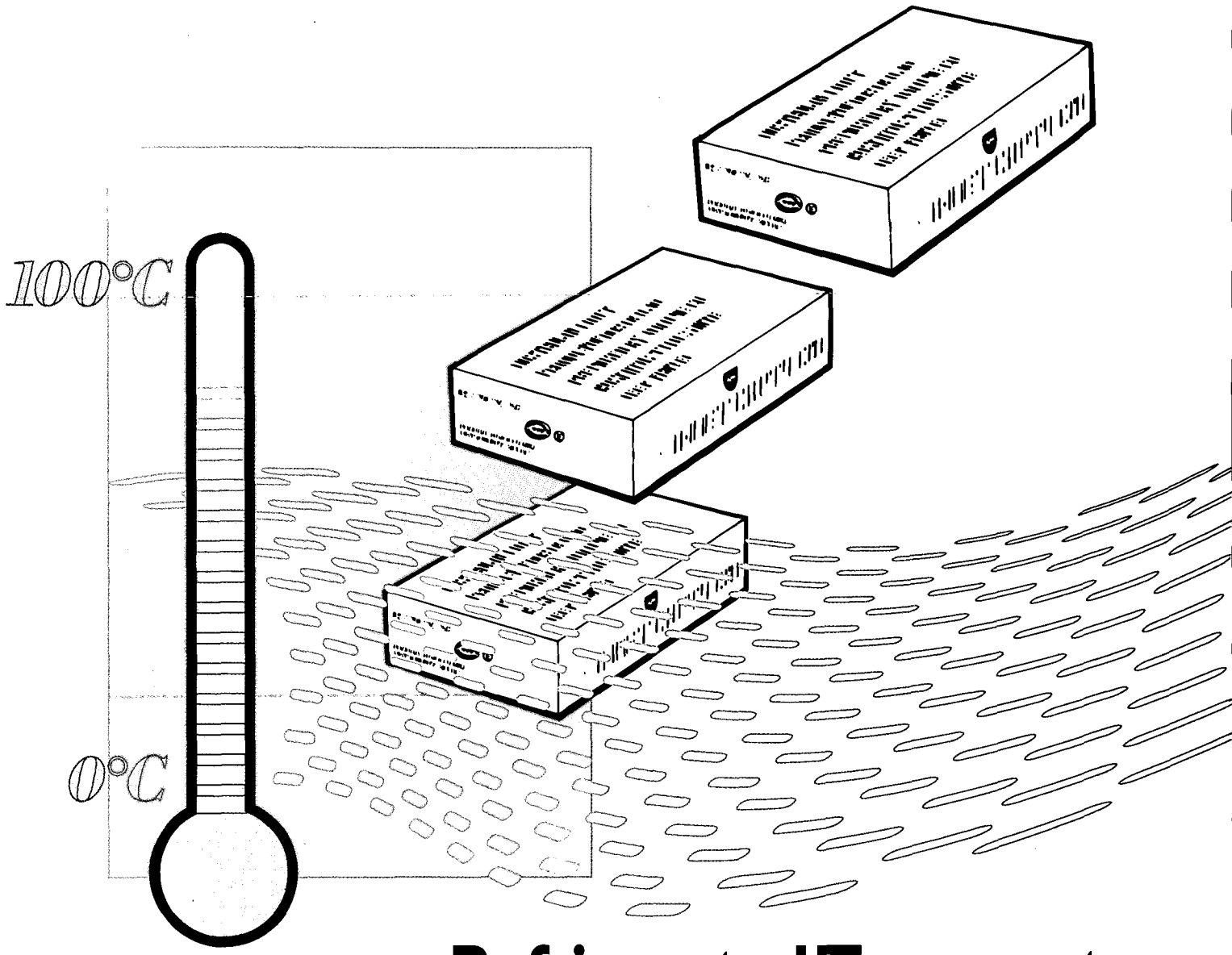

Refrigerated Transport of Cartoned Meat in Containers

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Meat Research Corporation

AMT
AUSTRALIAN MEAT TECHNOLOGY

Good product outturn relies on good cold-store temperature management and good container management. This, in turn, requires a thorough understanding of the use of shipping containers under refrigeration, and the limitations involved.

A product's packing job description should cover stowing of cargo and refrigeration. Packers must ensure that due regard has been given to the refrigerating air flow to avoid "short circuiting" and to the correct stowing of cargo to avoid damage to the container and its front machinery.

When operating on mechanical or ship's refrigeration, most of the air circulating through the container should form an "envelope" around the stow so that heat leaking through the top, bottom and all sides of the container is absorbed and removed. The container should not be packed loosely enough to let the circulating air short-circuit between the cartons at the expense of this "envelope" effect. Likewise, the container should not be over-packed to the point where there is interference or blockage of the "envelope" space. If the container is over-packed, the spaces between the back door and cartons may be blocked if the doors are forced up against the stow.

