MEAT RESEARCH REPORT

AMT
AUSTRALIAN MEAT TECHNOLOGY

Meat Research Report No. 2/96

Consideration of Relative Advantages of Small Capacity Plate and Air Blas Freezers for the Freezing of Cartoned Mea

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Executive Summary

Small plate freezers used for the freezing of cartoned meats have a number of advantages over air blast tunnel freezers. The major advantages are a lower use of electricity per tonne of product frozen and a lower capital cost of the refrigeration system (not including the plate freezer itself which has a higher capital cost than the equivalent air blast freezer).

It is estimated that in a 'green field' situation, the use of a plate freezer would recover the greater capital cost of the plate freezer in approximately 1.4 years. When freezing 420 cartons a day, the savings in the cost of electricity would be in the region of $12,000 per annum.

The above would also be the case where there is a need to add a small carton freezer to a system which has insufficient, or no low side refrigeration capacity.

In the situation where the plate freezer is added onto an existing refrigeration system which has adequate low side refrigeration capacity, it is estimated that it would take almost five years to recover the difference in capital cost between the plate and air blast freezer.

It is a common practice in the meat processing industry to judge investments on the basis of 'pay-back' period, with two to three years being generally accepted as reasonable. Using this criteria, the first two situations, i.e. a 'green field' or adding a small carton freezer to a system which has insufficient, or no low side refrigeration capacity, would justify the installation of a plate freezer.

1. Introduction

In 1995 the Australian meat industry exported a total of 783,445 tonnes of beef and veal and 77,648 tonnes of fancy meat. Allowing for the 300,000 tonnes of beef and veal, which was exported chilled or in quarter form, and ignoring the export of mutton and lamb, the industry would have handled, frozen and transported in excess of 21 million cartons of boneless product in that year. This suggests that any savings in the handling, freezing and transporting of cartons would be of significant benefit.

The most common method used by the meat industry for the freezing of cartons is automatic air blast freezing tunnels. However, in recent years there has been a significant increase in the number of plate freezers in use. The recent development of large capacity plate freezers, with mechanised loading and unloading of cartons, has overcome their previous major disadvantages of limited capacity and relatively high labour requirements.

It has always been recognised that plate freezing has a number of advantages over air blast freezing, including:

- faster freezing time;
- flat cartons with minimum bulge compared with air blast freezing, allowing the safe stacking in cold stores to greater heights without the necessity for racking;
- better stowage density in containers;
- lower refrigeration capacity requirements due to the absence of high capacity fans in the freezer.

If the development of mechanised loading and unloading systems were to be applied to smaller plate freezers, this could provide an opportunity for small-sized abattoirs to take advantage of the potential benefits of plate freezing.

2. Small Capacity Carton Freezers

In the meat industry, when a small number of cartons is to be frozen daily and the use of a fully automatic air blast freezer cannot be justified, it is common practice to use a static air blast tunnel freezer. The main justification for its use is low capital cost. A small capacity plate freezer is a possible alternative to the air blast tunnel freezer but, because of the perceived greater cost or lack of flexibility, this has generally been discounted. (An air blast freezer can be used for carcases [quarter beef] or cartons).

2.1 Air Blast Tunnel Freezer

An air blast freezer basically consists of a small insulated room, usually long and narrow, provided with a large capacity, ceiling-mounted, induced draught cooling unit. A part plenum ceiling and baffles may be provided to achieve some control of the direction of the air flow. The cartons to be frozen may be placed on standard 1168 mm pallets with battens between each layer of pallets, or on pallet racks (known as stillages). The pallet load usually consists of six cartons per layer, stacked five or six layers high. Loading and unloading of the pallets or racks is done with a forklift.

The air blast freezers are commonly sized to hold two pallets side-by-side and two pallets high, with the length of the tunnel being selected to accommodate the number of cartons to be frozen per cycle.

The time required to freeze cartons to below –10°C in the air blast freezer with air at a temperature of around -30°C is usually about 40 hours. However, the freezing time can be highly variable, due to the difficulty in achieving an evenly distributed high air flow throughout the carton stacks on the pallets. Also, freezing times will be influenced by other variables such as carton material and type, carton depth, space between adjacent cartons, type of product, etc.

The heat loads in an air blast freezer are made up of:

- product load which includes the sensible and latent heat extracted from the meat;
- heat gains through the freezer structure;
- heat input from fans in the induced draught cooling unit;
- heat gains from lighting and air infiltration through doors.

