



Chapter 35 – Refrigerated Container and Controlled Atmosphere Cargoes

The international transport of temperature controlled raw materials and final products is an essential link between producers and consumers. Most cargoes have properties that will determine their practical storage life (PSL), which is a key factor if they are to be carried by sea.

The container trade has seen changes in recent years, including, for example:

- More countries are exporting by sea, with products including fruit, fish, meat, flowers and other high value items
- some shorter life products spend more than half their PSL in transit
- supermarkets demand all year round supplies, reducing seasonality
- lower stock holding has increased demand for just in time deliveries and inventory control.

35.1 Claims and Incidents

The majority of cargoes are transported without damage as claims represent a fraction of only around 1% of the containers carried. However, for those cargo claims, the following list contains occurrences that are often reported:

- Lack of container preparation for loading, causing issues such as tainting and lack of general cleanliness
- containers off-power and, therefore, off-refrigeration for extended times beyond allowed times for power-off
- wrong settings due to incorrect information supplied or interpreted
- failure to monitor properly leading to failure to correct faults or wrong settings
- poorly pre-cooled or overcooled cargo
- cargoes with insufficient PSL
- badly stowed containers impeding airflow, many with low quality packaging
- use of inappropriate packaging materials
- excess fresh air ventilation for live cargoes causing evaporators to ice up
- physical damage
- broken security seals and issues of potential tampering
- air probe temperature sensor failures
- partial or complete loss of refrigerant and/or generator failure
- incorrect defrost interval where this has to be set manually
- incorrectly booked cargo leading to operational and commercial problems
- Fahrenheit and Celsius temperatures interchanged incorrectly or wrongly converted.

60% of claims can be attributed to human error. For example, mishandling by a gantry crane operator could damage the cooling plant or its controls, leading to incorrect readings on the Partlow charts or Cox recorders.

One of the main causes of damage to cargo carried in containers is poor stowage by the shipper, although as the number of claims is still small, the statistics are difficult to analyse. However, reports indicate a decline in the use of specialised reefer ships and an increase in demand for transport by refrigerated container. As the volume of refrigerated cargo increased, a shift from the use of 20 to 40 ft containers has become evident. Therefore, while the ratio of claims in the trade may not change, the actual number and value of claims is likely to rise.

Most temperature controlled containers contain data loggers that record a variety of information. Some are fitted with data transmission capabilities for remote access for both control and readouts. Increasingly, containers are connected via the SATCOM to allow external monitoring of temperatures and conditions. Independent loggers are also available so that a wide variety of audits and checks can be made. When reviewing a claim/incident, containers equipped with this information download can show:

- Pre-trip inspection records
- set point plus supply and return air temperatures at preset intervals

- defrosts
- times off-power
- basic faults
- relative humidity.

This is a major improvement from just recorder chart details and, when such remotely managed containers are more widely implemented, ships' crews involved in the cool chain should follow cargo care instructions directly from the reefer container operator.

35.2 Future Trends

Future trends are likely to include:

- Integral containers:
 - that are more reliable with improved airflow, calibrated air freshening vents, dehumidifiers and other programmable settings
 - with improved insulation and lower degradation over time
 - with reliable refrigeration machinery, controls and data loggers, with some providing wireless/satellite data transmission and remote access to controls
 - including more use of 40 ft containers making it easy to care, carry and discharge
- increasing uniformity of regulations
- food standards agencies or equivalent developments in some key countries
- majority of container ship operators providing information and guidance through their web-based systems.

35.3 Principles of Controlled Atmosphere (CA) Carriage

CA is a system whereby the gas concentrations to which a cargo is exposed are different from those of normal air.

The atmosphere naturally comprises about 78% nitrogen (N_2), 21% oxygen (O_2) and 0.04% carbon dioxide (CO_2), the remainder consisting of noble gases (eg argon). The aim of CA is to change the ratio of these gases. For example, an atmosphere of 2 to 5% O_2 and 2 to 5% CO_2 can extend the storage life of bananas beyond that which can be achieved by refrigeration alone.

CA is extremely effective on apples and pears but less effective on some other fruit. In general, it can be said that it gives a 50% increase in storage life and, for bananas, their 'green-life' is more than doubled.

Lowering the O_2 concentration results in a reduction of the respiration rate by up to 30%, thereby slowing ageing and also reducing sensitivity to the ripening hormone ethylene. Increasing CO_2 is beneficial in suppressing the growth of moulds. Further, when dissolved in water, it produces carbonic acid which is antibacterial. CO_2 also reduces production of ethylene and lessens its effect on produce.

Chilled produce is still alive and respiring during transport and storage, using O_2 and its own carbohydrate reserves, as shown in Figure 35.1.

