CHILLER QUALITY CONTROL

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There are many factors which contribute to the out-turn quality in carcass chilling. These factors are:

- microbial standard of the hot carcasses at chiller entry;
- the time to reduce the surface temperature to 7°C;
- effectiveness of electrical stimulation, if used;
- accuracy of instrumentation used to control the chiller
  - thermometer or thermostat
  - control valves and control system;
- chiller loading versus design capacity;
- chiller loading rate versus design loading rate;
- refrigeration plant
  - condensers
  - compressors
  - pipework
  - strainers
  - evaporator defrost system;
- cleanliness and microbial condition of chiller room
  - floor, walls, ceiling
  - evaporators and defrost system
  - doors, handles, tools
  - floor drainage (floor must be free of pools of water)
  - condensation;
- to suit end use
  - boning
  - transport.

1. Hygiene and Cleaning

Regulations governing the operation of carcass chillers include a specific requirement that chillers be cleaned as soon as they are empty. The recommended procedure is as follows:

- dry clean floor;
- cold water wash floor, walls, doors;
- detergent wash floor, walls, doors;
- scrub stains on floor, walls, doors;
- hot water wash floor, walls, doors;
- sanitise the room with fans running;
- sanitise the drains.

The procedures and safety instructions provided for using detergents and sanitisers should be strictly followed.

A regular program for ensuring that the evaporators and defrost drain trays are cleaned is also necessary – once per week is recommended.

Rail-work should be cleaned and re-oiled as necessary to prevent a build-up of dirty oil dripping onto the carcasses.

Doors, door handles, tools, rail switches, brooms, squeegees, etc., must also be cleaned daily. These items have been shown to cause microbial contamination with organisms such as Salmonella and Listeria.

2. Operation

Chiller Control System

Modern chiller control systems often incorporate computers and programmable systems which include control of fans which can operate at two or more speeds, temperature measurement of the deep-butt temperature and facilities to pre-set the control program to account for variations in:

- number and weight of carcasses;
- overnight or weekend chilling.

Measurement of the deep-butt temperature can be used to determine the optimum end of the blast-chill cycle before transfer to a holding cycle, rather than rely entirely on time and air temperature. Since the surface temperature drops rapidly, there is a temperature gradient within the carcass during cooling. If the aim is for a deep-

butt temperature of 10°C, then the fast-chill cycle should be terminated above this at about 20°C. Operators are encouraged to experiment to obtain the optimum settings. However, they should ensure that meat surface temperatures do not rise above 7°C during the equilibration period.

Some of the control systems currently installed are, in fact, quite complex but are designed to provide the abattoir with the benefits of:

- fast chilling and low microbiological growth (used in conjunction with electrical stimulation);
- low weight loss.

Abattoir operators should ensure that staff are fully trained in their use in order to optimise meat quality and temperature.

Temperature Measurement

Every abattoir or boning room should be equipped with an accurate thermometer. The most accurate device which can be used to calibrate all other thermometers or thermostats is a mercury-in-glass thermometer which has been calibrated and certificated.

Do not assume that the dial thermometer on the wall of your chiller, or the chart recorder or the computer print out is accurate – CHECK IT.

To check any dial thermometer or thermostat used to control a chiller or freezer, a suitable procedure with a mercury-in-glass or other thermometer of known accuracy is as follows:

- place the thermometer beside the sensor of the thermostat to be checked;
- note the readings of both instruments over a range of temperatures used for operating the chiller or freezer;
- adjust or calibrate the thermostat as required.

A simple check may also be carried out at 0°C by placing the sensor of a thermostat or thermometer in an insulated container filled with a mixture of melting ice and water. The water should be of demineralised quality as salts in solution can depress the latent point of water.

The surface temperatures of meat should only be measured using electronic-type thermometers which have a thermocouple sensor. This should be inserted parallel to the surface, immediately below the membrane covering the surface of the muscle or fat. The "Tel-Tru" type of thermometers are not suitable, as the length of the sensing tip cannot be embedded sufficiently into the surface of the meat to get an accurate measurement.

