M381

CR 448

Automated Packaging Machine Development

Feasibility Study

Final Report
M. 381

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EXECUTIVE SUMMARY

Meat preservation is critical for ensuring that consumers have a ready supply of meat that is both fit for human consumption and of comparable quality to "fresh." The twin technologies of refrigeration and packaging are the key methods widely used by the meat processing industry to provide meat of acceptable quality to the consumer.

The objective of this feasibility study was to determine what type of automated packaging machinery would most benefit the sheep and beef meat processing industries, and to make recommendations for further Research and Development.

The methodology for achieving the above objective comprised a processor survey and a packaging company survey. The authors visited 21 beef boning rooms and 8 sheep boning rooms for the processor survey. These boning rooms were selected in different geographic locations to allow the authors to view a broad range of facilities. The packaging companies provided information on packaging machinery suppliers that became the main focus of the second survey. A number of packaging machinery suppliers were visited to determine their latest equipment range and their plans for the future.

From the processor survey, the authors identified four generic packaging classes: bulk pack, layer pack, individually-wrapped cuts and vacuum-packaged cuts, all packed in cartons. All meat from the boning room is sent out in cartons in one of these packaging formats. For beef the percentage product in each packaging class was 41% bulk, 2% layer, 11% individually wrapped and 46% vacuum bagged. The average throughput of all the beef boning rooms visited was 450 carcasses per day with one packer required for every 18 beef carcasses processed per day. For sheep the percentage product in each category was 48% bulk, 5% layer, 37% individually wrapped and 10% vacuum bagged. The average throughput of all the sheep boning rooms visited was 2577 carcasses per day with one packer required for each 203 sheep carcasses processed per day.

The four different types of packaging; bulk, layer, individually wrapped and vacuum bag, were analysed to identify the component tasks to be automated. These tasks were combined to produce a list of generic tasks, common to some or all of the different packaging types. These tasks are a necessary part of the packaging operation and must be done, either by a human operator or a machine. The following generic tasks were identified:

- Identify a meat cut
- Compare with Specification
- Measure its properties such as its dimensions, weight, colour, percentage fat, etc.

- Place meat in a bag
- Individually wrap a meat cut
- Evacuate vacuum bag, seal, shrink and remove excess water
- Present bagged cut to vacuum-packaging machine
- Identify "leakers" in vacuum bags
- Re-process "leakers"
- Place meat cut into a carton or box
- Close liner on bulk pack
- Close carton (put on a lid)
- Weigh and label carton
- Strap
- Check chemical lean content of meat in a carton and relabel if necessary

The beef processing industry in Australia exports about four times the tonnage of the sheep processing industry and the value of beef exports is over eight times the value of lamb and mutton exports combined. In view of this, the authors recommend that the thrust of packaging system automation be aimed at the beef processing industry. Inevitably, however, the technologies developed will either apply directly or could be modified for sheep and lamb processing.

For most of the boning rooms we visited, the main product flow bottleneck in the boning room was centred on the meat packaging area, specifically once the meat was in the carton. The authors recommend that the next stage of the project start with a detailed study of new packaging system layouts to develop a new format that has been optimised for product flow and flexibility of application. However, other packaging research and development work need not be held up, as this study is likely to be completed before any other projects would be affected.

The packaging area is ready for the automation of many of its tasks, now done manually. A plant processing 800 carcasses per day with 46% vacuum-packaged product, requires, on average, 26 packers for placing meat cuts in bags and then into cartons. If this process can be fully automated, meat processing plants could save in the order of $750,000 per annum based on a cost of $30,000 per packer per annum. The same plant would require 13 packers, costing nearly $400,000, for packing bulk meat. There would be considerable benefits from automation for many plants, both in terms of labour reduction of and savings in packaging materials.

The authors recommend that MRC initiate a research and development programme with the aim of automating many of the tasks involved in vacuum-packaging beef cuts. The programme would be set up to:

1. Conduct a detailed analysis of beef vacuum packaging in its present form.

2. Investigate alternative technologies and assess their viability for vacuum packaging of beef cuts.

3. Seek industry opinion on the direction and priorities for the research and development tasks identified in the report.

4. Develop the equipment required to substantially automate the process of vacuum packaging beef cuts.

CONTENTS

1. BACKGROUND AND INDUSTRY CONTEXT

Fresh red meat presents a rich medium for the growth of microorganisms. If allowed to grow to sufficient numbers, these organisms will quickly render the meat unsuitable for human consumption. At ambient temperatures, fresh red meat cannot be kept for more than a few days. For people living in cities in earlier times, it was important to try to extend the shelf life of fresh red meat. It was found that spoilage could be delayed if meat was stored under cool, dry conditions so that meat could be stored for a week or more depending on the weather. Meat was found to keep longer in the winter than the summer. This led to the introduction of refrigeration. However, surface desiccation not only inhibited microbial growth, it also caused meat appearance to deteriorate as storage time increased.

The advent of plastic film and especially polyethylene, solved the problems associated with surface desiccation and its effect on meat appearance. Now meat could be, theoretically, stored and not dry out. However, because the plastic retained moisture, so that the meat surface was no longer dry, there was no restriction to microbial growth. This fuelled more research into the spoilage mechanisms of meat so that we now understand that there are three principal factors that control the storage life of chilled meat. These are the microbial burden at the time of packaging, storage temperature and the growth environment that the packaged meat presents to microorganisms.

The remote location of Australia from most of its markets requires that meat being exported be suitably protected against contamination and spoilage during transit. In early times meat was preserved by drying or salting to extend its shelf life. However, these techniques drastically changed the properties of the meat so that it no longer resembled fresh meat. Then, about one hundred years ago, refrigeration was introduced to stop the growth of pathogenic and spoilage bacteria during the long sea journeys to overseas markets. More recently vacuum and controlled atmosphere packaging have been added to control the immediate environment around chilled meat to reduce the growth of aerobic bacteria.

The increasing trend of the meat industry away from the commodity trade to produce meat cuts and portions for the hotel, restaurant and institutional (HRI) trade, and consumer markets, has required an increase in the quantity and quality of meat packaging. This is especially the case for chilled meat. Packaging is required to maintain meat quality after it has been processed so that after transport, storage, distribution and sale, it is still of high quality, fit for human consumption and acceptable to the final consumer.

In the packaging department of a meat processing plant, there is often a large pool of labour doing repetitive tasks suitable for automation. The purpose of this project is to investigate the automation of the tasks involved in the packaging of fresh red meat cuts.

Two main types of wrap are used for individually wrapping or packaging beef, sheep and lamb cuts, namely permeable plastic wrap and vacuum bags, which are generally impermeable but can also be permeable. The current process for wrapping beef, sheep or lamb cuts is totally manual. For vacuum packing meat cuts, many automatic vacuum sealing machines already exist. Although automated systems that will recognise product, align it, fill the bag and then vacuum seal it, exist for other food products, none is suited to the many different meat cuts produced by a single boning room.

For automated meat cut wrapping, the end user would be beef and sheep processing plants that have a cutting and/or boning facility. It is likely that such plants would have a high volume throughput of cuts that require individual wrapping. For the automated vacuum bag system, the end users would include lamb and sheep boning and cutting operations, beef boning operations and possibly other food packaging applications.

2. OBJECTIVES

By 30 June 1994 to undertake a feasibility study to determine what type of automated packaging machinery would most benefit the sheep and beef meat processing industries (ie shrink wrapping or vacuum packing equipment), and to make recommendation for further Research and Development.

3. OVERVIEW OF METHODOLOGY

3.1 Meat Processor Survey

Information was collected on current industry practices in meat packaging and on anticipated future trends. The study provided information about product flows, throughput for various plants and, where possible, production costings and individual operation costings. Analysis of this information focused our attention on those areas of the packaging operation that would benefit most from automation. It also provided an indicator for target machine costings that would allow a realistic payback.

We defined the scope of our study to include all operations that occur between the point where meat leaves the slicers until the meat is in the carton and heading for either the chillers or freezers. We included both lamb and beef processing plants from almost all States in the processor survey although our study focused more on beef than lamb, for reasons that will become clear later in the report.

At each plant, after meeting with the manager, we visited the boning room where we spent time observing its operation and asking the supervisor about the various boning and packaging operations, the labour levels and throughput. From the office staff we obtained information on wage rates, wages overheads and total production figures. These data were collated and the resulting information is presented in this report.

3.2 Packaging Companies Survey

The major packaging companies in Australia and New Zealand were surveyed, to obtain detailed information on existing products or products under development that may meet the needs of the processors, as determined in the initial survey. To enhance this information, the first author visited the main international packaging machinery companies, especially those with a strong tradition in research and development.

3.3 Proposal for Machinery Development

A feasibility study was then carried out, recommending the type of automated machinery to be developed and the future work program. This included:

(i) specifications for the automation equipment;
(ii) likely market size;
(iii) available technology to meet the specifications determined in (i);
(iv) research and development required to meet the specifications determined in (i);
(v) a fully costed proposal for the next stage/s of development.

4. ACHIEVEMENT OF OBJECTIVES

The project comprised three separate tasks, namely the meat processor survey, the packaging company survey and the writing of a proposal for further work. The following text discusses how these were achieved in more detail.

4.1 Meat Processor Survey

The 1992 AMLC list of licensed meat exporters included 87 companies with boning operations. This list mentioned only the companies, many of which had more than one processing facility. The project resources precluded a visit to each boning facility in Australia, so a range of facilities was selected for the survey.

The plants visited were selected for their geographic location and processing throughput. The complete list of plants visited is given in Appendix 1. We tried to visit several plants in each state in order to view a diversity of plants. The distribution of throughputs for all the beef boning rooms we visited, 21 in total, was almost uniform from less than one hundred carcasses per day to over one thousand.

We visited eight lamb boning rooms varying in throughput from less than six hundred carcasses per day to over seven thousand. It was far more difficult to define a pattern with these rooms, as the nature of their processing and products varied so much between individual processors.

4.2 Packaging Company Survey

The major international packaging companies active in Australia and New Zealand were identified and visited. The two companies with the major share of the market are W.R. Grace and Trigon. These companies were approached and asked where they sourced their packaging machinery from. This information was used as the basis for visiting the major international packaging machinery manufacturing companies.

Two other companies, Danaflex and Transpak, were also contacted about their involvement in the Australian market and their products are listed in Appendix 2 of this report.

4.3 Proposal for Further Work

The feasibility study has been completed. This report recommends the type of automated machinery to be developed and the future work program. Because of the broad scope of our study, we were not able to obtain detailed information on the costings of individual operations. This information will still be required for the specific projects resulting from this report. The report sets out broad specifications for the automation equipment as detailed specifications can only be set after consultation with industry representatives. The market size will depend on the equipment specifications, and these have not yet been finalised. However, the report sets out the potential Australian market for such equipment. Available technology has been covered as has the research and development requirements. The fully costed proposals for the next stage will be sent in a separate letter from this report.

5. RESULTS

5.1 Meat Processor Survey

During the survey period we visited 23 meat processing plants and 29 boning rooms. These ranged in size from beef rooms processing one thousand carcasses per day, to lamb rooms processing only a few hundred per day.

We restricted the scope of our survey to the packaging of fresh red meat for chilled or frozen export in cartons, that is, we did not look at the packaging of offals and other meat by-products. As a result, the focus of our attention during the processor survey was the boning room, as all the packaging of interest occurred there. Three different boning systems are used for both beef and sheep. These are discussed, as the system used in a particular boning room effects the design and layout of the room. The boning system also affects the design and layout of the packaging area, which will be discussed later in the report.

Beef and lamb processing systems are dealt with in separate subsections of the report as the two species are boned differently and have different requirements in terms of packaging systems.

5.1.1 Beef boning

There are three main techniques used for boning beef carcasses. They are side, quarter and table boning. Each system achieves a similar result using a different methodology, although the side and quarter boning systems are quite similar. A typical room layout for quarter boning is shown in Figure 1.

For a typical quarter boning system, carcasses are quartered before they are boned. This can be done before or after the chiller. Once in the boning room, the meat is cut from the bones by the boners. As the quarter progresses down the chain, each boner removes the particular cuts required and places them on the table to be further broken down by the slicers. The boners are often physically positioned above the tables so that they can use gravity to help them remove the meat from the bone and easily drop the meat onto the table. By the time the quarter reaches the end of the chain, all meat has been removed.

Once the meat is on the tables, the slicers separate the various cuts as required by the specifications for the particular cut set in operation at the time. When each cut is completed, it is passed on to the packer, who wraps the meat or puts it in a bag if necessary and then puts the meat into a carton. Once the meat is in the carton, it is conveyed to the appropriate processing area for chilled or frozen meat.

