

# Reducing Stressors on Cattle in Road Transport

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# Reducing stressors on cattle in road transport

Project DAQ.070

Meat Research Corporation

## *Final Report* *Part 3: technical report*

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## Preface

Project DAQ.070 investigated ways to reduce meat quality loss due to stressors experienced by cattle during transport. It also evaluated the logistical advantages and animal welfare benefits of alternative loading and transport methods.

The Department of Primary Industries, Queensland initiated and coordinated the project. CSIRO Division of Food Processing and the Livestock and Meat Authority of Queensland (LMAQ) performed essential sub-contracting roles related to meat quality assessment and bruise ageing.

The final report was prepared in 3 sections:

- Part 1 - Abstract
- Part 2 - Executive Summary
- Part 3 - Technical Report

This report (Part 3 - Technical Report) presents detailed information on the background, methodology and results of the project. Parts 1 and 2 were printed separately, but are also included as appendices F and G respectively in this report.

## Acknowledgments

All sectors of the beef cattle industry supported this project. Members of the Livestock Transporters Association of Queensland assisted by using the project's experimental trailer in their fleets during trials. The research team is particularly indebted to McIver Group Transport (Quilpie Depot), Robertsons Transport (Toowoomba), Frasers Transport (Warwick) and Hudsons Transport (Cloncurry) for their cooperation and collaboration.

On-road trials during the project needed large numbers of cattle - up to 180 per consignment. Cattle were sourced from both large pastoral companies and smaller private producers. The research team appreciates the assistance of the growers and pastoral companies who provided cattle for project trials.

Darling Downs Bacon (Toowoomba), AMH (Dinmore), and Toowoomba Public Abattoir allowed samples to be taken from trial cattle at their slaughtering and processing facilities. These samples were essential for meat quality and animal stress analyses.

The Meat Research Corporation (MRC) provided financial support for the project. This work would not have been undertaken without their input.

Alan Andrews, DPI, co-authored the DAQ.070 final report. The researchers specifically acknowledge Mr Andrews' assistance during editing and assembly of the report. His persistence, patience and constructive comments were greatly appreciated.



## 1. Background and industry context

The Australian beef industry must address the key issues of animal welfare, production efficiency and profitability if it is to remain viable. These issues are particularly relevant to the cattle transport industry.

Modifying road trains to minimise dust levels around cattle during transport would help to reduce animal welfare concerns. Lower dust levels may also improve final meat quality and reduce costs, resulting in improved efficiency and profitability within the Australian beef industry. These are important issues for an industry facing growing competition on international markets and from alternative protein sources.

Project DAQ.070 investigated whether modified cattle handling and transport practices would reduce stress on cattle and improve final carcass quality. The project focused on the effects of different loading ramp designs and modifications designed to reduce dust levels in cattle crates during transport.

Section 1.1 of this report shows that bruising and dark cutting are significant problems for the Australian beef industry, particularly when supplying 'quality' markets such as North Asia and Australia. Improving the quality of carcasses by minimising bruising and dark-cutting will have a positive impact on industry efficiency and profitability.



Figure 1 Dust obscures the second and third trailers of a road train carrying cattle in western Queensland. High dust levels exist within the cattle crates under these conditions.

## 1.1 Meat quality losses

The cost of bruising from all causes is estimated to be in excess of \$36 million annually (Wythes and Shorthose 1984). Poor transport environment contributes to this figure.

Browne and Beasley (1991) found in a survey of eight Queensland abattoirs that 12% of grassfed carcasses prepared for the Japanese market were downgraded due to bruising, either as the sole reason, or in combination with other reasons. They also reported that 10% of Korean grainfed carcasses were similarly downgraded. The estimated annual cost to the Queensland beef industry of downgrading due to bruising of grassfed carcasses for the Japanese market was reported to be \$1.9 million (Browne and Beasley 1991).

Browne and Beasley (1991) reported that over 90% of grassfed carcasses in their survey displayed AUS-MEAT Chiller Assessment muscle colour scores between one and six inclusive. Although this is considered acceptable for most markets it is a potential source of concern for the Japanese market.

Muscle colour range is well specified for grainfed carcasses entering the Japanese market, with scores between two and three preferred. Acceptable muscle colour scores for grassfed carcasses entering this market are not well defined because they are not currently included in the AUS-MEAT Chiller Assessment system.

If Japanese buyers were to impose tighter muscle colour specifications for grassfed product, similar to those applied to grainfed product, then only 60% of the grassfed carcasses surveyed would have been acceptable (Browne and Beasley 1991). Six per cent of grassfed carcasses were score one, which is considered by some to be too light in colour, tending towards exhibiting PSE (Pale, Soft and Exudative), whilst 34% were score four or greater. Six per cent of carcasses were muscle colour score seven to nine and would have been classified as dark-cutting carcasses.

Pre-slaughter stress increases the incidence of dark-cutting meat and the level of bruising, and reduces yield through psychological and physiological changes in the live animal (Eldridge 1989 p80). Stress-induced reduction in meat quality is characterised by an increased percentage of dark-cutting meat with Ph greater than 6.0 (Fjelkner-Modig and Ruderus 1983, Wythes et al. 1982).

Warner et al. (1988a) found that in Australia the incidence of dark-cutting ranged from 1.1% to 8.3% at small country abattoirs and between 7.7% and 16% at larger metropolitan abattoirs. Shorthose (1989, p69) estimated that about 8% of cattle (excluding mature bulls and animals younger than one year) slaughtered in Australia, have ultimate pH values greater than 6.0, the internationally agreed definition for dark-cutting meat.

Estimates of the incidence of dark-cutting meat due to all causes range from six to ten per cent - a loss of about \$11 million annually through downgrading (Shorthose 1980, Tarrant 1981).

## 1.2 Dust and animal stress

Cattle experience high dust levels for long periods when travelling in road trains on unsealed roads in the northern and western parts of Australia. Dust in a single trailer cattle transport reaches visibly high levels, and is even more severe in multiple trailer road trains. The second and third trailers on these road trains pass through dust thrown up by the prime mover and lead trailers as well as generating dust themselves.

Under high dust levels on unsealed roads animals may become stressed by progressive dust inhalation, leading to agitation and animals 'going down' in the trailers. Animals sometimes die if conditions are extreme. These effects contribute to higher bruising levels and subsequent reductions in meat yield.

Eldridge (1989, p80) points out that although a link between dark-cutting meat and low available muscle glycogen levels at slaughter is well established, there are many factors prior to slaughter which affect available muscle glycogen. As a result it is difficult to confidently attribute dark-cutting to particular causes such as dust levels during transport. Efforts to quantify the effects of reduced dust levels are complicated by interacting stressors such as loading density, road condition, handling during loading or unloading, and lairage conditions at the abattoir.

## 1.3 Transport management

Specific causes of dark-cutting and bruising have not been clearly established in previous work. Nonetheless, Eldridge (1989) suggests that improved management practices whilst cattle are en route to slaughter are needed to reduce the overall impact of pre-slaughter stress on meat carcass quality.

Poor transport management increases the potential for higher levels of bruising and animal mortality due to dust inhalation and heat stress. Many transport operators seek to reduce animal discomfort levels in road trains by:

- rotating trailers to limit animal exposure to dust; and
- avoiding particularly dusty roads where possible.

The above strategies generally result in higher operating costs due to factors such as lost time, longer transport distances and increased fuel use.

Research into the effects of pre-slaughter stress on cattle has mainly concentrated on cattle handling before and after transport, not during transit. Eldridge and Winfield (1988) studied cattle during transit in southern parts of Australia, but conditions in northern Australia are considerably different with several other influences involved. These include longer transport distances, more unsealed transport routes (often in poor condition, particularly on properties) and harsher environmental conditions including dust and temperature levels.



## 2. Objectives

Project DAQ.070, 'Reducing Stressors on Cattle in Road Transport', aimed to:

*. . . improve profitability in the Australian beef industry by reducing bruising, dark-cutting meat and mortalities caused by stress during cattle transport and loading, and to improve animal welfare.*

The specific project objectives were:

- to reduce stress on cattle caused by the transport environment (including dust and temperature) and the method of loading (single versus double-deck loading ramps);
- to compare the effect of transport innovations such as low-dust trailers and double-deck loading ramps with conventional systems by: monitoring and collecting data from environments in cattle transport systems; assessing the extent and age of bruising on cattle after transport; measuring animal stress levels using plasma constituents;
- to calculate economic losses to the meat industry caused by existing transportation systems; and
- to assess the effects of transport innovations on the incidence of dark-cutting, and the incidence, severity and location of carcass bruising.



Figure 2 Loading cattle in western Queensland. Note the dust (top right) caused by cattle movement in holding yards.





## 3. Methodology

The project was divided into two major phases:

- engineering development; and
- testing and evaluation.

### 3.1 Engineering development

The engineering phase focused on developing hardware and systems to reduce dust levels in cattle trailers during transport. It also involved development of instrumentation to monitor the environment inside cattle crates.

Mr W. Town (Agricultural Engineer) and Mr J. Lapworth (Livestock Transport and Handling Specialist), Department of Primary Industries (DPI), provided engineering and animal handling expertise respectively to this phase of DAQ.070.

#### 3.1.1 Flow visualisation

Air moves in complex profiles in and around the crates of road trains. Knowledge of air movement around road trains could allow design of modifications to direct clean air into crates and therefore reduce the amount of dust-laden air within them.

Methods for studying air movements around a road train include full-scale studies on commercial trucks, computer-based models and wind tunnel studies. Scale models in a wind tunnel using smoke for flow visualisation allow patterns to be seen easily. This contrasts with the practical difficulties of using commercial operators and full-scale trucks. Computer modelling of even simple air flow patterns requires sophisticated techniques. Extensive software development would have been needed to model the multiple-trailer configurations under investigation in this project, with no guarantee of an acceptable degree of performance.

Wind tunnels have a long record of successful use in flow visualisation studies, and allow considerable flexibility when testing new designs. Results can be obtained very quickly as models are modified. Prototype development using a wind tunnel also avoids time, weather and equipment constraints associated with full scale trials.

The project team chose wind tunnel modelling as it was the most cost-effective and reliable method of comparing air flow patterns of prototype designs.

#### 3.1.2 Wind tunnel modelling

Draw-through wind tunnels use a fan on the downstream side of the working section to pull air through the tunnel. This allows easier formation of laminar flow than is possible with blow-through designs which create turbulence on the downstream side of the fan.

Open-circuit tunnels expel air into the surrounding environment, whereas closed-circuit tunnels duct air back to the inlet. This study used an open-circuit, draw-through wind tunnel for flow visualisation studies.

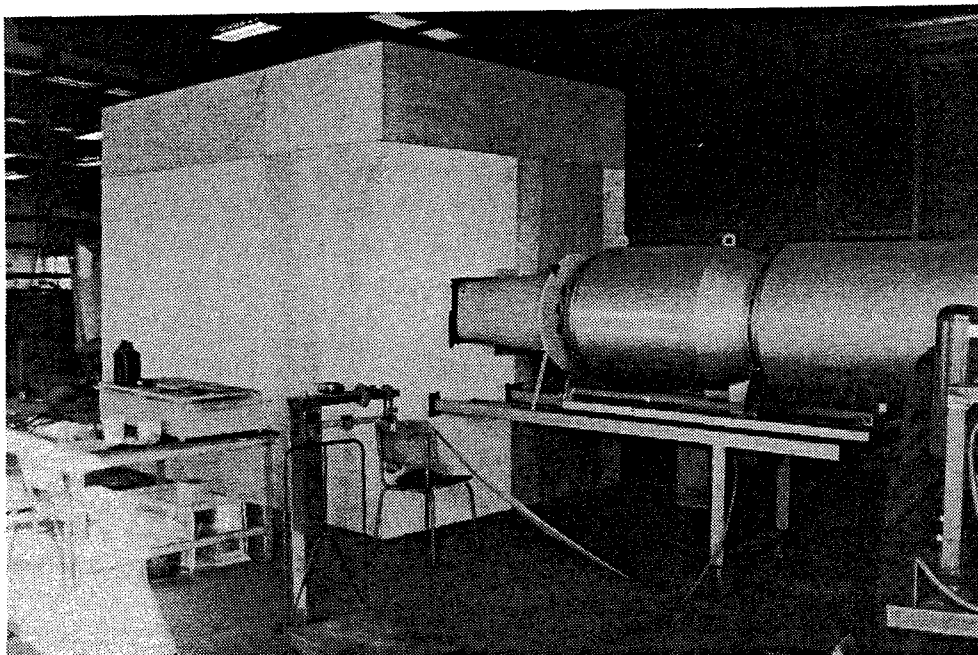
A manifold with a throat cross-section of 900 mm x 900 mm and containing a series of honeycomb flow straighteners formed the air inlet to the tunnel. This contracted to a 300 mm x 300 mm working section, 2.4 m long - enough to house a 3-trailer road train model. The section was manufactured from clear perspex with a removable lid to access the models.

A series of holes in the floor and roof of the tunnel provided entry points for smoke. They were blocked off when not in use to prevent leakage into the working section. An adjustable inlet, located downstream of the working section, allowed variation of velocity. When fully closed, all air was drawn through the working section allowing a maximum velocity of around 30 m/s. The velocity was varied down to 0 m/s by opening the inlet to allow some air to be drawn in from outside the tunnel section. A fan and silencer were positioned after the adjustable inlet.

### 3.1.2.1 Models

Scaled models of the prime movers, trailers, dollies and crates that make up road trains were needed to model on-road conditions in the wind tunnel. The models needed to fit inside the working section of the wind tunnel, but be large enough to allow air flow patterns to be observed easily. A scale of 1:25 was chosen as it satisfied the above conditions and off-the-shelf kits at this scale were readily available.

Two prime movers were chosen as being representative of the vehicles used in the stock transport industry - a conventional (long nose) design with sleeper cab, and a 'cab-over' type also fitted with a sleeper cab.



**Figure 3** A darkened chamber around the wind tunnel allowed easier observation of smoke plumes

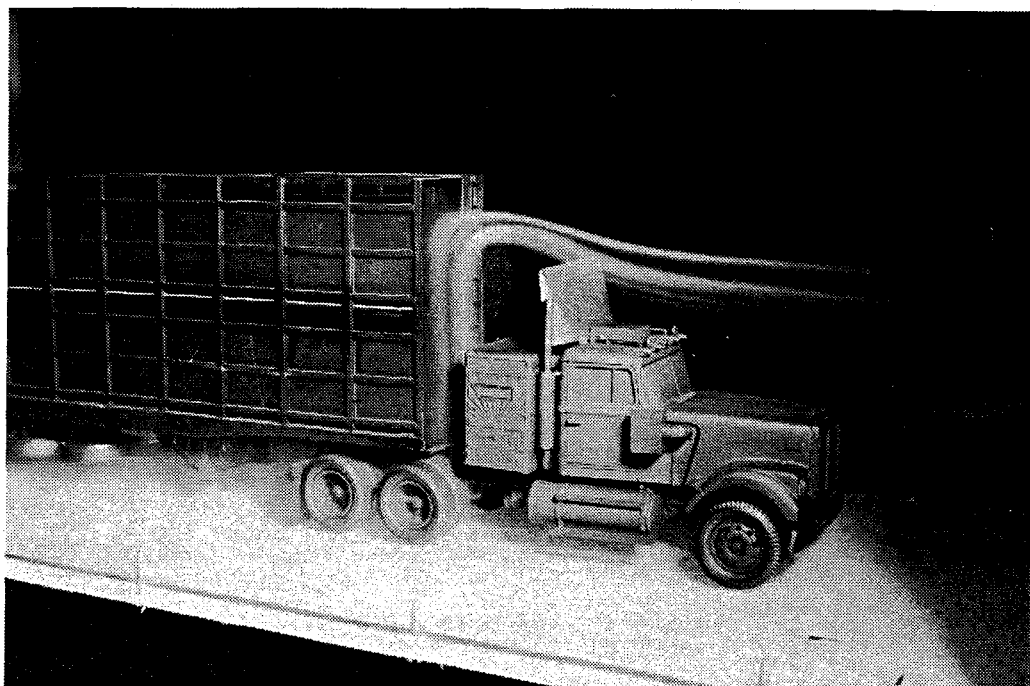


Figure 4 Example of model prime mover and trailer in wind tunnel - note the smoke plumes

Suitable models of stock crates, trailers, and dollies were not available in kit form so these were constructed from modified kits and sheet plastic sections. Three trailers similar to those produced by Haulmark (complete with belly tanks and spare tyres), three stock crates similar to gear from Whels Equipment, and two dollies were built. This allowed any configuration up to a three trailer road train to be modelled. The models were painted matt black to assist with the smoke visualisation and photography phases of the test program.

### 3.1.2.2 Air flow patterns

To monitor air patterns in and around the models in the wind tunnel, flow visualisation methods were used. By introducing particulate matter into the airstream and observing its progress down the tunnel, or by watching the movement of a flexible element within the working section, flow patterns were able to be monitored. Two methods were used in these studies - tufts and smoke.

**Tufts:** Short lengths of light cotton thread formed a series of 'tufts'. These tufts were placed strategically on models to determine the direction of air movement at particular points. Tufts were particularly useful for observing airflow movements into and out of the crates. By placing them on the sides of crates, visual observation showed whether they were drawn into, or blown out of, the crate. A disadvantage of this system was that tufts needed relatively high air flows to produce clearly defined direction changes.

**Smoke:** Smoke injected into the airstream allowed easy monitoring of flow patterns around the wind tunnel models. Generation of this smoke proved a major challenge. A small paraffin oil smoke machine was used in early trials. This machine

operated by heating paraffin oil until a white-coloured vapour was released. This was drawn off and piped to the inlet manifold of the wind tunnel. This system was only effective at low air flow rates because the small output of the unit was rapidly diluted and could not be seen at higher flow rates.

A commercial smoke generating machine was most successful. This machine vaporised a water based liquid, producing a dense cloud of white smoke. The amount of smoke was controlled by limiting the liquid supply. Smoke was usually piped directly to the inlet of the tunnel, but during some tests it was injected at several points in the tunnel section simultaneously. To enable this, the smoke generator was placed in a chamber which acted as a smoke reservoir. The reservoir was pressurised, and the smoke forced into the wind tunnel via several pipes.

### **3.1.2.3 Velocity measurement**

Velocity in a wind tunnel can be measured by several methods, most commonly by using a manometer to measure pressure. Alternatively, air velocity meters (anemometers) can be used. Two types of anemometer were used in this series of tests - 'hot wire' and propeller. Several measurements were made at each test flow across the tunnel cross-section. An average velocity was then calculated. Both instruments gave comparable results and operated satisfactorily.

### **3.1.2.4 Photography**

Photographic records of airflow patterns were made during the flow visualisation studies. Video and still photography were used. To assure high quality results a chamber was built around the working section of the tunnel to block out ambient light. Incandescent bulbs provided artificial lighting to enhance the visibility of smoke within the tunnel for both video and still photography. Standard 35 mm colour film produced a characteristic yellowing of prints due to a colour imbalance created by incandescent lighting. Tungsten film, a more costly option, would have compensated for the light imbalance, but was not needed because the clarity of prints was acceptable.

A 35 mm SLR camera mounted on a tripod and equipped with a 35-70 macro lens was used for the still photography. A polarising filter eliminated problems due to reflections from the perspex sides of the wind tunnel.

Video footage was professionally recorded for publicity purposes. Studio standard equipment was used and although the footage quality was high, the cost for routine use was unjustifiable.

### **3.1.3 Prototype fabrication**

The concepts developed in the wind tunnel were further developed into full-scale prototypes and installed on commercial road trains for field testing. Trucking companies and commercial fabricators provided advice on final design specifications.

Eagle Canvas Pty Ltd (Brisbane) fabricated prototype components. This company's professional expertise and close ties with the transport industry were major determinants in their selection. Larger scale models of two crates fitted with dust suppressing devices were constructed to assist Eagle Canvas in manufacturing the modifications.

### 3.1.4 Environmental monitoring

This project concentrated on monitoring the environment inside stock crates during transit. Existing information about conditions inside the trailers of road trains was largely anecdotal - very little data from formal monitoring programs were available. Lapworth (1985) conducted a preliminary investigation into the thermal and dust conditions inside crates, but was unable to monitor dust levels because no suitable commercial equipment was available.

To quantify the effects of modifications designed to improve conditions inside crates an instrumentation system capable of monitoring the trailer environment was required. The equipment used by Lapworth (1985) was not suitable for this study due to medium to long-term reliability problems. Robust instrumentation was essential because of the extreme conditions under which road trains operate. It needed to withstand severe vibration, high temperatures and prolonged exposure to high dust levels.

Five variables were considered for measurement in the crate environment:

- black body temperature;
- relative humidity;
- ventilation rate;
- dry bulb temperature; and
- dust level.

#### 3.1.4.1 Black body temperature

Black body temperature represents the temperature of a body that is capable of absorbing thermal radiation. It gives a more accurate indication of the heat stress experienced by animals than the dry bulb temperature of the air. For example, at identical air temperatures an animal exposed to direct sunlight feels 'hotter' than an animal under shade because it absorbs solar radiation directly. Black body temperature could therefore have provided the project team with useful data on differences between top (unshaded) and bottom (shaded) decks on road trains, and between day and night transport.

Instrumentation to measure black body temperature would need to be located amongst cattle in a trailer to obtain meaningful data. This was impractical due to the likelihood of instrument damage by cattle and unacceptable intrusion into the cattle area.

#### 3.1.4.2 Relative humidity

Transport of stock in road trains normally takes place in the 'dry season' from late March to early November. The relative humidity during this time is low and would not vary significantly inside a cattle trailer during transit. It was therefore not considered essential to monitor relative humidity.

#### 3.1.4.3 Ventilation rate

Equipment to monitor airflow is expensive and delicate, and would only yield an approximation of the ventilation rate in a cattle trailers. Multiple units would have been needed to determine ventilation rates in trailers, incurring a significant cost.

Even if cost was not an obstacle to airflow monitoring, the team considered it impractical to place airflow instruments among cattle on a trailer. The instruments are not robust enough to handle the severe vibration, shock loading and direct impact from cattle that occur during transport.

#### 3.1.4.4 Dry bulb temperature and dust level

Dry bulb temperature and dust level were both monitored during transport trials. These two variables provided a sound basis for comparison of environmental conditions in modified and conventional trailers. The instrumentation used to measure dry bulb temperature and dust level was sufficiently robust to operate reliably for extended periods in cattle transport environments.

#### 3.1.5 Dry bulb temperature measurement

The thermal environment inside double deck cattle crates has been widely debated since they were introduced in the late 1970s. Many people believe that poor ventilation in the bottom deck greatly increases temperatures, and that the effect is even more pronounced in fully sheeted crates. These concerns led to the development of instrumentation to monitor thermal environments inside crates during transit (for example, Lapworth 1985).

