Wetting Cattle to Alleviate Heat Stress on Ships Stage 1

Project LIVE.219
Report prepared for MLA and Livecorp by:

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ABSTRACT

This report details the results of an experiment investigating the physiological responses of *Bos taurus* cattle exposed to 4 days of thermoneutral conditions followed by 11 days of high heat and humidity in a controlled environment facility. The environmental conditions were similar to what could be experienced on a long haul live export voyage leaving southern Australia and travelling to the Middle East in July.

Both rectal temperatures and respiration rates were greater (P<0.05) and panting score moved from 0 to >2 following exposure to hot conditions compared what was recorded under thermoneutral conditions. Feed intake fell by at least 40% over the 11 days of exposure to hot conditions.

Wetting cattle, using warm (30 °C) salt water reduced rectal temperature, respiration rate and panting score, increased cattle comfort, and did not result in worsening of the micro-climate. The magnitude of the cattle response and the duration of the impact of wetting were a function of the severity of heat stress. Short duration wetting (less than 1 minute to wet six (6) steers) was effective when wet bulb temperature was ≤ 30 °C. Longer duration wetting (up to 10 minutes to wet six steers) was required when wet bulb temperature exceeded 30 °C. The short duration wettings (n=12) accounted for 518 L (86.4 L/head or 7.2 L/head/wetting), and the long wetting (n=2) accounted for 618 L (103 L/head or 51.5 L/head/wetting).
EXECUTIVE SUMMARY

Periods of high heat load on live export ships will have an impact on the welfare of cattle. In most cases death is rare (Norris et al. 2003), however even minor losses negatively impact on the industry (see The Weekend Australian, August 2-3, 2003 and September 27-28). The image of the Australian live export industry has been tarnished by incidences of death and/or health related problems – it is crucial that the industry presents a positive, informed, and progressive image to the public.

Reducing or alleviating the detrimental effect of heat stress on cattle is important for animal welfare and may also improve animal performance. Strategies such as altering feeding time (Brosh et al. 1998), amount (Holt et al. 1999), and dietary constituents (Mader et al. 1999) have shown promise in feedlot cattle. Benefits derived from these strategies are seldom immediate and in many instances require long periods of adaptation for their full potential in reducing heat stress to be reached and are therefore of limited value on live export ships. Application of water to heat stressed cattle may serve as an immediate relief measure to prevent death (Arp et al. 1983; Busby and Loy 1996; Gaughan et al. 2003), and is probably a better option for the live export industry.

The project LIVE.219 was commissioned by LiveCorp / Meat Livestock Australia to:

- Determine the benefit of emergency wetting of heat stressed cattle as feasible using current shipboard infrastructure by measuring body temperature, respiration (panting score), feed intake and live weight change.

Principal Findings:

1. Results from this study suggest that the critical threshold for relative humidity is approximately 60% and for wet bulb temperature approximately 30 °C. Above these thresholds the experimental cattle had difficulty in reducing their heat load.

2. Clinical signs of mild heat stress: Drooling, increased respiration rate (80 – 100 breaths per minute; bpm).

3. Clinical signs of moderate heat stress: Drooling, respiration rate 100 – 120 bpm, and occasional open mouth panting (panting score 1 – 2.5).

4. Clinical signs of severe heat stress: Drooling, respiration rate >120 bpm, open mouth panting, tongue out (panting score > 2.5). Cattle will also have an agitated appearance and will often have their heads down. At this stage wetting should be undertaken.

5. Wetting had a positive impact on cattle comfort as measured by significant (P < 0.05) reductions in respiration rate, panting scores and rectal temperature. Wetting often encouraged eating but had no effect on overall feed intake. When the steers were under moderate heat stress short duration wettings of less than 1 minute were effective for up to 24 h. As the duration of exposure to hot conditions lengthened short duration wetting was less effective i.e. more wettings were required in a 24 h period. However it was only under extreme conditions where multiple wettings were required in a 24 h period.

6. Wetting is a useful strategy but will need to be undertaken more often (as seen by the 4 wettings on day 15), and water application (volume) may need to be higher than was used in the present study.

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1 An assessment of nine (9) live export vessels was also undertaken in order to gain an understanding of shipboard infrastructure. The water reticulation system of the ships were evaluated to ensure adequate supply of water for wetting cattle. The capacity of the bilge/waste systems to collect, convey and then discharge waste waters and sludge generated from any wetting operation was also determined. The pen areas and fire retardation / fighting systems were inspected for consideration of water reticulation and drainage. Photos were collected of the on-ship systems to document the findings of the visit. Interviews with nine captains and ships engineers were conducted at the time of the ship visits. Ship details are presented in Appendix 1.
LIVE.219 - WETTING CATTLE TO ALLEVIATE HEAT STRESS ON SHIPS

7. The longer duration wetting did not appear to have any substantial benefits in terms of extending the period between wettings over the short duration wettings, especially under high heat load. The little and often approach to wetting (e.g. wetting for 3 minutes every 30 minutes) often used in the dairy industry may serve as a useful model. This approach would only work if sprinklers were used.

8. Wetting of cattle had minor effects of short duration on the micro-climate. The major impact was the reduction in dry bulb temperature (DBT) especially with the longer duration wettings. Short duration wetting resulted in a mean increase in relative humidity (RH) of approximately 2.5% (range 0% - 4%), a mean reduction of DBT of approximately 0.5 °C, and a mean increase in WBT of 0.2 °C (range 0 to 0.5 °C) following short term wetting. These changes generally lasted one to three hours. The first of two long duration wetting resulted in a DBT reduction of almost 5 °C (38.40 to 33.68 °C). A slightly lower reduction of 4.4 °C was seen following the second long duration wetting (39.33 to 34.93 °C). In both cases DBT remained down for approximately 20 minutes before steadily climbing back to pre-wetting levels within three hours. RH increased by approximately 3% and remained elevated for 30 to 40 minutes. WBT increased slightly (0.3 °C).

9. Wetting can be undertaken with minimal water usage.

10. Wetting did not have a positive effect on live weight – all cattle lost weight over the 15 days.

11. Warm salt water did not have any harmful effects on cattle.

Principal Recommendations:

1. The Stockman’s Handbook and the Livestock Export Accreditation Program (LEAP) be modified to include the following clinical signs of heat stress, a panting score guide, and recommendations for wetting.
   - Decisions for wetting cattle should be made primarily on clinical symptoms and behaviour rather than just climatic conditions. That is use the animal as the indicator.
   - Clinical signs of mild heat stress: Drooling, increased respiration rate (80 – 100 breaths per minute; bpm).
   - Clinical signs of moderate heat stress: Drooling, respiration rate 100 – 120 bpm, and occasional open mouth panting (panting score 1 – 2.5).
   - Clinical signs of severe heat stress: Drooling, respiration rate >120 bpm, open mouth panting, tongue out (panting score > 2.5). Cattle will also have an agitated appearance and will often have their heads down.
   - Wetting should commence when more than 5% of cattle are showing clinical signs of severe heat stress: Drooling, respiration rate >120 bpm, open mouth panting, tongue out (panting score > 2.5). Cattle will also have an agitated appearance, will have a hunched stance and will often have their heads down.
   - Water should be applied to the head and back of cattle, and enough water needs to be applied to cattle so that it is running off their backs and down their sides. The duration of the wetting will depend on the volume from the hose, water pressure and stocking rate.
   - Do not use high pressure jets on cattle. Using a high pressure hose to apply water to hot cattle may cause injury (and possibly death) especially if they are frightened. If fire hoses are to be used the nozzle should be set to fan water.
   - If cattle are still showing severe heat stress within 1 hour of initial wetting then repeated wetting will be necessary.
   - Once wetting has commenced it will need to be continued until severe heat stress symptoms are no longer exhibited.
At all times ensure that there is adequate air movement (in the current study a pen air turnover (PAT) of 130 m/h was adequate, however it is likely that a higher PAT e.g. 150 m/h could be necessary especially where stocking rates are as per current guidelines) – if the ventilation system fails – DO NOT wet cattle.

If bedding material becomes wet and sloppy it will need to be removed immediately after wetting.

Cattle can move from mild heat stress to severe heat stress very quickly e.g. less than 30 minutes to 1 – 2 hours. Therefore if cattle are detected with mild heat stress extra vigilance is needed i.e. check cattle often (at least every 30 minutes). If mild heat stress is detected ensure that wetting facilities are ready to go if the situation worsens.