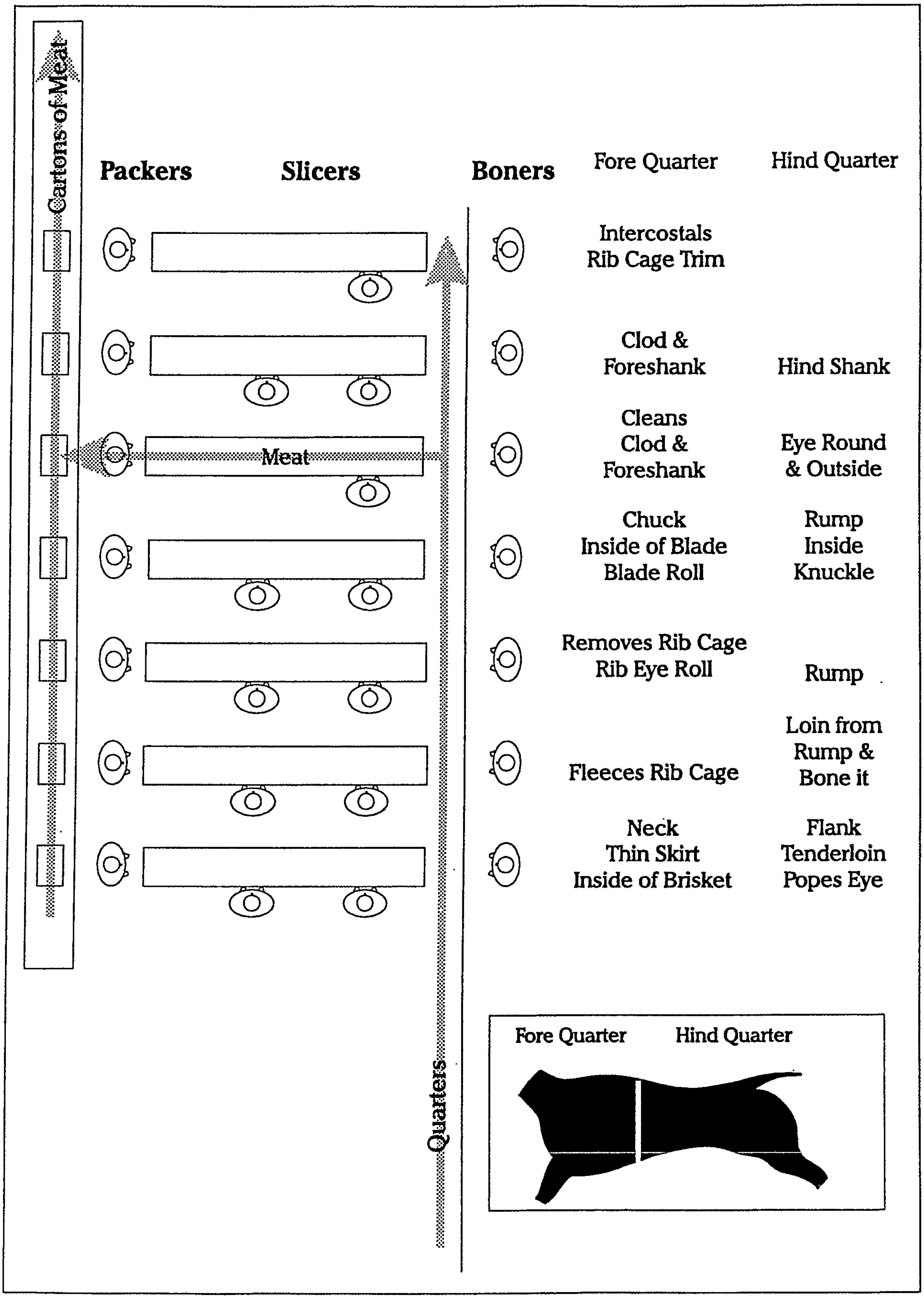

Figure 1. A typical beef quarter boning room layout.

The side boning operation, illustrated in Figure 2, is very similar to quarter boning except that the boners work on the entire side rather than a quarter. Beyond the boner, the systems are identical. In fact, some plants bone the forequarter using the entire side and then remove the bones so that the hind quarter is boned as a quarter boning system.

The other class of boning system is called table boning (Figure 3). This system is quite different from side and quarter boning in that carcasses are broken down into primals using a saw. The individual primal cuts are placed onto a central conveying belt where boners remove the cut from the belt and bone it on a table. The bones are placed on another belt and the meat is placed back on the original belt, where it may be further processed by other butchers or slicers sited further down the belt. The result of this process is that after the boners and slicers have completed their work, all the meat ends up travelling on one belt. Cuts to be vacuum-bagged and chilled are then removed from this belt and sent through the vacuum packaging machines while the rest of the cuts are packaged as required.

The boning room operation essentially involves breaking a carcass down into many individual cuts. The number of cuts taken from a carcass depends on several factors including the type of carcass, eg bull, cow or prime, the market, product specifications and customer orders. The situation therefore is extremely complex, as the number of individual products is immense and can exceed two or three hundred for a typical boning room.

The boning operation produces many products that include boneless meat, bone-in meat, bones, fat and trim. The bones and fat generally go to rendering. All meat, whether boneless or bone-in, leaves the boning room in cartons, to be either frozen or chilled.

5.1.2 Packaging of beef cuts

Types of packaging for beef

As all meat leaves the boning room in cartons we were interested to see if there were any identifiable trends in the packaging of these various meat products. We found that the cartons of meat could be classified into four generic categories namely; Bulk Pack (BP), Layer Pack (LP), Individually-wrapped (IW) cuts and cuts sealed in vacuum bags. These packaging classes are described in detail in Appendix 3. In broad terms, vacuum-packaged meat is usually chilled while the rest is frozen.

Within the four basic classes of packaging there exists a very large range of product specifications. Thus we cannot assume, for instance, that all bulk-packed meat is the same - it is not. However, in terms of packaging systems, these are the generic types.

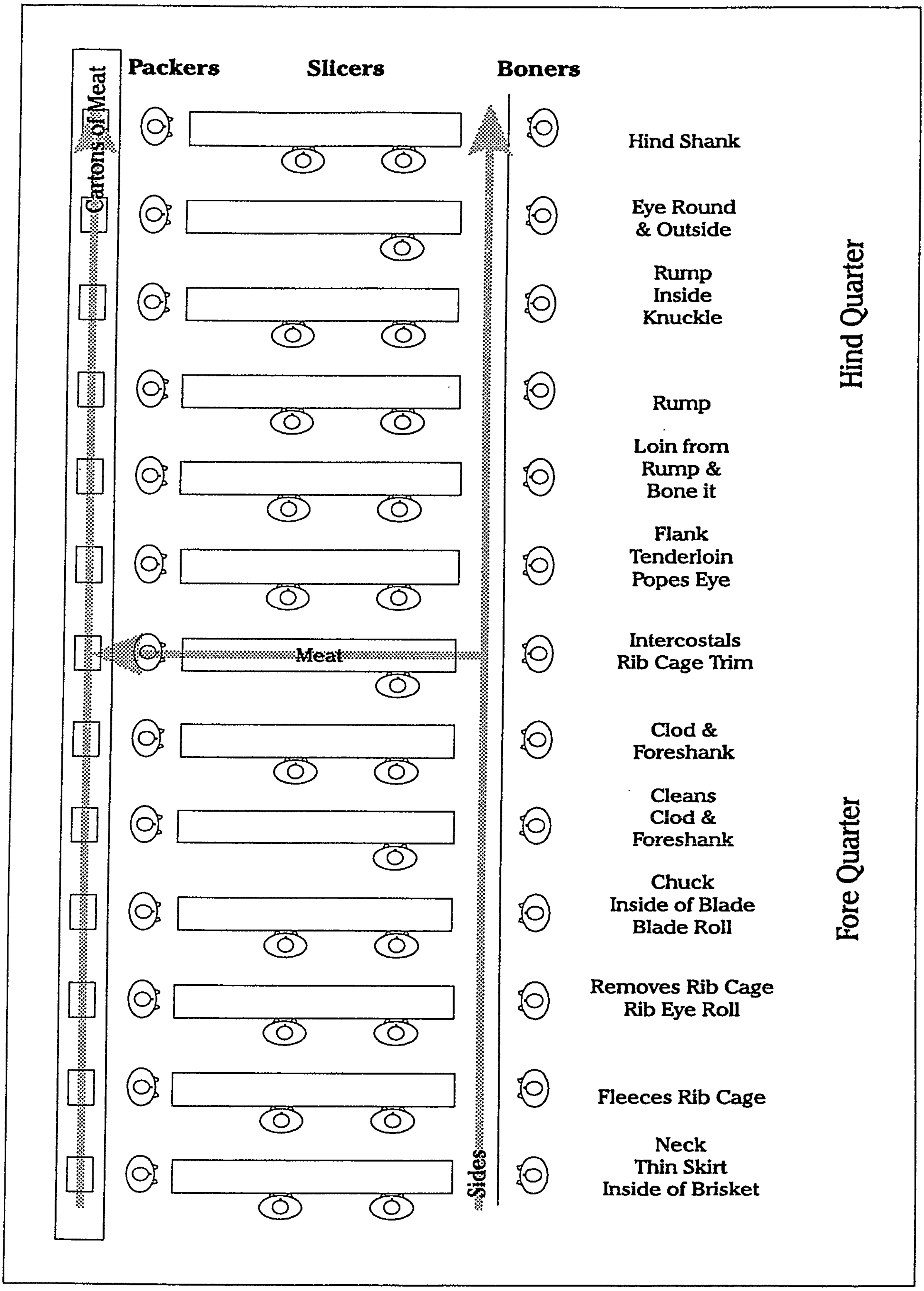

Figure 2. A typical beef side boning room layout.

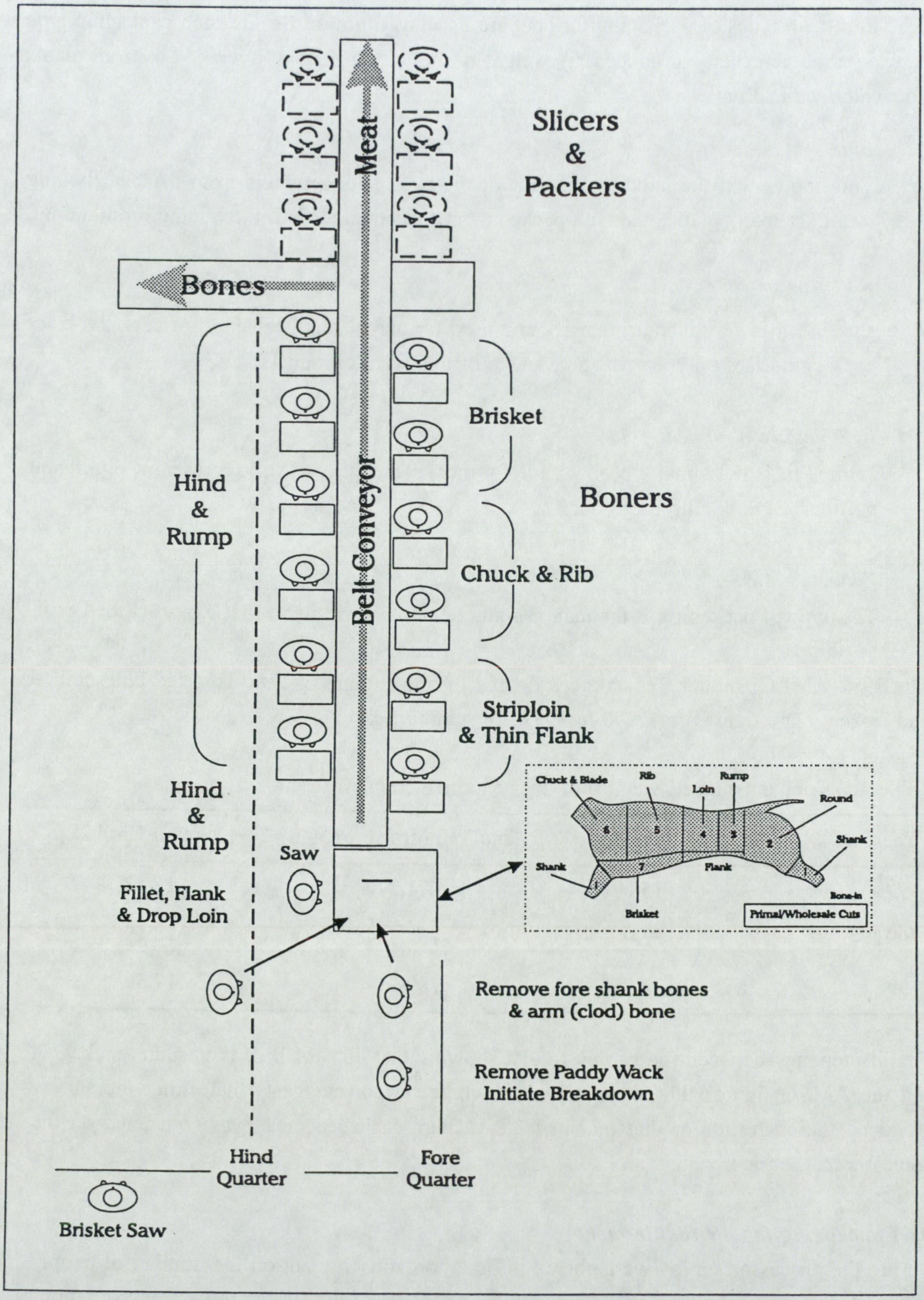

Figure 3. A typical beef table boning room layout.

The four main types of packaging for beef are listed as follows. Beside each packaging type is shown the percentage produced, by weight or number of cartons, averaged over all plants for which we had data.

- *Bulk - 41%*

  This shows that the bulk pack is one of the two major products from the beef boning room. In many plants, the bulk-packed meat accounted for half the boning room output.

- *Layer Pack - 2%*

  Because it is very labour intensive and used for only a small selection of cuts, the layer pack comprises only a small percentage of the overall product.