The instrumentation developed by Lapworth (1985) performed satisfactorily in the short term but experienced reliability problems over longer periods of monitoring. That work provided the impetus for the work proposed in DAQ.070, and clearly demonstrated that robust, reliable equipment was needed to withstand the harsh conditions encountered on road trains.

The selection criteria for dry bulb temperature sensors included low power consumption, noise resistance, analogue output signal, robustness, ease of installation and low maintenance. Low power consumption was desirable as it allowed instrumentation to run on a battery back-up when trailers were disconnected from the prime mover. Signal noise was considered a potential problem as long cables were used to connect sensors to the recording device. Cable length ranged from 5 m to 16 m. Cables were also run together in conduit on the trailer so interference between cables had to be considered. An analogue output signal was needed to deliver a suitable signal to the logging equipment.

Copper-constantan thermocouples were chosen to measure dry bulb temperatures. Thermocouples provided a simple and cheap method of monitoring temperature without sacrificing accuracy or reliability, provided they were installed and calibrated correctly. The data logger and thermocouples were connected via an iso-thermal block. The iso-thermal block compensated for the thermocouple effect experienced at the junction of the copper-constantan thermocouple with the input leads to the data logger.

Normally the sensing point or junction of the thermocouple is formed by twisting the ends of the copper and constantan wires together. Silver soldering of the wires at their junction would have improved the joints strength. This approach was rejected because errors sometimes occur due to a thermocouple effect at silver-soldered junctions.

An alternative method, known as the 'quick tip', crimps a metal sleeve over the two wires. The system allows unskilled operators to quickly produce secure, neat joints, but requires an expensive crimping tool (approximately \$A900.00 - November 1992).

A modified 'quick-tip' system was developed for use on temperature sensors used during these trials. It involved crimping a copper capillary tube over a twisted pair of thermocouple wires using conventional tools. The system was simple and cheap, but allowed reliable and accurate monitoring of the thermal environment during transport.

### **3.1.6 Dust measurement**

Dust levels inside the cattle crates were difficult to monitor continuously. Commercially available electronic instrumentation was designed for use in laboratories or smoke stacks. This equipment was expensive and too big for practical use in crates on road trains.

#### **3.1.6.1 Continuous versus discrete monitoring**

The project required continuous monitoring of dust levels. Instantaneous comparisons within crates and between crates were needed to compare variations in dust levels over short stretches of dusty road bed. This requirement precluded filter systems, which required extended periods to collect samples, unlike the instantaneous results given by an electronic instrument.

A further disadvantage of filter systems was the need to collect and replace sampling filters. It would have been necessary to remove and replace filters, then weigh them - a difficult task on a fully laden road train located several thousand kilometres from a laboratory.

#### **3.1.6.2 Previous work**

A literature review conducted in the early stages of the project yielded information on prototype instruments for monitoring dust levels in mines (Cashdollar et al. 1981) and measuring grain dust level (Rajendran and Stockham 1985). Both applications related to the human safety aspects and explosion risks of dusts. The instruments were unsuitable for monitoring dust levels in this trial because they were not robust enough and did not perform adequately across the particle size range typically found in cattle transport applications. Developmental work was therefore started to build a meter suited to the needs of this project.

#### **3.1.6.3 Specification and development**

The design specifications developed for the dust monitoring equipment reflected the type of data sought and the environment within which the meter was to operate. The dust sensing assembly needed to be:

- small - a nominal maximum intrusion of 100 mm into the crate;
- capable of continuous monitoring;
- energy efficient - limited power available;
- robust - to withstand severe vibration and shock loadings; and
- relatively inexpensive.

Comparisons between trailers in different road trains required a minimum of eight instruments. Therefore the cost of each instrument was important if dust sensing was to remain economically viable.

DPI and Monitor Sensors (Caboolture) collaborated to develop appropriate dust meter technology, and provided workshop and electronic development expertise respectively. The process of researching and developing sensing elements for the dust meters took much longer than originally scheduled in the project timetable. This time input was, however, unavoidable due to the crucial role that dust detection played in the project.

#### 3.1.6.4 Dust meter development

Three dust-sensing principles were pursued during the development of meters. These were ultrasonics, infra-red radiation and attenuation of visible light.

Ultrasonics avoided the problem of false readings due to dust build-up on the instruments. The concept depended on detection of density changes in air samples as dust concentrations changed. A signal frequency of 40 kHz was used in screening trials. The system failed because interference from wind noise prevented differentiation between the dust and the air.

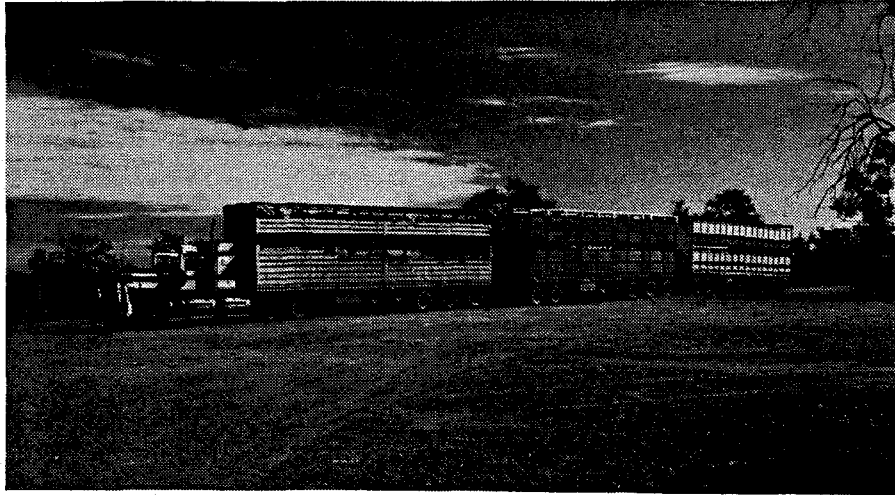
Dust sensing using infra-red radiation allowed a higher degree of sensitivity than was possible with ultrasonics. Infra-red sensing was trialled before techniques using visible light because of the lower likelihood of interference from external light sources. A prototype infra-red dust meter was tested at the Department of Mines Safety Laboratory (Brisbane). Data obtained during testing indicated lower rather than higher dust concentrations as dust level in the air was increased. This anomaly was partly attributed to the infra-red wavelength being long enough to miss or pass around dust particles below a certain size. In addition, a 'bounce effect' occurred whereby light was reflected from dust particles that were not in line with the emitter and detector, thus increasing the amount of infra-red radiation reaching the detector. Infra-red sensing of dust levels was rejected because of poor performance of the prototype instrument.

Dust sensing by attenuation of visible light relied on dust particles presenting a barrier between a light source and a detector. As the dust concentration in an air sample increased, the light intensity at the detector decreased.

The first prototype of a visible light meter used a red light emitting diode (LED) as the light source, and a path length of approximately 75 mm from the LED to the detector. A 75 mm diameter axial flow fan drew the air sample through the tube fitted with the light source and detector. This system suffered problems due to dust depositing on the lenses of the detector and the LED. As a result, readings from the meter indicated much higher dust concentrations than were present in the air. The dust seemed to be held to the lens by electrostatic forces, most likely caused by the fan mounted on the tube. Electrical interference and ambient light entry to the sensor caused further problems, resulting in unstable output signals from the prototype unit.

The dust coating problem was solved by mounting the LED and detector inside a recessed tube. The region of the tube between the LED or detector and the free stream of dusty air was pressurised to prevent dust leakage into the recessed area. During the test program this air was supplied from a cylinder of compressed oxygen. This worked well during laboratory testing of the instrument, but an alternative supply was needed when the instruments were mounted on trailers.





**Figure 5** Typical instrumented road train used in field trials - middle trailer contained dust sensors, temperature sensors (thermocouples) and data logger.

Options to supply air to the meters included installing a compressor on the trailer, a separate air pump and filter for each meter, or using air from the truck's brake system. The latter was chosen after consultation with trailer manufacturers. This system is outlined in the section of the report describing the instrumentation of the crates.

Electrical interference problems were minimised by shielding all signal-carrying wires in the dust meter's electronic circuitry.

Tests to isolate problems due to ambient light entry revealed that the signal from the detector was 'chopped' at a frequency similar to the rotational speed of the fan used to draw air into the meter. Further analysis revealed that this fan was chopping ambient light entering one end of the tube. Elbows attached to each end of the dust sampling tube solved the problem.

Prototype dust meters based on the attenuated visible light principle were tested and calibrated in a specially constructed dust chamber. This chamber was used to keep a dust sample in suspension while tests were carried out. Calibration was essential to allow comparison of data from dust meter in various positions in the trailer. Each meter had different characteristics due to variation in performance between electrical components used in their construction.

Three options were available to calibrate the meters - dust samples prepared by the Department of Mines; filters in series; or direct comparison between meters at different dust levels in a dust chamber. The first method was abandoned when a suitable medium in which to suspend the dust particles without coagulation occurring could not be identified. Coagulation was due mainly to the nature of clay particles in the dust sample.

Final calibrations used a combination of the remaining two methods. A series of semi-transparent filters was constructed. All dust meters were tested using these filters, and the results combined to give a series of reference points. This allowed comparisons to be made between meters.

The dust meters developed for use in DAQ.070 gave a relative reading of dust concentration, not an absolute reading in  $\text{mg}/\text{m}^3$ . This was satisfactory for the nature of the work undertaken during cattle transport trials. The final meter design was configured to give an output varying from approximately 200 mV at the dust free end of the scale to approximately 1.2 V at the upper end of the spectrum.

The meter design used in trials during DAQ.070 would benefit from further developmental work to improve its performance further.

### 3.1.7 Data logger

An electronic logging device was needed to store data from the temperature sensors and dust meters. A microprocessor-based Datataker DT100 data logger was chosen as it had sufficient data storage capacity and could be programmed to down-load data to a portable IBM-compatible computer. These loggers proved to be extremely reliable under conditions of severe vibration.

### 3.1.8 Video monitoring

A video system capable of monitoring and recording inside the cattle trailer during transit was assembled and installed on the modified trailer. This enabled the environment inside the crates, and the response of the cattle to this environment to be visually monitored from the cabin of the prime mover while the truck was in motion. This information was recorded on videotape to allow further analysis.

The video system comprised:

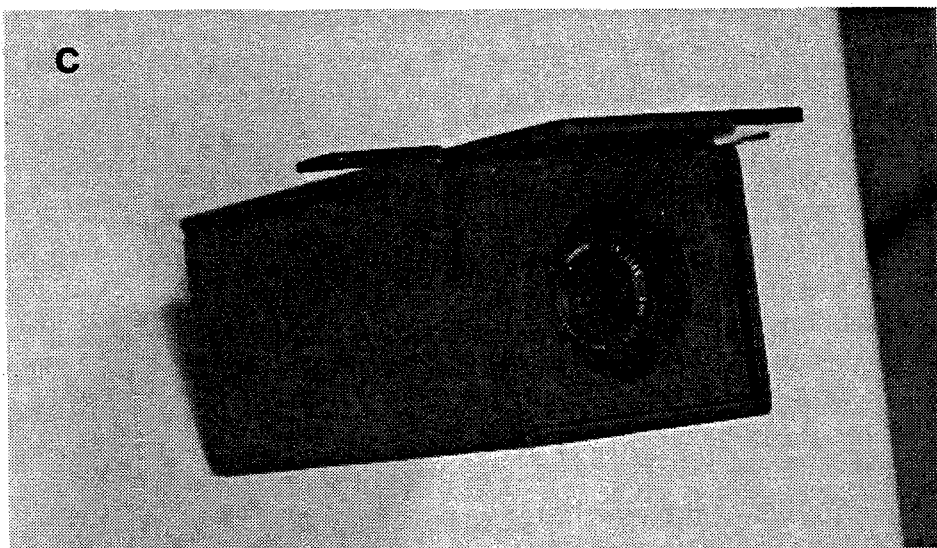
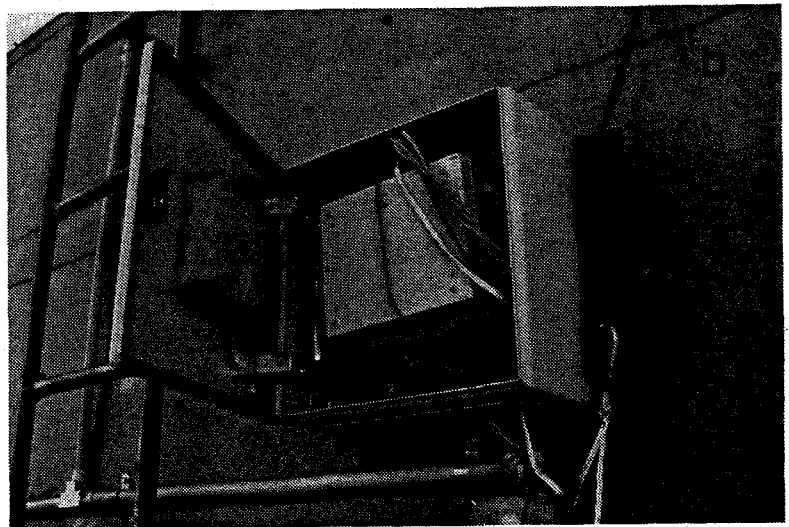
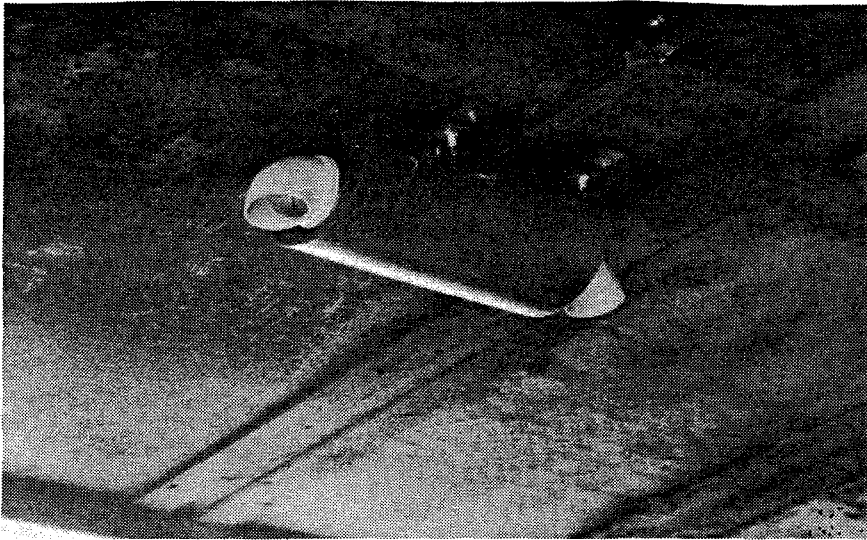
- four B&W video cameras, each fitted with auto iris lens;
- VDU monitor;
- quad controller; and
- time lapse video recorder.

The system was powered by a 12 V supply from the truck batteries. Where 240 V was required an inverter was used. The video cameras were housed in weather proof protective boxes. The monitor and recording equipment was mounted in a protective frame inside the prime mover sleeper cab.

## 3.2 Testing and evaluation

Two areas were covered during the testing and evaluation process:

- evaluation of the low-dust modifications developed in the engineering phase of the project using environmental data recorded in both the modified and unmodified trailers; and
- field trials aimed at quantifying the effect that transport innovations such as the low-dust trailer and double deck loading ramps had on animal stress levels and meat quality.



**Figure 6** Examples of instrumentation fitted to cattle trailers - (a) dust meter; (b) data logger; (c) video camera in sealed, shock-proof housing

### 3.2.1 Low-dust trailer trials

Testing and evaluation of the low-dust modifications occurred in two phases. The first involved a direct comparison of the environments of a modified trailer and a typical unmodified commercial trailer. The second stage of the evaluation concentrated on the effect of the modified environment on stock travelling in the trailer. Several trials were conducted in northern and western Queensland during the first phase in preparation for work undertaken during the second phase.

Two road trains were needed for these evaluations. One unit, a control, was a typical commercial combination of truck and two or three trailers. The other unit contained the modified trailer fitted with modifications. The modified trailer was always the second trailer in the road train.

Both the modified trailer and the control trailer were fitted with instruments to monitor dust and temperature. The modified trailer was also fitted with video cameras to monitor animal behaviour and dust flows in the crate.

Collection of environmental data from the modified and unmodified road train trailers allowed an assessment of the effect of low-dust modifications. This involved fitting environmental monitoring equipment to trailers in the control and 'experimental' road trains.

The two road trains, one with a modified trailer, then travelled the same route approximately 0.5 to 1 km apart. It was assumed that each road train was subjected to the same external conditions such as wind, temperature and road conditions. Cattle carried during these trials had to be travelling from a property to an abattoir for slaughter. Journeys involving a significant proportion of travel on unsealed roads were used when possible. Other consignments were used if the only cattle movements available were from properties relatively close to sealed roads.

Approximately 160 cattle were needed to fill the minimum of four trailers required for each trial.

Each consignment of cattle was accompanied by researchers for the entire journey from property to abattoir - typically more than 1000 kilometres. Before arrival at an abattoir, cattle in both the top and bottom decks of the modified and unmodified trailers were marked with paint to assist in identifying the experimental and control groups. During transport the cattle were monitored closely and abnormal behaviour such as extreme agitation noted.

Upon arrival at the abattoir each group was penned separately and allowed to rest for a period of one to three days before slaughter. Samples and measurements were taken during slaughter and the resultant data analysed to determine whether the modified trailer reduced stress levels and improved meat quality.

### 3.2.2 Animal stress and meat quality analyses

Experimental procedures for this section of the project were coordinated by Frank Shaw (CSIRO Meat Research Laboratory, Cannon Hill) and Gavin Browne (LMAQ, Brisbane).

The impact of handling and transport modifications on stress was determined for the trial cattle by measuring:

- plasma constituent levels in post-slaughter blood samples - a biochemical indicator of stress; and
- levels of dark-cutting meat using muscle colour assessment.

The impact of the modifications on the level of bruising was assessed using the AUS-MEAT beef bruise reporting system. An attempt was also made to identify those bruises which occurred during transport. This was done using bruise ageing techniques.

### 3.2.2.1 Plasma constituents

Blood samples were collected in polypropylene tubes (containing the anti-coagulant EDTA) while blood was flowing freely during exsanguination. After gentle mixing, the tubes were placed on ice for transport back to the laboratory. Approximately 3 hours after the samples were collected, the tubes were placed in a refrigerated (5°C) centrifuge and plasma obtained by centrifuging at 2600 rpm for 20 minutes. Plasma was stored in polypropylene vials at -20°C until required for assay.

Radioimmunoassay (RIA) kits<sup>1</sup> were used to assay blood plasma for cortisol and adrenocorticotrophic hormone (ACTH). Quantitative kinetic determinations<sup>2</sup> at 340 nm were used to assay for creatine phosphokinase (CPK).

### 3.2.2.2 Muscle colour assessment

Muscle colour, as a determinant of dark-cutting, was measured by two methods, objectively with the Colormet probe and subjectively with the muscle colour chips as used in the AUS-MEAT Chiller Assessment system.

**Colormet probe:** Colormet probe technology was developed in Canada. It uses a similar principle to that of the Minolta chromameter for surface reflectance, but also measures internal reflectance over a range of wavelengths when inserted into a carcass.

The probe provides standard  $L^*a^*b^*$  (CIELAB) values. Any colour may be matched exactly by a suitable mixture of the three primaries: red, blue and green. The relative amounts of these colours required to match a given colour are known as the tristimulus values and are measured in terms of:

- $L^*$  (lightness) - zero equals black and 100 equals white;
- $a^*$  (redness/greenness) - positive value for red, negative value for green; and
- $b^*$  (yellowness/blueness) - positive value for yellow, negative value for blue.

When  $a^*$  and  $b^*$  are both zero, the colour is white or grey or black, depending on the value of  $L^*$ . As  $a^*$  and  $b^*$  values move further away from zero, in either direction,

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<sup>1</sup> Incstar Corporation, Minnesota, USA (Cortisol): Diagnostic Systems Laboratories Inc, Texas, USA (ACTH)

<sup>2</sup> Sigma Diagnostics, Missouri, USA

colours become more 'saturated' i.e. brighter or deeper. Highly saturated colours have a\* or b\* readings of 80 or more.

One side of each carcass was probed during trial work. The Colormet probe was inserted into the *m. longissimus dorsi* (LD) on a vertical plane, to reach an area of the muscle tissue where there was unlikely to be any interference from deposits of intramuscular fat. Insertion was deep enough to ensure that the measurement ring on the probe was entirely enclosed by the sample.

Generally only one measurement was taken, however a second measurement was made where an error message was displayed or the readings appeared to be incorrect, e.g. where the L\* value was higher than expected given the range of measurements being obtained on the day, possibly indicating that the measurement ring had been surrounded by a fat deposit.

The probe avoids the possible subjectivity in muscle colour assessments made by human assessors. Despite this advantage, the probe is not in widespread use in Australia. Further studies to confirm its effectiveness are needed before abattoirs are likely to widely accept it.

**AUS-MEAT Chiller Assessment:** To supplement the Colormet probe, muscle colour was also assessed using the standards as employed by the AUS-MEAT Chiller Assessment system. Chiller assessment is currently used by the export sector (Japanese grainfed market) of the beef industry and is gradually being accepted by the local trade sector. It was therefore appropriate that muscle colour was assessed by means of the prevailing industry standard.

Muscle colour was assessed by holding numbered chips against the LD and comparing the colour of the muscle with the chips. Muscle colour scores range from one through to nine, nine being the darkest. If the colour matched that of one of the chips exactly, the carcass was given the number of that chip. If, however, the colour fell between that of two chips, the carcass was assigned the lower score.

Assessments were made by an accredited chiller assessor. To achieve accreditation, abattoir employed assessors must achieve a sustained minimum level of 90% accuracy and consistency on carcass testing and pass a theory exam. AUS-MEAT employed chiller assessors must maintain a 95% proficiency level.

### 3.2.2.3 AUS-MEAT beef bruise reporting system

Carcass bruising was recorded using the AUS-MEAT beef bruise reporting system. Under this system carcass bruising is scored at the scales on the slaughter floor by the grader, being assigned a score of one to nine based on the site, and number, of bruises. The system is outlined in Appendix A.

The bruise scores were obtained following the slaughter of the trial animals from abattoir records listing daily kill details. These records also provided sex, carcass weight, dentition and fat depth information.

### 3.2.2.4 Bruise ageing

Abattoir workers who were trimming carcasses placed all bruised tissue in plastic collection bins that were strategically placed on the slaughter floor. This tissue was not correlated with individual animals, however tissue from different groups (for example, cattle from modified trailers) was separated. For each experimental group of animals a mean bruise trim weight per carcass was calculated.