Future Research Areas:
1. The effects of duration and timing of water application on cattle and on the micro-climate onboard ships needs to be further investigated.
2. Sprinkler/misting system studies are necessary to ensure adequate timing and duration of wetting cattle exposed to hot conditions.
3. Recording of on board micro-climate (e.g. using data loggers) needs to be undertaken in conjunction with animal factors (e.g. panting scores, possibly body temperature and feed intake). This should be incorporated with a livestock vessel wetting study. This is necessary in order to quantify actual conditions on vessels with animal responses. Collection of “spot” climatic data has little meaning when assessing animals that are exposed to the conditions on a continuous basis. It would also be useful to quantify any diurnal variations in micro-climate, and to determine any impacts from wetting and pen washing on the micro-climate. Ideally this study should be carried out on a number of vessels and on a number of voyages. It would also be useful to have the loggers in place if vessels are returning to Australia empty. This would give a good indication of how much the animals contribute to the micro-climate in terms of temperature (dry and wet) and humidity. This study would build on work already undertaken on ships and in simulated conditions. An applied “real world” study of this nature would give the industry a firm scientific basis for management decisions.
4. Develop clear guidelines for pen cleaning, bedding material management and wetting cattle, incorporating the interrelationship between these issues.
5. Determine best wetting method for onboard ship conditions.
6. The capacity of ships to handle waste bedding and additional water needs further investigation.

1.0 INTRODUCTION
1.1 Project Background

Recent studies into the efficacy of ventilation on livestock ships (e.g. MAMIC 2001), and the physiology of heat stress in cattle (Barnes et al. in progress) have highlighted the need to provide industry with clear guidelines on wetting cattle as a tool for managing heat load on ships. The live export industry is developing a risk management approach to heat stress, which will significantly reduce the incidence of shipboard heat stress. Under most conditions the negative impacts of heat stress can be minimised using existing protocols, such as the Australian Livestock Export Standards (ALES) section 6.8.7 and ALES Table 2. The development of the Livestock Export Risk Management – Heat Stress will lead to further improvements.

Sudden severe heat stress situations are difficult to predict and can occur at anytime. Therefore practical guidelines and strategies that are based on sound science are needed in the event of emergency heat stress situations.

One of the few practical options for alleviating heat stress of cattle on board ship is via wetting. Two key industry documents, “Best Practice Management of Beef Cattle on Long Haul Voyages” and the most
recent “Stockman’s Handbook” discourage washing or wetting cattle while in tropical waters due to concerns about elevated humidity. Nevertheless based on interviews with ships captains, the wetting of cattle is sometimes used to reduce heat stress on ships. In interviews with nine (9) ships captains and four (4) senior officers it was recorded that wetting of cattle was used as a method of alleviating heat stress on their vessels.

The use of water may increase relative humidity, especially where there is limited air movement, and this reduces the ability of cattle to dissipate heat via evaporation. However, the effect of a rise in relative humidity is somewhat negated if there is a corresponding fall in ambient temperature and removal of heat from the surface of the animal. It would also appear that wet bulb temperature (WBT) is a better indicator of air moisture on ships (MAMIC 2001). The 2001 MAMIC study suggests that a rise in WBT does not follow wetting or washing cattle on board ships.

The benefits of cooling cattle with water and fans are evident by lower respiration rates, rectal temperatures and heart rate. This has been demonstrated in a large number of studies involving Bos taurus cattle - dairy cows (Findlay, 1950; Stewart and Brody, 1952; Morrison et al. 1973; Flamenbaum et al. 1986; Igono et al. 1986; Srikandakumar et al. 1993) and for beef cattle (Gaughan et al. 2003).

1.2 BRIEF METHODOLOGY

This study was undertaken in a controlled climate facility using six Angus steers in individual stalls. The purpose of the study was to investigate the effect of cooling cattle exposed to hot conditions, using salt water. The salt water was formulated from sea salt to be similar to seawater (3% NaCl) and was heated to 30 °C. The temperature of the salt water was similar to sea surface temperatures in the Persian Gulf, Oman Gulf and the north west Indian Ocean (Stacey pers. comm. 2003). For the purpose of this study a simulated 15-day voyage from southern Australia to the Middle East was used. A temperature regime was established based on actual below deck climatic records for long haul vessels (McCarthy pers. comm. 2003). These were slightly altered to ensure hot conditions were experienced.

1.2.1 Animal measurements: Animal responses to climatic conditions and the effect of wetting were assessed by measuring, rectal temperature, respiration rate and feed intake. Behaviours such as standing or lying were also recorded. Live weight and body condition scores were also assessed.

1.2.2 Climatic measurements: Dry bulb temperature, wet bulb temperature, relative humidity and air movement were recorded.

1.2.3 Animal welfare: Animal ethics clearance was obtained from The University of Queensland animal ethics committee prior to commencement of the study. During the study the cattle were inspected by the UQ Gatton animal welfare officer Dr Michael Campbell, and the Chair in Animal Welfare Professor Clive Phillips.

Strict animal welfare/health protocols were followed throughout the study, with at least one person on duty at any one time (24 hour roster). These are presented in Appendix 2.

2.0 METHODOLOGY ~ WETTING STUDY

2.1 Materials and Methods

2.1.1 Cattle: Six Bos taurus steers (Black Angus) were used in the study. The cattle had been held in the UQ Gatton feedlot for 40 days prior to the study (June/July 2003). They were adapted to a diet comparable to that fed on long haul voyages. Prior to commencement the steers were treated against parasites (Cydectin pour-on). All steers had previously been vaccinated with a 5 in 1 vaccine (clostridial disease). No hormonal growth promotants (HGP’s) were used.

The steers did not have any heat adaptation and all had a winter coats. At the start of the study the steers had a mean live weight of 451.4 kg with a mean condition score of 4+ (using the 1 – 5 scale). The steers were transported to a controlled climate facility on commencement of the “voyage”.

7
All steers had been trained to lead prior to the commencement of the study. This was a necessary procedure due to the close handling required for data collection while under test conditions.

2.1.2 Cattle Housing: The steers were housed in 3 x 1 m (3 m$^2$) stalls in the controlled climate facility at UQ Gatton. The pen space allocation was 1.85 times the minimum allocation of 1.620 m$^2$ as per ALES. This was necessary in order to collect the data required. Each stall was fitted with an individual water bowl and feed bin. The steers were restrained via a head halter tied to the front of the stall. They had enough room to stand up and lie down but could not turn fully around. The steers had adequate manouevrability for self-grooming. The front half of the stall was a solid floor covered by rubber matting and the back half of the stall floor was wooded slates. Faeces and urine fell between the slates into a steel storage tray, the trays were designed to allow the urine to flow away but retain the faeces.

The stalls were cleaned every four days. All waste material (water, urine and faeces) were washed into a sump and removed to an effluent holding pond.

2.1.3 Feeding: Cattle were fed their daily ration at 0800 h and 1400 h in equal proportions. Feed allocation at the start of the “voyage” was 2.5% of their live weight (ALES November 2002 state a minimum of 2% of live weight per day). Throughout the voyage feed intake was adjusted so that cattle would consume their allocated amount with minimal residue – at no time were cattle without feed. At each feeding time residue feed was removed, weighed and dried (to determine % dry matter).

The diet used was a moderate energy grain based diet (8.0 MJ ME; 12 % Crude Protein, 25 % roughage ~ as fed). The diet was formulated to be similar in nutrient content to the “standard” ration fed on live export ships. The ration was not pelleted. (NB Future work should use shipping pellets).

Cattle had access to drinking water at all times. Water temperature for each bowl was measured daily.

2.1.4 Wetting Cattle: Cattle were primarily wetted on the basis of physiological factors (rectal temperature $\geq 41.5$ °C and/or respiration rate $\geq -120$- bpm), animal behaviour (agitated appearance, head down), and other factors such as drooling and/or open mouth panting (panting score $>3.0$). Cattle were wetted using a 25 mm diameter hose attached to a pressure pump. The heated (30 – 31 °C) salt water was used in an effort to mimic the maximum seawater temperatures that would be typical in the north west Indian Ocean, the Gulf of Oman and the Persian Gulf during July to September (Stacey 2003 pers. comm.). The heating and salt-water unit is described in Appendix 3.

It was a requirement of the study that water use was to be kept to a minimum. Based on the water flow of 29 L/min from the pumping system it was determined that all six cattle could typically be wetted in under 1 minute. Water was applied to the back and head of cattle in sufficient quantity so that water was just beginning to run off the animals. If a steer was lying down and access was blocked by a standing animal no attempt was made to have the lying animal stand.

During the study, two long duration wettings (approximately 10 minutes) were undertaken to compare the results of the short duration wetting to a longer wetting period. The duration of the wetting is not however as critical as the volume of water used. It is more useful to think in terms of volume rather than duration. The key is to ensure that cattle are adequately wetted.

2.1.5 Climate control: The facility was heated using a gas fired industrial heater located approximately 2 m above and to the front of the cattle stalls. The gas heater was controlled by a thermostat located in the climate facility. Two heat pumps and two electric bar heaters (2400 watts) were used as required to maintain heat levels. Fans were used to ensure adequate circulation and mixing of hot air. Fans did not blow air on to the steers.