- *Individually Wrapped - 11%*

  While this is not a major product line for most plants, it does still represent a significant portion of the boning room output.

- *Vacuum - 46%*

  This type of packaging is the major product line for most plants that export chilled beef.

The 1992 AMLC Annual Report gives figures for the amount of beef exported both chilled and frozen. The figures for 1990 to 1992 are summarised in Table 1.

Table 1. Tonnes (shipped weight) of beef exported from Australia.

Year	Chilled	Total (Chilled & Frozen)	Percent Chilled
1990	115,020	671,870	17.12
1991	132,967	732,944	18.14
1992	138,950	789,934	17.59

The discrepancy between the survey results showing that 46% of beef is vacuum-packaged, and the AMLC figures that show only 18% chilled export suggests that either the survey produced biased results or that much of the vacuum-packaged meat was consumed on the domestic market or frozen.

Beef packaging labour requirements

During the processor survey we gathered information at each plant on the number of people involved in packaging. The results for both beef and lamb showed that the amount of labour used for packaging varied between plants. This is not surprising as the amount of labour used in packaging relates to the products being packaged, and these are often set by the type of stock being processed. Thus, the number of packers on a line can vary between plants and within a plant, according to the type of stock being processed and the types of cuts being produced. Therefore the ratio of packers to throughput is variable and a fixed value is difficult to assign.

We calculated the ratio of packers to stock throughput for all plants visited. The number of packers is defined as those people wrapping meat and placing it into a carton. It does not include the staff involved in weighing and labelling cartons of meat to be frozen, or those involved in feeding or packing off the vacuum packaging machine. *For the beef plants, the average ratio of carcasses per packer per day was 18, with a minimum value of 8 and a maximum of 27. The average hourly wage, for both beef and sheep plants, for a person working in the packaging area was $11.34 (max $14.62, min $8.00) with an overhead factor of 36% (max 50%, min 15%).*

Table 2 shows the number of packers involved in each packaging class based on a throughput of one hundred carcasses per day. The percentage production values are taken from an actual plant. The third column is the number of packers working on each packaging type normalised to a throughput of one hundred carcases per day. The last column is the percentage divided by the labour, a figure that shows the throughput per packer.

Table 2. Labour required for packaging beef at a particular plant normalised to a throughput of one hundred beef carcasses per day.

Packaging Class	Percentage	Packers	Ccs/Packer/Day
Bulk	42	1.2	35
Individually Wrapped	30	1.3	23
Vacuum	20	1.0	20
Layer	8	0.6	13
Total	100	4.1	24

This plant required only 4.1 packers per one hundred carcasses processed per day or 24 carcasses per packer per day. This figure is higher than the average of 18 over all beef plants in our survey. The most interesting feature of Table 2 is the individual throughput per packer. While one packer can process the equivalent of 13 carcasses per day of layer-packed meat, another packer can process the equivalent of 35 carcasses per day of bulk-packed meat, nearly three times as much! Therefore, cost of packing 1 kg of bulk meat is one third of the cost of packing 1 kg of layer-packed meat.

The labour requirements for each of the packaging classes are clearly different as is shown in Table 2. The ratio information can be interpreted in another way. If this plant wanted to maintain its output but increase its percentage of vacuum-packaged meat and simultaneously decrease, say, its individually-wrapped meat, the number of packers would have to increase. This is because the throughput per packer is less for vacuum-packaged meat than for individually-wrapped meat.

Beef packaging trends

The trends in beef packaging tend to be along the lines of refining the existing packaging technologies. In the area of bulk meat, the industry has been investigating ways of reducing the costs associated with packaging and handling. The direction of the research and development has been to find ways of supplying the same quantity of meat in larger units. This has led to the investigation of larger carton or bulk bins, but the problems associated with freezing large blocks have been a limiting factor. Some companies are now investigating the use of 27.2 kg moulds for bulk meat and freezing these in a plate freezer. Once the individual 27.2 kg blocks are frozen, they can then be consolidated and handled as a larger unit.

There is also a definite trend to packaging more cuts in vacuum bags. In a survey of retailers in the USA the Cryovac division of W.R. Grace found that between 1979 and 1993 the percentage of all beef primals and sub-primals sent to retailers as boneless sub-primals increased from 30% to 72%. Most boneless beef is shipped chilled in a vacuum bag. Thus, the trend is evident.

5.1.3 Sheep boning & cutting

When dealing with sheep, the boning procedure is in many ways similar to beef. There are three main systems for boning sheep carcasses. These are frame, trunk and table boning.

Frame boning is equivalent to beef side-boning, except that the boner works on the entire carcass rather than the side used for beef boning. For this type of boning operation the carcass is suspended from the rail by one leg while the other leg is cut at the pelvic bone. The meat is then separated from the skeletal frame down the entire length of the carcass on one side initially. This procedure produces two "soft sides" of meat with the leg and shoulder bones in the meat. The legs and shoulder are then boned on a table to produce the final boneless meat.

Trunk boning involves a similar series of operations, but in this case the legs are not boned.

For table boning the carcass is roughly divided into three primals, the legs, loin and shoulders, with a bandsaw. The table boning operation is similar to that used for beef where the meat is placed on a central conveyor belt. Butchers remove cuts from the belt, remove the bones, which are placed on another belt, and the meat is placed back onto the belt. The meat cuts are then packaged using techniques similar to that used for beef.

In addition to boning, many frozen sheep carcasses are merely cut into primals, which are trimmed, then packaged. We will see, in the next section, that these cuts are more likely to be individually wrapped.

5.1.4 Packaging of sheep cuts

Types of packaging for sheep

The cartons of meat, from sheep boning or cutting, have been classified, as for beef, into bulk pack, layer pack, individually-wrapped cuts and cuts sealed in vacuum bags. These are described in detail in Appendix 3. Vacuum-packaged sheep meat is usually chilled while the rest is frozen.

As with beef, there is a large range of product specifications across the four different packaging classes.

The four main types of packaging for sheep meat are listed below. Beside each packaging type is shown the percentage produced, by weight or number of cartons, averaged over all plants for which we had data.

- *Bulk - 48%*

  The bulk pack is clearly one of the two major products from the sheep boning room. A common bulk pack for sheep comprises all the boneless trunk meat from mutton carcasses.

- *Layer Pack - 5%*

  Because it is very labour intensive and only used for a small selection of cuts, the layer pack comprises only a small percentage of the boning room output.

- *Individually Wrapped - 37%*

  For sheep processing, this packaging type has several variations that are not found for beef. For example, shoulder meat may be rolled and packed into a plastic tube approximately 100 mm in diameter. The ends will be sealed and the individual rolls packed to a specified weight. Sometimes the whole carcass is split around the middle and folded into itself, telescoped, before being placed into a bag and then into a carton. We consider this to be an individually-wrapped product.

Some sheep carcasses are cut frozen and the cuts individually wrapped in shrink film. These also add to the figures for individually-wrapped sheep meat.

Individually-wrapped meat cuts are clearly a major line for most sheep processing plants, and represent the second most common wrapping type.

- *Vacuum - 10%*
  This type of packaging is not a major product line for most sheep processing plants. Although vacuum-packaged lamb and sheep meat represents only a small percentage of all product by weight, it's value, in dollar terms, will be considerably higher.

Sheep packaging labour requirements
As with beef, we gathered information, at each sheep processing plant, on the number of people involved in packaging. The results for sheep showed that the amount of labour used for packaging also varied between plants.

We calculated the ratio of packers to stock throughput for all sheep processing plants visited. *For the sheep plants, the average number of carcasses processed per packer per day was 203 with a minimum of 117 and a maximum of 370.* The average hourly wage, for both beef and sheep plants, for a person working in the packaging area was $11.34 with an overhead factor of 36%.

Table 3. Labour required for packaging sheep and lamb meat.

Packaging Class	Percentage	Packers (Estimated)	Ccs/Packer/Day
Bulk	48	1.77	271
Layer	5	0.47	106
Individually Wrapped	37	2.03	182
Vacuum	10	0.66	152
Total	100	4.93	203

Table 3 shows the estimated number of packers involved in each packaging class based on a throughput of one thousand carcasses per day, a ratio of one packer per 203 carcasses and the percentage values taken from the preceding section. As we did not get detailed information on the number of packers involved in each packaging operation these figures are scaled from the data Table 2 and illustrates how the throughput per packer differs across the four types of packaging.

Packaging sheep meat in vacuum bags is time consuming. Because the volume of product being vacuum-packaged is not large, this operation is even more labour intensive than in a beef processing plant. For example, the vacuum sealing machines typically used in these plants do not have the throughput of the rotary machines used for beef. Consequently, the machines are manually loaded and unloaded. In addition, the machines operate on a batch cycle where the operator must wait until the cycle is completed before the machine can be unloaded. Several companies have devised different methods to overcome this deadtime in the process. Most solutions require an operator to work two machines simultaneously so that while one machine is performing its vacuum sealing cycle, another machine can be unloaded and reloaded. Several variations on this theme exist, all designed to improve the throughput of product through a number of batch cycle machines.

Sheep packaging trends

The trends in sheep packaging tend to be along similar lines to those for beef packaging. However, there are some trends that are more specific to sheep processing and these are mentioned below.

The new technology of Controlled Atmosphere Packaging is increasing its market share. It has definite advantages, mainly in terms of storage life, over conventional vacuum packaging for lamb. This technology allows chilled sheep meat to be sea-freighted to most markets, a definite cost saving over airfreight. Several machines are already installed in Australia and this number is likely to increase.

With the trend to further processing of meat cuts in the plant, there is a need to package these cuts individually. This implies a trend to more wrapping of individual cuts rather than the old practise of selling carcasses or cartons of bulk meat.

5.1.5 Observations of packaging areas

For most of the boning rooms we visited, the main bottleneck in the room was centred on the meat packaging area, specifically once the meat was in the carton. It was obvious that improvements to the design and layout of these areas would greatly improve product flow and avoid the considerable congestion observed.

5.1.6 Packaging area layouts

As previously described, three different systems are commonly used for boning beef carcasses. The type of boning system influences the design and layout of the boning room and also influences the design and layout of the packaging area. *As a result of the processor survey, we identified two main types of packaging system. The two types of packaging system differ primarily in the way meat is transported through the system.*

In the first system (Figure 4), all the meat is immediately packed into cartons by packers working at the end of the tables where the slicers work. This work requires much manual lifting and twisting of the body as meat is taken from the table, placed in a bag or wrapped if necessary, and put into a carton or tub. Beyond the slicing tables all meat is transported through the rest of the boning room in cartons or tubs.

The meat to be vacuum-packed has already been placed in barrier bags and leaves this area in cartons or tubs to be transported to the vacuum packaging machines. At the vacuum-packaging machines the bags of meat are removed from the carton or tub, put through the vacuum packaging system, including shrink tank and water-removal machine, before being packed back into the carton. This system involves a lot of extra handling, as the meat must first be placed in the carton, then removed for vacuum packaging and be finally placed back into the carton.

Once the cartons of bulk meat, layer packs and individually-wrapped meat cuts have left the slicing table area, they are transported to another area of the plant. In this area the bulk meat cartons are check weighed, with meat added or removed if necessary, sealed, labelled, strapped and, in some plants, checked for Chemical Lean (CL) content before being frozen. The layer packs and cartons of individually-wrapped cuts are also weighed and strapped before being sent to the freezers.

In the other system (Figure 5), the meat, after trimming by the slicers, is transported as individual cuts on belt conveyors to a packaging area. The meat to be vacuum-packaged is placed into barrier bags and is sent to the vacuum packaging machine, often on its own belt conveyor. The bagged meat cuts travel through the vacuum packaging machine, shrink tunnel and water removal machine and is finally placed in a carton.

