final report

Project code: W.LIV.0283

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Date published: March 2014

PUBLISHED BY
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LATSA 2.1 Validation Report

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

The Livestock Air Transport Safety Assessment (LATSA) software program estimates the generation of key physiological data such as heat, moisture, and carbon dioxide from livestock during transportation by aircraft. The LATSA software provides a tool for exporters to assist with planning for the safe transport of livestock by air to export standards.

The information used to predict heat, moisture and carbon dioxide production inside an aircraft hold is however based on theoretical data. Little real time data exists for the environments that are being modelled. The purpose of this project is to validate the predictions of the LATSA 2.0 software through the acquisition of real time data.

Using temperature and humidity data loggers, real time data were collected during livestock air shipments. The data was validated against modelled predictions to estimate the software's accuracy. Validation showed errors of 25% and 7^{o}C between modelled and actual relative humidity's and temperatures respectively. Alteration of software parameters concluded inaccuracies to be on a more fundamental basis, warranting further studies.

Throughout the extent of the project, administration of software improvements was continuous. Refinements were made to the software outputs based on industry use and feedback resulting in the first instalments of LATSA 2.1.

Greater research into the live export of animals by aircraft will ensure a continual development of the LATSA predictions, and an overall enhancement in industry standards and improvements in animal welfare.

Executive Summary

The Livestock Air Transport Safety Assessment (LATSA) software program estimates the generation of key physiological data such as heat, moisture, and carbon dioxide from livestock during transportation by aircraft. The overall objective of the LATSA software is to ensure compliance with the Australian Standards for the Export of Livestock (ASEL).

The information used to predict heat, moisture and carbon dioxide production inside an aircraft hold is however based on theoretical data. Little real time data exists for the environments that are being modelled. The purpose of this project was to validate the predictions of the LATSA 2.0 software through the acquisition of real time data.

Using temperature and humidity loggers, real time data was collected during eight (8) shipments of livestock by air. Analysis of the flights showed there were issues with temperature consistency within and between holds, temperature uniformity inside and outside the crates and air quality. Problems with stopovers during transit were also observed, with critical wet and dry bulb temperatures reached and exceeded during one flight. Analysis of carbon dioxide revealed an overall increase of concentrations during transport indicating an underperformance in the ventilation of carbon dioxide, and most probable, other noxious gases.

Validation of LATSA with real time data was successful in identifying errors with the model. These included:

1. Relative humidity is too low when modelled in LATSA;
2. Modelled dry bulb and wet bulb temperatures were in error by about 5^{o}C in the main hold and 7^{o}C in the bottom holds; and
3. Modelled dry bulb temperatures were too high in the main hold, and always too low in the bottom holds.

Throughout the validation process, modification of sensitive parameters concluded that many inconsistencies do not lie at the administration level, but rather on a more fundamental level. Further data should be gathered to understand the issues with thermodynamic and microclimatic factors that are occurring within the crates. Little is known about these factors and further investigations will improve the validation process and the overall precision of LATSA.

With the onset of LATSA 2.0 in a new platform, as with any new software, issues emanating from programing issues and bugs were to occur and improvements to be identified. These Issues and improvements were identified through software use and consultation with industry. Refinement and enhancement of the web based LATSA software prevailed in the first instalment of LATSA 2.1.

Initial findings have been encouraging, however it is indicating that further studies into the environmental conditions being produced on-board during the freighting process need to be carried out. These include investigation into how crate permeability, size and positioning affects airflow and the conditions produced within the crates. Collection and analysis of carbon dioxide concentrations should be carried out to better understand its prevalence and its effects on animals during transportation. These studies will ensure a continual development of not only the LATSA predictions, but an overall enhancement in industry standards and an improvement in animal welfare during transportation.

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1. Background

The Livestock Air Transport Safety Assessment (LATSA) software program estimates the generation of key physiological data such as heat, moisture, and carbon dioxide from livestock during transportation by aircraft. These estimates are compared with ventilation capacity for a specific aircraft and an assessment of risks associated with animal physiology and hold environment is calculated. Risks include animals becoming stressed due to high dry bulb temperatures (ambient temperatures above 30^{o}C); high wet bulb temperatures (the temperature to which air will cool to when moisture is added to it, in this case evaporation losses from stock. Stress levels can be reached with wet bulb temperatures above 30^{o}C); high humidity's and increased carbon dioxide (CO_2) concentrations. Based on these risks assessments, adjustments can be made to stocking densities and/or the total number of animals to minimise the risk, refine carrying efficiencies and better improve animal welfare conditions during transport. The overall objective of the LATSA software is to ensure compliance with the Australian Standards for the Export of Livestock (ASEL).