Relative humidity was maintained by the use of sprinklers (no water was allowed to spray on cattle). Two sprinkler units were used, each located at the rear of the facility. A 250 L drum with an electric heater unit was also used to increase humidity (via evaporation of water from the drum). Additional water could be sourced as required to maintain humidity.

Wet bulb temperatures were adjusted and maintained by adjusting dry bulb temperature (DBT) and relative humidity (RH) as required.
The climatic conditions were designed to move from a 4-day thermoneutral period to a hot period (HOT) that ran for 11 days. The HOT period was designed to see an increase in dry bulb and wet bulb temperature each day over the 11 days.

2.1.6 Data Collection: Rectal temperatures were collected at 60-second intervals throughout the study. Each steer was fitted with a 210 mm rectal probe attached to a data logger (see Gaughan et al., 1996 for full details). A real time display was available in a control room outside the climate facility. Respiration rate (RR) was measured hourly by counting 10 flank movements and recording the time (seconds) for this to occur. Respiration rates were also recorded immediately prior to and following a wetting event. Observations were made every 5 minutes for 60 minutes following wetting. In addition to RR panting scores (PS) were recorded. The PS's were determined with reference to a photo guide previously developed for the feedlot industry (see FLOT.316) (Table 1). 

<table>
<thead>
<tr>
<th>Breathing Condition</th>
<th>Panting Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>No panting.</td>
<td>0</td>
</tr>
<tr>
<td>Slight panting, mouth closed, no drool or foam.</td>
<td>1</td>
</tr>
<tr>
<td>Fast panting, drool or foam present.</td>
<td>2</td>
</tr>
<tr>
<td>As for 2 but with occasional open mouth.</td>
<td>2.5</td>
</tr>
<tr>
<td>Open mouth + some drooling, neck extended and head usually up.</td>
<td>3</td>
</tr>
<tr>
<td>As for three but with tongue out slightly.</td>
<td>3.5</td>
</tr>
<tr>
<td>Open mouth tongue out + drooling Neck extended and head up.</td>
<td>4</td>
</tr>
<tr>
<td>As for 4 but head held down.</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Panting scores were also recorded when RR data was collected.

Animal position (standing or lying) and activity (eating, drinking or sleeping) was also recorded at hourly intervals. Other factors such as drooling, ruminating, head down or any signs of abnormal behaviour were recorded. Most observations were done via a video monitor display located in the control room. Two video cameras were located in the facility. Each video allowed observation of three steers. The use of the videos allowed observations to be made without the presence of humans in the facility, which may change cattle behaviour.

Feed intake was measured at 10-minute intervals via load cells linked to a computer in the control room. Dry bulb temperature and relative humidity were measured at 10-minute intervals via weather stations located in the facility. Wet bulb temperature was measured via a wet bulb thermometer hourly, immediately prior to a wetting event and at 5-minute intervals for 1 hour after the end of a wetting event. Wet bulb readings were checked against a psychrometer (at least 4 times each day). Dry bulb and relative humidity were also recorded at 5-minute intervals (to a data logger) at two locations in the facility.

2.1.7 Pen Air Turnover (Ventilation Rate): The major source of fresh air into the facility was via heat pumps (3) which were vented to the outside. Approximately 2370 m³ of air per hour was moved through the facility. Pen surface area was 18 m² (6 x 3.0 m² pens). Based on this approximate pen air turnover (PAT) was 131.6 m³/h (2370 m³/h ÷ 18 m²). This was at the low end of the range (100 to 300 m³/h) reported in LIVE.211 (MAMIC 2002).

2.1.8 Definition of Day: For this study a day was deemed to start at 0900 h and finished at 0859 h (the following morning). This was necessary in order to correspond cattle observations to feeding events. It should be noted that time of the day is somewhat irrelevant in this discussion, the important factor(s) are the climatic variables, not time per se.
3.0 RESULTS AND DISCUSSION ~ SIMULATION STUDY

3.0.1 Animal Welfare: No animals were removed from the study or required veterinary treatment, however all cattle lost hair due to shedding of their winter coat during the study.

Wetting was undertaken in accordance with the described protocols, and all conditions of the UQ animal ethics approval were met. The cattle returned to the UQ feedlot at the end of the study in good health. One animal had a slight swelling around the anus, but this subsided within 3 days of the animal’s return to the feedlot.

Some two weeks after the completion of the study a complaint was made to the Queensland RSPCA by a person or persons unknown. The complaint specifically was in regard to the cattle not having access to feed or water, and being subjected to harsh environmental conditions. Following discussions with an RSCPA veterinarian no further action was taken. All cattle had been returned to the feedlot 7 days prior to the complaint.

3.0.2 Climatic Conditions: Similar conditions (P>0.9) were found throughout the facility for the measured parameters. Days 1 to 4 were thermoneutral days, where dry bulb temperature was maintained below 22 °C and wet bulb below 22 °C.

The mean daily dry bulb temperature (DBT), relative humidity (RH) and wet bulb temperature (WBT) for the hot period (HOT) are presented in Table 2, and hourly data for each day is presented in Figure 1.

Apart from day 9 when there was a problem with the thermostat, DBT and WBT increased each day until day 15. On day 15 mean DBT was lower (1.6 °C) than on day 14 primarily due to the number of wettings carried out on day 15. However WBT was only 0.4 °C lower on day 15 compared to day 14.

<table>
<thead>
<tr>
<th>Day (Day of HOT)</th>
<th>DBT (°C)</th>
<th>WBT (°C)</th>
<th>RH (%)</th>
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<tbody>
<tr>
<td>1 – 4</td>
<td>20.7</td>
<td>21.6</td>
<td>92.0</td>
</tr>
<tr>
<td>5 (1)</td>
<td>23.4</td>
<td>22.5</td>
<td>93.1</td>
</tr>
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<td>6 (2)</td>
<td>26.9</td>
<td>25.0</td>
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</tr>
<tr>
<td>7 (3)</td>
<td>30.3</td>
<td>26.9</td>
<td>80.1</td>
</tr>
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<td>8 (4)</td>
<td>29.8</td>
<td>27.4</td>
<td>86.6</td>
</tr>
<tr>
<td>9 (5)</td>
<td>31.9</td>
<td>26.2</td>
<td>76.1</td>
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<td>10 (6)</td>
<td>31.5</td>
<td>27.7</td>
<td>77.1</td>
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<td>11 (7)</td>
<td>35.0</td>
<td>30.4</td>
<td>75.8</td>
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<td>35.9</td>
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<td>75.5</td>
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<td>72.2</td>
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<td>14 (10)</td>
<td>38.5</td>
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<td>71.6</td>
</tr>
<tr>
<td>15 (11)</td>
<td>36.9</td>
<td>31.5</td>
<td>74.9</td>
</tr>
</tbody>
</table>
3.1 ANIMAL RESPONSES TO CLIMATE AND WETTING

3.1.1. Wetting: Wetting was initiated based on the criteria outlined in 2.1.4. The cattle were wetted on 14 occasions over the 15-day study. As each “day” commenced at 0900 h, a wetting at 0600 h was toward the end of a “day”. The first wetting occurred on 2150 hours on day 6 of the study (second day of HOT). This was followed by wetting on day 7 (2300 h), day 8 (2020 h), day 9 (1045 h), day 10 (2108 h), day 11 (1830 h), day 12 (2100 h), day 13 (1558 h and 2210 h), day 14 (1800 h) and day 15 (0620 h, 1500 h, 1925 h and 0310 h). The mean duration of the short wettings was 85 seconds to wet all six (6) steers.

The first wetting on day 13 was a long duration wetting of 9 minutes for all animals using 48 L water per head. A second long duration wetting of 9 minutes 57 seconds minutes for all animals was undertaken on day 15 (0620 h). Approximately 55 L water/head was used during this wetting.

Total water used over all wettings was 1136 L (189 L/head or 13.5 L/head/wetting). The short duration wettings (n=12) accounted for 518 L (86.4 L/head or 7.2 L/head/wetting), and the long wetting (n=2) accounted for 618 L (103 L/ head or 51.5 L/head/wetting).

In this study the diameter of the hose used was 25 mm, the average water pressure was 20 psi and the average flow rate of 29 L/min. This compared with a hose diameter of 40 – 50 mm, a pressure of 60 – 90 psi and an output of 166 – 333 L/min on the vessels inspected.

Using the amount of water used in this study as a guide i.e. 7.2 L/head/wetting for short duration wetting, and 51.5 L/head/wetting for long duration wetting. A pen of 25 steers needing 7.2 L/head would result in a total of 180 L of water will be used for short duration wetting. The duration of the short wetting would be on average less than one minute.