Representative samples of bruised tissue were selected for both the bilirubin test and for histological examination. For the bilirubin test, 20 g of bruised fat was cut into small pieces and placed in a screw top 50 ml centrifuge tube. Ten millilitres of chloroform was added, the tube inverted several times, and placed in a dark area and left overnight. Ictotest tablets were used the following day to detect the presence of bilirubin in the chloroform extract (Shaw 1977).

For histological purposes, 15 g of bruised tissue was placed in 150 ml 10% buffered neutral formalin and allowed to fix for a time in excess of 72 h. Standard automated histological procedures for wax impregnation were used. Sections (7  $\mu$ ) were cut using a Spencer microtome. Initially, staining techniques for Haematoxylin and Eosin (H & E) and Prussian Blue were used as described by McCausland and Dougherty (1978). The H & E stain was subsequently replaced by a combined Verhoeff's Elastic-Martius-Scarlet-Blue trichrome stain (Buk 1984) while a modified version of the Prussian Blue stain was subsequently used.

Histological ageing of bruises was based on the methods of McCausland and Dougherty (1978). Changes in the polymorphonuclear cells : monocytes ratio and changes in the morphology of different white cell types and the ability of these cells to stain differentially in the histological process were all used to determine the time that bruising occurred. The trichrome stain was used for this purpose.

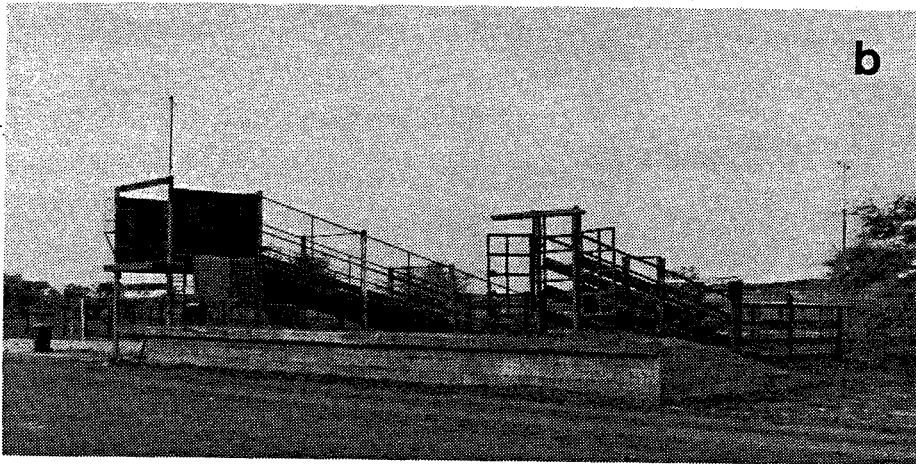
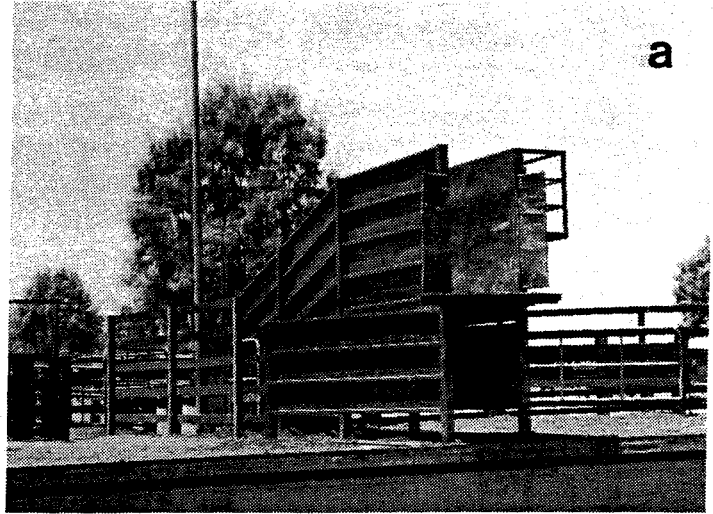
Prussian Blue stain was used to demonstrate the presence of haemosiderin, a product of the lysis of erythrocytes, both intercellularly in the tissues and intracellularly in macrophages. Bruises were classified as having occurred 0 to 8, 8 to 24, 24 to 48, or more than 48 hours before slaughter.

### 3.2.3 Loading method comparisons

The loading systems used by the industry have evolved over time. The original system involved using a ramp to load cattle onto the lower deck of a trailer. The cattle then gained access to the upper deck of a trailer by an internal ramp.

The double deck loading ramp, though more expensive than single deck ramps, was an improvement on this procedure. It allowed cattle to be loaded directly onto the top deck more easily, possibly with less carcass damage. Unloading is also easier.

The loading method trials investigated whether the improved systems were effective in reducing the levels of animal stress and bruising that occurs during loading and unloading operations.





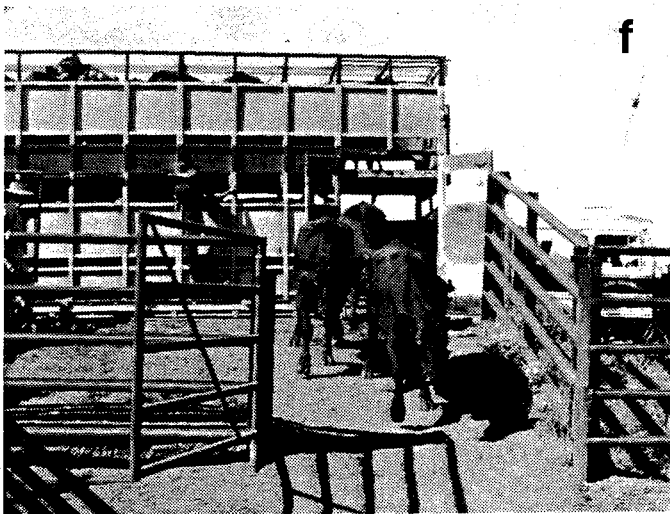
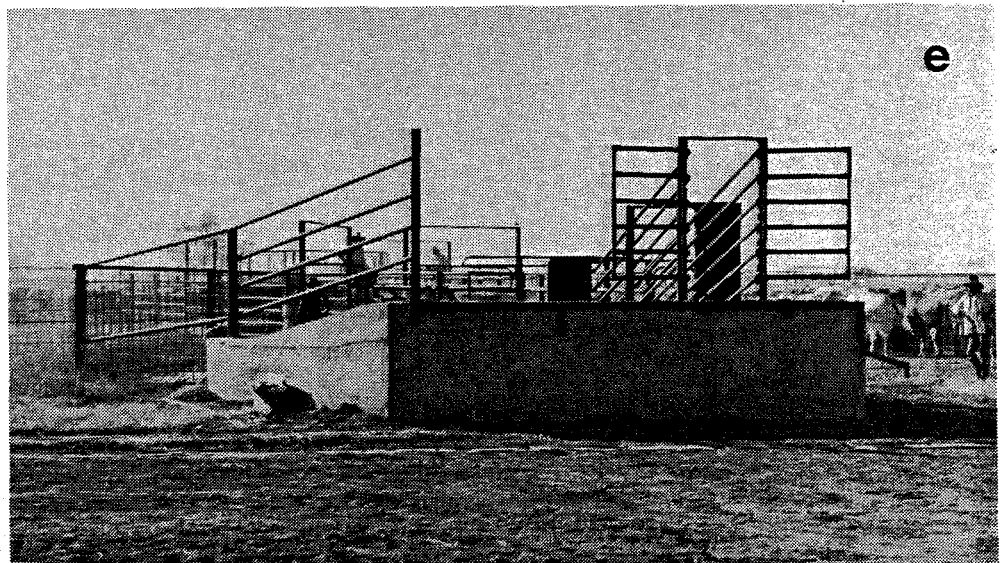
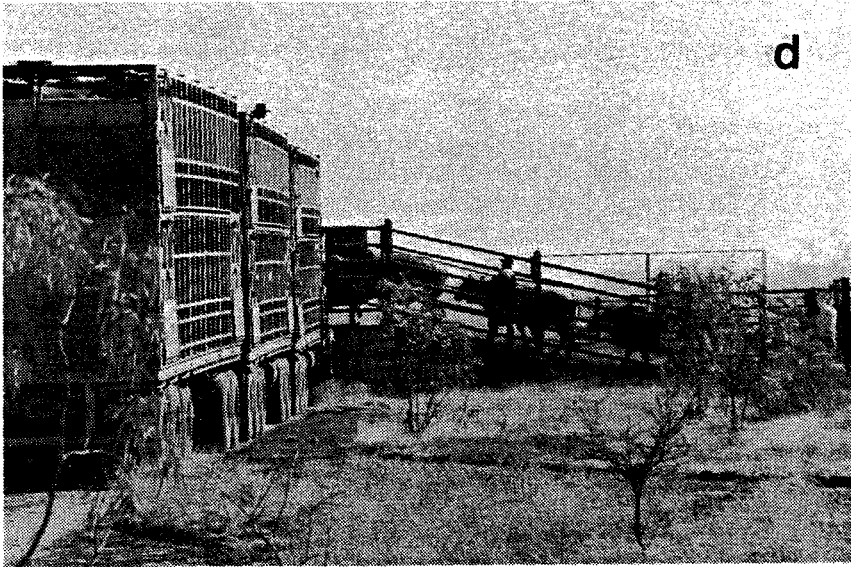


Figure 7 (a-f) The beef cattle industry uses a variety of single and double deck ramp designs to load and unload cattle.

Cattle were monitored during loading at properties, transportation, and then unloading at abattoirs. They were marked to identify whether they travelled on the top or bottom deck of a trailer, then penned separately at the abattoir. Stress and bruise levels at slaughter were recorded using the techniques described above. These data were analysed to ascertain the differences in animal stress levels and bruising between each group and to determine the value of double deck loading ramps.

These trials also provided an opportunity to undertake preliminary testing of procedures to be used in the low-dust trailer trials.

## 4. Results and discussion

### 4.1 Modelling

Wind tunnel studies allowed direct visual assessment of air flow patterns in and around a range of trailer configurations. This provided a basis for modifying road trains to improve the environment inside crates.

Preliminary wind tunnel flow studies concentrated on characterising typical air movement patterns around road trains. Three major findings emerged:

- air flows within the leading trailer were markedly different to those in the following trailers;
- some air deflector designs used on prime movers performed poorly; and
- air entry to trailers was affected markedly by floor type.

In the lead trailer, air tended to enter both the top and bottom decks of the crate around the middle half of the crate side. Air then flowed towards the front of the crate and exited from the sides in the front quarter of the crate. This meant that all air entering the front three quarters of the crate returned to the front before exiting. There also appeared to be an area in the rear quarter of the crate where the air exited from the sides of the crate. Air movement in the top deck of the lead trailer was more vigorous than that in the bottom deck but it followed a similar pattern.

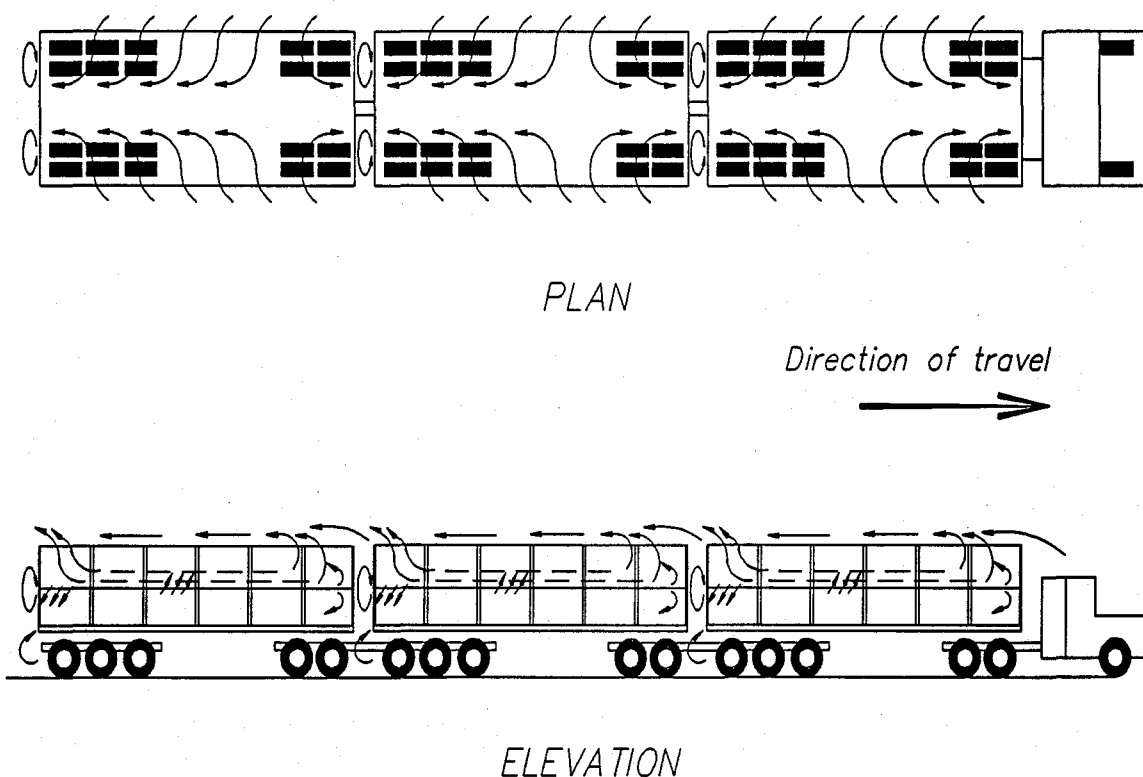


Figure 8 Schematic of conventional three-trailer road train - typical air flow patterns

The second and third trailers did not exhibit the strong forward movement of air observed in the leading trailer. Air movement in the bottom decks of these trailers was much steadier than in the lead crate. Air typically entered the crate in the front quarter region and travelled rearwards before exiting at the back of the trailer. Similarly in the top deck air moved rearwards rather than forwards. There was also much less air movement through the sides of the second and third crates when compared to the lead crate.

Further observation of smoke patterns in wind tunnel trials explained the differences in flow patterns. At the front of the road train, including the leading sides of the first trailer, a zone of air flow separation existed. The flow re-attached further down each side of the first trailer, then remained attached for the remaining length of the road train. As a result, a zone of low pressure formed in the front portion of the lead crate. This explained the strong forward movement of air in the lead crate, towards the low pressure zone.

Wind tunnel tests also showed that some air deflectors designed for general freight carriers do not work sufficiently well with the higher stock crates used in the cattle industry. Some deflectors did not deflect the air flow enough to move the impact point above the front wall of the leading crate. Whilst any reduction in the amount of air striking the front wall is useful, a deflector designed specifically for use with double deck livestock transports would be more effective.

It was clear from the modelling performed in the wind tunnel that solid floors on both decks would aid in keeping dust out of the crates. In the crates tested which had semi-permeable floors, a considerable amount of air entered them from under the floor. In full-scale trailers on unsealed road this air would be heavily dust-laden. The use of solid floors on the bottom deck should pose only marginally greater problems related to the accumulation of manure and urine than currently exists on top decks.

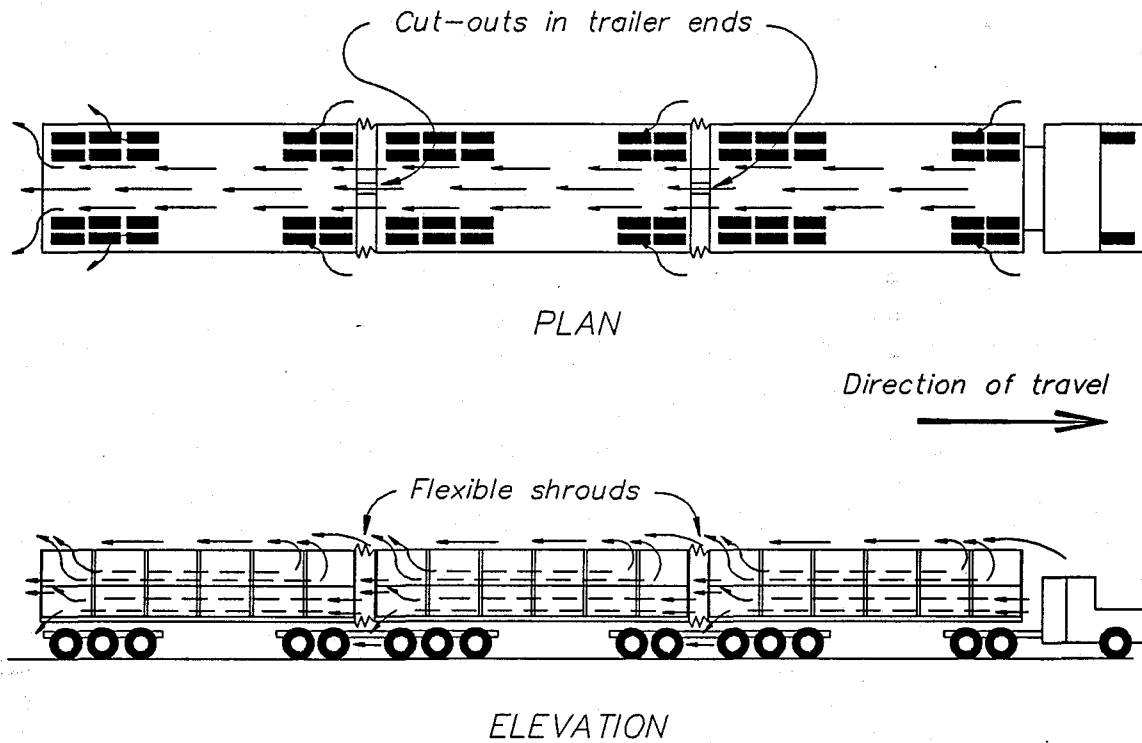
Once the basic air-flow patterns in conventional transports were understood, a range of modifications were tested in the wind tunnel.

#### **4.1.1 Air channelling**

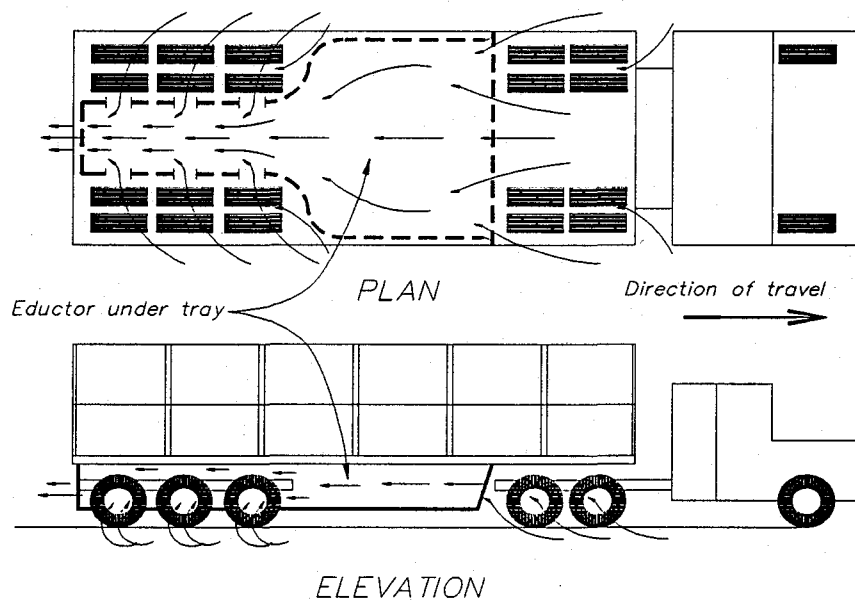
Air containing the lowest level of dust is found above the trailers, especially towards the front of the road train. It was proposed that by directing this air into the trailers, temperatures and dust levels around the cattle could be reduced. Such a system would also reduce the volume of dust-laden air entering the second and third trailers through the side walls.

Ventilation slots were cut in the ends of each trailer to allow air movement from the front to the rear of the road train during transport. Box-section shrouds were fitted across the gap between the model trailers to facilitate this air movement (see figure 9).

The shrouds were designed to prevent air rising between the trailers during transport. Under on-road conditions this was expected to reduce the dust concentration of air entering the trailers.



**Figure 9** Schematic of modified (low-dust) three-trailer road train - typical air flow patterns in wind tunnel. Note flexible curtains (shrouds) between trailers.



**Figure 10** Venturi eductor (concept only) - typical air flow patterns in wind tunnel

In combination with a solid floor on the bottom deck, these modifications reduced the movement of air through the trailer sides. It was this air that carried much of the dust into the crates. Extensive wind tunnel modelling established the effectiveness of the concept.

#### 4.1.2 Venturi

Another concept was developed in the wind tunnel but not fully developed for use on commercial units. The system utilised ducting suspended beneath each trailer to channel air as shown in figure 10. The ducting contracted to a slotted venturi throat around the wheel unit region. This drew dust-laden air, normally generated at the wheels, back under the trailer through the slots in the ducting instead of allowing it to move outwards and upwards past the sides of crates.

Problems with the size and location of the proposed venturi unit precluded its further development in this project. Researchers and industry agreed that an underslung duct system of the size needed would have little hope of surviving the road conditions under which many road trains operate. The system does, however, have potential to reduce water spray from heavy vehicles during wet conditions on highways.

### 4.2 Commercial prototypes

Transition from wind tunnel modelling to prototypes on commercial road trains involved extensive consultation with the transport industry. All prototype equipment had to withstand harsh operating conditions and not interfere excessively with the normal operating methods used by collaborating transport and pastoral companies.

The modifications were designed around a project trailer (DPI trailer) to ensure unlimited access during fabrication and fitting of prototypes. The DPI trailer was set up to act as the centre unit of a three trailer road train.

A full size prototype dust curtain, based on the box section used in the wind tunnel, was designed for insertion between trailer ends. The section needed flexibility to accommodate large movements between trailers and to provide a seal at both the front and rear of the trailer. In consultation with members of the Livestock Transporters' Association, the enclosure was made of canvas as it was cost-effective, easily modified and flexible. Eagle Canvas (Brisbane) assisted in specifying and constructing the curtain.

Large relative movements occur between the rear of a crate and the front of the following crate on road trains. Greatest movement occurs when a road train turns or passes through steep undulations and creek crossings. A support system for the dust curtains needed to accommodate these large movements.

Two curtain support systems were tested. The first, a telescoping linkage mounted between the trailers, was fabricated from sections of RHS steel. After testing, this approach was rejected because the linkages would have been prone to seizure in dusty environments. In addition, non-standard RHS sizes were needed meaning that fabrication costs would be high.

