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Economies of Meat Chilling and Freezing

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Meat chilling and freezing is a complicated subject on which I could talk for many hours, having been closely involved with the meat industry for the last thirty years. On the basis of a twenty minute talk, I will try to highlight the most relevant and fundamental requirements of these technologies and how they are related to the overall cost of producing a high quality product. My paper will highlight the important technical and economic factors that affect chilling and freezing and then will emphasise how the refrigeration plant room of a medium sized meat works should be designed for an overall economic refrigeration performance.

Meat Chilling

In essence, the question of chilling meat can be divided between carcass chilling where carcasses arrive directly from the dressing floor as against chilling boneless meat either as further processed products or boneless cuts coming out of a hot boning system, i.e. a meat factory that bypasses the carcass chilling function. The advantages and disadvantages of hot boning is a subject of its own and all I would say here is that generally the markets are not yet ready to accept this process for a variety of reasons and thus I will keep my discussions on meat chilling to carcass chilling which is the industry norm and is likely to stay so for the foreseeable future. Processed meat product chilling by means of belt or spiral chillers is relatively straightforward, while carcass chilling is a complicated subject.

In chilling meat carcasses, the two fundamental requirements are to reduce the growth of bacteria as rapidly as possible while ensuring the final product remains as tender and tasteful as possible. The slower the reduction in temperature of the carcass, the faster the growth of bacteria and the shorter the ultimate shelf life of the product. However fast chilling can result in a phenomenon called “Cold Shortening” which toughens the meat and this is an irreversible function. Figure (1) below better explains the “cold shortening” phenomenon.

Figure (1) shows the toughness of meat on a time basis from slaughter. Meat cooked immediately after slaughter is tender - it has been given a rating of 3 toughness units. If handled normally and cooked in rigor (after 24 hours) it is excessively tough (up to 9 equivalent toughness units); after the resolution of rigor (2 - 3 days), the toughness will decrease rapidly to about 6 units and from then it will disappear slowly during ageing until, at about 14 to 20 days,

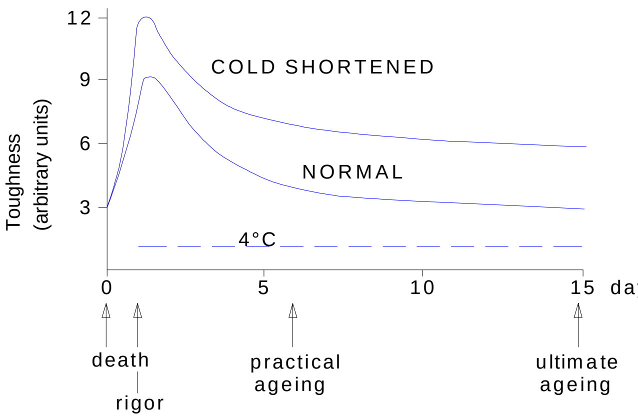


Figure 1 - Changes in the toughness of meat after cooking

it returns to the original value of 3.

Figure 1 also shows the same profile of toughness for cold shortened meat which comes about from fast chilling, and the toughness also reduces during the ageing process, as before, but the final aged product can end up with double the toughness factor of normal non-cold shortened product. This difference is unfortunately irreversible and the cold shortened product toughness cannot be further improved with ageing.

Thus, for today's high quality chilled product requirements, cold shortening meat products is simply not acceptable.

Cold shortening occurs in a carcass if on entering the chill room the pH of the meat is above 6.2 and the carcass is then rapidly chilled. Under normal processing, beef and lamb carcasses reach the chill rooms with pH readings well in excess of 6.2. Each species of meat is affected differently with beef and lamb the most seriously damaged with rapid temperature reduction. The following table highlights the differences:-

Species	**Temperature**	**Time From Slaughter**
Beef	10^{O}C	10 hours
Lamb	10^{O}C	10 hours
Pork	10^{O}C	5 hours
Poultry	10^{O}C	3 hours

Table (1) Temperature/time relationships for cold shortening.

What Table (1) shows is that if a beef carcass is chilled below 10^{0}C in under 10 hours from slaughter, then the part of the carcass so affected will become "cold shortened". Likewise, if a pork carcass was reduced to below 10^{0}C in under ½ hour from slaughter, then it would be toughened likewise. Thus we have a problem in achieving long shelf life by fast chilling for beef and lamb by toughening the meat as shown in Figure (1), when the carcass is too rapidly chilled.

Fortunately, due to extensive work carried out in New Zealand in the early 1970s, a solution to this problem was developed by the application to the carcass of electrical currents. By passing these electrical currents through the carcass either shortly after slaughter or during dressing, the process of rigor mortis is accelerated and the pH of beef and lamb carcasses after 30-45 minutes on the dressing floor can be reduced below 6.2 prior to entering the chiller. This immediately allows rapid chilling to be carried out while preventing the toughening process taking place.

So we now have a solution for introducing fast carcass chilling to improve shelf life while retaining a tender product.

Fast reduction in carcass temperatures is easy for lambs, but much more difficult for pig carcasses and particularly

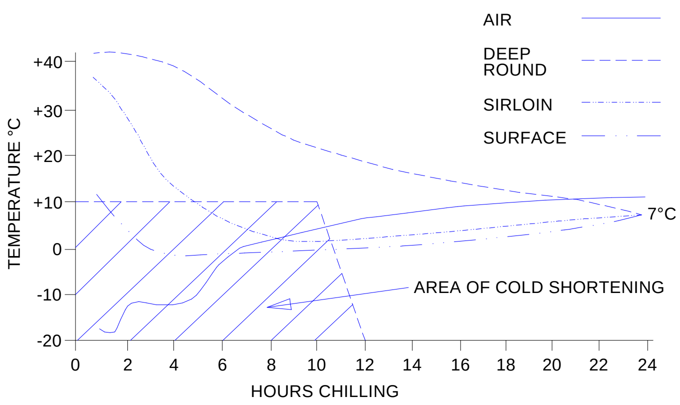


Table (2) Temperatues recorded during rapid beef carcass chill test

beef carcasses, where the distances from the internal parts of the best cuts to the outside of the carcass is much greater. Normal beef carcasses can be effectively reduced to an internal deep leg temperature of 7^{0}C within 24 hours by refrigerating in an air stream of approximately-2^{0}C and 1 metre per second, dependent upon carcass weight and fat cover. This then allows deboning the carcass the following day with meat temperatures below 7^{0}C, which is an EC requirement. See Figure (2).

