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CHAPTER 2
COLD STORE REQUIREMENTS

1. COLD STORE REGISTRATION

The PPECB Act and Regulations require that all cold stores used for the export of South African perishable products shall be registered with the PPECB and annually re-inspected. Fundamental reasons for cold store registration are to protect the product, the owner of the product and the consumer of the product. Apart from minimizing losses, the international trade becomes increasingly more demanding on aspects such as food safety and traceability. PPECB however does not prescribe any specific design, construction, materials or management, but has the responsibility to ensure an efficient cold chain to expand consumer confidence in South African perishable products. This chapter describes, in generic terms, the more important basic requirements for cold stores used for the export of perishable products from South Africa. It is also necessary to understand the following two definitions frequently used in the cold store and cold chain environment.

- Precooling is the process where the field heat of the product is removed and the product is cooled down to the optimum storage temperature.
- Storage (or cold storage) is the process where the product is kept at the optimum temperature to achieve maximum storage life.

2. COLD STORE CONSTRUCTION AND INSULATION REQUIREMENTS

The basic requirement, from a product storage perspective, is that the air and product temperatures inside the cold store are efficiently reduced during precooling and kept constant during storage. It is therefore essential to absolutely minimize heat leakage from the outside environment into the cold store. The following are some of the basic requirements:

2.1 Foundation
Must be well drained and well above the ground water table to minimize heat leakage through the floor.

2.2 Structure
Must be stable without movement that may cause stress and cracks in the vapour barrier and insulation

2.3 Vapour barrier
An efficient water vapour barrier must be installed and maintained on the warm side (outside) of the insulation. The outer skins (usually sheet metal) of sandwich panels serve as barrier for the ingress of water vapour into the insulation. It is however essential that all the joints on the outside are very well sealed. Joints on the inside may be left unsealed to allow the migration of moisture, that may be left trapped in the insulation, to the inside atmosphere.

> Important: Moisture is the worst enemy of insulation integrity. A vapour barrier must be installed in the floor, roof and walls and must be kept intact to keep the insulation dry at all times.

2.4 Doors and fittings
Must make a vapour tight seal (gas tight in the case of controlled atmosphere cold stores). Door seals must be intact and seal all round. Pipes, cables, brackets etc. must be sealed with an appropriate sealant to prevent water vapour to enter the insulation. Door locks on the in and outside, must comply with all National Safety Requirements.

2.5 Insulation
Must be the correct type and thickness to provide an efficient barrier to heat leakage and must be kept dry to maintain insulation integrity. Minimum specifications are given in Table 2.1.

Table 2.1 Minimum required thickness for polystyrene and polyurethane insulation for cold and deep freeze stores.

Type of store and position	Minimum thickness mm	
	Polystyrene	Polyurethane
Cold store		
Floor	Not necessary[1]	Not necessary[1]
Walls	100	75
Ceiling	100 to 150[2]	75 to 100[2]
Deep freeze store		
Floor	150	100
Walls	150	100
Ceiling	150 to 200[2]	100 to 150[2]

Notes:
1. Insulation in cold store floors not necessary provided the under floor structure is kept dry.
2. Thicker insulation required in the ceiling in the warmer climates.

2.6 Cargo protection
Must be provided inside and outside the store facility at all times. An air lock structure to protect the cargo against the elements and to prevent heat leakage from the outside into the cold environment should be fitted. This should also maintain the cold chain during loading of produce into and out of the cold store.

2.7 Drip trays
Must be installed under the cooling units to drain the defrost water to the outside via a U-tube or water trap. Pipes transporting the coolant must be well insulated to prevent the formation of condensation that may drip onto the cargo or the floor.

3. REFRIGERATION CAPACITY

In terms of this document, refrigeration (cooling) capacity can be defined as the ability of the cooling installation to precool (remove the field heat) the product to the optimum storage temperature and to maintain such a temperature (store) according to specific product requirements. The cold store must therefore be designed, built and managed to precool and store the product under optimum conditions. Some important factors that must be considered are:

- Intake volumes and product temperatures must be known to calculate the heat load to be removed within a specified precooling time (e.g. 24 hours).
- Other additional heat sources such as heat leakage, forklifts, air circulation fans, opening and closing of doors.
- Factors affecting the circulation of cold air such as packaging, stacking patterns and dimensions of the cold store.
- Cooling rates required, temperature and relative humidity ranges that must be maintained.