Air temperatures should be measured on the return air side (air on) to the coil where adequate mixing will ensure that average air temperatures "off the carcase" are measured. False readings of air temperatures are obtained in the following positions:

- direct discharge from the evaporator;
- near walls;
- near doorways.

Air Flow Distribution

Chilling rates are sensitive to three primary variables:

- carcass weight;
- air temperature;
- air velocity.

Many chillers exhibit significant variations in air velocity throughout the room. Given sufficient evaporator capacity and chiller loading within design limits, some improvement can be achieved by the installation of baffles or additional fans. Additional fans, if used, raise the heat load in the room which must also be taken into consideration.

Where carcass chillers exhibit low chilling zones (hot spots), the first step should be, where practicable, to place light carcasses in these zones.

An anemometer may be used to identify the air velocity distribution within a chiller to locate low and high air velocity areas.

Both vane-type and hot-wire anemometers are available.

Air flow distribution is affected by the chiller loading pattern. Air flow will always follow the line of least resistance between the discharge from the evaporator to the return side.

Chillers should not be overloaded as this restricts the air movement which is necessary for efficient heat in addition to imposing a load on the refrigeration system for which it is probably not designed.

Part-loading of chillers also leads to uneven performance as air will tend to by-pass carcasses by taking the path of least resistance. However, if part-loading is necessary, Figure 1 shows two examples of part-loading arrangements which can be used depending on the position of the evaporators.

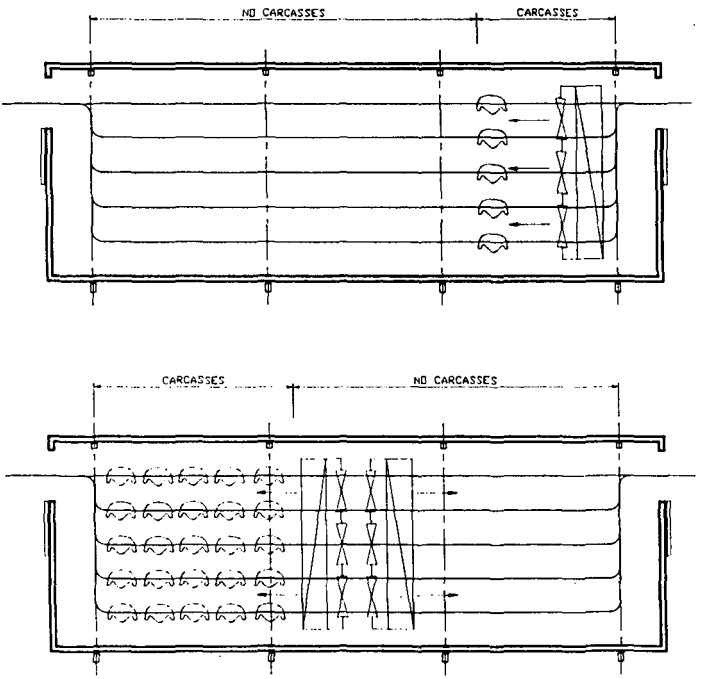

Figure 1: *Examples for part-loading for carcass chillers*

3. Relative Humidity and Condensation

Relative Humidity (RH) Measurements

Relative humidity is a measure of the amount of water vapour in the atmosphere relative to the capacity of the air at that temperature. At 100% RH the air is fully saturated and any attempt to add more water vapour will result in fog formation. The capacity of air to hold moisture reduces at lower temperatures and as air is cooled in passing over an evaporator surface it can reach 100% RH (dew point) and moisture may condense out on the surfaces. If a chiller evaporator is operated at high T.D. (temperature differential) through the coil, excessive condensing will occur and can result in high product weight loss.

In the early stages of chilling we rely on the circulating air reaching dew point as it passes through the evaporator, thus drying and cooling the surface of the carcasses by extracting latent to vaporise the moisture.