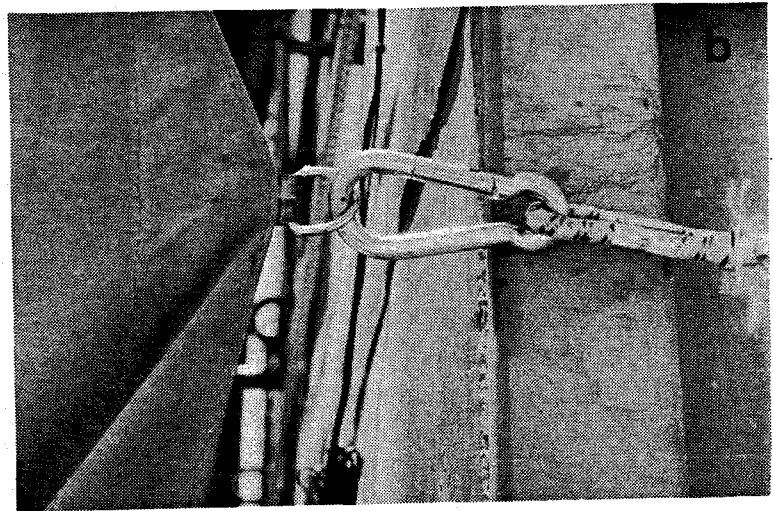
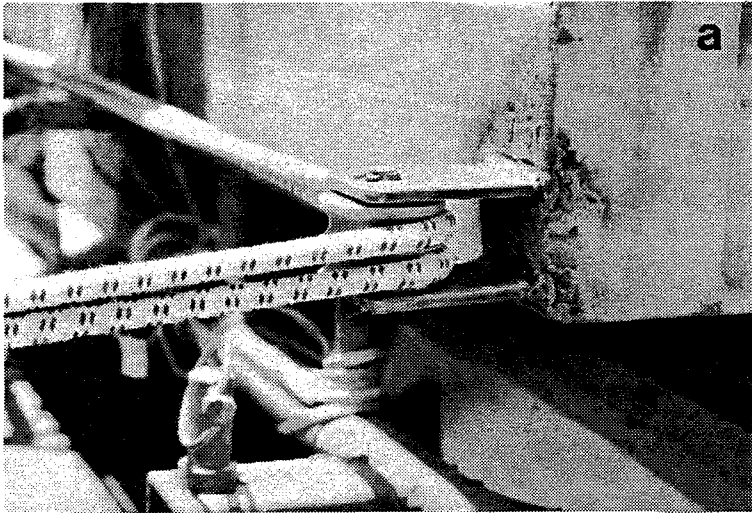


Figure 11 (a,b,c) Prototype low-dust curtains: (a) Elastic rope and roller supports attached to trailer; (b) 'Quick-hitch' connectors on curtain support ropes; (c) Curtain fitted between trailers.

The second method of supporting the canvas relied on elastic cord as shown in figures 11a and 11b. The elastic cord was attached rigidly to one rear corner of the lead trailer, run in a horizontal plane around rollers at both corners of the following trailer, then terminated at the other corner of the lead trailer. Four cord support sets were installed between trailers - one at the bottom of the crate, one at the top, and two spaced equally between the top and bottom. The canvas curtain was then suspended on these cords.

The cord system operated well on sharp turns and when crossing undulations such as creek beds. The rollers allowed free movement of the support rope whenever horizontal movement occurred between trailers. The elasticity of the cord accommodated vertical movements.

The first curtain prototype was manufactured in three sections, a base section and two side sections. Velcro® fastening strips joined the sides to the base, but did not seal adequately. This was overcome by sewing the base section and the sides together. The curtain was fixed permanently to the rear of the lead trailer and held back against the second trailer with an elastic rope. This allowed the enclosure to stretch during turns and return to the rear trailer during straight ahead operation.

The last modification involved cutting ventilation slots in the front and rear ends of the DPI trailer.

The prototype modifications stood up to the harsh cattle transport environment well. Minor tears in the canvas curtains were the only damage noted. Further design work is needed if these modifications are to be commercialised. In particular, the system needs to be configured for rapid attachment and removal by one person.

#### **4.2.1 Environmental monitoring**

During development of the prototype modifications, temperature and dust levels were monitored in both modified and conventional trailers. In the latter stages of testing the video system was used to provide visual records of the environment and animal behaviour in the modified trailer. Visual comparisons of dust movement around the modified and conventional road trains were also made from observation points along transport routes.

##### **4.2.1.1 Temperature**

The air temperatures inside the crates were recorded during several transport trials. Typical temperature trends for a one hour period in conventional and modified crates in western Queensland are shown in figures 12 and 13 respectively. The road trains from which this data came were travelling up to 1 km apart.

These results are typical of those recorded during the testing period. The graphs show that there was little difference in temperature between the modified and conventional trailers. This trend appeared throughout all temperature trials undertaken during the project.



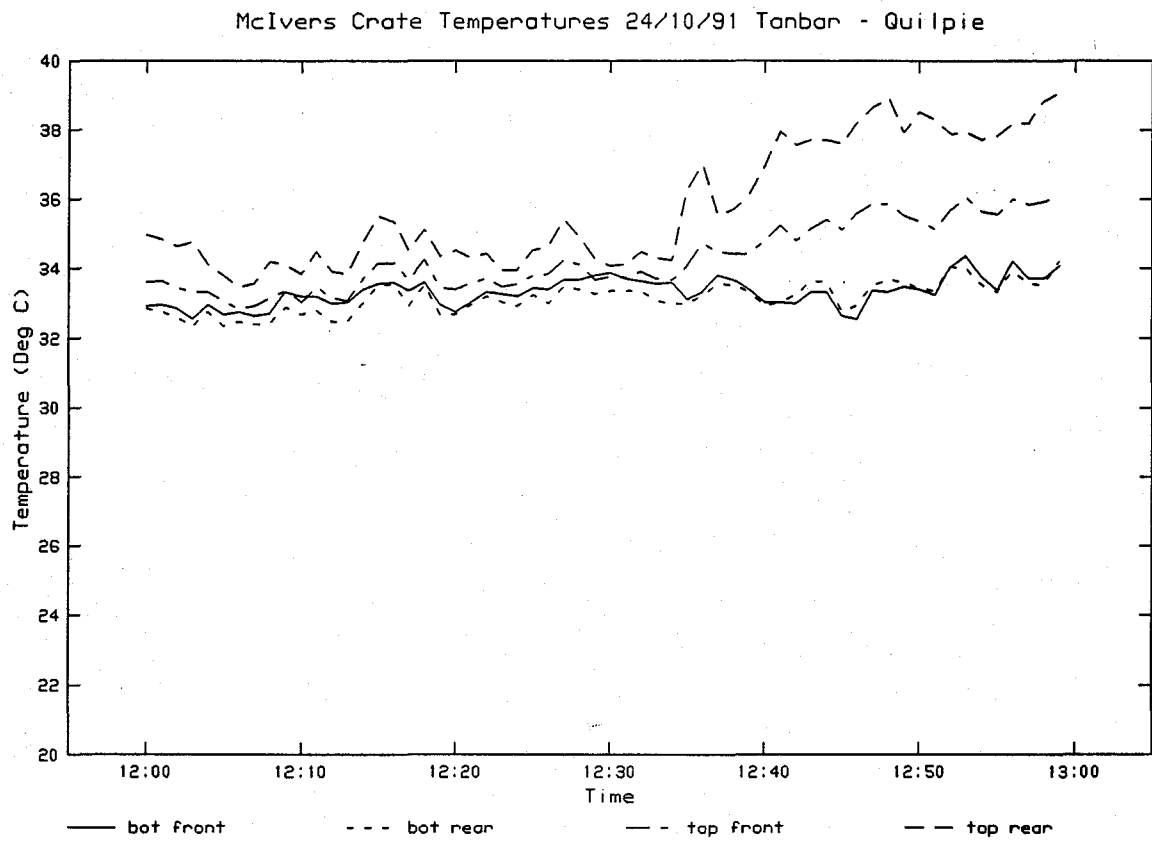


Figure 12 Typical temperature readings - unmodified trailer

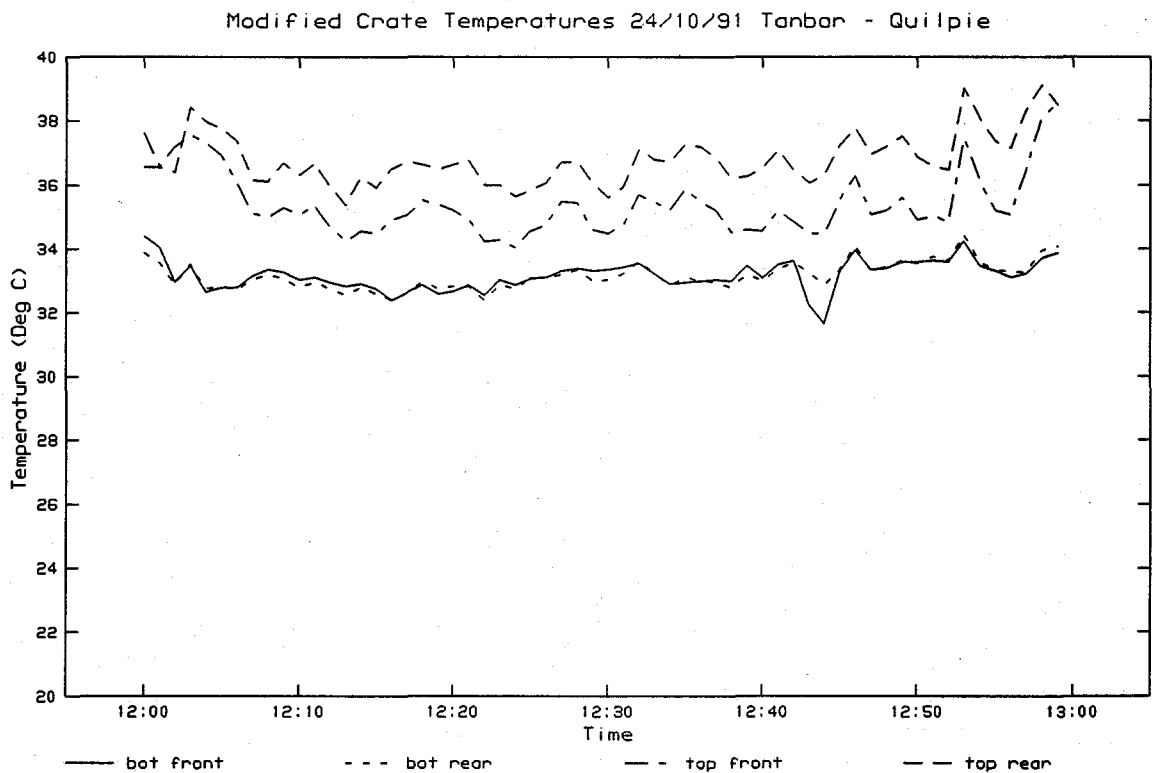


Figure 13 Typical temperature readings - modified trailer

#### 4.2.1.2 Dust Level

Typical examples of dust levels during the first low-dust trial from Durham Downs to Dinmore Abattoir are shown in figures 14 and 15. The data recorded during trials revealed two important points.

Firstly, only small variations in output signal values occurred during the logging period. This was due to the meters operating at the lower end (low dust levels) of their total range - between approximately 220 and 1200 Mv. Figures 14 and 15 show that most variations were only a few Mv.

Secondly, variation can occur over time if meter sensing elements are contaminated with dust. During one field trial, a meter gave a continuously rising output signal due to progressive dust contamination after failure of the air supply used to flush sensing element enclosures. This meter blocked completely later in the trial.

Greater sensitivity to low dust levels would have improved the quality of data available to the project greatly. In addition, easier calibration against standard dust concentrations would have allowed more reliable comparisons between meters.

#### 4.2.1.3 Video

Video equipment installed on the modified trailer provided a visual record of the environment inside the crates. Images recorded by the cameras and video unit showed that dust conditions inside the trailer were not severe.

Highest dust levels occurred when the road train was travelling slowly to negotiate deep areas of bulldust. During this time the road train was travelling at speeds of between 0 and 20 km/h, far too slow for aerodynamic aids to be effective. At no time were cattle observed to be visibly stressed or agitated.

#### 4.2.1.4 Remote Visual Observation

Strong evidence of improvements provided by the modifications came from direct observations of road trains. Altered air flow patterns around the modified unit were clearly evident.

Dust was held at lower heights along the modified road train by the curtains enclosing the gap between trailers. They prevented dust-laden air rising up between the trailers from where it would normally flow either along the sides, or over the top of the trailers. The reduced air turbulence along the sides of the road train also tended to restrict the upward movement and subsequent entry of dust into the crates.

#### 4.2.1.5 Conventional versus modified trailers

In general there was little difference between the environments within modified road train trailers and those currently in use. This was most clearly evident with respect to the thermal environment where the data showed similar conditions existed in both crates.

The dust meter results were inconclusive. Further development of the dust meters is needed before these units will be able to provide reliable, comparative data.

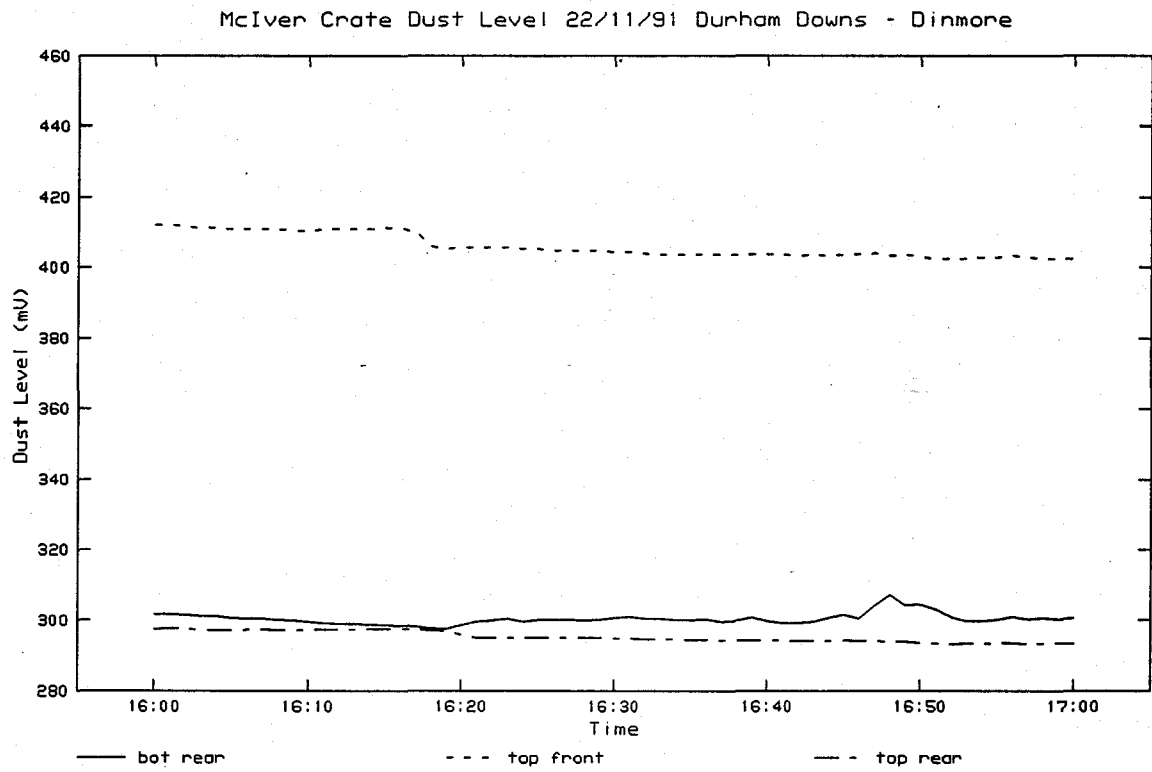


Figure 14 Typical dust readings - unmodified trailer

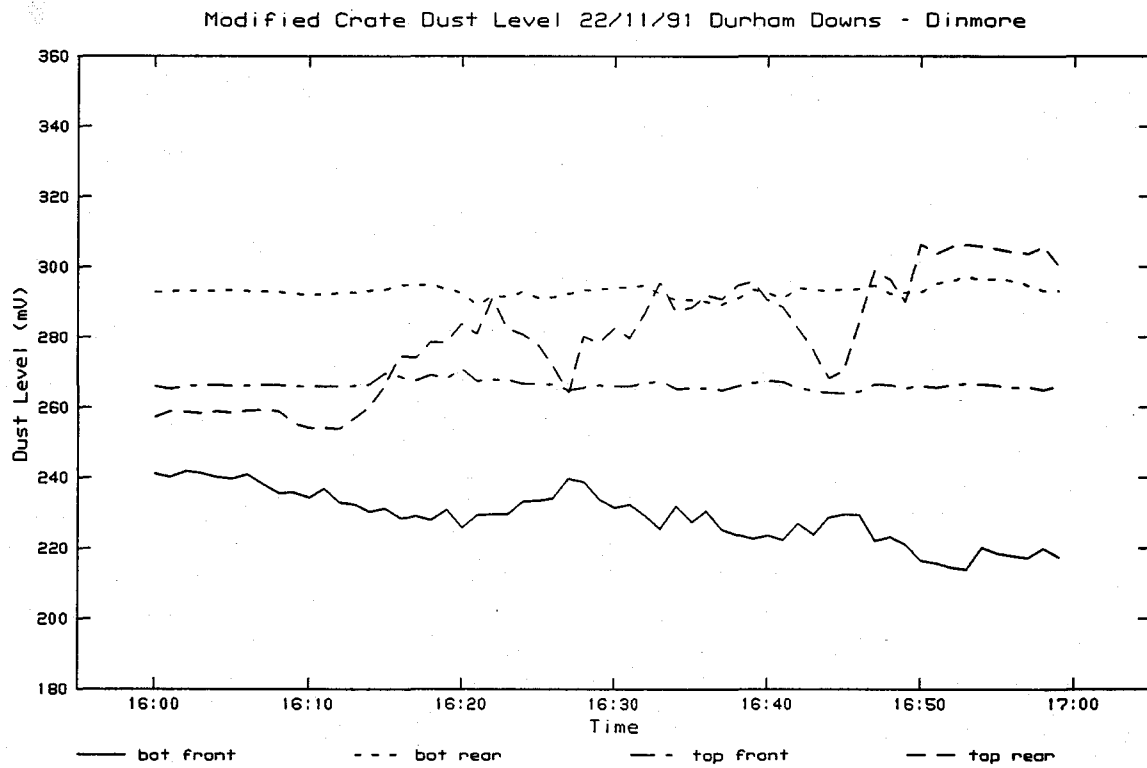


Figure 15 Typical dust readings - modified trailer

No comparison was able to be made using the video equipment as it was used exclusively on the modified trailer. Only one set of equipment was available. Visual observations of modified and unmodified trailers under typical transport conditions confirmed that modifications changed the air flow patterns around road trains.

### 4.3 Bruising and meat quality - trial results

Three trials quantified the effects of different loading methods on animal stress, carcass quality and meat quality. Cattle from southern Qld and northern New South Wales were used and slaughtered at abattoirs in Toowoomba. Appendix B details the trials.

Two further trials quantified the effects of the low-dust trailer. Both trials used stock from south-western Queensland carried in 3-trailer road trains. One modified and one control road train were used in each trial. The middle trailer was monitored in both units. Appendix C gives the trip logs and details of cattle transported.

To determine the effect of the low-dust modifications and the different methods of loading, the trial cattle and their carcasses were assessed at the abattoir for stress levels and bruising. Muscle colour was assessed approximately 24 hours after slaughter.

#### 4.3.1 Bruising

A summary of bruising damage occurring during the loading-ramp and low-dust trials is given in table 1.

**Table 1** Summary of bruising damage for loading ramp and low-dust trials - DAQ.070

	Bruise trim weight (g) <sup>1</sup>	% sides bruised <sup>2</sup>
<b>Loading ramp trials</b>		
1	240	0
2	175	1
3	145	ND <sup>3</sup>
<b>Low-dust trials</b>		
1 - steer	630	14
1 - cow	2150	17
2 - cow	340	18

<sup>1</sup> Bruise trim weight = mean bruise trim weight/carcass (g)

<sup>2</sup> % sides bruised = percentage of sides with an AUS-MEAT bruise score > 0

<sup>3</sup> ND = Not determined

In loading-ramp trial 1, all sides had an AUS-MEAT bruise score of zero (nil bruising). In trial 2 one side had a score of 1 while all other sides had a score of zero. AUS-MEAT bruise scores were not available for trial 3. Appendix D gives details of the AUS-MEAT bruise scores for individual bruised carcasses in the low-dust trials.

The bruise trim weights and the AUS-MEAT bruise scores recorded during the loading ramp trials indicate that only minimal bruising occurred during these trials.

In the low-dust trials, the low percentage of sides bruised, even in the 1 cow group, indicated that only a few animals sustained bruises. It can be seen from Appendix D that the majority of bruising in the 1 bullock group was derived from one animal (body no. 288; left/right side bruise scores of 8/8). This animal was observed to be down on several occasions during the journey (see Appendix C).

Similarly, the results in Appendix D indicate that a significant amount of the bruising in the 1 cow group occurred on 3 carcasses (body numbers 319, 321 and 328 ; left/right side bruise scores of 7/7, 7/7 and 8/4 respectively). The log of the trip (Appendix C) records that 3 cows were difficult to unload at the abattoir and bruising may have occurred then. If so, the animals in the 1 cow group would have sustained minimal bruising during transport.

The bruise trim weights listed in table 1 should be compared with those obtained in other similar experiments. Table 2 lists the results of several other bruising trials.

**Table 2** Bruising in cattle transported over various distances - literature review

Distance (km)	Min. bruise (g) <sup>1</sup>	Max. bruise (g) <sup>1</sup>	Reference
<b>(a) Steers and bullocks</b>			
40	420	2200	Meischke et al. (1974)
130	1150	2280	Meischke et al. (1974)
195	200	1500	Tarrant et al. (1988)
360	240	1025	Eldridge and Winfield (1988)
780	1700	2500	Yeh et al. (1978)
1000	460	1060	Tarrant et al. (1992)
1100	890	890	Yeh et al. (1978)
1500	1600	1600	Yeh et al. (1978)
Various	760	760	Wythes et al. (1985)
<b>(b) Cows</b>			
460	850	1920	Wythes et al. (1981)
780	2100	3220	Yeh et al. (1978)
870	2600	2600	Wythes et al. (1981)
1100	1310	1310	Yeh et al. (1978)
1500	3350	3350	Yeh et al. (1978)
Various	1250	1250	Wythes et al. (1985)

<sup>1</sup> Minimum and maximum figures are for different trials/treatments over the same distance.

