Department of Primary Industry
Australian Bureau of Animal Health

A survey of handling practices and facilities used in the export of Australian livestock

Temple Grandin
Livestock consultant

Australian Government Publishing Service
Canberra 1983

Contents

ISBN 0 644 02687 1

Acknowledgments

The author expresses her appreciation to the Australian Bureau of Animal Health for its confidence in her consulting firm. She also expresses gratitude and appreciation to all of the agencies and individuals who assisted her during this study.

Appreciation is extended to George Fahey, ruminant nutritionist at the University of Illinois, for his assistance in the preparation of the nutrition and feed formulation portions of this report. The author also expresses appreciation to the companies listed below whose co-operation made this report possible.

Elder Smith Goldsbrough Mort Ltd
Fares Rural Company Pty Ltd
Metro Meats Ltd
Ridge H. Pearce Trading Pty Ltd
Rural Export and Trading (W.A.) Pty Ltd
SIBA Australia Pty Ltd

Printed by Canberra Publishing & Printing Co.

Co

Introduction

This consultancy was conducted for the Australian Bureau of Animal Health to examine and evaluate the handling of Australian livestock in the export chain. R.W. Gee, Director of the Australian Bureau of Animal Health, states that, 'the government has given the investigations high priority in view of the need to ensure the continuing growth and prosperity of the livestock export trade as well as the undoubted need to respond to the concerns expressed by animal welfare organisations'. The scope of the consultancy was livestock preparation procedures, handling facilities and methods, feeding, watering, housing, penning on the ship and ventilation, up until the ships left port. During the six-week consultancy in May and June 1982, I toured six sheep preparation feedlots in South Australia and Western Australia and five sheep ships in Adelaide and Fremantle. It was not possible to view the Portland Victoria, facilities due to time constraints. All shippers co-operated fully and permitted tours of all ships which came into port at the time of my visit, but a few feedlots would not permit tours. Interviews were conducted with feedlot managers, shippers, ships' officers, State Department of Agriculture personnel, veterinarians, researchers and Department of Primary Industry personnel. I was accompanied by an Australian Bureau of Animal Health official who made most of the appointments and arranged the itinerary. A literature review was conducted of the relevant scientific literature, and findings from the literature review are included along with my observations. I also conducted seminars on livestock handling at the Departments of Agriculture in South Australia and Western Australia, RSPCAs, a producer group, the Australian Bureau of Animal Health, Australian National University and the National Rural Press Club.

Sheep preparation

The live sheep export trade is a large industry. Approximately six million sheep are shipped annually from Australia to the Middle East. Sheep are prepared for shipment in large feedlots near the main shipping ports. At the feedlots the sheep are introduced to the pelleted feed they will receive on the ship, shorn if necessary, drafted and vaccinated.

The shipping industry has made some major improvements during last year in sheep preparation feedlots. Impressive new handling and feeding facilities have recently been completed at Elder's feedlot and Ridge Pearce Trading Pty Ltd in Adelaide and the Fares Rural feedlot in Kojonup, Western Australia. The new pellet mill at the Fares feedlot is a first class installation.

Most of the people managing the feedlots were sincere and tried to do a good job of preparing the sheep. Some companies are doing an excellent job of sheep preparation, but, unfortunately, a few companies cut corners and do not keep the sheep in the feedlot long enough to fully introduce them to the pellets.

Why is preparation so important?

'Expert handling, feeding and management during this depot (preparation) stage is critical to the success of the entire venture' (Australian Meat and Live-stock Corporation 1981). Several ships' officers stated that the preparation is essential to minimise death losses.

To prevent health problems on the ship, the sheep must be readily eating the pellets before loading, otherwise they may refuse to eat on the ship. Good fodder intake is the key to a successful voyage according to Peter Arnold, consulting veterinarian. Time off feed is very detrimental to sheep, because deprivation of feed will predispose sheep to salmonella infections (Grau et al. 1969, Gardiner and Craig 1970). Salmonella infections are a major cause of death losses on ships. Research by Gardiner and Craig (1970) indicated that 33% of the death losses that occurred on board ship were due to salmonellosis. A recent study by Jelinek et al. (1982) revealed that 'at least one-fifth (20%) of the animals that died on the voyage had salmonella bacteraemia'. When sheep are off feed salmonellae multiply and are shed in the faeces. Salmonellae increased 300-fold after 48 hours of starvation and *E. coli* increased 2000-fold after 24 hours without food (Grau et al. 1969). Well-fed sheep and cattle are relatively resistant to salmonella infection (Brownlie and Grau 1967, Grau et al. 1969). Proper preparation will greatly reduce problems with sheep going off feed.

According to interviews, good preparation is especially important for sheep which come off green pastures. 'It is likely that failure of sheep taken off green feed to become accustomed to dry feed prior to embarkation is a significant factor in subsequent in-transit loss' (Gardiner and Craig 1970). Prefeeding rams from green pastures with a dry feed for ten days prevented many of the ill effects of a 3058 km journey (Franklin and MacGregor 1944).

Obtaining sheep and time off feed

Sheep are either obtained directly from a property or through a sale yard. Time off feed should be minimised to reduce problems with loss of appetite or salmonella (Franklin and MacGregor 1944, Swan et al. 1980, Fels 1982). Sheep starved two to three days had a drastic drop in appetite the second day after feeding resumed (Arnold 1976). Both Swan et al. (1980) and Fels (1982) state that sheep should be purchased directly from the properties and sale yard sheep should be avoided. Colin McDonald, Department of Agriculture in Western Australia, reports that shippers in Western Australia avoid sale yard sheep as much as possible and 80% of the sheep are obtained directly from the property of origin. Time off feed and water for more than 24 hours should be avoided (Fels 1976a, Swan et al. 1980). Starvation for four days results in the loss of many rumen micro-organisms in sheep (Warner 1962). In order to comply with the 24 hours recommendation long haul sheep should be avoided.

Malcolm Smith, Metro Meats in Adelaide, and Fels (1982) both state that sheep must have access to feed immediately after arrival at the feedlot. To reduce time off feed, most shippers had feed in the troughs when the sheep were loaded on the ship. Water was withheld until after a section had been loaded and fed. Water should be withheld until the sheep settle down (Australian Bureau of Animal Health 1981). This is similar to the husbandry practices in cattle feedlots. Calves arriving by truck are fed before they are watered to prevent digestive upsets (Grandin 1981a). On most ships the sheep started eating the pellets immediately which is one sign of good preparation.

Preparation time

The ideal way to prepare sheep for ship transport would be for the farmer to introduce them to eating pellets at the farm (Swan et al. 1980), and then truck them directly to the wharf. Compared to other livestock, sheep are most difficult to train to eat from a trough. It is easier to introduce sheep to pellets in a familiar environment such as the home farm (Kilgour 1976). In most cases this is not practical so the sheep have to be introduced to pellets at a preparation feedlot.

The Australian Bureau of Animal Health (1982) recommends that 'exporters should allow a minimum period of four to five days to prepare sheep off pasture to accommodate to dry shipboard rations and to rest after travel'. The Australian Meat and Live-stock Corporation states that sheep are normally held in the feedlot for three to ten days. Truscott (1977) reports that ten to fourteen days are required to prepare sheep for shipment and to cull high risk sheep such as shy feeders. When sheep are introduced to a new feed 'about ten days are needed to complete the major adjustments in the rumen microbial population' (Warner 1962). In order to induce all of the sheep to eat from a trough, a minimum of one week is required (Arnold 1976). George Fahey, ruminant nutritionist at the University of Illinois, states that ten to fifteen days are required to introduce sheep to a new diet depending on the roughage level of the feed.

Interviews with feedlot managers were conducted to obtain opinions on the minimum period sheep needed to remain in their feedlots for proper preparation. Since it takes time to buy and assemble 30 000 to 100 000 head of sheep, many of the animals would remain in the feedlot for longer than the minimum time required for preparation.

For agricultural sheep, Teissier, SIBA Australia Pty Ltd (1982) stated in a letter to the Department of Agriculture of Western Australia, 'in our operation we insist that the sheep are on our farms (feedlots) no later than eight days before loading (on the ship) to ensure that we have the opportunity to prepare them sufficiently'. Teissier prefers to have agricultural sheep held in his feedlot for ten days. Malcolm Smith, Metro Meats in Adelaide, states that he keeps sheep in his feedlot for ten days. Tom Rogers at Elder's Feedlot in Adelaide said he keeps sheep for seven to ten days depending on his client's requirements. Don Clark, Fares Rural in Adelaide, maintains that seven days is the minimum time required for preparation and ten days is preferable. Neville Pearce, Ridge Pearce Trading Pty Ltd, reports that they will not accept sheep from clients with unreasonable preparation programs. Rod Menzies, Fares Rural in Perth, states that the time required for preparation depends on how well the sheep eat the pellets and the firmness of their faeces. Sheep coming off green feed must have firm excreta to prevent hygiene problems on the ship (Australian Bureau of Animal Health 1981). If the sheep have been on green pasture they adapt less readily to dry feed. This could be explained by differences in rumen microbiology (Moir 1976). Sheep coming from fairly bare pastures are easier to shift to pellets than sheep from good pasture (Kilgour 1976).

Reports from ships' officers indicated that well-prepared sheep travel better and have lower death losses. One officer stated that he can maintain an 0.4% death loss with well-prepared sheep, but death losses on his ship rose sharply when he carried a load of improperly prepared sheep. Some people in the shipping industry stated that sheep can be adequately prepared in three to four days. Several feedlot managers reported that sheep need more time in the feedlot unless they have been introduced to pellets or supplementary feed on the farm. Controlled studies need to be conducted with commercial sized mobs of sheep held in preparation feedlots for different lengths of time.

Station sheep

Guy Teissier, SIBA Australia Pty Ltd, maintains that five to seven weeks may be required to prepare Western Australian station sheep. In Western Australia very few station sheep are purchased for shipping; however, in South Australia up to 15% of the sheep loaded onto ships are station sheep during certain times of the year (McDonald 1981). One feedlot manager in the Adelaide area reported that station sheep require at least two weeks of preparation, and they need special handling compared to local sheep. He said, long haul sheep from New South Wales which have travelled 600 to 1 600 km by train should be placed on pasture for three or four days before being introduced to the pellets. Holding New South Wales sheep in an Adelaide area feedlot for only two to three days or loading them directly onto a ship will result in very high death losses according to a feedlot manager and a ship's officer. Some organisations which reviewed this report prior to publication thought that some of the statements in this paragraph highlighted rather extreme situations. I have found from my experience with many types of livestock operations that 'so called' extreme situations occur more frequently than the heads of livestock organisations would like to admit.

Shy feeders

Shy feeders are a persistent problem in sheep preparation feedlots. Shy feeders are sheep which refuse to come up to the trough and eat the pellets. The shy feeder problem has been researched by Arnold and Maller (1974), Arnold (1979), Kilgour (1976) and Fels (1982). Most feedlot managers introduce sheep to pellets by feeding hay first and then gradually introducing the pellets and removing the hay. Problems have been reported if the hay is not removed. Some sheep may never start eating the pellets and may go off feed on the ship.

Adequate trough space is essential. In feedlot sheds 5 cm per sheep is adequate for sheep fed almost as much as they can eat (Fels and Malcolm 1973). Sheep fed concentrates from self-feeders in paddocks require 1 cm of self-feeder space per animal (Fels 1982). If the feed is rationed, 16 cm of trough space is required so that most of the animals can eat before the feed is gone (Arnold and Maller 1974). However, if the feed will all be consumed in a few minutes, 32 cm of trough space is required (Fels 1982).

Arnold (1976) and Marshall (1980) recommend separating shy feeders from the other sheep by quietly drifting them away from the rest of the mob a few minutes after the feed has been put out. The shy feeders should be kept in a separate mob and trained to eat by driving them up to the trough. If shy feeders are not recognised early, they may become health risks because they are not getting enough to eat. This increases the probability of salmonella infections and digestive upsets.

To reduce shy feeder problems, sheep should be separated into different age, sex and breed groups (Arnold and Maller 1974, Arnold 1976, Fels 1976a). Agricultural and station sheep should not be mixed (Hawes 1976). Teissier (1982) recommends separating large from small sheep.

The size of the paddock and the number of animals in a mob may also affect feeding behaviour. Hawes (1976) found that sheep placed in a huge paddock were slow to adapt to pellets. Colin McDonald, Department of Agriculture, Western Australia, discovered that sheep which had been shy feeders in a small dirt pen started eating when they were transferred into a shed with a slatted floor. Guy Teissier, SIBA Australia Pty Ltd, also reported that sheep settle down quickly when they are put in sheds with slatted floors. He prefers the sheds over intensive feedlot pens or large paddocks.

Present and future sheep preparation research

Trials are now under way by the Department of Agriculture, Western Australia, to study the behaviour of shy feeders. Feed troughs equipped with coloured marker bars are being used to determine how often different animals come up to the trough to eat. Richard Norris, Department of Agriculture, Western Australia, is experimenting with different preparation practices and then putting the sheep in a shed to simulate a ship. This kind of research is useful for obtaining research directions, but controlled studies with commercial-sized mobs loaded onto real ships are needed to accurately evaluate preparation methods.