Air moves across the top of the stow, and **there must be a sufficient gap between the top of the stow and the container ceiling to allow unimpeded flow.** For guidance purposes, containers are marked with a red line near the top of each side wall inside the container.

To ensure that air flow along the length of container to the door end is maintained to the full, obstructions (e.g. dunnage) should not be placed in floor side channels and material should not be allowed to drop between the channels in the T-sections of the container floor. Similarly, care must be taken with slip sheets to ensure free air passage from floor to ceiling at the door end of the container.

Refrigerated shipping containers are designed to maintain temperature – not to rapidly cool cargo to its carriage temperature.

Cartons in the top corners of a container warm up fastest because they receive heat from three adjacent surfaces: the top, the side and the end. Return air temperature is not the mean temperature of the cargo but is the recorded temperature of the air at – or, at least, very close to – its highest level.

- Packers should ensure the *set point* is set accurately. They should check with the shipping company as to what the set point refers and what the recorded temperature indicates, and they should also physically check the container machinery to ensure that the fresh air vents are fully closed to avoid the flow of air into and out of the container.
- Packers should also ensure that, when transportable temperature data loggers or recorders are used, they are placed appropriately (usually at the hottest point – meat surface temperature, corner carton) to record the temperature of product. This will provide a valuable record of times and temperatures and may assist to diagnose the history of events in the event of a poor outturn.

Frozen Meat

The doors of partly packed containers should be closed if there are any delays when containers are being packed with frozen meat. Similarly, cartons of meat should not be left outside the cold-store during work breaks or for unduly long periods of time. If unduly long breaks in packing periods are envisaged/unavoidably incurred, then the doors should be closed and refrigeration should be applied with the refrigeration unit switched on to preserve the integrity of the product. (Refer to Table 2 for maximum safe times off-refrigeration).

It takes only a few hours for the temperature of frozen meat in air to rise to relatively high levels. This time is a function of both the ambient temperature and the temperature of the meat.

Table 1 presents the results of trials and shows the time for the carton corner meat surface to rise to -6°C and the meat centre to rise to -10°C at initial meat temperatures of -20°C and -15°C over various ambient temperatures. In all cases, the controlling factor is the time for the surface to reach -6°C. Once ambient temperatures exceed 25°C, the surface temperature of the meat in a carton can rise to -6°C in less than 30 minutes.

Quarter beef and carcases can undergo faster

temperature rises than cartoned meat. This is because the total mass of meat per volume is less than with cartons and a greater surface area per kilogram is exposed for heat exchange.

TABLE 1 Time in hours for the meat surface temperature to rise to -6°C and the centre temperature to rise to -10°C at various ambient temperatures.

Ambient Temperature	Initial Meat Temperature			
	-15°C		-20°C	
	Surface	Centre	Surface	Centre
10	1.2	5.0	2.8	7.1
15	0.8	4.3	1.8	6.0
20	0.6	3.9	1.3	5.4
25	0.5	3.5	1.0	4.0
30	0.4	3.4	0.8	4.6
35	0.4	3.2	0.7	4.3

If the meat warms significantly on the loading dock, the rate of temperature fall once it is loaded into a shipping container may be very slow, which could lead to some loss of storage life. Corrective action for this circumstance includes reducing the cold-store temperature, reducing container loading time by unit load handling or enclosing the loading dock and/or using an enclosed, cooled loading area.

Major problems can occur when condensation forms on cold product exposed to warmer atmospheres, since this can lead to a reduction in the strength of the carton.

There is also a limit to the length of time frozen meat can be stored in insulated containers before the meat temperatures rise to a point where deterioration begins. Since the cartons at the top corners next to the container door warm up more quickly than cartons in any other position, they are the ones to consider when deciding how long to allow an insulated container of frozen meat to be held without refrigeration. The criterion recommended by the CSIRO is that the meat temperature at the top corners of a stow, measured at the corner, 25mm from each side of the carton, should not be allowed to exceed -7°C.

When an integral unit or a porthole container of frozen meat is moved in Australia by a road or rail carrier, mechanical refrigeration is not usually supplied during transit from meatworks to shipping port. Table 2 has been prepared from tests conducted by the CSIRO to indicate how long frozen meat in an insulated container can be left unrefrigerated before the meat temperature in the top corners reaches -7°C.