Previous research project W.LIV.0269 reviewed, upgraded and enhanced the LATSA software to a web based platform which expanded the software's capabilities. This allowed for the extrapolation of all weights of cattle, sheep and goats to fill known consignment number and crate types with different species and average weights to ASEL standards. It also integrated physiological and thermodynamic calculations into the upgrade. These calculations modelled the predicted heat, moisture (and therefore humidity) and carbon dioxide that would be produced for a particular consignment. Modelled predictions were calculated with available aircraft ventilation data to determine if the aircraft had the basic capabilities to control heat, moisture and carbon dioxide production. The upgraded version, LATSA 2.0, provides a tool for exporters to assist with the planning for the safe transport of livestock by air to export standards.

The information used to predict heat, moisture and carbon dioxide production inside an aircraft hold is however based on theoretical data. Little real time data exists for the environments that are being modelled.

The purpose of this project was to validate the predictions of the LATSA 2.0 software through the acquisition of real time data. A further consequence of this purpose was the gaining of data that to date had been limited. Throughout the extent of the project, administration of the software was continuous, and as part of this project, refinements were made to the software outputs based on industry use and feedback resulting in the first instalments of LATSA 2.1.

2. Project Objectives

As part of the requirements for the successful completion of the project, the following four (4) objectives were set:

2.1 Objective One

Validate LATSA 2.0 predictions for heat and humidity for sheep, goats and cattle. Validation is to be achieved by the gathering of real time data during flight.

2.2 Objective Two

Where appropriate, use the results if objective one (1) to amend and improve the accuracy of the LATSA predictions.

2.3 Objective Three

Refine and enhance LATSA 2.0 software based on industry consultation.

2.4 Objective Four

Act as administrator of the LATSA software over a twelve (12) month period and provide recommendations and advice to exporters as required.

3. Methodology

3.1 Methods for Achieving Objective One

Using temperature and humidity loggers, data were collected during eight (8) shipments of livestock by air. A Boeing 747-400 Freighter was used for all eight (8) air shipments. These shipments are summarised below in Table 1. The flights ranged from five (5) to fifteen (15) hours with stopovers occurring at Singapore during longer duration flights 1 and 3. Data loggers were placed on both the main and lower holds (forward and aft) for flights 1, 2, 3, 6 and 8 and throughout the main (only) for flights 3, 5 and 7. Information and data from each flight can be viewed in Appendix A. Photographs associated with the freight process including crate alternatives, hold positioning and logger placement can be viewed in Appendix B.

Table 1: List of live air shipments used to obtain temperature and humidity data within the holds during flight.

Flight Details				Consignment Details		Total Space Used Per Hold		
Flight N^{o}	Departure	Destination	Aircraft	Species	Total N^{o}	Main	Bottom Forward	Bottom Aft
1	Sydney	Japan	747-400 F	Cattle	345	100%	100%	100%
2	Melbourne	Indonesia	747-400 F	Cattle	308	100%	100%	100%
3	Sydney	Malaysia	747-400 F	Cattle	452	100%	100%	100%
4	Melbourne	China	747-400 F	Sheep	1345	96%	100%	100%
5	Sydney	Malaysia	747-400 F	Goats	980	56%	0%	0%
6	Sydney	Indonesia	747-400 F	Cattle	200	100%	100%	100%
7	Sydney	Malaysia	747-400 F	Cattle / Goats	196 / 60	83%	0%	0%
8	Perth	Malaysia	747-400 F	Sheep / Goats	1480 / 1012	100%	100%	100%

Data loggers were placed onto the side of crates at alternating positions throughout the holds, opposite inlet and outlet vents. A typical layout of loggers is presented in Figure 1 below for a full consignment.