If a long duration wetting was imposed on the same pen of cattle then a total of 1287.5 L of water will be used. The duration of the long wetting would be between 6 and 10 minutes depending on flow rate.

While time is an important constraint, the volume of water is important in terms of cooling the animal, not necessarily the time it takes to apply the water.

3.1.2 Wetting water temperature: Wetting water temperature ranged between 29.6 and 31.4 °C. The mean wetting water temperature was 30.8 °C.
3.1.3 Drinking water temperature: Drinking water temperature ranged from 25 °C and 29 °C, with a mean of 28 °C. There was no difference (P>0.1) in mean drinking water temperature between stalls or over time. Hot drinking water may have a negative impact on both feed intake and water intake especially if cattle are already hot (Lott pers. comm. 2003).

3.1.4 Respiration Rate: Prior to day 1 (when the steers were at the feedlot), the mean respiration rates were 72, 54, 76, 78, 65 and 43 respectively for steers 1, 2, 3, 4, 5 and 6. Mean daily RR in the climate room were lower under the cool conditions (days 1 to 4) than during exposure to HOT (days 5 – 15). However, almost as soon as the steers entered the climate room RR increased. Previous studies have shown an increase in RR of non-acclimatised cattle as DBT rises above 21 °C.

The mean daily RR increased over the first three days of HOT (days 5, 6 & 7) (Table 3). In line with previous studies RR were reduced from the 5th day (day 9 of the study) of exposure to hot conditions and were maintained within a fairly narrow range for 3 days (Figure 2). Respiration rates became erratic after day 7 of the study. The reduction in RR after day 7 of the study was probably a function of reduced feed intake, and therefore lower metabolic heat production, and not an indication of acclimatisation.

Except for steer 5 the greatest RR were seen on day 7. On the 4th day of HOT (day 9 of the study) mean daily RR's were lower (P<0.01) than on the preceding day, and remained at the lower levels over the remainder of the study. Mean daily RR fell again on the 9th HOT day (day 13 of the study) and then increased the following day. However RR did not reach the levels experienced on day 7. In some cases this may be interrupted as cattle coping with the conditions. When other factors are assessed, e.g. feed intake, animal behaviour and panting score it was clearly evident that the cattle were not acclimatising to the conditions.

3.1.5 Panting Score: The mean hourly Panting Scores (PS) are shown in Table 3. For all steers mean panting scores were greater than 2 (fast panting, drool or foam present) after the 3rd day of exposure to HOT. Three steers showed a PS >3.5 (open mouth, tongue out slightly). Steer 1 showed a PS 4 (open mouth, tongue extended, head held up) on two occasions on day 10. Steer 2 also showed PS 4 on day 10, and progressed to PS 4.5 on at least two occasions on day 10. Steer 5 showed a PS 4 on 3 occasions, once on day 9 and twice on day 10. Panting Scores were used as a basis to commence wetting. If any one steer had a PS > 2.5 wetting was initiated. In all cases PS fell to a PS 2 or lower following wetting.

Panting scores are a more reliable indicator of the heat load status than respiration rate. It is common for cattle with PS above 3 to show a reduction in respiration rate, because they move from rapid shallow breathing to slow deep breathing.

<table>
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<tr>
<th>Day (Day of HOT)</th>
<th>Steer 1</th>
<th>Steer 2</th>
<th>Steer 3</th>
<th>Steer 4</th>
<th>Steer 5</th>
<th>Steer 6</th>
</tr>
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<td>87.49 (1)</td>
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<td>87.73 (1)</td>
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<td>101.09 (1)</td>
<td>78.35 (0.5)</td>
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<tr>
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<td>132.50 (2.5)</td>
<td>112.63 (2)</td>
<td>139.00 (2.5)</td>
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<td>99.17 (1)</td>
</tr>
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<td>137.64 (2.5)</td>
<td>124.44 (2)</td>
<td>138.04 (2)</td>
<td>101.43 (2.5)</td>
<td>103.31 (2.5)</td>
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<td>132.62 (2)</td>
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<td>101.89 (2.5)</td>
<td>93.70 (2.5)</td>
<td>92.05 (2.5)</td>
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</tbody>
</table>
3.1.6 Rectal Temperature: Mean daily RT for each steer over the 11 days of HOT are presented in Table 4. For all steers mean daily RT were lower (P<0.01) on days 1 to 4 than for days 5 to 15. During HOT, mean daily RT on day 5 were lower than mean daily RT for all days between day 6 and day 15, for all steers. RT followed a similar pattern to RR, increasing over the first 4 days and then decreasing slightly.

Steers 1, 4, 5 and 6 all had mean RT above 40 °C. Steer 5 maintained the greatest RT. During day 14 the RT of this steer exceed 42 °C a number of times. This steer also had the greatest percentage rise (4.25%) in RT compared to levels during days 1 to 4.

Individual rectal temperatures varied over a 24-hour period, but tended to remain fairly constant (± 0.1 °C variation) for up to six hours. Over the duration of the 11 days HOT, small incremental rises in RT were additive. There was no consistency in the rise, with some increases of 0.5 °C followed the next day with a 0.01 °C increase. Decreases in RT also occurred but at no time did RT return to levels of days 1 – 4.

Clear diurnal patterns were seen for RT over the first 8 to 9 days of exposure to HOT (Figure 3). However on day 10 of exposure the diurnal pattern was not seen, and as with the change seen for RR may be an indicator of failure to cope. Diurnal patterns seen in previous studies were usually associated with significant diurnal changes in climatic conditions. It is possible that cattle “store” heat during the hot part of the day and then dissipate this heat when conditions are cooler. The data from this study suggest that cattle will use this mechanism even where diurnal variations in climatic conditions are small or non-existent but will reach a point were the mechanism fails largely because the ambient conditions do not alleviate.

Minimum rectal temperature is an important measure. Except for day 5 and 9 of HOT the minimum RT increased each day. At no time did the mean return to per heat stress levels. There is also evidence of reduced diurnal movement (day 8, 10 and 11). This suggests that the cattle were not “dumping” their heat load. Without some method of alleviation on these days death would be likely.
An overlay of RR and RT is presented in Figure 4. It is clear from these data that reliance on RR alone is not sufficient to assess the heat load status of the steers in this study. A falling RR may indicate that cattle are coping. However if RT is increasing then it is likely that the animals are failing to cope. The reduction in RR may in fact suggest a shift to shallow deep breathing. Panting scores are a better indicator as seen in Table 2 where a falling RR was not necessarily an indicator that the cattle were coping with the conditions.

Table 4. Mean daily rectal temperature

<table>
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<tr>
<th>Day</th>
<th>Steer 1</th>
<th>Steer 2</th>
<th>Steer 3</th>
<th>Steer 4</th>
<th>Steer 5</th>
<th>Steer 6</th>
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<td>39.88&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>40.08&lt;sup&gt;b&lt;/sup&gt;</td>
<td>39.66&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>6 (2)</td>
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<td>39.17&lt;sup&gt;c&lt;/sup&gt;</td>
<td>39.13&lt;sup&gt;c&lt;/sup&gt;</td>
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</tr>
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<td>39.76&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>40.19&lt;sup&gt;b&lt;/sup&gt;</td>
<td>40.31&lt;sup&gt;g&lt;/sup&gt;</td>
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<td>39.87&lt;sup&gt;g&lt;/sup&gt;</td>
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<td>40.45&lt;sup&gt;f&lt;/sup&gt;</td>
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<td>39.97&lt;sup&gt;g&lt;/sup&gt;</td>
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<td>41.65&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>15 day means</td>
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<td>39.80</td>
<td>39.59</td>
<td>40.34</td>
<td>40.57</td>
<td>40.32</td>
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</table>

Means within a column with the same superscript are significantly different P<0.05.
3.1.8 Feed Intake and Live Weight Change: Prior to exposure to HOT mean feed intake (FI) was 9.99 kg/head/day. Feed intake was reduced on the first day of HOT (day 5) and continued to fall over the remainder of the study (Table 5 and Figure 5). By day 15 the mean reduction in FI for all steers was 45.1% of their intakes prior to HOT. Occasionally the FI of an individual steer would increase slightly, but would then fall the next day. By day 15 of the study mean intake was approximately 1.2% of live weight. Wetting cattle did not improve feed intake or prevent weight loss. Wetting did however induce an eating response. The reduction in FI resulted in a mean weight loss of 17 kg/head. This was not unexpected as the conditions were designed to ensure a high level of heat stress. Under normal shipping conditions only small changes in live weight would be expected.

3.1.9 Behaviour: Cattle activity was determined by hourly observations each day (144 observations each day). The observations were for the most part undertaken via video camera at the start of each hour (e.g. 0700 h, 0800 h etc.). When this was not possible as many observations as possible would be made prior to entry to the climate rooms. In most cases cattle would stand, or stop drinking/eating when humans entered the room. The major exception was when cattle were sleeping. The observational data is presented in Table 6.