Cattle in the loading ramp trials were transported 220 - 320 km and had mean bruise trim weights of 145 - 240 g. Low-dust trial 1 cattle travelled 1170 km. The steers had a mean bruise trim weight of 630 g, while the cows had a mean bruise trim weight of 2150 g. The low-dust trial 2 cattle (all cows) travelled 1280 km and had a mean bruise trim weight of 340 g.

Table 2 shows that Meischke et al. (1974) reported the smallest mean bruise trim weight/carcass (420 g) for a group of cattle in Queensland. Mean values in excess of 1000 g were commonly recorded by Meischke et al. for groups of cattle transported short distances (<150 km). Similarly, in overseas work, Tarrant et al. (1988) reported mean bruise trim levels of between 200 g and 1500 g for groups of animals transported 195 km by road. Thus, when compared with previous studies, the bruising levels recorded in the loading ramp trials conducted during project DAQ.070 are very low.

The mean bruise trim weight for the bullocks in low-dust trial 1 was 610 g, markedly lower than values of 1730 g and 2590 g reported by Yeh et al. (1978) for bullocks transported approximately 800 km by road and rail. Based on data from other experiments, Wythes et al. (1985) considered that the additional handling involved in transfer of animals from road to rail does not cause extra bruising. Wythes et al. (1985) reported that the mean bruise trim weight for steers transported over various distances and under a range of conditions was approximately 760 g.

Table 1 indicates a marked difference in bruise trim weights between the steer and cow groups in low-dust trial 1. On the basis of previous experiments by Yeh et al. (1978), and assuming that transport factors were similar, the cows would have had on average 0.5 kg more bruise trim/head than the bullocks. Similarly, Wythes et al. (1985) reported that mean bruise trim scores for cows and steers differed by approximately 4 points, equivalent to 0.5 kg bruise trim.

The mean value of 2150 g for the cows in low-dust trial 1 seems high. However, mean values of 2100 g and 3220 g have previously been reported for cows transported by road/rail over a similar distance (Yeh et al. 1978). In another experiment cows transported a distance of 870 km had a mean bruise trim weight per carcass of 2600 g (Wythes et al. 1981).

The mean bruise trim weight/carcass for all cows in the low-dust trials was 810 g. This can be compared with a mean value of 1250 g for cows transported over varying distances (Wythes et al. 1985). Thus, the bruising levels for the cows in the low-dust trials could be described as average, or below average, when compared with previous published data.

The data of table 3 revealed no statistically significant difference between right and left sides ( $X^2 = 0.920$ ,  $df = 1$ ).

**Table 3** Right and left side comparisons of bruising (low-dust trials)

	Right side		Left side	
	No.	%	No.	%
Low-dust trial 1	13	15	15	17
Low-dust trial 2	15	14	20	18
<b>Aggregate of trials 1 &amp; 2</b>	<b>28</b>	<b>14</b>	<b>35</b>	<b>17</b>

### 4.3.2 Bruise ageing

On the basis of histological examination, bruises collected during the various trials were placed into one of four categories which indicate the time pre slaughter when they occurred. These results are listed in table 4.

**Table 4** Histological ageing - percentage of bruises in age categories

Trial	U <sup>1</sup>	0 - 8 h	8 - 24 h	24 - 48 h	> 48 h
Loading ramp trials	22	43	2	8	2
Low-dust 1 - bullock unmodified	25	0	0	3	45
Low-dust 1 - Cow modified	5	10	15	25	4
Low-dust 2 - modified trailer	0	5	5	65	25
Low-dust 2 - unmodified trailer	15	0	0	4	45

<sup>1</sup> U - Age unable to be determined

**Note:** Cattle in loading ramp trials were held at abattoirs for approximately 24 hours before slaughter. During low-dust trials 1 and 2, animals were held at the abattoir for approximately 4 days and approximately 36 hours respectively.

#### 4.3.2.1 Loading ramp trials

A total of 52 samples from the three loading ramp trials were processed for histological ageing. It should be noted that very few of these samples could be described as being bruises of commercial significance. The ageing techniques indicated that the majority of the bruises were less than 24 hours old and that only one bruise was more than 48 hours old.

These findings were largely supported by the results of the bilirubin test which was conducted on 20 samples of bruised tissue. All samples gave a negative result, indicating that all bruises were less than 48 hours old.

Some bruises in the 8 - 24 h category of table 4 could have occurred during transport. This is because although the approximate holding time at the abattoir before slaughter was 24 hrs, some groups were held for less than this. The 43 per cent of bruises in the 0 - 8 h category would definitely have been sustained at the abattoir.

It must be emphasised that the overall bruising levels were very low and that these results should not be interpreted as indicating poor animal handling procedures at the abattoirs.

#### 4.3.2.2 Low-dust trials

The distribution of bruise ages in low-dust trial cattle was, in general, counter to that recorded for the loading ramp trials. With the exception of the cows in low-dust trial 1, virtually no bruising occurred during the 24 hours before slaughter, while up to 45% of bruises were more than 48 hours old.

The histological findings were largely supported by the bilirubin test, with 54 % and 27% of bruises tested in trials 1 and 2 respectively returning a positive test indicating that they were more than 48 hours old.

In low-dust trial 1 all bruises less than 24 hours old, and possibly some of the bruises greater than 48 hours old, would have occurred at the abattoir. The results indicated that the cows continued to sustain bruising throughout their stay at the abattoir. This result is consistent with the cortisol values at slaughter which suggested that, despite abattoir rest, the animals were still stressed at the time of slaughter. As mentioned previously, three cows became excited during unloading and presumably experienced a degree of stress at this stage.

Eldridge (1988) reported that cattle in "noisy" yards at abattoirs had more bruising than those held in "quiet" yards. However, it needs to be emphasised that in this trial 76 per cent of carcasses had no recordable bruise, as defined by the AUS-MEAT scoring system. Therefore when the trial animals are considered as a group, abattoir factors did not contribute significantly to bruising.

In low-dust trial 2 the animals were held at the abattoir for approximately 36 hours and thus bruises in the 24 - 48 hour category may have occurred at the abattoir or during transport.

The high percentage of bruises in the U category (age unable to be determined) from the low-dust trial 1 steer group and from the loading ramp trial groups was largely due to the very low level of bruising displayed by these groups. It was difficult to select an adequate number of bruises for histological examination. Some of the "bruises" selected were comprised of predominantly "normal" or "near-normal" tissue.

Figures 16 to 19 are photomicrographs of paraffin sections of bruised tissue stained with Prussian Blue and Neutral Red. They illustrate the use of histological techniques for the ageing of bruises. In figures 18 and 19 the presence of ferric iron derived from haemosiderin is indicated by the blue pigment present in macrophages.



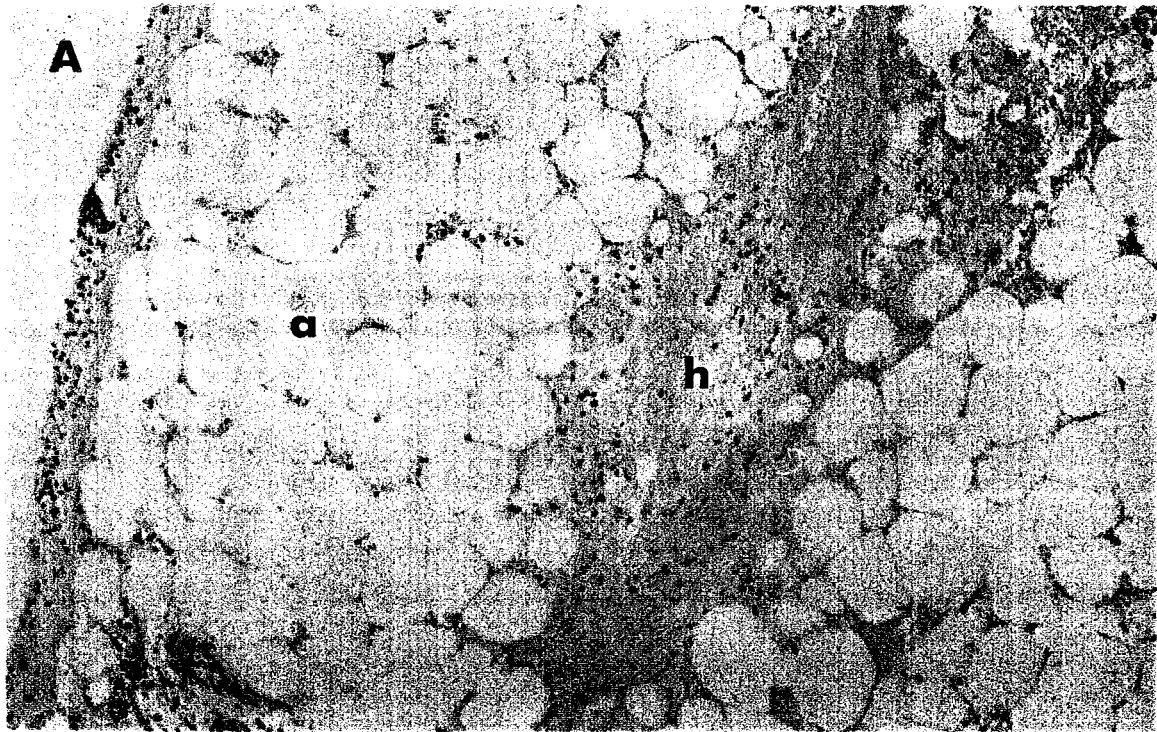


Figure 16 Low power (x25) magnification of bruised tissue section showing adipose tissue (a) and region of haemorrhage (h). Ferric iron (and therefore haemosiderin) is not present.

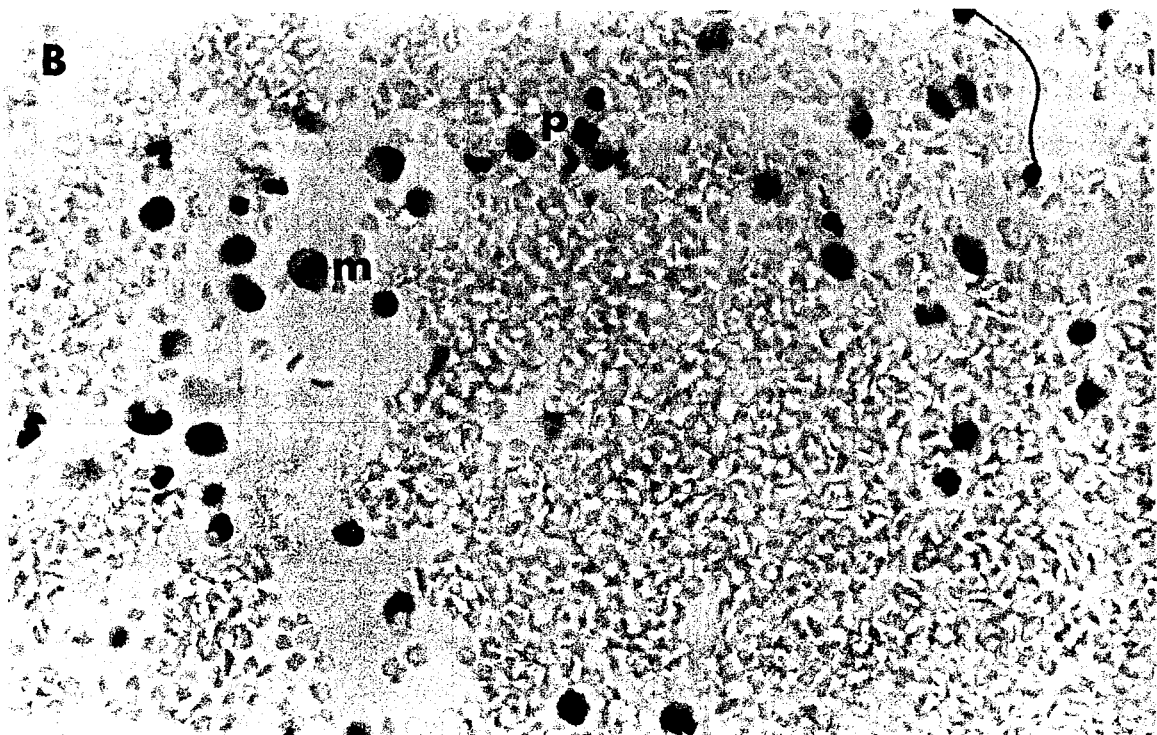


Figure 17 Higher magnification (x125) of section A - note almost equal numbers of polymorphs (p) and macrophages (m). This bruise is placed in the 8-24 hrs pre-slaughter category.



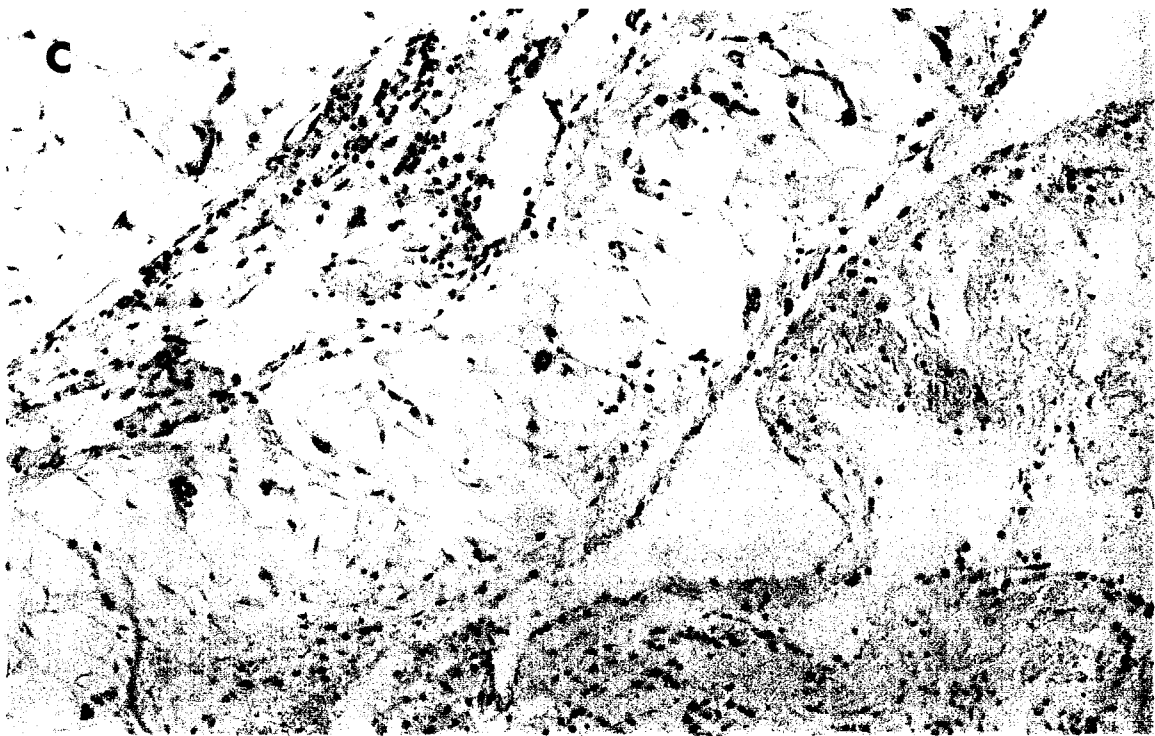


Figure 18 Low power (x25) magnification of bruised tissue section showing macrophages stained positive (blue) with the Prussian Blue stain.

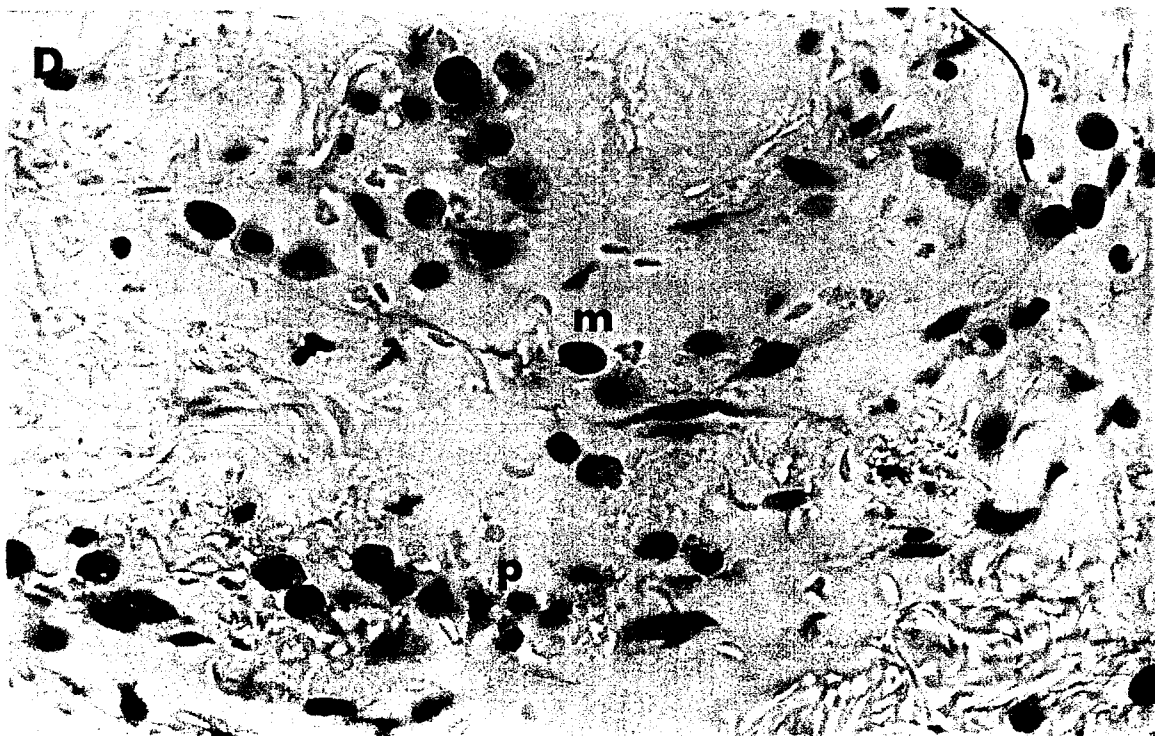


Figure 19 Higher magnification (x125) of section C - note few polymorphs (p) and the many macrophages (m) stained positive (blue) for haemosiderin. This bruise is placed in the >48 hrs pre-slaughter category.



### 4.3.3 Plasma constituents

A summary of the mean ACTH, cortisol and CPK values for all trials is given in table 6 while details for the individual trials are given in tables 7 - 11. Tables 12 and 13 give comparisons for animals of the same sex.

#### Notations, definitions and units - tables 6 to 13

- values in each column are the mean  $\pm$  SEM;
- means in the same column with a common or no superscript do not differ significantly from one another (i.e.  $P > 0.05$ );
- results are expressed in the following units:
  - ACTH - pg/ml;
  - cortisol - nmol/l;
  - CPK - Sigma units/ml;
- ND = Not Determined.

**Table 6** Mean values of ACTH, cortisol and CPK - all trials

	ACTH	Cortisol	CPK
Loading ramp 1	ND	105.8 $\pm$ 7.2 <sup>c</sup>	16.1 $\pm$ 2.1 <sup>b</sup>
Loading ramp 2	78.2 $\pm$ 8.4 <sup>ac</sup>	89.5 $\pm$ 4.4 <sup>b</sup>	17.6 $\pm$ 1.9 <sup>b</sup>
Loading ramp 3	82.6 $\pm$ 5.5 <sup>ac</sup>	144.0 $\pm$ 8.4 <sup>c</sup>	31.0 $\pm$ 6.5 <sup>c</sup>
Low-dust 1 - Steer	47.7 $\pm$ 2.9 <sup>b</sup>	61.5 $\pm$ 4.6 <sup>a</sup>	10.9 $\pm$ 1.6 <sup>a</sup>
Low-dust 1 - Cow	73.6 $\pm$ 10.7 <sup>a</sup>	121.4 $\pm$ 9.0 <sup>cd</sup>	19.0 $\pm$ 2.7 <sup>b</sup>
Low-dust 2	113.7 $\pm$ 8.9 <sup>c</sup>	140.3 $\pm$ 5.3 <sup>c</sup>	20.3 $\pm$ 1.6 <sup>b</sup>

**Table 7** Mean values of ACTH, cortisol and CPK - loading ramp trials

	ACTH	Cortisol	CPK
Loading ramp 1	ND	105.8 $\pm$ 7.2	16.0 $\pm$ 1.5
Loading ramp 2	78.2 $\pm$ 8.4	89.5 $\pm$ 4.4	17.5 $\pm$ 1.4
Loading ramp 3	82.6 $\pm$ 5.5	144.0 $\pm$ 8.4 <sup>a</sup>	30.8 $\pm$ 4.1 <sup>a</sup>

**Table 8** Mean values of ACTH, cortisol and CPK - low-dust trials

	ACTH	Cortisol	CPK
Low-dust 1 - Steer	47.7 ± 2.9 <sup>a</sup>	61.6 ± 4.6 <sup>a</sup>	10.9 ± 1.6 <sup>a</sup>
Low-dust 1 - Cow	73.5 ± 10.7 <sup>b</sup>	121.4 ± 9.0	19.0 ± 2.7
Low-dust 2 - unmodified trailer	123.9 ± 12.3 <sup>c</sup>	142.3 ± 7.6	17.6 ± 1.2
Low-dust 2 modified trailer	98.1 ± 12.1 <sup>bc</sup>	138.4 ± 7.4	23.1 ± 3.0

**Table 9** Mean values of Cortisol and CPK - loading ramp trial 1

	Cortisol	CPK
Top deck	102.4 ± 11.2	17.3 ± 2.4
Bottom deck	115.4 ± 8.5	15.0 ± 1.8
Mean	105.8 ± 7.2	16.1 ± 2.1

**Table 10** Mean values of ACTH, cortisol and CPK - loading ramp trial 2

	ACTH	Cortisol	CPK
1st trailer	77.7 ± 10.8	89.3 ± 6.4	19.7 ± 2.3
2nd trailer	78.8 ± 13.5	90.0 ± 6.3	15.6 ± 1.5
Mean	78.2 ± 8.4	89.5 ± 4.4	17.6 ± 1.9

**Table 11** Mean values of ACTH, cortisol and CPK - loading ramp trial 3

	ACTH	Cortisol	CPK
Top deck	88.5 ± 9.8	155.4 ± 13.6	35.7 ± 8.4
Bottom deck	75.7 ± 2.3	127.8 ± 10.9	27.1 ± 3.4
Mean	82.6 ± 5.5	144.0 ± 8.4	31.0 ± 6.5

**Table 12** Mean values of ACTH, cortisol and CPK - steers

	ACTH	Cortisol	CPK
Loading ramp trial 1	ND	105.8 ± 7.2 <sup>a</sup>	16.1 ± 2.1
Loading ramp trial 2	78.2 ± 8.4 <sup>a</sup>	89.5 ± 4.4 <sup>b</sup>	17.6 ± 1.9
Low-dust trial 1	47.7 ± 2.9 <sup>b</sup>	61.5 ± 4.6 <sup>c</sup>	10.9 ± 1.6 <sup>a</sup>

**Table 13** Mean values of ACTH, cortisol and CPK - cows

	ACTH	Cortisol	CPK
Loading ramp trial 3	82.6 ± 5.5 <sup>a</sup>	144.0 ± 8.4	31.0 ± 6.5 <sup>a</sup>
Low-dust trial 1	73.6 ± 10.7 <sup>b</sup>	121.4 ± 9.0	19.0 ± 2.7
Low-dust trial 2	113.7 ± 8.9 <sup>ac</sup>	140.3 ± 5.3	20.3 ± 1.6

#### 4.3.3.1 ACTH

Adrenocorticotrophic hormone (ACTH) triggers the release of cortisol from the adrenal cortex. Elevated levels of ACTH could be expected in stressed animals. However, with one exception (Mitchell et al. 1988), ACTH measurements do not appear to have been used in the assessment of stress in the pre-slaughter and slaughter periods. Presumably one reason for the limited use of ACTH measurements is the difficulty in obtaining an inexpensive, reliable assay.