The greatest heat load in air blast freezers is that contributed by the sensible and latent heat of the meat being frozen. The next major contribution of heat load is from the fans in the induced draught cooling units, which can be as much as 20% to 40% of the product load.

The general arrangement of an air blast tunnel freezer is indicated in Figure 1.

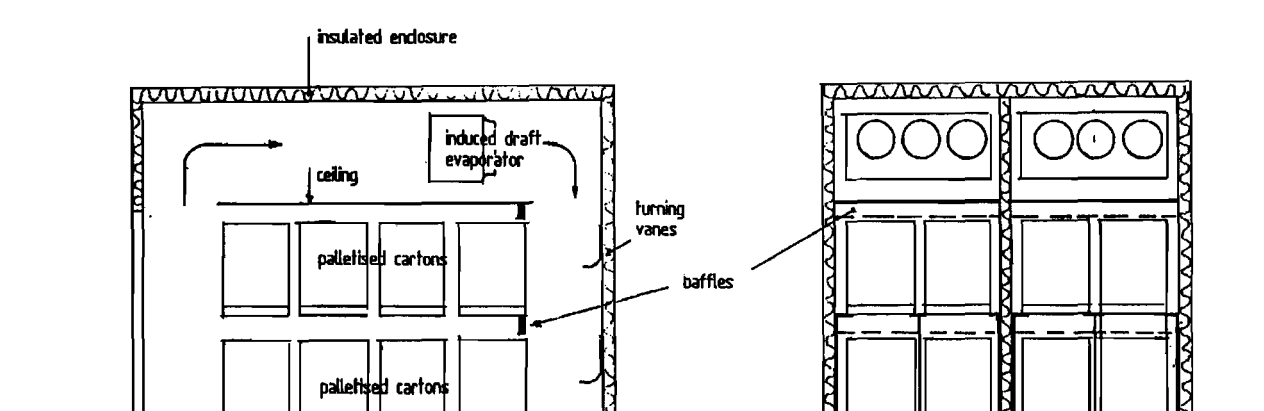

Figure 1. General Arrangement of Tunnel Air Blast Freezer

2.2 Plate Freezer

A plate freezer consists of hollow, flat plates constructed from aluminium or mild steel.

Aluminium plates are formed from a number of hollow extruded sections, butt-welded to each other along their length. At each end, the sections are connected to a header which allows ammonia to flow to and from each section of the plate. The use of aluminium extruded sections aided the introduction of very large plate freezers, as the depth of the plate could be increased to provide the necessary strength to carry large loads on long plates.

Mild steel plates are formed from hollow, square sections welded between two flat plates. As in the aluminium plates, headers are provided at each end to achieve an even flow of ammonia across the plates.

A complete plate freezer unit is formed by stacking a number of plates horizontally, one on top of the other. The stack of plates is placed inside a steel frame with each plate connected to each adjacent plate in a manner which allows the plates to be moved apart to form a gap of sufficient width to allow a carton to be placed between two adjacent plates. A hydraulic ram(s) is used to both move the plates and apply an even pressure on the cartons between the plates during freezing.

Each plate is connected to the refrigeration supply by means of pairs of flexible hoses, with the supply and return lines being at opposite ends of the plate.

The plate freezer unit is completed by the erection of an insulated housing around the plate stack. Access to the plate stack for loading and unloading operations is by means of a vertically rising door(s).

Because heat is transferred from the carton directly to the plates, which are in close contact with the carton, high heat transfer rates are achieved. The time required to freeze cartons of conventionally chilled and boned meat to below –10°C, with refrigerant at a temperature of around -30°C, is usually less than 24 hours. Provided an even flow of refrigerant is achieved over all sections of the plate and carton heights are sufficiently uniform, there is little variation in freezing times between cartons.

The heat loads in a plate freezer are made up of:

- the product load;
- heat gains from within the enclosure through the edges of the plates, flexible hoses and refrigerant headers.

The major advantages plate freezers have over air blast freezers is the absence of high powered fans, which in air blast freezers contribute significantly to the refrigeration load and the much higher heat transfer rate achieved by direct contact between the refrigerated plates and the cartons.

The general arrangement of a plate freezer is indicated in Figure 2.