Much of the literature suggests that heat stressed cattle will spend more time standing than lying. In the present study the cattle spent 70% of their time lying. In this study it is probable that the cattle spent more time lying because (i) the floor was wet (urine, faeces and spilt water) and therefore provided some relief, (ii) it was an attempt to escape from the heat (because hot air rises, it was slightly (0.5 °C) cooler at pen floor level over the first 2 days of HOT.

However as their exposure to hot conditions continued there was a behavioural change. On 6 of the 11 hot days more standing observations were made than laying observations (420 vs. 388). On days 12 – 15 standing cattle generally had their head over or resting on the water trough but were not drinking. Standing on these days was also accompanied by other behaviours such as a spread stance, head down, and some restlessness.
### Table 5. Feed Intake (kg/d) and percent reduction in feed intake over 15 days

<table>
<thead>
<tr>
<th>Day (day of HOT)</th>
<th>Steer 1</th>
<th>Steer 2</th>
<th>Steer 3</th>
<th>Steer 4</th>
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<td>4.85</td>
<td>4.79</td>
<td>6.11</td>
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</table>

| Reduction in FI| 44.1%  | 44.4%  | 46.5%  | 38.9%  | 54.7%  | 42.1%  |

**Figure 5. Change in Feed Intake**
Table 6. The number of observations of cattle activity.

<table>
<thead>
<tr>
<th>Day (Day of HOT)</th>
<th>Eat</th>
<th>Lying</th>
<th>Standing</th>
<th>Sleeping</th>
<th>Drinking</th>
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3.1.10. Conclusion: Respiration rate, panting score and rectal temperature increase when cattle are exposed to hot conditions. However there is considerable variation between cattle in regard to the magnitude of responses.

A decrease in respiration rate for housed cattle exposed to hot conditions is not necessarily a sign that cattle comfort has increased or that the animals are coping better with the hot conditions. As was seen in Table 3 and Figure 2, RR first increased and then decreased as exposure to hot conditions continued, however it could not be argued that the cattle were more comfortable on day 11 of HOT than on day 1.

**Panting score is the best visual indicator of heat load status and should be used when assessing cattle exposed to hot conditions.**

A fall in feed intake is a good early indicator that cattle are having difficulty coping with hot conditions, and may serve as a better indicator than either rectal temperature or respiration rate. However as reductions in individual feed intake will be difficult to assess on ships an increase in respiration rate and particularly PS are the best indicators.

While the tendency was for cattle to stand when exposed to hot conditions the data from this study is not conclusive. Furthermore housing conditions and the presence of stockman on ships may also impact on this behaviour. Therefore standing may not be a good indicator of “stress” on ships.

3.2 ANIMAL RESPONSES TO WETTING

Wetting had a positive effect on both respiration rate and rectal temperature. The impact of wetting on these parameters was a function of volume of water applied and ambient conditions.

3.2.1 Rectal Temperature: In general the short duration wetting on days 6 to 11 lowered (P<0.05) RT by about 0.5 °C (range 0.3 to 0.6 °C). There was variation in response time. On occasions RT fell within 20 minutes of water application, however in most cases the fall was seen between 40 minutes and 60 minutes after application. Rectal temperatures were maintained at the lower levels for approximately 6 to 8 hours when wet bulb was below 30 °C.

Under extreme conditions (WBT > 30 °C), such as those encountered on days 12 to 15, the short duration wetting resulted in a reduction in RT, however the effect was of short duration. When wet bulb was greater than 30 °C the reduction in RT was for a shorter period (2 to 3 hours).
The effect of the first long duration wetting on rectal temperatures were similar to the short duration wettings. However, the second long duration wetting resulted in a significant (P<0.05) reduction (1 °C) in RT. The lower rectal temperatures were maintained for approximately 5 hours.

Rectal temperature is probably the best indicator of the heat load status of cattle. The difficulty in measuring RT on board ship is recognized.

3.2.2 Respiration Rate and Panting Score: The effect on RR and PS was almost immediate following the first water application (2140 h; 11/8). Respiration rate dropped from an average of 122.5 bpm to 115 bpm over the first hour following wetting, and continued to fall over the next hour to 102 bpm (16.73% reduction; P < 0.05). Generally RR fell within 20 minutes of water application. However in some cases no change was noted for almost 1 hour. Panting scores dropped from 2.5 to 1 within 20 minutes of water application. As the study progressed the effect of wetting on RR and PS was less dramatic, probably because the micro-climate was less favourable for heat dissipation. However, PS always fell below 3 following wetting.

There was an immediate response (reductions of 20 bpm P < 0.1, to 50 bpm P <0.05)) to the long duration wetting, however the effect was short term (i.e. less than 30 minutes). Within 1 hour of wetting RR returned to or were just below the pre-wetting level, especially under extreme conditions, while PS remained below 3 for up to 6 hours.

The reduction in PS was a good indicator that the wetting improved cattle comfort.

3.2.3 Behaviour: On initiation of wetting cattle that were lying down would generally stand. In some cases cattle would eat and drink immediately after wetting. However this may simply be due to the fact that they stood and not as a result of wetting. There did not appear to be any wetting avoidance strategies.

3.2.4 Conclusions: Wetting had a positive impact on cattle comfort.

As DBT approaches RT the ability of cattle to dissipate heat is greatly reduced, especially where relative humidity and WBT are high. Results from this study suggest that the critical threshold for relative humidity is approximately 60% and for wet bulb temperature approximately 30 °C. Above these thresholds the experimental cattle had difficulty in reducing their heat load. Wetting was a useful strategy but was needed more often (as seen by the 4 wettings on day 15), and water application (volume) may need to be higher than was used in the present study.

The longer duration wetting did not appear to have any substantial benefits in terms of extending the period between wettings over the short duration wettings, especially under high heat load. The little and often approach to wetting (e.g. wetting for 3 minutes every 30 minutes) often used in the dairy industry may serve as a useful model. This approach would only be practical on ship if sprinklers were used.

Based on the present study water application will be needed at least every 3 to 5 hours. Interviews on board live export ships revealed that on average (5 ships) it would take between 4 and 6 hours to wet all cattle using existing infrastructure (fire hoses). Under extreme heat load conditions this will probably not be sufficient to provide relief to cattle, therefore a “sprinkling/misting” system may be necessary. In the event of a heat stress occurrence It is unlikely that all cattle on a vessel will be suffering and in many cases there may only be a few if any at risk. The Heat Stress Risk Management Model will “tell” the exporter to load the more heat susceptible cattle where ventilation is best and water supply is best. Therefore substantially less time and water may be used in the event that wetting becomes necessary.

It is important that once the decision has been made to wet cattle as a heat stress relief strategy that the procedure is continued for as long as cattle exhibit symptoms of severe heat stress. Failure to do so may result in increased susceptibility of cattle to severe heat stress (Gaughan et al. 2003), and possibly death (based on anecdotal evidence from feedlot managers and ships officers). The reasons for this have not yet been fully investigated and were not explored in this project. In the study by Gaughan et al. (2003) cattle that were exposed to wetting, attempted to maintain lower RT, by elevating RR, while the non-wetted cattle continued the adaptation and acclimation to moderate heat stress via elevating homeostatic RT set-point as a coping mechanism. It appears that the level of risk of hyperthermia in cattle unaccustomed to artificial cooling would be less than those that were accustomed to cooling. As cattle are
continually exposed to elevated ambient temperatures, adaptations such as reduced feed intake (Mitloehner et al. 2001) and reduced production of metabolically active hormones occur (Minton 1994) to allow coping in adverse conditions. Based on these results and observations it is important that once application of water to reduce heat stress in cattle has been initiated that timing and duration remain consistent for as long as the cattle exhibit signs of severe heat stress.

Long duration wetting or higher volume per head (complete saturation of the head, back and sides of the animal) is better under extreme micro-climate conditions (WBT > 30 °C) than short duration or low volume per head wetting.

Respiration rate is a useful indicator of heat load, however panting score and body stance (standing with head down, head over the water bowl, or dipping nose into water bowl) are better indicators of the severity of the heat load. At times RR decreased even though it was obvious from visual appraisal that cattle were under high heat load. A decreased respiration rate may be an indicator that the animal is failing to cope due to a shift from rapid shallow breathing to deep phase breathing.

Overall wetting had a positive impact on cattle comfort in the present study as measured by reductions in rectal temperature and respiratory rate. Wetting often encouraged eating but had no effect on overall feed intake. Wetting did not have an effect on live weight – all cattle lost weight over the 15 days.

Based on observations and data collected in this study and others the following clinical signs of heat stress have been developed.

Mild heat stress: Drooling, increased respiration rate (80 – 100 breaths per minute; bpm). At this stage close monitoring of cattle is necessary. Cattle should be inspected at least every 30 minutes.