Rod Menzies and Fares Rural Co., in conjunction with the Department of Agriculture, Western Australia, are conducting trials with mobs of sheep prepared at their feedlot in Kojonup. They plan to research preparation variables such as mob size, pen density, pen shape, trough length, preparation time, type of sheep, pasture type at farm of origin, and pellet formulation. Sale yard sheep, direct from farm sheep, and long haul sheep should also be evaluated. Tagged sheep which have been subjected to different preparation times and procedures should be carried on the same ship in similar deck locations. Their performance should be monitored until they are unloaded in the Middle East. Results of trials should be published in refereed scientific journals to ensure objectivity and high standards, and analysis of variance and other statistical methods should be used to analyse the effects of the different variables.

The sheep shipping industry has matured and it is now time for it to participate in scientific programs along with the rest of the agricultural community. Rod Menzies and Fares have been leaders in sponsoring research and working on ways to improve conditions for the sheep.

Ship size and sheep preparation

Another area of concern is the proper preparation of the large numbers of sheep required to fill the big ships, which hold more than 90 000 head. 'When large numbers of sheep are being assembled, often hurriedly for export, then breakdown in standards can occur' (Australian Bureau of Animal Health 1981).

There is probably an optimum size for a ship. It has to be big enough to achieve a good economy of scale, but still small enough to ensure that suitable sheep can be purchased and prepared properly. Interviews indicated that a 60 000 head ship may be the optimum size, but this requires further investigation. Teissier (1982) states that ships which carry in excess of 90 000 head are detrimental to the trade because nowhere in Australia are there facilities to care for and prepare such large numbers of sheep. A ship's officer on a ship with a capacity of over 90 000 stated that 60 000 head would be an ideal capacity for a ship.

Observations of large feedlots in the United States have revealed a similar problem. Large feedlots which hold over 80 000 head of cattle often have management problems when they receive large numbers of cattle in the spring and fall. Properly receiving, vaccinating and medicating, twenty truck loads of cattle per day is very difficult. During the peak season, receiving procedures often become sloppy in the biggest operations. Feedlots in the 30 000 to 40 000 head range have a good economy of scale and they are more manageable.

Design of preparation feedlots

The new trend in feedlot facilities is having semi-intensive paddocks instead of smaller intensive feedlot pens. Intensive feedlot systems are described by Fels (1976a, 1982). Several of the large shippers stated they preferred semi-intensive paddocks. A typical semi-intensive paddock is five acres and holds 1000 to 2000 sheep (Hawes 1976). If the paddock is too large the sheep will walk continuously and not settle down and eat (Hawes 1976). There are differences of opinion, however, on paddock size. Malcolm Smith, Metro Meats in Adelaide, states that northern sheep are accustomed to walking long distances and at Metro Meats they are first placed in a large paddock to prevent them from pacing the fences.

There may be a critical paddock size in relation to mob size that promotes pacing. A very small or very large paddock may inhibit pacing. Fels (1982) reports that too much space may be harmful in the absence of pasture. Studies with cattle cited by Grandin (1980) indicated that long narrow pens may reduce stress and fighting. The use of long narrow paddocks may reduce pacing and stress.

The location of the feedlot and the annual rainfall are also factors which are relevant to feedlot design. Good drainage is essential. To help control salmonella infections and other diseases, puddles that sheep can walk through and defecate in should be filled in. Spreading feed or hay on the ground should be avoided, because it may predispose sheep to salmonella (Pierson et al. 1972). Truscott (1977) also reports that feeding on the ground allows feed to become contaminated and predisposes to infection by the mouth, nose or conjunctivae. If sheep need to be fed on the ground to entice them to start eating, the feed should be placed in a clean dry area. When the sheep start eating, ground feeding should be discontinued. Only two out of the six feedlots toured routinely fed on the ground. Feed troughs had been recently installed in two feedlots.

Shade and shelter

None of the intensive feedlots toured had any shade, but they were equipped with sprinklers to control dust and help cool the sheep. The lack of shade in some sheep preparation feedlots has been criticised by animal welfare groups and the Australasian Meat Industry Employees Union. Most of the feedlots with semi-intensive paddocks had either rows of wind break trees around the perimeter or some single trees for shade and shelter. Trees have to be fenced or have guards around them to prevent the sheep from destroying them by ring barking. The Metro Meats and Fares Rural semi-intensive paddocks in Adelaide were completely surrounded by trees (Figure 1). This type of paddock is probably cooler than smaller intensive pens. Studies by Ittner et al. (1954) indicated that heavy wood corrals reflect and radiate heat. Livestock in wire pens surrounded by vegetation were several degrees cooler.

Interviews and a literature search were conducted to try to determine the shade and shelter requirements for sheep in both intensive feedlot pens and semi-intensive paddocks. During stormy weather sheep were observed seeking shelter on farms in Western Australia. Lynch and Alexander (1977) found that recently shorn Merino ewes made extensive use of shelter provided by hedges of tall grass (Phalaris hybrid). Ewes would also use wind breaks constructed from polyethelene garden mesh (sarlon 60% porosity) but hedge wind breaks were preferred because the hedges were more effective in blocking the wind. Fleeced ewes seldom used either type of shelter. Sheep seek wind breaks when the air speed exceeds 10 m/sec. especially when the temperature is below 0 degrees C (Curtis 1981).

Max Cameron, a farmer in Western Australia, observed that British breeds of sheep in large paddocks will seek shade during the summer, but the Merino sheep will stand out in the sun. His farm is located in an area with an average maximum temperature in January of 30 degrees C (Department of National Development 1972). Merino sheep in south-western New South Wales camped daily during the hottest part of the day and used the limited shade of *Atriplex nummularia* thickets (Squires 1974). During the observations, the mean daily maximum temperature was 32 to 38 degrees C. In Armidale, New South Wales, during the winter there was some evidence that unshorn Merino ewes would seek shade during warm sunny

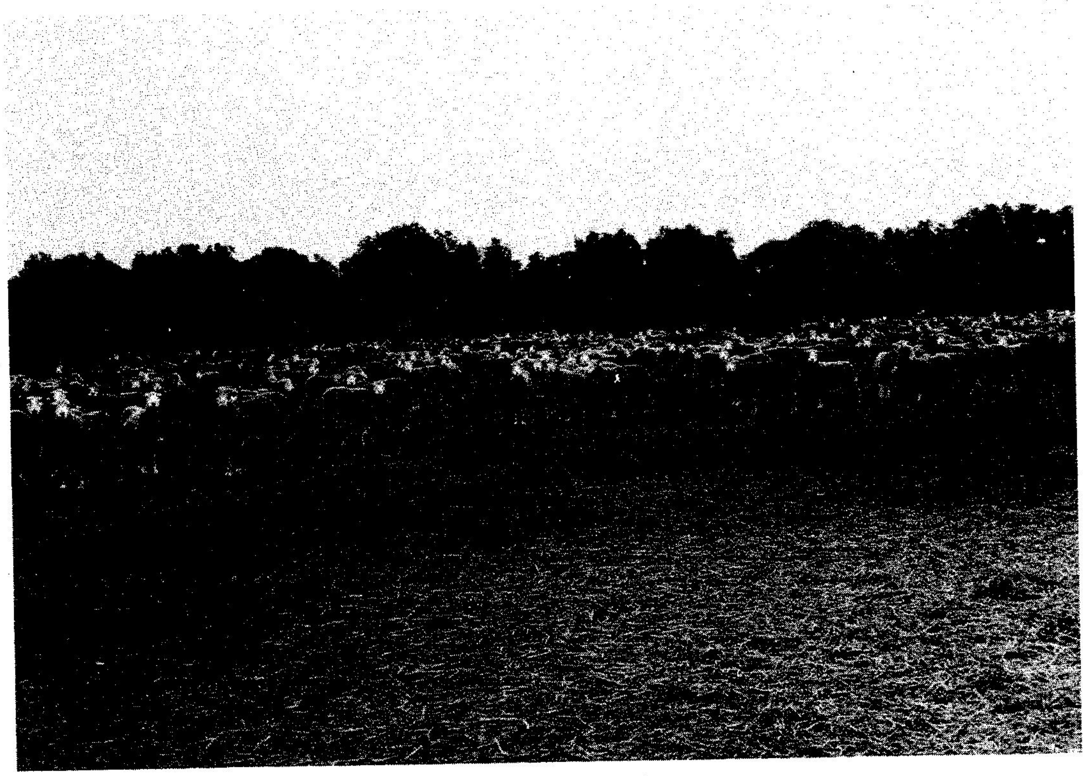

Figure 1 *Semi-intensive paddocks in Adelaide with wind break trees.*

days (Lynch and Alexander 1976). During their observations night temperatures fell below 0 degrees C. Roger Meischke, Australian Bureau of Animal Health, states that Merinos in paddocks with trees may seek a cool area near a dam instead of the partial shade of a tree. He has observed Merino sheep seeking the shade of a single utility pole. The animals positioned themselves so that the slender shadow fell on their heads. Hafez (1968) also reports that sheep will seek shade especially for their heads.

British breeds of sheep are more susceptible to heat stress than the Merino breed (McDonald 1981b). McDonald recommends that sheep yards should have shade and sheep should not be left standing in parked trucks on hot sunny days. The majority of the sheep shipped on ships are Merinos. The Merino is a very heat tolerant animal (Lee 1950). However, shorn Merino sheep standing in the summer sun at Julia Creek, Queensland, had twice the respiratory rate of fleeced sheep, because the fleece acts as a sun shade. 'But this strain on the organism is reduced if the sheep are in the shade or carry more than 3 cm of wool to offer insulation' (MacFarlane et al. 1958). The mean monthly maximum temperature during MacFarlane's et al. (1958) observations was 35 degrees C or over with a humidity of 20 to 50%. Laboratory studies by Parer (1963) with an artificial radiant heat source indicated that Merino sheep with less than 1 cm of wool had sharply increased heat conduction through the fleece. 'Respiration rate decreased with increasing wool length' (Parer 1963).

A more recent study by Hopkins et al. (1978) indicated that rectal temperature and respiration rate were elevated in freshly shorn sheep for one day after shearing. Eight days after shearing the shorn animals adapted and their rectal temperatures returned to almost the same levels as unshorn sheep. There are several factors which could account for the apparently contradictory results between McFarlane et al. (1958) and Hopkins et al. (1978). The critical variables are the interval between shearing and temperature measurement and the time of day of temperature measurement. McFarlane (1958) does not provide information on these variables. In order to come to a definitive conclusion, another study would have to be conducted on sheep which had been shorn at least eight days prior to temperature measurements. The temperature measurements should also be conducted at frequent intervals to take into account diurnal fluctuations. Hopkins et al. (1978) procedures for determining the environmental adaptability of sheep would have to be followed to get accurate results.

Brockway et al. (1965) states that sheep rely on respiration for cooling. Studies by Hopkins et al. (1978) in a hygrometric tent indicated that over half of a sheep's evaporative water loss was non-respiratory. Hopkins concludes: 'It is not possible accurately to calculate the cutaneous heat dissipation rate from these data, since the portion of the latent heat of evaporation which represents a net heat loss to animals with varying amounts of wool cover is open to conjecture'.

In some environments, 'Shades do lead to the remission of symptoms of heat stress in the middle of the day but the animal can readjust its heat content during the relatively cool night — there may be little effect of shade on productivity' (Curtis 1981). Givens et al. (1966) found that shades failed to improve weight gains in cattle in an area with an average maximum temperature of 31 degrees C. When shade was provided the cattle used it. In the US, shades are provided in Arizona and Southern California cattle feedlots because they improve weight gains in these desert areas. Shade is not provided for cattle in the Texas Panhandle feedlots because the small increase in production does not justify the cost of the shade. The desert areas are hotter than the Texas Panhandle. The daily normal maximum temperature in Phoenix, Arizona, on 15 July is 40.5 degrees C compared to a daily normal maximum of 32.7 degrees C in Amarillo, Texas (National Climate Center, 1973). The relative humidity in July is under 40% in both areas (Curtis, 1981).

It is difficult to make a specific recommendation on shade for intensive sheep preparation feedlots because I observed the sheep during the winter. The shade needs of Merino sheep in preparation feedlots are probably similar to the previous cattle example. The animals would prefer to stand under the shade, but they are not harmed physiologically if they are deprived of shade. Building shades in the intensive feedlot pens would make shorn Merinos more comfortable during the summer.

Weather data indicates that the average minimum temperature during January in the inland areas around Adelaide and Perth is 30 degrees C. The coastal areas have an average maximum temperature of 27 degrees C (Department of National Development, 1972). Interviews indicated that Adelaide temperatures will reach 36 degrees C and on rare occasions 40 degrees C.

Shade would definitely be required if British sheep or British cross sheep were prepared for shipment. Shades installed in intensive feedlot pens should be oriented north and south so that the shadow keeps moving. This will keep the ground under the shade dry. Position the shade so that the shadow will not fall outside the pen (Curtis, 1981). Some shade designs are cooler than others. A shade covered with a mat of hay is cooler than galvanised iron. Metal shades can be improved by painting the top white and the underside black (Curtis, 1981).

In semi-intensive paddocks shelter and shade in the form of windbreaks and trees should be provided. Windbreaks for shelter may be more important than shade to protect freshly shorn sheep from bad weather. Severe storms will kill freshly shorn sheep from bad weather (Geytenbeek, 1962). Interviews also indicated that heavy storms sometimes killed hundreds of sheep in Western Australia. Research should also be conducted on the use of artificial windbreaks in sheep preparation feedlots.

Wool length and shearing

The Australian Bureau of Animal Health (1981) states that export standards require that the average wool length on the sheep should not be greater than 25 mm. The majority of the sheep observed during ship loading in Fremantle and Adelaide were strong and vigorous and had wool 25 mm or less in length. About 5 to 10% of the sheep had wool slightly longer than 25 mm.