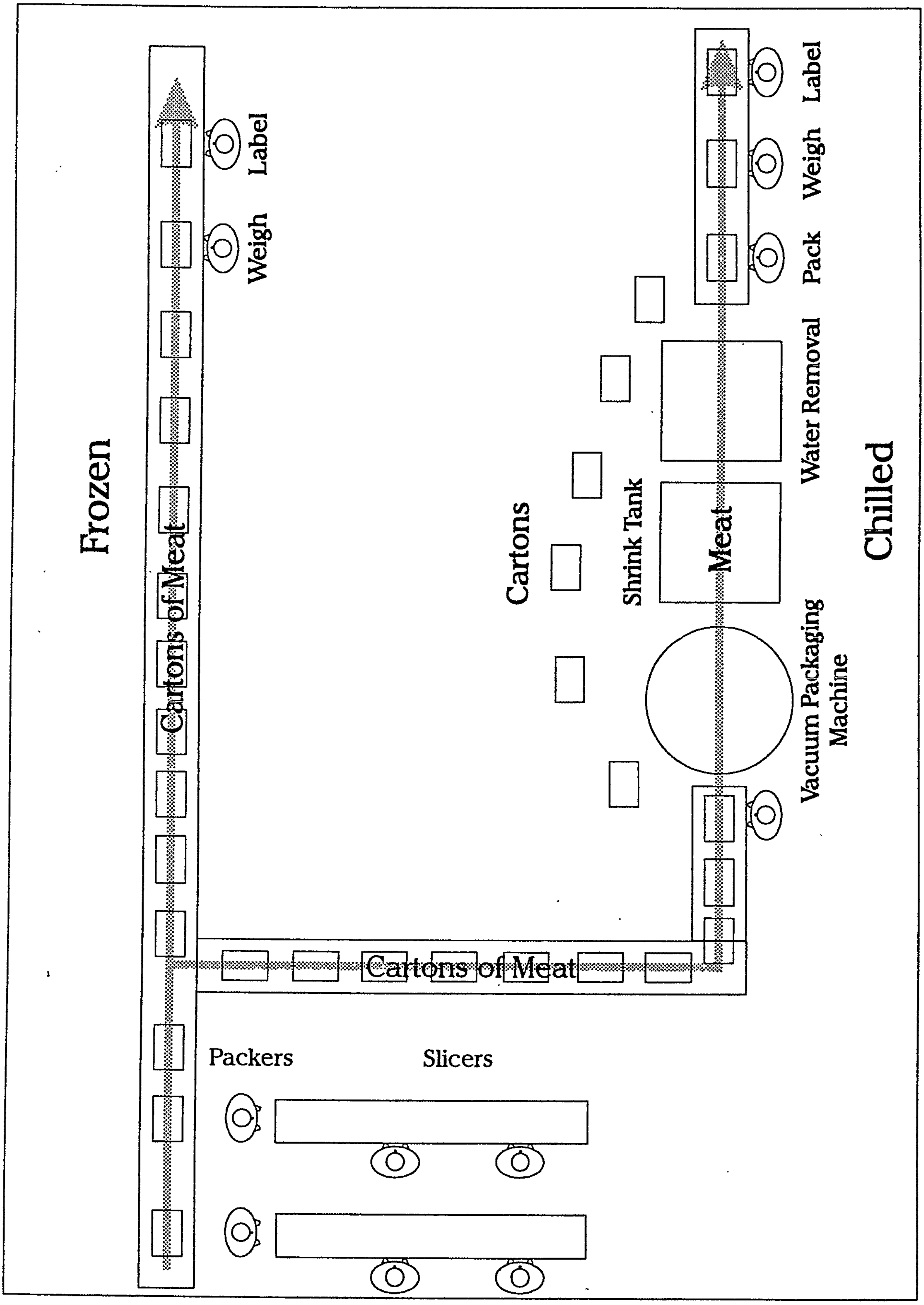

Figure 4. Typical packaging system layout with meat transported in cartons.

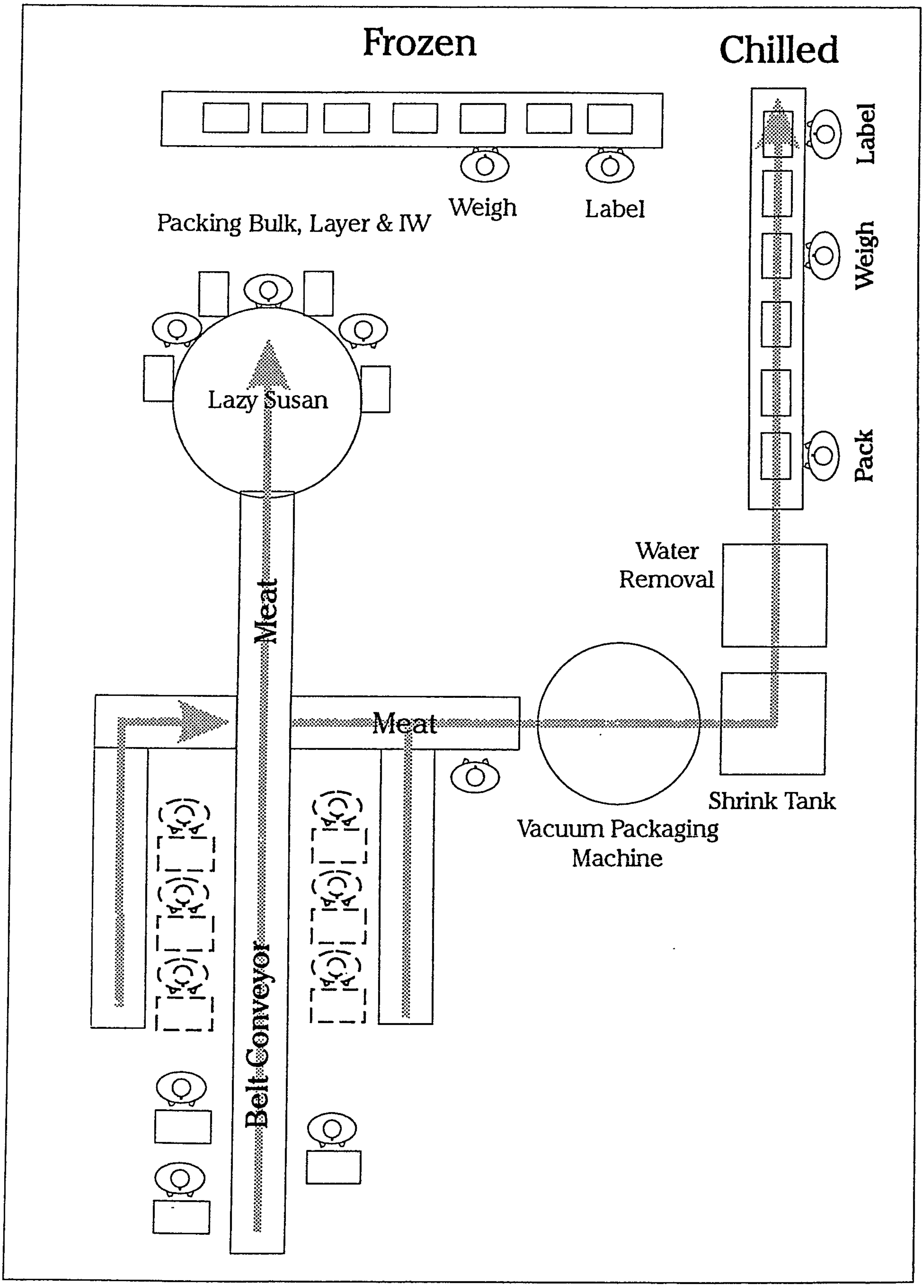

Figure 5. Typical packaging system layout with meat transported on conveyor belts.

Cuts to be bulk-packed, layer packed or individually wrapped continue on the belt, which tips them onto a lazy susan or table, where the packers put the meat into cartons. The cartons then go through the normal processes of weighing and strapping common to all bulk-packed, layer-packed and individually-wrapped meat.

Of the two types of packaging system, the system where individual meat cuts are transported is more efficient, as the amount of product handling is much less.

There are also three systems commonly used for boning sheep and lamb carcasses. Again, the type of boning system influences the design and layout of the boning room and packaging. We found similar types of packaging systems in sheep plants as in beef plants, so they will not be discussed again. However, there was one significant difference between the two.

The figures in Tables 2 and 3 show that the volume of vacuum-packaged meat is significantly less in most sheep processing plants than in beef plants. Because of this, the vacuum packaging equipment tended to be manually operated rather than automatic, as is found in most large beef processing plants. This often resulted in poor product flows around the vacuum packaging equipment.

5.2 Packaging Company Survey

5.2.1 Introduction

For the packaging company survey we focused our attention on the major packaging companies supplying plastic film to the Australian market. We did not look at the supply of cardboard cartons, as these are used in all plants and the technology for their supply and storage is well developed. We saw ample evidence of new and innovative carton products, but felt that the technology was mature and readily available. Most larger plants had automatic carton erection systems, or were in the process of installing them. The hand erection of cartons is an important area that required automation because the nature of the job made workers highly susceptible to occupational overuse syndrome (OOS) type injuries.

Packaging costs for the average meat plant are very high and are generally rated as the third or fourth largest operational cost. In a typical plant the largest operating cost is the procurement of stock, the second is labour and the third and fourth are packaging and energy.

The two major companies supplying plastic for wrapping meat are very large. The largest is W.R. Grace and the next largest, Trigon. For both these companies, the supply of packaging materials is their major line of business. The supply of packaging machines tends to be more of a service to help the customer use their packaging material. In fact, the authors were told that there was intense competition in the supply of packaging machinery if it meant that a particular company's packaging film would be used.

5.2.2 Packaging machinery

The first author visited or contacted seven international packaging machinery companies that supply equipment to the Australian market. Between them, these companies produce most of the fresh red meat packaging equipment currently used by the Australian meat processing industry. A report on each company and its products is given in Appendix 2. The areas where automatic machines are available are also noted later in the report.

5.3 Proposal for Machinery Development

The processor survey portrayed the current situation with fresh red meat packaging in the Australian meat processing industry. In many plants the packaging area was not well designed or laid out and, consequently, it was a significant bottleneck in the flow of meat through the boning room. Thus, product flow through the boning room could be significantly improved by redesigning the packaging area.

The authors suggest that the entire packaging area requires a redesign, using a systems approach with an emphasis on obtaining good product flows. The two key design factors for this area, in the opinion of the authors, should be product flow and layout flexibility. In the meat processing industry each plant is unique and has its own space constraints. Because of this, a new packaging system design would need to be flexible to find application in different plants. A modular system would also allow plants to make incremental improvements to their operation by taking only those modules they required.

In the following section, the four different types of packaging; bulk pack, layer pack, individually wrapped and vacuum bag, are analysed to identify the individual component tasks required to produce each carton of meat.

5.3.1 Packaging component tasks

In the tables below, most of the tasks labelled "automatic" are also done manually in many meat processing plants. However, by identifying them as automatic we are saying that technology is available to do these tasks automatically and that this technology is operating at one or more meat processing plants. The tasks labelled "mechanised" show that an operator is still required although a machine will be doing most of the work.

The descriptions in the following sections apply mainly to beef, although they are also applicable to sheep and lamb. Besides the tasks listed below there are a few operations and packages that apply to lamb and sheep processing in particular. Examples are tubed or rolled shoulders and trays of tenderloins that are vacuum-packaged. There will always be niche markets for meat in particular types of packaging and unless they become mainstream type products, they will probably continue to be packed manually.

Two other issues relate to all of the packaging classes discussed below. These are:

- Plastic entrapment
  This is particularly important for bulk packs but also applies to layer packs and individually-wrapped meat cuts. The problem is that the plastic carton liner can become folded between layers of meat. Once the meat is frozen, it is extremely difficult to extract the plastic from the meat. This is especially important, because much of the bulk meat is not completely thawed before further processing. Thus plastic that cannot be removed from the meat goes into the product, which is to be used for human consumption. This is clearly not desirable for the health and safety of the consumers.

- Presence of bone chips or foreign bodies
  Most of the meat produced by a boning room is described as boneless. Thus, any bone chips or other foreign objects in the meat become a consumer health and safety issue. Buckshot is of particular concern in many parts of Australia, as some cattle from the North are rounded up using shotguns. Therefore, most plants in Australia are interested in a low-cost system that could detect bone chips, buckshot, knives and other foreign bodies in cartons of meat before they get to the consumer.

Bulk pack

The bulk pack is described in Appendix 3. The main tasks involved in packing meat into a bulk pack are:

Table 4. Packing bulk packs - the main tasks.

Task	How it's done now	Comments
Identify a cut	Manual	
Compare with specification	Manual	
Estimate its fat content	Manual	Difficult to estimate accurately
Blend product if necessary	Manual	Can cause problems with product flow
Put in carton	Manual	
Pack to weight (usually 27.2 kg)	Manual	Adjusting weight takes extra time
Check weight and adjust if required	Semi-Automatic	Requires an operator
Label	Automatic	
Close liner	Manual	
Close lid	Automatic	
Strap	Mechanised	Automatic machines are available
Check CL content of carton	Automatic	Requires an operator
Dispatch to freezer	Automatic	

While most of these tasks may seem straightforward to a human operator, their automation raises some questions as to exactly what the operator is doing. The first two tasks on the list may seem trivial, but are important to ensure that the correct product is put into the correct carton. The carton is usually packed to a target chemical lean content, so it is important for the operator to be able to estimate this for each cut as well as for the entire carton. Some specifications require meat from different parts of the carcass to be blended, so this must also be known by the operator.

Once the meat is ready to be placed in the carton, the operator must be careful to avoid plastic entrapment of the carton liner. The operator must also pack to a given weight, usually 27.2 kg, and the meat must be placed in the carton evenly so that the carton can be properly closed and lidded.

Once the carton has been filled, it is generally conveyed to a check weighing station where any discrepancy in weight is rectified, the carton is then closed, labelled, strapped, checked for CL content and sent to the freezer. The exact order of these operations will vary, depending on the particular procedures used at each meat plant. For example, some plants with automatic machines for checking CL do this operation last. Other plants that do this manually, must sample selected cartons before they are closed.

Individually-wrapped cuts

The process of individually wrapping cuts is described in Appendix 3. The main tasks involved are:

Table 5. Packing individually-wrapped cuts - the main tasks.

Task	How it's done now	Comments
Identify a cut	Manual	
Compare with specification	Manual	
Determine its size	Manual	
Select an appropriately sized bag or piece of plastic	Manual	
Wrap cut	Manual	
Weight range if necessary	Manual	
Put in carton	Manual	
Weigh	Automatic	May have an operator
Label	Automatic	
Close liner	Manual	
Close lid	Automatic	
Strap	Mechanised	Automatic machines are available
Dispatch to freezer	Automatic	

In addition to the comments in the previous section, the task of individually wrapping meat cuts requires that the cuts be sized so that the appropriate size of wrapping material can be selected. The type of wrapping must also be selected. Some specifications may require the plastic to be folded around the cut while others may require a lolly wrap.