The mean values for ACTH were in the range 43 - 117 pg/ml, considerably less than the mean values of 210 and 460 pg/ml recorded for live animal and post-slaughter blood samples respectively (Ganhao et al. 1985; Mitchell et al. 1988).

The measurement of ACTH in cattle plasma is relatively uncommon. Standard methods for collecting and handling blood samples, and storing and assaying plasma samples have yet to be defined.

Mean values of ACTH recorded for steers differed significantly from the mean values for cows in the low-dust trials. Gender may have contributed to this difference, as will be discussed later.

#### 4.3.3.2 Cortisol

It is generally accepted that increased levels of cortisol are indicative of stress. The use of mean cortisol values to compare stress levels of groups of animals transported to abattoirs has been reported by Mitchell et al. (1988) and Tarrant et al. (1988 & 1992), while measurements of plasma cortisol concentrations have been used to assist in the evaluation of pre-slaughter and slaughter treatments of cattle (Dunn 1990; Cockram & Corley 1991; Ewbank et al. 1992).

The mean cortisol value (61.5 nmol/l) for the low-dust trial 1 steer group (see table 12) is perhaps the lowest mean value recorded for cattle slaughtered at a commercial abattoir. Mean values of 67.6, 71.3 and 124.8 nmol/l have been reported by Ewbank et al. (1992), Mitchell et al. (1986), and Dunn (1990) respectively (see table 14). The low mean cortisol value, and the absence of dark-cutting meat, suggest that the abattoir environment did not stress the animals in this low-dust trial.

**Table 14** Mean Cortisol values (nmol/l) in post-slaughter blood samples (from literature)

Minimum <sup>1</sup>	Maximum <sup>1</sup>	Reference
41.0 <sup>2</sup>	123.2	Tume and Shaw (1992)
67.6	143.1	Ewbank et al. (1992)
71.3	117.0	Mitchell et al. (1988)
124.8	259.6	Dunn (1990)

<sup>1</sup> Minimum and maximum values were obtained from different treatments/trials.

<sup>2</sup> The minimum value for Tume and Shaw (1992) was recorded at a research abattoir, whilst all other values in the table were recorded at commercial abattoirs.

#### 4.3.3.3 Creatine phosphokinase (CPK)

Creatine phosphokinase (CPK) is an enzyme present in skeletal muscle. It is released from the muscle cells following muscle damage and exercise and thus elevated plasma concentrations could be expected in association with bruising and transport stress.

It has been reported that carcass bruising scores and CPK values increased with stocking density during road transport over both short (200 km) (Tarrant et al. 1988) and long (1000 km) (Tarrant et al. 1992) distances. Warriss (1984) and Eichinger et al. (1991) reported that meat with higher ultimate Ph values came from animals which had elevations in CPK levels. CPK has also been reported to be of value in the diagnosis of heat stress (Blackshaw and Blackshaw 1992).

Comparisons of the CPK values reported by different research groups is difficult. At least two different systems are used for expressing results (Sigma units and International units) and there can be wide variations in values for individual animals and in mean values for groups of animals. This variation is such that some results are reported in log units.

Mean CPK values ( $\pm$  SEM) which have been reported in post-slaughter blood samples include  $150 \pm 2$  International Units/L (Eichinger et al. 1991) and  $331 \pm 2$  International Units/L (Warriss 1984). Mean values in the range 80 to 165 International Units/L were obtained in the loading method and low-dust trials.

#### 4.3.3.4 Gender differences

There were no statistically significant differences for treatments within the individual loading ramp trials. However, loading ramp trial 3 cattle had significantly elevated



cortisol and CPK values in comparison with trial 1 and 2 cattle (table 7). Loading ramp trial 3 cattle were predominantly heifers, whilst in the other trials the cattle were predominantly steers.

Similarly, the low-dust trial 1 cows had significantly greater mean ACTH, cortisol and CPK values than the trial 1 steers (table 6).

The question arises as to whether the loading ramp trial 3 and the low-dust trial 1 differences are due to gender or treatment. Moriya et al. (1988) and Cockram and Corley (1991) reported no differences between steers and heifers in plasma cortisol concentrations, while Mitchell et al. (1988) reported that, in general, there were no differences in plasma ACTH and cortisol concentrations between oxen and heifers. However, the latter group reported that transport produced significant increases in plasma ACTH and cortisol concentrations of heifers when compared to oxen.

The possibility of gender differences in ACTH and cortisol values following transport of cattle should be considered when using these measurements as an aid in the assessment of pre-slaughter treatments. For example, Ewbank et al. (1992) refer to measurements made on blood samples collected from normal slaughter stock, while Dunn (1990) measured serum cortisol in blood samples from cattle of random breed and sex. It would seem prudent to collect all blood samples from animals of the one gender and breed during such investigations.

#### 4.3.3.5 Stress indicators

The biochemical indices of stress indicated that the animals in loading ramp trial 3 were stressed, however there was no evidence of dark-cutting meat in this trial (see table 15). One possible explanation is that the animals were stressed in the period immediately prior to slaughter, not allowing time for depletion of muscle glycogen. Observations at the knocking box indicated that the animals were excitable.

In low-dust trial 1 (table 8), the plasma constituents indicated differences in stress levels between the animals in the modified trailer and those in the unmodified trailer. However, as discussed above, it is not possible to state whether these differences are due to treatment or gender.

In low-dust trial 2 (table 8), the plasma constituents provided no evidence of differences in stress levels between animals in the modified trailer and those in the unmodified trailer.

In table 9, no statistically significant differences exist between the two (top and bottom) decks. It is noted, however, that for all three plasma constituents the mean values for the top deck are numerically greater than those for the bottom. Thus a stress index based on a combination of all three parameters may have indicated the statistical significance of a difference between the two decks. It is interesting that the transport observer noted "unloading the top deck took more effort than usual due to non-cooperation of some animals" (Appendix B).

The combination of measurements of several plasma constituents may assist in quantifying stress. Additionally, Mitchell et al. (1988) consider that various plasma

constituents respond differently to the different stresses of transport, handling and slaughter. Thus, the measurement of several plasma constituents may provide considerably more information than can be obtained from the measurement of one constituent in isolation.

#### 4.3.4 Muscle colour

##### 4.3.4.1 Loading method trials

Data from the loading method trials are summarised in table 15. The results of these trials were largely inconclusive with respect to muscle colour.

From the data of table 15, no significant difference in muscle colour was found between animals transported on the top deck and those transported on the bottom deck in the first trial. However in the third trial there was a significant difference in the  $L^*$  (measure of lightness/darkness) value between the top and bottom decks. In trial 2, no significant difference in muscle colour was observed between animals transported on the first trailer and those transported on the second trailer.

The mean  $L^*$  and  $a^*$  values for trial number three carcasses were significantly higher than for the other two trial groups. The higher means can probably be attributed to the fact that the cattle were younger, and in addition they were grainfed cattle. Forrest et al. (1975) maintain that muscle myoglobin, which constitutes 80 to 90% of the total pigment in muscle tissue of a well-bled carcass, varies with species, breed, age, sex, muscle, plane of nutrition and physical activity of the animal.

**Table 15** Mean values for  $L^*$ ,  $a^*$ , and  $b^*$  - loading ramp trials

	Position	$L^*$	$a^*$	$b^*$
Loading ramp trial 1	top deck	21.1	-1.7	6.5
	bottom deck	22.0	-1.8	6.7
	whole sample	21.6	-1.7	6.6
Loading ramp trial 2	first trailer	21.0	-1.9	6.0
	second trailer	19.5	-1.7	5.9
	whole sample	20.9	-1.9	6.1
Loading ramp trial 3	top deck	26.2	-3.6	5.6
	bottom deck	24.5	-3.3	5.5
	whole sample	25.3	-3.5	5.5

The third trial also demonstrated a significant difference ( $P < 0.05$ ) between the top and bottom decks with respect to the  $L^*$  value.  $L^*$  was higher (muscle colour lighter) for

carcasses from those cattle transported on the top deck. This result could not be explained, especially since the top deck cattle were harder to unload and therefore more likely to have exhibited dark muscle tissue.

#### 4.3.4.2 Low-dust trials

The results of the low-dust trailer trials are outlined in table 16. Muscle colour was assessed using both the Colormet probe and the Chiller Assessment system colour chips. In both trials, those cattle transported by modified trailer had a significantly lighter ( $P < 0.05$ ) muscle colour, as assessed by the colour chips, than did those cattle transported by conventional trailer.

**Table 16** Mean values of muscle colour,  $L^*$ ,  $a^*$  and  $b^*$  - low-dust trials

	Trailer type	$L^*$	$a^*$	$b^*$	Muscle colour
Low-dust trial 1	Conventional	-	-	-	1.82
	Modified	-	-	-	1.47
Low-dust trial 2	Conventional	24.8	6.7	-8.3	3.70
	Modified	25.2	4.1	-5.7	2.30

In the first trial, those cattle transported by modified trailer had a mean muscle colour score of 1.47, significantly lighter ( $P < 0.05$ ) than the mean score of 1.82 for the conventional trailer. The corresponding muscle colour score means for the second trial were 2.30 and 3.70 respectively. They were also significantly different ( $P < 0.05$ ).

With respect to the first trial, there was probably a sex effect as all the cattle on the modified trailer were cows, whilst all the cattle on the conventional trailer were steers. Cows generally have a darker muscle colour than steers (Shorthose 1989, 69), therefore the difference in muscle colour between the two groups may have been somewhat understated than if there had also been steers in the modified trailer.

The results of the second trial, in which all the cattle were cows, would appear to support this assumption as there was a more marked difference between the mean muscle colour scores. There was a difference of 1.40, as compared with 0.35 in the first trial.

There were no significant differences between the modified and conventional trailer groups in the second trial (the Colormet probe was not used in the first trial) with respect to mean  $L^*$  (lightness) or  $b^*$  (yellowness/blueness) values. The mean  $L^*$  values for the modified and conventional groups were 25.2 and 24.8 respectively, whilst the respective mean  $b^*$  values were -5.7 and -8.3.

There was, however, a significant difference ( $P < 0.05$ ) in  $a^*$  (redness/greenness) values between the two groups in trial 2. The cattle transported in the modified trailer

had a mean  $a^*$  value of 4.1, compared with 6.7 for the conventional group, ie. the muscle colour of the conventional trailer cattle was more red than that of the cattle transported in the modified trailer.

An age effect may have existed in the second trial because the mean dentition of the cattle transported in the conventional trailer was 5.4, significantly higher ( $P < 0.01$ ) than that of the modified trailer group, which had a mean dentition of 3.7. Older animals tend to display darker muscle colour (Shorthose 1989, 69). Both groups in the first trial had a mean dentition of 5.4.

## 5. Success in achieving objectives

Project DAQ.070, 'Reducing Stressors on Cattle in Road Transport', aimed to . . .

*. . . improve profitability in the Australian beef industry by reducing bruising, dark-cutting meat and mortalities caused by stress during cattle transport and loading, and to improve animal welfare.*

### 5.1 Objectives

Four major objectives were set to achieve the above aim. These objectives, which covered engineering, meat quality, animal welfare and economic issues, were to:

- (1) reduce stress on cattle caused by the transport environment (including dust and temperature) and the method of loading (single versus double-deck loading ramps);
- (2) compare the effect of transport innovations such as low-dust trailers and double loading ramps with conventional systems by: monitoring and collecting data from environments in cattle transport systems; assessing the extent and age of bruising on cattle after transport; measuring animal stress levels using plasma constituents;
- (3) calculate economic losses to the meat industry caused by existing transportation systems; and
- (4) assess the effects of transport innovations on the incidence of dark-cutting, and the incidence, severity and location of carcass bruising.

The following sections summarise both the methodology used to pursue these objectives, and the key achievements of the project. Constraints which prohibited more extensive field trials of the prototype equipment and methods are also discussed.

### 5.2 Modelling and prototype development

Wind tunnel modelling was used extensively during off-road research and development. The method provided a cost-effective and convenient means of rapidly predicting the performance of prototype equipment.

Trials using model road trains in the wind tunnel showed that 'dust curtains' between trailers altered air flow patterns significantly and reduced the likelihood of dust intake by cattle crates.

Instrumentation and techniques were developed for on-road monitoring of environmental conditions in road train trailers. This technology will allow future researchers to more rapidly gear-up for on-road trials, avoiding the long lead times often associated with development of instrumentation.

Further refinement of the dust monitoring equipment developed during the project will allow more accurate evaluations of the performance of methods used to reduce dust levels in trailers. It will also allow wider ranging studies of the effect of dust on cattle during transport.

### 5.3 Field trials

Prototype curtains were successfully trialled on commercial road trains. Air flow patterns were similar to those found in the wind tunnel and dust levels within the crates were reduced.

Trials were conducted to compare modified with conventional trailers, and single versus double-deck loading ramps. Bruises on carcasses were analysed to determine the extent and time of bruising. Stress levels were assessed by analysing blood plasma constituents from samples collected at slaughter.

Loading methods were compared by analysing data collected by the researchers during this project and from previous trials. Low levels of carcass damage were indicated by all data, so no clear benefit could be attributed to any loading method. Similarly, analysis of samples from cattle transported on modified and conventional trailers during low-dust trials revealed no significant improvement in quality attributable to trailer modifications.

The low levels of carcass damage found during both the loading method and low-dust trials precluded a meaningful cost benefit analysis of the different systems. Absence of hard economic data to justify use of the alternative systems will not, however, necessarily preclude their adoption by operators.

Many road train operators already rotate trailer positions or avoid particularly dusty routes to improve animal welfare. Adoption of innovations such as the low-dust curtain would allow operators to avoid these practices, with potential time and fuel-saving advantages.

With respect to double-deck loading ramps, animal welfare concerns, time savings, and lower levels of manual handling will continue to stimulate their further adoption. This trend will continue regardless of improvements in carcass and meat quality.

### 5.4 Constraints

Weather, market forces and transport logistics determined the number and extent of field trials conducted during the project. Each trial required effective coordination of diverse groups and resources. Examples of groups involved include pastoral companies, transport companies, livestock agents, mustering camps, research staff, and abattoir personnel.

Trials were often mobilised on short lead times, and without a guarantee of suitable consignments at the designated trial departure point. This occurred due to the combined effects of volatile beef cattle markets and uncertain weather conditions.

Trial assembly points were often more than 1000 km from research facilities, and research staff and resources were usually on-site before cancellation or changes to consignments were advised. In these cases, significant investment of staff time and funds resulted in little or no data.

Examples of factors which restricted the number of trials or limited the amount of useful data collected included:

- changes to number and gender of cattle booked for consignment by property managers - 250 to 300 head were needed to fill two 3-trailer road trains;
- alteration of nominated market destination;
- cancellation of consignments due to rain;
- insufficient dust data to compare consignments due to wet weather;
- changed departure points - little travel on dusty routes before bitumen;
- logistical challenges in locating both instrumented trailers at trial sites - trailers were used commercially during non-trial periods, and were often operating on different consignments at considerable distance from the departure point.

The uncertainty associated with each of the above factors meant that the extent of their impact on trials during Project DAQ.070 could not have been predicted. Future research using commercial consignments of cattle should include contingency funding and make provision for time extensions to accommodate the unpredictable influences of markets, weather and transport logistics.

## **5.5 Industry progress**

Both the experimental and the control cattle used during loading ramp and low-dust trials exhibited low levels of stress and animal damage. The levels were so low that no clear benefit could be attributed to the innovations used during the trials.

Project DAQ.070 clearly demonstrated that marked improvements in stock transport and handling, particularly long distance transport, have occurred over recent years. This outcome is significant for the beef industry. The industry is well-progressed towards the overall project aim of increased profitability through reductions in bruising, dark-cutting meat and mortalities caused by stress during transport and loading, and improved animal welfare.





## **6. Intellectual property**

Project DAQ.070 researched and developed methods and prototype equipment to improve beef cattle transport and handling environments, particularly on long-distance road trains. Techniques and instrumentation to gather data and analyse samples were also developed specifically to suit this project.

None of the methods or results associated with project DAQ.070 were sufficiently unique or innovative to class as intellectual property.



## 7. Progress in commercialisation

Project DAQ.070 produced two concepts with commercial potential, the low-dust curtain and the venturi eductor. Both modifications were designed to reduce dust levels inside cattle crates when travelling on unsealed roads.

The relative performance of solid versus slatted floors in reducing dust entry to cattle trailers was also investigated using wind tunnel modelling. Results from these experiments will provide design guidance to trailer builders.

The project team, in consultation with industry, selected the low-dust curtains for further development to the prototype stage within project DAQ.070.

Venturi eductors, though technically capable of suppressing dust levels significantly, would be highly vulnerable to damage in the operating environments of beef cattle transports. The venturi concept does, however, have potential for use outside the cattle transport industry to reduce road spray around heavy transport equipment on sealed roads during wet weather.

### 7.1 Low-dust curtains

Field trials of low-dust curtains and trailer modifications proved the feasibility of reducing dust levels during cattle transport. However, the meat quality component of the trials yielded inconclusive results, with little impact on cattle stress levels and final meat quality. Therefore it would be difficult to introduce the technology into the transport industry on the basis of these results.

Lack of economic incentive and the resultant uncertainty of potential market size has limited the interest shown in manufacture of the curtains. As a result, no commercial agreement has been entered into with a manufacturer.

Eagle Canvas (manufacturer of prototype curtains used in the trials) remain interested in the technology but require evidence of attributable economic benefit before commercialising the product. Commercial development of the low-dust curtain should initially aim at reducing its weight and simplifying the attachment system.

The beef cattle industry, particularly the transport sector, is concerned about animal welfare. Lower dust levels in trailers carrying cattle will provide animal welfare benefits regardless of whether an economic advantage is demonstrated.

### 7.2 Venturi eductor

The venturi eductor trialled during the modelling phase of the project remains in concept form. Extensive testing in the wind tunnel would be required before it could be translated into a working prototype.

Discussions with livestock transporters confirmed that a system which relied on ducting slung under trailers would be highly vulnerable to physical damage. Therefore further developmental work on the device as a dust suppressor was not pursued.

The venturi eductor system may, however, have application in reducing spray from around heavy transport equipment on sealed roads during wet weather. This application has definite commercial potential but lies outside the scope of this project.

### **7.3 Solid versus slatted floors**

Solid floors are available commercially as an option to slatted flooring. Wind tunnel comparisons of slatted versus solid flooring confirmed that there was considerable air movement upwards through slatted flooring. This air would carry dust into the interior of crates.

The wind tunnel findings confirmed that solid flooring should be used to minimise dust levels inside cattle crates during transport.

## **8. Impact on meat and livestock industry**

Cattle transportation is a potential focus for animal welfare concerns and subsequent media attention. Animal welfare is, therefore, a major issue in the cattle industry. All sectors of the industry recognise their responsibility for animal welfare as evidenced by their co-operation in this project.

The transport sector of the industry has already moved ahead with research aimed at highlighting potential problem areas and finding ways to reduce or eliminate them.

### **8.1 Immediate impact**

Project DAQ.070 helped industry to focus on the issue of stock transport and further encouraged the adoption of practices which improve cattle welfare and meat quality. It demonstrated that significant improvements in areas related to animal welfare have already occurred in the transport sector of the Australian beef industry.

Analysis of trial data revealed that medium to long distance transport does not necessarily have a deleterious effect on carcass and meat quality. This result confirmed that the industry has improved animal handling equipment and practices in recent years.

The cattle industry could be required by legislation or community pressure to improve animal environments in cattle crates during transport (for example, limits could be placed on maximum allowable dust level). If this occurs, the transition will be made more easily and faster as a result of achievements by the DAQ.070 project team.

The benefits of welfare-related outcomes from project DAQ.070 will accrue progressively, as wider adoption occurs.

#### **8.1.1 Loading**

Lapworth (1992) believes that double-deck loading ramps (DDLRL) should be installed in yards where 2000 head or more are handled each year. Benefits include:

- quicker loading and unloading;
- less bruising; and
- reduced stress on the animals during loading.

No hard data are available to support these statements but livestock handlers agree, based on industry experience, that the above benefits are achievable. Industry has already acknowledged the benefits of DDLRLs through their installation at all major abattoirs and saleyards north of Brisbane.

#### **8.1.2 Air deflectors**

Research showed a need to move dust-laden air uniformly along the outside of road train trailers, and clean air through the trailers. Minimal impingement of external air onto the surrounding ground surface is also necessary to avoid contributing to the dust load generated by wheels on the prime mover and trailers.

For the above reasons, the transport sector of the industry should scrutinise the performance of air deflectors currently in use. Some deflectors, such as the nose cone type, are designed to push air in all directions. Others do not lift the air high enough to avoid it being directed downwards and subsequently adding to dust problems.

Air deflectors used on livestock transports should be purpose-built to suit specific prime mover and trailer combinations, and allowing for a maximum legal trailer height of 4.6 m. The trend of modern truck cabs to be designed aerodynamically makes this consideration even more important.

## **8.2 Longer term (5 year) impact**

The outcomes of this research will still be relevant to the industry in five years. It has covered new issues and shown that dust levels within trailers can be reduced. With further modifications (for example, quick hitching) and improved materials, the use of curtains to reduce dust could become commercially acceptable and would add little extra weight to trailers.

During the next five years, roads can be expected to improve through the provision of better gravel surfaces and more bitumen. Property roads will change little so many thousands of kilometres will still be travelled over unsealed, dusty roads.

Drought causes particular problems associated with dust during transport. Producers are now more aware of the benefits of moving cattle to other properties or to agistment during droughts to give them access to better feed. The increased stock movement during droughts results in rougher and dustier roads. Deaths amongst cattle that are already weakened by drought are likely to be higher if additional stressors, such as elevated dust levels, are imposed on them.

