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ICCT

ICCT guidelines on Cargo Temperature Maintenance

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Introduction

Why temperatures need to be maintained

The basic requirement in carriage of temperature-controlled cargoes is to deliver the goods in, as far as is possible, the same condition as that at which they were received. As temperature-sensitive goods deteriorate at a rate that is temperature dependent, temperature maintenance is paramount.

For frozen goods, this requires the maintenance of a temperature low enough to effectively stop deterioration. For chilled goods, temperature must be maintained at the lowest possible temperature that will not damage the cargo. The actual temperature required will depend on many factors, and may require expert advice.

Factors to be considered

Factors to be considered to ensure proper temperature maintenance include precooling of cargoes and carriage spaces, packaging and stowage, air circulation rate, and time off power. This is in addition to the fundamental requirement of providing air at the correct temperature to the cargo space. These factors are considered in more detail below.

Precooling of cargoes

Transport refrigeration equipment is designed to maintain temperature, not to reduce it. It is therefore usually essential that temperature-sensitive goods are loaded at the carriage temperature. Specialist equipment for cooling fruit and vegetables can cool from ambient to storage temperature in a few hours or less. If warm produce is loaded into transport equipment, cooling times of several days will be experienced (though with high respiration produce, temperatures may rise uncontrollably due to the heat produced).

There are two general exceptions of note. The first is hardy citrus fruit, which combines low respiration rates with long storage life and therefore is often acceptably cooled over a period of days. The second is banana, which has a high carriage temperature (meaning there is usually plenty of refrigeration capacity available) and a relatively low stowage density. Banana is usually cooled successfully within 48 hours in suitable transport equipment. Although these exceptions are substantial in terms of tonnage carried, they are very much exceptions in their precooling requirements.

Precooling of the cargo space itself is worthwhile, whenever it does not introduce other problems such as ice or condensation. For ships' holds, precooling is normal. For containers and trucks, it is only advisable when loading from a temperature-controlled space. Pre-cooled containers and trucks loaded from ambient are liable to excessive condensation on surfaces, resulting in immediate defrosting and consequent lack of cooling at the time when it is most needed, immediately after loading. There can also be handling and safety issues if ice forms on the floor during loading.

For frozen goods, pre-cooling is done as part of the production process. It is important that adequate time is allowed for full freezing of thick items. If the goods are only partially frozen, there will initially be an averaging out of temperature in transport which could lead, amongst other things, to softening and consequent stowage problems.

For fresh produce, purpose-designed forced air coolers are preferred. For some produce, more rapid cooling using ice banks or vacuum coolers is used. It is unlikely that leaving goods in a cool store without any special provision for produce cooling will ever be sufficient.

Whatever the method of cooling used, it is important that it is effective in cooling through to the centre of pallets and does not only cool the outer layers of the cargo.

In some trades, it is regular practice to insert thermocouples into pallets when they are loaded, so that cargo centre temperatures may be monitored. In some cases the thermocouples may be long enough to allow cargo temperature checks from outside the closed container. This practice is recommended where it is practicable, but care is needed in the selection of probes and instruments to ensure accuracy of results.

Temperature gradients

The temperature in a cargo will never be completely uniform; gradients always exist. If cool air enters a cargo space, it gains heat from the flow through the walls of the space, from any cargo that is warmer than the air, and from respiration heat from fresh produce. Cargo that is isolated from the airflow by packaging will receive less cooling. It is important that produce with high respiration rates is packaged in well-ventilated packages to allow heat to be removed.

The heat ingress through the walls of the space will depend on the difference between cargo temperature and ambient temperature, and also on the quantity and quality of thermal insulation in the walls. Thermal insulation deteriorates with time, and deteriorates rapidly if damaged so that moisture can enter. Other things being equal, there will be greater temperature gradients in older trucks and containers. It is worth remembering that in winter conditions when ambient temperatures are colder than cargo temperatures, temperature gradients may be reversed.

The greater the rate of air circulation in the cargo space, the less the temperature gradient will be, but the greater the power required for fans and refrigeration. It is usual to use a reduced air circulation rate for frozen goods (which are less critical regarding gradients) compared to chilled goods. The design of transport refrigeration equipment is always a compromise between low temperature gradient and low power requirements.