Some plants are moving away from plastic film and putting all their individually-wrapped product in polyethylene bags. Their reasoning is that while the bags may be more expensive than film, the labour required to wrap the cut will be less. From an automation viewpoint this makes life easier, as the same type of machine that puts meat cuts in barrier bags for vacuum packaging can also be used to put meat cuts to be individually wrapped, into bags.

The task of putting the individually-wrapped cuts in a carton is more complex than putting meat in a bulk pack. The cuts need to be placed in the carton to fit in with other cuts, and the number of cuts and their position will vary with the size and shape of each cut. This complicates the task from an automation viewpoint.

Layer pack

The process of placing cuts in a layer pack is described in Appendix 3. The main tasks involved are:

Table 6. Packing layer packs - the main tasks.

Task	How it's done now	Comments
Identify a cut	Manual	Only shank and intercostal meat
Compare with specification	Manual	
Determine its size & orientation	Manual	
Put in carton	Manual	Must conform to layer pack requirements
Weigh	Automatic	May have an operator
Label	Automatic	
Close liner	Manual	
Close lid	Automatic	
Strap	Mechanised	Automatic machines are available
Dispatch to freezer	Automatic	

For the layer pack the initial tasks are similar to those from the other types of package. However, for the layer pack, the position of each cut within the carton is critical for obtaining the correct visual appearance for the carton. This type of package may be well suited to automation, as the pattern for placing meat within the carton is highly regular.

Vacuum bag

The process of sealing meat cuts in a vacuum barrier bag is described in Appendix 3. The main tasks involved are:

Table 7. Vacuum packaging - the main tasks.

Task	How it's done now	Comments
Identify a cut	Manual	
Compare with specification	Manual	
Determine its size & orientation	Manual	
Select or make an appropriately sized barrier bag	Manual/Automatic	Manual selection/Automatic bag making
Place cut in barrier bag	Manual/Mechanised	Mechanised system available but may not suit many plants
Align bag on machine platen	Manual	
Evacuate and seal bag	Automatic	
Shrink bag	Automatic	
Remove water	Automatic	
Check for "leakers"	Manual	
Re-process leakers	Manual	Labour intensive
Identify cut	Manual	To put in correct carton
Weight range if necessary	Manual/Automatic	Some product requires this
Sort by colour if required	Manual	Some product requires this
Put in carton	Manual	Care is needed with bone-in product
Weigh	Automatic	May have an operator
Label	Automatic	
Close lid	Manual/Automatic	Manual for separate lids
Strap	Mechanised	Automatic machines are available
Dispatch to chiller	Automatic	

The tasks that are different for this type of package start with the requirement to place a meat cut within a plastic bag. This task has been automated for regular, firm products such as cheese or salami but not for fresh red meat. A mechanised system exists for meat although it requires an operator to select the correct bag and place it over the exit of the machine. It is also designed to operate with a belt conveyor system so that the meat is conveyed to the machine and falls into the loading part of the mechanism. The system would have very little advantage for those plants that wrap meat at the end of the slicing tables. We saw none of these machines operating in Australia.

Once the meat is in the bag, the next problem is to align it on the platen of a vacuum packaging machine. At this stage we consider only the large rotary vacuum machines. The problem is to get the bag to sit correctly on the platen with the bag smoothed over the sealing bar. In one plant we found three people performing this task, to ensure that every platen of the machine was used.

Once the bags have been evacuated, sealed, and shrunk, and the excess water removed, they are ready to be placed into cartons. This task has many aspects that are not apparent at first. The staff performing this task first check the bags for "leakers," which must be recycled. This task requires extra labour, as the meat must be removed from the old bag, placed in a new bag and transported back to the entrance of the vacuum packaging machine.

Once the leakers have been removed, the cut must be identified again, as the various cuts will have been all mixed up through the vacuum packaging system. Some cuts may need to be weighed if they are to be weight-ranged, and some cuts may require sorting by colour. The cuts must then be placed in the correct carton, taking care to arrange the cuts within the carton for minimum damage during transit. This is particularly important for bone-in meat cuts.

Once the cartons are filled, they go through the rest of the system and are usually sent to the chillers or loadout area.

Generic tasks

From the above list obviously many tasks were common to some or all of the packaging classes. The task lists were therefore combined to form a list of generic tasks. These tasks are necessary as part of the packaging operation and must be done, either manually or by a machine.

Table 8. Generic packaging tasks.

Task	How it's done now	Bulk	Layer	IW	Vac
Identify a cut	Manual	✓	✓	✓	✓
Compare with specification	Manual	✓	✓	✓	✓
Determine its size, orientation, fat content, colour, weight etc.	Manual	✓	✓	✓	✓
Select or make an appropriately sized bag or piece of plastic film	Manual/Automatic			✓	✓
Place cut into a bag	Manual			✓	✓
Individually wrap cut in plastic	Manual			✓	
Align bag on vacuum machine platen	Manual				✓
Evacuate and seal bag	Automatic				✓
Shrink bag	Automatic				✓
Remove excess water from bag	Automatic				✓
Check for "leakers"	Manual				✓
Reprocess leakers	Manual				✓
Weight range cuts	Automatic			✓	✓
Sort cuts by colour	Manual				✓
Put meat into a carton	Manual	✓	✓	✓	✓
Weigh carton	Automatic	✓	✓	✓	✓
Adjust weight of bulk pack	Manual	✓			
Label a carton	Automatic	✓	✓	✓	✓
Close liner	Manual	✓	✓	✓	
Close lid	Manual/Automatic	✓	✓	✓	✓
Strap carton	Mechanised	✓	✓	✓	✓
Check CL content of carton	Automatic	✓			
Dispatch to freezer or chiller	Automatic	✓	✓	✓	✓

The tasks in Table 8 are typical of those routinely carried out in a fresh red meat packaging operation at a meat processing plant. The list is deliberately concise and requires elaboration of each task. This is done in the following paragraphs.

The task of identifying a meat cut is easily done by an experienced worker but is more difficult to do using a machine. However, new technology is already available, in the research laboratories, to automate some aspects of this task.

The task of comparing a cut with a specification is generally done by the slicers who prepare the cut in the first place. This task is then repeated, as the packer placing the meat into the carton must ensure that the correct meat is being placed into the appropriate carton. This seemingly trivial task is critical for the correct operation of an automated packaging facility.

Deciding the dimensions of cuts is done unconsciously by most packers as they perform their tasks. If meat cuts are to be automatically placed into bags, then the machinery will need to know the dimensions of a particular cut to ensure that it is placed into a bag of the correct size. With many cuts, the cut orientation will also need to be known so the cut can be correctly placed into a bag. Other factors such as weight, colour, percentage fat may need to be known by automatic machines at various points in the packaging process.

Placing meat cuts in bags is the sole job of many packers in beef processing plants producing vacuum-packaged meat. Factors that may need to be considered are the bag type and size and whether bone guard is required. Some companies are placing their individually-wrapped product into polyethylene bags because they find it easier to do this than individually wrap each cut.

If plants are individually wrapping meat cuts, then an automated machine would need to know the size and orientation of the cut, the type of film, its size and the style of wrapping. For example, some specifications require a lolly wrap while others require a simple folding style.

The operations that involve evacuating a vacuum bag, sealing it, shrinking and removing excess water are all automated now, with machinery available from a range of manufacturers.

Placing meat into a carton is a task that is entirely manual at this time. There are four different methods for packing meat into a carton, so each of these must be dealt with individually. Common to all will be the selection of the carton type and size.

Bulk, layer and individually-wrapped packs require a polyethylene liner in the carton. Packing bulk meat into a carton is quite different from the other types of packs. This process is amenable to automation, although the techniques used may resemble a processed meat operation rather than a typical meat packing operation. Placing bulk meat into a carton is constrained by the volume of the carton, and by the target weight. The aim would be to maintain a close tolerance on the weight of each pack to minimise the amount given away.

The layer pack is very labour intensive to produce at present. However, the required product regularity makes it a good candidate for automation.

Packing individually-wrapped meat cuts into a carton is an interesting problem to automate. It is difficult to know at this point whether individually wrapped and vacuum-packaged cuts can be treated the same as far as automatically placing them in a carton is concerned. This remains to be seen.

Most companies have a least one person aligning bagged cuts on the infeed to a vacuum packaging machine. This task has been automated for rigid products such as cheese or salami, but not for fresh red meat.

Identifying "leakers" in vacuum bags is required by all plants producing vacuum packs. This is done manually now, although for a fully automated packaging operation, this task would need to be automated.

Closing the liner on bulk packs is another operation that will need to be automated for a fully automated packaging operation. Some plants already have automatic carton lidding machines.

The operations of weighing and labelling a carton are mostly automated these days. However, most plants still seem to use an operator at the weighing station. This person could be removed as automatic weighing and labelling systems are available.

Carton strapping is generally mechanised, in that a machine does the hard work. However, most plants still use an operator on the strapping machine.

Finally, automatic machines exist to check chemical lean content of bulk-packed meat cartons and to relabel them if necessary. However, these machines also have an operator for reasons unknown to the authors at this time. Clearly, a fully automated packaging system would require this operator to be removed.

The above tasks represent a summary of most of the operations involved in the wrapping and packaging of fresh red meat cuts as is currently the practice in most meat processing plants. No attempt has been made to prioritise the list at this point. Those tasks not labelled automatic on the above list represent scope of the research and development effort required to develop a fully automated packaging system for fresh red meat. Some tasks will require significant research before any development can take place, while for others the development effort can start immediately.

5.3.2 Equipment specifications

Bulk pack

The processing rate for cartons of bulk meat was calculated as follows. The plant throughput was multiplied by the average carcass weight, where available, to give the total tonnes of meat processed per day. Where the average carcass weight was not available, the figure of 230 kg was used for beef and 19 kg for sheep, as this was the average carcass weight in 1992 for all Australia as reported by the AMLC in its annual industry statistics. This total tonnage was multiplied by the average yield for the plant, where available, or the figure of 68% set by the authors. This figure was multiplied by the percentage bulk meat from the survey, to give the total tonnes of bulk meat produced per day. When divided by 27.2 kg, the average weight of a carton of bulk meat, the result was the average number of cartons processed per day. Finally, when divided by the number of hours worked per day, the result was the average number of cartons of bulk meat processed per hour.

For all the beef plants in the survey, the average number of cartons of bulk meat processed per hour was 155 with a maximum of 381 and a minimum of 10. The labour figures for the individual operations indicated that *a single packer processed an average of 21 cartons per hour with a maximum of 27 and a minimum of 3.5.* Expressed another way, *a single packer processed an equivalent of 26 carcasses per day with a maximum of 35 and a minimum of 4.5.*

For all the sheep plants in the survey, the average number of cartons of bulk meat processed per hour was 74 with a maximum of 158 and a minimum of 22. The labour figures for the individual operations indicated that *a single packer processed an average of 18 cartons per hour with a minimum of 8.*

The chemical lean specification for cartons of bulk meat could take any value from 50 to 90% and increased in steps of 5%. Thus, for an individual carton, a tolerance of ±2.5% could be allowed before the carton had to be reclassified. However, for a container load of cartons, the average chemical lean content should be as close as possible to the specification.

Finally the weight of a carton of bulk beef is specified as 27.2 kg. At different plants, the authors were given specifications of ±50 grams and ±100 grams for the weight tolerance of cartons of bulk beef.

Thus, the specifications for an automatic machine to produce cartons of bulk meat and replace a single packer, would be:

- Throughput rate of 21 cartons per hour for beef
- Throughput rate of 18 cartons per hour for sheep

- Chemical lean content of carton to be within ±2.5% of target
- Weight of carton to be within ±50 grams of 27.2 kg.

Layer pack

The processing rate for cartons of layer-packed meat cuts was calculated using a similar method to that used for bulk meat, as described above. However, the average carton weight was set at 23.2 kg, instead of the figure of 27.2 kg used for cartons of bulk meat. This figure was calculated from actual plant data.

For all the beef plants in the survey, the average number of cartons of layer-packed meat processed per hour was 15 with a maximum of 57 and a minimum of 2.3. The labour figures for the individual operations indicated that *a single packer could process an average of 10 cartons per hour with a maximum of 12 and a minimum of 2.* Expressed another way, *a single packer processed an equivalent of 10 carcasses per day with a maximum of 23.*

For all the sheep plants in the survey, the average number of cartons of layer-packed meat processed per hour was 12 with a maximum of 23 and a minimum of 3. The labour figures for the individual operations indicated that *a single packer could process an average of 8.5 cartons per hour.*

The weight of a carton of layer-packed meat does not need to be controlled. It is sold on catch weight, which is the actual weight of the carton of meat.

Layer-packed meat comprises many individual cuts. During this survey no attempt was made to try to estimate the number of cuts per carton. This figure would be necessary to know when the automation of this task was considered because it represents the number of operations required to place the individual meat cuts into the carton.

Thus, the specifications for an automatic machine to produce cartons of layer-packed meat and replace a single packer, would be:

- Throughput rate of 10 cartons per hour for beef
- Throughput rate of 8.5 cartons per hour for sheep.

Individually wrapped

The processing rate for cartons of individually-wrapped meat cuts was calculated using a similar method to that used for bulk meat, as described above. However, the average carton weight was set at 23.2 kg, instead of the figure of 27.2 kg used for cartons of bulk meat. This figure was calculated from actual plant data.