These and other factors must be calculated by the refrigeration engineer and incorporated into the design and construction of the installation. PPECB registration does not consider refrigeration capacity per se, but insufficient refrigeration capacity will result in slow cooling, a big variation in product temperatures and desiccation of the product. This will result in product loading temperatures not being met. A number of factors must be considered but the cold store should be capable of precooling the designed maximum intake volume within 24 hours. Some exceptions to the rule are products packed in polyethylene bags (e.g. grapes – maximum 72 hours) and some less temperature sensitive products (e.g. Granny Smith apples – maximum 5 days). The cold store should also be capable of maintaining the optimum storage temperature of the product within a maximum tolerance of plus/minus 0,5°C (temp ±0,5°C). The RH of the air in the cold store is also a design criterion of the refrigeration capacity (see chapter 2 par 5) and must be maintained within the following values:

- During precooling – a minimum RH of 70% for very short periods only
- During storage – an average RH of at least 90 ±5%
- Exceptions – onions, garlic and certain flower bulbs must be stored at a RH of 70%

4. TEMPERATURE INSTRUMENTATION REQUIRED

Cold stores must be fitted with temperature controlling devices (thermostat), sensing devices (thermometers) and recording or logging devices. Cold stores hired out to other users or where products of other exporters are handled, must also be equipped with suitable calibrated temperature data loggers to record storage conditions to the satisfaction of the user and relevant underwriting insurance companies.

4.1 Temperature controlling devices
These devices are generally known as temperature controlling thermostats. The function of the thermostat is to control the temperature in a given spot at a pre selected value or also referred to as the temperature set point (SP). The following general requirements can be listed:

4.1.1 **Position of thermostat sensor** – Care must be taken to install the sensor in such a position that it senses the average temperature in the immediate environment. The sensor must therefore never be placed directly in front of an air circulating fan or any other heat or cold source but in the air stream entering the product (chilled produce) or the air coming off the cargo (deep frozen produce).

The best position for the thermostat sensor depends on a number of factors such as cold store and cooling coil dimensions, position of air circulating fans and stowage patterns. In the case of chilled produce, the best position is normally about 3 meters in front (air delivery or supply) of the cooling coils or where most of the air comes in first contact with the product.

4.1.2 **Accuracy of temperature control** – The temperature must be controlled within a maximum range of plus/minus 0,5°C from the set point (SP ±0,5°C). Some cold treatment protocols for insect sterilization however require an accuracy of plus/minus 0,25°C (SP ±0,25°C).

4.2 Temperature sensing or measuring devices

The most well known temperature measuring device is the thermometer. The hand held thermometer is still used extensively to measure temperatures of an object (fruit, fish, etc.) but was superceded by electronic devices with a fast response time, easier to read and sometimes also with recording or logging facilities.

4.2.1 **Thermometers** – The mechanical dial types are not recommended because the temperature graduations are too big and therefore less accurate.

> WARNING: Thermometers containing mercury or glass must never be used in the food supply chain.

4.2.2 **Electronic hand held thermometers** have a fairly quick response time with very fine (usually 0,1°C) graduations, but a correction factor may have to be applied to compensate for calibration deviations. Electronic thermometers of well established brands and with an accuracy of plus/minus 0,25°C (±0,25°C) or less can be recommended for temperature spot checks.

4.2.3 **Thermocouples** – A thermocouple is created when the two metals copper and constantan are fused together. An electric current, directly related to the temperature at the fusion point is generated and measured. The two thermocouple wires can be extended to allow remote temperature readings and recording. Only the best quality “Type T” thermocouple wires must be used and very specific and precise procedures must be followed to achieve the required accuracy of at least plus/minus 0,5°C (±0,5°C).

4.1.1 **Resistance thermometers** – Generally known as a thermistor that measures the voltage drop caused by and directly related to the temperature of a resistor. The resistor can be connected to lead wires allowing for remote temperature reading and recording. Thermistors can be made very small and are usually mounted in a sharp pointed thin (±5mm outer diameter) stainless steel tube. This configuration is generally known as a spear point thermometer or temperature probe. Thermistors are fairly robust and consistent with accuracy better than plus/minus 0,1°C (±0,1°C). It can be used over and over again, but much more expensive than thermocouples.

4.2.5 **Mechanical bi-metal strips or coils** – Used in the older types of air temperature controllers and chart recorders (e.g. Partlow and Ryan recorders). This concept is almost completely replaced by electronic equipment and therefore not recommended.

4.3 Temperature recording and logging devices

These devices coupled to a temperature sensing device (thermocouple, thermistor) either mechanically record or electronically log the measured temperature.