A very fast chilling regime, as shown in Figure (2) for beef, which is faster than normal practice, will result in all lamb carcasses being cold shortened, with most of the best

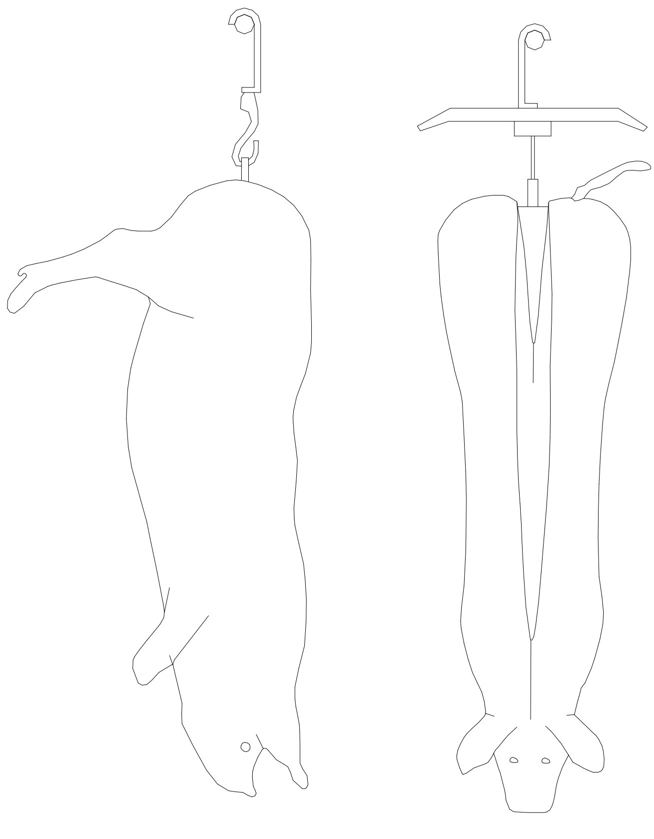
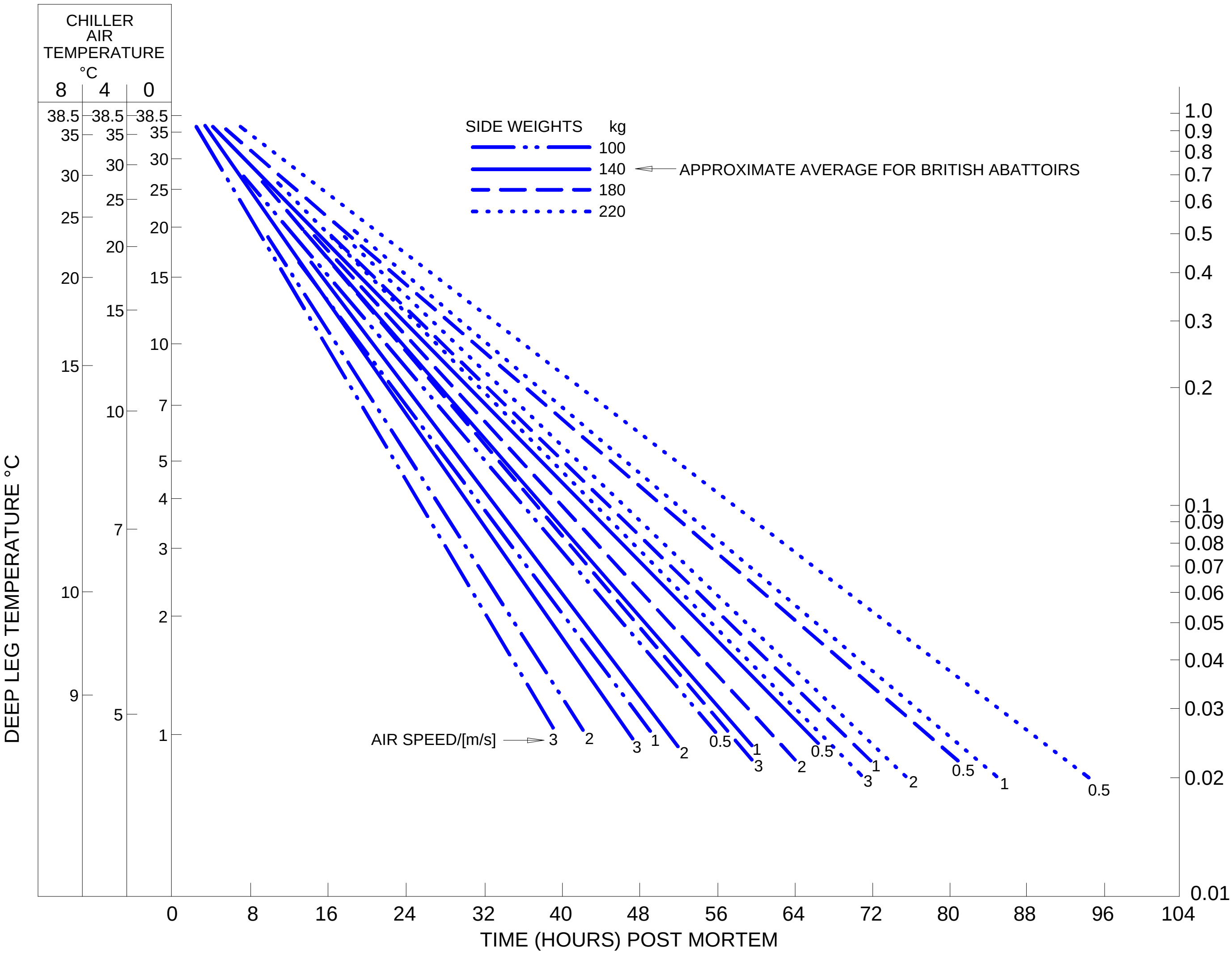


Table (3) Aitchbone hanging for pork carcasses



Relationship between deep leg temperature and cooling time for individual beef sides of average fatness (MRI Grade 4) and weights of 100, 140, 180 and 220kg, in air at temperatures of 0, 4 and 8°C, velocities of 0.5, 1, 2 and 3 m/s and R.H. of 94%

Figure (4) Air Velocity/Temperature Options for Beef Chilling

beef cuts being likewise affected. With electrical stimulation this problem is overcome because the pH of the carcass reaches a value below 6.2 before chilling starts. Thus the chilling regime in Figure (2) is allowable without the disastrous toughening effects demonstrated in Figure (1). Thus electrical stimulation for lamb and beef carcasses is essential in order to produce tender products while allowing rapid chilling to extend shelf life. Pork carcasses are not necessarily affected, as pork carcass pH drops faster than lamb or beef carcasses (see Table (1)).

During the chilling process, tenderisation is further enhanced by hanging carcasses by the aitchbone rather than the leg which is the conventional requirement - see Figure (3). This prevents muscle contraction in the leg and loin which are the most valuable parts of the carcass.

Ageing the best cuts of a carcass is essential for achieving tender product (see Figure (1). Some retailers insist that the abattoir supplying them hang the carcasses for two days prior to deboning and preparing primal cuts with a further day's hanging of the hind quarter.

This procedure is expensive and unnecessary. Firstly, it is only necessary to age the best cuts - there is no advantage in ageing meat destined for manufacturing products such as burgers or sausages or most of the forequarters. To build carcass chillers for two days' chilling and hold product longer than necessary is uneconomic. The chiller building costs are almost doubled and the working capital is also doubled by continuously holding a day's product in the chillers. Export cuts should be vacuum packed after boning and ageing can be achieved during the transport period. Ageing longer than 15 days produces marginal improvements in tenderness, and seven days with electrical stimulation is generally the minimum for acceptable quality.