Shippers shear sheep because the animals travel better with less than 25 mm of wool (Hawes, 1976). Guy Teissier, SIBA Australia Pty Ltd, states that sheep travelling into the hot Middle East summer have lower death losses if they have only 13 mm of wool. Suiter (1976) adds that it has been the practice of importers to shear sheep so they have 13 mm or less of wool. Reducing the length of the fleece increases sensible heat loss in sheep (Blaxter et al., 1958).

Research by Klemm (1962) and Lee (1950) indicated that shorn Merino sheep were more tolerant of hot humid atmospheres compared to fleeced sheep. 'In general, moderately hot and hot wet atmospheres are better tolerated by shorn animals, but hot dry atmospheres are better tolerated by the unshorn' (Lee, 1950). Shearing increased heat tolerance in rams kept in a humid room at 40.6 degrees C (Wodzicka, 1960). The environment inside a ship is often hot and humid (Suiter, 1976, Australian Bureau of Animal Health, 1981). One ship's officer reported that freshly shorn sheep can become dehydrated. Merino sheep do sweat (Lee, 1950).

The ideal fleece length depends on many factors and more research is needed. Possibly sheep which are travelling to hot dry areas in the Middle East should carry more fleece than sheep travelling to hot humid areas. Sheep travelling to hot and dry areas need to have enough fleece to protect them from the sun after they arrive. Stanley Curtis, environmental physiologist, University of Illinois, suggested that sheep travelling on more humid enclosed decks may need shorter fleeces than sheep travelling on outer open decks where they are exposed to the sun and stormy weather. Sheep travelling on open decks across the Australian Bight during the winter need enough fleece for protection during the Bight crossing, but still need a short enough fleece to avoid heat stress problems when they encounter hot humid weather after they cross the equator.

The Australian Bureau of Animal Health (1982) recommends that shearing be conducted at least seven days prior to shipment to enable sheep to recover from shearing stresses. Swan et al. (1980) recommend shearing sheep on the property of origin and allowing them to recover on pasture before they encounter the stress of transport and preparation. Malcolm Smith, Metro Meats, states that only about 5% of the sheep received in his feedlot are shorn there, but the farmer still needs to do a better job of caring for the sheep so they are not full of parasites when they receive them.

Shearing is definitely stressful to sheep (Hutchinson and McRae, 1969). Deaths within twelve days after shearing increased if the sheep had a high rate of body weight loss four weeks prior to shearing (Hutchinson and McRae, 1969). The important variable was rapid weight loss prior to shearing, not the absolute body weight or condition at shearing. Sheep which had sustained rapid weight loss prior to shearing may require more than seven days to recover from shearing stress to be fit for shipment.

If sheep arrive at the preparation feedlot with a slightly over-long fleece, the added stress of shearing has to be balanced against the relief from heat stress that removing the excess wool will provide. The best way to handle these sheep would be to ship them in an open deck in an outer pen. On the other hand, Teissier (1982) believes that shearing all sheep lessens their discomfort during the journey. Sheep from Teissier's feedlot are loaded on ships at Fremantle and do not have to cross the Bight. Wool length is an area where controlled studies on ships are needed.

Dusty feed

Feed pellets manufactured in the Adelaide area were excellent and did not crumble or create a dust problem. Pellets manufactured in Western Australia crumbled apart after being conveyed through the pneumatic feed handling system on the ship. Some batches of Western Australian pellets were 50% dust when they reached the sheep's trough in the ship. Dusty feed is recognised as a problem which needs to be corrected, according to Lloyd Beeby, Australian Meat and Live-stock Corporation and A.S. Pells, Department of Agriculture, South Australia.

Even though sheep will eat the dust, it may have less nutritional value because the small particles pass through the animal more quickly. If a roughage feed is ground into fine particles, the rate of passage through the system is increased and the portion digested may be reduced (Milne and Campling 1972, McDonald 1981a, Fels 1982, Van Soest 1982).

Dusty feed is less palatable, and sheep will eat less of a dusty food compared to a feed presented without dust (Wilkins et al. 1972, Arnold 1976). Malcolm Smith, Metro Meats, states that dusty feed fed to sheep on ships causes pinkeye. Dust can also cause localised inflammation of the eyes and conjunctivitis (Howard 1981). Dust in the air can impair animal performance and is detrimental to respiratory health (Sweeten 1978, Fairbank and Addis 1979). A ship's officer stated that dusty feed gets stuck in the animal's throat.

Interviews indicate that part of the problem is that binders used to hold the pellets together are scarce in Western Australia. They also have a limited choice of feed ingredients. SIBA Australia Pty Ltd has partially solved the Western Australia dust problem. Instead of using the standard 5/16 in pellet die they are having feed manufactured through a 3/16 in die. The smaller pellets are less prone to crumbling, and can withstand being conveyed through the ship's feeding system. One problem with this method is that smaller pellets are 10 to 20% slower to manufacture and there is a possibility that the roughage may have to be ground more finely to pass through the smaller die.

There are many interactions between particle size, type of feed ingredient and binding agents. SIBA reported that peat worked well as a binder to hold the pellets together. When ships are being renovated, bucket elevators should be installed to convey the feed out of the feed bins instead of pneumatic systems. This would help prevent crumbling.

John Suiter, Department of Agriculture, Western Australia, stated that research on pellet formulation is definitely needed. The shipping industry needs to employ a nutritionist with practical pellet mill experience to work on improving the feed. The new Fares pellet mill at Kojonup would be a good place to develop a palatable nutritious pellet which would not crumble easily.

Handling

Sheep being loaded onto trucks were observed at the Fares Rural Feedlot in Kojonup. Observations were also made of cattle being loaded onto the deck of a sheep ship. One large sheep ship and one medium sized sheep ship were observed loading sheep in Adelaide. In Fremantle two large sheep ships and one medium sized sheep ship were observed during loading. The large ships had a capacity of 90 000 or more sheep, and the medium sized ship had a capacity for 30 000 to 40 000 head.

Ship ramps

All the ships observed had a wide loading ramp which could accommodate six to ten sheep abreast. The wide ramps on the newer ships were lowered like a drawbridge and they were a big improvement over the narrow ramps on older ships. The ramps worked on the same principle as a wide shearing shed ramp (Barber 1979). Most of the ramps had a separate walkway for the handlers. This feature is definitely recommended. The ramps were solidly constructed and most of them had solid side fences.

At high tide the angle of the ramp exceeded 25 degrees on a few ships. The sheep moved up the steep ramps easily. Sheep will move up hill more readily than down hill (Hitchcock and Hutson 1979a). Ramps exceeding an angle of 25 to 30 degrees may cause problems with sheep slipping or falling during unloading at the destination port. Ideally a ramp should not exceed 20 degrees for unloading (Grandin 1979, Warren 1980). One ship had a good system which eliminated a steep ramp at high tide. During high tides, the regular ship's ramp was pulled up and a door in the hull under the ramp was opened to admit the sheep.

Western Australia — truck loading and handling

Sheep preparation feedlots operated by two companies were visited. At the Fares Feedlot in Kojonup, truck loading was observed the night before ship loading. Truck loading was a smooth operation and the handlers and truck drivers were gentle and professional. The trucks were in good repair. A few well-trained dogs were used to fill the loading pens, but dogs were not used in confined areas such as the forcing pens and loading ramps. The use of dogs in confined spaces can contribute to bruising (Stevens and Lyons 1977, Holmes 1980). Poorly trained dogs that bite and excite sheep will cause more stress compared to well-trained dogs (Kilgour and DeLangen 1970 and Thurley and McNatty 1973).

The loading area was equipped with five loading ramps and observations indicated that multiple ramps are essential for a smooth operation. The loading ramps had partially solid sides and the sheep moved easily up the ramps. Sheep movement may be further enhanced by installing completely solid sides. Solid side fences are recommended in all areas where livestock are crowded (Grandin 1980). Sheep moved more rapidly through narrow races with solid sides (Hutson and Hitchcock 1978). Each loading ramp had narrow pens behind it which held two truck loads of sheep. The pen closest to the ramp had three compartments which held one truck deck of 120 sheep each.

Installation of additional lighting over the trucks is recommended because it would entice the sheep into the trucks at night. Animals have a tendency to move from a darker place into a lighter place provided that the light is not glaring in their eyes (Kilgour 1971, van Putten and Elshof 1978 and Grandin 1980).

The design of the new handling and drafting facilities at Kojonup was excellent. The curved bugle race drafting yards were very well designed. Curved races and yards are recommended by Marshall (1966), Kilgour (1971), Barber (1977), and Grandin (1980).

The livestock loading, handling and shearing facilities were toured at two SIBA Australia Pty Ltd feedlots. Their handling facilities were old but adequate. Shearing was observed, the sheep were handled gently and seldom nicked with the shears. Several other feedlots in the Fremantle area would not permit tours. Interviews indicated that some of these feedlots may need to improve their facilities and sheep preparation practices.

Western Australia — sheep loading

The loading procedures for the three ships observed in Fremantle were excellent. The sheep were loaded quickly with a minimum of excitement. Veterinary inspectors observed each animal as it walked past them in a single file race. Sheep which were unsuitable for transport were quietly drafted out, and the strong vigorous animals were loaded. Sheep were drafted out if they were injured, diseased, blind, parasitised or in poor condition. The unsuitable sheep were loaded back onto trucks and returned to the feedlot. Within a two hour period about twenty head of unsuitable sheep were drafted out. No sheep were held overnight on the wharf and no dogs were used.

Two of the ships were loaded by Fares Rural and SIBA Australia Pty Ltd. They used a unique loading system which consisted of a series of trailers (Figure 2). The system had either four or six unloading ramps and two to five trucks could unload at a time. The trailer system is an excellent piece of equipment and 4000 sheep per hour could be loaded easily. Since the trailer floors were at the same height as the bottom decks of the trucks, a ramp was only needed for unloading the top decks.

The sheep passed from the unloading ramp through a single file race past the veterinary inspector. The inspector stood on the wharf and observed the sheep as they walked past him at eye level on the trailers. Several inspectors stated that they preferred the trailer system because they could examine sheep more easily on the raised platform. Since the sheep passed the inspection at eye level the inspector could easily observe the underside of the animals and see conditions such as pizzle rot. The unsuitable sheep were drafted out into a small pen on the trailer.

The wide ship's ramp rested on one of the trailers. The wheels on the ramp rested in guides so the ramp could move with the tide. This system also has the advantage of reducing the steepness of the ship's ramp. After the ship is loaded the ramp is winched up and the trailers are hitched to vehicles and towed off the wharf.

The third ship loaded by Rural Export and Trading Pty Ltd had a system of portable unloading ramps and single file races which were set up directly on the wharf (Figure 3). This system was very good and the sheep were handled calmly and efficiently. The system had four portable sections. The races had solid sides except for one section where the veterinary inspector stood. The unsuitable sheep were drafted out and held in a pen between the races. The four single file races lead up to the bottom of the ship's ramp which rested on the