Moderate heat stress: Drooling, respiration rate 100 – 120 bpm, and occasional open mouth panting (panting score 1 – 2.5). At this stage cattle should be inspected every 30 minutes and ensure wetting facilities are ready to be used.

Severe heat stress: Drooling, respiration rate >120 bpm, open mouth panting, tongue out (panting score > 2.5). Cattle will also have an agitated appearance and will often have their heads down. At this stage wetting should be undertaken.

Cattle can move from mild heat stress to severe heat stress very quickly e.g. from less than 30 minutes to 1 – 2 hours. Therefore if cattle are detected with mild heat stress extra vigilance is needed i.e. check cattle often (at least every 30 minutes). If mild heat stress is detected ensure that wetting facilities are ready to go if the situation worsens.

It does not appear that saltwater application had any negative effects on the steers. Furthermore application of 30 °C water did not appear to have negative effects. It is possible that warm water may be better than application of cold water which causes vasoconstriction of blood vessels which may upset the animals ability to dissipate body heat. There is no evidence from this study to support this statement but it may be worthy of further investigation.

Continued wetting of feet especially in soft cattle may lead to lameness. Although not seen in this study it was a concern expressed by those interviewed on ships. Therefore if wetting is being used and bedding is wet for prolonged periods stockmen will need to keep a close watch on legs and feet. Removal of bedding may be warranted. However, there may be other welfare implications by removing bedding.

Wetting of cattle had minor effects of short duration on the micro-climate. The major impact was the reduction (P <0.05) in dry bulb temperature especially with the longer duration wettings.

Wetting can be undertaken with minimal water usage.
3.3 MICRO-CLIMATE RESPONSES TO WETTING

3.3.1 Short duration wetting: Short duration wetting resulted in a mean increase in RH of approximately 2.5% (range 0% - 4%), a mean reduction of DBT of approximately 0.5 °C, and a mean increase in WBT of 0.2 °C (range 0 to 0.5 °C) following short term wetting. These changes generally lasted one to three hours.

3.3.2 Long duration wetting: The first long duration wetting resulted in a DBT reduction of almost 5 °C (38.40 to 33.68 °C). A slightly lower reduction of 4.4 °C was seen following the second long duration wetting (39.33 to 34.93 °C). In both cases DBT remained down for approximately 20 minutes before steadily climbing back to pre-wetting levels within three hours. RH increased by approximately 3% and remained elevated for 30 to 40 minutes. WBT increased slightly (0.3 °C).

3.3.3 Wash Down: Wash down had an immediate effect of reducing ammonia levels, and as a result of a concurrent reduction in DBT cattle (and human) comfort was improved. There were not enough data points to analyze the changes. However, following wash down there was no smell of ammonia. These results are consistent with previous findings (MAMIC 2001).

3.3.4 Conclusions: Wetting cattle had a short duration effect on the micro-climate. The major impact was the reduction in DBT especially with the longer duration wettings.

Wash down reduced ammonia levels and resulted in a DBT reduction.

Wetting cattle with large volumes of water will have an impact on bedding. It may be required that floors are cleaned at the same time.

3.4 FINDINGS FROM SHIP VISITS

3.4.1 Pen Areas: Pen areas and layouts in the ship are an important constraint in establishing options for the wetting systems and their viability.

Of the ships inspected, there were four (4) basic pen layouts; each is schematically shown in Figure 6. All ships had two (2) or three (3) walkways for the length of the ship. The layout of these walkways is important as this is where the pens are serviced from, including: feeding, watering, inspection and pen washing. Once cattle have been loaded all operations occur from the walkways, as nobody enters into the pens with the cattle.

Single pen areas in a ship typically range from 8 – 20 m². The pen shape and sizes are determined by the physical constraints of the ship and the floor layout. The depths of the pens range from 3 – 5 m, with the maximum distance between walkways being 8 m. The height to the ceiling was similar for all visited ships (2.5 – 3 m).

The pen areas that were noted to be of higher concern in regard to heat stress by the ships officers were the enclosed decks above the waterline. It was also noted that the western side of the ship may be hotter in the afternoon. Some ships have painted the external decks white to reduce heat load and heat reflected into the open decks, while others are black and as a result, significantly hotter. The lowest deck, which is below the waterline, was noted as the coolest. Although this may not be the case if the ventilation efficiency on the lower decks was not comparable with other decks.

The ventilation systems were of similar design across the range of ships, large PVC pipes running the full length of each enclosed deck. They are supported from the roof and had perforations to allow inducted air into the pen areas. However the capacities of these systems varied significantly. The open decks generally have some through flow of wind that reduces the heat stress.

3.4.2 Water Reticulation: The water reticulations systems varied significantly from ship to ship, both in the pump systems and supply networks. All pumps were based on a centrifugal pump design. Most ships have the main pumps on a manifold system together with a valve chest, enabling all pumps and pipe systems to be interchangeable, increasing safety and reliability. The emergency pumps are typically
located in a separate location. The main pumps on the ships are general service, ballast, bilge, fire and emergency pumps. There was some variation in the use of the general service pumps. Some ships had the general service pumps using salt water for general duties like pen washing, while other used it to supply freshwater to stock for drinking. The ballast pump normally pumps freshwater (produced onboard ship) between the ballast tanks and in some cases to provide drinking water to the stock. The bilge pumps remove excess water from the bilge, including effluent water generated from pen washing. The emergency pumps use saltwater and are only used in an emergency as a backup. There was also variation in the use of the fire pump. Some ships used the fire pumps for pen washing, while some kept the fire pumps for an onboard fire only.

The capacity of these pumps is significant (30 - 60 t/hr) compared to the water requirement for high volume wetting (10 t/hr) and washing (2 t/hr). All ships pumps currently have the capacity to adequately wash out the pens. Most ships currently run 4 - 6 hoses of 50 mm diameter simultaneously. The pressure was typically between 400 - 600 kPa (58-87 psi).

The water supply networks were relatively consistent between ships. Typically there were supply mains for both fresh water for cattle, and seawater for pen washing along the length of the ship on each deck. The hydrants are typically in line with the walkways. In some cases there was an additional supply line containing seawater for emergency purposes. These supply lines had several locations where hoses could be connected. There were two ships that didn’t have this supply network. They only have one supply point in the middle of each deck, for both fresh and salt water. In this case they relied on long hoses to service each deck.

**FIGURE 6. BASIC PEN LAYOUTS ON INSPECTED SHIPS**

3.4.3 Bilges: The bilge pumps were found to be an important aspect of the system. It was typically the limiting factor in the system for blockages and/or the most problematic component of the washing/wetting and waste management system. The type of bilge pumps varied from inductor, grinder and centrifugal pumps.
Blockages were the most common problem in the bilge system during washout. The blockages are caused by bale twine, ear tags, wire, bedding material and manure. The extent of blockages seemed to be dependant upon the type of bilge pump system, with the centrifugal pump being most problematic and grinder pumps being least problematic. The age and the design of the bilge systems varied significantly with the age of the ship.

3.4.4 Management of Bedding Materials: On some shipping routes bedding materials are used on the pen floor as a cushion for the cattle. This is to prevent injury and bruising to the cattle. Bedding material is important on the southern shipping routes due to the rough seas encountered. Bedding materials include sawdust, woodchips and hay, with sawdust and woodchip being the most common in Australia.

The main issues outlined with wetting cattle were the management of the bedding material. This includes maintaining the bedding material in a dry condition so it doesn’t impact the microclimate in the pens. The bedding material becomes wet from urine, manure and wetting. This increases the heat and relative humidity of the pen atmosphere and also ammonia production; all of which increase the stress on the cattle. There were no clear guidelines to when pen cleaning occurred and what procedures were followed on any of the ships. The occurrence of pen washing seemed to be very subjective and dependent upon the head stockman on each particular ship.

Pen washing is a significant task, typically taking 5 - 6 crew, 4 - 6 hours depending on the ship. Further to this fresh dry bedding material needs to be put back into the pens, which is done manually with wheelbarrows and buckets. As a consequence bedding material wasn’t always used.

3.4.5 Wetting of Cattle: Wetting cattle to alleviate heat stress already occurs on some ships, if the conditions are extreme. Like pen washing, the management and procedures used for wetting are very subjective, variable and dependent upon the ship’s crew. Clear guidelines and recommendations for wetting don’t seem to be available, at least to the ships captain/crew. It ends up very much a trial and error system.

Wetting the cattle for cooling purposes adds water into the environment, increasing the need for washing out of the pen areas. This increases the relative humidity and ammonia production, increasing the stress on the cattle. After pen washing or cattle wetting occurs once, it needs to continue daily. Captain’s that had experienced severe heat stress conditions on livestock vessels all commented that cattle wetting reduced animal distress (heat load) but once it was commenced it had to be continued.