Hopefully we have now prepared the carcass for various options for chilling. We can rapidly chill obtain good shelf life and have a tender product. However, rapid chilling has a further most important advantage over slower forms of chilling and that is the reduction in weight loss.

Figure 4 above gives air velocity/temperature requirements to achieve beef carcass temperatures in different time spans. The usual modern chilling combination of air velocities and temperatures are worked out on the basis of achieving beef carcass internal temperatures of 7^0C after 24 hours. 7^0C is necessary before removing the carcass from the chill room for EC requirements, while 24 hours is necessary to eliminate the requirement of building double the chiller capacity to hold for 2 days, and in any case, two days holding will reduce shelf life and significantly increase weight loss.

Generally speaking, the faster the chill speed, the lower the weight loss of the carcass, but unfortunately fast chilling increases the plant capital cost and increases quite dramatically the refrigeration plant electrical consumption. Therefore, as far as the economies of carcass chilling is concerned, the increased capital and running cost must be equated to the increased factory revenue due to the lower carcass weight loss. Table 2 below provides typical weight loss figures for beef and pork carcasses against different refrigeration parameters.

	Option 1 0.2 m/sec 4°C	**Option 2** 1 m/sec -1°C	**Option 3** 2 m/sec -10°C
Beef	2.5%	1.2%	0.6%
Pork	2.7%	1.4%	0.8%

Table (2) Carcass weight loss for different chilling parameters

The first option in Table 2 unfortunately is the norm for most medium and small sized abattoirs in the UK. Most plants are operating with beef carcass weight losses over 2.0% and pork even higher, resulting in some 1.2% higher evaporation from the carcass than with a well designed system (Option 2). With a beef plant processing some 100 head of beef per day, this could represent a revenue loss to the business

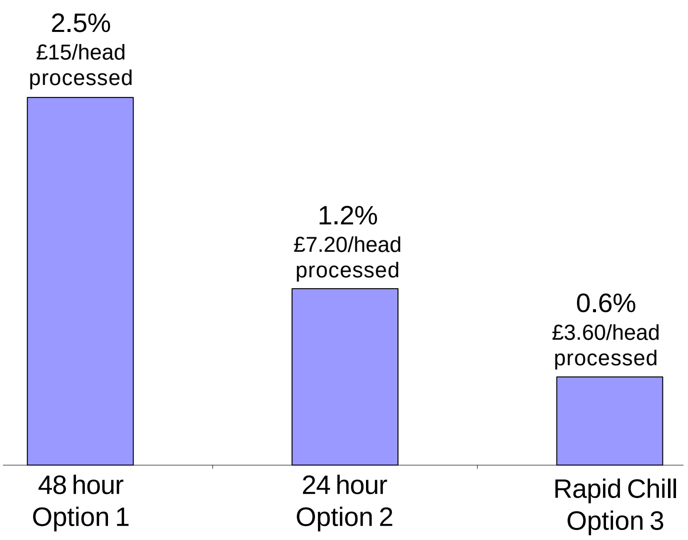


Table (3) Changed Revenue from Different Chilling Speeds

of some £780 per day or £200,000 per year. This loss would only be relevant if the factory cut and vacuum packed the beef the day after chilling. If the carcasses were to be left for longer periods in the chillers, or the meat was turned into processed products, then most of the weight gain from more rapid chilling would be lost in any case. Table 3 summarises the increased revenues relevant to slow, medium and rapid chilling.

It can be seen from Table 3 that the improved weight loss figures by faster chilling provides a remarkable gain in revenue. I must stress once again that these figures are only relevant if the carcass after chilling is immediately sold or cut and vacuum packed so that the weight gain is retained.

Having established the importance of fast chilling to improve shelf life and increase revenue, I propose now to assess the question of how the refrigeration plant should be designed to achieve the results of Option 2 and 3 in Table 2, so that the weight loss savings of Table 3 can be achieved.

Option 2 is the chilling system that all plants should use in order to achieve good shelf life. Thus even if weight loss is considered secondary due to the further processing particulars of the factory, then at least the designer should be looking to achieve a constant air temperature from the beginning of the cycle of -1^0C, certainly for beef and pork with air velocities around the hind quarters of 1 metre/second or higher.

System A is ideal for pork carcasses split down the middle, suspended on a gambrel, but held together at the head, whether hung from the gambrel or the aitchbone. This carcass hanging mode allows the air flow to pass parallel to the rails as there is a constant gap between the two sides of the carcass due to the splitting. Air flow from system B would be totally ineffective as pigs hung in this fashion would allow no air flow through the carcass at right angles to the rails. System C for the same reasons is also not effective.

For beef carcasses where the sides are separated, the gap between the carcasses allows an effective air flow at right angles to the rails. Thus system A is not suitable while systems B and C are acceptable.

The point about all this is that for effective rapid chilling, we require the maximum air velocity unrestricted across the hind quarters of the carcasses where the thicker meat lies. The forequarters do not need the same velocities and a certain amount of convection cooling can be built into the design.

If we now turn to Option 3 - Table 2 - the rapid chill option - where the maximum weight saving is required, then a different solution for evaporator and chiller design is needed compared to the options shown in Figure 5.

In order to achieve the exceptionally low weight losses of blast chilling, it is essential to hold the air temperatures at -10^0C or below right from the beginning of the chilling cycle (see Figure 2). This low temperature together with an air velocity of over 2 metres/second must be maintained until all the heat is removed from the carcass, which will be about