For all the beef plants in the survey, the average number of cartons of individually-wrapped meat cuts processed per hour was 80 with a maximum of 171 and a minimum of 4. The labour figures for the individual operations indicated that *a single packer could process an average of 17 cartons of meat per hour with a maximum of 21.* Expressed another way, *a single packer processed an equivalent of 17 carcasses per day with a maximum of 23.*

For all the sheep plants in the survey, the average number of cartons of individually-wrapped meat cuts processed per hour was 66 with a maximum of 102 and a minimum of 21. The labour figures for the individual operations indicated that *a single packer could process an average of 15 cartons per hour with a minimum of 9.*

The weight of a carton of individually-wrapped meat cuts does not need to be controlled. It is sold on catch weight, which is the actual weight of the carton of meat.

Cartons of individually-wrapped meat cuts comprise several individual cuts. During this survey no attempt was made to estimate the number of cuts per carton. This figure would be necessary to know when the automation of this task was considered because it represents the number of operations required to place the individual meat cuts into the carton.

Thus, the specifications for an automatic machine to produce cartons of individually-wrapped meat cuts and replace a single packer, would be:

- Throughput rate of 17 cartons per hour for beef
- Throughput rate of 9 cartons per hour for sheep.

Vacuum pack

The processing rate for cartons of vacuum-packaged meat cuts was calculated using a similar method to that used for bulk meat, as described above. However, the average carton weight was set at 22 kg, instead of the figure of 27.2 kg used for cartons of bulk meat. This figure was calculated from actual plant data.

For all the beef plants in the survey, the average number of cartons of vacuum-packaged meat cuts processed per hour was 195 with a maximum of 482 and a minimum of 56. The labour figures for the individual operations indicated that *a single packer could process an average of 15 cartons per hour with a maximum of 42 and a minimum of 13.* Expressed another way, *a single packer processed an equivalent of 14 carcasses per day with a maximum of 40.*

For all the sheep plants in the survey, the average number of cartons of vacuum-packaged meat cuts processed per hour was 37 with a maximum of 57 and a minimum of 17. The labour figures for the individual operations indicated that *a single packer could process an average of 13 cartons per hour.*

The weight of a carton of vacuum-packaged meat cuts does not need to be controlled. It is sold on catch weight, which is the actual weight of the carton of meat.

Cartons of vacuum-packaged meat cuts contain several individual cuts. From the survey data, we estimated that there was an average of 7 cuts per carton.

The number of cuts processed per hour or minute is also important for the correct sizing of bagging machinery. The largest rotary vacuum packaging machines have a throughput of 30 cuts per minute. Thus, at the top end, the machinery to put meat cuts into bags would need to operate at a rate that could feed one of these machines. For vacuum packaging the number of carcases per worker, involved in feeding the vacuum packaging machine and packing off after it, is approximately 60.

For all the beef plants in the survey, the average number of vacuum-packaged meat cuts processed per minute was 6 with a maximum of 40. The labour figures for the individual operations indicated that *a single packer could process an average of 2.9 cuts per minute with a maximum of 5 and a minimum of 1.7.*

Thus, the specifications for an automatic machine to produce cartons of vacuum-packaged meat cuts and replace a single packer, would be:

- Throughput rate of 15 cartons per hour for beef
- Throughput rate of 13 cartons per hour for sheep
- Throughput rate of 2.9 cuts per minute for placing beef cuts into bags.

Summary

Table 9. Throughput rates, in cartons per hour per labour unit, for packaging beef and sheep meat.

Packaging class	Beef	Sheep
Bulk pack	21	18
Layer pack	10	8.5
Individually wrapped	17	15
Vacuum bag	15	13

The data in Table 9 show the throughput rates, in terms of cartons per hour per labour unit, required for an automatic machine if it is to replace one packer. The typical operations performed by these packers include the identification of the meat cut, selection of a bag or piece of plastic if required, wrapping the cut if necessary and placing it into the carton. The figures for vacuum packaging do not include the removal of the meat from the carton before it goes through the vacuum bagging machine, aligning the cut on the vacuum machine platen, checking for "leakers," reprocessing leakers or re-packing the bagged cuts into the carton. The figures for bulk-packed meat do not include final check weighing of bulk meat cartons, strapping, labelling or lidding.

The broad nature of this study precluded the detailed study of any of the four packaging classes. In this respect, there is still some data to be collected on the detailed analysis and costing of individual operations that were beyond the scope of this work. Such data as the number of cuts in a layer pack, the average weight and dimensions of all cuts that are vacuum packaged and individually wrapped are required before a detailed proposal can be developed for the automation of each operation listed in Tables 4 through 8. Because of the detail required, the authors propose that the next stage of this project include a specific study to collect this information.

5.3.3 Likely market size

Many factors influence the market size for a particular piece of equipment. The figures in Table 10, taken from the 1992 AMLC annual report and statistics book, give the 1992 Australian red meat production and export figures, in thousands of tonnes.

Table 10. Australian meat production and export in 1992.

	Beef and Veal	Mutton	Lamb
Production ('000 tonnes)	1757.4	366.9	274.4
Export ('000 tonnes)	789.9	180.8	37.6
Export Value (A$'000 FOB)	2,767,573	273,601	121,130

The information in Table 10 shows that beef exports are four times larger than mutton exports, which are in turn five times larger than lamb. Table 10 gives a good indication of the relative size of the export processing industries for each type of stock.

The July/August 1993 issue of Feedback magazine lists the top 25 processors in Australia. The authors of that article estimated that those companies processed about 60% of the national kill, controlled 64 abattoirs and employed 20,000 people. They added that the 22 largest export processors, with 58 plants, accounted for 75% of Australia's total meat exports. The balance was processed by 22 other plants. On the local scene, 21 companies processed 34% of the domestic market while another 140 abattoirs processed the rest. However, the top 25 companies tend to be dominated by beef processors.

The Macarthur Consulting Group, Program Identification Report of November 1992 on Automated Sheepmeat Processing, identified a total of 160 Australian establishments slaughtering any number of sheep or lamb. Only 15 of the 160 plants had a throughput of more than 600,000 lambs and sheep per year in 1991. Of the 160 plants, 117, comprising 43 export and 74 domestic, participated in a previous survey on new technology.

To summarise, the figures show that there are approximately 88 beef export abattoirs and about 143 domestic beef abattoirs in Australia. This gives a total of 231 beef plants and 160 sheep and lamb processing plants, as shown in the table below.

Table 11. Sheep and beef plants in Australia.

	Export Plants	Domestic Plants	Total
Beef	88	143	231
Sheep and Lamb	58	102	160
Total	146	245	391

These plants range in size with many domestic abattoirs being of smaller size. However, this is an excellent total market size, in Australia alone, for meat processing machinery. As the machinery market is not limited to just Australia, export markets could see these figures increase significantly.

The figures in Table 11 represent the total potential market for all types of equipment, However, for individual items the actual market size will depend on many factors including the equipment size, price, payback time and throughput. Thus for a particular machine that has not yet been specified or designed, the actual market size is difficult to estimate.

5.3.4 Available technology

Looking over the generic packaging tasks described in Table 8, there are many for which equipment is available. In this section we will examine the list of tasks, by packaging type, to identify currently available equipment that can perform the required tasks. If a piece of equipment is mentioned under one packaging type, it will not be mentioned again, to avoid confusion.

Bulk pack

A product is available that estimates the fat content of diced or minced meat on-line. The company is Glafascan, and the equipment uses ultraviolet light and a vision sensor to estimate the fat content of the meat passing on the conveyor through the sensor. The system is designed to work on small pieces of meat and will not work on large meat cuts.

Many companies offer on-line weighing systems for measuring the weight of meat cuts and sorting them by weight if necessary.

There are also systems available for automatically weighing and labelling cartons of meat. Most abattoir computer supply companies provide such equipment.

Some meat processing companies have automatic machinery for closing the lids of cartons. Although automatic strapping machines exist, most meat processing companies tend to use semi-automatic machines; that is, they still use an operator.

There exists at least one product for automatically measuring the fat content of meat in a carton. The machine is produced by Meat Quality Inc. in the USA. Many larger beef processing plants in Australia now have an MQ25 or 27, used to check the fat content of all cartons produced by their plant.

Individually-wrapped cuts

There are many systems for dispensing plastic film or bags at the point of wrapping. Although several automated wrapping technologies exist, none is specifically designed for wrapping fresh red meat the way that it's now done in meat processing plants.

Layer pack

No automated equipment is known to exist in this area.

Vacuum bagged cuts

While there exists equipment to put other food products into vacuum bags, the authors are not aware of any machines for automatically placing fresh red meat in vacuum bags. However, Cryovac, in the USA, does have some mechanised equipment, which still requires an operator, for putting meat into bags. Once the meat is in the bag, no machinery is known to exist that automatically aligns the bags containing the meat on the platen of the vacuum machines. Machines do exist for aligning bags containing other products, but none is known for fresh red meat.

There is an excellent range of equipment available from several manufacturers for evacuating vacuum bags and sealing them. Cryovac makes the largest machines, with the highest throughput being around 30 bags per minute. For throughputs below this figure, several companies have products that are well suited to the task. Many of these companies also supply the follow-on automated equipment for shrinking the bags and removing the excess water.

Some x-ray equipment exists for detecting foreign bodies in cartons of meat. This equipment could be used where buckshot in meat is a serious problem.

5.3.5 Research and development requirements

Scanning the generic task list (Table 8) for tasks labelled "manual" clearly shows many tasks for which research and development effort is required if our aim is to produce a fully automated packaging system. The following list represents those tasks for which no equipment is known to exist:

- Identify a cut
- Compare with specification
- Determine its size, orientation, fat content, colour, weight, etc.
- Place cut into a bag

- Individually wrap cut in plastic
- Align bag on vacuum machine platen
- Check for "leakers"
- Re-process leakers
- Sort meat cuts by colour
- Put meat into a carton
- Adjust weight of bulk pack
- Close liner.

Having listed the tasks that require further research and development, it is important to evaluate these tasks to determine a priority order for their achievement. Most of these tasks are technically feasible to automate, so the priority will be to do those tasks that are economically feasible and give the highest return. Appendix 4 describes the tasks and sub-tasks required to fully automate each of the four packaging classes.

From the data in Table 10 clearly the volume, in tonnes, of beef exports is four times larger than the volume mutton and lamb combined and that beef exports earn the country eight times more than mutton and lamb combined. In view of these facts, *the remainder of the report will be aimed at the automation of beef packaging operations.* Some of these techniques will be applicable to lamb and mutton with very little modification.

Based on the data in Section 5.1.2 and Table 2, the research priorities should be aimed at bulk and vacuum-packaged meat, as nearly 90% of all Australian export beef is in these two types of packaging. Therefore, most of the packaging labour is involved in packing bulk meat into cartons or vacuum packaging meat.

The authors recommend that the research and development effort into packaging system automation be spread across several coordinated projects. The priority list suggested by the authors is presented below. These priorities may be modified after consultation with industry representatives. The prioritised list is:

Table 12. Suggested priority of automation tasks.

Task	Priority
Develop a conceptual framework for automated packaging, using a systems approach	1
Place meat cut into a plastic bag	2
Identify a cut	3
Compare with specification	3
Determine its size, orientation, fat content, colour, weight etc.	3
Pack meat into a carton	4
Individually wrap cut in plastic	5
Align bag of meat on vacuum machine platen	6
Check for "leakers"	7
Re-process leakers	8
Close the liner on a bulk pack	9
Sort meat cuts by colour	10
Adjust weight of bulk pack	11
Integrate the above into a complete system	12

We will now discuss each of these tasks in more detail.

1. Develop a framework for automated packaging
The two methods for transporting meat in packaging areas, either in cartons or with the meat sitting directly on conveyor belts, show marked differences in their efficiency. The authors consider it important to develop a framework (systems approach) for the design and operation of the fresh red meat packaging area of a meat plant. This framework would form the basis of packaging automation future projects, which would be designed to fit into it. This would allow plants to start upgrading their packaging areas immediately and continue to improve their efficiency through the installation of automated machinery designed to fit into the system. The framework would define a system that would be modular in nature, thus allowing individual meat processing plants to install only those modules they felt necessary. This step is a necessary precursor to the automation of the other tasks. A microbiological study of both meat transport

systems would also be of use, as anecdotal evidence suggests that meat transported on belt conveyors can have a shorter shelf life.

2. Place meat cut into a plastic bag

   There is a large pool of labour at most beef processing plants placing meat cuts into plastic bags for vacuum-packaging or for individual wrapping. The authors consider that the automation of this operation is technically feasible. The major unknown now is the sizing of the machine in terms of its cost, throughput and range of meat cuts handled. Clearly it would be desirable, from an occupational health and safety viewpoint, for the machine to be targeted at the larger and heavier cuts initially. Further information is required on the dimensions and weights of all cuts to be placed in bags.

3. Identify a cut

   This task is critical to many operations involved with packaging meat. Although the task of identifying a meat cut and comparing it with a specification has already been done by the slicer, once the slicer has passed the cut on, this information may be lost and need to be re-evaluated. This is the case with systems that transport individual meat pieces on belts. Unless a way can be found for all meat pieces to be instantly identifiable during the entire packaging process, research and development effort will be required, to find automatic ways of performing this task.

