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Practical Aspects of Beef Carcass Chilling

This presentation concentrates on practical aspects which need to be taken into consideration when designing beef carcass chill rooms

Removal of Heat from Carcass

The heat from the product is transferred to the cooling coils (evaporators) inside the chill rooms by means of the circulating room air. It is the condition of this air and air velocity over the product that determines the chilling rates, weight loss and appearance of the carcass.

Over time extensive investigations have been carried out by numerous researchers in the field and their findings are used for formulating guidelines for chilling of beef carcasses.

Conditions of Circulating Air

As far as weight loss and temperature reduction of the carcasses is concerned the researchers are fairly unanimous on the individual influence of:

- Air temperature
- Air velocity
- Relative humidity of the air

However, opinion still differs on the best combination of the above factors to achieve low weight loss within given cooling cycles.

At the same time it can be said that higher air velocities and lower air temperatures are generally recommended during the initial stages of cooling with higher air temperatures and lower air velocities during the latter stages of the cooling process. These conditions will only apply where electric stimulation is used so as to avoid cold shortening.

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Steps Required to Arrive at a Chill Room Configuration

A number of individual aspects need to be determined to arrive at a final beef carcass quick chill room configuration. The end result being the rail layout as well as position of the cooling coils with fans sized to achieve the deep bone temperature within the specified time. The condition of the circulating air also determines the degree of weight loss to a substantial extent and guidelines are suggested to minimise these losses.

1. Rate of Loading / Room Carcass Capacity / Carcass Mass

The rate of loading is determined by the dressing rate. The room capacity to be limited to preferably 2 or 2.5 times the hourly loading rate. This establishes the time available to achieve the deep bone temperature. Typically for a 2 hour loading capacity the available cooling time would be some 19 hours. This is based on 2 hours loading and 3 hours for unloading and cleaning thus leaving 19 hours. Also at this stage the range of carcass mass to be child is to be established.

2. Carcass/Deep Bone Temperature Requirements

Carcasses and meat products that are transported from the abattoir to other sites require a maximum deep bone temperature of +7°C.

3. Air Velocity and Air Temperatures at the Carcasses

It is recommended that the refrigeration capacity, associated air velocities and conditions be designed to be flexible. The availability of controls and instrumentation is such that air temperatures and air velocities can be varied during the chilling cycle at preselected conditions.

For the beginning of the chilling cycle the following data are suggested.

- Air velocity over carcasses 3m/sec
- Air temperature -3^{o}C

During the chilling cycle the air velocity is to be gradually reduced and the air temperature raised so as to avoid freezing the surface of the carcass. The range for raising the air temperature is up to +7^{o}C whilst the air velocity can be reduced to 0,5m/sec. To achieve these variations the use of variable speed drives on the fans and modulating temperature controls are necessary.

4. Peak Chilling Load Requirements

Determine the peak cooling load using the air temperature and velocity selected for the peak chilling load at the start of the chilling cycle. The load calculation can be done manually but is not simple.

Computer programmes are available for the refrigeration load calculations and estimated cooling times.

As a general guide the peak load could well be 3,5 times the average load. Typically if the average load calculated at 40 kW then the peak load could be 140 kW. The additional loads of fans and insulation must be added. Electric lights should be switched off and the doors are closed thus avoiding these cooling loads.

Refrigeration Plant Room Peak Load

The maximum refrigeration load for the plant is determined as the last carcass chiller is finished loading. By that time the first carcass chiller has been in operation some 6 or 7 hours and the demand well down from the peak load. It is thus necessary to assess the demand of the individual chillers at the time of loading the last carcass.

5. Cooling Coil Particulars

The cooling coils (evaporators) to be sized for peak load at a mean log temperature difference (MLTD) not exceeding 5,5^{o}C. The circulating air volume to be such that the temperature difference between “air on” and “air off” the coil is in the order of 1,9/2,3^{o}C. The air volume thus established to be matched to the selected air distribution over the carcasses.

