INTRODUCTION

Over the last 10 years the New Zealand meat industry has invested heavily in developing technology for automated processing of sheep and lamb carcasses. Original work concentrated on the dressing process, but more recently effort has also been directed toward the mechanization of sheep and lamb boning. The objective of this work is not only to reduce cost but also to improve quality and, in the case of the boning developments, to achieve an increase in the meat recovery or yield.

The two programmes have been broadly based with inputs from meat processing companies, producer boards, government research agencies, commercial engineering companies and the Meat Industry Research Institute of New Zealand (MIRINZ).

This paper describes the major developments in the order that they appear in the sheep slaughter, dressing and boning process rather than in the chronological order in which they were designed and built.

Mechanical dressing developments will be discussed first followed by a description of the major boning development.

DRESSING DEVELOPMENTS

Automatic stunning

Automation of high voltage electrical stunning not only reduces costs but also improves workers' safety. All automatic stunners developed to date use a Vee restrainer system for controlling the location of the sheep throughout
the operation. MIRINZ developed an automatic stunner in which a single Vee restrainer brings the animal to a position adjacent to two grids of electrodes, after which the grids move to contact each side of the head. Nozzle electrodes disposed throughout each grid then administer electrical current to the head, and at the same time release water to assist current passage (Fig. 1).

Figure 1. Automatic stunner for sheep.

Pelting

Most of the developmental effort involving sheep slaughter and dressing has been in the area of pelt removal. In New Zealand alone, many different groups, organizations, and engineering companies have developed and refined concepts designed to reduce the manpower needed for pelting.

In 1981 MIRINZ developed an inverted manual dressing system that incorporated several existing and new butchery techniques. This system gave considerable manpower reductions over existing systems and has been the basis of virtually all subsequent developments to date. Its major attributes include simplicity and ease of installation.

The New Zealand Mechanical Dressing Project has developed additional systems to further reduce the manpower needs for pelt removal. It first developed the six-head rotary pelting machine, which removes the pelt from the belly and lower back area as well as the hind legs (Fig. 2). The Project also developed a two-stage pelting operation involving two machines - a shoulder puller (Fig. 3) and a final puller (Fig. 4). The shoulder puller removes the pelt from the shoulder and back regions while the final puller completes the pelt removal by pulling the pelt off the hind legs.
Figure 2. Rotary pelt
In this multihead rig, a ring is pushed between the carcass and pelt. The carcass is then lifted from the sock.

Figure 3. Shoulder puller
Front leg skin flaps are gripped, then pulled out and down to clear skin down to middle of the back.

Pelt removal from the sternum or brisket has been the subject of a number of new designs. Various hand tools have been developed over the years to improve productivity. Recently a brisket clearing machine has been developed, which simplifies the entire brisket workup, particularly in inverted dressing systems (Fig. 5).
Figure 4. Final pelt puller.
The partially pulled pelt is pulled over the hind legs and discharged.

Figure 5. Brisket clearing machine
Counter rotating drills free the skin from the brisket and cut a narrow strip of skin from the centre line.

Automatic front and rear hock removal machines have also been produced, to fit in with the inverted mechanized dressing concept. To assist in the
transfer of the forelegs from the wide spreader to the narrow hock holder, a special transfer machine was developed (Fig. 6). Since this hock holder grips the radius and ulna bones, the front hocks (or trotters) can be removed without the support of the carcass being lost. If this removal occurs early in the dressing process, potential contamination from the front trotters onto the carcass is eliminated during most of the pelting operation.

Figure 6. Wide-to-narrow transfer

Evisceration
After depelting, evisceration and offal handling are the next biggest users of manpower. Several developments have been undertaken to partly mechanize this area. Brisket cutting and belly opening was the first area studied. An early machine, again developed within the New Zealand Mechanical Dressing Project, mechanically cut the brisket. Since then, a new machine that not only cuts the brisket but also opens up the belly area has been designed and is now awaiting production trials. Work is continuing on improved and mechanized methods of viscera removal and handling, but it is too early to report on any of the outcomes.

Head Processing
The regulation requiring heads to be presented with the carcass for inspection was partially relaxed in 1987, so that only those heads from which brains and tongues are to be saved need be inspected.

Developments arising from this regulatory change included automatic atlas joint severing, automatic head splitting, and automatic brain extraction (Fig. 7).

Performance of a Mechanized System
Table 1 gives the potential manning levels for a mechanized sheep slaughter and dressing system, processing eight lambs per minute and based on developments so far. This manning level (25 plus 11 assistants) is much less than that of a traditional system, which needs a manning of 44 plus 15 assistants.

Cost Savings
Rigorous assessment of the cost savings is difficult due to the experimental nature of some of the machines. An estimated cost saving of 50 cents per carcass (about 12%) is achieved by replacing a conventional dressing chain with an inverted manual dressing system, which uses only the final puller of the machines listed in Table 1. The potential savings of incorporating all the machines listed in Table 1 and allowing for suitable servicing and replacement costs is an additional 40 cents per carcass (an additional 9%). These estimates are based on the assumption that overall carcass and pelt
quality remain the same, and on a normal daily kill of 3200 lambs per chain. No account has been taken of any associated building costs.

Figure 7. Automatic head splitting and brain extraction
The head conveyed to machine is positioned, cleaved from the underside, then opened to allow the brain to be sucked out.

Table 1. Potential chain manning for mechanized sheep and lamb slaughter and dressing.