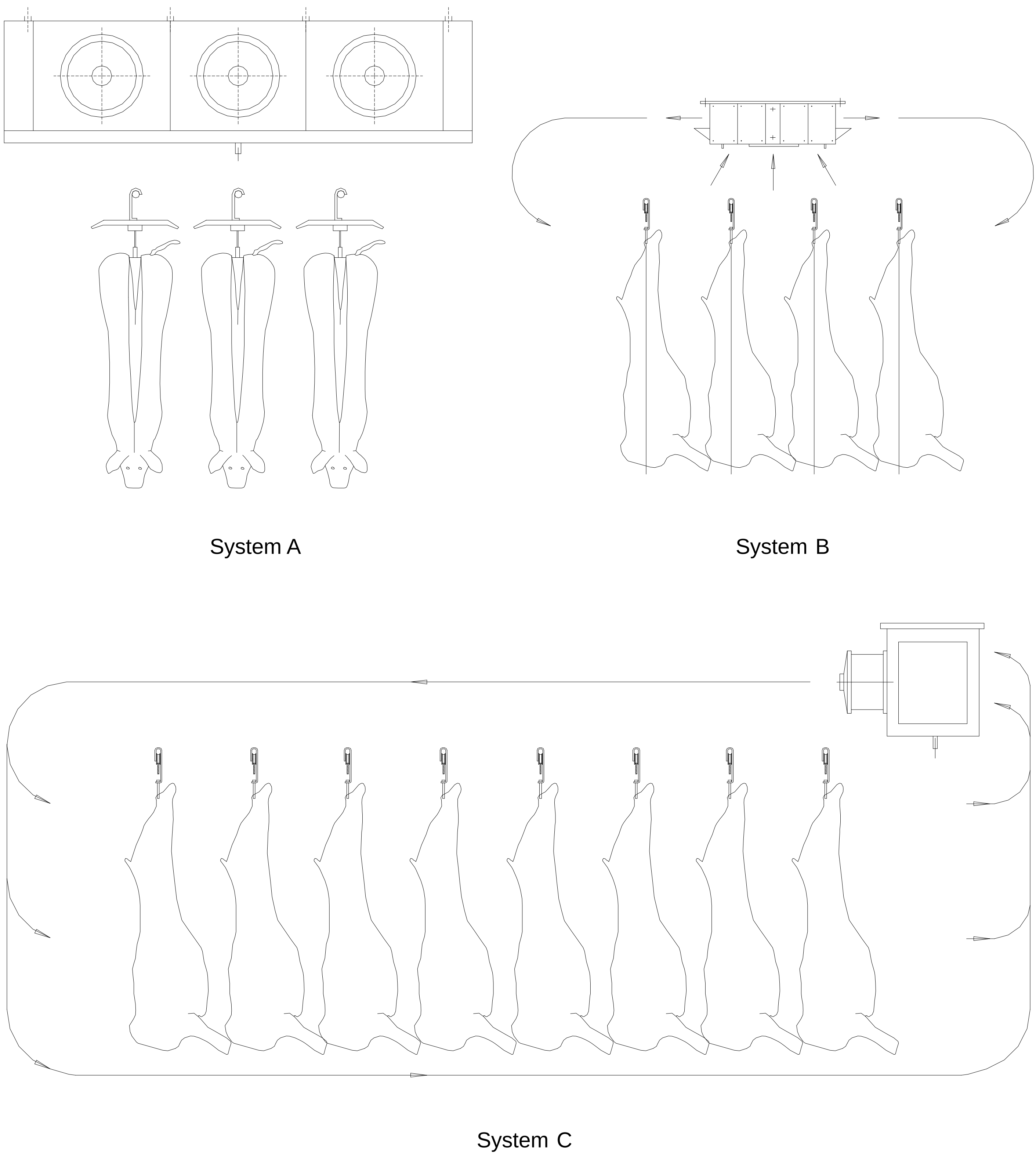


Figure (5) Evaporator Position Options

4 - 5 hours for beef before minimal air velocities with no refrigeration equalise the carcass temperature over the remaining 20 hour period. This procedure requires a very large installed evaporator surface area. If each chiller was fitted with this requirement, then the cost of the installation would be prohibitive. Thus for blast chilling it is essential to design a rail conveyor through a specially designed pre-chiller so that the carcasses achieve their first hour chill prior to moving onto batch units. See Figure 6.

The batch chillers which complete the process can have evaporator configurations similar to Figure 5, system B or C, with the necessary enhanced surface areas to deal with the

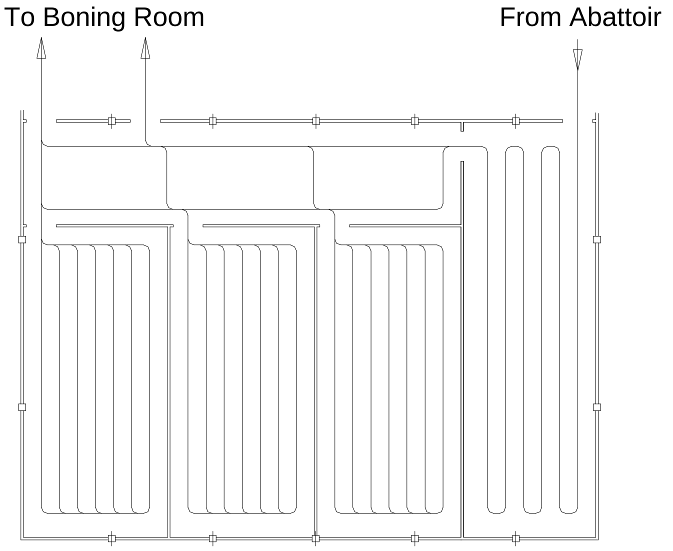


Figure (6) Blast Chilling System

maximum heat transfer requirement for the second hour of chilling. The conveyorised first hour chiller must have the air flows directed down over the hindquarter of the carcass.

In order to understand the necessity of having continuous conveyored pre-chilling, we must consider the heat transfer from a hot carcass over the chilling period.

Many designers not aware of the rate at which heat is extracted from a carcass, design evaporator surface areas on the basis of the total heat removal over the chill period. As can be seen in Figure 4, the required carcass temperature can only be achieved if the air temperature remains constant over the chill cycle. Newton's law of cooling tells us that the rate of cooling is proportional to the temperature difference between the cooling medium and the cooled product. Thus the average temperature difference between the carcass and the cooling air may be some 18^{0}C, while the temperature difference in the first hour could be some 30^{0}C, giving a rate of cooling increase of some 70%. Thus for Option 2, the evaporators should be increased in surface area by 70% over the average heat extraction load to achieve the necessary constant air temperature and the necessary chilling performance. For Option 3 of rapid chilling, the surface area must be further increased in order to achieve the necessary constant air temperature.

Considering the beef chilling situation, then our calculations and experience, taking into account the very large heat dissipation in the first hour of chilling compared with the average rate and the necessity to maintain a constant air temperature throughout the heat extraction period, have shown that the evaporator surface areas for the three options shown in Table 2 should be based on approximately 4m^2/ head chilled for Option (1), 9.5m^2 for Option 2 and 28m^2 for Option 3. Hence the very large increase in capital costs for the rapid chill plant of Table 2 Option 3.

Finally, we must look at the plant room requirement. Figure 7 below shows the vastly increased size of plant room necessary for the blast chill Option 3, which as the daily processing builds up, requires some 2 kws/head of beef/ day.

The figures are typically of a one shift operation with the worst situation occurring in the 9th hour after processing starts. This compares with a maximum requirement of only 0.9 kWs for option 2 the usual chilling cycle and when the high capacity requirement for blast chilling is also equated to the machinery having to operate at a suction pressure of -25^{0}C for the blast chiller, as against -10^{0}C for option 2, the enormously increased plant room refrigeration capital and electricity costs can be better understood.