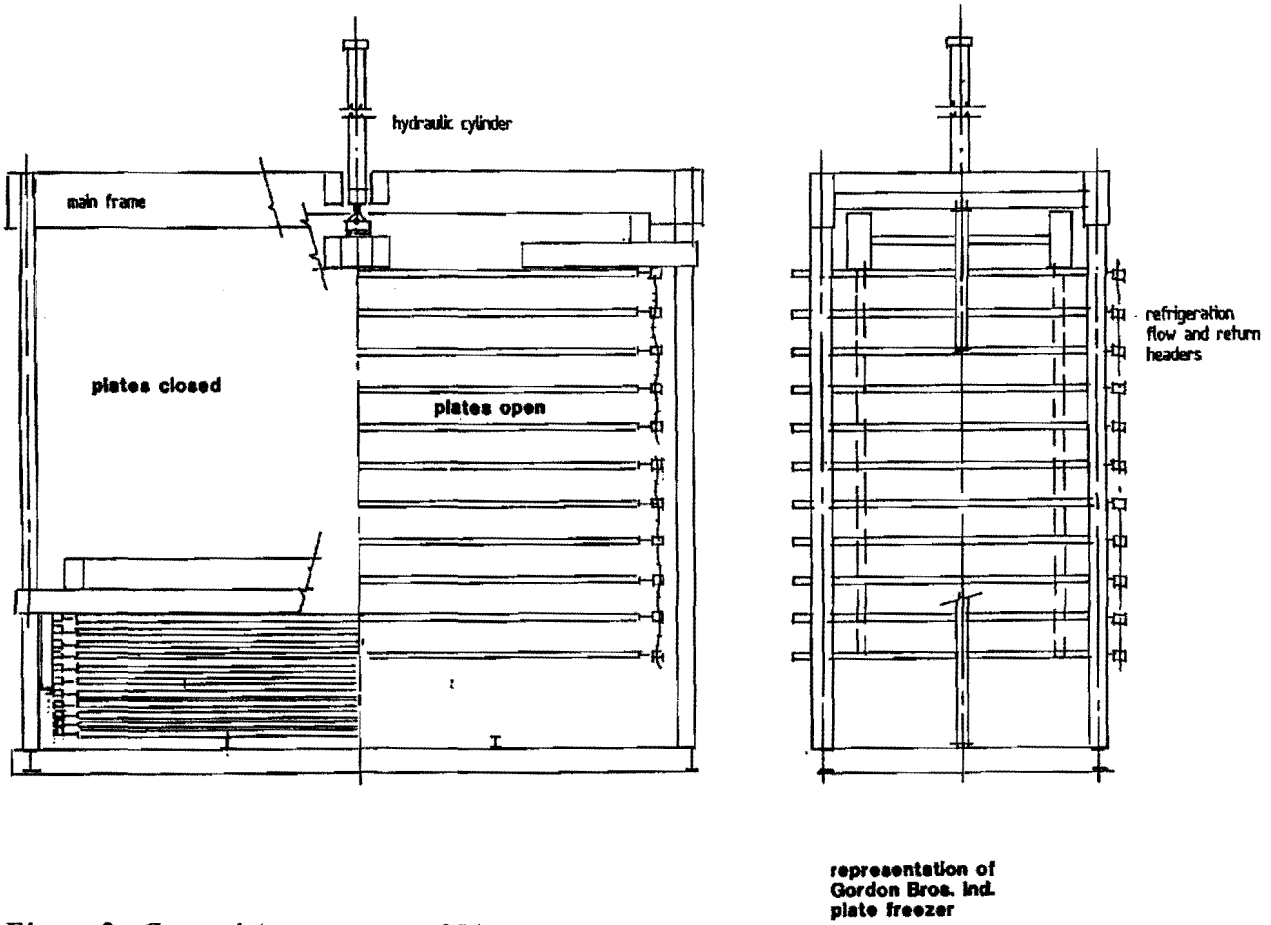

Figure 2. General Arrangement of Plate Freezer

2.3 Comparison of Freezing Rates

Cartoned meat freezes faster in plate freezers than in air blast freezers, due to the direct contact between the plates and cartons, as shown in Figure 3. It is generally accepted that plate freezing is the only method capable of meeting the existing Australian Quarantine and Inspection Service (AQIS) time/temperature requirements when processing hot boned meat in a single operation. In general, air blast freezers can only satisfy the existing AQIS requirements by the use of pre-cooling or decontamination of the carcases prior to boning.