<table>
<thead>
<tr>
<th>Task</th>
<th>Manning</th>
<th>Equivalent Traditional Manning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stun (auto)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Shackle, Open, Bleed</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Auto Neck Break</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Head Cheek, Remove</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Y Cut, Push Flap</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Clear Neck, Lift Shanks</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Auto Wide to Narrow Transfer</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Auto Front Trotter Remover</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Load Brisket Clearer</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pull Brisket Piece, Y Cut Rear Legs</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Load Shoulder Puller</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Clear Breaks, Punch Tunnels</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Auto Final Puller</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Trim Anus</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Auto Rear Trotter Remover</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td>Auto Wash</td>
<td>-</td>
<td>21</td>
</tr>
<tr>
<td>Auto Brisket Cut</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Gambrel</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Evisceration</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

Total: 25 44
The major objective of the mechanical boning programme is to improve the efficiency of recovering structurally intact, whole-tissue meat from carcass bones. The first major development of this programme is the frame boning machine.

Frame Boner
The frame boner removes the soft sides from mutton carcasses. To minimize labour input, maximize yields, maximize processing rate, produce a product of consistently high quality and accommodate a range of carcass sizes, a fully automated machine configuration was chosen.

Figure 8 sketches the machine.

A prototype has been constructed that has a throughput of 190 carcasses per hour. To date, the meat recovery (yield) is greater than that which can be achieved by manual boning.

FUTURE DEVELOPMENTS

Butchery
Most butchery and dressing operations require skilled staff. The tasks require high levels of hand/eye coordination (Clarke et al. 1988): subtle tactile, force and torque feedback; dexterity; and skill. Intricate tasks must be carried out rapidly to maximize throughput while maintaining high yield.

Implications for Automation of Butchery
It is unlikely that a single machine would be able to completely dress or bone a single carcass (c.f. solo butchery). Thus any future automated system is likely to consist of a number of specialist machines of varying complexity, interconnected by suitable materials-handling and communications
systems (Gater 1988). The mechanized dressing developments just described show this approach, as a number of separate machines have been developed for specific tasks.

Most automatic machinery consists of three basic components:
- Sensors
- Mechanics
- Controller

As the tasks become more complex, any or all of these components will become more complex. The current array of machinery developed by MIRinz has tended towards machines using relatively simple components in each of these areas.

Perhaps the greatest research needs at present are in the areas of sensing and control. Suitable sensors are a prerequisite for many control tasks, and areas such as machine vision, tactile sensing, and force and torque sensing require development before they can be applied to meat and meat products.

It may be necessary to apply knowledge-based systems to machine control for specific tasks. This type of control would be used in conjunction with appropriate sensors. Controllers may require information derived from other machines and stored in a database. For example, critical dimensions for each carcass could be measured before processing starts and stored in a database available to all machines working on that carcass or a cut from that carcass.

The new generation machinery should be versatile in its operation. A person can often compensate for the mistakes of others, but the current generation of machinery tends to be intolerant of previous mistakes. Therefore, versatility is an important design criterion in the research and development phases of the next generation of machinery.

Dressing
Dressing involves the production of carcasses for human consumption. New Zealand leads the world in the automation of sheep dressing. Most of this work has been done at MIRinz where the development philosophy has been to use the lowest level of technology able to do the job, an approach that has been very successful.

However, at present it would not be cost effective to automate the entire dressing process completely. This is because, for some jobs, a person can perform far better than a machine, for the reasons just outlined. Dressing tends to be a sequential process that incorporates a number of specific tasks, time delays (e.g. time is needed for an animal to bleed completely) and rate limitations (e.g. pelt removal is rate limited). Thus a totally automated dressing system would probably consist of a series of machines, each of which performs a specific function. To achieve maximum throughput, each machine would have a short queue of material, and slower machines could work in parallel.

Boning and Cutting
Boning and cutting involve the production of consumer portions of meat. In contrast to dressing, this area may require a high-tech approach, because separation of meat, fat and bone usually involves cuts being made, but not always at natural interfaces (Frazerhurst 1986). Instead, cuts are generally made relative to definable structures or surfaces, which implies a need for accurate sensing. Also, machinery working in this area must allow for flexibility, to give different final products to meet different consumer requirements and specifications.
The major objectives of the mechanical boning and cutting projects at MIRINZ have been to improve yield, productivity and product quality and to produce structurally intact, whole-tissue meat.

Because of the need for fast and accurate sensing in this area, MIRINZ has been overseeing the development of continuous sensors for fat depth and bone location. Workers in Australia have been using vision systems to fit models that will guide water-jets and powered knives. The powered-knife system also uses force/torque feedback.

Having successfully boned carcass soft sides we are now concentrating on mechanical leg and shoulder boning.

**Plant-Wide Automation**

Automation is not restricted to the slaughterboard and boning rooms. There are many other areas of a meat processing plant where significant automation has already been implemented. Some examples are automatic enginerooms, automatic carcass and carton freezers, effluent treatment plant control and rendering department control, and some of these control systems are very sophisticated. Work is continuing in many areas including the application of knowledge-based systems to engineroom control.

In future it is likely that meat processing plants will have large plant-wide communications networks, such as Manufacturing Automation Protocol (MAP), with a hierarchy of computers resembling a Computer Integrated Manufacturing (CIM) environment. Such a system would give the enlightened manager up-to-date information on all aspects of plant performance and would be a valuable tool for communication and co-ordination of management information throughout the plant.

New sensors are also of interest, including sensors for identifying animals, pelts, etc. Factors such as eating quality of the meat also need to be measured, and the development of an on-line tenderness transducer is being considered.

**CONCLUSION**

The meat industry has come a long way, from being a totally manual system to the present state where chain manning can be almost halved with current automatic machinery. The scope for innovation, invention and automation is enormous and there is much opportunity to increase the profitability of sheepmeat processing plants.

**REFERENCES**

