Reefer matters

A focus on some of the issues surrounding the carriage of refrigerated cargoes
Carriage instructions for refrigerated cargoes

Many shippers and carriers are prepared to accept inadequate instructions either through ignorance or through unquestioning acceptance of what has been accepted previously.

Introduction

Refrigerated cargoes are invariably perishable to a greater or lesser degree, and their safe carriage depends on maintaining suitable storage conditions during transportation. This is true for all modes of transport and all cargoes, though conditions are more critical for longer journey times and for more perishable commodities.

Refrigerated cargoes include both frozen and chilled goods, the latter including fresh fruits and vegetables. Generally, frozen goods do not suffer if over-cooled, whereas chilled goods can be damaged by low temperatures, either by freezing or by chilling injury to fresh produce. Much tropical and sub-tropical produce is liable to chilling injury if subjected to temperatures below those usually experienced in the growing area.

Successful transportation is dependent on the carriage instructions, which define the conditions in which the goods are to be carried. If these instructions are incomplete, inadequate, contradictory, or wrong, then problems can be expected. For the shipper, there is the risk of loss of cargo. For the carrier, there is the risk of a claim even if the goods are undamaged. Many shippers and carriers are prepared to accept inadequate instructions either through ignorance or through unquestioning acceptance of what has been accepted previously by themselves or others. Instructions may be based on goods of different origin, which may have different requirements.

The way in which cargo is stowed into holds or stuffed in containers is important for successful carriage, and is dealt with later.

These recommendations have been drawn up to assist both shippers and carriers to re-assess their carriage instructions in order to improve the operation of refrigerated transport chains. Any suggestions for improving these recommendations would be welcome. First, general requirements are considered. Thereafter, separate sections relate to containerised cargoes and to shipments in reefer vessels. For ease of reference, points that are the same for both types of transport are repeated in the appropriate sections.

General requirements

The responsibility for specifying carriage instructions is that of the shipper, the owner of the goods. Only the shipper knows the full nature of the goods, their prior history and their requirements. Frequently this responsibility is passed to the carrier, but in this case the shipper should agree the acceptability of the specified conditions prior to shipment. In either case, the exact nature of the cargo needs to be known – in the case of fruit, for example, carriage requirements may vary dependent on type, variety, maturity, origin and growing season conditions.

- If mixed loads of differing commodities are to be carried in a single cargo space, it is necessary to consider compatibility of temperature, atmosphere (especially ethylene levels) and liability to taint. This will usually require specialist cargo care advice.

Generally frozen goods do not suffer if over-cooled
It may be necessary to ensure that carriage conditions are specified to all carriers in the transport chain, as on occasions an international journey may use different carriers at the start and end of the journey.

Items such as relative humidity and maximum time without refrigeration should not be over-specified but should meet the necessary requirements of the goods.

Over-specification of requirements is to be avoided as it tends to lead to more, and sometimes spurious, claims regarding technicalities which have not actually affected cargo quality.

Many of the items listed here may be taken for granted in the case of regular shipments, but may need to be specified if a new carrier is used.

Specific requirements for containerised cargoes
The parameters that may be included in carriage instructions for containerised refrigerated cargo are listed below:

- Pre-stuffing sanitation.
- Pre-cooling of containers.
- Cooling during part-loaded conditions.
- Prohibition of stuffing cargo at mixed temperatures.
- Stowage requirements.
- Ventilation.
- Carriage temperature.
- Maximum time with refrigeration.
- Air circulation rate.
- Relative humidity.
- Measurement and reporting requirements.
- Special conditions for cold weather.
- Need to pass instructions to subsequent carrier.
- Need to notify if limits exceeded.

For controlled atmosphere shipments, additionally:

- Levels (ranges) for O₂, CO₂, humidity, ethylene.
- Permitted time to reach specified levels.
- Procedure in event of CA system failure.

Safety requirements.

Discharge atmosphere requirements.

Each of these is considered below:

**Pre-stuffing sanitation**
The proper cleanliness and lack of odour in containers to be used for refrigerated goods should be a matter of normal good practice, but any special or particular needs should be identified.

**Pre-cooling of containers**
Pre-cooling is only useful when loading from temperature-controlled loading bays; in other conditions, it can result in excessive moisture ingress from the atmosphere and is not recommended.

**Cooling during part-loaded conditions**
Part-loaded containers should be closed and temperature maintained if there is a delay before complete loading.

**Prohibition of stuffing cargo at mixed temperatures**
Properly pre-cooled cargo and substantially warmer cargo should not be mixed.

**Stowage requirements**
Any special stowage requirements, such as a protected or underdeck stow, should be stated.

**Ventilation**
The rate of fresh air ventilation for fresh produce should be specified. This should be as an absolute figure in cubic metres per hour. The specification of a percentage rate of ventilation only has meaning if related to a specific container size and a specific model of refrigeration unit.
Carriage temperature
It is not physically possible to provide refrigeration in the absence of temperature differences, both between air and goods and within the bulk of the goods. The only temperature which can be controlled is the set point, which corresponds to air delivery temperature for chilled goods and to air return temperature for frozen goods.

The term 'carriage temperature' therefore has little meaning, and 'set point temperature' should be specified. If appropriate, this may be augmented by a maximum allowable temperature during periods without refrigeration.

Although degrees Celsius (°C) are the international standard, in the USA degrees Fahrenheit (°F) are still commonly used. As zero degrees C is a common chilled goods temperature and zero degrees F is a common frozen goods temperature, great care is needed to avoid possible confusion of units.

Relative humidity
When equipment with humidity control is used, a range must be specified. It is difficult to measure humidity regularly to better than the nearest 2 to 3%, so an acceptable range of at least ±5% should be specified, albeit with a tighter target. Special equipment is available to maintain either high (e.g. 90%) or low (e.g. 50%) humidity. Without such equipment, relative humidity is not controllable and should not be specified.

Measurement and reporting requirements
It is normal to record air temperature in refrigerated containers, and some equipment also records delivery air temperature. Any specific shipper requirement for reporting temperatures should be stated. When the refrigeration unit is not running, the recorded temperatures do not reflect cargo temperatures. Shippers may choose to put their own recording equipment within cargo, in which case they should inform both carriers and receivers.

Special conditions for cold weather
Sometimes special requirements exist for exceptionally cold conditions. However, it should be noted that most transport refrigeration equipment will control temperature using either cooling or heating as necessary to maintain specified conditions.

Need to pass instructions to subsequent carrier
If there is uncertainty at the start of a voyage as to who will be the final carrier, it may be necessary to request the initial carrier to pass on carriage instructions.

Need to notify if limits exceeded
Procedures for notification of out of specification conditions should be established prior to acceptance of cargo for shipment. This could apply to warm loading, or to equipment failures, for example. Standard procedures and safe limits should be available.

Additional requirements for controlled atmosphere shipments
Controlled atmosphere (CA) systems are designed to maintain an atmosphere different from normal, usually with low oxygen and increased carbon dioxide. They enhance the storage life of some produce when used in conjunction with refrigeration. There are additional requirements for such shipments, as follows:
Levels (ranges) for O₂, CO₂, humidity, ethylene
For each of the atmospheric gases to be controlled, upper and lower concentration limits should be specified.

Permitted time to reach specified levels
The maximum time allowed to reach the specified levels may be laid down.

Procedure in event of CA system failure
The failure of a CA system will not necessarily have a drastic effect on the produce if the refrigeration continues to run. In these circumstances it will be necessary to introduce fresh air ventilation to fruit and vegetable cargoes. This should be specified.

Safety requirements
CA produces an atmosphere which is deadly to humans – breathing an oxygen-depleted atmosphere induces rapid unconsciousness and may result in death. Adequate safety systems must be in place, and these may need to allow for the possibility of stowaways in the cargo.

Discharge atmosphere requirements
The safety requirements extend to those unloading cargoes. Proper ventilation prior to entering containers and training of workers are both necessary.

Containerised transport of perishables without refrigeration
Some perishable commodities are carried without refrigeration, possibly for very short-duration journeys, or in ventilated equipment. In these cases it is wise to consider which of the previous requirements may still apply.

Products with limited temperature sensitivity may be carried under refrigeration for certain journeys only. The following guidelines suggest when this may be appropriate:

● For any goods requiring close temperature control, refrigeration is essential. If temperatures need to be maintained within a band of 2°C or less, refrigeration should be virtually continuous.

● At the other extreme, for less sensitive goods with a maximum temperature tolerance of 30°C or above, refrigeration is only necessary for storage on land at high ambient temperatures. For containerised shipments at sea, a protected stow may be requested.

● If the maximum permitted temperature is 25°C or lower, refrigeration should be used for any journeys through the tropics and for any journeys anywhere in a summer season.

● If cargo requirements are marginal, either in terms of temperature tolerance or in terms of possible delays at high ambient temperatures, then the only safe option is to use refrigeration.

● Frozen foods may sometimes be carried without refrigeration for short journeys as long as the cargo is not subjected to more than the specified maximum temperature. This should only be done with the consent of the owner of the goods.

Specific requirements for reefer ships
The parameters that may be included in carriage instructions for refrigerated cargo are listed below:

● Pre-loading sanitation.

● Pre-cooling of cargo space.

● Cooling during part-loaded conditions.

● Prohibition of loading cargo at mixed temperatures.

● Stowage requirements.

● Ventilation (or lack of) during cooling.

● Ventilation thereafter.

● Carriage temperature.

● Air circulation rate.

● Relative humidity limits or targets.

● Carbon dioxide limits or targets.

● Ethylene limits.

● Measurement and reporting requirements.

● Special conditions for cold weather.

● Need to pass instructions to subsequent carrier.

● Need to notify if limits exceeded.

For controlled atmosphere shipments, additionally:

● Levels (ranges) for O₂, and CO₂, humidity, ethylene.

● Permitted time to reach specified levels.

● Procedure in event of CA system failure.
Kiwi fruit need to be carried using a fresh-air ventilation system, so the possibility of cross contamination of the atmospheres from different cargoes must be considered carefully at the time of loading - see page 15

- Safety requirements.
- Discharge atmosphere requirements.

Each of these is considered below.

**Pre-loading sanitation**
The proper cleanliness and lack of odour in compartments to be used for refrigerated goods should be a matter of normal good practice, but any special or particular needs should be identified.

**Pre-cooling of cargo space**
The pre-cooling of cargo spaces removes heat from steelwork and provides a check on the operation of the refrigeration system. However, an excessive pre-cooling time only wastes energy and time. Duration of 24 hours after the required temperature has been reached is sufficient. The required pre-cooling temperature may be a few degrees lower than required transport temperature.

**Cooling during part-loaded conditions**
Part-loaded spaces should be closed and temperature maintained if there is a delay before completing loading. Care should be taken to ensure that under these conditions the temperature is not held at a precooling temperature below the required transport temperature for long enough to damage the cargo.

**Prohibition of loading cargo at mixed temperatures**
Properly pre-cooled cargo and substantially warmer cargo should not be mixed at loading.

**Stowage requirements**
Any special stowage requirements should be stated.

**Ventilation (or lack of) during cooling**
For most refrigerated cargoes, the cargo should be loaded at the required carriage temperature. For some cargoes, notably bananas and the less sensitive citrus varieties, cooling in transit is normal. In these cases a period of 48 hours should be specified, during which fresh air ventilation is stopped to allow maximum refrigeration.

Reference is sometimes made to the ‘reduction period’ which is the time from hatch closure to the air return temperature reaching within 18°F of the requested air delivery temperature. This is a parameter which may usefully measured and reported but should not be specified.

**Ventilation thereafter**
After cooling, or throughout in the absence of cooling, the rate of fresh air ventilation for fresh produce should be specified. This may be as an absolute figure in cubic metres per hour, or as a rate in air changes per hour of the empty volume of cargo space. Alternatively it may be linked to measured values of humidity, ethylene or carbon dioxide. Care is necessary to avoid requirements that conflict.