4.3.1 **Fixed installations** – These recorders or data loggers are installed as fixed installations in cold stores, refrigerated road vehicles, refrigerated containers and ships’ decks. Temperatures can be recorded or logged continuously or at certain preset intervals. These logs can give an accurate record of storage and transport temperature conditions. The complete system i.e. temperature sensor, connecting cables (or infra red connection) and recording/logging device must be regularly calibrated in melting ice at 0,0°C by an accredited institution.

The accuracy of these installations must not exceed plus/minus 0,5°C (±0,5°C) for general cold storage conditions or plus/minus 0,25°C (±0,25°C) for cold treatment of fruit against quarantine pests. The frequency of recording or logging of most of these devices can be programmed to record the temperature at preset intervals. Recording frequency shall be short (less than 2 hours) during unstable temperature conditions (precooling, loading in or out) and longer (not more than 8 hours) when all temperatures have stabilised. Continuous temperature recording is however strongly recommended.

4.3.2 **Mobile data loggers** – These temperature recorders or loggers are self contained temperature measurement and recording devices. The battery powered electronic devices are recommended because of better accuracy and reliable operation. Mobile data loggers usually only record the air temperature directly in contact with the temperature sensor. External temperature sensors (usually thermistors) can be fitted to certain types to also record product temperature. Mobile temperature recorders are used to record temperatures – usually only air temperatures – in certain positions in the load or pallet. This means that air temperatures are recorded at random positions within pallets and within the refrigerated space. These air temperatures may vary considerably according to position and fluctuate according to defrost cycles and handling operations. It very seldom records the true temperature of the delivery or return air over an extended period. It is therefore very difficult and in many cases impossible to correlate the recorded temperature data with the specified set point or delivery air temperature. Mobile temperature recorders are therefore many a time regarded as an “event recorder” at its best. The accuracy of these data loggers is usually better than plus/minus 0,25°C (±0,25°C) at 0,0°C but it must be calibrated in melting ice at 0,0°C and the correction factor applied. The frequency of recording or logging of these devices can be electronically programmed into the device. The recording intervals should be as short as possible taking into account the storage capacity of the built in memory and battery life.

4.4 Calibration of temperature measuring, controlling and recording devices

Detailed calibration procedures are described in the PPECB Quality Management System (QMS). These procedures are in line with international requirements and only general procedures are therefore given below. (See also chapter 4 part 5.2 and chapter 5 part 3.5 for more detail on the calibration of containers and conventional decks to be used for in-transit cold treatments).

- Prepare ice cubes of approximately 2 x 2 x 2cm from pure distilled water.
- Fill suitable insulated containers or ice buckets with the clean ice cubes. A Very small amount of clean distilled water can be added to form an ice-water mixture.
- Continuously stir the ice-water mixture to ensure a constant temperature.
- The ice-water mixture must register a constant temperature of 0,0°C on a certified calibrated standard thermometer.
- Submerge the temperature sensor to be calibrated in the ice-water mixture while continuously and slowly stirring the mixture.
- Observe the temperature reading of the temperature-measuring device and take the temperature reading when it has stabilized.
- The difference between the reading of the calibrated standard thermometer (0,0°C) and the temperature device gives the accuracy of the temperature-measuring device.
- The accuracy of the temperature device must be within the relevant temperature specification (i.e. standard or special cold treatment conditions).
- The calibration factor for the specific temperature-measuring device is the difference between the temperature readings of the standard thermometer (0,0°C) and the temperature-measuring device.
- The calibration factor must be applied if the temperature measuring device cannot be manually or electronically adjusted to 0,0°C.

5. RELATIVE HUMIDITY

The importance, role and management of Relative Humidity (RH) is not really appreciated or understood when it comes to the storage and transport of perishable products. RH is also influenced by many factors, making it difficult to understand and control. Without going into the physical science of RH, the following important factors should be mentioned.

5.1 Definition of RH

RH can be defined in very simple terms as the ratio of water vapour present in the air relative to the maximum amount of water vapour which can be present in the air (at saturation point) at the same temperature and atmospheric pressure. RH is expressed as a percentage where 100% represents a fully saturated atmosphere at a specific temperature.