In large ships' holds with small external surface area, temperature gradients under steady conditions will often be less than 1ºC. In trucks and containers, gradients can be very variable; the following table indicates the likely temperature range in non-respiring goods. This table is based on some general assumptions regarding air circulation rate and wall heat leakage which are representative, but may not cover all cases. The data is based on “new” equipment which meets ISO or ATP standards, and on “old” equipment which is in generally good condition but is at least ten years old.

Table 1 – predicted temperature ranges in non-respiring cargoes in refrigerated trucks or containers.

Type of equipment	Cargo temperature	Ambient ºC	Range ºC
New	-20ºC frozen	30	4.0
New	-20ºC frozen	10	2.4
New	0ºC chilled	30	1.7
New	0ºC chilled	10	0.6
Old	-20ºC frozen	30	5.5
Old	-20ºC frozen	10	3.3
Old	0ºC chilled	30	2.3
Old	0ºC chilled	10	0.8

Times off power

If a transport refrigeration unit is without power, there will be no temperature control and no air circulation. Time off power should therefore be minimised. From what has been said above regarding temperature gradients, it will be clear that the effect of time off power will depend on cargo temperature, ambient temperature, quality of insulation, and respiration rate. It will also depend on the density and other characteristics of the cargo and its packaging, and on the mass of cargo carried. Any time off power will lead to an increase in temperature gradient, as warming will be from the outside surfaces and by respiration of the cargo.

Because of all these factors, there are no reliable rules of thumb for estimating the effects of time off power. There are some relatively straightforward graphical methods which can give useful estimates, but accurate calculations require detailed computer simulations.

Times off power include delays in loading when partly loaded cargo spaces may be left awaiting further cargo. Such delays, if no refrigeration is provided, can result in excessive cargo warming.

The rule should be to always avoid any longer loss of power than is absolutely necessary.

Air gaps and chimneys

If air gaps or chimneys are left in a stow, they provide an easier route for airflow than that through the cargo. Air that does not go through the cargo cannot remove respiratory heat, and air moving through chimneys near the air distribution area cannot reach the further parts of the cargo. So, gaps and chimneys can reduce the ability to maintain temperature.

There is evidence to show that a total free floor area of up to 5% of total area has a limited effect on airflow, but a free area of 10% can reduce the useful airflow by 20%. This means that any free area for chimneys or gaps must not exceed 5% of total floor area. Furthermore, the free area must not be adjacent to the air distribution point, or excessive short-circuiting of air can occur. As a general rule, gaps and chimneys are to be avoided, and if they are a necessary part of the stow, their effects should be minimised by covering open floor areas with board or other dunnage materials, and by blocking off the sides of pallets adjacent to chimneys.

The air gap above the cargo is critical to good airflow. Maximum load lines are usually provided in cargo spaces, and these must be observed. Loading above these lines will result in reduced overall air circulation and poorer temperature control.

The design of packaging also affects airflow. Cartons are sometimes designed to be suitable for horizontal airflow in pre-cooling facilities, with little consideration of the vertical airflow in transport equipment. In this case, the ability to recover any increase in temperature during times off power is severely reduced.

<u>References</u>

The information relating to temperature gradients in containers is based on a fuller discussion which may be found as follows:

Heap, R D, *Design and performance of insulated and refrigerated ISO intermodal containers*, Int. J. Refrig. 1989 Vol 12 May, 137-145.

Data on temperatures actually measured in containerised cargoes is reported in:

Heap, R D, Pryor, G J, *Cargo temperatures in containerised transport,* IIF-IIR Commissions B1, B2, D1, D2/3 – Palmerston North (New Zealand) – 1993.

Effects of air gaps and chimneys are discussed in:

Mohlin,R,Oleszco,J, *Studies of air distribution in the holds of a refrigerated ship….* IIF-IIR Commission D2/3 – Gdansk (Poland) – 1994, 106-116.

Lindau,LEH,Mathisen,IV, *Transportation and ripening of palletised bananas,* IIF-IIR Congress – Venice – 1979, Vol.4, 477-491.

There are also four relevant papers authored by N.Amos et al. in the proceedings of the IIF-IIR Washington Congress, 2003.