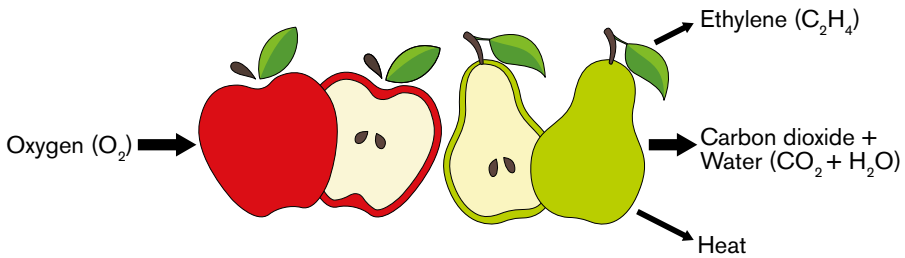


Figure 35.1: Produce respiration.

Regardless of commodity, the strongest influence on the quality of the final cargo outturn is the initial quality of the produce.

As well as prolonging storage life, CA also maintains the firmness, texture, crispness, acidity and appearance of some products. It further opens possibilities for the produce to be harvested in a riper state.

The optimal temperature and gas composition for different perishable cargoes depends on variety, growing area and season. For this reason, the precise values must be defined by the shipper.

CA systems currently in use

The two current CA methods are:

- Nitrogen gas flushing
- fresh air replenishment with CO_2 absorption.

Nitrogen gas flushing employs air and N_2 injection to adjust the balance of O_2 and CO_2 inside a refrigerated hold or refrigerated container. Air separation units are used to obtain N_2 from the outside atmosphere. It is injected to dilute the O_2 in the refrigerated space. If (through respiration of the cargo) the concentration of O_2 becomes too low or that of CO_2 becomes too high, the system automatically adjusts the gas concentrations.

A fresh air exchange system with CO_2 absorption relies on the respiration of the product to vary the gas concentrations. When the CO_2 or O_2 level reaches a preset point, the system activates, drawing in outside air to add O_2 and flush excess CO_2 . As respiration consumes O_2 and evolves CO_2 , it is not possible for this system simultaneously to achieve low O_2 and low CO_2 levels unless a CO_2 absorption system is used.

Detrimental effects of CA

Generally, CA is beneficial to the long-term storage of produce, but there can be some less desirable consequences.

Inadequate O_2 can result in anaerobic respiration, leading to the production of alcohol and giving the affected produce a characteristic off-taste. Excessive CO_2 can produce

tissue damage and 'fizzy' fruit. In apples, the final effect is a condition known as brown heart, where the core tissue turns brown.

Premature ripening of bananas during shipment under air-stored carriage will turn the fruit yellow, easily identified as 'ship-ripes'. Under CA conditions, however, the raised CO₂ concentration prevents de-greening of the peel and the bananas arrive with soft pulp, known as 'green-soft' or 'green-ripes'. If CO₂ levels are excessive, bananas may develop a black blotchy appearance. A combination of elevated temperature and CO₂ levels above 5% can even kill the fruit.

35.4 Safety Issues with CA

Safety is an important consideration for carriers because low oxygen atmospheres are incapable of supporting life. Entering an area during CA operation will have fatal consequences, so all CA areas must be clearly indicated by warning signs. Stevedores, ships' officers and crew should be adequately trained to understand the dangers of CA. Doors should be alarmed and adequate precautions taken against stowaways. Protection for doors may include dedicated safety door locks to prevent easy unauthorised access.

Enclosed space entry procedures must be followed before entering a space that has earlier been subject to CA, or an adjacent space where the O₂ concentration may have been depleted. Anyone entering such a space should carry an O₂ detector with a low-level alarm.

Symptoms of O₂ deficiency are similar to drunkenness and the subject is unaware that they are being affected. Table 35.1 lists the effects at different concentrations.

Oxygen content %	Symptoms
~21	Normal atmospheric concentration
15 to 19	Loss of coordination, impaired work ability
12 to 15	Loss of judgement, confusion and elation
10 to 12	Increased loss of judgement and coordination, general confusion
8 to 10	Mental incapacity, nausea and vomiting
5 to 8	Death in 8 minutes, recovery possible providing exposure less than 5 minutes
<5	Rapid unconsciousness followed by death in under 1 minute

Table 35.1: Symptoms of O₂ deficiency.

Increased CO₂ levels also pose a danger, causing headaches, dizziness, confusion and ultimately loss of consciousness. Long-term exposure limits are 5,000 ppm (8-hour period) and short-term exposure limit 1,500 ppm (15 minutes).

The safety requirements extend to those unloading cargoes. It is essential that workers are adequately trained and that proper fresh air ventilation is applied prior to opening cargo spaces.