The importance of RH during cold storage
All fresh produce contain a large amount of water in the tissue. The RH in the intercellular spaces is 100% in almost all fresh produce. Water vapour always moves from a high pressure (high RH) to a low pressure (low RH). This means that water vapour will move out of the product into the atmosphere if the RH in the atmosphere is less than 100%. If too much water is lost in this way, the product will become desiccated, will shrivel, loose weight as well as cosmetic appearance and eating quality. A number of factors however limit the movement of water vapour from the product. Some of these are the nature of the skin, natural and artificial waxes and polyethylene bag packaging as well as a high RH of the surrounding atmosphere. Being a living organism, fresh produce can also absorb moisture from the surrounding atmosphere should the atmosphere become oversaturated with water vapour. Skin cracks in Golden Delicious apples are a typical example of moisture uptake through the skin. It is therefore very important to maintain an optimum RH in the cold store during both the precooling and storage phases.

5.2 Optimum RH
For most fresh produce the optimum RH in the atmosphere is in the order of 90% to 95% with a fluctuation of not more than plus/minus 5% (RH 90 ±5%).

- Products requiring a RH of close to 100% are leafy vegetables (e.g. lettuce, cabbage) and flowers.
- Products requiring a low RH in the order of 70% are onions, garlic and some flower bulbs.

The optimum RH for fresh perishable products exported from South Africa is given in Chapter 8 under the different product headings.

5.3 Measurement of RH
The psychrometer, or wet and dry bulb thermometer, together with the psychrometric chart is still the more reliable method. Electronic RH meters are becoming more accurate and superceded the older mechanical types. It is however very important to carefully follow the instructions of the instrument manufacturer to arrive at a reasonable accurate reading. The effects of temperature and atmospheric pressure changes as well as air distribution patterns in the cold store should also be taken into account.

5.4 Factors affecting RH
The dominating factors affecting the RH of the atmosphere are temperature fluctuations and temperature gradients or differences. Some of the more important factors resulting in a low RH in a cold store are:

- Heat load of the product in the store is too big (e.g. specific heat, respiration heat)
- Heat leakage into the cold store e.g. open doors, bad seals (doors, pipes insulation panels), air circulating fans and forklifts.
- Packaging material absorbing moisture from the atmosphere.
- Too low cooling coil surface temperatures resulting in condensation and ice formation.

These factors can however be managed to a large extent provided that the cold store is designed and built to maintain a RH of 90 to 95 ±5%. This calls for the correct cooling coil design especially in terms of total coil surface area and coolant temperature. The bigger the cooling coil surface area the warmer the coolant temperature and the lower the temperature difference across the coil and the higher the RH. Other factors also influencing the temperature difference across the coil are the type and placement of the air circulation fans that must move the cold air across the coil into the cold store. It can therefore be stated that correct RH maintenance and control requires:

- Correct design parameters to ensure sufficient cooling coil surface area
- Correct building procedures to ensure an air tight structure with minimum heat leakage
- Correct management to minimize exceeding the designed heat load capacity

6. PALLET HANDLING EQUIPMENT

The bulk bin or the pallet became the standard unit to be stored, handled and transported. These heavy loads require special handling equipment. Some of the more important deciding factors on which equipment to use are:

- Efficiency, especially to move and lift heavy loads and large volumes quickly over uneven terrain.
- Cost effectiveness, especially running and maintenance costs.
- Safety in terms of personnel safety as well as food safety and product quality protection.

There are basically only three types of pallet handling equipment available, each with its own positive and negative characteristics. These are:

6.1 The **internal combustion powered forklift** that can lift and move heavy loads quickly over uneven terrain. The exhaust gasses however can be a serious health hazard, may release minute carbon particles (diesel powered) into the air that will settle onto the packing material and product and hydro carbon gasses that may induce ripening and senescence.

Recommended usage
- Diesel powered forklifts can only be used for pallet handling in the open air and must never be used in cold stores or other confined spaces.
- Liquid Petroleum Gas (LPG) powered forklifts may only be used in cold stores when fitted with an approved efficient exhaust gas purifier. These forklifts may however not be used in confined spaces such as containers or ships' decks.

6.2 **The battery powered forklift** presents no human and food safety hazards, does not pollute the storage atmosphere, but cannot handle heavy loads over uneven terrain.

Recommended usage
Although not very efficient for uneven terrain, the battery powered forklift lends itself perfectly for loading into and out of cold stores, loading of refrigerated road vehicles, containers and ships' decks.

6.3 The **hand operated pallet jack** is only effective in moving small volumes of palletized products on level and solid surfaces.

Recommended usage
A very cost effective method for the smaller operation where low volumes must be handled on solid level surfaces. Can be used for loading of refrigerated road vehicles and containers but T-bar floor of container may restrict maneuverability.