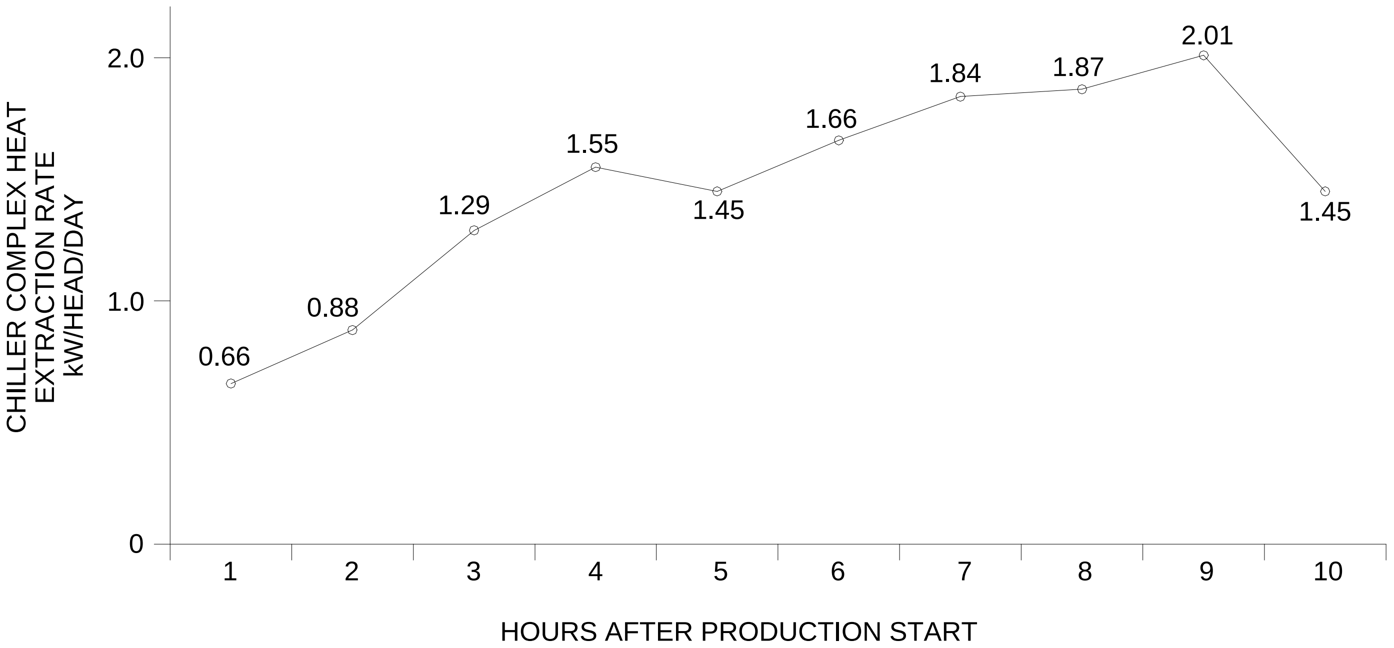


Figure (7) Plant Room Refrigeration Loads Versus Time

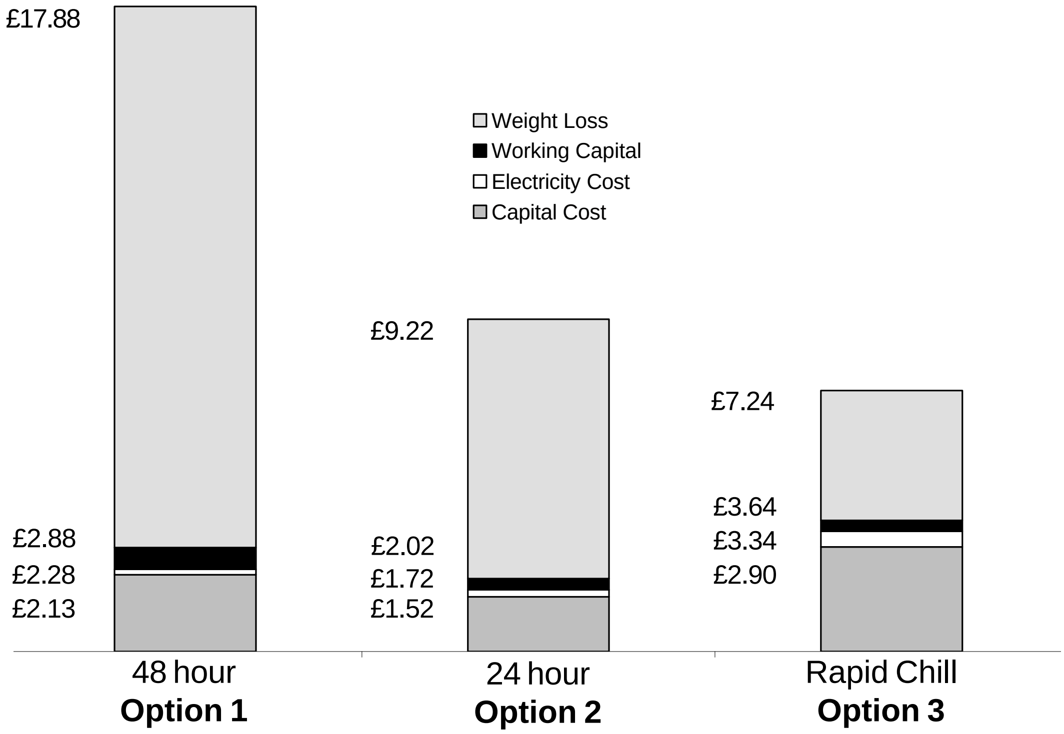


Figure (4) Production Costs/head of Beef for different Chilling Systems

To summarise the conclusions we reach from our extensive experience on the economies of beef carcass chiller design, Table 4 shows the relevant cost differences of capital costs, electricity consumptions, working capital and weight losses for each of the three chilling options.

These figures have been assessed from actual operating plant and show how Option 3 the rapid chiller could save overall some £2.00 per carcass processed over Option 2 or for a medium size beef factory processing 100,000 head/year approximately £200,000/year. It must also be concluded that even if this option is not implemented due to restrictions on capital expenditure or because the factory will further process much of the output, then at the least Option 2 with electrical stimulation must be chosen to produce high quality good shelf life product at acceptable costs. Option 1 in my opinion which is often the norm in UK abattoirs operating with undersized inadequate refrigeration plant is totally unacceptable to any efficient meat-works management.

In both Options 2 and 3, adequate evaporator surface areas and fan capacities must be installed to achieve the required air temperature for the whole heat removal cycle time with the most suitable configuration of rails, carcass hanging position and evaporator location to obtain the required air velocities across the carcasses and achieve the necessary heat extraction rates.

Although due to lack of space and time, the details shown are related to beef chilling, the same principles apply to the other species and particularly to pork, and again the most economic design solution should be chosen.
have higher air temperatures and the product will not be frozen in the time chosen.

Meat Freezing

Meat freezing plant design will differ considerably between meat products that are packed and cartoned as against unpacked products. The latter are relatively easy to freeze and as far as this paper is concerned, I will keep my detailed assessment to the refrigeration requirements necessary for carton freezing.