The cooling coils sizes and fan capacities can now be established. Care is to be taken that the coil face velocities be in the order of 2,7 to 3m/sec so as to avoid water carry over from the coils over the product during chilling

6. Room Air Distribution

The air distribution is to be arranged with the aim to have all carcasses exposed to the same air velocity. Horizontal air flow parallel to the rails is to be avoided as the carcasses are positioned behind one another and the air flow largely bypasses the carcasses.

In essence there are 2 choices for air movement over the carcasses. This can be either horizontal under right angles to the rails or vertically downwards from above the rails.

Horizontal Airflow

The horizontal air flow has up till now been the most widely used in South Africa. See Sketch 1. The cooling coils are arranged along the length of the room and air is circulated overhead of the rails with some air deflecting downwards over the carcasses below. However the bulk of the air travels to the other side of the room where it is forced to turn downwards, will hug the wall and turn again to travel along the floor back up to the cooling coils. This system can be improved by installing deflectors on the opposite wall from the cooling coils. These deflectors will divert the air towards the carcasses where it is needed. With the directed horizontal airflow one can work with an obstruction of the carcasses of some 60% i.e. the passage for the air is 40% of the cross-sectional area of the length of the room below the meat rail.

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Horizontal Airflow – Chiller Room Configuration

The chiller room configuration resulting from the calculated air quality is that a room of five rails is optimum for this type of air distribution. The length of the room varies with the number of carcasses for which the room is to be sized. Typically a 60 carcass room measures some 5,8m wide by 10,12m long internally whilst a 140 carcass room measures 5,8m wide by 20,68m long internally.

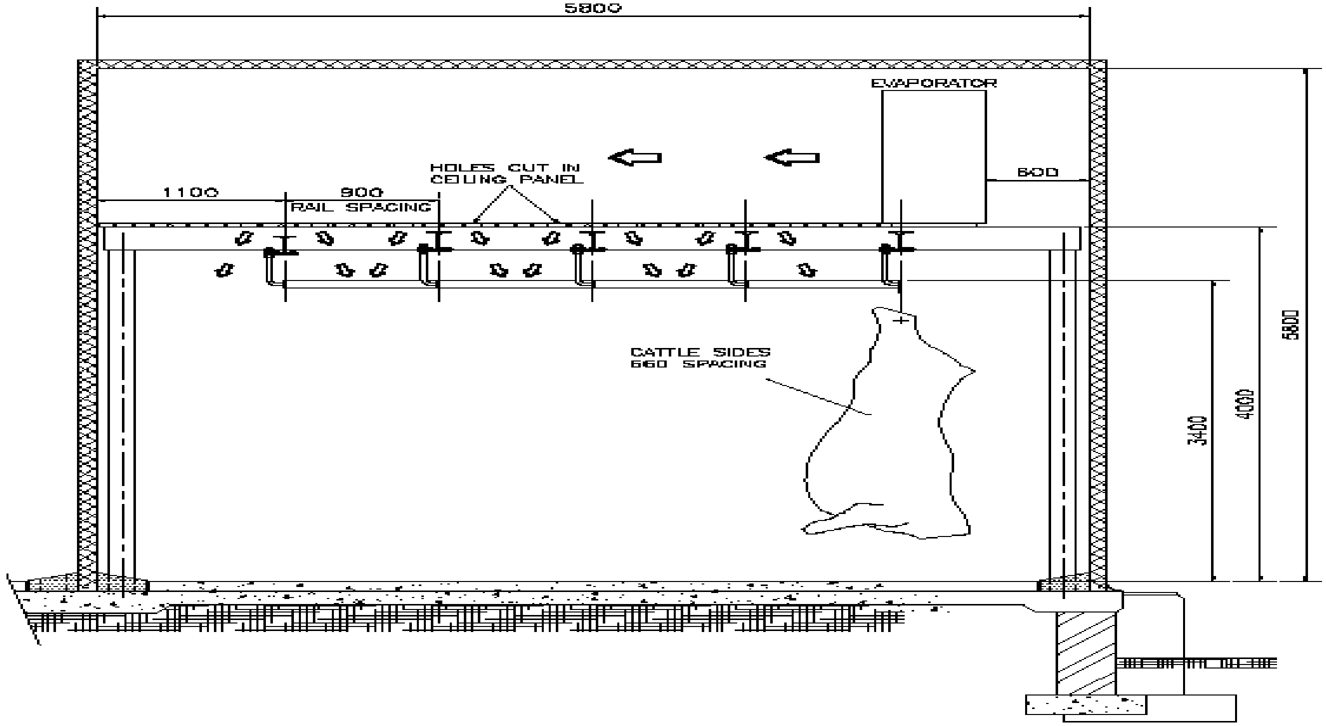
The cooling coils with fans to be arranged parallel to the rails along one of the walls parallel to the rails.