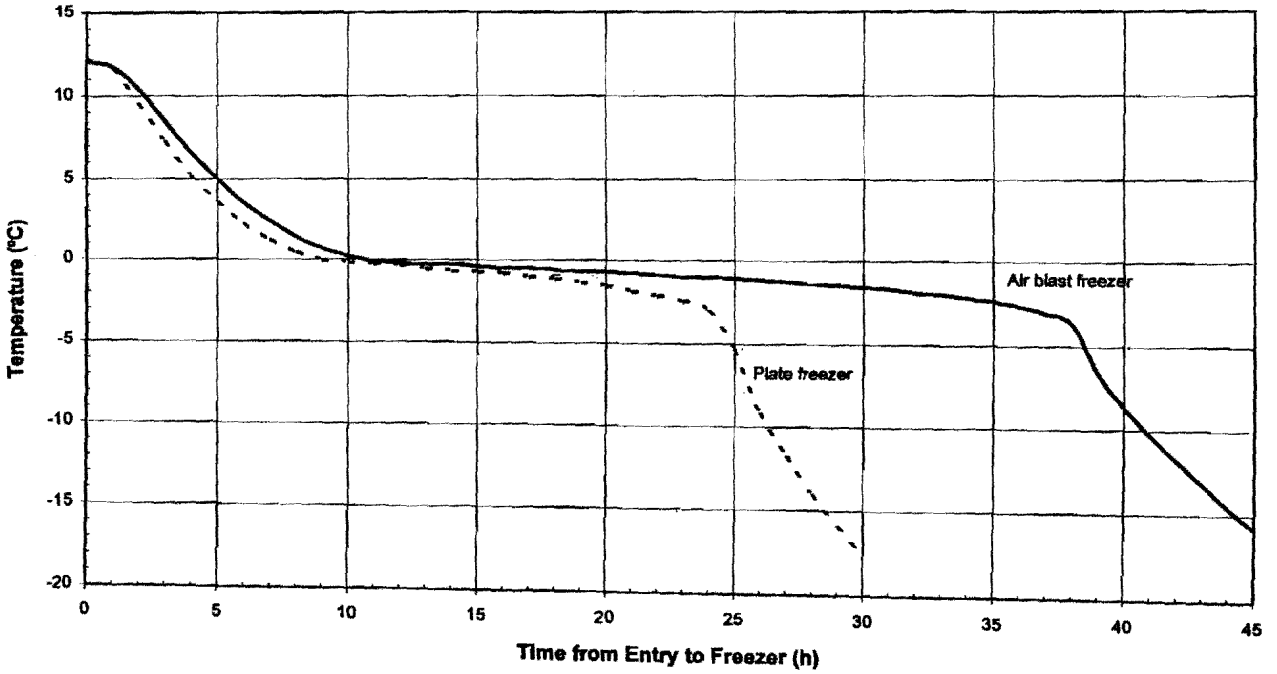

Figure 3. Comparison of Air Blast Freezing and Plate Freezing Cooling Rates

The existing AQIS time/temperature requirements for the freezing of hot boned meat are as follows:

Initial Temperature (°C)	Time (hours) to Fall to 7°C	
	No Prior Decontamination	Effective Prior Decontamination
40	6.27	9.23
39	6.43	9.50
38	6.65	9.82
37	6.90	10.13
36	7.17	10.52
35	7.50	10.08
34	7.80	11.42
33	8.10	11.83
32	8.42	12.27
31	8.75	12.75
30	9.12	13.25
29	9.47	13.73
28	9.88	14.40
27	10.33	15.08
26	10.85	15.73
25	11.38	16.50
24	12.00	17.42
23	12.67	18.40
22	13.42	19.90
21	14.23	>20.00
20	15.13	

2.4 Loading and Unloading of Plate Freezers

The major disadvantages of plate freezers, compared to blast freezers, were the higher capital cost and greater labour requirements for the loading and unloading of cartons. In large plate freezers the high labour input has been overcome by the development of an automatic system of loading and unloading. However, in the case of small plate freezers the high cost of a similar automatic system is difficult to justify.

One of the main reasons for the high cost of the automatic loading/unloading system was the fact that, in plate freezers, individual plates were at different levels when stacked one on top of the other. It was therefore necessary to align the infeed and outfeed conveyors and the plate being loaded. When large aluminium plates are used, the difference in plate heights is increased due to the greater thickness of the plate and associated header.

In small plate freezers the same difficulties apply, particularly when using aluminium plates. For this reason a mechanised system of loading and unloading, with manual controls, is preferred. The simpler system is less expensive and labour requirements are reasonable.

A recent plate freezing installation has incorporated small plate freezers which have been designed to raise and lower the entire stack of plates as a single unit. This allows the station being unloaded and loaded to be brought to a fixed height loading/unloading station.