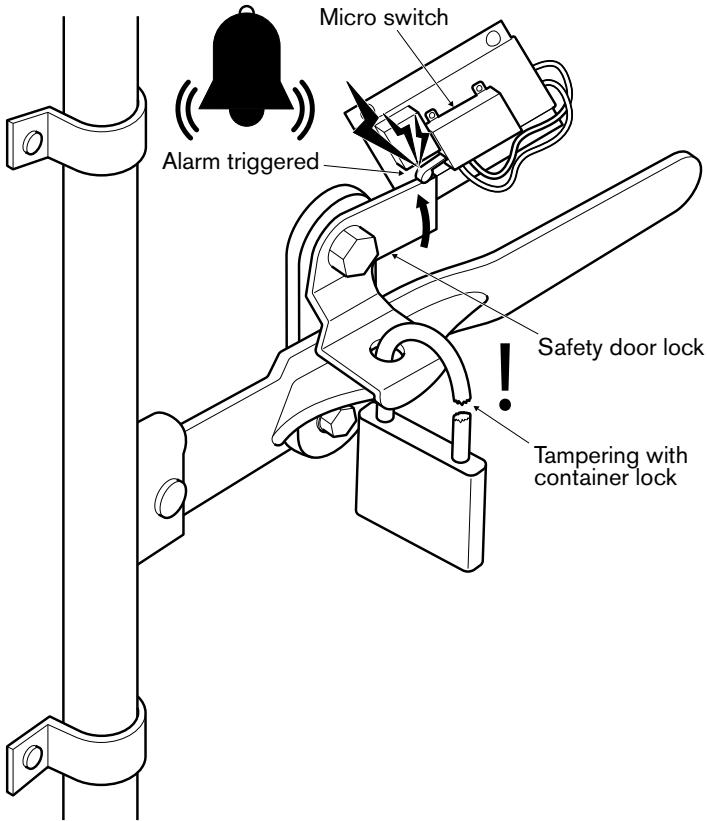


Figure 35.2: Safety door lock in a CA reefer container.

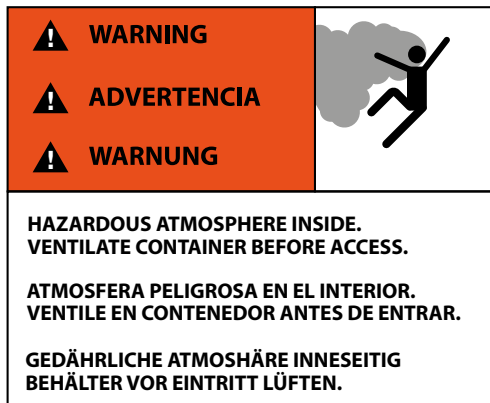


Figure 35.3: Safety decal on a CA reefer container.

35.5 System Failure

Prompt action must be taken in the event of CA system failure. In most cases, the refrigeration system will continue to function and so complete cargo loss is not inevitable. CA failure can be caused by a variety of faults, such as mechanical breakdown, sensor malfunction, unexpected air leakage or even exhaustion of a chemical CO₂ absorbent.

Without intervention, system failure may cause the O₂ to fall too low, causing anaerobic respiration, and/or the CO₂ may increase causing tissue damage.

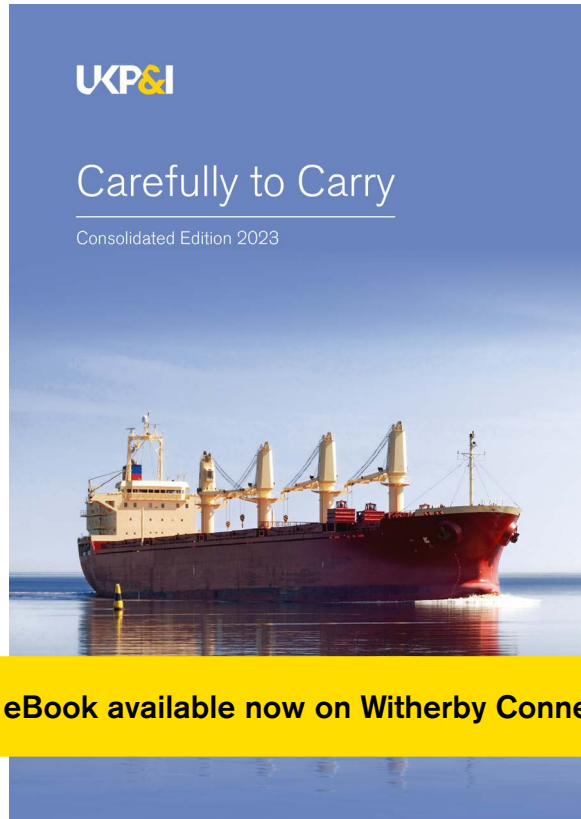
The crew should be provided with clear guidance to identify those circumstances where it will be necessary to break the CA and introduce fresh air. The procedure should be documented in the CA cargo handling and carriage instructions.



Figure 35.4: Rear door curtain in a CA reefer container.



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