Vertical Downward Airflow

Vertically downward airflow from above the rails requires either distribution socks or a false ceiling with air distribution slots above the rails to direct the airflow. See Sketch 2. The air needs to be spread evenly as it travels downwards so as to cover all carcass surfaces. The quantity of air that needs to be calculated is higher as compared to the horizontal airflow as described under 6.1. The reason being that the cross section of the chill room in plan is greater (for the same carcass capacity) as compared to the cross section in elevation. With directed air flow it is possible to partly negate this extra airflow required but is unlikely to be less than an extra 40/50% above the air flow requirement under 6.1.

The extra air pressure drop of socks or false ceiling as well as the additional air quantity requires extra fan power. In addition to the operational cost it also affects the relative humidity adversely if the fans are placed after the cooling coil (induced draft).

Further negative aspects are the maintenance and hygiene of socks/false ceiling.



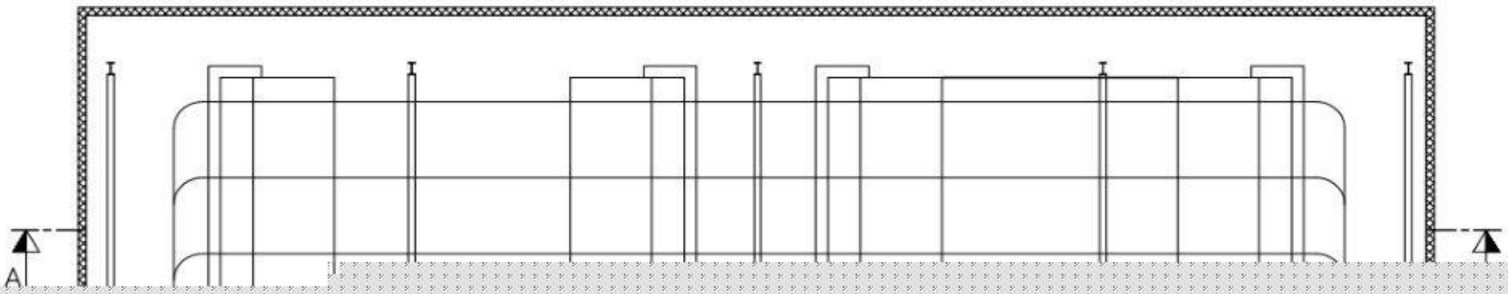
TYPICAL SECTION THROUGH CHILLERS
(VERTICAL AIR FLOW)
SKETCH 2

Other Chill Room Configuration

In Australia a variant of the vertical downward flow is used by placing the cooling coils above the rails under right angles. See Sketch 3. These can be either induced or forced draft cooling coils. The air is discharged under an angle downwards and then returns to the cooling coil by travelling upwards. This arrangement halves the air volume as half is downward and half upward. The airflow is such that not all carcasses may get the minimum airflow required. This can be compensated for by increasing the circulating air volume.

The placing of the cooling coils with their own circulating air volume suggests that individual temperature control per cooling coil is desirable so as to avoid differential temperatures inside the chiller specifically towards the end of chilling cycle.