Some ships didn’t use wetting to control heat stress as they believed adding the water would negatively impact the pen microclimate. Further to this they preferred not to remove the bedding material, as either the bilge system couldn’t handle the solid waste volume or it was considered too much work.

3.5 DISCUSSION ~ SHIP VISITS

The pen layout will be the primary factor in determining the design of the wetting system.

If wetting is undertaken through hosing, the existing system has abundant capacity and ability. The hose system currently used for pen washing requiring 10 t/hr compared to 2 t/hr required by hose wetting (NB there was no indication from ships officers how much water was applied to cattle). All infrastructures required for hose wetting is currently on all ships inspected. If a ship has the ability to washout pens it will have excess capacity for hose wetting of cattle.

It would be anticipated that 2 - 3 dedicated service pipelines would be required to adequately supply water for wetting purposes. The number of service pipelines would correspond to the number of walkways. In newer ships inspected, the existing service pipelines would be able to be utilised as they typically correspond with the walkways.

In all ships, the existing water supply networks and pump capacities to each deck have sufficient capacity for all options relating to wetting systems (e.g. misting, wetting and washing).

3.5.1 Bilge System Constraints: The bilge pumps were found to be the limiting factor in the water reticulation system. The type and design of the bilge pump will be the major factor in determining the
suitability of ships for wetting. The type of bilge pumps varied from inductor, grinder and centrifugal pumps.

The ability of the bilge system correlated with the age of the ship, the newer purposed built ships had superior bilge systems. The older ships had bilge systems that were problematic and incapable of handling the wastes generated with pen washing when bedding materials were used. These bilge systems either had centrifugal or small inductor pumps. However the new ships had large inductor or grinder pumps, which allowed them to handle the wastes generated by pen washing when bedding material was used.

Blockages were the most common problem in the bilge system during washout. The blockages were caused by bale twine, ear tags, wire, bedding material and manure, and were only noted on the older ships which were centrifugal and smaller inductor pumps. This is due to the lower capacity of these older pumps and the inferior design of the drainage systems.

3.5.2 Management of Bedding Materials: The management of bedding materials is an important issue in wetting cattle to alleviate heat stress. There are no clear guidelines for pen cleaning, bedding material management and wetting cattle to alleviate heat stress. As a result there is significant variation and subjectivity surrounding the management of these issues. Clear guidelines, incorporating the interrelationship between these issues, needs to be developed.

Bedding material is important on the southern shipping routes due to the rough seas that are often encountered. However, according to ships' masters once these ships leave the southern ocean, the requirement for bedding material is dramatically reduced, as rough seas are less common. While bedding materials are only required for the southern ocean, it is typically used for the duration of the journey. After pen washing occurs, the bedding material is replaced.

Bedding material significantly increases the waste generated from pen washing, incapacitating some ships bilge systems. This means these ships don't wash out when needed as the ships systems are unable to handle the waste. Pen washing is much easier and less problematic without bedding material. On southern shipping routes, bedding material should only be used while required. Once the ship has left the southern ocean, bedding material could be omitted from pens, enabling easier pen washing. This will allow pens to be washed more regularly and consistently, lowering stressors, and alleviating heat stress in cattle. However this is beneficial only from a heat stress point of view, and there may be other animal welfare benefits for cattle to have access to bedding, e.g. more likely to lie down.

3.5.3 Conclusions ~ ship visits: After an inspection and assessment of onboard ship conditions, coupled with interviews with the ships captains and engineers, several beneficial conclusions have been noted. Wetting cattle to alleviate heat stress onboard ship can be an effective means of cooling cattle.

All ships water supply systems have ample capacity to adequately supply water for wetting cattle and pen washing. The water distribution systems already exist in the majority of ships. In the ships that don't have adequate water distribution system, they have other systems that are also inadequate, such as the bilge systems.

Wetting in ships can occur in several different ways: by hose washing, through a fixed sprinkler system or through misting. The best and most suitable wetting method onboard ship needs to be determined, as most of the ships have the capacity to utilise all these wetting methods. In most cases, minimal additional infrastructure, is needed whatever type of wetting method is adopted. For hose wetting no further infrastructure is required. The only additional infrastructure required for wetting with a sprinkler system is common, readily available agricultural sprinklers, and their connection into nearby existing supply lines. The cost associated with the incorporation of a wetting system would be minimal.

The critical issue with wetting is waste management. This is the most limiting and problematic issue. The bilge systems in old ships are the limiting factor as they are incapable of handling waste generated by pen washing. The newer purpose built ships have superior systems which have an increased ability to handle the waste generated. Only the ships with adequate bilge systems should be used for the southern routes where bedding material is essential.
The management of wetting is essential and needs to encompass pen washing, bedding material management and wetting. These aspects are interrelated and need to be managed holistically, and not as three separate issues.

Clear guidelines for pen cleaning, bedding material management and wetting cattle, incorporating the interrelationship between these issues, need to be developed. This will enable the whole industry to adopt practices that are consistent and robust. It will ensure sound procedures are being adopted.

4.0 SUCCESSS IN ACHIEVING OBJECTIVES

No difficulties or problems were encountered through the duration of Stage 1. All of the objectives of the study were met.

5.0 IMPACT ON MEAT AND LIVESTOCK INDUSTRY

This study has shown that wetting cattle under simulated on ship conditions will result in a reduction in respiration rate, a reduction in panting scores and a reduction in rectal temperature, and will have minimal negative impact on the micro-climate.

Wetting cattle can be undertaken on many of the current livestock vessels. The implementation of the recommendations presented in this report will enable stockman on ships to minimize the adverse effects of high heat load and thereby reduce the likelihood of unfavourable animal welfare situations. However, implementation of these recommendations is not a guarantee that there will be nil losses associated with heat stress.

6.0 RECOMMENDATIONS AND FUTURE RESEARCH

The Stockman’s Handbook and LEAP be modified to include the clinical signs of heat stress, a panting score guide, and recommendations for wetting.

- Decisions for wetting cattle should be made primarily on clinical symptoms and behaviour rather than just climatic conditions. That is use the animal as the indicator.

- Clinical signs of mild heat stress: Drooling, increased respiration rate (80 – 100 breaths per minute; bpm).

- Clinical signs of moderate heat stress: Drooling, respiration rate 100 – 120 bpm, and occasional open mouth panting (panting score 1 – 2.5).

- Clinical signs of severe heat stress: Drooling, respiration rate >120 bpm, open mouth panting, tongue out (panting score > 2.5). Cattle will also have an agitated appearance and will often have their heads down.

- Wetting should commence when more than 5% (1 head in 20 head) of cattle are showing clinical signs of severe heat stress: Drooling, respiration rate >120 bpm, open mouth panting, tongue out (panting score > 2.5). Cattle will also have an agitated appearance, will have a hunched stance and will often have their heads down.

- Water should be applied to the head and back of cattle, and enough water needs to be applied to cattle so that it is beginning to run off their backs and down their sides. The duration of the wetting will depend on the volume from the hose, water pressure and stocking rate.

- Do not use high pressure jets on cattle. Using a high pressure hose to apply water to hot cattle may cause injury (and possibly death) especially if they are frightened. If fire hoses are to be used the nozzle should be set to fan water.

- If cattle are still showing severe heat stress within 1 hour of initial wetting then repeated wetting will be necessary.
Once wetting has commenced it will need to be repeated until the cattle are no longer showing signs of severe heat stress.

At all times ensure that there is adequate air movement (in the current study a pen air turnover (PAT) of 130 m/h was adequate, however it is likely that a higher PAT e.g. 150 m/h could be necessary especially where stocking rates are as per current guidelines) – if the ventilation system fails – DO NOT wet cattle.

If bedding material becomes wet and sloppy it will need to be removed immediately after wetting.

Cattle can move from mild heat stress to severe heat stress very quickly e.g. less than 30 minutes to 1 – 2 hours. Therefore if cattle are detected with mild heat stress extra vigilance is needed i.e. check cattle often (at least every 30 minutes). If mild heat stress is detected ensure that wetting facilities are ready to go if the situation worsens.