RH examples - 30°C air can hold 27.2 g kg^{-1}

- 0°C air can hold 3.8 g kg^{-1}

Instruments for measuring relative humidity are based on the wet and dry bulb principles. Assman and sling-type psychrometers are most commonly used in the meat industry. A psychrometer consists of two accurate thermometers fixed into a frame which can be whirled around on a handle. The bulb of one of the thermometers is covered with a cotton wick wetted with distilled water. When the psychrometer is whirled, the thermometer without the wetted bulb should remain at ambient temperature and the thermometer with the wetted bulb should fall in temperature. Water evaporates from the cotton wick on the bulb causing the temperature to fall. The fall in temperature is dependent on the relative humidity of the atmosphere. When whirling ceases, the thermometers should be at a constant reading. The temperature is then read against psychrometric tables which give the relative humidity of the atmosphere.

Hair hygrometers are also available for measuring relative humidity. These consist of lengths of hair which absorb and desorb water according to the relative humidity. The hairs change length as they absorb water and this length change can be used to indicate relative humidity. Hair hygrometers are slow to respond to changes

in relative humidity and are affected by temperature. The instrument must be calibrated with a sling-type psychrometer at the temperature at which it will be used.

Electronic thermometers can be used for measuring and recording relative humidity. The air speed over the wetted wicks must be at least 3m/sec. and this can be achieved by using electric or clockwork fans to drive air over the wet and dry bulbs of the thermometer.

If there is a build-up of salts on the cotton wick due to the use of non-distilled water, there will be a reduction of evaporation and inaccurate wet-bulb temperatures will result. The wick should be replaced with a new one and fresh distilled water used.

Very few abattoirs try to control the relative humidity in their chillers and if some control were practised, condensation problems could be alleviated and weight loss could be reduced.

Reliable humidity measurement above 90% is difficult on an ongoing basis.

4. Condensation

In carcass chilling for minimum weight loss, the objective is to maintain high humidity and control the chiller temperature to avoid condensation. Condensation is not permitted in carcass chillers because the attendant drips which can fall on to the carcasses may cause contamination.

Condensation on the chiller structure will occur when the temperature of the structure (steel-work, rails, walls) is below the dew point of air in the chiller.

Condensation commonly occurs in the following circumstances:

- on evaporator drain trays (particularly if they are uninsulated).
- on ducting which carries cold air discharged from the evaporators. In both cases, the surface temperatures are usually less than that of the surrounding air.
- Areas which have intermittent contact with outside air, e.g. via a loading door. The entry of warm, moist air may result in considerable condensation on all surfaces at a lower temperature.

- raising the room temperature prior to boning to soften fat. If this is done too rapidly, the differential between the room temperature and some surface temperatures may result in condensation.
- condensation can occur during rapid loading if the evaporators have insufficient capacity to remove excess water vapour and prevent the room temperature from rising.

5. The Refrigeration System

It is important not only that the refrigeration system is correctly designed for carcass chilling, but that it be operated in the correct manner and be properly maintained. Any deviation in chiller performance should be promptly investigated.

Maintenance

Faults which can cause inadequate chilling performance due to lack of maintenance are the following:

- failure of one or more fans (evaporators and condensers);
- inadequate defrosting;
- lack of adequate compressor and condenser capacity in the plant room;
- pipelines to the evaporators being too small;
- blocked strainers or partially closed valves in the refrigeration pipelines;
- faulty or under-sized control valves which, depending on the type of system, include
  - back-pressure regulators
  - solenoid-operated valves
  - expansion valves
  - accumulation of oil inside the evaporator coil.

A refrigeration maintenance program should incorporate a periodic inspection of each of these items. For example:

Defrost system

Inspect evaporators at the end of the defrost cycle. Evaporators should be clear of ice.

If ice is present on the evaporators after defrosting, then either the defrost time requires adjustment, the defrost system may require maintenance or, in the case of hot gas systems, the gas temperature is too low.

Condensers

Condensers should be sized and maintained for peak summer conditions.

Adequate water treatment is required in evaporative and recirculating water types.