Nevertheless, I will summarise the various different systems available. It must be understood that most unwrapped products would be frozen on a belt system either as a straight line belt or, more commonly, to save factory space a spiral freezer which is simply a belt configured in a spiral manner so that the floor space occupied is reduced to the minimum. Belt freezing in this manner allows unpacked meat products to be frozen IQF preventing any binding together of the individual meat products.

Depending upon the size and type of product to be frozen generally the refrigeration plant would be designed with a plant room compressor suction of -40^{0}C with air temperatures over the product of around-32^{0}C with freezing times ranging from some 30 minutes, depending upon the weight and dimensions of the individual meat products.

Liquid nitrogen freezing is often put forward as the latest and best technology that should be replacing belt or spiral freezers.

The liquid nitrogen companies usually provide the freezing equipment at no cost together with nitrogen tanks and then charge purely on the nitrogen consumed.

The process consists of a long belt suitably enclosed with the product entering at one end and discharging totally frozen at the other end. The liquid nitrogen is then sprayed onto the product as it travels down the belt at temperatures of -196^{0}C. The plant is a total loss system, with the gas dispersing to atmosphere being totally inert and harmless.

Freezing is achieved with most products in a matter of seconds, resulting in very rapid freezing.

The problem is that the cost of the nitrogen is usually such that the on cost to the product is some four to six times that of conventional freezing and can result in placing the product and sometimes the whole factory into a net loss position.

Nevertheless, liquid nitrogen does have a use. In such products as soft fruits like strawberries and raspberries it is only liquid nitrogen that can provide the speed of freezing that will achieve an acceptable product - conventional slow freezing results in large ice crystals which when such soft fruit is thawed causes an unacceptable mushy product. Usually special soft fruits can accept the freezing on cost with an elevated selling price. In my opinion, liquid nitrogen freezing for meat products results in a totally uneconomic freezing solution, unless the freezing requirement is only needed for, say, one month per year, when the negligible capital cost can support the very high operating cost of a low throughput..

Turning now to the most common freezing requirements for meat plant products, namely meat carton freezing, it is rare to find in the UK freezing tunnels designed with the necessary plant capacity to give the right performance.

There are three systems of carton meat freezer available that will meet the necessary requirements - namely plate freezing, air batch freezing or continuous air freezing.

From a heat transfer point of view, plate freezing is best. The cartons of meat, after being placed between the freezer plates, which in turn are filled with liquid refrigerant