2.5 Cost of Small Carton Freezers

Air blast tunnel freezers are simple structures and are cheaper to construct than equivalent capacity plate freezers. However, as the carton freezing cycle is generally of the order of 48 hours, two units are required, each capable of holding the daily production of cartons. It is estimated that the cost of an air blast tunnel freezer consisting of two chambers, each capable of holding 480 cartons on 16 pallets stacked two pallets side by side and two pallets high, as in Figure 1, would be approximately $80,000. The structure would have the approximate external dimensions of 10 m long by 7.5 m wide by 4.0 m high.

The cost of plate freezers is influenced by the materials of construction. Aluminium plates are more expensive than mild steel plates. Advice from a number of plate freezer manufacturers indicates that the cost for the supply and installation of the plate stack, supporting structure and hydraulic system, ranges from around $260 to $395 per carton capacity. The cost of the insulated enclosure and mechanised loading/unloading system would be additional. The least expensive plate freezer is one that uses mild steel rather than aluminium plates.

For a plate freezer using mild steel plates, the estimated cost of a 432 carton freezer, including the insulated enclosure, mechanised loading/unloading system and associated building work, would be $145,000. The enclosure would have the external dimensions of 4.5 m long by 3.0 m wide by 3.7 m high.

The two examples above have similar throughputs.

2.6 Labour Requirements of Small Carton Freezers

The labour requirements of both the plate and air blast freezers would be similar.

In the air blast system it is necessary to arrange the cartons on pallets – 6 cartons per layer, 5 cartons high, with spacers between each layer of cartons – before placing the pallets in the freezer. Alternatively, portable galvanised steel pallet racking can be used, which allows more uniform air flow over the cartons. Handling of the palletised loads to and from the freezer would be by forklift truck.

Following freezing it is necessary to break up the palletised load to remove the spacers, sort cartons and re-palletise. It is estimated that two operators would be required to handle both the loading and unloading operations.

In a plate freezer system fitted with a manually controlled, mechanical loading and unloading system, it is estimated that two operators would be required – one to control the unloading/loading operations and the other to sort and palletise the frozen cartons.

3. Advantages and Disadvantages of Plate Freezers

Plate freezers were examined in detail in a report by K. Visser & Associates (1988). The advantages and disadvantages were listed in the report and are reproduced here in Sections 3.1, 3.2 and 3.3.

3.1 Advantages

- The energy consumption of the freezing process is between 45% and 65% less than current Australian meat industry freezing practices with automatic air blast freezers.
- After plate freezing, a pack with almost perfectly flat top and bottom surfaces results, which has the following advantages:
  - Increased payload in containers.
  - The product becomes suitable for automatic mechanical handling for such purposes as sorting, palletising and cold storage.
  - On an industry average basis the cold storage utilisation will increase by up to 35%, due to the more stable pallet loads created.
  - Substantially improved productivity as it is possible to load containers mechanically with 10 to 20 unitised loads of meat products, loading up to 780 cartons in a container.
  - Stock rotation control, recording and tallying of unitised loads is greatly simplified.
- A plate freezer is the only mechanically refrigerated freezer available to reduce the temperature of hot boned meats to 7°C within the time presently required by AQIS.
- Short freezing times of 12 hours to 16 hours for chilled, cold boned meat and 16 hours to 19 hours for hot boned meat, depending on plate temperature.
- Excellent product presentation in overseas markets.
- When freezing hot boned pre-rigor meat pieces in 70 mm to 80 mm thick slabs, the superior manufacturing properties of hot boned meat may be retained.
- Plate freezers require a smaller building and thus occupy less land than automatic air blast freezers of equivalent capacity.
- The required refrigeration plant for a plate freezing system is about 35% smaller than that required for an equivalent capacity automatic air blast freezing system.
- Because of the relatively gentle handling of cartons from the boning room into the freezer, cartons may be made from E-flute corrugated fibre, rather than B-flute or solid fibre. E-flute is cheaper than either B-flute or solid fibre and it has approximately the same heat transfer characteristics as solid fibre.
- Low noise level during operation due to the absence of fans. The only sounds are from conveyors and hydraulic systems.

It was also stated that at some time in the future further developments will result in the following advantages:

- It is intended to develop the freezing of meat in plastic-lined metal moulds, thus doing away with the carton. This would result in a substantial reduction in packaging costs.
- Due to a reduction in packaging material weight, a further increase in container payload becomes possible as more meat and less packaging material is shipped.