TABLE 2 Indication of maximum safe time (hours) off-refrigeration for frozen beef packed in an insulated freight container

Meat Temperature at Door Closure	Ambient Temperatures				
°C	16°	21°	27°	32°	38°
-22°	*	*	*	71	53
-20°	*	*	71	51	39
-18°	*	71	49	35	27
-16°	87	57	39	28	22
-14°	53	34	23	17	12
-12°	27	17	11	8	7
-10°	10	6	4	3	3

Maximum safe transport time without refrigeration is extremely dependent upon ambient temperature and initial meat temperatures. Obviously, meat must be loaded out of the works or cold-store and loaded into the container, or onto the ship, at a temperature as near as possible to the carriage temperature but, in any case, at not more than -10°C.

If the expected transit time between meatworks' cold-store and dockside refrigeration is greater than the maximum safe transport time (as indicated in Table 2), containers must be refrigerated, either mechanically or, more commonly, with liquid carbon dioxide (CO_2). This procedure is called "snow shooting" and involves injecting liquid CO_2 into a container via a lance. Correct metering of the required quantity of liquid CO_2 is essential.

The amount of carbon-dioxide "snow" required depends on the meat temperature at container door closure, ambient temperature, the insulating properties of the container and the maximum likely time off-refrigeration. Snow shooting should not be used to compensate for products loaded at a temperature which is too high.

Several critical factors affect the control of meat temperatures during transit:

- The cargo should be stabilised at the carriage temperature prior to loading and

3°C. Meat temperatures were not affected by carton type.

- Using an actual delivery air temperature of -1°C in an ambient temperature of 20°C, all cartons of meat were kept below 1°C (i.e. within a range of 2°C). At an ambient temperature of 40°C and a delivery air temperature of -1°C, 5% of the cartons were above 1°C. Apart from the two cartons in the top corners at the door end, all cartons were below 2°C.

  Actual meat temperatures achieved depended on the accuracy of the "pre-trip" calibration of the temperature controller and its stability with ambient temperature changes.

- In some containers, changes in the ambient temperature altered the temperature of the air delivered to the container. Between containers, there was a difference of 1°C in the mean temperature of chilled meat. This was due to a combination of differences in "pre-trip" calibration and the ability of the control sensor to measure the true mean temperature of the air delivered to the container. Sometimes the position of the sensor can cause a variation of 1°C across the T-bar floor.

- Dunnage (vertical battens to give air spaces through the load) was not necessary, provided meat was loaded out at recommended temperatures, -1.5°C to 0°C. Dunnage may, in fact, lead to temperature increases at the door end.

- When the power was turned **off**, product at the door-end top corners warmed fastest, followed closely by that at the bottom corners. Product at the centre of the stow warmed up very slowly.

Changes in ambient temperature had a large effect on the rate of temperature rise of the meat. The rate of warming of meat at points 25mm in from the container corners increased by 60% when the ambient temperature was increased from 20°C to 40°C.

Additional information

More detailed information on this subject is provided in the following:

CSIRO *Final Report, CS128* "Optimisation of Chilling During the Processing, Containerised Transport and Storage of Meat", (Part B: Chilled Meat Containerisation)

CSIRO *Final Report, CS133/8* "Freight Containers Loaded with Cartoned Frozen Beef: Safe-Time-Off-Power and Snowshooting"

CSIRO *Meat Research News Letter No. 78/5*, "Holding of Frozen Cartoned Meat in Insulated Shipping Containers"

CSIRO *Meat Research News Letter No. 86/1*, "Unit Loading of Cartoned Meat"

AMT *Meat Technology Update No. 95/3*, "Chilled Cartoned Meat in Shipping Containers"

43rd ICOMST 1997 Congress Proceedings, "Cold Chain Technology and the Meat Industry"

Additional information

Additional help and advice are available from Food Science Australia, Meat Industry Services Section:

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prior to snow shooting. Users must understand that massive thermal shocks can occur to the container, its sensitive machinery and the cargo. Users should also strictly follow the *Snow Shooting Manual.*

- To accommodate the required amount of "snow", sufficient clearance must exist between the top of the load and the ceiling of the container.
- The more "snow" required, the larger this head space must be. The cargo should be stowed to ensure sufficient access for the Snow Shooting machinery to function effectively.
- The "snow" must be distributed evenly over the top of the load.
- The correct amount of snow must be used. This can be determined from the *Snow Shooting Manual* which details quantities of snow to be injected into refrigerated containers, relevant to ranges of ambient temperatures and for determined periods of transit. The recommendation for dosages presumes that the product has been packed into the container at the correct temperature. Recommended dosages will merely maintain the product at the temperature of meat at the time of snowshooting over the selected period. If, however, product is "warm" or "hot" loaded, these dosages will not be sufficient to achieve the desired result, and acceptance of the container could be refused. Do not simply rely on using the same amount of "snow" each time.

To enable control, relevant information regarding the time and date of packing, and amount of carbon dioxide snow applied, should accompany the container to the terminal.