3. PRECOOLING AND STORAGE

7.1 Precooling can be defined as the process where the field heat of the product is removed and the product is cooled to the optimum storage temperature. The process must be completed as fast as possible to slow down respiration and associated ripening. The RH in the cold store is also very low during the precooling phase as a result of a big temperature difference between the air coming off the product (RAT) and the air coming off the cooling coil (DAT). The following precooling systems can be used:

7.1.1 **Forced Air Cooling (FAC)** or also known as Pressure Cooling is a process where additional fans are used to create a low pressure across the pallet forcing the cold air horizontally through the cartons. FAC fans must be switched off immediately when the optimum product temperature is reached throughout the total load to stop high rates of moisture loss from the product and to minimize chilling or freezing injury.

7.1.2 **Hydro cooling** makes use of a cold water shower over the product removes heat quickly and does not remove any moisture from the product. This system is not favoured by the South African fruit and vegetable industries.

7.1.3 **Room cooling** by just loading a product into a cold store without ensuring an active flow of cold air through the pallets and cartons is not recommended. This process takes too long to cool the total load, results in a big temperature variation through the load and a much reduced RH during the extended cooling period.

7.2 **Storage** is the process where the product is kept within plus/minus 0,5°C of the optimum storage temperature and at a constant RH of 90% to 95%. The temperature in the cold store must be kept at the optimum with an absolute maximum fluctuation of plus/minus 5,0%. This means that the doors must be kept closed, no warm product must be loaded into a store with already cold product. An efficient stock management system must be practiced to avoid over storage and to comply with traceability requirements.

7.2.1 **Regular atmosphere (RA) storage** is the term used for cold storage in a standard (regular) atmosphere containing approximately 22% oxygen and 0,03% carbon dioxide.

7.2.2 **Controlled atmosphere (CA) storage** refers to storage in an atmosphere where the oxygen and carbon dioxide is accurately controlled and maintained at certain very specific levels.

7.2.3 **Modified atmosphere (MA) storage** is achieved by packing the product into a differentially permeable bag (usually laminated polyethylene). The product then creates lower oxygen and higher carbon dioxide concentrations inside the bag during the process of respiration.

8. TEMPERATURE AND RH RECORDS

The value of the cold store and contents require accurate measurement, management and record keeping of products and storage conditions. Accurate and complete record keeping is essential when products are stored for another party and should the owner of the product institute an insurance claim. The following are some of the more important aspects that must be recorded.

8.1 Products handled
Accurate records of products taken into and loaded out of cold stores must be kept at all times. This includes product type, product volume or mass packaging, dates and times. Compliance to product traceability requirements (Chapter 1 par 3.2) is of absolute importance especially when a perishable product is exported.

8.2 Product temperature
Accurate product temperatures of representative samples must be taken at loading into and out of the cold store. These temperatures must be taken with reliable calibrated instruments (chapter 2 par 4) and the required correction factor be applied where necessary.

8.3 Calibration of instruments
All temperature controlling and measuring instruments, recorders and data loggers must be calibrated at least once a year by an accredited organization who must also issue proof (certificate or label) of calibration.
All mobile and hand held temperature measuring instruments must be calibrated at least once a week during the cold storage operation. This calibration must be done in pure melting ice at 0,0°C according to standard procedures. (See Chapter 2 par 4.3.3).
A sticker stating the correction factor must be attached to the thermometer if the instrument is not fitted with an internal zero calibration facility.

8.4 Frequency of temperature readings

- Product temperatures must be taken and recorded during loading into and out of the cold store as well as during the precooling and storage phases to identify hot and cold spots. These temperatures must be used in determining the temperature set point of the thermostat controller.
- Air temperatures, both delivery air (DAT) and return air temperatures (RAT) should be recorded continuously. The recorder can be programmed to record at 2 hour intervals during precooling and at least once every 8 hours during cold storage.
  Room air temperatures should also be recorded in larger cold stores especially in areas where air circulation is restricted or where a heat built-up is expected.

> Dial thermometers do not give a true reflection of the temperature conditions inside the cold store.

8.5 Temperature records
Accurate records of all temperatures must be kept for at least five (5) years to substantiate traceability and insurance requirements.
Hand written DAT and RAT records are not acceptable for insurance claim purposes.