3.2 Disadvantages

The disadvantages of plate freezers were identified as:

- High capital cost compared with conventional air blast freezing systems.
- Plate freezers require a large refrigerant charge which is widely fluctuating, depending on refrigeration load generated in the plate freezer.
- If cartons of varying height are to be handled, the product has to be sorted to different locations in the plate freezer. This does not present a problem with cold boned meat, but with hot boned meat, given the time constraints, carton heights should be standardised as much as possible.

3.3 Summary of Benefits – Cold Boned Meat

The report included costings which are listed here in 1988 dollars.

	Dollar Savings per Tonne of Meat	
	Minimum	Maximum
Energy savings	4.50 to 11.25	4.50 to 11.25
Freight savings (due to increased payload)	15.00	25.00
Improved cold storage utilisation	2.00	4.00
Container loading	2.00	10.00
Reduced shipping and sales documentation	0.50	1.00
Cheaper cartons (E-flute)	6.00	12.00
Range of savings	30.00 to 36.75	56.50 to 63.25
Realisable savings, say 75%	22.50 to 27.56	42.38 to 47.44

The wide range in energy savings was a reflection of the wide range in the cost of electricity throughout Australia.

3.4 Consideration of Claimed Advantages and Disadvantages

It should be noted that all of the possible advantages stated in Section 3.1 could only be achieved if a determined effort was made to implement all of the changes made possible by the improved carton shape. It is unlikely that some changes could be justified in a meat plant where a small plate freezer is considered adequate. Also, the passage of time has seen changes which would reduce the potential benefits.

The greatest indicated saving was that given for freight, due to increased payload. The introduction of transport charges on the US shipping routes based on the weight of containers, rather than a unit charge per container, has reduced the direct benefit of an increased payload to our largest market for frozen meat. However, the benefit of increased payload to other markets remains.

For the present exercise, a very conservative approach has been adopted by assuming that the only benefit which would be achieved by the use of a plate freezer would be a reduction in the cost of energy in the freezing process. This approach is not intended to suggest that most of the other claimed benefits could not be achieved and the possibility of additional benefits should be kept in mind, as they may be directly applicable in particular situations.

3.5 Energy Savings

The energy savings achieved by the use of plate freezers were indicated to be between $4.50 and $11.25 per tonne of cartoned product when compared with 48-hour air blast freezing. The savings obtained over 48-hour air blast freezing were based on the following:

- For air blast freezers operating on a 48-hour cycle it was considered that the hours of operation would be 24 hours per day for six days at full refrigeration capacity and one day at eight hours' full refrigeration capacity, i.e. 152 hours per week at full refrigeration capacity.
- For plate freezing the equivalent operating hours were determined to be 116 hours per week, based on 20 hours per day for five days and 16 hours over two days at full refrigeration capacity.

The relative energy consumption and savings in kWh per tonne were indicated as follows:

Freezing Method	Energy Consumption (kWh/tonne)	
	Cold Boned	Hot Boned
48-hour Air Blast	122	147
Plate Freezing	47	62
Energy Saving from Plate Freezing	75	85

The cost of electricity was taken as ranging from 6 cents to 15 cents per kWh, which gave a saving in energy cost of plate freezing over 48-hour air blast freezing of:

Cold boned	$ 4.50 to $11.25 per tonne
Hot boned	$ 5.10 to $12.75 per tonne

4. Refrigeration Systems

4.1 Sizing and Selection of Equipment

A refrigeration system suitable for both small capacity plate and air blast freezers would be similar to those used in larger capacity systems. The system would be based on the recirculation of liquid ammonia. The associated compressors, condenser, liquid circulation pump, etc. would have to be selected to ensure adequate capacity to cater for all conditions.

The refrigeration system components, operating conditions and power requirements for plate and air blast freezers, having carton freezing capacities of around 420 cartons per day, would be as follows:

Equipment	Plate Freezer	Blast Freezer
Freezing time	24 hrs	48 hrs
Load for freezing 420 cartons	60 kW	80 kW
Compressor – Sabroe	1 x TSMC108S	1 x TSMC108L
Compressor capacity @ –32/35°C	64.9 kW	84.2 kW
NH_3 Pump – Nikkisso	HQ 213	HQ 213
Condenser – BAC	VKC 30	VXC 38
Absorbed power (compressor)	30.7 kW	39.4 kW
Motor size	37.0 kW	45.0 kW
Total absorbed power	39.1 kW	58.8 kW
Cost of refrigeration system	$147,000	$195,000

Note: The ammonia reservoir (accumulator) would be larger for the plate freezer due to the variation in volume stored during the freezing cycle.