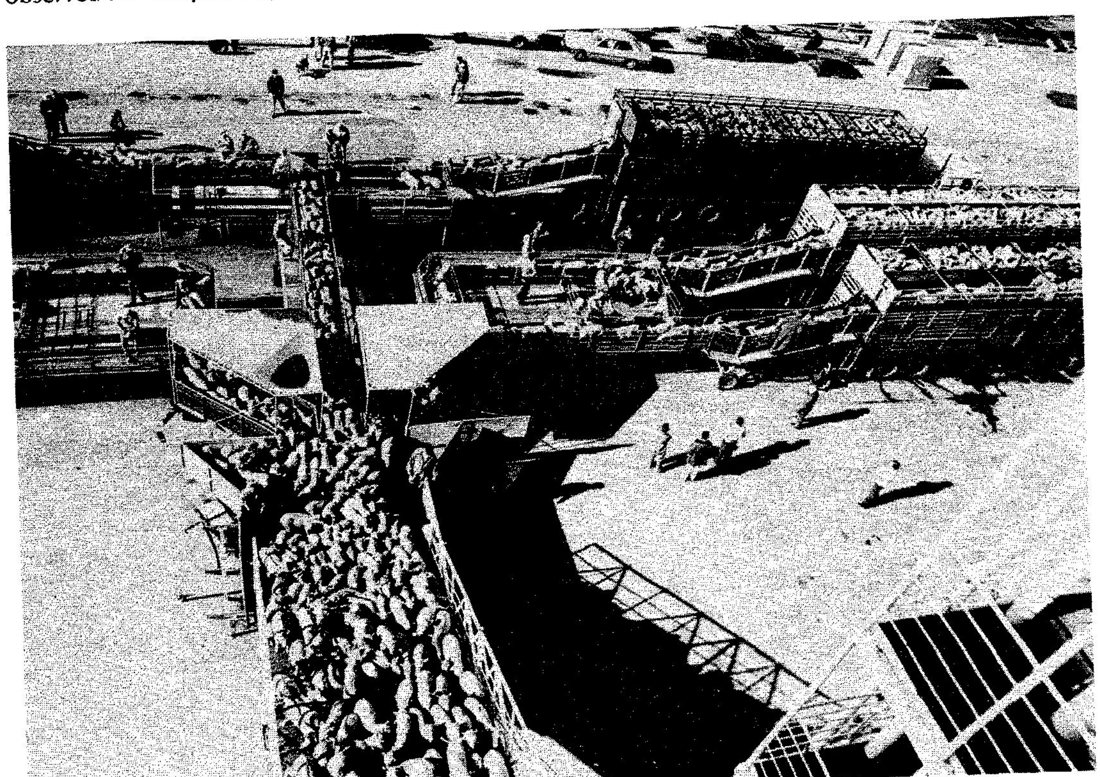

Figure 2 *An excellent trailer-mounted loading system in Fremantle.*

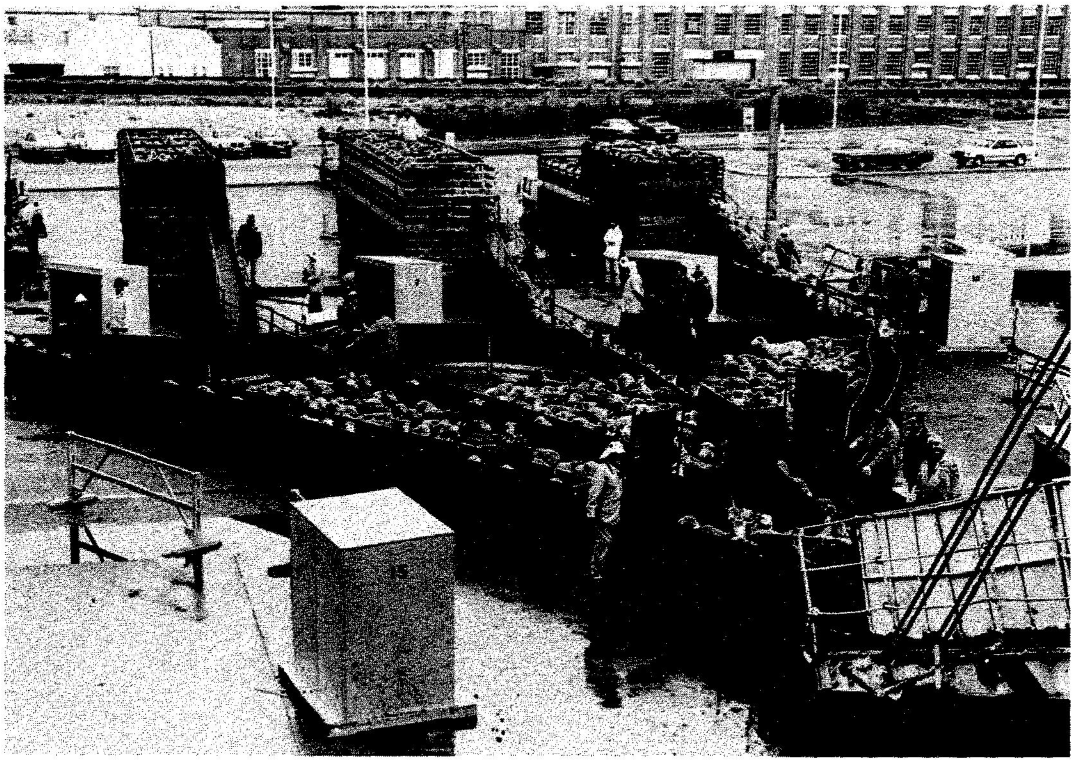

Figure 3 *Very good loading and inspection system constructed from panels. Sheep which are unsuitable for export are drafted out and held in the pens in between the four single file races.*

wharf. In both this system and the trailer system, two truck decks could be unloaded simultaneously.

The sheep handling and loading systems in Fremantle were excellent. These systems should be used as a model for improving facilities and methods at other ports.

Western Australia — cattle loading

I observed one ship loading cattle in Western Australia (Figure 4). The handlers and truck drivers were calm and professional. There was no rough handling or abuse. The captain of the ship assisted in loading the cattle and showed concern for them. The ramp system needed some improvement. The cattle were unloaded directly from a truck onto the wide ship's ramp. Some of the cattle slipped and fell because the cleats on the ramp were too small. Recommended cleat dimensions are 3.8 cm by 3.8 cm with a 20 cm space between the cleats (Mayes 1978). At the top of the ramp some cattle slipped on the deck. A grid constructed of 2.5 cm rods running in both directions on 30 cm centres will prevent slipping in alleys and handling areas. The rods must be securely attached to the deck.

There were also problems aligning the ship's ramp with the truck. Some cattle had difficulty exiting from the truck and immediately ascending the ramp, while part of their bodies were still inside the stock crate. When cattle are unloaded from a truck, a level surface should be provided for them to walk on before they reach the ramp (Stevens and Lyons 1977, Grandin 1979). A single portable trailer similar to the ones used for loading sheep would make cattle loading easier and safer for both cattle and people (Figure 5). The trailer should have solid side fences and a separate walkway for the handlers.

South Australia — truck loading and handling at the feedlot

Sheep preparation feedlots operated by four different companies in the Adelaide area were visited. At Elder's feedlot elaborate new loading and drafting facilities have been completed. The

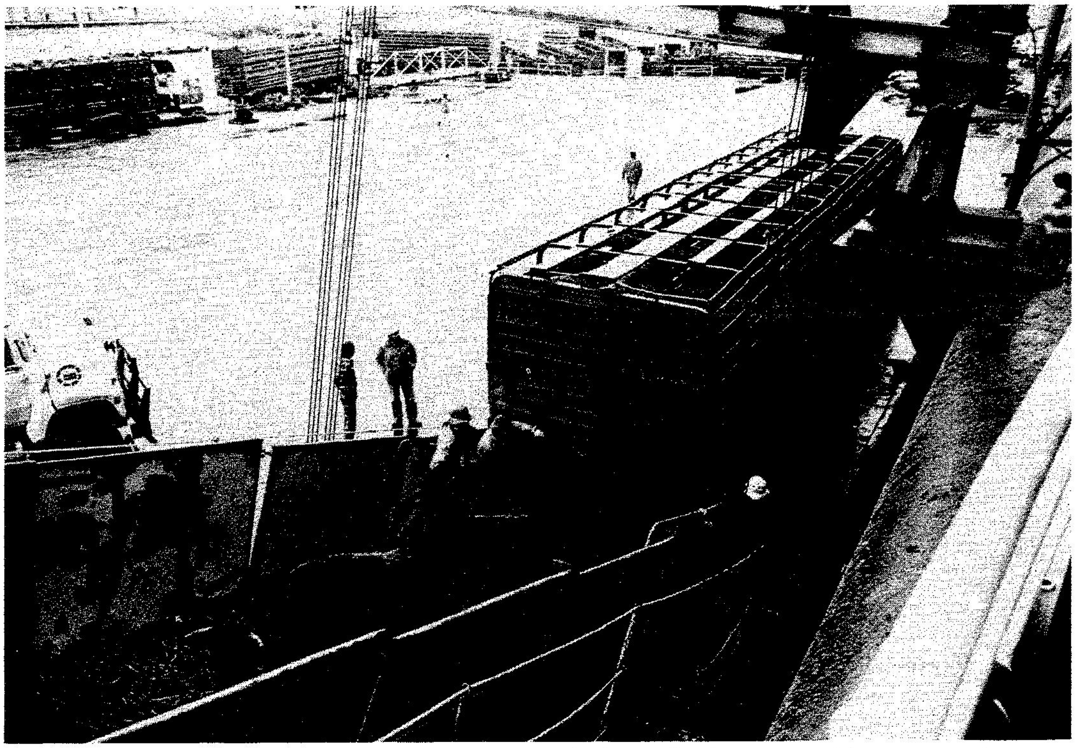

Figure 4 *Cattle being loaded onto a ship. The truck is backed up to the ship's ramp. This system needs some improvement.*

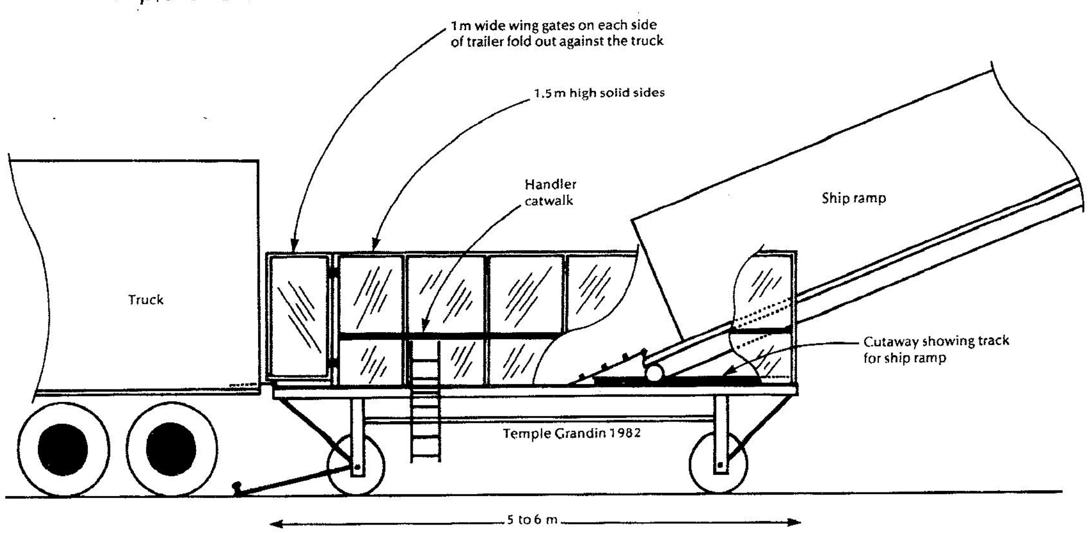

Figure 5 *A portable cattle loading system. A trailer provides a level surface for the cattle to walk on when they exit from the truck. This reduces injuries and balking.*

new system had five double deck loading ramps. A six stand shearing shed was built with a large area under cover for holding sheep for shearing. The Metro Meats and Ridge Pearce feedlots also had good handling facilities. Metro has a 32 stand shearing shed and four different sets of races for drafting and vaccinating sheep. They also had an extensive system for loading rail cars. I did not observe the rail system in operation, but it looked like a good design.

Fares Rural keeps some sheep at a small feedlot outside Adelaide. The handling facilities were old and needed repairs. Don Clark, Fares Livestock Manager, drafted some sheep himself in those old facilities. He put a rain coat on over his business suit and operated the drafting gate. I have respect for a manager who will get his hands dirty instead of trying to run his operation from an office desk.

Sheep loading at Adelaide

Ship loading was observed at Outer Harbor and Port Adelaide. Both Adelaide ports are equipped for rail car unloading. Only truck unloading was observed because the railroad tracks were torn up due to wharf construction work.

At Outer Harbor, several thousand sheep were brought to the wharf the night before ship loading and placed in a converted cargo shed. Portable ramps were used to unload the animals into the shed. The unloading operation was conducted in a decent manner, but a few improvements in the equipment are recommended. Some sheep slipped and fell on the concrete floor at the bottom of the ramps. Installing sheets of welded mesh on the floor would prevent slipping. The installation of lights

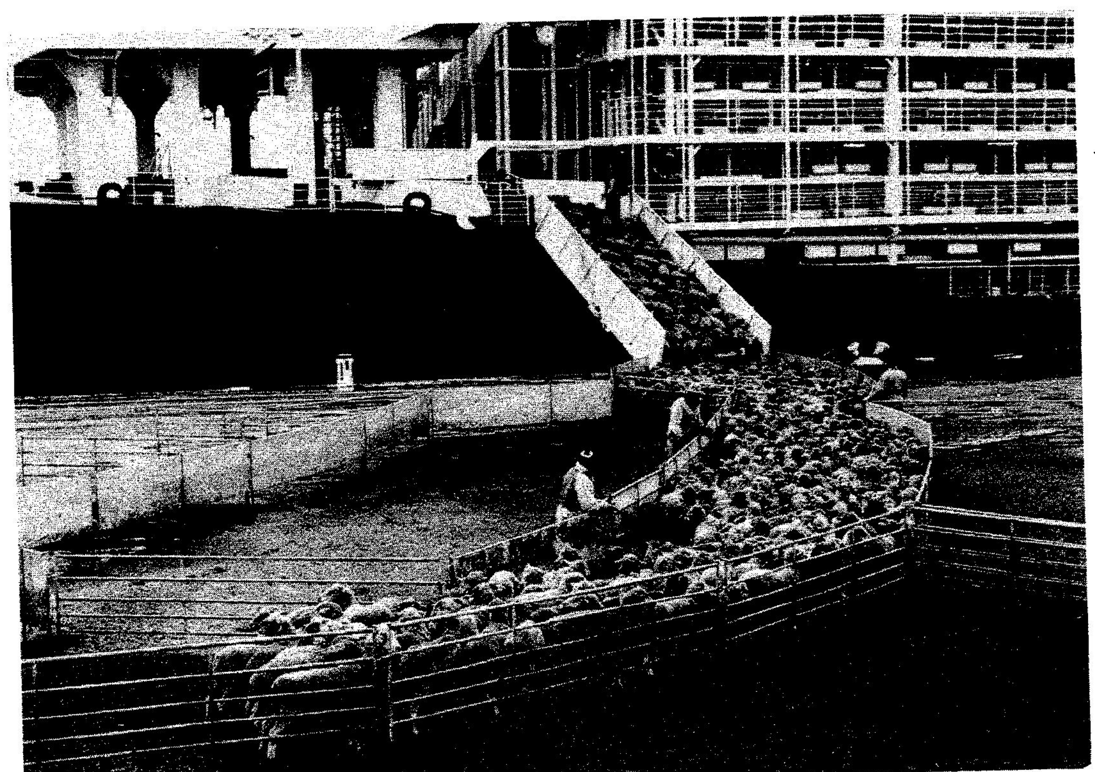

Figure 6 *Loading a ship at the Outer Harbor in Adelaide with portable yards. This system needs to be improved, because it has no inspection races and the sheep are sometimes difficult to handle in this system.*

over the unloading ramps would facilitate unloading at night. The lights should illuminate the ramps with diffuse light. Bare bulbs should be covered to prevent glare in the eyes of approaching animals (Grandin 1980). Solid side fences on the ramps are also recommended. The sheep were watered in the shed but not fed. Animals which are held overnight should be fed (Swan et al. 1980).