**Carriage temperature**
It is not physically possible to provide refrigeration in the absence of temperature differences both between air and goods and within the bulk of the goods. Carriage temperature for chilled goods must therefore be specified as the air delivery temperature. Pulp temperatures may usefully be measured and reported.

It may be required to specify a lower temperature for a limited period to ensure rapid cooling of warm cargo, known as ‘shock treatment’. Dual-temperature regimes, in which the delivery air temperature is changed after a specified period of days, may also be stipulated.

For frozen cargo, it is usually sufficient to specify a maximum temperature that should not be exceeded. This may be subject to qualification for short periods. For example:

*Cargo temperature shall not exceed -18°C, except for short periods during power disconnection or defrosting, when temperatures shall not exceed -15°C. A single specified 'carriage temperature' is a meaningless specification that should never be accepted.*

Although degrees Celsius (°C) are the international standard, in the USA degrees Fahrenheit (°F) are still
commonly used. As 0°C is a common chilled goods temperature and 0°F is a common frozen goods temperature, great care is needed to avoid possible confusion of units.

For USDA and other cold treatment quarantine requirements, maximum pulp temperature may have to be maintained below a specified temperature throughout a continuous period of days or weeks, and only approved equipment may be used.

**Air circulation rate**
The rate of circulation of air around and through the cargo controls the range of temperature within the cargo, and also the rate of cargo cooling. Minimum rates may be specified, usually as multiples of the empty volume of the hold per hour. Often these multiples are misleadingly referred to as 'air changes per hour', or 'ACH', a term best used for ventilation rather than circulation rates.

**Relative humidity limits or target**
Relative humidity may not be specifically controllable in shipments; if there are critical requirements, either special equipment or special packaging or both will be required. A sensible specification is as follows:

*Relative humidity should be maintained at the maximum possible, after the delivery air temperature and fresh air ventilation requirements have been met.*

Over-specification of humidity requirements is likely to lead to conflicting instructions. When special equipment with humidity control is used, a range must be specified. It is difficult to measure humidity regularly to better than the nearest two to three percent, so that an acceptable range of at least plus or minus five percent must be specified, albeit with a tighter target.

**Carbon dioxide limits or target**
For many fruits, a maximum level of carbon dioxide may be specified, this to be the overriding parameter for ventilation rate control. Care is necessary to avoid conflicting ventilation requirements.

**Ethylene limits**
The measurement or specification of ethylene levels is rare, as accurate measurement at very low concentrations needs specialised equipment. If limits are to be specified, the measurement and control regime must also be specified.

**Measuring and reporting requirements**
It is normal for carriers to measure temperatures of the air in ships’ holds. Any specific shipper requirement should be stated, especially if it involves cargo rather than air temperature. Shippers frequently choose to put their own recording equipment within the container/cargo in which case they should inform both carriers and receivers.

**Special conditions for cold weather**
Sometimes special requirements exist for exceptionally cold conditions. However, it should be noted that most transport refrigeration equipment will control temperature using either cooling or heating as necessary to maintain specified conditions.

**Need to pass instructions to subsequent carrier**
If there is uncertainty at the start of a voyage as to who will be the final carrier, it may be necessary to request the initial carrier to pass on carriage instructions.

**Need to notify if limits exceeded**
Procedures for notification of out of specification

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Frozen boneless chicken

Plums, being loaded on board this reefer, are climacteric and tend to ripen rapidly during transit and storage.
conditions should be established prior to acceptance of cargo for shipment. For example, this could apply to warm loading, or to equipment failures. Standard procedures and safe limits should be made available.

**Additional requirements for controlled atmosphere shipments**

Controlled atmosphere (CA) systems are designed to maintain an atmosphere different from normal, usually with low oxygen and increased carbon dioxide. They enhance the storage life of some produce when used in conjunction with refrigeration.

There are additional requirements for such shipments as follows:

**Levels (ranges) for oxygen, carbon dioxide, humidity and ethylene**

For each of the atmospheric gases to be controlled, upper and lower limits should be specified.

**Permitted time to reach specified levels**

The maximum time allowed to reach the specified levels may be stipulated.

**Procedure in the event of CA system failure**

The failure of a CA system will not necessarily have a drastic effect on the produce if the refrigeration continues to run. In these circumstances it will be necessary to introduce fresh air ventilation, which should be stated.

**Safety requirements**

CA produces an atmosphere that is fatal to humans – breathing an oxygen-depleted atmosphere induces rapid unconsciousness and may result in death. Adequate safety systems must be in place, and these should always admit the possibility of stowaways in the cargo.

**Discharge atmosphere requirements**

The safety requirements extend to those unloading cargoes. Proper ventilation prior to opening cargo spaces and training of workers are both essential.

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**Air changes**

*If the master follows the instructions to the letter, is the ship liable for the damage which arises to what otherwise would have been a sound cargo?*

**Ventilation of cargo compartments**

The term ‘air changes’ can give rise to misleading carriage instructions from shippers to ships’ masters, or otherwise correct carriage instructions can be misinterpreted by ships’ officers. The object of this article is to provide support for those who know what they are doing, and to provide non-technical people with sufficient understanding to avoid the usual pitfalls.

**Simple air changes**

A general cargo vessel with a hold ventilation system which is not fan-assisted, can only change the air in the cargo compartments to the extent that the ventilator cowls, of whatever type, can be trimmed/opened to the external atmosphere. This will allow inward passage of outside air and outgoing exhaust of stale air. To all intents and purposes, therefore, this type of vessel tends to fall outside the groups to which this article applies and to which the term ‘air changes’ may refer.

**Fan-assisted air changes**

Three modes of air movement in ships’ holds are considered:

- Open-circuit systems
- Closed-circuit systems
- Closed-circuit systems with fresh air input.

The term ‘air changes per hour’ refers to how many times the fans extract and replace the total volume of air in the empty cargo compartment in one hour. A fan-rating of ‘20 air changes per hour’ for a hold of 1,300 cubic metres air capacity, means that, with the fans
operating at full speed on full power, all the air in that hold could be continuously changed with fresh air 20 times in any one hour in an ‘open’ system – or that the original air could be re-circulated within the hold 20 times in any one-hour period in a ‘closed’ system. In other words the fans can generate an air throughput of 26,000 cubic metres per hour.

It would seem to follow that, if there is cargo in that hold, the same fans operated in the same manner should be capable of changing, or recycling, the air surrounding the cargo at an increased rate because some of the hold’s space is occupied by cargo; but it is not necessarily so. The degree to which that rate may be increased depends upon the nature of the cargo itself, the manner in which it is stowed, the direction(s) in which dunnage is laid, and the extent to which it is required for the moving air to pass through and around the cargo. Those same circumstances may equally decrease the rate of change due to the ‘blockage’ effect of the stowed cargo. And herein lies the first step towards misunderstanding.

A shipper and/or charterer may specify their need of a vessel having a ‘15 air change/hour fan capability’ but the cargo, say, onions in crates and/or slatted bins, blocks most of the hold space to the extent that even operating the fans at full speed on full power will not achieve 15 complete air changes per hour. The master, however, may know from experience, that the very thing he should not do is to run the fans at full speed throughout the voyage, because to do so would cause the vegetables to dry-out and become unacceptable as sound cargo at the port of discharge. So the master runs the fans at speeds, and at times, in keeping with the nature of the cargo balanced against the day-to-day atmospheric conditions encountered during the voyage. But what if the cargo arrives ‘spoiled’ in any event?

When the dust has settled, the three-part question to be answered will be:

- If a shipper and/or charterer writes that fans must be operated at a given rate throughout the voyage, must the master follow that instruction even though he knows from experience that such continuous forced ventilation will damage the cargo – or lack of ventilation where instructions involve too little?
- If the master follows the instructions to the letter, is the ship liable for the damage which arises to what otherwise would have been a sound cargo?
- If he follows his own experience and operates the fans accordingly, is the ship liable for alleged damage to the cargo even if such damage was primarily due to the pre-shipment condition of the cargo itself?

**Open-circuit systems**

An open-circuit system is one in which external fresh air is drawn into the hold by fan induction and is exhausted from the hold by fan extraction; or, in which only induction or exhaust is created mechanically. Whatever the exact disposition of the fans, this is totally an ‘external for internal air change’ system, because there is no re-circulation of used air within the system. The rating will be expressed in the ship’s documentation as somewhere within the range 10 air changes to 25 air changes, per hour, depending upon the type of ship and its individual ventilation arrangements.

Such systems are to be found in many general cargo ships, and in purpose-built vessels engaged in the carriage of perishable commodities which do not require artificial cooling, chilling or refrigeration. Such cargoes are often of the bagged kind, e.g. rice, potatoes, onions, and similar items. Many fresh vegetables often require some degree of artificial cooling, depending upon the location of harvest, the port of destination, and the intended length of the voyage.

**Closed-circuit systems**

Alternatively, an entirely closed-circuit system is required in purpose-built refrigerated vessels carrying deep-frozen products and in which there is the intention to retain the foodstuffs biochemically inert so that they are giving off no odour, gas or moisture. Low-level temperatures are the only consideration. Two methods may be employed to achieve this end result.

The most modern closed-circuit systems nearly always involve fan induction of air through low-level cooling machinery. In such instances, the fans will be rated as
so many ‘air changes per hour’. As explained earlier, in the deep-freeze context this may not refer to outside or fresh air. The phrase, as considered for deep-freeze compartments, relates to the ability of the fans to extract and re-circulate the volumetric air capacity of the compartment, when empty, through the cooling machinery, at so many times per hour. Such a system has to be entirely closed, otherwise the vessel’s machinery would continuously be cooling fresh warm air from outside, instead of re-circulating the cold air already reduced to the required temperature level for the deep-freeze compartments.

In the alternative closed-circuit system, the deep-freeze atmosphere is attained by, and maintained with, cooling coils fixed throughout the cargo compartment. In this system there is no air change or air movement at all: the atmosphere is entirely static without any circulation of re-used air, and without any input from outside air. In this type of vessel ‘air changes per hour’ has no meaning.

Closed-circuit systems with fresh air input

Where closed-circuit systems of the types outlined above are involved, there is little doubt in the minds of those most closely concerned as to what is required and what must be done to achieve it. The difficulties seem to arise in situations where, while the system itself is basically ‘closed’, some induction of fresh air is also required.

In vessels carrying vegetable cargoes which are required to be cooled, such as bananas, carrots, often potatoes and tomatoes – depending upon the port of shipment and the length of sea voyage involved – there may be a requirement both to reduce the temperature of the air within the cargo compartment artificially, and also to ensure that the natural gases and moisture given off from the vegetables/fruit by respiration will not attain levels likely to cause deterioration of the cargo itself.

For instance, bananas will respire ethylene, which is used in the ripening process. If the ethylene content in a cargo compartment was allowed to accumulate, an exponential ripening process may result independent of the exactitude with which the carrying temperature is maintained.

So the requirement will be for a closed-circuit system, with the means of venting stale air and inputting a measure of fresh clean cooled air in a manner sufficiently controlled to remove unwanted gases, without giving the cooling machinery an impossible task and without loss of the required compartment carrying temperature.

This may be done in one of three ways:

- By fitting trunkways with small slide panels, positioned so that the cooled air circulating fans themselves can draw fresh air down the ducts at a given rate, which should be specified as ‘fresh air changes per hour’. If such rating is given, it will probably be in the range 6/10 changes per hour and will relate to the fans’ capacity to change the volume of air in the compartment that number of times through the fresh air system, whether or not the cooling machinery is in operation. With such a ‘fresh air system’ the slide panels can be adjusted to produce a continuous ‘fresh air trickle’ or, alternatively, opened fully at given times and closed at other times.