The general arrangement of the refrigeration systems is indicated in Figure 4.

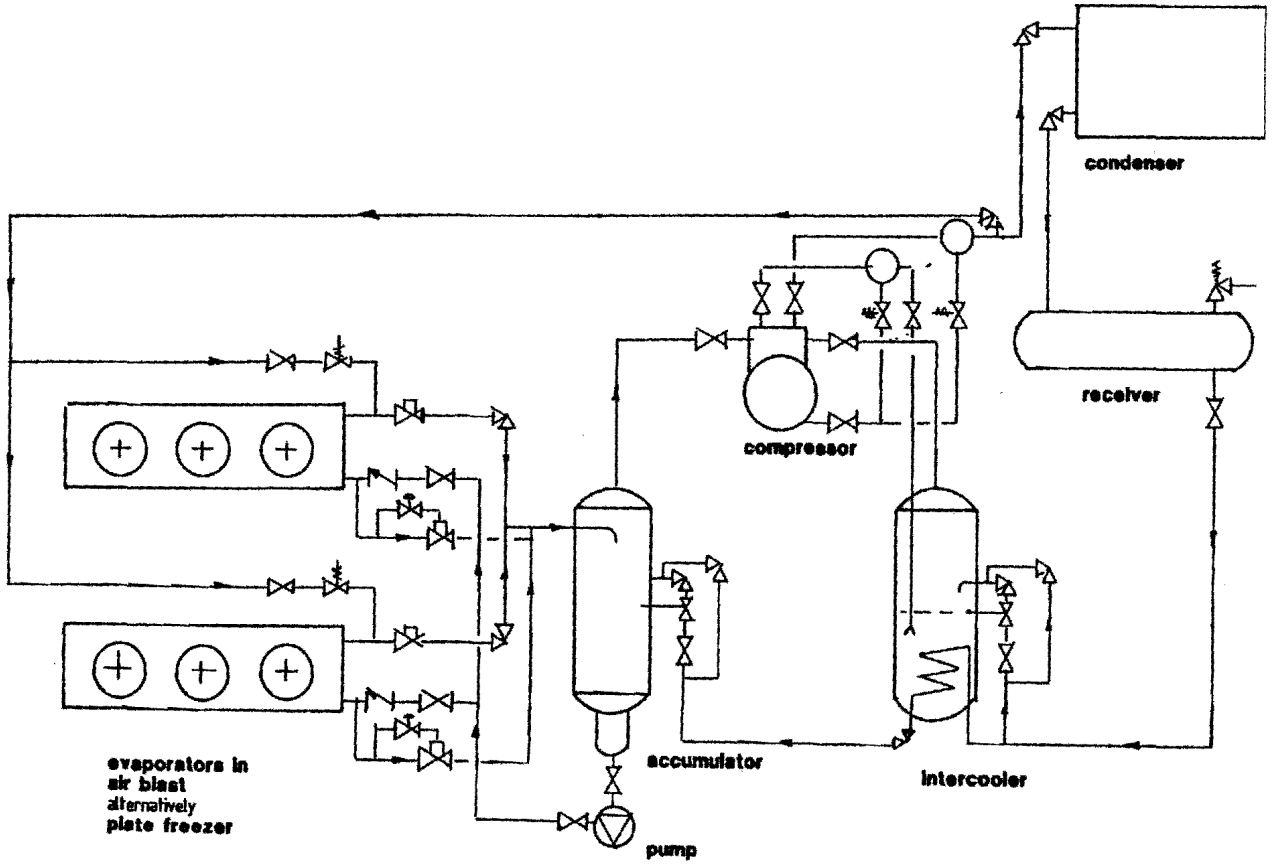

Figure 4. General Arrangement of Refrigeration System

5. Financial Costs and Benefits of Plate vs Air Blast Freezing

5.1 Capital Cost of Systems

The capital costs of both the plate and blast freezing systems of similar throughput are estimated to be:

	Plate Freezer	Air Blast Freezer
Freezing equipment	145,000	80,000
Refrigeration system	147,000	195,000
Total capital cost	$292,000	$275,000

The additional cost of the plate freezer over the cost of the air blast freezer is $17,000.

5.2 Operating Cost of Systems

If it is assumed that the small plate and air blast freezers are used to their capacity over 235 days per year, the tonnage frozen annually would be approximately 2,700 tonnes.