Portable fence panels were set up on the wharf next to the shed to form a wide alley up to the ship's ramp (Figure 6). The alley was longer than usual due to wharf construction work, and rain made the sheep more difficult to handle. The handling by the first shift of wharfies was inept. They stood at the top of the ship's ramp and made the sheep balk. Sheep should not be able to see people ahead of them (Kilgour 1971, Freeman 1975). The second shift of wharfies was more skilled in sheep handling and the animals moved easily into the ship. The second shift loaded many more sheep than the first shift. The wharfies need to be educated in sheep handling methods. There was no brutality or rough treatment of the sheep by the wharfies.

A second ship was observed loading at Port Adelaide. Portable fence panels and two portable unloading ramps were set up on the wharf. Sheep unloaded from the trucks were directed to the ship's ramp through a portable yard. The sheep moved easily into the ship until the flow was disrupted. Restricting the flow of sheep was sometimes difficult. No sheep were held overnight on the wharf and the wharfies were trying to do a good job.

Adelaide handling facilities need improvement

The design of the loading facilities in Adelaide need to be improved. One major problem is that it is very difficult for the veterinary inspectors to draft out the unsuitable sheep, because the sheep do not pass through a single file race before boarding the ship. The shipper informed me that the sheep had been inspected at the feedlot. Unfortunately I did not have an opportunity to observe feedlot inspection. In my opinion drafting at the wharf is the best method of inspection because sheep which have sustained injuries in the trucks or on the wharf could be easily observed and drafted out. Another advantage of wharf inspection is that it would eliminate the additional handling which would be required to inspect and draft out unsuitable sheep at the feedlot. Passing the sheep through a single file race is essential in order to do a proper job of inspection.

There are some problems which would have to be overcome before the excellent Fremantle loading and inspection systems could be used in Adelaide. Neither Fremantle system has any provision for storing sheep on the wharf. In order to load the sheep rapidly and efficiently, there have to be at least three trucks unloading all the time. One shipper informed me that trucks are less plentiful in South Australia and obtaining enough trucks to maintain a constant flow of sheep onto the ship may be difficult.

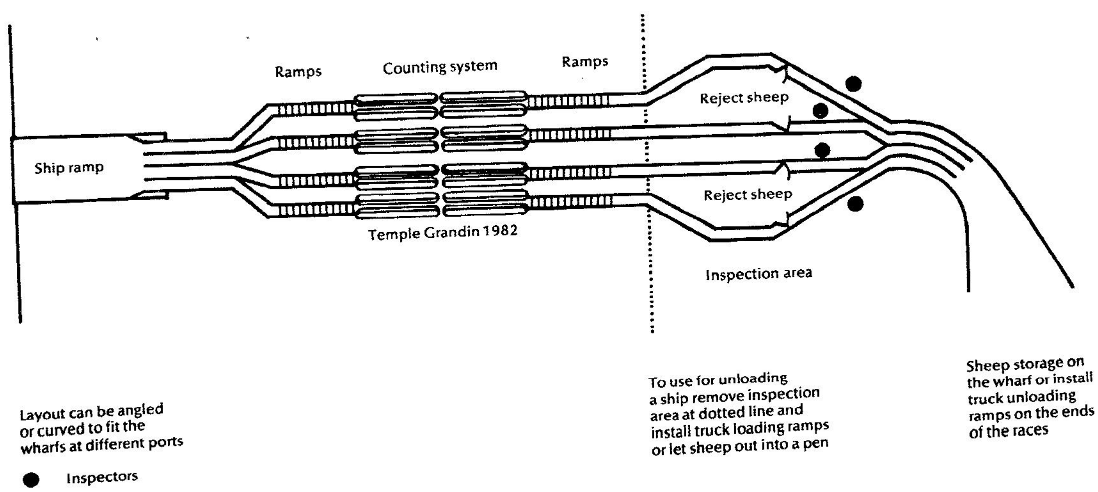

Figure 7 *A loading and unloading system which can be used for inspecting sheep in ports where sheep storage on the wharf is required due to a shortage of trucks.*

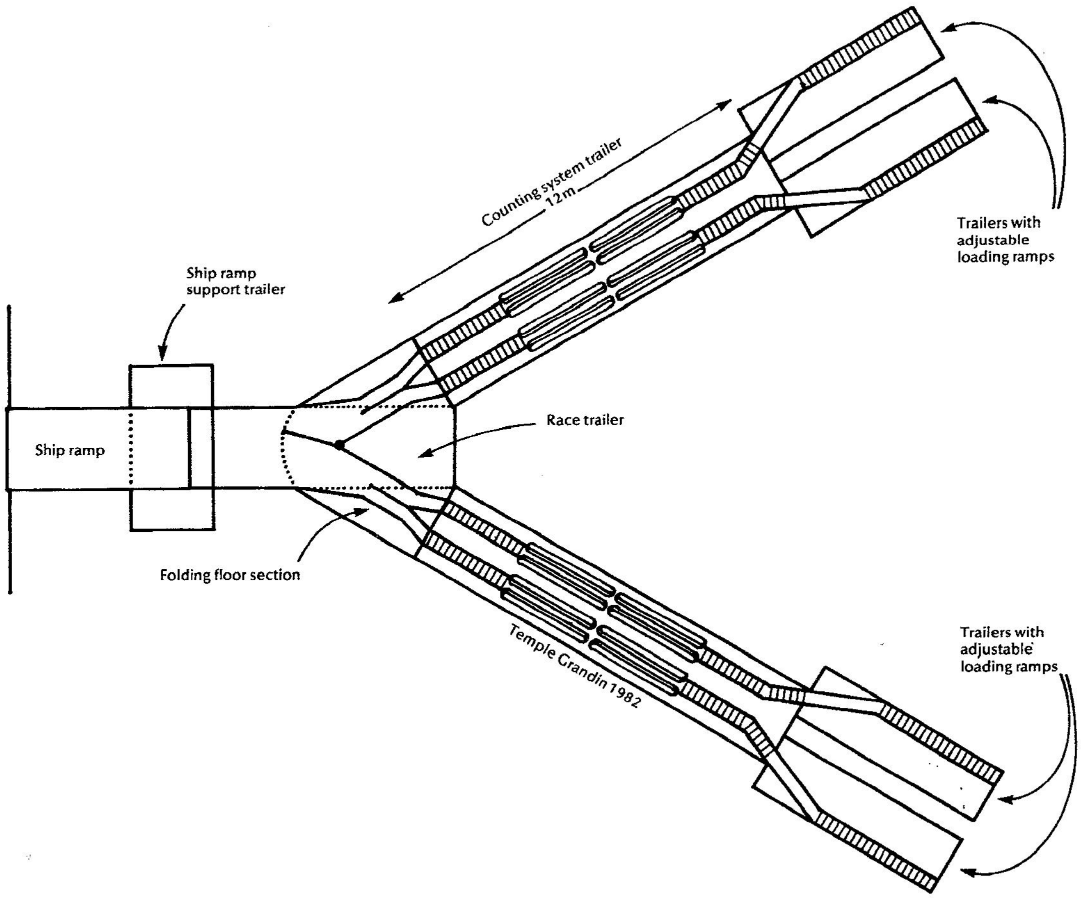

Figure 8 *A trailer-mounted counting and unloading system which unloads sheep directly into trucks. This can be converted to a loading system by adding inspection trailers shown in Figure 2.*

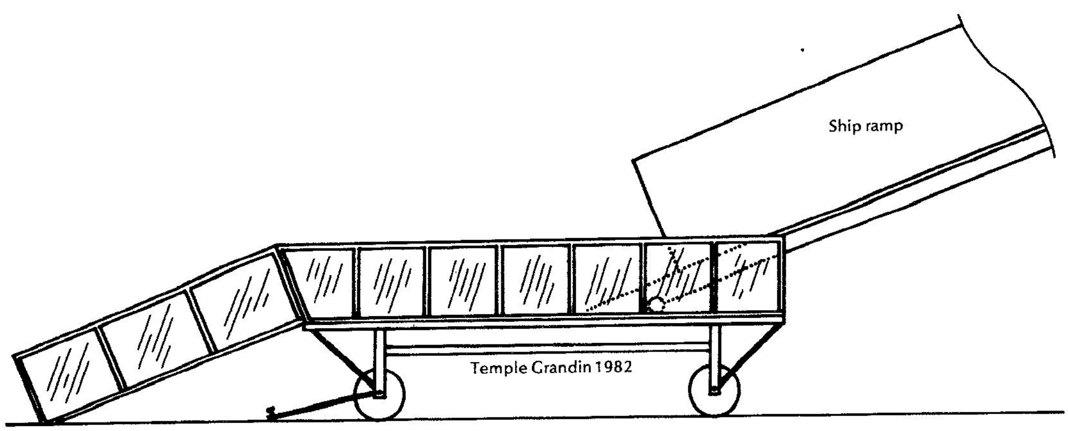

Figure 9 *A system to reduce ship ramp steepness at high tide. Excessively steep ramps can cause problems during unloading.*

Another problem in South Australia is greater tide movement. The trailer system could be modified so that it has a longer track for the ship's ramp to move in. If sheep storage on the wharf is needed due to a truck shortage the layout in Figure 7 would still provide sheep storage on the wharf or in the shed but enable sheep to be inspected in single file and counted accurately. The layout in Figure 7 can be converted to an unloading system by removing the inspection races. In parts of the layout where the races are side by side, the outer fences should be solid to block out outside distractions, but the fences in between the races should be constructed from bars to promote following behaviour (Syme 1982, Grandin 1982a). When a sheep in one race moves forward, the sheep in the adjacent race will follow.

Unloading at Middle East ports

Interviews with ships' officers and other people in the shipping industry indicated that some Middle East ports had good unloading facilities and others needed improvement. At some ports the sheep are unloaded directly onto trucks from the ship's main ramp which is a slow cumbersome process. In ports where direct loading into trucks is required a folding raised unloading platform could be carried on the ship and set up at the destination port. The system could be similar to the trailer systems used by Fares Rural and SIBA Australia Pty Ltd (Figure 8). Instead of using trailers the platforms would be unfolded and bolted together. The system should be equipped with adjustable ramps which could load at least four trucks at a time. If a system could be kept at each port requiring it then trailers could be used. A system consisting of trailers is easier to assemble and counting devices could also be installed on trailers.

In ports where the sheep are unloaded directly onto the wharf, the ramp on some ships may be excessively steep at high tide. Ramps used for unloading should not exceed a 25 degree angle — 20 degrees is ideal (Grandin 1979, Warren 1980). Sheep will move up a steep ramp easily but walking down a steep ramp is more difficult. To reduce steepness the main ship's ramp could be rested on a platform with a ramp extension (Figure 9).

Counting system needed

Accurate counting of the sheep loaded onto the ship is almost impossible. Peter Arnold, consulting veterinarian, states that tally disputes of 2 to 3% are common. Sheep are counted manually by people with hand counters as the sheep pass through the single file races in Fremantle. In Adelaide sheep are counted coming off the trucks at the wharf.

Figure 10 illustrates an idea for an automatic counting system which may be able to count over 1000 sheep per hour. Four of these units could be used to count the sheep during loading or unloading (Figure 7 and 8). The proposed counting system would consist of two sets of conveyors which form a V shape. They would be similar to the restrainers used in a slaughter plant or a sheep handling machine. The entrance conveyor would move more slowly than the counting conveyor. The difference in speed between the two conveyors would separate the sheep. Separation is the key to accurate counting. Either an electric eye or a feeler switch would trigger the counter as each sheep passed.

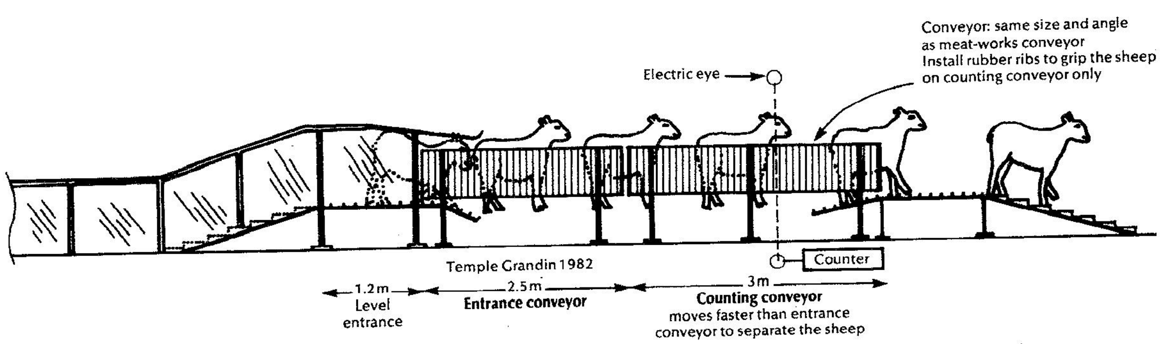

Figure 10 *A design for an automatic counting system with a capacity of 1000 or more sheep per hour.*

Shipping contracts and sheep welfare

Shipping companies with good death loss records were often integrated companies which were responsible for the sheep during both preparation and shipping. If a shipper is paid when the sheep are loaded on the ship there is less incentive to prepare them well compared to a shipper whose pay is based on the number of live healthy sheep delivered.