A consequence of the cooling coil placement is a greater height requirement for the cooling coil 2m above the steelwork is recommended.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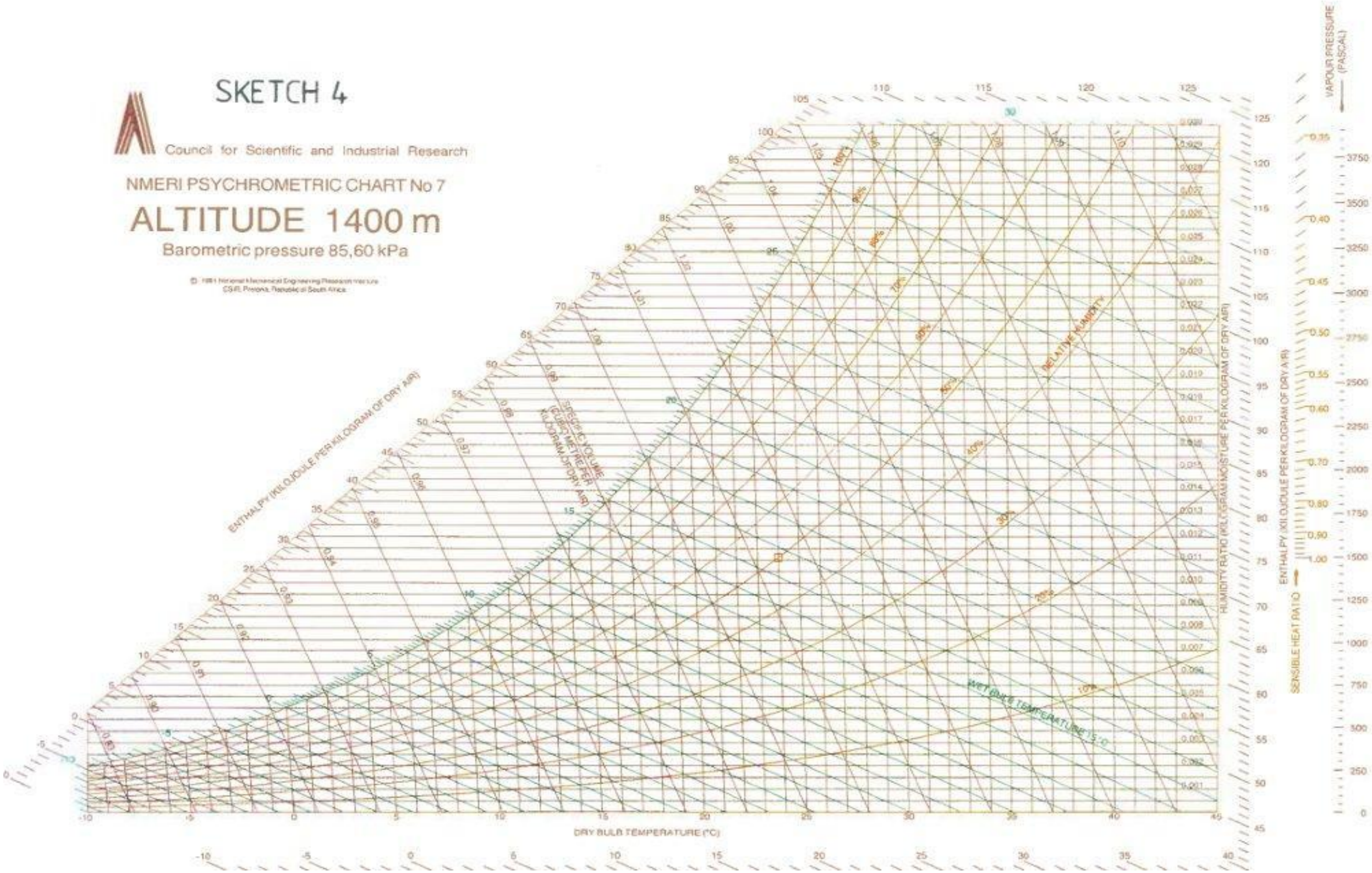
7. Weight Loss / Circulating Air Characteristics

Water vapour is always present in air and the quantity is measured in kg of moisture per kg of air. In ambient air the pressure of the water vapour is some 2 kPa whereas at 0^oC it is 0.6 kPa. Inevitably the water vapour will travel towards the lower pressures (lower temperatures) and, if these points are below the dewpoint, will settle there as water (condensed vapour).