- There may be a separate small fan system, to induce fresh air and extract stale air through independent ducts – which may or may not be given a ‘rating’.

- Less commonly nowadays, there may be just simple trunking to allow intake and exhaust served by small cowls, much on the principle of the old general cargo ventilators, and opened and closed at certain times of the day, only, weather conditions permitting.

There are many ships whose cooling arrangements are based on the fixed-coil system, in which the cooled atmosphere is more-or-less static, as indicated earlier. Where fruit and vegetables are being carried in cooled conditions however (as opposed to deep-frozen conditions), there remains the requirement to keep the compartment air ‘fresh’, which can only be achieved by venting stale air and replacing it with fresh air. Such ‘freshening’ may be effected by means of any of the three options referred to previously. And, of course, nothing excludes the use of refrigerated vessels for the carriage of some non-cooled cargoes.

Conclusion

When referring to fan-assisted cargo compartment ‘ventilation’, the speaker or writer should make clear the difference between ‘open-circuit’ and ‘closed circuit’ systems and the nature of the ‘air changes’.

If it is of the non-cooled general cargo type or of the circulated cooled type it should be stated as ‘air changes per hour’.

When it is inducted fresh air/exhaust of stale air in an otherwise closed-circuit system it should be stated as ‘fresh air changes per hour’ whenever the rate is known.
Fresh fruit and vegetables

The shipper should have full knowledge of the history of the produce and which temperature must be maintained by the carrier throughout the period under his control.

The transport of fresh fruit and vegetables is a complicated topic. Differing fruit and vegetables have widely varying requirements for their safe preservation. The rate at which living fruits and vegetables age and eventually submit to senescence (old age), attack by micro-organisms and inevitable demise depends upon the environmental status afforded during storage and transit. During which periods the quality and condition of fruits and vegetables are maintained by retention at all times of their optimum temperatures. For safe carriage this will usually require that the commodities are pre-cooled and maintained at that temperature prior to being loaded into the transport unit, be it refrigerated ship, container or other mode of transport. Refrigerated systems used in transportation of commodities only have the capacity to adjust minor reductions of, and to maintain, the product temperature.

All fresh fruits and vegetables are living products and their life processes continue after harvest; the two most important being respiration and transpiration. The former being a complicated sequence of chemical reactions involving conversion of starches to sugars and the change of those sugars into energy. The normal respiration results in the fruit and vegetables consuming oxygen and giving off carbon dioxide; water; and varying, albeit immense, amounts of heat. The higher the ambient temperature surrounding the commodity the greater will be the temperature of the commodity itself and consequently the larger its rate of respiration. The second process, transpiration, is the loss of water by evaporation which will occur once the fruit or vegetable is removed from its tree or plant which has been the source of water during its formative period. Thus the storage/carriage conditions afforded the produce should be such that excessive water loss does not ensue.

Temperature

Many reference books include tables which provide data, including optimum temperatures, for the safe storage of commodities. Other publications specifically list the optimum transit (carriage) conditions. The storage data may, depending upon the commodity, refer to long term refrigerated storage requirements with any period quoted being that from harvesting to entry into the marketing chain. Published data applicable to sea-going carriage requirements may indicate slightly higher optimum temperatures. However it is essential to understand that published values of optimum temperatures for storage or transit are not absolute – the accurate optimal requirements are dependent upon varietal, climatic and other details of the produce. The optimum and required transport temperature of fruits and vegetables should be provided in writing by the shipper who will, or should, have full knowledge of the history of the produce and which temperature must be maintained by the carrier throughout the period under his control. Optimum temperatures determine low rates of respiration extend storage life and in addition reduce the rate of development of micro-organisms. Generally speaking the higher the temperature the faster will be the growth of moulds and bacterial infections.

Freezing points

The lowest safe limit of temperature for each commodity is its highest freezing point. This temperature is invariably slightly below 0°C, the freezing point of pure water, as the natural juices contain dissolved substances in solution which have the effect of lowering the freezing point. Thus generally speaking the main contents being sugars the sweeter the produce the lower the freezing point. Nonetheless it must also be remembered that stalks of fruit contain much less sugar and may freeze at a higher temperature than the fruit itself, resulting in death of the stalk tissue with possible consequences when the fruit is restored to ambient temperatures with likely loss of sound market values.

Chill damage

A second factor which establishes the lower safe limit of carriage temperature of some produce is that of chilling, which is a reduction in temperature that does not reach the freezing point of the produce. Numerous commodities especially those grown in tropical climates, or alternatively from plants originating from the tropics, are easily affected by low temperatures.
and inclined to injury to their tissues at temperatures well above their freezing point. Typical symptoms not only include pitting of surface tissues, discolor of flesh but also an increased susceptibility to decay.

**Relative humidity**

Relative humidity may be defined as the ratio of the water vapour pressure present in air at an existing temperature to the water-vapour pressure which would be present if the vapour were saturated at the same temperature. Relative humidity is usually expressed as a percentage.

Difference of vapour pressure may cause water vapour to move from or to the produce within the ambient air. The water-retention capacity of air is directly proportional to the temperature of the air, i.e. an air mass at 90% relative humidity at +10°C contains a greater mass of water than a similar air mass at 90% relative humidity at a temperature of 0°C.

Nonetheless water is lost from produce at about double the rate when carried in a compartment whose air is at +10°C and 90% relative humidity when compared with the same air being at 0°C and 90% relative humidity.

Thus the relative humidity of the air within a cargo compartment of a refrigerated vessel, insulated refrigerator container or trailer directly determines the retention of the condition of the products carried. Relative humidity below the optimum range will result in shrivelling or wilting in most produce. The maintenance of an optimum range of humidity is often one of the more difficult to resolve during the carriage of fresh produce.

Relative humidity of air of 85% to 95% is usually recommended for the carriage of most perishable produce in order to preclude/impede wilting or shrivel caused by moisture loss. Exceptions to the above include the carriage of onions, dates, coconuts, ginger rhizomes, yams, dried fruits and some horticultural produce. If the relative humidity increases to 100% condensation may occur which would increase the likelihood of mould growth within the compartment and on the produce itself.

**Air circulation**

The circulation of cooling air within cargo compartments must be kept at an even required temperature throughout. Despite variable heat leakages which may occur in various parts of the system, and the inevitable increase in the circulating air temperature at return compared with delivery, the result of removal of respiratory heat from the produce, only a small increase should be acceptable. The comparison of delivery air temperatures and return air temperatures being one of the critical monitoring requirements of carriage. As the majority of produce carried should be presented to the vessel/container or trailer as precooled, the exceptions will include cargoes of bananas, the field heat having already been removed. The circulating cooling air should therefore only be required to remove respiratory heat of the produce and the heat exchanged via exterior surfaces. A high velocity of circulating air should be unnecessary and in fact undesirable. Cooling air in modern refrigerated vessels and containers is usually circulated vertically, from the deck/floor, upwards. The system is designed to produce equal air pressures over the full area of the cargo space. However, any elaborate arrangement for air distribution can be rendered useless if incorrect stowage of the produce eliminates or reduces efficient air flow which tends to follow the route of least resistance. The difficulties of ‘properly and carefully’ stowing packages of fresh produce have become more complex with the use of palletised units and pallet boxes/bins.

**Air exchange**

During the carriage of fresh fruits and vegetables under ordinary conditions of refrigeration accumulations of gases such as carbon dioxide (CO₂) and ethylene (C₂H₄) will occur. Undesirable odours or volatiles may also contribute to off-flavours and hasten deterioration of the produce. These problems can be prevented by repeatedly refreshing the circulating air within the holds by admitting atmospheric air into the system. The introduced air entering at a point of lowest pressure within the circulation and the polluted air exiting the system at a point of highest pressure, or alternatively by use of an auxiliary air system driven by separate fans.

**Rates of respiration and heat generation**

Fresh fruits and vegetables and similar produce are live and as with all living products respire, i.e. the process by which oxygen from the air combines with the organic material of the produce to form, ultimately, water and carbon dioxide. The by-product of this chemical reaction being energy released as heat. The rate at which fruits and vegetables produce heat varies, some have high rates of respiration and they require more refrigeration to maintain an optimum carriage temperature than those which respire more slowly. The rates of respiration are determined by temperature and as before noted for every 10°C rise in temperature the rates may be doubled or in some instances tripled.

The storage life of produce varies inversely with the rate of respiration. Produce with short storage expectancy
will usually have higher rates of respiration, e.g. fresh broccoli, lettuce, peas and sweet corn. Conversely potatoes, onions and some cultivars of grapes with low respiration rates have longer storage lives. The rate of respiration for any given product will depend upon its variety (cultivar), area of growth, the seasonal and climatic conditions experienced during periods of growth.

Climacteric fruit and vegetables

Some varieties of fruit and vegetables have rates of respiration which do not decline during their ripening period – that is between maturation and the onset of senescence. In fact their respiration rates increase, a critical event or period known as their climacteric. Produce may therefore be categorised as climacteric or non-climacteric. The former continuing to ripen post-harvest, where as the latter does not. The ripening processes include development of colour, texture (tissue softening) and flavour.

Many fruits are climacteric, such as peach, apricot, banana, mango, papaya, avocado, plum, tomato and guava and tend to ripen rapidly during transit and storage. Examples of non-climacteric fruit and vegetables include cucumber, grape, lemon, lime, orange, temple fruit (satsuma, tangerine, mandarin) and strawberry.

Weight loss in transit

Weight loss from harvested produce can be a major cause of deterioration during transit and storage. Most fruit and vegetables contain between 80% and 95% of water by weight, some of which may be lost by transpiration (water loss from living tissue).

To minimise loss of saleable produce weight and to preclude wilting and shrivelling, the produce must be maintained during transit at the recommended humidity and temperature. Whereas some weight loss will inevitably occur due to the loss of carbon during respiration, this will only be of relative minor proportions.

However, the loss of water will not only result in weight reduction but also in produce of poor quality. Loss of moisture can often be minimised by the use of protective packaging to complement carriage under optimum temperature and humidity.

Supplements to refrigeration

Opportunities have been tried and tested to slow down ripening after harvest and thus extend the transit, storage and shelf life of fruit and vegetables – especially those in the climacteric category. This can be achieved with controlled atmosphere (CA) storage and carriage; modified atmosphere packaging (MAP), storage and carriage (MA); or alternatively with edible coatings.

Basically and in all cases the atmosphere created is one of low oxygen \( \text{O}_2 \) and high carbon dioxide \( \text{CO}_2 \) when compared to atmospheric air. The low oxygen and high level of \( \text{CO}_2 \) depress the production of ethylene \( \text{C}_2\text{H}_4 \), a gas emitted in small quantities by plant tissues, which accelerates during the ripening process and in turn expedites the process itself in the form of a chain reaction, especially true in the case of bananas.

Caution: Modified and controlled atmospheres are non-life supporting. Proper ventilation instructions of compartments/containers under CA/MA must be carefully followed prior to entry.

Edible coatings can create a modified atmosphere, similar to that of modified atmosphere packaging (MAP), which can delay ripening of climacteric fruit, delay colour changes in non-climacteric fruit, reduce water loss, reduce decay and maintain quality appearance.

It has been stated that edible coatings which should be tested and tailored for each product are a simple safe and relatively inexpensive means of extending the ultimate shelf life of fruit and vegetables provided there are good storage, shipping temperature and humidity controls.

Carriage of mixed produce

At times carriers are required to load and stow different produce in the same vessel, hold, or cargo container. Should a mixture be necessary it is essential that the produce is compatible in respect of:

- Temperature
- Relative humidity
- Odour production
- Ethylene production.

Generally deciduous fruits, if having the same temperature requirements, can be stowed together.