The operator must move the container to refrigeration facilities before the meat temperature in any carton can rise to a level at which deterioration may occur, or adequate refrigeration during transit (and storage off-power) must be applied to prevent excessive temperature rises.

On arrival at the terminal, the container must be supplied with refrigeration without delay. If a container does not arrive at its destination within the anticipated transit time, the container operator must locate the container and determine the cause of delay and the extent of temperature rise. If still acceptable, the container can be put under refrigeration, or "snow shot" if necessary. If any doubt exists as to meat safety, AQIS and the shipper should be informed, with the meat inspected prior to export.

Containers should be operated with a set point of -18°C or lower. With frozen meat, where there is a thermograph (chart recorder), the *set point, control, recording (logging)* may be on *Return Air or Delivery Air*, depending on the equipment utilised. In most cases, it is on *Return Air.*

Air temperature control is achieved by monitoring air temperature and applying refrigeration when the air temperature rises above a pre-set value. To maintain this (recorded) temperature at a constant level, it may be necessary to cool the return air some 2°C (dependent on cargo temperature and ambient conditions) before delivery back to the container.

Chilled Meat

Given the duration of transportation involved in export shipments, meat will spend a considerable proportion of its shelf-life in the shipping container. Therefore, every effort should be made to keep the temperature of the meat below 0°C at all times during chiller loadout, container stuffing and container storage and transport. At as low a temperature as possible, without freezing the meat, is best, and, generally speaking, meat and offal should be stored and transported at -1.5°C to 0°C.

If insufficiently chilled meat is loaded, it is unlikely that its temperature will drop at a satisfactory rate during shipment,

particularly if the ambient temperature is high. Temperature reductions of 1°C to 2°C per week may be all that are generally achieved for product at the centre of containers.

Shipping at temperatures greater than 0°C will reduce shelf-life and may produce excessive weep in the packs. Some temperature variations between cartons in different locations in the container are inevitable.

A basic requirement for any successful load is that the meat be loaded out at the correct temperature. If this is not done, the container refrigeration system will only reduce the temperature of the load slowly.

Meat should not be left on unrefrigerated loading docks during loadout because these docks are well above the ideal load temperature of 0°C. In unrefrigerated loadout facilities, the cartons should be transferred directly from the holding chiller to the container. Doors should be closed during breaks.

Container refrigeration units should not be run during the loading operation for two reasons. Firstly, little can be gained in terms of temperature reduction in the product. Secondly, high ambient humidity will cause the refrigeration unit to ice up, reducing its efficiency in the important period immediately after container closure and sealing. Icing up of the evaporator could lead to the equipment assuming a permanent "defrost cycle" which may have adverse effects on the cargo temperature.

For the same reason, pre-cooling of containers prior to packing is not recommended. When the doors of a pre-cooled container are opened, large quantities of condensation will form on walls and the floor of the container. Removal of this moisture will be required after the container is packed and refrigeration is switched on, thus reducing the refrigeration effect available to the cargo in the container in the important period immediately after closing and sealing the container.

Voids in the container leave cartons loose. To prevent movement of the stack in transit, vertical packing (e.g. polystyrene foam) should be used to fill the gaps. Cartons should be stacked directly, one above the other.

The last tier of cartons should be stowed no further than 50mm from the doors. If necessary, vertical packing should be placed between the last two tiers to reduce the gap at the doors.

Because container insulation deteriorates with time, containers more than 12 years' old should not be used for chilled meat, unless the heat leakage is known to be less than 35 W/K (i.e. 35 watts/°C). The manufacturer's plate will reveal relevant information.

There are many models and makes of refrigerated containers in use, and some may be unsuitable for transporting some chilled produce to some markets. Thus, containers must be chosen to satisfy the requirements of the produce to be carried, appropriate to the length of voyage. It is the shipper's responsibility to provide all relevant details of the product to be carried (and the desired air/meat temperatures) so that the shipping company can furnish a container suitable for the carriage of the specified product.

With chilled meat, the *set point* and the *control* may be on *Delivery Air* or *Return Air Temperature* and the thermograph may indicate either of these readings. In most refrigerated containers in use at present, however, the *control, set point temperature* and the *recorded temperature* are generally functions of the *Delivery Air Temperature* (which is the lowest temperature in the container).

Ideally, meat (and offal) should not be loaded out until the product is below 0°C. Transport and storage at a temperature as low as possible, without freezing the meat, is best. Ideally, product temperature should be between 0°C and -1.5°C.

Recent MRC-funded research findings

- When cartons were stacked directly on top of each other, the load remained stable during transport but cartons which were partly off-set collapsed.
- When the power was on, the highest product temperatures were at the top corners at the door end of the container. Increasing the ambient temperature from 20°C to 40°C increased the spread of meat temperatures in the container by 2°C to