Future areas of research include:

1. The effects of duration and timing of water application on cattle and on the micro-climate onboard ships needs to be further investigated.
2. Sprinkler/misting system studies are necessary to ensure adequate timing and duration of wetting cattle exposed to hot conditions.
3. Recording of on board micro-climate (e.g. using data loggers) needs to be undertaken in conjunction with animal factors (e.g. panting scores, possibly body temperature and feed intake). This should be incorporated with a livestock vessel wetting study. This is necessary in order to quantify actual conditions on vessels with animal responses. Collection of “spot” climatic data has little meaning when we are assessing animals that are exposed to the conditions on a continuous basis. It would also be useful to quantify any diurnal variations in micro-climate, and to determine any impacts from wetting and pen washing on the micro-climate. Ideally this study should be carried out on a number of vessels and on a number of voyages. It would also be useful to have the loggers in place if vessels are returning to Australia empty. This would give a good indication of how much the animals contribute to the micro-climate in terms of temperature (dry and wet) and humidity. This study would build on work already undertaken on ships and in simulated conditions. An applied “real world” study of this nature would give the industry a firm scientific basis for management decisions.
4. Develop clear guidelines for pen cleaning, bedding material management and wetting cattle, incorporating the interrelationship between these issues.
5. Determine best wetting method for onboard ship conditions.
6. The capacity of ships to handle waste bedding and additional water needs further investigation.

7.0 ACKNOWLEDGEMENTS

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Dr Simon More
Dr Conrad Stacey
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APPENDIX 1 Description of Ships Visited

Ship 1
Capacity: 1200hd
Bilge Pump System: 2 Centrifugal pumps
Decks: 5 – 2 Enclosed & 3 Open
Year Built: 1974
Year Converted: 1993
Freshwater System: Reverse Osmosis (60t/day)

Ship 2
Capacity: 1200hd
Bilge Pump System: 2 Inductor pumps (60t/hr) with 6 outlets (30t/hr).
Decks: 4 – All Enclosed
Year Built: 1970
Year Converted: 1984 (from bulk carrier)
Freshwater System: Evaporators, 25T/day

Ship 3
Capacity: 2300-2500hd
Bilge Pump System: 2 Inductor Pumps (60t/hr) with 4 outlets (30t/hr).
Decks: 4, All Enclosed
Year Built: 1998
Year Converted: Purpose Built for Live Export
Freshwater System: Evaporators, 30T/day.

Ship 4
Capacity: 2700-2900hd
Bilge Pump System: 2 Grinder Pumps
Decks: 5, All Enclosed
Year Built: 1998
Year Converted: Purpose Built for Live Export
Freshwater System: Reverse Osmosis, 70T/day
**Ship 5**
Capacity: 2400hd
Bilge Pump System: 2 Inductor Pumps (60t/hr) with 4 outlets (30t/hr).
Decks: 5, All Enclosed
Year Built: 1998
Year Converted: Purpose Built for Live Export
Freshwater System: Evaporators, 30T/day

**Ship 6**
Capacity: 1300hd
Bilge Pump System: (Still to be supplied by owner)
Decks: 6, 4 Enclosed & 2 Open.
Year Built: 1981
Year Converted: 1997
Freshwater System: Reverse Osmosis (100t/day)

**Ship 7**
Capacity: 1200-1300hd
Bilge Pump System: 2 Inductor Pumps (60t/hr), with 2 outlets (35t/hr).
Decks: 6, 3 Enclosed & 3 Open.
Year Built: 1980
Year Converted: ~1993 (from bulk carrier)
Freshwater System: Reverse Osmosis, 60t/day

**Ship 8**
Capacity: 1200hd
Bilge Pump System: Inductor Pump (60t/hr), with 1 outlet.
Decks: 4, 2 Enclosed & 3 Open
Year Built: 1972
Year Converted: Early 90’s (from General Cargo)
Freshwater System: Reverse Osmosis, 40t/day.
Ship 9

Capacity: 900-1000hd

Bilge Pump System: Centrifugal Pump

Decks: 5, 3Enclosed & 2 Open

Year Built: 1970

Year Converted: ~1994 (from General Cargo)

Freshwater System: Reverse Osmosis, 30t/day.
APPENDIX 2 Animal Care Statement

Cattle welfare comes before the study.

If a steer is at any time distressed, i.e. wont stand, has excessive salivation, rectal temperature above 41 °C and/or respiration rate greater than 120 breaths per minute – IMMEDIATELY – turn off heat source and open doors. Place large fan to blow air across the animal and then apply limited quantities of fresh water to the animal. DO NOT apply a large volume of cold water on to the animal.

Once the animal has recovered – it should be removed from the study.

Cattle are to be observed at least every 30 minutes, via video camera, and hourly by entering the room. Rectal temperature can be observed via the computer screen.

Call me – at any time 0419664380.

AEC number: SAS/112/03/Livecorp

Valid: 04/03/03 to 04/03/04

Animals: 24 x Bovine

Contacts:

Dr John Gaughan
Ms Amy Tait
APPENDIX 3 Wetting Trial System Design and Description of Infrastructure

Introduction

The system used in the wetting trials at the University of Queensland (Gatton) incorporate a salt water supply system with a recycling system. The water supply system has an integrated pump system which delivers water at a specified temperature with the salt content of sea water. The cattle’s responses to the duplicated ship conditions determined the application of saltwater onto the cattle for cooling.

Design Constraints

The system had particular design constraints which influenced which system was selected. The cattle’s response to the duplicated ship conditions determined the water system requirements. The system was operated when the cattle’s body temperature reached 41°C and/or the respiration rate reached 200 breaths per minute. In addition to this, a complete pen washing occurred every 4 days for the duration of the trial.

The flow rate of the system needed to be variable, as it was also determined by the cattle’s responses. An aim of the trial was to determine how much water was required to cool cattle and what corresponding flow rate was needed. The flow rate was estimated to vary between 40 and 120 litres per minute. This range catered for misting, sprinkler wetting and hose wetting.

The water temperature needed to be consistent at a specified temperature, which could range from 20 to 40°C. Conductivity of the water needed to be representative of seawater, which is 50,000µS. The temperature needed to remain consistent or constant despite variable flow rates.

With the budgetary constraints, there are no commercially available control systems that could cater for the required flow variation. This meant a custom system was required and needed designing. Sourcing individual components available within Australia that catered for this large flow variation was difficult.

A salt recycling system needed to be incorporated into the system, ensuring environmental responsibilities are maintained. With the system being set up and operated within University of Queensland requirements, there were associated requirements.

The system needed to be consistently operated by a range of people. This meant it needed to be simple to use and reliable. The salt crystals needed to be mixed into solution, ready for incorporation into the system. The system needed to meet workplace health and safety obligations.

System Design and Details

The system consists of an integrated pump control system, an instantaneous gas hot water system, salt solution mixing vat, freshwater and recycle tank, and a recycle pump. This system produces saltwater at the specified temperature.

The integrated pump control system consists of a temperature and electrical conductivity (EC) sensor, controller, 2 variable speed drive pumps, a systems pump, and pressure regulator. Through the controller the sensor controls the speed of the 2 variable speed pumps, one for the hot water and the other the salt solution. The capabilities of the controller exceed the requirements for this specific trial.

The hot water system is an instantaneous gas hot water system, allowing for the flow variation. Conventional hot water systems are unable to supply the volume of water that this trial requires.
The salt solution mixing vat is a second hand milk vat. The primary reason a milk vat was selected was its competitive price. Further to this it contained an agitator, is insulated and is made of stainless steel.

The recycle system consists of a pump in the sump of the animal room, which pumps the water into a tank. This water is then able to be recycled back through the system. After several uses this water can be disposed by a waste removal contractor, preventing this salt being dumped into the waste system.

Benefits to the Project

This system had to be custom designed to meet the functionally required by the project. It is has a large capacity and is capable to of operating over a large range of parameters. This enables the system to be suitable for a large range of wetting and pen washing trails, without further capital expenditure.

The system operated very successfully during Stage 1 of the LIVE.219 project. It has the capability to undertake all the needed tasks for stage 2 of the proposed experiment with little change other than selection of nozzles for misting.

Salt Requirements

The output from the system is saltwater at the concentration of seawater, which is 34g/L, or 50 000 µS/cm. This relates 50mS/cm (which is the reading on the controller).

The concentration of the brine solution is aimed to be 10 times the concentration of the sea, or 340g/L. This relates to 34kg of salt / 100 litres of water added.

Adding salt to the brine tank

Turn on the agitator.

The amount of water added can be calculated from the dip stick in the salt tank.

Calculate the corresponding amount of salt required.

Plug the outlet of the salt tank, using the rod painted green.

NB while this outlet is plugged the system cannot be operated!

Add the salt and the water into the tank. NB do not place too much salt directly under the agitator as will not be able to turn.

Allow plenty of time to mix into the system.

Using the fresh water hose, wash any undissolved salt away from the outlet.

Unplug the outlet.

The agitator needs to be operated for a significant amount of time before a wetting occurs, at least 1 hour. The agitator also needs to be operated at least twice a day for a minimum of an hour.

Water Requirements

The estimated approximate times are as follows:

4-6 min for start-up.
2 min of operation.
2 min to turnoff.

The system is operating at about 20-24L/min or 25-30sec to fill a 10L bucket. So for a wetting operation it will use about 200 – 240L of water, for a 10min wetting. As an estimation, this will use about 20-30L of concentrated brine solution.