Cross tainting should be avoided at all costs whereby strongly scented fruit and vegetables are stowed together. The many products which produce considerable ethylene naturally, including apples, avocados, bananas, pears, peaches, plums, melons and pineapples should not be stowed with or in
adjacent compartments to kiwi fruit, water melons, lettuce, carrots etc. which can all be seriously affected by the ethylene.

Two commodities that have produced substantial cargo claims, pears and kiwi fruit, are dealt with in this article. There is also a brief comment on research into procedures for the ocean carriage of particularly sensitive fruits. Some data in that section also covers the storage of pears and kiwi fruit.

Pears

Pears are shipped to Europe and North America from South Africa and Chile. They are also shipped in quantity from New Zealand and Australia. Although pears are considered to have a relatively long life it is essential that they are picked at the right stage of maturity and pre-cooled if optimum life is to be achieved.

There is a scientific procedure for determining the correct data for picking which is based on the starch content in the fruit. However, once the fruit has been picked, the starch is rapidly converted into sugar and it becomes impossible at a later date to determine whether the fruit was at a proper stage of maturity when picked. Pears are susceptible to various physiological disorders caused by chilling, excess atmospheric CO₂, and skin contact (bruising). They are also subject to microbiological damage resulting from infection by various organisms prior to harvesting. The two most serious types of disease are mild species monilinia fructigena and botrytis cinerea. The latter species can grow at temperatures as low as -4°C and the growth of this organism can, therefore, only be controlled by low temperature storage. The rate of decay increases rapidly as the temperature rises. As invasion usually occurs through damaged tissue the proper selection of fruit at the packing station is of paramount importance.

The prescribed temperature for the carriage of pears is 0°C to -1.1°C. It is therefore recommended the carrying temperature should be 0°C or marginally lower where ships have equipment which can control the delivery air temperature to plus or -0.2°C or better. The set points for the carriage of pears in containers should be 0.6° to 1.7°C.

Pears may suffer chilling injury at temperatures below -1.5°C. Certain fruit can tolerate lower temperatures and, even if freezing occurs, very slow thawing at low temperatures can result in the fruit remaining undamaged. Thus, claims for damage due to the delivery air temperature falling marginally below -1.5°C for short periods must be viewed with some scepticism.

Because of their comparatively large size and high thermal capacity, cooling of individual fruits through the whole tissue is a fairly slow process. When checking a cargo shipped as pre-cooled, the ship’s representative should ensure spear temperatures are taken at the centre of specimens selected for checking. Other points to be checked are the nature of the packaging and the general appearance of the fruit, particularly skin blemishes. Caution should be observed when attempting to assess the maturity of the fruit and a surveyor should be consulted if in doubt.

Pears are susceptible to damage if the CO₂ concentration in the atmosphere rises much above about 1% so it is necessary to maintain fresh-air ventilation at regular intervals when carrying this cargo.

Where unsatisfactory outturns occur it is essential that expert advice is obtained as soon as possible.

Kiwi fruit

These are mainly shipped from New Zealand and California and increasingly from Chile. They have a long storage life if picked at the right stage of maturity.
and thereafter stored at temperatures in the range - 0.5°C to -1.0°C. Storage at temperature only slightly above this range (+3°C to +4°C) will substantially reduce the storage life.

Kiwi fruit are particularly sensitive to traces of ethylene in the atmosphere. This will prompt rapid ripening. Particular care must therefore be taken when kiwi fruit is loaded, whether in containers, which is usual, or in conventional refrigerated ships to ensure that the atmosphere in contact with the fruit cannot be contaminated with the atmosphere from other sources, e.g. containers stuffed with cargoes such as apples which release considerable amounts of ethylene and even exhaust fumes from certain types of forklift. As it is necessary for the kiwi fruit to be carried using a fresh-air ventilation system, the possibility of cross contamination of the atmospheres from different cargoes must be considered carefully at the time of loading.

Kiwi fruit are also subject to microbiological deterioration, primarily due to invasion by *botrytis cinerea*.

It is again of paramount importance for expert advice to be obtained as soon as possible where damage is feared.

**Recent developments in the carriage of delicate fruits, exotic fruits and similar products**

World trade in delicate products such as strawberries and certain tropical fruits has expanded. The products concerned frequently have a short shelf-life and are therefore transported by air when the distance between the growing region and the market methods of extending the shelf life of delicate products to enable them.

It has been known for many years that increasing the CO₂ concentration in a cargo space will depress the metabolic rate of living natural products and this fact has been utilised when carrying apples from Australia to Northern Europe and during storage worldwide. Recent research has developed more sophisticated gas mixtures, for use in containers or similar carrying units, which will not only slow the ripening rate of fruit and the onset of senescence in other living products but also render such products less susceptible to decay and damage caused by micro-organisms, insects and physiological disorders.

Controlled or modified atmospheric systems involve original dosing to produce an atmosphere of the composition required and then monitoring the atmosphere with automatic analytical equipment which, coupled to recycling equipment, maintains the original composition of the atmosphere by removing the excess of some components and dosing to increase the concentration of others.

Research work carried out has established that:

- Ethylene gas which promotes ripening of fruits is less effective in atmospheres containing less than 1% carbon dioxide.
- If the CO₂ content of the atmosphere is too high, serious physiological damage may result.
- As levels of carbon dioxide in the range 10-15% *botrytis* rot of strawberries and some other fruit is substantially inhibited.

Storage of certain products in modified atmospheres can cause problems such as irregular ripening in bananas, pears etc. at low oxygen levels (2%). Development of black heart in potatoes and brown heart in pears and apples at lowered oxygen levels are other examples.

Some products which clearly benefit from controlled-atmosphere storage are listed below, showing the optimum conditions for such storage, as reported by scientists in the USA.

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Temp. °C</th>
<th>% O₂</th>
<th>% CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples</td>
<td>0.5</td>
<td>2 – 3</td>
<td>1-2</td>
</tr>
<tr>
<td>Kiwi fruit</td>
<td>0.5</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Pears</td>
<td>0.5</td>
<td>2 – 3</td>
<td>0.1</td>
</tr>
<tr>
<td>Strawberries</td>
<td>0.5</td>
<td>10</td>
<td>15 – 20</td>
</tr>
<tr>
<td>Nuts/Dried fruits</td>
<td>2.25</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Bananas</td>
<td>12 – 15</td>
<td>2.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

The addition of carbon monoxide at levels of 1-5% in atmospheres containing 2-5% oxygen has been shown to reduce discoloration of damaged or cut lettuce tissue. At levels of 5-10% it will inhibit the development of certain important plant pathogens. Use of this gas has been the subject of experimentation in the USA.