Air-cooled condensers should be periodically cleaned to remove dust and dirt.

Inspect fans for correct operation.

6. Weep

Fast chilling minimises weep. It is important that the deep-butt temperature is reduced to less than 30°C as quickly as possible after slaughter, preferably in less than 10 hours. For heavy carcasses, this is difficult to achieve and requires a refrigeration system capable of reducing the chiller air temperature to 0°C, as soon as practicable after the fast chilling cycle is commenced, with an air velocity of up to 2.0 m/sec. There must be a minimum of delay from slaughter to the commencement of the chilling cycle.

Once the deep butt is below 25°C, the rate of chilling can be reduced, e.g. by a reduction of the fan speed or raising of the refrigerant temperature in the evaporators.

With heavy sides, a slow chilling rate, combined with electrical stimulation, can worsen the problem of drip in vacuum packs. Pale colour in the deep muscle is an indication that excessive weep will occur.

In small stock, an excessive chilling rate which leads to cold shortening will also lead to excessive weep. However, experiments with ultra-rapid chilling of sheep (e.g. -20°C for 3.5 hours, -32°C for

2 hours and -16°C for 4 hour with subsequent holding at 0 to 4°C) show that cold shortening does not occur under these conditions. The mechanism by which cold shortening is avoided under these conditions can probably be explained by skeletal restraint caused by crust hardening, but other factors may be involved.

7. Two-toned (Pale and "Dark") Meat

Fast chilling gives evenly coloured meat. This is not easy to achieve in heavy carcasses, as has been shown elsewhere in this manual.

In two-toned meat, there are undesirable colour variations in meat colour within a cut, with the deep tissue being paler than the normal red meat colour close to the surface. This problem, most commonly seen in heavy beef, is the direct result of slow chilling. It is sometimes called "heat ring". The problem is caused by partial denaturing of the meat proteins whilst the temperature is above 30°C, i.e. slow chilling. Electrical stimulation reduces this effect.

Considerable variations can also occur in pork in the condition known as "pale watery pork" or PSE (pale soft exudative). PSE may be stress related but a delay in the on-set of chilling will also contribute to the incidence of PSE. Genetic factors also contribute to the incidence of PSE.

8. Quality Assurance Program

Each meatworks should develop its own quality assurance program. CSIRO Meat Research Laboratory has, for some time, advocated the HACCP (Hazard Analysis Critical Control Point) quality approach which must be tailored to individual plants.

This technique has been applied to a range of processes in the meat industry, including:

- Listeria in processed meats;
- Salmonella in meat meal;
- carcass chilling;
- vacuum packed chilled meat.

A HACCP program consists of the following elements:

- identification of hazards;
- determination of critical control points (CCP) at which identified hazards can be controlled;
- specification and documentation of criteria which show control of a CCP;
- implementation of monitoring procedures to check control at CCP, preferably by objective measurement;
- specification of corrective action when monitoring has indicated that a CCP is out of control;
- verification that HACCP is working (by end product testing and process auditing).

The steps to a HACCP-based quality assurance program are:

1. Draw a process flow chart;
2. Identify hazards
   - potentially hazardous raw materials
   - sources of contamination
   - potential for microbial growth and survival from production to consumption
   - risk and severity analysis

In the case of carcass chilling, hazards include:

- inadequate slaughter hygiene
- inadequate chiller-temperature control
- chiller overloading
- inadequate chiller cleaning and hygiene
- hot meat placed in a chiller with cold meat
- condensation
- carcasses inadequately spaced or touching
- cold shortening
- cleaning operations inside a chiller containing meat (especially hosing down the floor).

3. Verify by sampling and inspection that quality standards have been met. Figure 2(a),(b) and Table 1 give, by way of an example, a typical flow chart and hazard analysis for the process production and quality control of chilled quarter beef for export.

9. References

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Sheridan, J.J. "The Ultra-Rapid Chilling of Lean Carcasses", Meat Science, 28 (1990), pp. 31-50.