Changes are already occurring in western beef producing enterprises. Larger pastoral companies are becoming more market oriented and are moving younger stock to growing or fattening areas closer to the abattoir. The reasoning is that younger, smaller animals can be transported longer distances at a reduced freight cost per head. From these fattening areas they expect to achieve increased growth rates and a younger turn-off age to meet future market demands.

This trend towards long distance transport at a younger age will reduce the effect of dust on carcass and meat quality. However, animal welfare issues related to dust problems will remain.

## 9. Total funding and MRC contribution

Project DAQ.070 was a joint project between the Meat Research Corporation (MRC), Department of Primary Industries Queensland (DPI), CSIRO Meat Research Laboratory (CSIRO), and the Livestock and Meat Authority of Queensland (LMAQ).

In addition to funds provided by MRC, the research organisations (DPI, CSIRO and LMAQ) provided significant support in the form of salaries, administration and facilities.

Table 17 gives details of MRC funding.

**Table 17** Total funding contributions to MRC Project DAQ.070

Financial year	CORPORATION FUNDS							
	Operating Cost		Overseas Travel		Capital		Total Cash Flow	
	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual
1990/91	83 804.00	78 458.15	-	-	17 000	13 141.86	100 804.00	91 627.01
1991/92	90 065.00	94 107.25	-	-	-	1 132.00	90 065.00	95 239.25
<b>TOTAL</b>	<b>173 869.00</b>	<b>172 565.40</b>	<b>-</b>	<b>-</b>	<b>17 000.00</b>	<b>14 273.86</b>	<b>190 869.00</b>	<b>186 866.26</b>
<i>BALANCE (BUDGET - ACTUAL) 4 002.74</i>								

Budget = Contracted amounts

Actual = Expenditure + Commitments





## **10. Conclusions and recommendations**

### **10.1 Instrumentation**

Instrumentation was developed to log environmental conditions inside cattle crates during transit. The data logger and temperature monitoring equipment proved reliable and accurate in extremely harsh conditions. Closed circuit video equipment was adapted to suit conditions inside cattle crates, and was used to successfully monitor and record visible dust levels and animal behaviour.

Dust monitoring instrumentation developed for use during the project proved reliable and, at high dust concentrations, allowed comparisons of relative dust levels. Meter sensitivity was insufficient to allow direct measurement of absolute dust concentrations inside the crates. Further developmental work is needed to improve meter sensitivity.

### **10.2 Plasma constituents**

It was demonstrated that the measurement of cortisol and creatine phosphokinase (CPK) in the plasma of post-slaughter blood samples can assist in evaluating the stress status of groups of animals. In this project, these measurements provided additional evidence which helped confirm that the majority of cattle experienced little stress.

The researchers believe that measurement of plasma constituents should be used in all future evaluations of transport methods to abattoirs. Measurement of Adrenocorticotrophic hormone (ACTH) could provide additional information on the stress status of animals. Further work needs to be done to ascertain normal values for this plasma constituent in post-slaughter blood samples.

### **10.3 Loading method**

Biochemical and bruise data indicated that, with the possible exception of loading ramp trial 3, cattle experienced minimal stress at all stages of handling prior to slaughter. Although the biochemical indices of stress were elevated in trial 3 this had no apparent effect on carcass or meat quality. This indicated that the stress most likely occurred just before slaughter.

No carcasses from the loading ramp trials displayed dark muscle colour. Therefore no advantage related to muscle colour could be attributed to the method of loading.

Data collected in this study indicated that improved meat quality alone cannot be used to justify the cost of installing double-deck loading ramps (DDLRs). However, logistical advantages such as faster and easier loading have already resulted in widespread use of DDLRs in yards around Australia.

### **10.4 Low-dust trailer**

The biochemical and bruise data for steers in low-dust trial 1 indicated that the animals experienced minimal stress during transport, lairage and abattoir handling. Conversely, the data indicated that the cows were stressed, although it is possible that the journey

itself was free of stress for the cattle. Some animals were stressed during unloading at the abattoir and this may have affected the entire group.

Trailer modifications designed to minimise dust inflow appeared to have a positive effect on carcass muscle colour as those animals transported in the modified trailer displayed lighter muscle colour than those transported in the conventional trailer.

However the results were far from conclusive and there were a number of other factors which had an impact, such as animal age, sex, lairage time at the abattoir, and weather conditions during transport and at time of slaughter. From a meat quality aspect it was not possible to conclude from the trial that trailer modifications were justified. Aspects other than meat quality, such as transport fuel efficiency and animal welfare, need to be considered.

## 10.5 Recommendations

Project DAQ.070 did not establish a conclusive relationship between dust exposure during transport, cattle stress and final meat quality. Similarly, significant differences in animal stress levels and final meat quality were not clearly identified when using alternative systems to load cattle for transport. Further trial data is needed to definitively relate dust level and loading method to cattle stress and meat quality. To facilitate this, it is recommended that future research into cattle transport issues should:

1. *Quantify the relative effects of stressors such as elevated dust levels during transport on carcass and meat quality.* This data will help identify transport improvements which yield a high cost/benefit return.
2. *Improve the sensitivity of dust monitoring equipment as developed in this project.* Greater sensitivity will allow more accurate assessments of dust effects on cattle during future long-distance transport trials.
3. *Measure plasma constituents in all future experiments involving methods of transport to abattoirs.* Cortisol and creatine phosphokinase (CPK) levels in the plasma of post-slaughter blood samples from trial cattle assisted greatly in evaluating their stress status. Adrenocorticotrophic hormone (ACTH) values could provide additional information, but further work is needed to identify normal values for this plasma constituent.
4. *Develop quantitative techniques to analyse for the various breakdown products which occur in bruised tissue.* Accurate information on the age of bruises would allow easier identification of their cause. Histological techniques provide a useful starting point for bruise ageing studies, but quantitative methods would be a valuable adjunct.
5. *Investigate further the stress-response differences that may contribute to the gender/bruising relationship indicated by the biochemical and bruise data from project DAQ.070.* A better understanding of why cows appear to be more susceptible to bruising than bullocks or steers would assist in identifying ways of reducing bruising.

## 11. Media coverage

This project received considerable press coverage. Media outlets included:

- Newspapers:                   The Australian  
                                  The Toowoomba Chronicle  
                                  Queensland Country Life  
                                  North-West Country  
                                  Beef Improvement News
- Magazines:                   Power Farming Volume 100 No.2  
                                  Australasian Science
- Television:                   Vision TV  
                                  ABC (Cross Country)  
                                  Aglink - subscription video service
- Shows/field days:        Toowoomba Show - 1989  
                                  Farmfest - 1988, 1990  
                                  MRC AGM Field Day, Rockhampton - 1989
- Radio:                        Radio 4WK, Toowoomba - three interviews  
                                  ABC rural - six interviews

Copies of selected media material are included in Appendix E.



## 12. Publications resulting from research

The following is a list of the publications arising out of the research conducted during this project:

Town, W.K. and Lapworth, J.W. (1990). The use of wind tunnel modelling to improve the transport environment in road trains carrying livestock on unsealed roads. *Agricultural Engineering Australia* **19** (2) pp. 11-13.

Jones, P.N. and Shaw, F.D. (1992). Maximising the cost-efficiency of assay procedures. *Meat Science* (accepted for publication).



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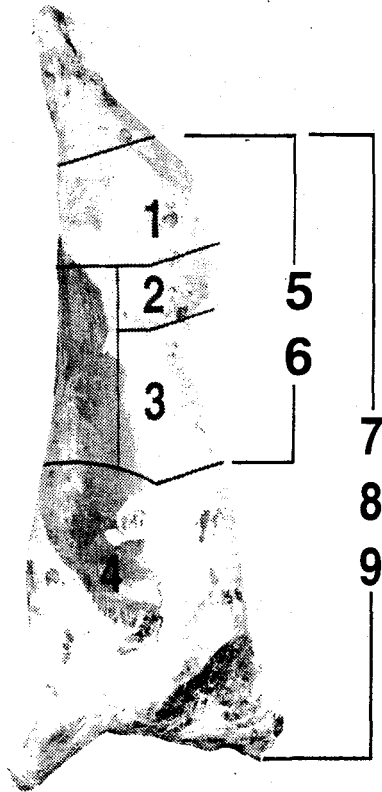


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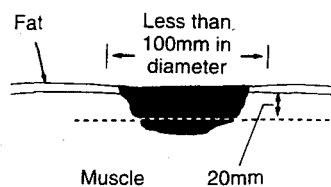
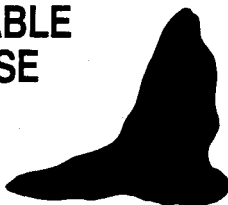
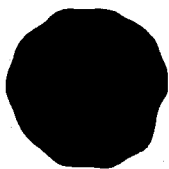


## Appendix A. AUS-MEAT Beef Bruise reporting system

## AUS-MEAT BEEF BRUISE REPORTING

NUMBER OF  
SERIOUS BRUISES

1	BUTT	1
2	RUMP	1
3	LOIN	1
4	FOREQUARTER	1
5	HINDQUARTER	2
6	HINDQUARTER	3
7	HINDQUARTER FOREQUARTER	2
8	HINDQUARTER FOREQUARTER	3
9	SIDE	4

SCORABLE  
BRUISE

## A) Description:

1 Where muscle is bruised, it qualifies as a scorable bruise if; an area of muscle (exposed) by trimming into the muscle tissue to the extent that it cannot be covered by a 100mm diameter circle or an irregular shaped equivalent area.

2 Where the trimming of a serious bruise has exposed muscle tissue smaller than 100mm and deeper than 20mm.

## B) Serious (flank bruise):

A serious bruise located in the thin flank area is recorded as a score (3) when the muscle tissue of the primal (striploin) is damaged.

## C) Where a bruise straddles two scorable areas:

1 The score will be recorded in the area where the bruise is most predominant.

2 A straddle bruise that covers at least 100mm in both scorable areas will count as separate bruises and be recorded as such.





## Appendix B. Loading ramp trials

- Trial 1**
- Date: 20/03/91  
 Property: Mills Bros., Tenterfield NSW  
 Destination: Darling Downs Bacon - Toowoomba  
 Distance: 218 km  
 Weather: Fine and warm  
 Loading time: 11:55  
 Unloading time: 16:00  
 Cattle: Hereford/Brahman X, horned  
 No. trailers: 1  
 Loading method: Single ramp and internal trailer ramp  
 Unloading method: Double ramp  
 Loading details: Top deck: 20 bullocks      Bottom deck: 22 bullocks  
 Comments: Cattle loaded and unloaded well. No problems during transport.
- Trial 2**
- Date: 22/05/91  
 Property: Wonga Hills, Barakula  
 Destination: KR - Toowoomba  
 Distance: 270 km  
 Weather: Fine and warm  
 Loading time: 07:00  
 Unloading time: 11:30  
 Cattle: Hereford bullocks  
 No. trailers: 2 rigs each with 1 single deck trailer  
 Loading method: Single ramp  
 Unloading method: Single ramp  
 Loading details: First trailer: 22 bullocks      Second trailer: 22 bullocks  
 Comments: Two single deck trucks were used. Cattle loaded and unloaded well. No problems during transport.
- Trial 3**
- Date: 03/07/91  
 Property: KLCO Meats feedlot, Wandoan  
 Destination: Toowoomba Public Abattoir  
 Distance: 319 km  
 Weather: Fine and warm  
 Loading time: 08:00  
 Unloading time: 14:30  
 Cattle: Mixed young cattle from feedlot  
 No. trailers: 1  
 Loading method: Single ramp and internal trailer ramp  
 Unloading method: Single ramp and internal trailer ramp  
 Loading details: Top deck: 26 mixed      Bottom deck: 30 mixed  
 Comments: Cattle loaded well. No problems during transport.  
 Unloading top deck took more effort than usual due to non-cooperation of some animals.









## Appendix D. AUS-MEAT bruise score data - low-dust trials

Body number	Right side bruise score	Left side bruise score
<b>Low-dust trial 1 (1991) - steer groups in conventional trailer</b>		
272	nil	4
276	4	nil
281	4	1
285	1	nil
286	nil	3
287	3	nil
288	8	8
289	4	nil
297	nil	1
298	nil	3
304	nil	1
<b>Low-dust trial 1 (1991) - cow groups in modified trailer</b>		
319	7	7
321	7	7
326	1	nil
328	8	4
332	nil	1
333	3	nil
334	nil	4
335	nil	3
336	nil	4
338	1	7
354	3	nil
<b>Low-dust trial 2 (1992) - 'silver.1' group in modified trailer</b>		
478	nil	4
480	1	1
481	nil	7
486	4	nil
490	nil	1
495	nil	4

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Body number	Right side bruise score	Left side bruise score
500	nil	7
501	nil	1
504	4	nil
506	3	nil
507	nil	5
509	1	nil
511	nil	4
512	nil	1
515	1	nil
516	4	nil
519	nil	1
525	1	1
<b>Low-dust trial 2 (1992) - 'green.2' group in conventional trailer</b>		
529	1	5
538	nil	4
542	4	nil
549	nil	4
550	nil	1
555	1	nil
560	3	1
562	1	1
565	5	nil
566	nil	1
575	3	nil
576	nil	4

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## Appendix E. Media coverage - sample articles

# Cut out all the bulldust

**T**wo quite different kinds of bulldust exist in Australia but they are equally annoying, unwelcome and dangerous.

Although the first kind — usually encountered among instant experts — can cost you money, it's the stuff found on outback roads that can be really costly to beef cattle producers.

Anyone who has ever been caught behind another vehicle on one of our powdery "highways" knows just how stressful it can be: you can't breathe, you can't see and the dust clogs everything.

Humans have some protection, especially in these days of air-conditioned cars and trucks, but what about the stock packed into road trains?

Research has shown that high dust levels can cause high animal stress which leads to lower meat quality.

This reduction in quality shows up in the incidence of "dark-cutting" meat with a pH greater than 6.0. It is estimated that the incidence of dark-cutting meat due to all causes is between 6 and 10 per cent — at a cost of about \$11 million a year.

The movement of beef cattle from property to market is one of the biggest costs for Australian graziers. In these times of reduced margins for primary producers all parts of the industry must be made as efficient as possible.

The development of livestock transport in this country has steadily evolved from the overland cattle drives to the use of double-deck, triple-trailer road trains that cover thousands of kilometres in our northern regions.

In these remote areas, road train operators are forced to travel long distances on surfaces that can only be described as bush tracks, especially in north-west Queensland, the Northern Territory and the top end of Western Australia.

The conditions for livestock are far better than in the days of the great cattle drives, but the environment experienced by cattle in trucks travelling on unsealed roads is still less than optimum.

Dust levels are too high. The problem is bad enough for single-trailer trucks, but it is even more severe for multi-trailer combinations common on the beef roads.

The second and third trailers must pass through dust thrown up by the prime mover and the first trailer, as well as the cloud they generate themselves.

High dust levels lead to greater agitation among the animals, and under extreme conditions animals can die.

All of this contributes to increased bruising and reduced meat yield.

The cost of bruising from all causes is estimated to be more than \$36 million a year.

To avoid the higher levels of bruising and mortality due to dust inhalation or heat stress, good transport operators swap trailers around so that animals in the rear get some time at the front.

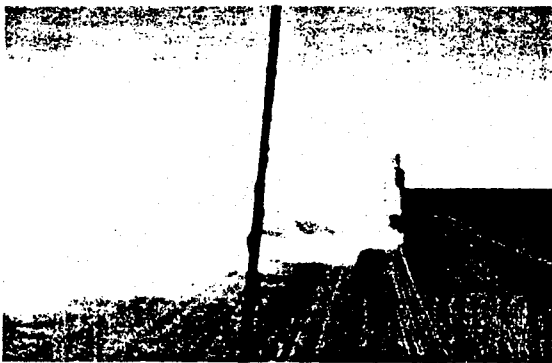
Some operators also try to detour around particularly dusty roads, but both of these strategies cost time and money — two things in short supply as



Roadtrains and their ever-present dust trail.



Wind tunnel testing of airflow.



The daunting sight when stuck behind a roadtrain.

the industry faces increasing cost pressures.

But help is on the way.

In an attempt to find solutions to these problems, the Australian Meat and Livestock Research and Development Corporation has given a research grant to the Agricultural Engineering Section of the Queensland Department of Primary Industries.

The project's aim is to improve the transport environ-

ment for livestock by reducing heat and dust levels inside truck crates.

Progress to date has centred on two main aspects: wind-tunnel modelling of the air flows in and around a road train and monitoring the environment in existing crates.

The wind-tunnel modelling phase of the project concentrates on testing design modifications to cattle crates and

trailers.

Scale models of 1:25 are used to monitor air flows, providing a cost-effective way of evaluating various modifications.

So far, results have shown promise: closing the gap between road train trailers, the use of air "curtains" and the ducting of fresh air from the front of the road train into the trailers.

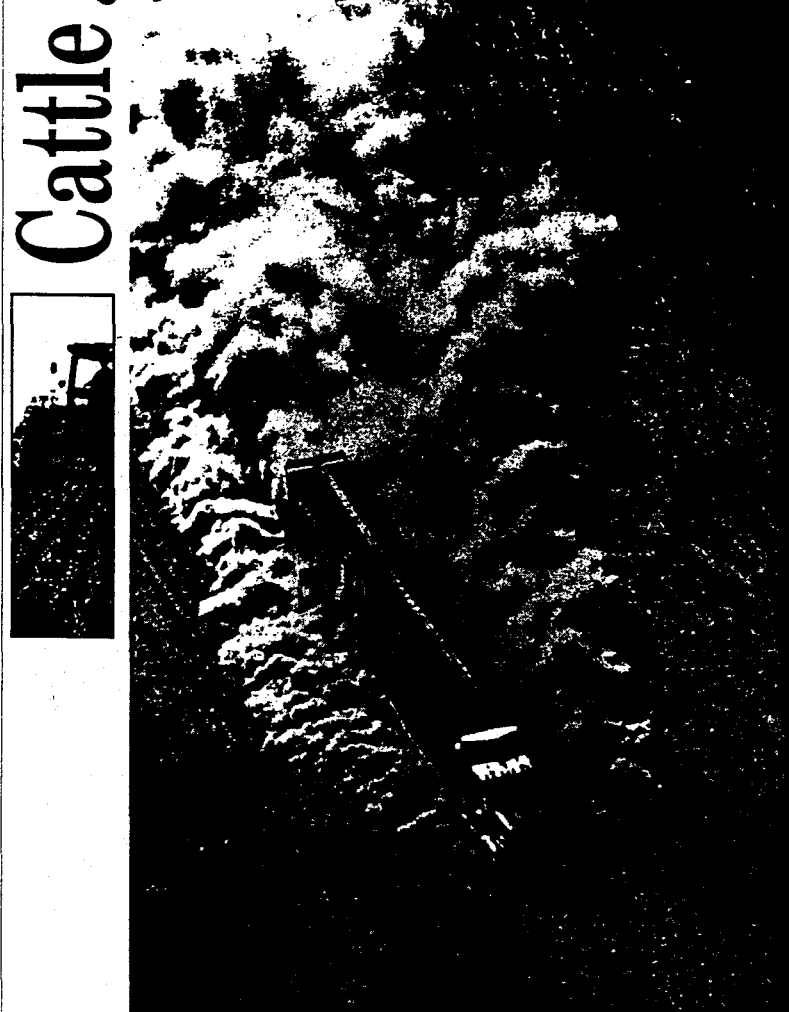
These modifications will be further tested on road trains in commercial use.

Monitoring of temperature and dust levels inside the crates will give a "real time" comparison between modified and current designs.

Temperature is measured by thermocouples, and records are kept to evaluate the effectiveness of channelling air into or out of the crates. Dust is measured electronically by an instrument designed for this project.

The research findings are expected to bring about a marked improvement in heat and dust levels in road train crates, making a big impact on the millions lost every year through dark cutting and bruising.

# Cattle and Roadtrains



by *Bill Town*

**Minimising the stress on cattle during transport is not only the ethical thing to do: it also helps to maintain the quality of the meat.**

**S**tress experienced during transportation causes both physiological and psychological changes in animals. The Agricultural Engineering Section of the Queensland

Department of Primary Industries have embarked upon a research programme to minimise this stress.

The environment experienced by cattle travelling in roadtrains on unsealed roads in the northern and western parts of Australia is far from ideal. The dust level inside the crates is often high for extended periods of time. The problem is bad enough for single-trailer trucks but becomes even more severe for multi-trailer roadtrains because the second and third trailers must pass through the dust thrown up

by the prime mover and the first trailer as well as the dust cloud they generate themselves.

It is thought that the high levels can result in excessive animal stress and therefore that a reduction in the dust intake would reduce stress thereby not only enhancing their physical well being, but also improving final carcass quality.

This will have a positive effect on the efficiency and profitability of all sectors of the industry, since both bruising and dark-cutting of meat are significant problems particularly in supplying 'quality' markets such as the North Asian and domestic markets.

How is this challenge being met? Whilst the main focus of this project has been towards an engineered solution to the problem, several other professional disciplines have played vital roles. The multi-disciplined research team is made up of engineers, beef cattle husbandry officers, meat scientists and economists. The strength of this form of research team lies in being able to call on the relevant professional for each stage of the project.

## Modelling the Roadtrain

Progress towards improving the environment for stock inside the crates has taken the following path. A wind tunnel was used to study the air movements in and around the roadtrain. By using scale models in a wind tunnel, the flow patterns can be seen quite easily. The wind tunnel has the great advantage of flexibility when developing new designs, for as soon as the models are modified, immediate results are obtained as to their effectiveness. 1:25 scale models of a roadtrain were used in a draw-through wind tunnel with a working section of 300mm x 300mm. Flow visualisation was achieved using smoke injection into the airstream. The path of the smoke was followed over the models and the flow patterns established.

The final modifications to emerge from the wind tunnel tests ready for trial on a full scale roadtrain were: a solid floor on both decks of the crate: the

positioning of an enclosure between the trailers to stop upward movement between the trailers and to allow ventilation from one trailer to the next; and the ventilation of the front and the rear of each crate to allow air from the front of the roadtrain to channel into all the trailers.

In order to test the modifications on a commercial roadtrain we needed the cooperation of a transport operator (The Livestock Transporters Association of Queensland) and equipment capable of monitoring the environment inside the crate.

### Collecting the Data

A data logging system was designed and assembled to allow the environment inside modified and unmodified crates to be compared. Variables monitored were dry bulb temperature and dust level. Temperature was taken care of with thermocouples, but measurement of dust level proved to be quite difficult. A continuous reading instrument was required and other constraints included robustness, resistance to vibration, compactness and low cost.

No instrument currently on the market met these specifications.