The following table of temperatures, maximum storage/transit and shelf life etc., is for guidance only. The required details of temperature and humidity should be provided in writing by the shipper who has the full knowledge of the product history. The shippers instructions should be maintained at all times.
<table>
<thead>
<tr>
<th>Fresh fruit and vegetables</th>
<th>Approx max storage, transit and shelf life</th>
<th>Optimum transit temperature</th>
<th>Container temperature set points</th>
<th>Highest freezing points</th>
<th>Relative humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples – non chilling-sensitive</td>
<td>90 – 240</td>
<td>-1.1 to +1</td>
<td>30 to 33.8</td>
<td>34 to 36</td>
<td>-1.5</td>
</tr>
<tr>
<td>Apples – chilling sensitive</td>
<td>35 – 45</td>
<td>+1.5 to 4.5</td>
<td>34.7 to 40</td>
<td>40 to 42</td>
<td>-1.5</td>
</tr>
<tr>
<td>Apricots</td>
<td>7 – 14</td>
<td>-0.5 to +1</td>
<td>31 to 33.8</td>
<td>34 to 36</td>
<td>-1.1</td>
</tr>
<tr>
<td>Asparagus</td>
<td>14 – 21</td>
<td>+2.2</td>
<td>36</td>
<td>+2.2</td>
<td></td>
</tr>
<tr>
<td>Avocados – Fuerte and Hass</td>
<td>21 – 28</td>
<td>+5 to +8</td>
<td>41 to 46.4</td>
<td>+5 to 12.8</td>
<td>-0.3</td>
</tr>
<tr>
<td>Bananas – green</td>
<td>14 – 21</td>
<td>13 to 14</td>
<td>56 to 58</td>
<td>13 to 14</td>
<td>-0.7</td>
</tr>
<tr>
<td>Blueberries</td>
<td>10 – 18</td>
<td>-0.5</td>
<td>31</td>
<td>1.1 to 2.2</td>
<td>-1.3</td>
</tr>
<tr>
<td>Carrots</td>
<td>30 – 180</td>
<td>0</td>
<td>32</td>
<td>0.6 to 1.7</td>
<td>-1.4</td>
</tr>
<tr>
<td>Cherries – sweet</td>
<td>14 – 21</td>
<td>-1.1</td>
<td>30</td>
<td>1.1 to 2.2</td>
<td>-1.8</td>
</tr>
<tr>
<td>Clementines</td>
<td>14 – 28</td>
<td>4.4</td>
<td>40</td>
<td>3.3 to 4.4</td>
<td>-1</td>
</tr>
<tr>
<td>Coconut – flesh</td>
<td>30 – 60</td>
<td>0</td>
<td>32</td>
<td>1.1 to 2.2</td>
<td>-0.9</td>
</tr>
<tr>
<td>Corn – sweet</td>
<td>4 – 6</td>
<td>0</td>
<td>32</td>
<td>0.6 to 1.7</td>
<td>-0.6</td>
</tr>
<tr>
<td>Courgettes</td>
<td>14 – 21</td>
<td>7.2</td>
<td>45</td>
<td>7.2 to 10</td>
<td>-0.5</td>
</tr>
<tr>
<td>Cucumbers</td>
<td>10 – 14</td>
<td>10</td>
<td>50</td>
<td>10 to 11.1</td>
<td>-0.5</td>
</tr>
<tr>
<td>Dasheens</td>
<td>42 – 140</td>
<td>13.3</td>
<td>56</td>
<td>11.1 to 13.3</td>
<td>-</td>
</tr>
<tr>
<td>Garlic</td>
<td>140 – 210</td>
<td>0</td>
<td>32</td>
<td>0.6 to 1.7</td>
<td>-1.1</td>
</tr>
<tr>
<td>Ginger rhizomes</td>
<td>90 – 180</td>
<td>13.3</td>
<td>56</td>
<td>12.8 to 13.3</td>
<td>-</td>
</tr>
<tr>
<td>Grapefruit</td>
<td>28 – 42</td>
<td>13.3</td>
<td>56</td>
<td>14.4 to 15.6</td>
<td>-1.1</td>
</tr>
<tr>
<td>Grapes</td>
<td>56 – 180</td>
<td>-1.1</td>
<td>30</td>
<td>1.1 to 2.2</td>
<td>-2.2</td>
</tr>
<tr>
<td>Guavas</td>
<td>14 – 21</td>
<td>10</td>
<td>50</td>
<td>9 to 10</td>
<td>-</td>
</tr>
<tr>
<td>Kiwi Fruit</td>
<td>28 – 84</td>
<td>0</td>
<td>32</td>
<td>1.1 to 2.2</td>
<td>-0.9</td>
</tr>
<tr>
<td>Kumquats</td>
<td>14 – 28</td>
<td>4.4</td>
<td>40</td>
<td>4.4</td>
<td>-</td>
</tr>
<tr>
<td>Lemons</td>
<td>30 – 180</td>
<td>12.2</td>
<td>54</td>
<td>10 to 12.8</td>
<td>-1.4</td>
</tr>
<tr>
<td>Lettuce – Iceberg</td>
<td>10 – 18</td>
<td>0</td>
<td>32</td>
<td>1.1 to 2.2</td>
<td>-</td>
</tr>
<tr>
<td>Limes</td>
<td>42 – 56</td>
<td>9 to 10</td>
<td>48 to 50</td>
<td>9 to 10</td>
<td>-1.6</td>
</tr>
<tr>
<td>Lychees</td>
<td>21 – 35</td>
<td>1.7</td>
<td>35</td>
<td>1.7 to 2.2</td>
<td>-</td>
</tr>
<tr>
<td>Mandarin</td>
<td>14 – 28</td>
<td>7.2</td>
<td>45</td>
<td>7.2</td>
<td>-1.1</td>
</tr>
<tr>
<td>Mangoes</td>
<td>14 – 25</td>
<td>13.3</td>
<td>56</td>
<td>12.8</td>
<td>-0.9</td>
</tr>
<tr>
<td>Melons – Honeydew</td>
<td>21 – 28</td>
<td>10</td>
<td>50</td>
<td>7.8 to 10</td>
<td>-1</td>
</tr>
<tr>
<td>Mineolas</td>
<td>21 – 35</td>
<td>3.3</td>
<td>38</td>
<td>3.9 to 6.7</td>
<td>-1.3</td>
</tr>
<tr>
<td>Nectarines</td>
<td>14 – 28</td>
<td>-0.5</td>
<td>31</td>
<td>0.6 to +/1</td>
<td>-1</td>
</tr>
<tr>
<td>Onions – dry</td>
<td>30 – 180</td>
<td>0</td>
<td>32</td>
<td>0.6 to 1.7</td>
<td>-0.8</td>
</tr>
<tr>
<td>Oranges – Blood</td>
<td>21 – 56</td>
<td>4.4</td>
<td>40</td>
<td>4.4 to 6.7</td>
<td>-</td>
</tr>
<tr>
<td>Oranges – California and Arizona</td>
<td>21 – 56</td>
<td>6.7</td>
<td>44</td>
<td>6.7 to 7.8</td>
<td>-0.8</td>
</tr>
<tr>
<td>Oranges – Florida and Texas</td>
<td>56 – 84</td>
<td>1.7</td>
<td>35</td>
<td>1.1 to 2.2</td>
<td>-0.8</td>
</tr>
<tr>
<td>Oranges – Jaffa</td>
<td>56 – 84</td>
<td>7.8</td>
<td>46</td>
<td>7.8 to 10</td>
<td>-0.7</td>
</tr>
<tr>
<td>Oranges – Seville</td>
<td>90 – 100</td>
<td>13</td>
<td>57.2</td>
<td>14</td>
<td>-0.8</td>
</tr>
<tr>
<td>Parsnips</td>
<td>120 – 150</td>
<td>0</td>
<td>32</td>
<td>0.6 to 1.7</td>
<td>-0.9</td>
</tr>
<tr>
<td>Peaches</td>
<td>14 – 28</td>
<td>-0.5</td>
<td>31</td>
<td>0.6 to 1.7</td>
<td>-0.9</td>
</tr>
<tr>
<td>Pears – Anjou</td>
<td>120 – 180</td>
<td>-1.1</td>
<td>30</td>
<td>0.6 to 1.7</td>
<td>-1.6</td>
</tr>
<tr>
<td>Pears – Bartlett</td>
<td>70 – 90</td>
<td>-1.1</td>
<td>30</td>
<td>0.6 to 1.7</td>
<td>-1.6</td>
</tr>
<tr>
<td>Peppers – sweet</td>
<td>12 – 18</td>
<td>10</td>
<td>50</td>
<td>10</td>
<td>-0.7</td>
</tr>
<tr>
<td>Peppers – hot</td>
<td>14 – 21</td>
<td>10</td>
<td>50</td>
<td>10</td>
<td>-0.7</td>
</tr>
<tr>
<td>Pineapples</td>
<td>14 – 36</td>
<td>10</td>
<td>50</td>
<td>10</td>
<td>-1.1</td>
</tr>
<tr>
<td>Plantains</td>
<td>10 – 35</td>
<td>13</td>
<td>57.2</td>
<td>14</td>
<td>-0.8</td>
</tr>
<tr>
<td>Plums</td>
<td>14 – 28</td>
<td>-0.5</td>
<td>31</td>
<td>1.1 to 2.2</td>
<td>-0.8</td>
</tr>
<tr>
<td>Potatoes – seed</td>
<td>84 – 175</td>
<td>4.4</td>
<td>40</td>
<td>5</td>
<td>-0.8</td>
</tr>
<tr>
<td>Potatoes – table</td>
<td>56 – 140</td>
<td>6</td>
<td>42.8</td>
<td>7</td>
<td>-0.8</td>
</tr>
<tr>
<td>Satsumas</td>
<td>56 – 84</td>
<td>4</td>
<td>39</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Sweet potatoes</td>
<td>90 – 180</td>
<td>14</td>
<td>57</td>
<td>14</td>
<td>-1.3</td>
</tr>
<tr>
<td>Tangerines</td>
<td>14 – 28</td>
<td>7</td>
<td>42.5</td>
<td>7</td>
<td>-1.1</td>
</tr>
<tr>
<td>Tomatoes – green</td>
<td>21 – 28</td>
<td>13.3</td>
<td>56</td>
<td>13 to 14</td>
<td>-5</td>
</tr>
<tr>
<td>Tomatoes – turning</td>
<td>10 – 14</td>
<td>9</td>
<td>48.2</td>
<td>10.6</td>
<td>-0.5</td>
</tr>
<tr>
<td>Ugli fruit</td>
<td>14 – 21</td>
<td>4.4</td>
<td>40</td>
<td>5</td>
<td>-1.1</td>
</tr>
<tr>
<td>Watermelons</td>
<td>14 – 21</td>
<td>10</td>
<td>50</td>
<td>8 to 10</td>
<td>-0.4</td>
</tr>
<tr>
<td>Yams – cured</td>
<td>49 – 112</td>
<td>16</td>
<td>61</td>
<td>16</td>
<td>-1.1</td>
</tr>
</tbody>
</table>
Frozen fish on reefer vessels and in containers

Factors which affect the condition of frozen fish cargoes during trans-shipment and transport and advice on how to spot signs that a fish cargo is running into problems.

Introduction

According to the UN’s Food and Agricultural Organisation, there are more than 28 million people engaged in fishing operations worldwide. The annual world catch of fish exceeds 100 million tonnes, of which around 25 per cent is processed into frozen fishery products. Each year, a high proportion of these frozen products enters international trade and is carried by sea.

Sometimes cargoes of frozen products are found to be damaged when they are unloaded from ships and rejected, leading to claims against shipowners and agents alleging that the damage is due to negligence on the part of the masters and crews of the carrying vessels.

Clearly a vessel is not liable for damage that was sustained before loading, or during handling if due to the actions of third parties. Frequently it is difficult to establish the precise cause and chain of events leading up to the damage. Specialised knowledge is required to sample and inspect fishery products, and relate their condition to the events of the voyage. However, vessel operators also need adequate technical knowledge to minimise the risk of problems occurring, and to act in the event of a claim.

These guidelines are intended to advise ships’ masters, officers and crew on good practices to be observed during the loading, storage, carriage and discharge of frozen fishery products carries as bulk cargoes. They also provide detailed guidance on how vessel operators can limit their liability for damage, by ensuring adequate pre-shipment inspection and by acting promptly to preserve evidence when a problem occurs. Other sections also provide background information on factors which affect the condition of frozen fish cargoes during trans-shipment and transport and advice on how to spot signs that a fish cargo is running into problems.

Frozen fishery products

Types of frozen fishery products

A variety of frozen fishery products are carried by sea in reefer vessels and reefer containers. The main types, in approximately descending order of frequency are as follows:

- **Whole, gutted¹, or dressed² fish individually frozen**
  1. Gutted fish are whole apart from removal of the viscera.
  2. Dressed fish have heads and guts, and perhaps tails and fins removed

Tuna intended for canning is a typical example.

Whole fish individually frozen

- **Whole, gutted, or dressed fish in blocks**
  This is a common form of presentation for small and medium-sized fish intended for further processing. Blocks are rarely more than 10cm thick or more than 50kg in weight. Common sizes are 25 and 50kg. Blocks are either unwrapped or wrapped in plastic film and are sometimes packed in strapped cartons.

Fillets of fish frozen in blocks

Fillets of fish are often frozen into geometrically shaped
blocks. Blocks are usually wrapped in plastic film and packed into inner display packs. The display packs are then commonly packed in outer cartons.

**Fillets of fish, individually frozen**
These are fillets frozen as separate pieces, and perhaps then coated with batter, or batter and breadcrumbs.

Fillets are either placed in packages for retail sale or loosely packed in plastic bags. Small display packs are packed in outer cartons while loosely packed fillets may be packed in bags within outer cartons.

**Cephalopods, frozen in blocks or as packaged products**
These include squid, cuttlefish and octopus. Both processed and unprocessed products are typically frozen in blocks weighing 10 or 25kg. Blocks are occasionally individually packaged, but more usually are overwrapped in plastic with several blocks being packed together in a single outer carton.

**Crustacean shellfish, frozen in blocks or as packaged products**
These include lobster, crayfish, shrimp and crab. Smaller crustaceans and crustacean meats are often frozen in blocks weighing up to 1kg. Blocks are packed individually in cartons or over-wrapped in plastic film and then packed into outer cartons.

**Crustacean shellfish, individually frozen**
Large crustacea, for example lobsters and crayfish are individually frozen, whole or as tails, wrapped and packed in cartons.

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**Freezing and storage of fishery products**

**Introduction**
The master of a vessel carrying frozen fishery products does not generally need to be concerned with how the products have been frozen and stored before delivery to the vessel. Indeed, he has no means of knowing or verifying these conditions, except perhaps when fishery products have been prepared and frozen at sea and transhipped directly to the carrier vessel. However, the quality of the cargo discharged from the vessel is affected by freezing, storage and distribution practices before transfer to the vessel, as well as by the manner of loading, stowage and carriage on the vessel.

The following is intended to inform masters and crew about the technologies involved in freezing and storage of frozen fishery products, and the effects of freezing and storage on product quality.

**The freezing process**
When a fish product is cooled in a freezer its temperature drops rapidly to about -1°C, when ice begins to form. However, not all the water in the fish turns to ice at this point. As more heat is extracted, more ice forms, but the temperature of the product drops only slowly until about -3°C. This period, when the product temperature changes very gradually, is known as the ‘thermal arrest period’.

The product’s temperature then begins to drop rapidly towards the operating temperature of the freezer. (Fig A)

When the product is allowed to thaw, the temperature will follow a curve similar to Figure A, but in the reverse direction. °C, then slowly to about -1°C as it passes through thermal arrest, then rapidly again until the product reaches the ambient temperature.
It is important for the quality of the frozen product that the thermal arrest period is as short as possible, preferably less than two hours. This rate of cooling can only be achieved in equipment designed for the purpose – merely placing fish in a cold store will not achieve a sufficiently high freezing rate. The refrigerated holds of reefer ships are designed as cold stores to maintain the temperature of already frozen products; they do not have the refrigeration capacity to freeze products at the required rate.

Examples of freezing methods

Brine freezing of individual fish
Brine freezing is used for larger, whole fish like salmon and tuna. The technique is used almost exclusively onboard fishing vessels, particularly tuna-catchers. The fishing vessel is fitted with one or more insulated tanks containing refrigeration coils. Before fishing starts, these tanks are filled with sea water, which is then cooled to around 0°C. As fish are caught, they are dropped into the tanks. When a tank is full, salt is added to lower the freezing point of the brine and the temperature is lowered so that the fish freeze. The temperature that can be achieved depends on the concentration of the brine – the minimum, when the brine is saturated, is about -21°C. In practice, fishing vessels aim for a solution giving a temperature of around -12°C. Once the fish are frozen, the brine is drained from the tank and the fish are held in dry condition with the refrigeration system on.