Animal handling and care will almost always improve in an integrated system because losses can no longer be passed on to the next market segment (Grandin 1982b). In a study conducted by Grandin (1981b) cattle sold on a live weight basis had almost twice as many bruises compared to cattle sold on a carcass basis. The producers were more motivated to handle the cattle carefully when they were sold on a carcass basis because each bruise was deducted from their payment. Within two months after a group of producers switched from live weight to carcass weight selling, their handling practices improved and new trucks were purchased for hauling cattle. Similar observations have also been made in the swine industry.

I recommend that payment for the sheep should be based on either the number of live sheep delivered at the Middle East port or a percentage of the payment should be withheld until delivery. Changing the shipping contracts will do more to improve sheep welfare than a whole lot of regulations. The contracts should be based on the number of live sheep delivered and not on weights. Contracts based on weights encourage salt feeding and detrimental changes in feed formulation which are designed to increase gut fill. An accurate counting device is essential for the establishment of live-delivered contracts, or withholding a percentage of the payment.

Condition of the ships

Some of the ships were really magnificent and it was obvious that a lot of time and effort had gone into designing, converting, maintaining and operating them. Three large ships with a capacity of 90 000 head or more and two medium sized ships with a capacity of 30 000 to 40 000 head were toured. Two of the ships had all above deck pens and three of the ships had both above and below deck pens.

Four of the five ships were well maintained and had good fluorescent lighting. The sheep in the back of the pens could be observed easily. Lighting on ships has undergone tremendous improvements, since the early 1970s and 1960s when Gardiner and Craig (1970) had to use strong electric torches to inspect sheep. One ship was rusty and had poor lighting. The sheep were difficult to observe in this ship. The lighting and maintenance on the rusty ship definitely needs to be improved, but interviews indicated that the rusty ship had a better death loss record than some of the better ships because the sheep were carefully prepared.

The officers on four of the ships were interviewed, and I was impressed with their genuine concern for the welfare of the animals. Several of the ships' captains actually assisted with loading the livestock. Mike Harries, Adelaide RSPCA, Roger Meischke, Australian Bureau of Animal Health, and Richard Willson, consulting veterinarian, travelled on ships and were impressed by the dedication of the officers. Some captains spent more time with the sheep than on the bridge.

Internal ramps and sheep passages on ships

On some ships the floor cleats were inadequate and sheep slipped and fell on the floor at the top of the main ramp and while going around corners. To prevent slipping, the cleats should be installed in both directions. This is especially important where the animals have to turn a corner. On ramps where the sheep do not turn a corner cleats installed horizontally are usually sufficient.

There are two basic types of ramp systems for loading sheep into the pens. The most common system is a series of ramps at one end of the sheep house. The sheep have to go around a number of 180 degree turns to reach the upper decks. The sheep moved easily around the 180 degree turns on ships that had smooth round turns. On ships with sharp blind corners the flow of sheep sometimes stopped because approaching sheep could not see other sheep ahead of them. To maintain flow, sheep should be able to see other sheep up ahead (Brockway 1975, Franklin and Hutson 1982). Sheep and other livestock will balk if a passageway appears to be a dead end (Kilgour 1971, 1976, Grandin 1979).

Another type of system consisted of a continuous straight ramp which ran along one side of the sheep house with landings at each deck. The advantage of this system is that the number of sharp corners is reduced. Both types of systems will work well if they are properly designed. Internal ramps between ship decks should not exceed an angle of 25 degrees. Twenty degrees is ideal (Grandin 1979, Warren 1980). The stationary internal ramps in most locations on most ships were not excessively steep.

A proposed system would consist of a series of ramps which are dropped down from the floor of the sheep pens like the ramps in the stock crate of a truck. Some shippers are interested in this system because they could put sheep in the space which is now occupied by ramps in the present systems. An advantage of the stationary ramps is that there are no moving parts to break. The proposed system would require a series of winches and cables to raise and lower ten to fourteen ramps.

The side fences on internal ramps and passages should be solid to prevent the sheep from being spooked by moving objects outside the fence (Grandin 1979–80). On several occasions the ship's crew covered open fence panels with canvas to facilitate the movement of the sheep. The principle of putting solid side panels on loading ramps and races is like putting blinkers on a horse bridle. The sheep should see only one path of escape.

Sheep movement could also be facilitated by installing shields for handlers to stand behind to prevent approaching sheep from seeing them (Kilgour 1971, 1976). This is especially important at the top of the main ramp. On numerous occasions sheep balked when they saw people standing at the top of the ramp. Once started, the sheep would move by themselves, but if they went up the ramp and balked, it was sometimes difficult to restart the flow.

Judas animals

The use of a Judas goat or sheep would make it easier to induce sheep which have balked to walk up the wide ship's ramp. A Judas animal would have been especially useful at both Adelaide ports. It could be trained to run up the ramp and down to the end of a long row of pens. The use of Judas animals on ships is also recommended by Kilgour (1976). In order to use Judas animals, problems with quarantine regulations would have to be worked out. Possibly the Judas animals could be kept at the wharf or handled under the same procedures which enable zoo animals to be brought into the country.

Sheep ship pens

Sheep are penned on decks which have two levels on each deck. On most ships the pens are laid out in rows with a feed alley on one side and a watering alley on the other side. The maximum size of the pens is 4.5 m by 9 m (Commonwealth Department of Transport (Draft) 1982). The marine order contains specific requirements for strength of pen fittings and design of railings, feed troughs and water troughs. The pens on the ships toured appeared to be in compliance. In each row, the pens are separated by gates which are hinged at the top and swung open like a flap. After a pen is filled the flap gate is closed and the next pen in the row is filled. As the sheep enter each row of pens, a man with a counter counts the sheep. The crews made a genuine effort to load the correct number of sheep into each pen, but sometimes they could not shut the flat gate until five or six extra sheep ran into the pen. Some of the pens appeared to be overstocked.

The average stocking rate for sheep pens is three sheep per square meter (Commonwealth Department of Transport 1978, Australian Bureau of Animal Health 1981). The Marine Orders also specify that spare pens must be provided equal to 0.25% of the load.

Pen capacity

The space requirements for sheep with a wool length of not more than 25 mm is provided below:

Body weight (kg)	m^2 per head
40	0.29
45	0.304
50	0.316
55	0.328
60	0.34

Fels (1976b) states that the present space requirements are adequate if there is good air movement, and that 0.33 m^2 is an adequate space allowance in practice for 50 to 55 kg wethers (Fels 1982). However, Fels and Malcolm (1973) state that for short-term lot feeding of Merino wethers in sheds, 0.47 m^2 is required so they have enough space to eat, drink, rest, and move. Cox and Bell (1957) recommend 0.38 to 0.47 m^2 per 41 kg lamb. Kilgour (1976) reviewed a number of studies which recommended 1 m^2 to 1.4 m^2. A study conducted by Arehart et al. (1969) with lambs indicated that 0.37 m^2 gave similar performance to 0.93 m^2.

Interviews with ships' officers and veterinarians indicated that the present stocking rates may be too tight for the larger 55 kg sheep. Several ships' officers stated that after they left port they opened the flap gates in between the sheep pens. This enabled the sheep to spread out and have more room to lie down. Mike Harries, Adelaide RSPCA, travelled on a ship and found that only four to six sheep could lie down out of twenty head if the gates were closed. If the gates were open a greater percentage of sheep could lie down at once. One captain let the sheep out into the feed alleys to provide more room during hot weather. His ship has had a respectable death loss record of 1 to 1.5% during the Middle East summer.

Opening the flap gates is against regulations, but Bill Thompson, Department of Transport and Construction in Fremantle, doubted that it would present a hazard to ship stability. Stocking rates need to be researched. Sheep going into Middle East summer may require more space, especially in areas of the ship that have poor air movement.

Feed and water systems

All the ships had fibreglass feed troughs and they were in a good state of repair on most ships. Three of the ships had automated equipment to bring the feed to the troughs. The best system consisted of plastic pipes which fed the troughs by gravity from bins on top of the sheep house. It was a simple system which would be easy to maintain. A system of this type should never be considered totally automatic. The crew must check often to make sure the feed is flowing into the troughs.

Two of the ships had a manual feeding system. The feed was put in wheelbarrows and scooped into the troughs. Bins on each deck were used to fill the wheelbarrows. One advantage of a manual system is that it would be easier to monitor feed consumption, because the pipe system refills the trough as the sheep eat. To make monitoring of the feed consumption possible some of the pipes on selected decks could be equipped with shut-off doors. The crew could open the doors to allow the feed to drop into the trough. This would enable feed consumption to be measured in selected pens.

To prevent the sheep from defecating in the feed and water troughs the Commonwealth Department of Transport (Draft 1982) states that for adult sheep the top of the trough should be mounted 55 to 60 cm from the floor. On some ships the troughs were lower. Peter Arnold, consulting veterinarian, states that the troughs should be above anal height to prevent contamination.

On one ship the feed troughs appeared to be too high, and it was difficult for the sheep to eat. Excessive height may reduce feed intake. Sheep naturally eat in a head down position. Kilgour (1976) reports that saliva flow may be hampered by high feed troughs. Research with cattle indicated that saliva flow is greater in the head down position and feed troughs should be as low as possible (McFarlane 1976). Observations of cattle in feedlots indicated that improperly adjusted cables or fence bars pressed in the animal's neck and inhibited feed intake.

One ship had a good system to prevent contamination of feed troughs. An extra bar was mounted inside the pen to prevent the sheep from backing up too close to the trough. Another method is to build a small step along the fence the feed trough is mounted on. Animals will step up onto the step to eat, but will seldom back up the step (Fairbank and Addis 1979). There are probably better methods of reducing faecal contamination of feed troughs than just making them higher and higher.

Water troughs, however, should be mounted as high as possible to prevent faecal contamination. All ships toured had either a board or a metal plate around the pen floors to prevent the animals from kicking manure into the feed and water troughs of the sheep on the lower levels.

Some ships had an automatic watering system and others had manually filled troughs. An advantage of automatic water troughs is that they are less likely to slosh and spill water, because only a small amount of water in a deep trough needs to be available to keep the sheep supplied. On some ships each trough had a separate float valve. The newest systems had up to twelve interconnected troughs which operated off one float valve. Water and feeding systems have definitely been improved during the last few years. Older poor systems are being phased out. In order to fully evaluate feeding and watering systems, I would have to travel on a ship.

The new ships carry their feed in at least two separate bins. If a fire or water leakage destroys the feed in one bin, the sheep can still be fed out of the second bin. A new draft of the Department of Transport Marine Orders (1982) will require all ships constructed or renovated after January 1982 to have at least two separate spaces for carrying feed. To prevent sparks which can start feed fires, feed loading equipment will have to be grounded.

Condition of sheep after a nine-day voyage

I observed sheep which had travelled on a large modern ship from Adelaide to Fremantle. The trip took place in May 1982, and the ship encountered stormy weather while crossing the Australian Bight. Upon arrival in Fremantle, the ship was delayed for two days due to wharf labour problems. The shipping industry, labour unions and the government need to work together to ensure that sheep are loaded promptly, and do not have to wait on trucks or in ships during strikes. When a ship has to wait in the harbour or stay at anchor the ventilation through the open deck pens is less effective. Air movement created by the ship's motion helps to provide ventilation (Australian Bureau of Animal Health 1981).

The ship observed had both above deck and below deck pens. The above deck pens had forced air ventilation through the central sections. The pens below deck were mechanically ventilated.

The sheep had been on the ship for nine days. The animals in the open deck pens were clean and the waste had packed down and formed a dry litter. Sheep in pens with dry litter had no faeces adhering to them. A few pens on the top row of the open deck section had been wetted by rain and a leaking water trough made two pens mucky. There was no leakage of manure or urine from upper pens down onto sheep in the lower pens. The pen floors were constructed from heavy overlaid plywood and the joints were sealed with a tarry sealer. The feed and water was clean. My overall impression of the top deck sheep was good.

The pens below deck were less dry, but most of them were still acceptable. Most pens were dry enough so that faeces did not adhere to the sheep. A few below deck pens were wet and mucky in areas where the ventilation system did not create enough air movement. In these areas faeces adhered to the wool of the sheep. The sheep in the worst areas were cleaner than feedlot cattle in a United States dirt feedlot during Midwest mud season.

Ammonia levels

Twenty-four hours after the sheep had been loaded in Adelaide the ammonia levels in the below deck pens were very strong. There was no equipment available to test the ammonia level, but it was high enough to make my eyes red and watery. After the ship arrived in Fremantle nine days later the ammonia levels in the below deck pens were greatly reduced. The ammonia level decreased after a fibrous mat of manure had formed in the pens.

Fels (1973) reports that ammonia was smelled when bedding was scraped from the pens during voyages. Fels (1973) recorded ammonia levels in below deck pens ranging from 2 to 20 ppm. He stated that ammonia levels were low on his voyage, but ammonia is often noted as an objectionable smell on some ships. Richard Willson, consulting veterinarian, measured ammonia levels on ships and often found levels of 35 ppm and sometimes levels up to 50 ppm. Ammonia levels are influenced by the sheep's diet and ventilation. Interviews indicated that some people in the shipping industry are concerned about high ammonia levels and others do not consider ammonia detrimental.