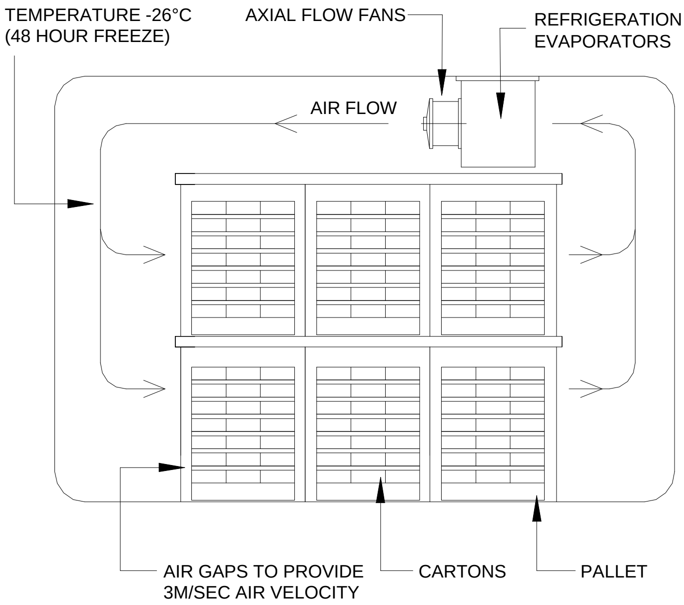


Figure (8) Air Batch Freezer

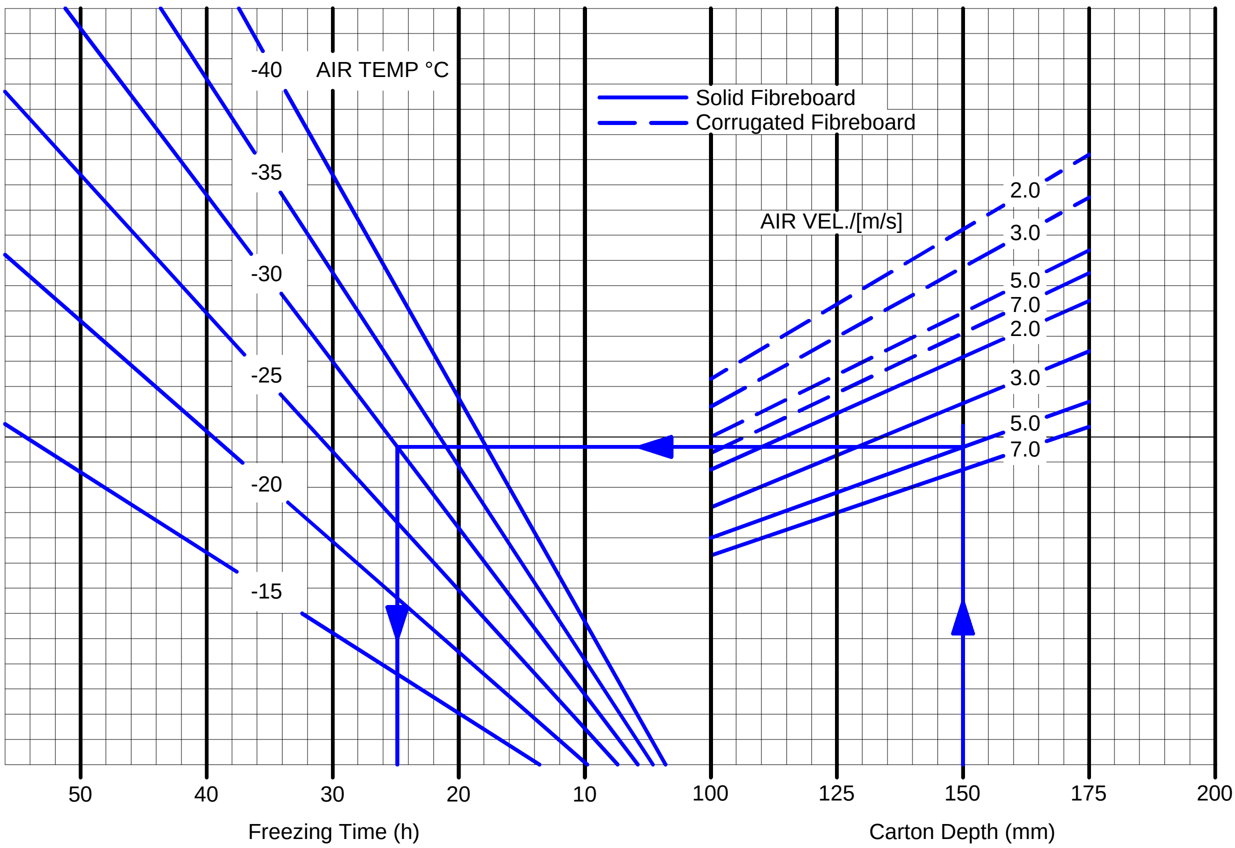
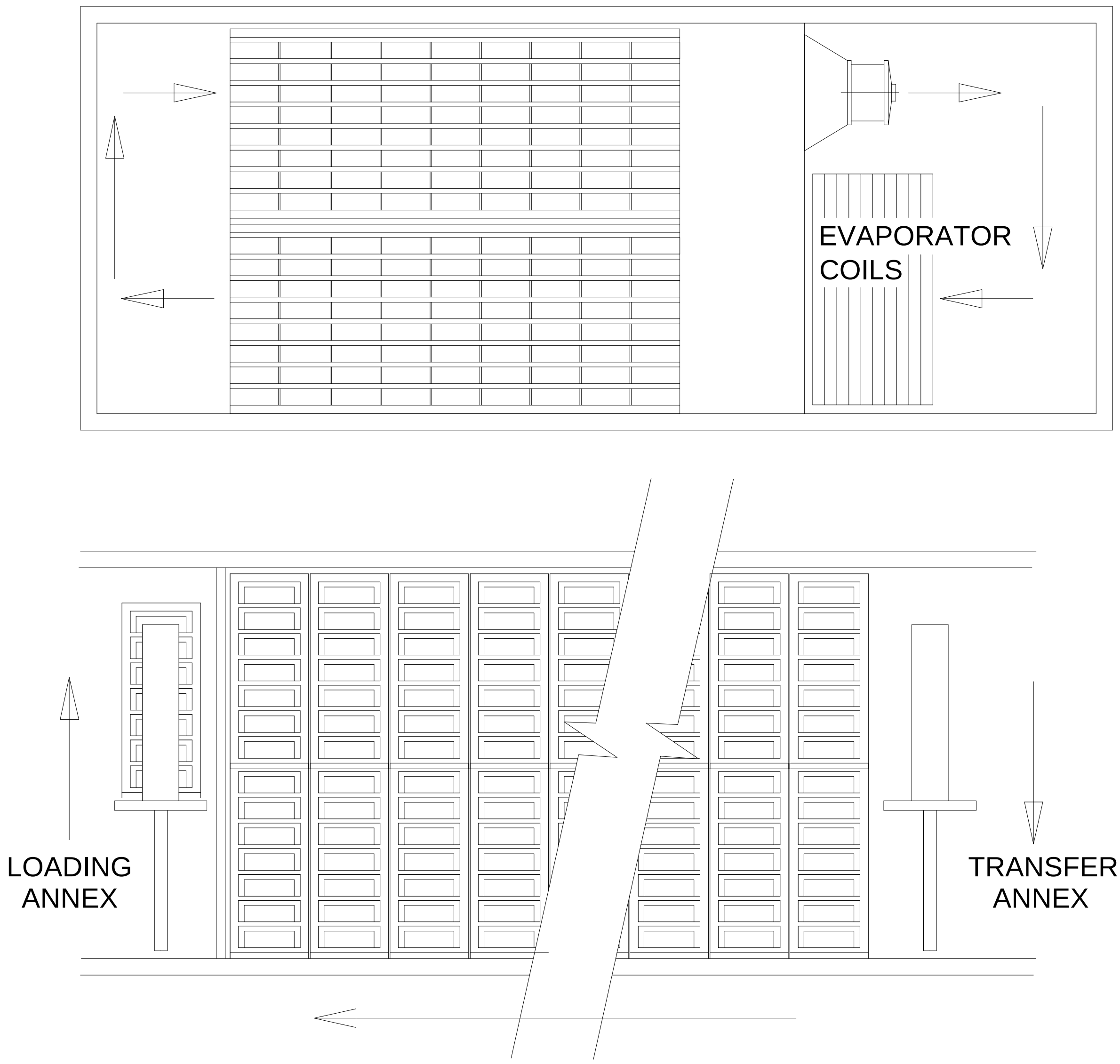


Figure (9) Air Blast Carton Freezing Tunnels - Temperature/Time Relationships



End and side elevations of automatic blast freezer

Figure (10) Automatic Air Blast Continuous Tunnel

are then pressed together between the plates providing a direct heat transfer surface. The usual thickness of cartoned meat is around 150 mm and with refrigerant at -38 to -40^{0}C, freezing is possible within some six to eight hours.

Plate freezers have three specific disadvantages over air freezing. Firstly the filling of the freezer is most usually carried out manually, the system being unable to be palletised. Secondly., the plate freezer is usually more expensive to build than its air equivalent. Thirdly, the freezer can only effectively deal with one thickness of carton at one time, which makes the system unacceptable for third party cold store freezers, where cartons of varying dimensions are serviced.

The first disadvantage of labour intensive loading has been overcome for large meat works operations by the design of automatic plate freezer tunnels

Such units developed in Australia are expensive and can only be used in large meat works with one size of carton to freeze. The big advantage is that if a two shift operation is required, then the unit can achieve twice the capacity per day as its air equivalent. The unit designed in Australia is similar in construction to the automatic air freezer (see Figure 10), but with horizontal freezing plates applied between each carton movement period.

A more adaptable carton freezing system is the air batch freezer. See Figure 8.

This unit is the most commonly used method for freezing carton meat. Cartons are placed onto pallets with air spaces between them, provided by corrugated sheeting or plastic “egg carton” spacers and air is circulated through the stow and over a suitable evaporator by means of powerful fans. Much work has been carried out on freezing times on such tunnels and Figure 9 is the result of these many tests carried out in New Zealand and Australia during the 1960s and 1970s.

From Figure 9 it is possible to calculate the air velocities and temperatures necessary to arrive at a suitable freezing time for a specific type of cardboard carton. Due to the pattern of factory or cold store operating schedules, it is usual to design the tunnel for either 24 or 48 hours turn round times. The 24 hour design will be more expensive to operate, but more economical on first cost.

In order to reduce the cost of loading and discharging such batch tunnels, the automatic continuous tunnel was designed in New Zealand in the late 1960s. See Figure 10. However, such an automatic continuous tunnel is only economical in meat works producing at least 2500 cartons of meat per day - some of the larger overseas works process 10-15,000 cartons/day. Smaller plants should operate batch units, as shown in Figure 8, and cold stores with clients sending different sized cartons for freezing must also use the batch air freezer which can handle a variety of different carton sizes.

In the same way as the carcass chiller, it is essential that the air temperature chosen in Figure 9 for a specific duty is maintained throughout the freezing time. It is necessary therefore to size the evaporators to at least 50% larger than the average refrigeration load for one day turn round units over the cycle time for the same reasons as discussed for carcass chilling where the first period of freezing with large temperature differences between the product and the cooling air is extracting much more heat than the latter period of the cycle. If this is not done, the initial period of the freezing cycle will have higher air temperatures and the product will not be frozen in the time chosen.

