of the products of chemical reactions taking place inside a fruit when fruits ripen. Other sources of ethylene are combustion of fuel in automobile engines, fluorescent light ballasts, and some fungi and bacteria. Though the quantity of ethylene generated is small (in ppm), it can affect the fruits to a considerable extent depending upon the type of fruit, and the amount and duration of exposure to the fruit. If not desired, ethylene produced while ripening of the fruit has to be drawn out from the atmosphere by using ethylene scrubbers which contain potassium permanganate which has the property of absorbing ethylene and converting it into harmless and ineffective products.

Depending upon their sensitivity to ethylene, fruits can be classified into *climacteric* or *non-climacteric fruits*.



Climacteric fruits are excessively sensitive to ethylene. They form an irreversible reaction which accelerates ripening uncontrollably. Once these fruits are exposed to even a small amount of ethylene, the ripening process cannot be retarded or controlled and they ripen at an accelerating pace. Such fruits must be consumed within a few days, otherwise they will become over-ripe and lose quality. Some fruits like tomatoes, bananas and honeydews are deliberately exposed to ethylene to ensure rapid and uniform cooling. On the other hand, for some fruits like kiwifruit and Bartlett pears, ethylene must be rigorously excluded, otherwise, they will become overripe and unusable.

Examples: apple, apricot, avocado, banana, blueberry, breadfruit, cherimoya, feijoa, fig, guava, jackfruit, kiwifruit, mango, muskmelon, nectarine, papaya, passion fruit, peach, pear, parsimmon, plantain, plum, sapote, soursop, tomato, watermelon etc.

Non-climacteric fruits are those fruits whose ripening process can be accelerated or retarded by exposing them to measured amounts of ethylene. By removing the ethylene at any stage of ripening, the process can be slowed down. The ripening process is not irreversible.

Examples: blackberry, cacao, cashew apple, cherry, cucumber, eggplant, grape, grapefruit, jujube, lemon, lime, loquat, lyches, olive, orange, pepper, pineapple, pomegranate, raspberry, satsuma mandarin, strawberry, summer squash, tamarillo, tangerine etc.

Examples: Some varieties of apples, apricots, avocados, asparagus, cantaloupes, snap beans, cherimoya, cranberry, cucumber, eggplant, flowering potted plants, foliage plants, grapefruit, kiwifruit, lemon, limes, olives, papaya, bell peppers, pineapple, tomatoes etc.

Recommended Storage Temperatures for Various Refrigerated Products

A. Fresh Fruits, Vegetables, Flowers etc

Item	**°C**	**Item**	**°C**
Apple, Golden Delicious	0-2	Lime	10-15
Apple, Granny Smith	0-2	Loquats	0-0.5
Apple, Jonathan	0-1	Lychee	5-12
Apple, Mcintosh	2-3.5	Mango	10-15
Apple, Red Delicious	0-1	Melon : Honeydew, Casaba, Florida, Texas, Crenshaw and Persian	7-10
Apricot	- 0.5 to 0	Mimosa (Cut)	6-8
Artichoke	0-1	Mushroom	0-2

Asparagus	1-3	Nectarine	- 1 to 0
Avocado	5-13	Okra	7-10
Bananas	13-14.5	Olive	5-10
Beans	4-7	Onion (Bulb)	0-1
Blueberry	- 0.5 to 0	Orange	5-10
Bonsai	9.5-12	Papaya	10-15
Broccoli	0-1	Parsley	0-1
Brussels Sprouts	0-1	Pea, sugar	0-2
Cabbage	0-2	Peach, Clingstone	- 0.5 to 0
Cantaloupe	2-5	Peach, Freestone	- 0.5 to 0
Carrots	0-1	Pear, Anjou	- 1 to 0
Cauliflower	0-1	Pear, Bartlett	- 1 to 0
Celery	0-1	Pear, Bosc	- 1 to 0
Cherry, Sweet	0 to -1	Pepper, Bell	7-12
Chili Pepper (Fresh)	5-8	Persimmon	- 1 to 0
Carnation (Cut)	- 1 to 1	Pineapple	8-13
Chrysanthemum (Cut)	0-1	Plum	- 0.5 to 0
Corn, Sweet	0-2	Potato	- 3-7
Cucumber	10-12	Radishes	0-1
Durian	13-17	Rambutan	8-15
Eggplant (Aubergine)	10-13	Raspberry	- 0.5 to 0
Fig	- 1 to 0	Rose (Cut)	0-1
Flowering Bulb	- 2 to 15	Spinach	0-1
Flowering Potted Plant	1-16	Strawberry	- 0.5 to 0
Foliage Plant	13-17	Sweet Potatoes	13-15.5
Garlic	0-2	Sweetsop (Sugar apple, Custard apple)	12-20
Ginger	12.5-13	Tomato	10-20
Gladiolus (Cut)	0-2	Tulip (Cut)	1
Grape, American	0 to 0.5	Turnips, Green	0.5-1
Grape, European	- 1 to 0.5	Watermelons	10-15.5
Grapefruit, Arizona and California	14-15.5	Yams	13-15
Grapefruit, Florida and Texas	10-15.5		
Kiwifruit	0-2		
Lemon	12-15		
Leeks	0-0.5		
Lettuce, Crisphead	0-1		
Lily (Cut)	1		

Recommended Storage Temperatures for Various Refrigerated Products

B. Dairy Products			
Item	**°C**	**Item**	**°C**
Butter, Fresh	4	Cheese	0-12
Butter, Frozen	- 23	Fresh Cheese	0-4
Margarine	1.7	Ice Cream	- 26 to - 29
Milk	0-1	Chocolate	10-18
Cultured Milk Products	0		

Recommended Storage Temperatures for Various Refrigerated Products

C. Fish, Meat etc.			
Item	**°C**	**Item**	**°C**
Meat and Seafood	- 2 to 5	Deep Frozen Fish and Deep Frozen Fruit	< - 20
Frozen Foods	< - 18	Juice Concentrate	< - 18
Poultry and Eggs, Fresh	- 3 to 1	Deep Frozen Vegetables	< - 20
Poultry, Hard Chilled	- 18 to - 3	Super Chilled Fresh Meat	10-18
Poultry, Eggs	4.5 - 7	Chilled Meat Products, Retail Packed	- 2 to - 1
Deep Frozen Meat, Poultry, Shellfish (lobster, prawns, shrimps etc), Fish (fatty)	< - 22	Manufactured Meat	- 1
Lightly-Preserved-Fish Products	1	Chilled Poultry	- 1
Semi-Preserved-Fish Products	1.5		

This list is not exhaustive. There are many more products which are not covered in the above list. The shipper's guidelines must be followed for all refrigerated cargoes for the correct storage temperature.