9. COLD STORAGE MANAGEMENT

Cold store management requires an understanding of the sciences of plant physiology, temperature dynamics, heat transfer, air characteristics, psychronomy and many others. These factors must be married with cost efficiency, throughput rates, human resources, market requirements and many more. Cold store management is therefore a culture that must be mastered. In the context of this discussion, the temperature of any object or substance is very dynamic and may differ substantially within the same object, or fruit, or over a very short time span. A number of readings must therefore be taken and the average of all the readings be considered. It is very strongly recommended that fruit pulp temperature sensors are placed in fruit at time of loading the cold store. The number of sensors depends on factors such as product type, consignment volumes and client requirements. These fruit temperature sensors must be regularly calibrated and the temperature readings recorded for future reference.

Cold store: In the cold store each forced air cooling tunnel must be equipped with a minimum of two pulp sensors and if pallets are stacked three high, four sensors that can reach the furthest point in the tunnel. For each three forced air cooling tunnels there must be at least one pulp sensor in the front (face) on the outside of the forced air-cooling tunnel.

Tunnel: Each forced air cooling tunnel must be equipped with a minimum of two pulp sensors and if pallets are stacked three high, four sensors that can reach the furthest point in the stack. In most cases a below average cold store managed well, performs consistently and much better than the best facility under average management. Management must also understand that a cold store is a facility that cannot, in itself, cool a product, but that the actual “work” is done by the cold circulating air. Know the product, manage the air and 80% of the problem is solved.

9.1 Set point temperature
The set point (SP) is the required setting of the thermostat, or other temperature controlling device, to ensure that the air coming off the cooling coil (evaporator) is controlled within plus/minus 0,5°C (±0,5°C) of the specified delivery air temperature (Chapter 8).

9.2 Delivery air temperature
The delivery air temperature (DAT) or sometimes also called the supply air temperature, is the temperature of the air just before it comes into contact with the product. The DAT may not vary by more than 0,5°C in various positions in the delivery air plenum to ensure an even product temperature. The temperature set point must be set in such a way to ensure that air is delivered to the product within plus/minus 0,5°C (±0,5°C) of the specified carrying temperature. Some of the important factors causing a variation in DAT in different positions of the refrigerated space are:

- Too wide a controlling range of the thermostat
- Uneven air flow through the cooling coil (clogging or icing of the coil fins)
- Faulty operation or placement of air circulation fans
- Too long an air path from the cooler to the cargo

- Obstructions in the air delivery plenum or ducting
- Short circuiting of the air off the cooler resulting in mixing of cold and warm air

9.3 Return air temperature

The return air temperature (RAT) is the temperature coming off the product. The RAT can vary considerably in different positions in the refrigerated space. Some of the important factors causing the variation are:

- Heat leakage into the refrigerated space
- Short circuiting of the cold air through open spaces between the cargo
- Variation in product temperature through the load
- Poor air circulation through the load
- Fruit ripening and sometimes also decay development resulting in heat of respiration released into the atmosphere

9.4 Space air temperature

Space air temperatures (SAT) are air temperatures taken at various positions in the cargo space (cold store, deck, container). In most cases SAT's can be regarded as RAT's in different positions. SAT's are very important indicators of hot spots (warm cargo, heat leakage etc.) in the refrigerated space and are therefore also considered in the case of low temperature insect sterilization (steri shipments) procedures. Factors causing a variation in SAT's are the same as listed for DAT and RAT as well as factors such as variation in air flow rates in different positions.

9.5 Product storage temperature

The product storage temperature or in shipping terminology the carrying temperature, is the optimum product or pulp temperature at which the product stores or transports best with minimum temperature related quality losses. The carrying temperature specification for apples for example is minus 0,5°C which means that the actual pulp temperature of all the apples in the population (consignment, load etc.) shall be minus 0,5°C. Factors that may cause a variation in product temperature are:

- Inefficient precooling
- Variation in product physiology such as maturity, ripeness, age and cultivar
- Packaging material and stacking patterns causing variation in air flow around the product (fruit)
- Variation in DAT over time in the same position or in different positions
- Variation in cold air supply rates to the load

9.6 Actual product temperature

The product temperature is the temperature of a single fruit as measured with a temperature measuring device such as a calibrated thermometer, a thermocouple or a thermistor. It is essential to use a calibrated temperature measuring device, to follow the correct procedure and to take a number of readings from different fruit in different positions in the population to arrive at a reliable average temperature.
Also important is the temperature range between the coldest and warmest readings and positions where these readings are taken. Product temperature should be within the range of plus/minus 0,5°C (±0,5°C) of the specified optimum storage or carrying temperature. In the case of cold sterilization (steri) treatments however the temperature range must not be more than ±0,25°C from the specified carrying temperature.