A typical section of a psychrometric chart showing the characteristics of air is shown in Sketch 4.


SKETCH 4
Council for Scientific and Industrial Research
NMERI PSYCHROMETRIC CHART No 7
ALTITUDE 1400 m
Barometric pressure 85,60 kPa
ENTHALPY (KILOJOULE PER KILOGRAM OF DRY AIR)
SPECIFIC VOLUME (CUBIC METRE PER KILOGRAM OF DRY AIR)
RELATIVE HUMIDITY
WET BULB TEMPERATURE 15°C
DRY BULB TEMPERATURE (°C)
HUMIDITY RATIO (KILOGRAM MOISTURE PER KILOGRAM OF DRY AIR)
SENSIBLE HEAT RATIO
VAPOUR PRESSURE (PASCAL)

To minimise moisture losses from the carcasses the vapour pressure differences between the circulating air and carcass surface as well as between circulating air and cooling coil should be kept to practical minimum values.

Higher air velocities over the carcass surfaces will increase evaporation and thus moisture loss. However the carcass surface temperature will reduce more rapidly which in turn will reduce the moisture transfer. A further reducing factor is that the initial more rapid loss of surface moisture dries out the surface. This needs to be replaced from the internal mass of the meat which takes time.

The general consensus is that the overall weight loss is minimised with higher air velocities and lower air temperatures driving the initial phase of the chilling. It also assists in more rapidly reducing the deep bone temperature so as to meet the required chilling time.

Adverse Effect on On/Off Controls

Weight loss is adversely affected if the wrong controls are selected such as ON/OFF control systems. During the “ON” cycle moisture is extracted from the air which then is built up again during the “OFF” cycle. This process repeats itself again and again thereby increasing moisture loss unnecessarily.

8. Water Sprays

Wash water sprays just prior to chilling will assist in reducing weight loss. This “free water” on the carcass surface will evaporate before the moisture from the carcass and thereby reduce the carcass temperature.

Sprays can also be used during the first phase of chilling whilst the carcass is still at a higher temperature. At air temperatures below 0^{o}C care is to be taken to avoid freezing such spray system.

9. Cooling of Sheep Carcasses

The suggested chilling conditions for beef carcasses do not apply to sheep carcasses. However the heat removal from the carcasses to the cooling coil is again by the circulating air.

Sheep carcasses are generally in the 17 to 21kg range as against beef carcasses 220 to 260kg. It is clear that the surface area to mass ratio for the sheep carcass is substantially larger as compared to beef carcasses. Heat extraction is quicker for the sheep carcasses. Chill room sizes vary substantially for the abattoirs. For small abattoirs a single chill room may be installed whilst for somewhat larger abattoirs there may be 2 or 3 rooms. Cooling times should not be a problem but weight loss probably is. The reason being that the first loaded carcasses are already substantially reduced in temperature whilst warm carcasses are still being loaded.

Optimum air temperature velocity and relative humidity are impossible to achieve under these loading conditions. Also one should avoid colder carcasses being affected by warmer ones being loaded.

Guidance figures for air temperature, air velocity and relative humidity are +1oC/-1oC, 0,5/1m/sec and 90% Rh or higher.

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Moisture Losses for Sheep Carcasses

As far as moisture loss is concerned the same rules apply as for beef carcasses. Modulating controls and fan speed control to be used. The relative humidity of the air to be as high as possible by limiting the temperature difference between “Air On” and “Air Off” cooling coil to be some 2^{o}C. It is recognised that smaller plants work on HFC refrigerants (hydroflurocarbons) which have limits in control and equipment sizing. Nevertheless multiplex compressor units, split circuits and electronic expansion valves are available to at least substantially aim in the right direction.

For larger abattoirs one may consider “In Line” chilling tunnel which can be designed for minimal weight loss at rapid cooling times. In New Zealand tests have shown that combined with wetting sprays the weight loss was reduced to almost zero.

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