Freezing of blocks
Small products, including small fish, fish fillets, squid, octopus and shrimps, are often frozen in blocks. The product is laid in trays and frozen, either in a tunnel through which cold air is passed or between pairs of hollow plates through which refrigerant is circulated. The frozen block is knocked out of the tray, protected by some form of over-wrapping and perhaps packed into cartons.

The quality of frozen fishery products

Quality of products
Complaints about defects in the quality of frozen fishery cargoes usually fall into one or both of two categories:

- Abnormal and offensive odours, flavours or texture, or any other defects that will influence the consumers’ perception of quality.
- Physical damage affecting the processability or merchantability of the product (can occur during the freezing process, though more usually happens during handling of the frozen product).

Quality defects in both categories can arise during handling, processing and storage of the product before delivery to the vessel, during loading into the ship’s holds, and while the product is stored on the reefer vessel.

Loss of quality can occur both before and after freezing. However, the nature of the defects differs in the two circumstances and an experienced assessor should be able to distinguish between them.

Loss of quality before freezing
Fish of all kinds are notorious for the speed at which they spoil (even when chilled) and for the unpleasant nature of the spoiled product. Spoilage affects the appearance, odour and flavour of the product. Freezing halts the spoilage process and fixes the quality as it was at the time of freezing. When frozen products are thawed out, the quality can be no better than it was at the time of freezing. If defects in the quality of frozen fishery products at time of delivery are shown to be a consequence of spoilage, then no blame can be attached to the carrier of the frozen goods unless the product had thawed out during the voyage.

Loss of quality during frozen storage
Frozen fishery products are not completely stable in the frozen state and will deteriorate over time, resulting in changes in texture, odour and flavour of the product. Changes in texture are similar in character across most fishery products – the product becomes dry, stringy and tough. But changes in odour and flavour depend on the type of fishery product. Lean fish with low oil content (such as cod) develop the characteristic odours and flavours described as ‘musty’, ‘cardboard’, and ‘wet dog’, while fish with high oil content (like tuna, herring and mackerel) develop rancid odours and flavours.
reminiscent of new leather, linseed oil or old-fashioned oil paints. Odour and flavour changes in frozen crustacean shellfish and cephalopods are similar to those in lean fish. Oily fish deteriorate faster, and produce off-odours more quickly than lean fish during frozen storage.

The main factors influencing the rate at which fishery products deteriorate during frozen storage are temperature of storage and exposure to air. The lower the storage temperature the slower the product deteriorates. The storage life of fishery products carried at -18°C ranges from 3 to 12 months. In general, storage life is halved for each 5°C rise in storage temperature. For example, a product with a storage life 8 months at -18°C will have a storage life of 4 months at -13°C. Since ship’ refrigeration systems can maintain products at temperatures below -18°C, and since voyages are generally less than a month long, there should be no significant loss of quality due to frozen storage-related defects during a voyage.

Rate of deterioration is also affected by exposure to air. Block-frozen products are usually protected by close wrapping with plastic film or by coating with a water glaze. To maintain quality, it is important that this cover, film or glaze is not damaged or lost.

Another defect arising during frozen storage is excessive loss of moisture from the product, which leads to general or localised dehydration known as a ‘freezer burn’. The dehydration is signified by white patches which appear where glaze is lost or where there are tears or breaks in the protective wrapping. In unprotected material, dehydration occurs first in thin parts of the product such as the fins of the whole fish and the tail-ends of fillets, or at the corners of blocks. These dried areas do not re-hydrate when the product is thawed and are indicated by blemishes in the thawed product.

Physical damage to frozen products
Physical damage takes a number of forms, but complaints about the quality of reefer cargoes are usually concerned with distortion or compression of the product. This kind of damage, which affects individually frozen fish or blocks of products, occurs when warm fishery products (i.e. warm relative to the recommended storage temperature) are subjected to pressure, for example in a stack of fish stored in the ship’s hold.

When water is frozen, it changes from a liquid to a hard solid, ice, at 0°C. Although fish typically contain 70-80% of water – the exact percentage depends on the species – the situation is more complicated than freezing water alone. Water in the fish tissues starts to freeze at about -1°C but at this point only a proportion of the water is converted to ice. Progressively, more water freezes as the temperature falls. At -18°C, the maximum temperature usually specified for carriage of frozen fish in reefers, around 90% of the water has turned to ice. It is very hard to deform frozen fish at this temperature and below, except under extremely high pressure.

If the product warms at all, some of the ice melts. The fish tissue holds an increasing proportion of liquid water and a decreasing proportion of ice as its temperature rises.

As the proportion of ice decreases, the fish tissue, though still partly frozen, becomes softer and can be deformed by moderate pressure. For example, it is possible to deform the surface of a product at -7°C by pressing hard with the point of a pen, a temperature probe, or even a thumbnail. At -3°C, ‘frozen’ fishery products are soft enough to deform and to sag under their own weight. If the cargo in the hold of a reefer is stacked to a height of 4 or 5 metres, as is often the case, there is sufficient pressure to distort fish to some extent at -7°C, and to distort and compress fish considerably at -5°C or higher.

Indentations caused when warmed, soft tuna were pressed on to ridged floor plates by the weight of the stack of fish above them

Indentations caused when warmed, soft tuna were pressed on to ridged floor plates by the weight of the stack of fish above them

Individually frozen fish can be severely indented where they lie across each other, and tend to take up the shapes of the surfaces they are pressed against – ridged floor plates or edges of structures in the hold. In an extreme case, a stack of fish can be compressed together into a solid mass, with almost no spaces between the fish. Blocks of products are squeezed, flattened and distorted and will extrude into gaps between cartons, they can also be indented by floor plates or pallet boards.
Frozen products at low temperatures are often brittle and prone to damage by rough handling. For example, tails are easily broken off whole fish and blocks can be shattered or chipped.

Products can also be damaged by contamination. If oil or chemicals are spilled, they may penetrate the wrappings and affect the contents. When cartons and wrappings are torn, the contents are more vulnerable to both contamination and dehydration.

Pre-shipment inspection

The need for inspection

Loss of quality in fishery products can be caused by damage both before and after freezing. Carriage of frozen fish by sea is just one stage in a long sequence of processing, handling, distribution and storage operations – products can be damaged or decline in quality at any stage. Receivers of damaged cargoes of frozen fishery products might allege that loss of quality occurred solely while the material was in the charge of the shipowner.

Pre-shipment inspection is therefore essential, to determine as far as possible the condition and quality of the product at the time of loading, and to note any circumstances that could lead to an exaggerated loss of quality during carriage in the vessel. Such information has an important bearing on any claim that loss of quality or damage occurred during carriage in the reefer. The inspection should take into account the nature of the material, its packaging and its presentation.

Pre-shipment inspection by the ship’s officers is generally confined to visual inspection of the cargo and to measurement of physical properties such as temperature. Officers are not expected to carry out detailed evaluations of the quality of the material, which would require examination of material after thawing and perhaps also after cooking.

Nature of the consignment

The deck officer should check that the materials to be loaded are consistent with the bill of lading. However, information provided on a bill of lading is usually very brief – a cargo may be described as ‘fishery products’, which encompasses many different product types. Wherever possible, deck officers should record any additional information, for example, in the case of individually frozen fish, the species or variety, the presentation (whole or dressed) and the name of the fishing vessel.

It is also important to record the details of any labelling on wrapped or cartoned material, particularly production dates or batch codes. The absence of any labelling, particularly of batch or production codes, should also be noted.

Information on the nature of the consignment and all details of labelling should be recorded on the mate’s receipt. If labels are detachable, one can be removed and attached to the receipt.

Temperature of the consignment

It is essential to measure the temperature of frozen fish presented for loading. Since fishery products suffer damage if they are stowed at a high temperature, temperature records provide important evidence of the state of the product at the time of loading.

The terms of carriage normally stipulate the temperature, or at least the maximum temperature, at which the cargo should be carried. Holds of reefer vessels are intended for storage of frozen material loaded at the required temperature of carriage.

Refrigeration systems have little spare capacity to lower the temperature of products which are put into the hold at above its operating temperature. Material that is above the operating temperature of the hold will take a long time to cool down and will lose quality as a result.

The terms of contract between the provider of the frozen products and the recipient sometimes specify the maximum temperature at which the products should be stored and delivered to the vessel – a maximum temperature of -10°C would be typical for frozen tuna delivered from a tuna fishing vessel. Even if there is no specific requirement for the cargo’s temperature on delivery to the vessel, the master may refuse to accept a product if he considers the temperature too high and the product at risk of damage during stowage and carriage.

The deck officer should ensure that sufficient measurements are taken to provide an adequate summary of the temperature cargo, and that the measurements are accurately recorded. Guidelines for temperature measurement are given in the Appendix at the end of this article.

During loading, supervising officers should note any softening of the flesh of fish during transfer to the vessel – this can be gauged by pressing the surface of the fish with a thumb nail or the point of a temperature probe. Even when the temperature measured at the
core of a fish is low, the flesh on the outside can be soft enough to be damaged by the pressure of a stack within the hold.

**Condition of the material**

It is not easy to assess the intrinsic quality of frozen products by visual examination, but, with experience, one can get some indication of pre-freezing quality from the appearance of the eyes and skin in the case of whole fish, from the colour of the shell in the case of shell-on crustacean shellfish, and from the colour of the skin in the case of cephalopods. Of course, these indications of quality will not be visible in packaged products unless some of the cartons are opened. Whenever possible, photographs should be taken of any defects.

**Visual indication of spoilage in individually frozen fish**

The inspecting officer should examine frozen fish individually for signs of spoilage before freezing. The table below summarises the difference in appearance between good quality and stale fish.

<table>
<thead>
<tr>
<th>Good quality fish</th>
<th>Stale fish</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Colours</strong></td>
<td></td>
</tr>
<tr>
<td>bright, demarcated</td>
<td>degraded and dull</td>
</tr>
<tr>
<td><strong>Eyes</strong></td>
<td></td>
</tr>
<tr>
<td>clear or slightly cloudy; flat to the head or even projecting slightly</td>
<td>yellowish or reddish; sunken or missing</td>
</tr>
<tr>
<td><strong>Skin</strong></td>
<td></td>
</tr>
<tr>
<td>clean – no discoloured slime or coating</td>
<td>abraded and covered with with yellowish slime or blood-stained brine; head region of tuna takes on a diffuse pinkish hue</td>
</tr>
</tbody>
</table>

Tuna spoiled prior to freezing – note sunken, discoloured eyes, dull colours, pinkish discolouration of head, loss of skin and dirty, bloodstained slime

Wrapping, which may or may not be supplemented by further packaging in a carton, is intended to prevent contamination and dehydration. Wrapping is only effective in protecting against dehydration if it is sealed or is closely applied to the product. The record should include details of the type and condition of any wrapping.

**Nature and integrity of packaging and wrapping**

Packaging is intended to protect the product from physical damage. The inspecting officer should record any damage to outer wrappings, particularly if the damage has caused exposure of the contents. Sometimes the packaging includes strapping, particularly where a carton contains individually wrapped, heavy products like blocks of fillets. The nature and integrity of any strapping should be noted.

The officer should note any staining of cartons and outer wrappings, including the character and nature of the stain – lubricating oil, fuel oil, water, fish juices, for example. Oils tend to be dark in colour and leave the wrappings soft, even when frozen; fish-juice stains are yellowish or reddish. The officer should note if the staining is extensive, covering all or most of the container or wrappings, or localised. When stains are localised, note whether they are predominantly on corners or edges of packages or on the sides.

**Blemishes, stains and contamination of the product**

When the surface of the product is visible, it should be inspected for blemishes and contamination. Blemishes include surface damage to whole fish like abrasions and tears to the skin or splits in the flesh, and surface damage to blocks such as patches of freezer burn. An attempt should be made to assess the proportion of the consignment affected.