Environmental chamber tests with lambs indicated that an ammonia concentration of 75 ppm for 28 days reduced weight gains by one-third and caused profuse lacrimation, coughing and nasal discharge (Drummond et al. 1976). Similar experiments with weaner pigs revealed that an ammonia concentration of 100 to 150 ppm reduced weight gains and caused an acute inflammatory reaction in the tracheal epithelium. Ammonia levels of 50 ppm had no effect on health (Drummond et al. 1980). Exposure of animals to ammonia may inhibit their ability to resist disease. There is evidence that ammonia levels as low as 20 ppm reduced resistance to Newcastle disease in chickens (Curtis 1981). Ammonia levels over 50 ppm during the major portion of the voyage would probably be detrimental to the sheep. Ammonia levels may be reduced by sprinkling superphosphate in the pens. Muller (1982) also reports that superphosphate applied at a rate of 100 kg per 1000 sheep reduced mortality from 2.27% to 0.11%. The influence of dietary nitrogen content and water intake on ammonia level require definition and control in practical feeding situations on board ships.

Ventilation

Above deck pen ventilation

A typical sheep ship has two to four floors below the deck and four to seven floors above the deck. Each floor contains two levels of sheep. Some of the ships have no below deck pens. On ships over 20 m wide, the Commonwealth Department of Transport (Draft 1982) requires mechanical ventilation in open deck pens, but this does not provide the entire ventilation needs for these pens. The most common system is a series of ducts which pass from fans on the roof of the sheep house down through the sheep pens. Some of the systems were designed better than others.

One innovative shipper installed expanded metal mesh sections in the feed and water alley floors. There was significant air movement through the gratings from the bottom to the top of the sheep house. John Suiter, Department of Agriculture, Western Australia, suggested that air flow through the sheep house may be enhanced by installing chimneys with turbines on the roof to create a venturi effect. Ducts extending down through the sheep pens could exhaust warm air.

Observers and researchers who have travelled on a ship which has both above and below deck pens, report that during the voyage, conditions for the sheep are better in the open deck pens compared to the enclosed below deck pens (Australian Bureau of Animal Health 1981, Richard Willson, consulting veterinarian). One ship's officer reported that when the ship is in port the below deck pens remain cooler during hot weather than the above deck pens. He also maintains that on this newly refurbished ship the enclosed lower decks are cooler and less humid than the open pens during hot weather. The environment on this ship should be objectively evaluated on a trip during the Middle East summer. The Australian Bureau of Animal Health (1981) recommends that a ventilation system should be designed so that proper ventilation is not dependent on ship movement. In order to evaluate above deck ventilation systems I would have to travel on several ships.

Ventilation in below deck pens

The ventilation system for the pens below deck usually consisted of a series of large fans which impelled air down tubes which ran along the inside of the hull. The outlets were located in the bottom section of sheep pens. Another series of fans on the deck exhausted air from the compartment below.

The new ships toured carried back-up engineering equipment for operating the ventilation system if the ship's engine failed. The ships were also equipped with indicators on the bridge to warn the captain of ventilation problems. The Commonwealth Department of Transport (Draft 1982) specifies that spare parts for ventilation systems and a secondary power source must be carried. Interviews indicated that some shippers may cut corners and the spare parts and secondary power source regulations should be strictly enforced. If the ventilation fails, it has to be fixed very quickly, otherwise large number of sheep will die.

The ventilation systems on the new ships are better than the ones used five to ten years ago. Improvement is still needed, because the air movement was rapid near the ventilation outlets and hardly detectable in some areas. Pens were wet and mucky in areas with little air movement and they remained dry in areas with good air movement.

Interviews indicated that most ships transporting sheep have a ventilation system which can exceed the minimum air changes required by the Commonwealth Department of Transport (1978). The problem is that the air is not being evenly distributed throughout the space occupied by the sheep. The standard states that the air must be changed every three minutes in spaces with a height of 2.3 m and once every two minutes in spaces with a height of 1.8 m.

Even air movement throughout the sheep pens is essential for animal welfare. Fels (1973) reported that improving the ventilation on a sheep ship immediately stabilised the death losses at a lower level. Extensive environmental measurements by Suiter and Dyer (1975) indicated that increasing the air movement reduced death losses dramatically. Increasing the air movement from 0.06 m/sec to 0.48 m/sec decreased the death from 4.8% to 0.1% and increased feed consumption by the sheep. The temperature recorded in the centre of the sheep pens ranged from 32.7 to 33.2 degrees C with a relative humidity of 80%. The small amount of increased air movement had no effect on temperature and possibly lowered the humidity slightly. At 20 degrees C an air speed of 2.25 m/sec will reduce the effective environmental temperature by 2 degrees C and a 4.50 m/sec air speed will reduce the effective environmental temperature for sheep with 10 mm of wool by 6 degrees C (Ames 1974).

On a recent voyage Richard Willson, consulting veterinarian, found that death losses were four times higher in areas of the ship that had low air movement. At elevated temperatures of 30 to 32 degrees C, wind reduced the respiration rate and rectal temperatures of shorn sheep standing in the shade (Eyal 1963a,b). Air movement had a greater effect on shorn sheep than on unshorn animals. The relative humidity during the observations was 50 to 60%.

Air movement of 0.48 m/sec is small and in a hot environment may not be perceivable by a person standing in the ship. At a temperature of 30 degrees C air movement of 0.6 m/sec is just perceptible by the human cheek (Curtis 1981). Increasing air speed up to 4 m/sec may have an additional benefit of reducing the humidity and allowing for more rapid removal of moisture from the pen floors (Suiter 1976). The amount of air movement required to prevent deaths due to heat stress is probably lower than the amount of air movement required to keep the pens in below deck areas dry.

Ways to improve below deck air distribution

On some of the newest ships the pen floors are designed to enhance air movement from the vent outlets at the bottom up through the sheep pens. Notches are cut in the floor along the bulk heads to permit movement between decks. Each notch is surrounded by a guard to prevent the sheep from stepping into it. Even ships equipped with this system have areas with little or no air movement. The placement of a series of small fans on each deck level may help to distribute air from the main vents. Another possible method for improving air distribution is the use of perforated plastic ducts hung in the feed and water alleys with the vent holes directed into the sheep pens.

An engineer with practical experience ventilating aircraft carriers, mines or large buildings would probably be of assistance in improving air distribution. The engineer should travel on a ship during the Middle East summer in order to obtain practical first hand knowledge of the problems and the right person when found should be assigned to solve the problem.

Interviews indicated that on some ships the ventilation system was designed to have good air distribution when the ship was empty. The only valid way to evaluate the air distribution characteristics of a ventilation system is when the pens are filled with sheep. The sheep act as a solid wall and change the air flow patterns. Wind tunnel research with models by Muirhead (1982) indicated that airflow through a cattle truck becomes weaker when the animals were put into it.

Stress index

Heat stress when sheep on ships encounter the Middle East summer weather needs to be researched. The literature review indicated that heat stress has caused problems on some of the older ships (Fels 1973, Suiter and Dyer 1975, Suiter 1976 and Australian Bureau of Animal Health 1981). An environmental stress index should be developed to determine the various levels of temperature, humidity and air speed required to maintain a tolerable environment for the sheep. These variables are also correlated with sheep condition, wool length, pellet formulation and stocking density. An environmental physiologist is recommended to develop the index.

Previous work on the effects of temperature, humidity and airspeed on sheep has only dealt with two variables at a time. Studies conducted by Joyce and Blaxter (1964) and Ames (1974) on sheep provide information on the effects of airspeed and air temperature. A detailed study by Lee and Robinson (1941) shows the relationship between high environmental temperatures and humidity on heat stress in Merino sheep. Their study contains no information on the effects of increasing airspeed to relieve the effects of high temperatures and humidities. Suiter (1976) adapted a heat stress chart from the Lee and Robinson (1941) data. Sweating rate is another possible method of assessing thermal strain in sheep (Hofmeyr et al. 1969).

Another possible measure of stress in sheep is wool breakage. Roger Meischke, veterinarian with the Australian Bureau of Animal Health, measured wool break with the Gordon technique. He found that there was a marked decrease in the force required to break the wool between the first day and day four and five of a voyage, and then a gradual recovery (Australian Bureau of Animal Health 1981). This could indicate stresses experienced by the sheep during preparation, loading and establishment of a routine on the ship.

Future ships

Several shippers stated that future ships may be almost totally enclosed. Many present sheep ships are converted oil tankers which are big and slow. Several people interviewed predicted that the sheep ships of the future may be converted container ships or possibly car carriers. They have abundant space and are faster than tankers. Due to the configuration of a container ship, the majority of the sheep would be carried in enclosed pens. When a container ship or car carrier is converted, serious consideration should be given to using refrigeration equipment to control heat build-up.

Conclusions and recommendations

The shipping industry has made some major improvements during the last one or two years, but there are still some problem areas. The main problem areas are sheep preparation, dusty feed and ventilation on the ship. In order to have a low death loss, the sheep must be adapted to eating pellets before they are loaded onto the ship. Research should be conducted to objectively determine the time required for shifting different types of sheep onto pellets. The dusty feed and ventilation problems need to be solved by people with practical experience in these areas. These two areas need immediate attention.

The conversion of sheep shipping contracts to a live-sheep-delivered basis would provide a powerful incentive for shippers to solve the few remaining problems. If a shipper is paid when the sheep are loaded, there is less incentive to prepare them well compared to a shipper whose payment is based on the number of live healthy sheep delivered. I recommend that shipping contracts be changed to either a live-sheep-delivered basis or a percentage of payment should be withheld until delivery.

The handling systems used in Fremantle to load the large sheep ships were excellent. They should be used as a model for other ports. The report contains designs and recommendations for improving handling at Adelaide and other ports. A proposed system for accurately counting sheep is also included.

References

Ames, D.R. 1974. Wind chill factors in cattle and sheep. Proceedings International Livestock Environment Symposium, 17–19 April, University of Nebraska, Lincoln, pp. 68–74.

Arehart, L.A.; Lewis, J.M.; Hinds, F.C. and Mansfield, M.E. 1969. 'Space allowances for lambs on slotted floors'. *J. Animal Sci.*, Vol. 29, pp. 638–41.

Arnold, G.W. 1976. Some factors influencing feeding behaviour of sheep in pens. Proceedings of the Sheep Assembly and Transport Workshop, Western Australian Department of Agriculture, Perth, Western Australia, pp. 85–93.

Arnold, G.W. and Maller, R.A. 1974. 'Some aspects of competition between sheep for supplementary feed'. *Animal Prod.*, Vol. 19, pp. 309–19.

Australian Bureau of Animal Health, 1981. *Sea Transport of Sheep*, AGPS, Canberra, A.C.T.

Australian Bureau of Animal Health, 1982. *Standards for the preparation and carriage of sheep by sea*. AGPS, Canberra, A.C.T.

Australian Meat and Live-stock Corporation, 1981. *An outline of the Australian Livestock Export Industry*, Sydney.

Barber, A. 1977. Bugle sheep yards. Fact Sheet, Department of Agriculture and Fisheries, South Australia, Adelaide.

Barber, A. 1979. Modern shearing shed design. Bulletin No. 1/79, Department of Agriculture, South Australia, Keith.

Blaxter, K.L.; McGraham, N.; and Wainman, F.W. 1958. 'Environmental temperature, energy metabolism and heat regulation in sheep. III The metabolism and thermal exchanges of sheep with fleeces'. *J. Animal Sci.*, Vol. 52, pp. 41–9.

Brockway, B. 1975. Planning a sheep handling unit, Farm Buildings Information Centre, Nat. Agric. Centre, Kenilworth, Warwickshire, England.

Brockway, J.M.; McDonald, J.D. and Puller, J.D. 1965. 'Evaporative heat-loss mechanisms in sheep'. *J. Physiol.*, Vol. 179, pp. 554–68.

Brownlie, L.E. and Grau, F.H. 1967. 'Effect of food intake on growth and survival of salmonellas and *Escherichia coli* in the bovine rumen', *J. Gen. Microbiol.* 46, pp. 125–34.

Commonwealth Department of Transport, 1978. Marine Standards Division Specification No. 1/1978, June 1978, Chapter 3 — Livestock Fittings, In: Australian Bureau of Animal Health (1981). Appendix 3, *Sea Transport of Sheep*, AGPS, Canberra, A.C.T. pp. 32–4.

Commonwealth Department of Transport 1982. Marine Orders, Part 43. Cargo and Cargo Handling — Livestock Fittings (draft only).

Cox, R.F., and Bell, T.D. 1957. 'Feeding range lambs in Kansas'. *Kansas State College Agric. Expt Stn Bulletin 387*.

Curtis, S.E. 1981. *Environmental Management in Animal Agriculture*. Animal Environment Services, Mahomet, Illinois.

Department of National Development, 1972. *Atlas of Australian Resources*, second series, Temperatures 2nd edition, Geographic Section, Dept of National Development, Canberra, A.C.T.

Drummond, J.G.; Curtis, S.E.; Lewis, F.C.; Hinds, J. and Simon, J. 1976. 'Exposure of lambs to atmospheric ammonia'. *J. Animal Sci.*, Vol. 42, p. 1343 (Abstract).

Drummond, J.G.; Curtis, S.E.; Simon, J.; and Norton, H.W. 1980. 'Effects of aerial ammonia on growth and health of young pigs', *J. Animal Sci.*, Vol. 50, pp. 1085–91.