4. Compare with specification

   Once a meat cut has been identified, it must be compared with a specification, to ensure that it is processed correctly by the rest of the system.

5. Determine its size, orientation, fat content, colour, weight etc.

   Beyond the identification of a cut, many other attributes of the cut may need to be known at various points in the process. While broad parameters for each type of cut may be known, individual cuts will need to be measured to determine their size so that, for example, the appropriate bag size can be selected. For cuts that need to be weight ranged, the weight must be measured, and so on. The list of attributes to be measured is likely to change continually as new information is required by the process or the customer.

6. Pack meat into a carton

   This task statement is very concise but, in practice, has many facets. Placing meat into a carton requires different solutions for bulk meat, layer-packed meat and vacuum packs or individually-wrapped cuts.

7. Individually wrap cut in plastic
There is a significant market for individually-wrapped cuts of beef. For lamb, this type of wrapping for individual cuts is the most common. A project to automate this operation would likely be aimed at both beef and lamb cuts.

8. Align bag of meat on vacuum machine platen
This operation requires several labourers at each meat processing plant. Our initial thoughts are that this project would be aimed at the large rotary machines. Once the problem had been solved for these machines, the project could continue to apply the technology to the manual or semi-automatic chamber machines.

9. Check for "leakers"
Most meat plants producing vacuum-packaged beef have a "leaker" rate of between 1 and 3%. With "leakers," the bags have not been properly sealed and air has leaked in. Most of these are immediately evident, although a percentage will not be detected until 24 hours or more after packaging. Some companies re-inspect all their vacuum-packaged product before it is shipped, to minimise the number of leakers sent to their customers.

10. Re-process "leakers"
Once a "leaker" has been detected, it must be re-processed. This means that the meat must be removed from the old barrier bag and put back into the packaging process.

11. Close liner on a bulk pack
Now all bulk meat cartons have a plastic liner that must be closed before the carton is sealed. This is now done manually and is a candidate for automation.

11. Sort cuts by colour
Some vacuum-packaged product is sorted by colour before being placed in the carton. If this is necessary, then an automated colour measurement and sorting system would be required.

13. Adjust weight of bulk pack
When bulk meat cartons are filled manually, there is considerable variation in their weight. This project would aim to automatically weigh all cartons, reject those not within the weight tolerance and either remove or add meat automatically.

14. Integrate the above into a complete system
Once several modules are functional it may be valuable to integrate them. Thus, data collected at one module could be passed on to other modules. This would be especially

relevant for the measurement module that could make its data available to other modules in the system.

Bulk packs

Bulk-packed meat forms a special case. Because of its nature, it may be advantageous to process the meat in bulk rather than as individual cuts. There seems to have been some work done already on the automation of packaging for bulk packs. Unfortunately the exact details of the projects are unknown to the authors at this time. It would be worthwhile setting up a project looking specifically at bulk packaged meat and assess the options for automated meat handling on that basis.

This project would involve the handling of meat in bulk, rather than as individual pieces, as is required for the other types of packaging. It has been suggested a system where meat to be bulk packed should be separated into lean meat and fat. The meat and fat streams are then diced or minced and combined into a carton to produce cartons of meat exactly matching the weight and chemical lean specifications. The MRC is already funding projects in this area.

5.3.6 Proposal for the next stage(s)

The authors propose that the next stage of the project start with a detailed study of new packaging system layouts, optimised for product flow and flexibility of application. This system design would form a framework for the other projects. However, other work need not be held up, as this study would be completed before any other projects would be affected. We propose that the initial emphasis for the work be on beef as this is the red meat species with the largest export production and export earnings. However, many results could be immediately applied to sheep processing where appropriate. Thus, work would begin with:

- Developing a framework for packaging systems automation
  The results probably can be applied immediately to existing plants, to reduce the congestion and bottlenecks often seen in packaging areas of meat processing plants.

Concurrently with the above study, the authors propose that work begin on the following items; in the order suggested and assuming the use of plastic bags for vacuum packaging:

- Placing meat cuts in plastic bags
  This task can initially be broken down into three components. These comprise the sizing of the meat cut, the physical placement of the meat in the bag and the selection of the appropriate sized bag.

- Identify a meat cut

- Compare with Specification

- Determine its size, orientation, fat content, colour, weight etc.
  We suggest that these tasks be developed together, because of the need to specify what properties are important before they are measured. By doing all tasks concurrently, the identification system can be tested by using the specifications already developed. The measurement system is likely to be needed to sort meat cuts by size and measure cut dimensions and therefore bag size for the automatic bagging machine.

- Placing meat cuts into cartons
  This development would concentrate on taking wrapped meat cuts and placing them in a carton. The clear emphasis in the project would initially be vacuum-packaged cuts. The technique finally developed may or may not apply directly to individually-wrapped cuts.

The following tasks are in a category where they could be started immediately, or be delayed pending the completion of other work or awaiting research and development funds to become available. Industry representatives may be better placed to advise on the relative priorities of these tasks.

- Align a bagged cut to vacuum packaging machine platen

- Identify "leakers" in vacuum bags

- Re-process leakers

- Individually wrap a meat cut
  This task may be better delayed until the work on placing meat cuts into bags has been completed. If successful, the technology could be used almost without modification to put these cuts into non-barrier plastic bags.

- Close liner on bulk pack

- Sort by colour if required
- Adjust weight if necessary

- Integrate the above into a complete system

6. INTELLECTUAL PROPERTY

No new intellectual property has been developed during this contract.

7. RECOMMENDATIONS

This report has shown that the initial emphasis should be on beef and that bulk and vacuum packaging account for 90% of all beef produced. Additionally, there is considerable R & D effort being spent on improvements in the area of bulk packaging.

The authors therefore recommend that MRC initiate a programme aimed at the automation of many of the tasks involved in vacuum packaging of beef cuts. The programme would be set up to:

1. Conduct a thorough analysis of beef vacuum packaging in its present form. This analysis would look at the types of cuts being currently, or likely to be, vacuum-packed. Information should be collected on each cut as to its dimensions, giving typical values as well as an indication of maximum and minimum values, its weight and other data that affect the vacuum packaging of each cut. This data would form a basis for later machine design.

2. Investigate alternative technologies and assess their viability for vacuum packaging of beef cuts in a meat processing plant. This requirement has come from a perception by the industry, that non-bag technologies may be preferable to bag technologies. This study would recommend a technology to go on with.

3. Seek industry opinion on the direction and priorities for the research and development tasks identified in this report. Industry representatives would also need to advise on the detailed specifications for each piece of equipment to be developed, especially in terms of throughput and range of meat cuts handled.

4. Develop the equipment required to substantially automate the process of vacuum packaging beef cuts and show a cost savings of at least 20% in the next two years.

8. PROJECT FUNDING

The major funder for the projects in their early stages would be the Meat Research Corporation. However, as projects progress and require plant trials, individual meat processing companies would be asked to contribute by sponsoring equipment trials at their plants. This would require a significant commitment from the plant management and staff, in terms of time, space and product to put through the new machinery.

Depending on the type of project, packaging companies could be very interested in investing in the development and resulting technology.

The New Zealand Meat Research and Development Corporation may also be interested in a joint development programme in this area, as the New Zealand market could also benefit from this type of technology.

Other international meat research and development funding organisations, such as the Meat and Livestock Commission in England, could be invited to participate in funding the programme.

9. IMPACT OF RESULTS

9.1 Now

This report sets out the research and development tasks required to develop a completely automated packaging system for the packaging of fresh red meat. As such, it forms a blueprint for much of the future automation work required in this area. The immediate impact of the report is in its definition of the research and development tasks ahead.

The report shows that there are immediate areas of research and development that have the potential to produce significant gains to the industry in the next few years.

9.2 In 5 Years

The benefits in 5 years will depend on the investment of funds into the research and development of packaging automation. However, given that adequate funding is invested into this area, the returns are likely to be significant. The exact returns are difficult to quantify at this time but as an example, Danaflex quote packaging savings of 20 to 40% with the introduction of their automatic bag-making machine.

The results in Section 5.3.2 indicate that one packer processes the equivalent of 14 carcasses per day in the vacuum packaging of meat cuts. Therefore, a plant processing 800 carcasses per day with 46% vacuum-packaged meat, requires, on average, 26 packers for placing meat cuts in bags and then into cartons. If this process can be fully automated, meat processing plants could save in the order of $750,000 per annum based on a cost of $30,000 per packer per annum. Another 6 people, costing $180,000 per annum, are involved in feeding and packing off the vacuum packaging machines.

The same plant would require 2 packers for producing layer packs, a cost of $60,000 pa, 13 packers, costing nearly $400,000, for packing bulk meat and 5 packers, costing $150,000 for producing individually-wrapped meat cuts. The packaging costs are significant as are the returns from successful automation.

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11. ACKNOWLEDGEMENTS

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Finally, we would like to thank our colleagues at MIRINZ, who have helped with innumerable discussions on various aspects of this project.

APPENDIX 1: MEAT PROCESSING PLANTS AND BONING FACILITIES VISITED DURING THE PROCESSOR SURVEY

Meat Processing Companies

Company	Plant	Type of Stock
Australia Meat Holdings (AMH)	Rockhampton	Beef
Smorgan Meat Group	Rockhampton	Beef
AMH	Dinmore	Beef
AMH	Toowoomba (Beef City)	Beef
Morex Meat Australia	Grantham	Beef
Nippon Meat Packers	Oakey	Beef
South Burnett	Murgon	Beef
McPhee Export Meats	Blayney	Beef
Fletcher International Exports	Dubbo	Sheep
AMH	Aberdeen	Beef
Clover Meats (Wynnes)	Waroona	Beef
E.G. Green & Sons	Harvey	Beef
Metro Meats	Katanning	Beef & Sheep
Metro Meats	Noarlunga	Beef & Sheep
Tatiara	Bordertown	Sheep
R.J. Gilbertson	Altona North	Beef
Castricum Brothers	Dandenong	Beef
R.J. Gilbertson	Longford	Beef & Sheep

Service Works

Stock Processing Company	Plant Location	Boning-Room Operator
Northern Co-operative Meat Co.	Casino	Northern Co-op
Livestock & Meat Authority of QLD	Brisbane - MRA	Associated Meat Exports
Livestock & Meat Authority of QLD	Brisbane - MRA	Remserv Australia
Cudgegong Abattoir	Mudgee	Namoi Valley Beef
Gunnedah Shire Council	Gunnedah	Throsby
Gunnedah Shire Council	Gunnedah	Fletcher International
Gunnedah Shire Council	Gunnedah	Namoi Valley Beef
South Australian Meat Corporation	Gepps Cross	Austral Meats
South Australian Meat Corporation	Gepps Cross	R.J. Gilbertson
South Australian Meat Corporation	Gepps Cross	Overland Meat Export Co

APPENDIX 2: PACKAGING MACHINERY COMPANIES VISITED OR CONTACTED

The largest supplier of packaging material and equipment is clearly the ***Cryovac*** division of ***W.R. Grace***. However, it was made clear that this company is primarily a supplier of plastic bags. Thus, it supplies machinery to ensure that customers use it's bags. The reader's attention is drawn to the use of the word bags above. This is an important point, as Grace is interested in selling bags to the industry. They also supply plastic film, but given the option or the ability to influence, they will opt for the supply of bags.

Cryovac supply the international meat industry with the large rotary vacuum sealing machines made by a Japanese sister company. These machines are well known in the meat industry internationally and seem to operate successfully. The company also supplies mechanised bag loaders for the US meat processing industry. One of these was seen by the first author, operating at a US beef processing plant with a production of five thousand carcasses per day. The bag loader required an operator to select the bag and place it over the outlet from the machine. The machine was designed to work with a boning room where the meat was transported on belts.

The European development centre for W.R. Grace, in Milan, has developed a single chamber vacuum machine for use in plants with a smaller throughput. It also produces the standard accessories of a hot water shrink tank and a unit for removing water from the package before it is placed in the carton. This last step of water removal from the pack is critical for the quality of the cartoned meat. Too much water and the bottom of the carton can fall out or it can encourage microbial growth that, although not affecting the meat, is extremely unpleasant and possibly dangerous to the people removing the meat from the carton at the consumer end. The centre has also developed an automatic feed system for regular shaped blocks of product such as cheese. However, it admits that an automatic feed system for fresh red meat would be much more difficult to develop.

Multivac is another company that was visited, and has an interesting range of machinery for packaging fresh red meat. They have two product lines, comprising a range of vacuum chamber machines and a range of horizontal rollstock machines. The vacuum chamber machines are of the batch cycle type and operate on a similar principle to other batch type vacuum chamber machines. Multivac offers a range of different machine sizes, from the small type suitable for butchers shops to large conveyor-fed machines suitable for medium sized meat processing plant's. They have a double chamber machine with a swing lid, which allows an operator to unload and reload one chamber while the other is evacuating. The chamber lid is then swung over and the operator works on the other half of the machine. They also supply a large chamber machine that will handle whole cartons of product for applications such as master packs or to evacuate liners in cartons.

Multivac also supply a range of horizontal rollstock machines. In these machines the packaging material starts as rolls of film. The film is fed into the machine where it is heated and formed into a mould. The machines are very long and comprise several stations that operate in parallel. After the tray has been formed, the meat is loaded into the cavities either by hand or automatically. The top film is then overlaid and the processes of evacuation, gassing and sealing are completed. Finally, the individual packages are separated at the cutting station. This type of machine, while not fast in its operation, makes a very attractive consumer-ready package that can also be used for the HRI trade.