		Plate Freezer	Air Blast Freezer
System power	(kW)	39.10	58.80
Hours run / week	(h)	116.00	152.00
Energy used / week	(kWh)	4,535.60	8,937.60
Weekly production	(t)	57.12	57.12
Energy used / tonne	(kWh/t)	79.40	156.50
Annual production	(t)	2,700.00	2,700.00
Annual energy use	(kWh)	214,420.00	422,525.00
Annual energy cost	($)	16,926.00	29,236.00

Difference in annual energy cost $12,310 .00 ($4.56 per tonne)

In the above example the cost of electricity was based on Queensland electricity costs, where electricity use is charged on the basis of a two part tariff, one part being the units used charged at 3.78 cents per kWh, the other being a Maximum Demand charge of $18.80 per month for each kW of maximum demand.

For other parts of Australia, the energy cost of both systems can be estimated using the following relationship:

Annual cost of power = (Annual energy use (kWh) x unit cost (cents/kWh) / 100) +
(System power (kW) x Maximum Demand charge ($/kW) x 12)

5.3 Financial Benefits of Plate Freezer

Owing to the uncertain nature of the meat processing industry it is common practice to judge investments on the basis of 'pay-back' period. It is generally accepted that an estimated pay-back period of less than three years is needed before serious consideration would be given to proceeding with a project.

The above comparison of capital and operating costs indicates that in a 'green field' situation the greater cost of the plate freezing and associated refrigeration system is recovered within a period of 1.4 years. In this situation the investment in a plate freezer would be fully justified.

The above would also apply where there is a need to add a small carton freezer to a system where there was either no low side refrigeration capacity, or the low side capacity was inadequate.

In the situation where consideration is being given to adding a small carton freezer to an existing refrigeration system having an adequate low side capacity, the saving in the cost of the refrigeration system associated with plate freezers does not apply. It was estimated that the installed cost of the plate freezer would be $145,000 compared with the installed cost of the similar throughput air blast freezer of $80,000. The greater cost of the plate freezer of $65,000 means that the pay-back period would be over five years. This would not be considered to be an attractive investment. However, were it anticipated that there would be further capacity expansion within a few years, then installing a plate freezer now could still be the correct investment decision.

6. Acknowledgements

This project was supported by the Meat Research Corporation. The assistance of Australian Meat Technology Pty Ltd (AMT) is acknowledged.

7. References

Report by Visser, K & Associates, 1988, *Advantages, Disadvantages and Benefits of Plate Freezing including Future Benefits to be derived from Hot Boning*, Bendigo, Vic.

Appendix 1

Manufacturers of Plate Freezers

There are at least five manufacturers of plate freezers in Australia:

Acme International Freezing Systems, Western Australia
Gordon Brothers, Victoria
Realcold Milmech, Victoria
Refrigeration, Engineering, Plumbing Services (REPS), Queensland
Western Refrigeration, Western Australia.

A number of plate freezing systems have been installed directly by meat processing companies, with plates being purchased from a fabricator and the balance of the system being manufactured in-house.

Acme International manufactures a standard 15-station plate freezer having a capacity of 250 cartons. The plates are formed from aluminium extrusions and are 2140 mm long by 1905 mm wide. The standard unit can be shipped as a complete module, fully tested, which simplifies site erection. Such a method has obvious advantages in remote areas and the company has shipped a number of systems to overseas customers. The company can manufacture larger capacity units.

Gordon Brothers manufactures the range of large plate freezers first developed by K. Visser & Associates. The range has been extended to include smaller capacity systems ranging from 360 cartons to 720 cartons per day. This range is based on a standard plate 4.5 m long by 3.4 m wide, formed from extruded aluminium sections, having a nominal capacity of 72 cartons per plate. The nominated capacity is achieved by varying the number of stations.

Realcold Milmech makes a range of both manually and automatically loaded plate freezers. The 52 mm thick plates of extruded aluminium sections are 4.5 m wide and 3 m to 6 m long in the case of the automatic units and as small as 1.8 m x 1.5 m in the case of the manual units. The automatic units have capacities of 1,500 to 2,000 cartons per day while the manual units have capacities of 100 to 1,200 cartons per day.

REPS manufactures a range of plate freezers using mild steel plates. The plate size has recently been increased to 3.1 m long by 2.4 m wide and has a nominal capacity of 36 cartons per plate. This company has also developed a low cost mechanised loading and unloading system, aided by the thinner mild steel plate. The flexibility of plate systems was demonstrated recently when the capacity of one of their standard 432 carton plate freezers was increased to 612 cartons by the installation of additional plates.