This led to a joint venture between Monitor Sensors of Caboolture and the Agricultural Engineering Section of the Queensland DPI which resulted in the design and construction of a dust meter. This instrument operates on the principle of interference with a light beam. Development of this instrument is an on-going process.

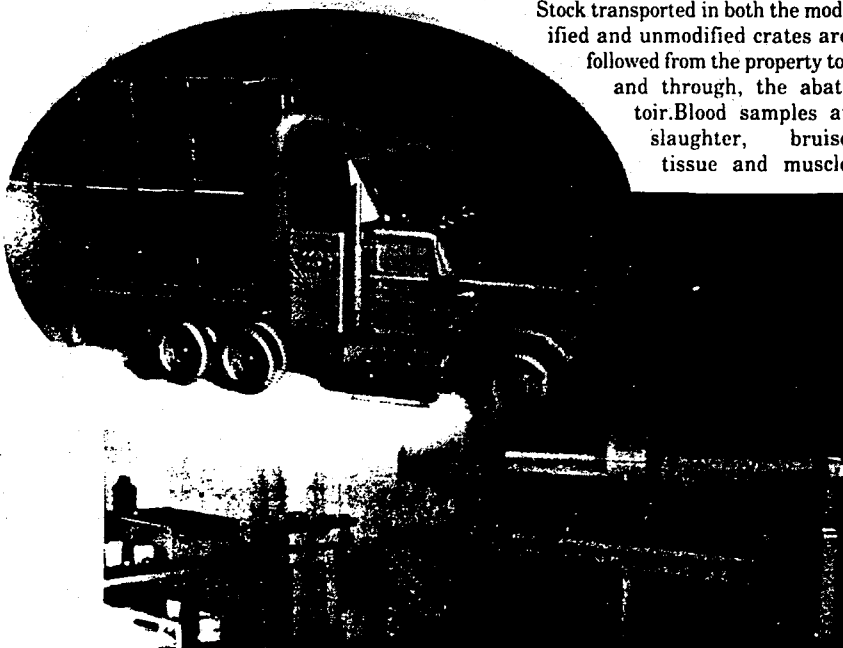
The data from the dust meters and the thermocouples was recorded in a DT100 Datataker mounted on the front of the crates. This was down-loaded with a portable IBM-compatible computer. This system proved to be reliable in what can only be described as an extremely harsh environment.

The modifications are currently under evaluation in western Queensland. The enclosure between the trailers has been manufactured from canvas and is supported on shock cord (elastic rope). This arrangement allows flexibility when manoeuvring the roadtrain. McIver Group Transport have supported this phase of the project by allowing their equipment to be fitted with the modifications then used in normal commercial operations.

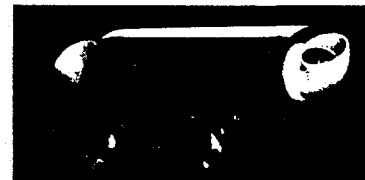
Stock transported in both the modified and unmodified crates are followed from the property to, and through, the abattoir. Blood samples at slaughter, bruise tissue and muscle

colour measurements are taken at the abattoir in an effort to determine the value in terms of meat quality of the modifications developed in the project. Any differences between the stock transported in the modified and unmodified crates will be expressed in economic terms because this is the bottom line as far as the Meat Research Corporation and therefore the industry is concerned. These results are still being gathered and it is too early at this stage to draw any conclusions.

This project is a good example of how researchers from different disciplines and organisations can work together towards a common goal for the good of the industry concerned. In this project the organisations involved are the Queensland Department of Primary Industries, CSIRO and the Livestock and Meat Authority of Queensland all being funded to some extent by the industry body, The Meat Research Corporation.



*Air movement around a roadtrain is modelled by use of a wind tunnel. Flow visualisation is achieved using smoke injection into the airstream.*



*The prototype dust meter operates on the principle of interference to a beam of light.*



*A canvas concertina gap enclosure between two trailers designed to reduce dust intrusion but permit flow-through ventilation.*

# Following a dusty trail to a masters

By PHIL BROWN

TAKING the stress out of cattle train travel to produce better meat for Australian tables is the aim of a research project being undertaken through the University of Southern Queensland.

To this end, agricultural engineering graduate Bill Town has spent the past year trying to take the dust out of cattle travel as part of his masters degree project.

It is just one of a long line of agricultural engineering research projects undertaken through USQ in the past decade. The Toowoomba campus is now the only tertiary institution to specialise in this area of engineering.

For Bill Town, at present studying externally while working for the Department of Primary Industries, it's an exercise that happily has positive side benefits for animal welfare, as well as being a quality control venture.

A stressed beast is not a happy beast, and more importantly, is not likely to be a tender beast when it ends up on the dinner table, he says.

"The concern in the industry is that on long hauls, cattle are subjected to very high levels of dust," Mr Town said. "This stresses them and therefore affects the meat quality. It really is an Australian problem because of the distances that road trains have to cover and the condition of those roads.

"Anything that's being trans-

ported a long distance will do part of the trip on dirt roads. In far western Queensland some oil companies involved in exploration out there are building good roads but elsewhere the dirt roads are still a real problem."

Mr Town points out that while dust is a serious enough problem in a truck carrying a single cattle trailer, on the big road trains that haul cattle in from the outback, life is hell — for the cattle, that is.

Mr Town has developed a concertina-like unit that bridges the gaps between the trailers and increases and maintains the air flow, thereby keeping the dust out, which may be a small step for man but is certainly a giant one for cattle.

"We developed this idea with the help of the university's wind tunnel and a model cattle train," he said. "We've closed the gap between the trailers, creating a better air flow.

"We're now carrying cattle to the saleyards in the test model and it makes a big difference. We're also testing the meat and we hope to find that it's of better quality, although there are a lot of other variables that can't be controlled."

The standard cattle train is around 12m long and houses two decks of cattle. Each trailer carries about 40 bullocks and hundreds of those road trains operate, mainly throughout the northern half of the continent.

In the southern Queensland region, the three-trailer road trains are not allowed east of Quilpe



Bill Town . . . dust causes stress — Picture: JOHN ELLIOTT

and the two-carriage trains can go no further than Toowoomba — the site of saleyards and abattoirs and the home of USQ and the research project.

Although the benefits of the dust-and-stress reducing exercise are intended for the Australian meat industry, there has already been some interest from South America where similar distances are covered and the road conditions are poor in outlying areas.

It may not be as glamorous as some projects, but this is grassroots research with direct market and economic implications. It's being funded by the Sydney-based Meat Research Corporation in the tradition of industry-

funded research projects at USQ.

The co-ordinator of higher degrees and research in the School of Engineering at USQ, Dr Harry Harris, said the past decade had seen a flurry of research activity in the agricultural engineering area.

"We've had good access to rural research funds and have been involved in research projects right across the board, including all rural industries," Dr Harris said.

"We're now the only agricultural engineering school in the country and we're well placed regionally to carry out that function. We're involved in mainly project-based research like Bill Town's work and many of the projects are done for specific clients.

Australian Newspaper 25 March 1992

# Transportation research needed for meat quality



DPI livestock transport specialist John Lapworth and agricultural engineer Bill Town are pictured with a wind tunnel used for research into stock transportation.

Dust and other stresses in transport can have a detrimental effect on cattle, and therefore on the quality of meat.

Department of Primary Industries livestock transport specialist Mr John Lapworth addressed the Cattle Marketing Forum on transport research.

He said that studies in Toowoomba involved a wind tunnel and a model cattle truck.

These studies had shown the patterns of wind, and dust, movement around the trucks.

The further along the trailer, the more dust there was, he said.

Experiments were being done to try to change the way the air flowed around the truck.

"Some of the changes would change the temperature within the stock crate," he said.

"That could be detrimental, but my feeling is that it won't be."

"We could get a chill factor, particularly on the bottom deck."

One possible way to reduce the dust would be to have covered areas between the prime mover and the trailers and to have skirts around the bottom of the vehicle.

Ducting would be needed to make sure some air did go through the stock crates.

"It could be done fairly simply and fairly cheaply," Mr Lapworth said.

"We are conscious

that whatever happens the cost has to be borne by the transport operator, and then goes to the producer and then the consumer.

"The cheaper they can do it the better."

He said another research project under way was in low tare weight vehicles.

The research followed on from an interstate commission into cattle transport, which recommended that volume loading be introduced on a national basis.

Volume loading would allow double deck cattle crates to be fully loaded at an optimum density in the interest of animal welfare, without having the problems of weighing the cattle.

The interstate commission's recommended maximum trailer tare weight was 10 tonnes.

Mr Lapworth said research had to look at the materials for making the stock crates.

They had to be able to stand up to the conditions of areas such as North West Queensland and the Northern Territory, but they also had to be made so they could be easily repaired on the spot if necessary.

"If something goes wrong in the bush, drivers don't want to be in the position where the only way to repair it would be to take it into town," he said.

The stock crates currently in use could be fixed with wire or a welder if necessary.

To reduce weight there was a tendency to use aluminium, but there would be problems in using aluminium in the field, if repairs were needed.

He said two New

South Wales companies used aluminium crates and believed they would stand up to the conditions in the north.

Apart from research to improve the conditions in which cattle arrived at their destination, there were other factors, which graziers had control over, which could improve the transportation of the animals.

One was to be sure the animals were kept from eating and drinking for an appropriate period of time before they were transported, depending on the distance they were travelling, and to make sure the animals had food and water prior to the fasting period.

"When you muster and get ready to transport, you could have cattle in pens for two or

three days, sometimes more before they are ready to go.

"In that time, they normally don't have the chance to eat and drink.

"If you expect them to stay on trucks for the next day and a half, you're putting pressure on the animals and the driver," Mr Lapworth said.

He said another area where graziers could help improve the condition of their cattle was to listen to the advice of the drivers as to how many cattle should go on the truck, and not to try to fit a few extra head on and then have increased bruising.

"You should feel comfortable with the driver having discretion to put an animal down if it is a bad way," Mr Lapworth said.

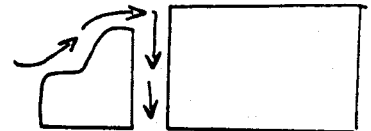


DIAGRAM 1: The direction air, with dust, travels over the truck while it is moving.

The code of practice is to ask a policeman or a vet, but in the bush it could be a long way to go to get them.

"You should also allow the driver to take the decision, if near the end of the journey animals are getting tired and falling down, to either try to get them up or to go straight through before the others go down as well."

"So often drivers try

to do the right thing, close to the end of the journey, and are left trying to get some cattle up while the others are restless and are going down."

He said graziers should have the cattle ready to put on the truck at whatever time they had told the driver to be there, or otherwise contact the driver to say there was a delay.

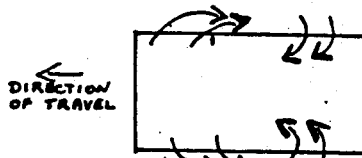


DIAGRAM 2: The direction of wind and dust over the top of a trailer.

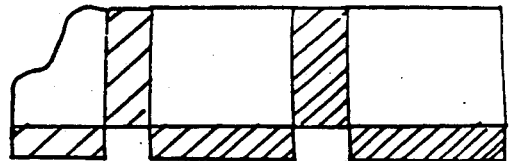


DIAGRAM 3: Skirting and covered areas could help reduce the dust problem.

## Wind tunnel tests should improve comfort

Modifications developed in a wind tunnel for a project to give cattle a more comfortable ride to sale or slaughter will soon be field tested.

DPI beef cattle husbandry officer, John Lapworth of Brisbane and agricultural engineer, Bill Town of Toowoomba, are working to cut down the dust entering cattle trailers hauled in road trains across outback roads.

The dust adds to the stress cattle are subjected to during transport, causing a darkening of meat and consumer resistance due to poorer quality.

The two officers have used a wind tunnel, smoke and a 1:25th scale model road train to develop inexpensive modifications that may substantially reduce dust entering the trailers of a three trailer road train. The smoke simulates the dust flow around the prime mover and the following trailers.

The wind tunnel tests have shown that ducting clean air through the crates may stop much of the dust flowing into the trailers. The ducted air will help counteract the negative pressures in the front of each crate that cause dust to be drawn into the crate.

For the field tests, the duct system will be made of an inexpensive material such

as canvas.

The modifications will be field tested, probably in May in either the Winton or Quilpie regions. Members of the Livestock Transporters' Association of Qld will provide two trailers and a prime mover for the trials of the modified road train. The second trailer on this road train, bought and equipped with funds supplied by the AMLRDC, will include monitoring equipment to measure the dust level inside the crate.

The second road train, also provided by LTAQ members, will be operated with the experimental trailers so that the effectiveness of the modification can be measured. One of these trailers will also be fitted with dust monitors.

Both the modified and control road trains will be used for normal stock transport work. Both will carry stock in the standard, two deck volume loaded configuration. As well as dust, temperature will be measured to provide information on possible wind chill should the modifications be adopted in the cooler southern States.

The trials will continue for several months. Bill Town and John Lapworth hope they will then have enough information to be able to recommend inexpensive modifications to reduce the dust problems.

North-west Country  
May 1990

Beef Improvement News  
May 1990





## Appendix F. Abstract (Final Report - Part 1)

*The abstract for project DA.070 is a non-confidential document, summarising key results and conclusions from the project. It will be printed in the Meat Research Corporation's annual project guide.*

- FOR PUBLIC RELEASE -

### Final report - Part 1 - Abstract

**Project Title:** Reducing Stressors on Cattle During Road Transport  
**Project Number:** DAQ.070  
**Research Organisation(s):** Department of Primary Industries, Queensland (DPI)  
 CSIRO Division of Food Processing (CSIRO)  
 Livestock and Meat Authority of Queensland (LMAQ)  
**Commenced:** 01 July 1990  
**Completed:** 30 June 1992  
**Project Investigator(s):** W. Town (DPI); J. Lapworth (DPI)  
 F. Shaw (CSIRO); G. Browne (LMAQ)  
**Phone No:** (07) 239 3547 (R. Byrnes,  
 Manager, Beef Industry Services)  
**Fax No:** (07) 239 3379

**Objective:**

To improve profitability in the Australian Beef Industry by reducing bruising, dark-cutting meat and mortalities caused by stress during cattle transport and loading, and to improve animal welfare.

**Abstract:**

Bruising and dark-cutting meat cost the Australian beef industry about \$50 million annually. This project investigated cattle handling and transport methods which might reduce these losses. It compared single and double deck loading ramps (DDLRs), and investigated ways to reduce dust levels and temperature in cattle trailers. The research team field-tested a prototype low-dust trailer which used 'curtains' between trailers to reduce dust entry.

Field trials revealed that DDLRs allowed simpler animal handling than single ramps. However, low levels of both bruising and dark cutting carcasses were recorded for both methods, so neither method could be recommended on the basis of meat quality alone.

Wind tunnel testing of model low-dust trailers showed that airflow could be altered to reduce dust entry. Road testing confirmed the wind tunnel results. Trial data did not, however, reveal significant changes in carcass or meat quality when comparing low-dust trailers with conventional trailers. Therefore, trailer modifications could not be justified on the basis of meat quality improvements alone. Other aspects such as transport fuel efficiency and animal welfare would need to be considered.

Bruising levels in trials were generally considerably less than those reported in previous experiments for cattle transported under similar conditions and over similar distances. Based on the test data collected during the project, it appears that the beef cattle industry has improved animal handling and transport practices in recent years.



## Appendix G. Executive summary (Final report - Part 2)

*The executive summary for project DAQ.070 is a non-confidential document. It was printed separately for distribution to MRC Directors and others requesting information on the project.*

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### 1. Background and industry context

The Australian beef industry must address the key issues of animal welfare, production efficiency and profitability if it is to remain viable. These issues are particularly relevant to the cattle transport industry.

Project DAQ.070 investigated the impact of modified transport and handling practices on cattle stress, and subsequent effects on carcass and meat quality. The project focussed on the effects of different loading ramp designs and lower dust levels in stockcrates during transport.

Better carcass quality due to reduced bruising and dark cutting would have a positive impact on the efficiency and profitability of all sectors of the industry. The cost of bruising from all causes is estimated to be in excess of \$36 million annually, while it has been estimated that dark-cutting carcasses cause a loss of about \$11 million annually. Bruising and dark cutting are of particular economic importance when supplying 'quality' markets such as North Asia and Australia.

The loading systems used by the industry have evolved over time. The original single deck system is being replaced by a double deck system which allows the animals to be loaded directly onto the top deck of the trailer. The improved loading systems are more expensive than the single deck ramps.

The DAQ.070 loading ramp trials aimed to justify the extra expense of these systems (in terms of reduced animal stress and bruising). The trials also provided a preliminary test of procedures used in subsequent low-dust trailer evaluations.

Although considerable research has been conducted into the transport of cattle in southern parts of Australia, the results of this work are not necessarily relevant to northern Australia where transport distances are generally longer, the roads are of lower standard and the environmental conditions are harsher, particularly with respect to dust and temperature.

Cattle experience high dust levels for long periods when transported over unsealed roads in the northern and western parts of Australia. Dust levels reach higher levels in multi-trailer road trains than in single trailer transports.

Many people assume that elevated dust levels stress cattle excessively, and therefore reduce the quality of carcasses and meat at slaughter. However, animal stress and final meat quality are influenced by many interacting stressors including loading density, road condition, handling during loading or unloading, and lairage conditions at abattoirs.

## 2. Project Objectives

Project DAQ.070 aimed to:

*. . . improve profitability in the Australian beef industry by reducing bruising, dark-cutting meat and mortalities caused by stress during cattle transport and loading, and to improve animal welfare.*

The specific project objectives were:

- to reduce stress on cattle caused by the transport environment (including dust and temperature) and the method of loading (single versus double-deck loading ramps);
- to compare the effect of transport innovations such as low-dust trailers and double-deck loading ramps with conventional systems by: collecting data from environments in cattle transport systems; assessing the extent and age of bruising on cattle after transport; measuring animal stress levels using plasma constituents;
- to calculate economic losses to the meat industry caused by existing transportation systems; and
- to assess the effects of transport innovations on the incidence of dark-cutting, and the incidence, severity and location of carcass bruising.

## 3. Methodology

The project was divided into two major phases:

- (i) engineering development; and
- (ii) testing and evaluation.

The engineering phase focused on developing hardware and systems to reduce dust levels in cattle trailers during transport. Initial concepts were trialled using wind tunnel modelling techniques. The results were then used to guide the development of full-scale prototypes which were installed on commercial road trains for field testing.

Instrumentation was also developed to monitor the environment, including dust levels, inside stockcrates during cattle transport.

Testing and evaluation covered two areas:

- evaluation of the low-dust modifications developed in the engineering phase of the project, using the environmental data recorded in both the modified and unmodified trailers; and
- field trials designed to quantify the effect that transport innovations such as the low-dust trailer and double deck loading ramps had on animal stress levels and meat quality.

The response of the animals to the different handling and transport treatments was assessed in three ways:

- using the levels of three plasma constituents (ACTH, cortisol and creatine phosphokinase (CPK)) in post-slaughter blood samples as biochemical indicators of stress;
- measuring the level of dark-cutting meat directly using muscle colour; and
- quantifying bruise damage by measuring bruise trim weights and using the AUS-MEAT beef bruise reporting system.

#### **4. Results and conclusions**

Wind tunnel tests indicated that the installation of a flexible curtain between trailers would lead to a less dusty environment within cattle crates. A full-scale prototype was manufactured and installed on a project trailer which was then used as the centre unit of a three trailer road train. Field testing over dusty transport routes revealed similar air flow around the modified trailers as was observed in the wind tunnel.

Data collected during the three loading ramp trials in this study indicated that improved meat quality cannot be used to justify the cost of installing double-deck loading ramps (DDLRs). Cattle carcasses from both the single and double-deck trials exhibited virtually no bruising. Analyses of plasma constituents and meat colour also indicated that the animals were subjected to minimal stress during transportation.

Despite the inconclusive results from the loading method trials, logistical advantages such as faster and easier loading have already resulted in widespread use of DDLRs in yards around Australia.

Apart from one group of cows, the low-dust trials also revealed very low levels of cattle bruising and stress in both the conventional and modified trailers. One group of bullocks and two groups of cows transported over distances in excess of 1000 km sustained minimal bruising while an average amount of bruising was recorded for another group of cows transported over a similar distance. Although plasma constituents did suggest that the animals in this latter group were stressed, no dark-cutting carcasses appeared in this (or any other) trial group.

Thus, in the low-dust trials, the levels of stress and animal damage were generally so low in both the experimental and control groups that no clear benefit of any modifications to existing practice could be confirmed.

##### **4.1 Conclusions**

Project DAQ.070 did not establish a conclusive relationship between dust exposure during transport, cattle stress and final meat quality. Similarly, significant differences in animal stress levels and final meat quality were not clearly identified when using alternative systems to load cattle for transport. Further trial data would be needed to definitively relate dust level and loading method to cattle stress and meat quality.

Modifying road trains to minimise dust levels around cattle during transport would help to satisfy animal welfare concerns. Low-dust transport and double-deck loading ramps also have potential to improve efficiency and profitability within the Australian beef industry - important issues for an industry confronted with growing competition on international markets and from alternative protein sources.

Based on the test data collected during the project, it appears that the beef cattle industry has improved animal handling and transport practices in recent years. Despite the limited quantity of this data, it allowed a more objective assessment of issues related to animal welfare during long distance transport of cattle than was previously possible.

## 4.2 Recommendations

The research team engaged on project DAQ.070 prepared recommendations to guide future research into cattle transport issues. These recommendations, not necessarily in order of priority, are:

1. ***Quantify the relative effects of stressors such as elevated dust levels during transport on carcass and meat quality.*** This data will help identify transport improvements which yield a high cost/benefit return.
2. ***Improve the sensitivity of dust monitoring equipment as developed in this project.*** Greater sensitivity will allow more accurate assessments of dust effects on cattle during future long-distance transport trials.
3. ***Measure plasma constituents in all future experiments involving methods of transport to abattoirs.*** Cortisol and creatine phosphokinase (CPK) levels in the plasma of post-slaughter blood samples from trial cattle assisted greatly in evaluating their stress status. Adrenocorticotrophic hormone (ACTH) values could provide additional information, but further work is needed to identify normal values for this plasma constituent.
4. ***Develop quantitative techniques to analyse for the various breakdown products which occur in bruised tissue.*** Accurate information on the age of bruises would allow easier identification of their cause. Histological techniques provide a useful starting point for bruise ageing studies, but quantitative methods would be a valuable adjunct.
5. ***Investigate further the stress-response differences that may contribute to the gender/bruising relationship indicated by the biochemical and bruise data from project DAQ.070.*** A better understanding of why cows appear to be more susceptible to bruising than bullocks or steers would assist in identifying ways of reducing bruising.