The ***Inauen Machinen*** company makes the VC999 range of vacuum chamber machines for meat processing plants. This company prides itself in excellent engineering and has made some advances in the technology including a very good sealing bar. They have also developed a good range of accessories necessary for a vacuum packaging operation in a typical meat processing plant. Their top end machine is a single chamber machine with a conveyor infeed that is synchronised with the machine operation. Thus, one operator need only get the product ready for the machine, the rest is all automatic. One sheep processing plant in Australia has 18 of the VC999 vacuum chamber machines in its boning room.

M-Tek is another company with a novel range of vacuum packaging and gas flushing machinery. Their probe technology for vacuum packaging is based on the philosophy of evacuating only the bag, not a large chamber. They have developed a range of machinery that can be used for vacuum sealing and gas flushing and have also developed a good sealing bar technology that looks superior to that of many of its competitors.

Transpak Industries use the ChillTech system. This system is based on a snorkel vacuum chamber type machine. The system differs from conventional vacuum packaging in that a foil bag is used to ensure that the oxygen permeability is zero, and the pack is flushed with a 100% CO_2 atmosphere to ensure that microbial growth is kept at a minimum. The equipment for this is manufactured in New Zealand and this system, and another similar system (CAPTECH) is already installed in several meat processing plants in New Zealand plus some in Australia.

Danaflex Industries have developed an automatic bag making machine with Machinery Developments Ltd in Auckland, New Zealand. They have a range of machines that make bags on demand from a roll of tubing. As the bag length can be set to any value, Danaflex is intending to produce a system that automatically measures the length of a meat cut and automatically make a bag of the correct length. Danaflex has patented this technology and have machines installed in several countries throughout the world, including Australia. They report that companies with their automatic bag maker can make packaging material savings in the order of 20% and total savings in the order of 40%. One situation noted was where a company did not have to put bags away at the end of the day because their automatic bagger could be locked with the material in it, and be cleaned at night. This allowed the company to process stock for an extra 15 minutes per day, because of the use of the automatic bagging machine. This would obviously significantly improve the benefits from installing such a machine.

Trigon Engineering has developed an automatic bag dispensing and opening machine for vacuum barrier bags. The machine starts with a roll of plastic tubing that is used to make the individual bags by sealing and cutting the tube. The bag is then dispensed onto the machine platen and automatically opened using a fan blower. The machine has been designed to make bags of a fixed width but of various lengths. With some modifications the machine could be coupled to an automatic meat cut measuring system and produce bags to order of the exact correct length for an individual meat cut. Early trials of the machine have shown savings in the order of 15% over the use of conventional bags.

APPENDIX 3: A DESCRIPTION OF THE DIFFERENT PACKAGING TYPES

All meat leaves a boning room in cartons. The authors identified four generic classes of packaging namely; bulk pack, layer pack, individually-wrapped cuts and cuts sealed in vacuum bags. Each of these generic packaging types is described below, along with the description of a Controlled Atmosphere Pack.

Bulk

For a typical bulk pack, meat is placed into a brown cardboard carton into which has been placed a plastic (polyethylene) liner. The carton is filled to a target weight of 27.2 kg, generally, with a tolerance between ±50 and ±100 grams. This represents an error in the order of ±0.2 to ±0.4%. The carton is also filled to a target chemical lean (CL), usually between 50 and 90 percent. This is checked by sampling some cartons from each production run, or by using an automatic, on-line CL analyser. Bulk-packed cartons are usually frozen before export.

Individually Wrapped

Individual wrapping of meat cuts tend to be used for larger cuts generally intended to be frozen. The cuts are individually wrapped in plastic sheet, or placed into non-barrier bags, before being placed into a carton. A common wrapping method is called the "lolly" wrap, where the cut is placed on a sheet of plastic and, after the cut is wrapped in the plastic, the ends are twisted as with a lolly. The twisted ends are then tucked into the exposed edge of the sheet. This type of packaging is quite attractive although it is labour intensive and can cause workers repetitive strain injuries (RSI), otherwise known as occupational overuse syndrome (OOS). This product is typically put into brown cardboard cartons and frozen before export.

Layer Pack

The layer pack is reserved for only a few selected cuts. These mainly comprise the fore and aft shank meat and the intercostal meat from the ribs. The meat is packed into a standard carton with a plastic liner as with the bulk pack. However, each piece of meat is placed by hand into neat rows in the carton. The bottom of the carton may contain, say, three rows of cuts to form a regular pattern or "layer" of meat. Once a particular layer is full, a thin sheet of plastic is placed into the carton to cover the meat and another layer is started. This process is continued until the carton is full. The result is, visually, very attractive although it is very labour intensive to produce. This product is typically put into brown cardboard cartons and frozen before export.

Vacuum Bag

Vacuum packaging is often reserved for the best cuts that will generate maximum returns. Individual meat cuts are placed inside either barrier or non-barrier bags, generally one cut per bag. This process is labour-intensive, in that each meat cut must be individually lifted off a table or belt and placed on a forked stand so that the bag can be pulled over the meat. The bags, with the meat inside, may then be placed in a carton and conveyed to the vacuum packaging machine or conveyed directly on a conveyor belt. At the vacuum packaging machine, the cuts are removed from the carton or belt, run through the vacuum sealing machine and shrink-tunnel, then placed into a carton.

Vacuum bags are also used for bone-in products such as racks of T-bone steaks with beef or (frenched) racks with lamb. These racks are vacuum-packaged using a bag with built-in or added bone guard.

For sheep, the main cuts to be vacuum-packaged are the loin, tender loin and backstraps. The meat cuts are placed inside barrier bags, generally with several cuts per bag and possibly on a tray filled to a specific weight. This process is labour-intensive in that each meat cut must be individually lifted off a table or belt, placed carefully and neatly on a tray, weighed and trimmed to the desired weight then placed in a bag. The bags of meat are then taken, perhaps manually, to the vacuum packaging machine. The bags are then run through the vacuum sealing machine and shrink tunnel, then placed into a carton.

The vacuum-packaged cuts are typically put into white cardboard cartons and exported chilled.

Controlled Atmosphere Pack

This type of packaging has been used mainly on lamb where there has been a requirement to increase the chilled product shelf life. Although vacuum packaging can be used successfully for lamb, the shelf life is less than beef. Thus chilled lamb has had to be air freighted to the market, which is very costly. Controlled Atmosphere Packaging has increased the shelf life for chilled lamb, enough to allow chilled meat to be sea-freighted to all major markets.

Individual meat cuts are placed inside bags made from metal-laminate film, generally one cut per bag. These films are completely impermeable to oxygen. The individually packaged meat cuts are then conveyed to the controlled atmosphere packaging machine. There are several different types of machines for delivering the controlled atmosphere to the pack. The two most common are the chamber and the snorkel machines. Both machines initially evacuate the bag then introduce a 100% carbon-dioxide atmosphere, which inhibits microbial growth. The bags are then packed into a carton in the usual way before chilling.

Controlled atmosphere packaging is also used for bone-in products such as whole lamb carcasses.

APPENDIX 4: TASKS REQUIRED TO FULLY AUTOMATE THE PACKAGING OF MEAT

Vacuum Packaging

The sequence of tasks, based on the use of bags, required to fully automate the vacuum packaging of meat cuts is given below. The primary tasks have already been described in Section 5.3.1 of the report. However, when developing an automation strategy, each task must be broken down into a set of elemental tasks that can be automated.

- Identify a cut

  The process of automating the vacuum packaging of meat cuts must begin with the selection of the cuts to be wrapped. While this may seem trivial, different classes of stock have different cuts vacuum packed. Thus, each cut to be vacuum-packed needs to be identified, either manually or automatically.

- Compare with specification

  Once a cut has been identified, it must be checked to see if it conforms to the specification or list of cuts to be vacuum-packed.

- Determine its size & orientation

  As the cut will be put into a bag, its dimensions and orientation will need to be known. If necessary, the orientation of the cut may need to be changed so that it will align correctly with the automatic bagging machinery.

- Select or make an appropriately sized barrier bag

  There are automatic machines already available to make bags on demand and these have been designed to interact with human operators. The problem now is to have a machine that can select or make bags on demand and present them to the bagging machine without human intervention. The bag size will clearly be decided by the size of the meat cut, and this will have been measured earlier.

- Place a meat cut into a barrier bag

  This task will require that the size of the cut is known and that an appropriately sized bag will be presented to the machine. This means that the sole task of the machine is to place the meat, of known size, position and orientation, into the appropriately sized bag that has already been selected and presented to it.

- Align bag of meat on the vacuum machine platen

  This task is difficult if the bag size and orientation are not known beforehand. Ideally this task would follow on from the previous one because the bagging machine will already have the bag in a known orientation. If the bag, with the meat inside can be passed from the previous machine on to this machine, its design would be greatly simplified.

- Evacuate and seal bag, shrink and remove excess water

  There are many companies that can provide equipment for these tasks. However, their design may require modification to ensure that all meat cuts retain a known position and orientation after they have passed through these machines.

- Check for "leakers"

  The incidence of leakers has been quoted as between 1 and 3%, although we are aware of situations where this rate has gone well into the double figures. In some extreme cases it can get close to 100%. A fully automated system would clearly need a means for detecting leakers. Meanwhile, detecting leakers could be done manually, but efforts should be made to automate leaker detection.

- Re-process leakers

  All leakers must be re-processed in that the meat must be removed from the bag and the cut placed back into the packaging system. The incidence of leakers will determine if this operation is done manually or automated. The authors would suggest that the leaker incidence rate should drop dramatically once the placing of meat into bags and bags onto the vacuum machines has been automated.

- Put vacuum-packaged cuts into a carton

  Once the meat cut has passed through the vacuum packaging machine, shrink bath and water removal unit it must be placed into a carton. This presents a new set of challenges, as many tasks previously undertaken must be done again. Unless that cut has been tracked through the entire process, something that is highly desirable, each cut must be re-identified. It may also need to be weight ranged and sorted by colour. If we are dealing with lamb, individual cuts may need to be labelled. Additionally the size and orientation of each cut will need to be known so that the system can select the appropriate carton to place the cut in, and how the cut is to be placed in the carton. Therefore, unless the information about a cut can travel with it through the process, many tasks already completed will need to be redone. Additionally, if the processing system loses the orientation of the cuts, they will need to be re-scanned to find out this information. Therefore, the need for a systems approach to the automation of this process to retain maximum benefit from the process information already collected.

- Close carton, weigh, label, strap and move into the chillers

  These tasks are already significantly automated, but will need to be completely automated to fit into the integrated system we are proposing.

Layer Packing

The sequence of tasks required to fully automate the layer packing of meat cuts is described below. The primary tasks are described in Section 5.3.1 of the report. However, when developing an automation strategy each task must be broken down into a set of elemental tasks that can be automated. This section will discuss in detail only those that are significantly different from the previous section.

- Identify a cut

  The cuts required are the fore and hind shank meat from both beef and mutton carcasses and the intercostal meat from beef carcasses.

- Compare with specification

- Determine its size & orientation

  As the cuts will be neatly layer-packed, the machine will need to know their dimensions and orientation.

- Put in carton

  Once the position, size and orientation of the meat cut is known, it must be placed into a carton. The fact that cuts are placed in a regular pattern in the carton should make the automation task much easier.

- Close liner, close carton, weigh, label, strap and move into the freezers

  Closing the liner is the only task, in this list, not currently automated.

Individually Wrapped

The sequence of tasks required to fully automate the individual wrapping of meat cuts is given below. The primary tasks were described in Section 5.3.1 of the report. However, when developing an automation strategy each task must be broken down into a set of elemental tasks that can be automated. In this section, we will discuss in detail only those items that are significantly different from the previous sections.

- Identify a cut

- Compare with specification

- Determine its size & orientation

- Select or make an appropriately sized bag or piece of plastic

  If the cut is to be placed in a bag, the process will be similar to that described in the vacuum packaging section except for the vacuum packing steps. These will not be discussed here. Otherwise the size of the film will be calculated from the size of the meat cut that will have been measured earlier.

- Wrap the meat cut in plastic

  This will require that the size of the cut is known and that an appropriately sized sheet of plastic has been presented to the machine. This means that the sole task of the machine is to wrap the meat, of known size, position and orientation, with the appropriately sized film that has already been selected and presented to the machine.

- Put in carton

  Once the meat cut has been wrapped, it must be placed into a carton. If the wrapping machine presents the cut correctly to this machine, its task would be greatly simplified because the cut would be at a known position and of known size and orientation.

- Close liner and carton, weigh, label, strap and move into the freezers

Bulk Pack

The sequence of tasks required to fully automate the bulk packing of meat cuts is given below. The primary tasks were described in Section 5.3.1 of the report. However, when developing an automation strategy each task must be broken down into a set of elemental tasks that can be automated. In this section, we will discuss in detail only those items that are significantly different from the previous sections.

- Identify a cut

- Compare with specification

- Determine its weight and fat content

  The carton must be packed to a particular weight and chemical lean content. Meat to be packed in the carton must be scanned so that its weight and fat content are known.

- Put in carton

  The carton must be packed to a weight of 27.2 kg, usually, and to a predetermined chemical lean content.

- Close liner, close carton, weigh, label, strap and move into the freezers

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