Refrigeration Plant

The most effective and economical refrigeration plant in a meat-works to achieve effective carcass chilling and carton freezing should be designed on a central basis with a pumped refrigeration system. See Figure 11.

Figure 11 shows a plant room layout using a two stage pumped refrigeration plant. This is the only acceptable system to achieve effective and rapid carcass chilling while also providing a suitable service for the plant's carton freezers. Although direct expansion systems are officially only some

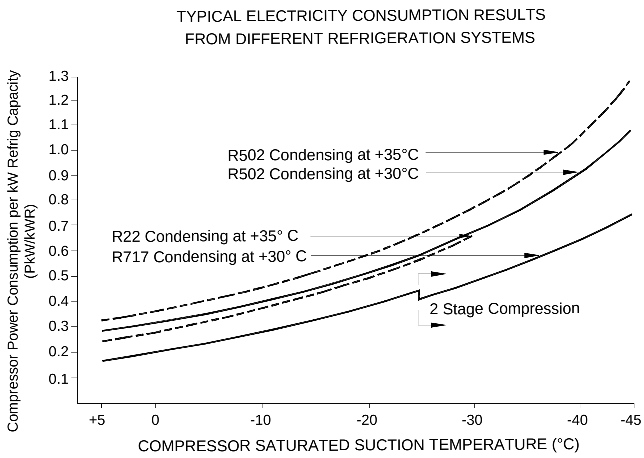


Figure (12) Compressor Electricity Comsumption for Different Refrigeration Systems

25% down on heat transfer rates across the evaporators which means that larger evaporators should result in similar refrigeration performance, in practice I have never found direct expansion systems can provide the required evaporator performance for either effective carcass chilling or carton freezing. I can only assume that the reason for this is that the large refrigeration loads and larger evaporators required in the first hour of chilling or freezing just cannot be consistently managed with the type of direct expansion valve available on the market. The valves inevitably hunt resulting in large areas of the evaporator becoming gas locked. A pumped system which keeps the coil surfaces continually wetted is the only system that can deliver the performance required for both meat chilling and freezing systems.

Having established the type of plant required, Figure 12 further emphasises the importance of opting for a more expensive plant working on a two stage system. If, as is often the case, the refrigeration contractor sells a single stage R 502 or equivalent substitute refrigerant, which is considerably cheaper to install, then the plant operation is simply going to

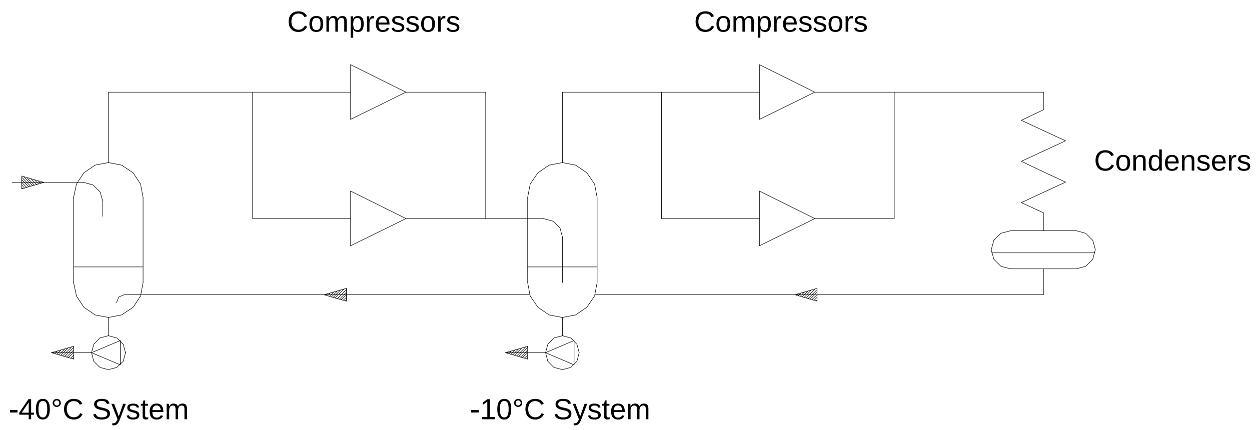


Figure (11) Typical Refrigeration System for Meat Chilling and Freezing

System	Capital Cost	Electricity Consumption at 40°C Suction	Typical Store Electricity Cost/Year	Typical Store Capital Cost
Freon/DX	£500 / kW	1.07 kW / kWR	£77,040	£150,000
NH_3	£800 / kW	0.62 kW / kWR	£44,640	£240,000
Pumped NH3	£880 / kW	0.75 kW / kWR	£54,000	£264,000

Table (5) Capital Cost & Energy Comparisons

be uneconomic to operate. Working on a -40^0 compressor suction, it can be seen that the plant room compressor electricity consumption will increase by some 70% compared with a well designed two stage system.

The R 502 single stage type plant is always claimed to be justified on low initial cost. Such a plant can be installed for a cost of approximately £500/kW refrigeration as against 800 kW for the two stage NH_3 system. A medium sized meat works freezing all forequarter meat may require a plant of some 300 kW refrigeration capacity at -40^{0}C plant room suction. Bearing in mind the comparison between the two types of plant can be summarised in Table 5.

It can be seen that the extra capital cost of the NH_3 plant will be paid off in approximately three years, with an ongoing saving of some £ 33,000 per annum. The larger the plant, the bigger the savings.

Conclusion

The economies of meat chilling and freezing is a complex calculation.

The chilling of carcasses must be fast to establish a good product shelf life but the carcass must be electrically stimulated to prevent toughness. Very fast chilling will save carcass weight loss which must be balanced against the type of products produced and the excessively high cost of the refrigeration plant. Most UK abattoir chillers neither produce good shelf life products or acceptable product weight loss figures.

Freezing meat products effectively in cartons requires either a one or two day turn round and the refrigeration equipment and sizing is dependent upon carton thickness and type. Once again most UK carton freezing tunnels are badly designed and freeze ineffectively.

Finally, both good chilling and freezing systems must be designed with pumped refrigerant systems and the plant room for one day turn round carton freezers must work on a two stage basis to provide an economic freezing cost. A low cost single stage plant will result in unacceptable electricity cost on an ongoing basis.

REFERENCES

(1) - Biochemical and Quality Changes in Meat During Cooling and Freezing -
Dr. D.N. Rhodes
Meat Research Institute (MRI) Bristol, UK, March 1976

(2) - Process Design Data for Beef Chilling -
C. Bailey & R.P. Cox
Institute of Food Research (AFRC) Bristol, UK, May 1976

(3) - New Measurements of Cooling Times in Blast Freezers -
L.S. Herbert & D.A. Lovett
CSIRO Queensland, Australia, September 1979

(4) - Experimental Tests on Rapid Chilling of Beef Carcasses
G. Gee & M. Day
Riverstone Meat Company, Sydney, Australia - January 1980