It is important to record an unusual discolouration or staining, and if possible the nature of the defect, for example, blood or bloody brine (particularly on brine-frozen tuna), oil, and chemicals. The product should also be examined for contamination by dust, organic matter such as fish offal or vegetable debris, and any other foreign matter.
In all cases of blemishes or contamination, the inspecting officer should note the extent of the damage and estimate the proportion of the consignment affected.

Individually frozen whole fish often have slight pressure marks formed during the freezing process. These minor distortions must be allowed for during examination of frozen products. The nature of the marks depends on the freezing process. For example, fish frozen in trays are slightly flattened or have indentations on one side where they have lain on the trays during freezing. Brine frozen fish tend to float in the brine tanks and are restrained below the level of the brine by a grating. As a result, the fish may have slightly flattened sides where they have been compressed, or shallow cylindrical-shaped depressions where fish lay across each other as they froze. Sometimes the pressure on tuna during brine freezing results in splitting of the skin and flesh, usually on the dorsal surface at the base of the dorsal fin. Any other splitting should be noted by the officer.

Any distortions other than slight flattening or the presence of minor depressions suggest that the product has warmed up, softened, and refrozen in the distorted shape. The officer should note the nature and extent of any distortions.

Blocks of fish should reflect the sharp angles and regular, geometrical shape of the tray or former in which they were frozen. Blocks of fish which have thawed while stored on pallets or in stacks show signs of slumping, bending, or compression and material is often squeezed into spaces between blocks. Restraints such as strappings and the framing of pallets and shelf-supports cause indentations in the blocks of fish. Again, the inspecting officer should note the nature and extent of distortions.

**Release of liquid**

Fish release liquid as they thaw. The cargo officers should check for pools of liquid collecting within wrappings, and for signs that liquid has been squeezed from the blocks and has refrozen on the sides of the

**Signs of thawing or partial thawing**

Sometimes claims are made against shipowners on the basis that a cargo had thawed or partially thawed during the voyage, and had then frozen again to the stipulated carriage temperature. It is therefore important to check that a potential cargo does not show signs that it had thawed and refrozen before it had been presented for shipment. Such thawing or near thawing is often indicated by distortion of product shape and release of liquids from the product.

**Distortion**

Distortion of whole or blocks of fish indicates that the material has thawed or partially thawed since freezing, or was distorted during the freezing process.
stack or on shelves and pallets. Staining of cartons is
sometimes an indication that the contents have
thawed and released liquid.

Transfer, stowage and carriage

Temperature control during loading

It is very important for maintaining quality that frozen
fishery products be held at low temperatures at all
times. Although it is inevitable that the product’s
temperature will rise during loading into the hold, the
loading operations must be conducted so as to keep
this rise to a minimum. The product’s quality suffers not
only due to the immediate rise in temperature as
material is stowed in the hold, but also because of the
time taken to bring the product back down to the
required temperature after stowage.

As far as possible, the cargo should be loaded at, or
below, the required temperature of carriage – typically
around -18°C. Officers and crew should attempt to
minimise warming of the cargo while it is being loaded
and stowed in the holds, preferably so that the
temperature of the cargo is not above -10°C by the
time it is stowed. Although the ship’s crew may have
little control over loading operations, the master should
co-operate with the ship’s agent, and particularly with
the stevedoring company, to ensure that good practices
are adopted during loading and stowing.

Good practices during loading

● Ensure that delivery to the ship’s side is matched to
loading onto the vessel to reduce the time that
products are waiting on the quay.

● Products should be delivered in insulated containers
or lorries, or at least in covered vehicles.

● If the material must be unloaded onto the quay or
held on the deck of the reefer, it should be placed on
pallets or on an insulating base, packed as tightly as
possible and covered with a tarpaulin or similar
protection against sun and wind.

● The cargo should be protected from exposure to
wind, rain and sun until it is about to be transferred to
the vessel.

● In tropical climates, avoid loading for two or three
hours either side of noon and consider loading the
vessel at night.

Good practices during stowage

● Ensure that the hold is cooled to below the carriage
temperature before loading begins.

● During breaks in loading, cover holds or decks with at
least the hatchcovers, even if the thermal covers are
not put in place.

● Refrigeration to the holds should be turned on during
long breaks.

● Transfer cargo as rapidly as possible from the quay or
discharging vessel to the hold.

● Once loaded, the cargo should be covered with
tarpaulins.

● Where consistent with efficient loading, use only one
hatch at a time to avoid through currents of air in the
hold.

Maintaining low temperatures during

carriage

There is usually an explicit or implicit requirement to hold
the cargo below -18°C during carriage. The ship’s
refrigeration system must be capable of delivering air to
the holds at a temperature a few degrees below the
target temperature to allow for heat leaks though the
ship’s structures. Cargo spaces in reefers are usually
cooled by re-circulating air systems, which are only
effective if the air can circulate freely through and
around the stow.

Most heat leaks into the cargo hold occur through the
sides and bulkheads, and it is important to ensure that
there is free circulation between the cargo and the
structures to the hold. Sides and bulkheads should be
fitted with vertical dunnage (without horizontal battens
which could obstruct air flow) to keep the cargo away
from the structures. There should be an even gap of at
least 20cm between the top of the stowed cargo and the
lowest part of the deckhead.

Cartons should be stacked with gaps between them
while stows of individually frozen fish will inevitably have
spaces between the fish unless the fish are deformable
and have been compressed.

The ship’s engineer should ensure that refrigeration
equipment is well maintained and can achieve the
design temperatures. Evaporator coils must be defrosted
as required to maintain the cooling capacity. Frequent
need for defrosting is a sign of high temperatures in the
cargo and should be noted in the engine room log. In
addition, the engine room log should record
temperatures at critical and meaningful positions in the
refrigeration system – for example, the outlet and return
air streams in air cooling systems, and the outlet and
return fluid temperatures in pipe-cooled systems.

It is vital to take and record temperature measurements
in the hold. How meaningful these measurements are depends on the location of the temperature sensors. Material in the centre of the stow is the slowest to cool because the source of refrigeration is mainly around the sides of the stow. Refrigerated air percolates gaps between fish or between cartons and the cooling effect depends very much on the existence of uninterrupted spaces. Sensors attached to the sides or bulkheads of the hold are exposed to cold air circulating through the dunnage against the sides or bulkheads and therefore tend to indicate temperatures lower than the bulk of the cargo. Sensors should be attached to posts or other structural members running through the hold, where they are more likely to reflect the temperature of the bulk of the cargo accurately.

Protecting the cargo from contamination

Every effort must be made to protect the cargo from contamination. Good shipboard practices will prevent direct contamination by sea water, bilge water, fuel oil and the like, but it is important to be aware that fishery products are rapidly tainted by odours picked up from the ambient air. This is a vital consideration when using air-cooled refrigeration systems – the air must not become polluted by odiferous materials such as fuel oil, paints or chemicals used on the ship. A simple guideline is that if the air circulating through the hold has an odour, then that odour will be picked up by the fish products.

Unloading

When a cargo is unloaded from the ship, similar precautions should be taken to those recommended during loading to minimise warming. Unloading should be completed as quickly as possible and the cargo should be protected from wind, rain and high temperatures.

Documentation

The importance of documents

Documents are fundamentally important in the investigation of any claim involving damage to cargo. They will be examined by the technical surveyors, and may be used as evidence in any subsequent legal proceedings. The following documents are likely to be important in the event of a claim.

- Ship’s log.
- Bill of lading.
- Mate’s receipts and attached record of the inspection of the cargo prior to and during loading.
- Deck log of loading and unloading.
- Stowage plan.
- Engine room log.
- Any documentation arising from disputes during unloading and/or receipt of cargo.

In addition, photographs and video recordings can provide important evidence in support of statements in the logs and inspection reports.

Mate’s receipts

The mate’s receipts should include the record of the pre-shipment inspection (see previous section). This record should detail all observations on the cargo’s condition at time of receipt, including results of at least a visual inspection of each part of the consignment.

Records should also include temperature measurements, taken at sufficiently frequent intervals to provide a fair indication of the average temperature of the cargo.

Any observations which indicate that cargo temperature is high, or that cargo was delivered in a damaged or deteriorated condition, should be supported as far as possible by further evidence. This evidence might include photographs taken during pre-shipment inspection or results of reports by cargo surveyors.

The mate’s receipt should include any information on the nature of the consignment supplementary to the bill of lading, as well as details of any labels.

Deck log for loading

Loading

Many charterparty agreements specify a minimum rate of transhipment or loading. To demonstrate compliance with this, and to provide evidence in case of claims concerning damage to the cargo during loading, the timing and sequence of events during loading should be noted in the deck log. At minimum, the log record should include the following:

- Time alongside.
- Where cargo was loaded from – quay, lighter, fishing vessel.
- Times of opening and closing of hatches.
- Arrival and departure of stevedores onboard.
- Times when the refrigeration system was turned on and off.
- Start and finish of cargo stowage.
● Any breaks in loading.
● Weather conditions (sun, wind, rain, ambient temperature).
● Any unusual or irregular events which might affect the condition of the cargo during stowage or subsequent carriage.

Deck log for unloading

Unloading

Normally, unloading may be the responsibility of the receiver, and the master of the vessel could consider that his responsibility for the cargo is over. However, the deck log should continue to record conditions during discharge, logging similar information as listed above for loading.

Stowage plan

A stowage plan should be drawn up for all cargoes – an accurate plan is a central piece of evidence in any damage claims arising against the vessel.

The stowage plan should indicate the location of each consignment and part of consignment and should include the following information:

● Number of units (pallets, cartons or blocks) in each location.

● Gross and net weight.

● Origin of each part.

● The corresponding bill of lading.

Engine room log

The engine room log is one of the most important documents, since it contributes evidence about the temperature of the ship’s cargo during stowage and carriage.

The log should document at least the following:

● The locations of temperature sensors in the holds.

● Temperatures at the sensors in the holds.

● Times when compressors were turned on and off.

● In air-cooled systems, the temperatures in the air streams entering and leaving the holds and compartments.

● In pipe cooled systems, the temperatures of refrigerant to and from the cooling pipes.

Actions in case of dispute

Action by the master of the vessel

The master must load the cargo in apparent good order and condition and act to maintain it in this state. This section describes actions to be taken when a potential problem is identified.

In the event of any concern or dispute over the condition of the cargo while loading or unloading, the master of the vessel should contact his owners or charterers or his P&I correspondent. Best practice would indicate that loading or unloading should cease until instructions have been received, although this may not always be possible.

As soon as any question is raised over the condition of the cargo, the ship’s master should begin to document the events surrounding the discovery of defective material, and the nature and possible extent of the alleged defects.

If possible, loading or unloading of the vessel should be halted and the hatches closed until a cargo surveyor is present. Ideally, cargo should be inspected and sampled while still in the hold, or even during discharge, allowing the surveyor to determine if the nature and extent of the damage is in any way related to the position in the hold.

Once the cargo has been discharged into store, relating damage to location in the hold is obviously more difficult, or impossible, unless the cargo is adequately labelled. Therefore, if loading or unloading must continue, the master should ensure that each cargo unit is labelled with the hatch number and deck as well as location within the hatch and deck, as it leaves the hold. The deck log should also record the destination of the material and the agent responsible for handling it.

Records

The master should ensure that all records and documents relevant to the dispute are secure, and that they are only made available to parties representing the ship’s interests.

Services of surveyors

When a problem is identified during loading or unloading – for example, if the temperature of the material is too high – loading or unloading should cease until the cargo has been inspected by a specialist surveyor.

If the dispute concerns the quality of the product, it will probably be necessary to call in at least one
specialist surveyor to examine the cargo, establish its current quality and determine the nature and cause of any defects.

If it is suspected that defects result from maritime causes – for example, physical damage from movement of cargo, or from contamination with sea water, fuel oil or bilge water – an expert in ship operations should be called in. However, if the defects could be attributed to the initial quality of the material when loaded, or to the way the product was stowed and carried on the vessel, a specialist surveyor would be appropriate.