Weigh sides, measure fat depth, apply grade stamps and AUS-MEAT ticket. Record classification details.

Wash sides.

Expose patella and stiffle joint.

Transfer sides to chiller.

Load carcasses onto chiller rails, check for correct spacing between sides.

Chill carcasses (air temp. set on 0-2°C). Deep-butt temperature after 10 hrs = 30°C max. Deep-butt temperature after 20 hrs = 16°C - 18°C.

Quarter and grade sides.

Apply plastic sheet to exposed loin muscle, weigh and bag quarters.

Transfer quarters to holding chiller.

Chill quarters (air temperature -2 to 0°C)

Deep-butt temperature after 24 hours in holding chiller = 6°C max. deep-butt temperature after 48 hours in holding chiller = 3°C max.

Load-out quarters in jumbo containers. Deep-butt temperature -1.5°C to 3°C.

Figure 2: *(a) Example of process flow chart for chilled quarter beef production*

SYMBOL	
	OPERATION An operation is the act of deliberately changing the physical, chemical or microbiological characteristics of a material. It includes assembly or disassembly of material as in carcass dressing and boning. Operations usually require input of labour and use of equipment.
	INSPECTION Inspection is a physical act requiring labour and/or equipment. Inspections occur when material is sampled, counted, examined, identified measured or compared with a standard. Inspections do not take materials any nearer to completion. They verify that an operation has been carried out correctly.
	TRANSPORTATION Transportation means moving material from one place to another, but without any change in the nature of the material.
	DELAY Delays occur when material cannot move directly to the next planned step in the process. Exceptions are when material is held up as an integral part of the process e.g. material is held in a cooker as a part of an operation; or when material is in deliberate controlled storage.
	STORAGE Storage is when material is under permanent or controlled storage. This means the material is protected against unauthorised removal or other interference. Storage usually applies to finished product but could also apply to intermediates in the process.
	COMBINED Symbols may be combined when an individual step is classified in two or more ways, e.g. a step may be an operation and inspection, or an operation and transportation.

Figure 2: (b) Explanation of symbols for flow chart

Table 1: Hazard Analysis - chilled quarter beef production

Hazard Analysis - chilled quarter beef product							
Critical Control Point	**Potential Hazard**	**Control**	**Specifications and related documents**	**Monitoring procedure**	**Person responsible**	**Where recorded**	**Corrective and preventive action**
Carcass chilling	Slow chilling can result in bone taint, two-toned meat and discolouration	Sides must be chilled to deep-butt temperature of 20°C in 20 h	Use and standardisation of thermometers. Engineer's specification for air temp. setting and air velocity over carcasses	Use digital thermometer to check deep-butt temperature of 2% of sides in chiller after 10 h and 5% of sides after 20 h	QA Officer	Daily QA check sheet	Check for bone taint in sides not cooled to 16°C in 20 h by inserting skewer to acetabulum. Bone out all sides suspected of bone taint. Inform Engineer that improved chiller performance is required
	Poor chiller hygiene will cause contamination of sides and early spoilage	Clean chiller and evaporator units	Cleaning procedures operations manual Methods of microbiological sampling and testing	Daily check on visual cleanliness & odour in chillers Weekly bacteria test on chiller walls & evaporator	QA Officer Chiller Foreman	Daily QA check sheet	Reclean chillers Instruct Cleaning Foreman to re-train cleaners
	Carcasses pushed together cause slow chilling and accelerated bacterial growth at contact sites	Space carcasses	Chiller operation manual	Check carcass spacing during loading	QA Officer Chiller Foreman	Daily QA check sheet	Re-train chiller operators to load chillers correctly
Load-out	High temp. of meat should be less than 3°C Surface temp. should be less than 1°C	Deep-butt temp. of meat should be less than 3°C Surface temp. should be less than 1°C	Use and standardisation of thermometers	Check deep-butt temperature of 5% of bodies at load-out	QA Officer	Daily QA sheet	Continue to chill carcasses until deep-butt of 3°C is reached