Eyal, E. 1963a. 'Shorn and unshorn Awassi sheep, 1 Body temperature'. *J. Agric. Sci.*, Vol. 60, pp. 175–81.

Fairbank, W.C. and Addis, D.G. 1979. *Selected feedlot facilities*. University of California Co-operative Extension, University of California, Riverside, California.

Fels, H.E. 1973. Lot feeding sheep on ships, I. Feeds and feeding. Technical Bulletin No. 22, Western Australian Department of Agriculture.

Fels, H.E. 1976a. Feedlots, facilities, design, and routine procedures. Proceedings of the Sheep Assembly and Transport Workshop, Western Australian Department of Agriculture, Perth, Western Australia, pp. 110–26.

Fels, H.E. 1976b. Shipboard environment — Modification and alleviation of lot feeding on ships. Proceedings of the Sheep Assembly and Transport Workshop, Western Australian Department of Agriculture, Perth, Western Australia, pp. 140–53.

Fels, H.E. 1982. Principles of lot feeding: the design and operation of feedlots. In R.J. Suiter (editor) Feeding Sheep to Produce Meat, Bulletin No. 4071, Western Australian Department of Agriculture, pp. 38–48.

Fels, H.E. and Malcolm, B. 1973 'Lot feeding sheep in sheds'. *J. Agric. Western Australia*, Vol. 14, pp. 251–4.

Franklin, J.R. and Hutson, G.D. 1982. 'Experiments on attracting sheep to move along a laneway. III. Visual stimuli'. *Applied Animal Ethology*, Vol. 8, pp. 457–78.

Franklin, M.C. and MacGregor, C.H. 1944. 'An experimental investigation of the cause of death of Merino rams after long journeys by rail'. *Aust. Vet. J.*, Vol. 20, pp. 328–31.

Freeman, R.B. 1975. 'Functional planning of a shearing shed'. *Pastoral Review*, Vol. 85, pp. 9–13.

Gardiner, M.R. and Craig, J. 1970. 'Factors affecting survival in the transportation of sheep by sea in the tropics and subtropics'. *Aust. Vet. J.*, Vol. 46, pp. 65–9.

Geytenbeek, P.E. 1962. A survey of post-shearing losses'. *Proc. Aust. Soc. Animal Production*, Vol. 4, pp. 185–6.

Givens, R.L.; Garrett, W.N. and Bond, T.E. 1966. 'The California environment and the use of shade for feedlots'. *6th Annual California Feeder's Day Report*, 28 Oct., p. 38.

Grandin, T. 1979. 'Understanding livestock psychology facilitates handling livestock'. *Vet. Med. and Small Animal Clin.*, Vol. 74, pp. 697–706.

Grandin, T. 1980. 'Livestock behaviour as related to handling facilities design'. *Int. J. Study Animal Problems*, Vol. 1, pp. 33–52.

Grandin, T. 1981a. Feeder calf handling in south-western feedlots. Amer. Soc. Agric. Eng., Technical Paper No. 81-6002, St Joseph, Michigan.

Grandin, T. 1981 b. 'Bruises on south-western feedlot cattle'. *J. Animal Science*, Supplement I, Vol. 53, pp. 213–14 (abstract).

Grandin, T. 1982a. 'Understanding hog psychology simplifies handling'. *Vet. Med. and Small Animal Clin.*, Vol. 77, pp. 267–71.

Grandin, T. 1982b. Welfare requirements of handling facilities. Commission of the European Communities Seminar, Housing and Welfare, Aberdeen, Scotland, July 18-30, 1982.

Grau, F.H.; Brownlie, L.E. and Smith, M.G. 1969. 'Effects of food intake on number of salmonellae and *Escherichia coli* in the rumen and faeces of sheep'. *J. Appl. Bact.*, Vol. 32, pp. 112–17.

Hafez, E.S.E. 1968. *Environmental Effects on Animal Production in Adaptation of Domestic Animals.* E.S.E. Hafez Ed., Lea and Febiger, Philadelphia, USA.

Hawes, B. 1976. Assembly, preparation and dispatch of live sheep for export. Proceedings of the Sheep Assembly and Transport Workshop, Western Australian Department of Agriculture, Perth, Western Australia, pp. 44–56.

Hitchcock, D.K. and Hutson, G.D. 1979. 'The movement of sheep on inclines'. *Aust. J. Exp. Agric. Animal Husb.*, Vol. 19, pp. 176–82.

Hofmeyr, H.S.; Guidry, A.J. and Waltz, F.A. 1969. 'Effects of temperature and wool length on the surface and respiratory evaporative losses of sheep'. *J. Applied Physiol.*, Vol. 26, pp. 517–23.

Holmes, R.J. 1980. 'Dogs in works: friend or foe?' *4 Quarter*, Ministry of Agriculture and Fisheries, New Zealand, Vol. 1, No. 3, pp. 16–17.

Hopkins, P.S.; Knights, G.I. and Le Feuvre, A.S. 1978. 'Studies of the environmental physiology of tropical Merinos'. *Aust. J. Agric. Res.*, Vol. 29, pp. 161–71.

Howard, J.L. (editor) 1981. 'Current Veterinary Therapy'. *Food Animal Practice*, W.B. Saunders, Philadelphia, p. 1055.

Hutchinson, K.J. and McRae, B.H. 1969. 'Some factors associated with the behaviour and survival of newly shorn sheep'. *Aust. J. Agric. Res.*, Vol. 20, pp. 513–21.

Hutson, G.D. and Hitchcock, D.K. 1978. 'The movement of sheep around corners'. *Appl. Animal Ethol.*, Vol. 4, pp. 349–55.

Ittner, N.R.; Bond, T.E. and Kelly, C.F. 1954. 'Increasing summer gains in livestock'. *J. Animal Sci.*, Vol. 13, pp. 867–76.

Jelinek, P.D.; Franklin, D.A. and Iveson, J.B. 1982. 'The recovery of salmonella from sheep that died during transportation by ship'. *Aust. Vet. J.*, Vol. 58, pp. 170–1.

Joyce, J.P. and Blaxter, K.L. 1964. 'The effect of air movement, air temperature and infrared radiation on the energy requirements of sheep'. *Brit. J. Nutrition*, Vol. 18, pp. 5–27.

Kilgour, R. 1971. Animal handling in works, pertinent behaviour studies. Proceedings of the 13th Meat Industry Research Conference, Hamilton, New Zealand, pp. 9–12.

Kilgour, R. 1976. Sheep Behaviour: Its importance in farming systems, handling, transport and preslaughter treatment. Proceedings of the Sheep Assembly and Transport Workshop, Perth, Western Australia, pp. 64–84.

Kilgour, R. and deLangen, H. 1970. Stress in sheep resulting from management practices. Proceedings of New Zealand Soc. Anim. Prod. Proceedings, Vol. 30, pp. 65–76.

Klemm, G.H. 1962. 'The reactions of shorn and unshorn sheep to hot wet and hot dry atmospheres'. *Aust. J. Agric. Res.*, Vol. 13, pp. 472–8.

Lee, D.H.K. 1950. 'Studies of heat regulation in the sheep, with special reference to the Merino'. *Aust. J. Agric. Res.*, Vol. 1, pp. 200–15.

Lee, D.H.K. and Robinson, K. 1941. Reactions of sheep to hot atmosphere. Proceedings of the Royal Society of Queensland, Vol. 53, pp. 189–200.

Lynch, J.J. and Alexander, G. 1976. 'The effect of gramineous windbreaks on behaviour and lamb mortality among shorn and unshorn Merino sheep during lambing'. *Appl. Animal Ethol.* Vol. 2, pp. 305–25.

Lynch, J.J. and Alexander, G. 1977. 'Sheltering behaviour of lambing Merino sheep in relation to grass hedges and artificial wind breaks'. *Aust. J. Agric. Res.*, Vol. 28, pp. 691–701.

Marshall, P.C. 1966. 'New look for circular sheep yards'.

New Zealand Journal of Agriculture, Vol. 112, no. 5, May, pp. 9–11.

Marshall, T. 1980. Drought feeding sheep. Agdex 420/56, Western Australian Department of Agriculture.

Mayes, H.F. 1978. 'Design criteria for livestock loading chutes'. *Amer. Soc. Agric. Eng.*, Technical Paper No. 78–6014, St Joseph, Michigan.

McDonald, C.L. 1981. Feeding sheep for live export. Agdex 420/55, Western Australian Department of Agriculture.

McDonald, J.W. 1981b. Heat stress in sheep. Proceedings No. 58, Australian Veterinary Association, Postgraduate Refresher Course, Sydney 1981.

McFarlane, I. 1976. 'A practical approach to animal behaviour'. In: M.E. Ensminger (editor), *Beef Cattle Science Handbook*, Vol. 13, Agriservices Foundation, Clovis, California, pp. 420–6.

MacFarlane, W.V.; Morris, R.J.H. and Howard, B. 1958. 'Heat and water in tropical Merino sheep'. *Aust. J. Agric. Res.*, Vol. 9, pp. 217–27.

Milne, J.A. and Campling, R.C. 1972. 'Intake and digestibility by sheep of artificially dried forages in several physical forms'. *J. Agric. Sci.*, Cambridge, Vol. 78, pp. 79–86.

Moir, R.J. 1976. Feeds composition and preparation II. Proceedings of the Sheep Assembly and Transport Workshop, Western Australian Department of Agriculture, Perth, Western Australia, pp. 103–9.

Muirhead, V.U. 1982. Interim report on investigation of the internal and external aerodynamics of cattle trucks. Official Proceedings, Livestock Conservation Institute, 239 Livestock Exchange Bldg, South St Paul, Minnesota, pp. 115–20.

Muller, W. 1982. 'Transportation of sheep by ship from Australia to the Middle East'. In R. Moss (editor) *Transport of Animals Intended for Breeding and Slaughter*. Current Topics in Veterinary Medicine, Vol. 18, Martinus Nijhoff, London, pp. 166–76.

National Climate Center 1973. *Daily normals of temperature and heating and cooling degree days 1941–70*. US Dept of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, National Climate Center, Asheville, North Carolina, USA.

Parer, J.T. 1963. 'Wool length and radiant heating effects in sheep'. *J. Agric. Sci.*, Vol. 60, pp. 141–4.

Pierson, R.E.; Poduska, P.J.; Cholas, G. and Brown, G. 1972. 'Relationship of management and nutrition on salmonellosis in feedlot lambs'. *J. Amer. Vet. Med. Assn*, Vol. 161, pp. 1217–20.

Squires, V.R. 1974. 'Grazing distribution and activity patterns of Merino sheep on a saltbush community in south-east Australia'. *Appl. Animal Ethol.*, Vol. 1, pp. 17–30.

Stevens, R.A. and Lyons, D.J. 1977. *Livestock bruising project: Stockyard and crate design*. National Materials Handling Bureau, Dept of Productivity, Australia (no city listed).

Suiter, R.J. 1976. Shipboard environment — definition and effects. Proceedings of the Sheep Assembly and Transport Workshop, Western Australian Department of Agriculture, Perth, Western Australia, pp. 127–39.

Suiter, R.J. and Dyer, H.P. 1975. *Live shipping of sheep*. Technical Bulletin No. 29, Western Australian Department of Agriculture.

Swan, R.A.; Arnold, P.; Jarvie, D.; Robertson, G.; Purcell, A.; Chapman, H.; McDonald, C. and Fels, H. 1980. Report to the Australian Veterinary Association Standing Committee on Animal Welfare.

Sweeten, J.M. 1978. 'Control of dust in cattle feedlots', *Great Plains Beef Cattle Feeding Handbook*. Texas A and M University, College Station, Texas, pp. 7803.1–7803.6.

Syme, L.A. 1981. *Improved sheep handling, design for a self feeding race*. CSIRO, Division of Land Resources Management, Western Australia.

Teissier, G., 1982. Letter to B.J. Gabbedy, Western Australian Department of Agriculture.

Thurley, D.C. and McNatty, K.P. 1973. 'Factors affecting peripheral cortisol levels in unrestricted ewes', *Acta Endrocrinologica*, Vol. 74, pp. 331–7.

Truscott, G.M.C. 1977. Control measures for the major diseases of live export sheep. Proceedings 54th Annual Conference, Aust. Vet. Assn, pp. 190–1.

van Putten, G. and Elshof, W.J. 1978. 'Observations on the effect of transport on the well-being and lean quality of slaughter pigs'. *Animal Reg. Stud.*, Vol. 1, pp. 247–71.

Van Soest, P.G. 1982. *Nutritional Ecology of the Ruminant*. D and B Books, Corvallis, Oregon.

Warner, A.C.I. 1962. 'Some factors influencing the rumen microbial population'. *J. Gen. Microbiol.*, Vol. 28, pp. 129–46.

Warren, D.P. 1980. 'The carriage of sheep by sea: A quarter of a century of experience'. *The State Veterinary Journal*, Vol. 35, No. 104, pp. 139–53.

Wilkens, R.J.; Lonsdale, C.R.; Tetlow, R.M. and Forrest, T.J. 1972. 'The voluntary intake and digestibility by cattle and sheep of dried grass wafers containing particles of different size'. *J. Animal Prod.*, Vol. 14, pp. 177–88.

Wodzicka, M. 1960. 'Seasonal variations in wool growth and heat tolerance of sheep. II Heat tolerance'. *Aust. J. Agric. Res.*, Vol. 11, pp. 85–96.