Many of the surveyors appointed by local shipping agents are general marine surveyors, often with a seagoing background; they are not necessarily skilled in the evaluation of the quality of fish cargoes. Masters and agents are therefore advised to check the expertise and qualifications of surveyors carefully to ensure that their technical background and experience are appropriate for the particular job.

As a general rule, a single surveyor should not be commissioned for both a cargo survey and a survey of vessel condition. Since the skills required for each type of assessment are very different, it is unlikely that one person would have experience in both areas at the levels of expertise required. A fish cargo surveyor should have a background in food science and the inspection of food products, and, ideally, some experience in assessing the quality of frozen fishery products.

**Official inspectors and sampling procedures**

Where official inspectors – for example, port health officers or veterinarians – are involved, the master should document the authority under which the officers visited the vessel and the name and status of each officer.

The master is also advised to record the nature and amounts of any samples taken by representatives of the owners or by officials. Such records should include the location of the samples within the hatch or deck, the authority under which the samples were taken and the destination of the samples.

If part of the sample is given to the master, he should ensure that it is fully labelled, and, if possible, that it is sealed in a container under the impress of the person taking the sample. The master should store the sample in a secure place, under conditions such that the quality of the sample will not change.

If the cargo is in store, the surveyor should take into account the manner of discharge and delivery to the store, in case these operations could have affected the quality of the product or could in themselves be responsible for any damage.

**Appendix**

**Measuring the temperature of frozen fishery products**

**Equipment**

The most convenient thermometer for measuring the temperature of frozen food products is a water resistant K-type thermometer with a digital display reading to 0.1°C. Typically, these thermometers have a measuring range down to minus 50°C and an accuracy of ±0.5°C in the range required when measuring temperature of chilled or frozen foods. This accuracy is adequate for the purposes described in these guidelines.

![Thermometer and probe](image)

There are several types of probe available for plugging into the instrument. The best all-round probe for measuring temperatures of fishery products is a 100mm long, 3-4mm diameter, stainless steel penetration probe on a 1m lead. There are also stouter, hammer-in probes on the market for forcing into frozen fish (provided the temperature is not too low), but these have long response times. It is usually preferable to drill holes and use a thinner probe.

**Measuring the temperature of frozen fish**

It is not usually possible to push a probe into frozen products. Normal practice is to drill a hole, with an
ordinary engineer’s hand or power drill, of such a diameter that the probe fits tightly. The bottom of the hole should be at the thermal centre of the object that is at the position that will cool down or warm up most slowly. The thermal centre is usually at the backbone in the thickest part of a fish, or at the centre line of a block of fillets. The hole should be around 100mm deep – that is, sufficiently long to take the whole length of the probe. This may mean that the hole must be drilled at an angle to the surface of a fish, or along the centre line of a block from one of the smaller side faces.

![Fig B. Inserting temperature probe into frozen fish or block of fish](image)

Once the probe has been inserted, note the lowest temperature reading given in the next 2-4 minutes. While the hole is drilled and the temperature measurement taken, the product warms up, so measurements should be taken as quickly as possible, and preferably while the product is still in the hold.

**Measuring the temperature of products in cartons**

Products in cartons may be delivered in regular stacks or in random loads. In a regular stack of cartons – for example cartons on pallets – temperatures can be measured by inserting the probe between cartons. The warmest areas are the corner of the stack.

Temperature should be measured at diagonally opposed top and bottom corners and in the centre of a face. Insert the whole length of the probe between cartons, or between the flap and body of a carton, on the mid-line. Insert the probe between vertically stacked cartons rather than horizontally adjacent cartons as the weight of the cartons above ensures a good thermal contact with the carton. Record the minimum reading. Pushing the probe between cartons will result in some frictional heating, so five to ten minutes may be required to reach equilibrium. When measuring temperatures of cartons, it is useful to have several probes, cover the stack to avoid heat loss, and allow 5 to 10 minutes before connecting the probes in turn to the thermometer.

When cartons are loosely stowed, it is necessary to measure the temperature within cartons. If the contents are loose – IQF fillets, for example – the probe can be forced through the side of the carton into the product.

Thermal contact is poor in such cases – it may take 10 minutes, or more, to reach thermal equilibrium. If the cartons contain blocks, it should be possible to insert the probe between blocks to drill a hole in a block through the side of the carton. The carton usually has to be split to locate gaps between blocks and the centres of faces of blocks.

**Calibration of the thermometer and probes**

Instruments are calibrated by their manufacturers, but it is possible to check thermometer/probe combinations at 0°C on the vessel.

Finely crush some ice made from fresh or distilled water, and pack it tightly in a vacuum flask or jar. Add cold water to fill the flask and insert the probe to its full length in the ice/water mixture in the centre of the flask and leave the flask and probe for a while in a cool place – perhaps a refrigerator or chill room – before taking a temperature reading. Since a mixture of ice and fresh water at thermal equilibrium has a temperature of 0°C, any deviation of the probe/thermometer combination from 0°C is the correction for that system.
Dealing with claims

The following lists show the type of information that is needed to help the Club deal with a refrigerated cargo claim.

### Instructing party
- Data and time of construction
- Name and address of ship
- Voyage number
- Number of tons
- Number of holds
- Cleaner stowage
- Rate
- Port
- Date and time of arrival

### Certificates
- manifests loading/discharge port
- manifest cargo claimed
- Manifest cargo release after discharge of previous cargo

### Discharge particulars
- Date and time of arrival at discharge port
- Disposition of cargo in compartments before discharge
- War cargo discharged (adding, routing, etc.)
- Cargo was discharged into (metal, trunk, etc.)
- Type of refrigeration used in the cargo holds (electric/combination)
- Weather conditions during discharge
- Slippage during discharge
- Times of discharge of each individual compartment

### Temperature
- carriage instructions
- Snipe/pulp temperatures of the cargo during discharge (individual readings: no averages)
- Average air temperature during the loading
- Temperatures in compartments on commencement of the loading
- Temperatures and other parameters (delivery air, return air, CO2, CO2) in compartments after final stowing (see Appendix no.3)
- Temperature and other parameters (delivery air, return air, CO2, CO2) during voyage
- Stowage period (see Appendix no.4)

### Refrigeration arrangement
- Type of refrigeration machinery
- Type of air circulation in the compartments, and whether decks are paired or independent
- Type of refrigeration, and whether direct or indirect system
- Capacity of the air coolers and fans in the compartments (see Appendix no.2)
- Type of fresh air system
- Capacity of fresh air system
- Location of fresh air intake
- Location of fresh air outlet
- Location of ventilation, humidity, etc., sensors

### Controlled atmosphere arrangement
- Type of equipment (feed or automatic)
- Condition of equipment for injection
- Condition of equipment for monitoring of atmosphere
- Type of machinery
- Chart of equipment
- Arrangement of ventilation and control to decks

### Condition of cargo
- Relative humidity in the compartments (varies, count, number per package)
- Description of package
- Details and number of packages
- Spiking and packing dates
- Stowage of packages
- Description of condition of the cargo
- Number of tons on the date
- Construction of cable load
- Difference in condition when considering grower packing dates, packing date, variety, count, location on hold, location in cargo compartment or other compartment
- Location in cargo compartment of cargo claimed upon
- Type of commodity before loading
- Estimated sound market value of the cargo (CIF, DAF, FOB)
- Estimated sound market value of the cargo
- Estimated total extent of the damage

### Further particulars
- Description of condition of cargo holds and air ventilation/circulating ducts
- Number of packages
- Stowage and condition of cargo
- Presence and condition of side shoveling
- Description of condition of refrigeration of air gaps in the above and behind side shoveling
- Cleanliness of discharge premises

### Further points of interest
- Set of photographs
- Photographs taken by other parties
- Copy of relevant scrap notes
- Copy of documentary validating the sound market value
- Copy of commercial invoice
- Copy of sea protest
- Copy of certificate of origin
- Copy of B/L (both sides)

### Appendix no.1

<table>
<thead>
<tr>
<th>General arrangement and stowage</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tr>
<td>Voyage particulars</td>
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<tr>
<td>Discharge particulars</td>
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</tbody>
</table>

### Appendix no.2

<table>
<thead>
<tr>
<th>Refrigeration arrangement and airflow</th>
<th>A</th>
<th>B</th>
<th>C</th>
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</thead>
</table>
**Appendix no.3**

**Table: Date, time and parameters in each individual compartment before opening in discharge port**

<table>
<thead>
<tr>
<th>Compartment</th>
<th>Date/time</th>
<th>Delivery air temp</th>
<th>Return air temp</th>
<th>Space temp</th>
<th>CO₂ %</th>
<th>O₂ %</th>
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<tbody>
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**Notes**

- Normally the plant will produce 90 air circulations per hour at full speed (by volume of empty hold space). Usually the cooler rooms will be inspected once or twice daily for the purpose of taking manual temperatures of the cargo in the hold through the cooler room access doors. Also CO₂ and humidity can be examined at the same time if required.
- Investigate if fixed equipment (hot gas for example) has been used for defrosting. If manual defrosting has been carried out find out why. Check the dimensions / construction of the drain pan under the evaporators and was crew in attendance in cooler rooms to observe the defrost operation and to see if that the drain pan did not overflow into cargo compartment.
- Fresh air ventilation
  - When applicable control of the fresh air ventilation is equally important as the air circulation and response proper attention. Fresh air may be bled into the air circulation as required. For frozen cargoes and some grounds fresh air is not required and the circulation fans and fresh air ventilation should both be shut off as stated in the carriage instructions.
  - Fruit and vegetable cargoes are nearly always ventilated (as well as being cooled) to reduce the ethylene gas produced, (as reflected by the CO₂ content), which is detrimental to the condition of the produce in the case of fruit may lead to early ripening.
  - Fresh air circulation can be controlled generally between the 2 – 5 changes per hour (by volume of empty hold space) utilizing the fan speed and adjustment of fresh air ventilation flaps which can be opened and closed according requirements.
  - In colder weather there may be a conflict between the need to maintain circulated air delivery temperatures and the need to ventilate and to introduce cool fresh air.
  - Air circulation fans are normally run on the specified speed. It is a good idea to check the remote fan switches in the switches house personally when possible.

Any difficulties with the operation of the air circulation of the fresh air ventilation systems or with the maintenance of temperatures should be reported to all parties.

**Appendix no.4**

**Reduction period**

<table>
<thead>
<tr>
<th>Compartment</th>
<th>First recorded temperature after final closing</th>
<th>End of reduction period</th>
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**Pre-cooling**

- Investigate details of pre-cooling and compliance with instructions.
- In the pre-cooling that is not completed in time for loading bananas or exotic fruits as required by the carriage instructions, and providing the plant is fully operable and the shippers issue full indemnities in agreement with owners / operators, it will sometimes be preferable to load the cargo as soon as possible, rather than to leave it in open sheds or transport with no cooling.
- Special attention is to be paid to the time of loading of (for example) bananas an thus the time that the fruit is exposed to the cooling down temperature being lower than the carriage temperature.

**Condition of cargo**

- This block is to indicate the Port arrival and berthing times as well as the times (charging/discharging) period for each compartment. Further more all relevant details also can be recorded.

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**Appendix no.5**

**Table: Date, time and parameters in each individual compartment after final closing in loading port**

<table>
<thead>
<tr>
<th>Compartment</th>
<th>Date/time</th>
<th>Delivery air temp</th>
<th>Return air temp</th>
<th>Space temp</th>
<th>CO₂ %</th>
<th>O₂ %</th>
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</table>

**Notes**

- The voyage begins for each compartment on final closing at the load port where after the data logger will record the compartment air circulation delivery and return temperatures, CO₂ content and humidity (also CA parameters) every four hours.