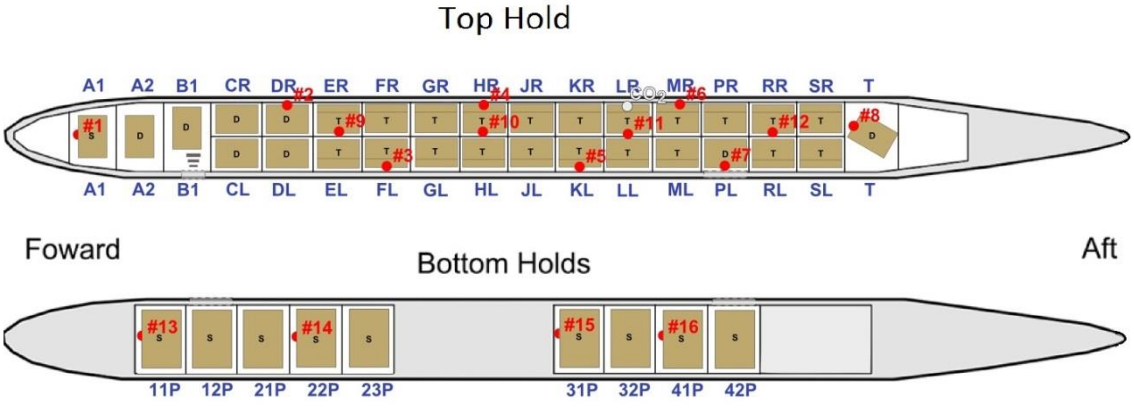


Figure 1: Crate layout for a Boeing 747-400 Freighter with a full consignment. Temperature and relative humidity loggers, along with a CO_2 sensor, were purposely positioned to obtain a spatial representation of the conditions occurring throughout the holds during flight.

The positioning of the loggers was undertaken with the view of obtaining a spatial representation of the microclimatic conditions throughout the entire holds of the aircraft. All data were collated and analysed for each flight, with the aim of comparing it with the LATSA model condition outputs for the same flight detail. Wet bulb temperatures were calculated post flight using the temperature and humidity real time data.

3.2 Methods for Achieving Objective Two

LATSA 2.0 was upgraded to incorporate several complex algorithms designed to model environmental conditions. Due to the complexity of the software, as well as being based on theoretical data, it was merited that real time data be obtained to assess the accuracy of the software.

Based on the goals explained in the aims of objective one, real time data were compared with data calculated by the LATSA software. Each flight was run in LATSA to compare modelled conditions with real time data conditions.

Of the many model parameters that can be modified at an administrative level within LATSA, three (3) were chosen due to their overall influence (and potential sensitivity) on the calculated dry and wet bulb temperatures, relative humidity and CO_2 production. They included:

- Excitement Factor;
- Evaporation Coefficient; and
- Ventilation Rates.

Flights were remodelled in LATSA with changes in model parameters following initial runs. Comparisons between initial and remodelled runs were undertaken to indicate whether these changes allowed alignment between the data sets. Modification of parameters and the validation process also helped to inadvertently identify any unknown limitations and/or omissions that may be associated with the LATSA software.

3.3 Methods for Achieving Objective Three

Upgrade and enhancement of the LATSA software to a web based platform, helped to expand the software's capabilities. With the onset of this new platform, as with any new software, issues were to originate and improvements to be identified. The technical administration of the LASTA software was inherited by Data Info Tech Pty Ltd. They provide software development and technical support, aiding EnviroAg in the identification and correction of any issues. Refinements and further enhancements were made to the software through industry use and feedback.

Three roll outs of improvements to LATSA have been performed. The first two consisting of requirements set out in objective three, the third was to cover an unaddressed problem in LATSA.

Debugging of difficult user problems was approached by cloning LATSA and running this copy in an environment that would allow 'stepping through the code' to identify problems and later testing solutions without impacting to LATSA. This was done on three occasions which ultimately led to the third roll out of fixes.

This test system allowed for the alteration of code without interfering with the official platform, maintaining the availability for use by the public throughout the refinement process.

Refinements to the platform were migrated through a managed migration process of the software. This process migrated upgrades to a test system in the form of a LATSA 2.0 copy.

Once that process of migration was tested and approved the migration and its updated code was integrated back into official LATSA 2.0 platform. On completion of all migrations, the platform was designated LATSA 2.1.

Identified issues and their solutions are described in detail in section 5.3 of the report.

3.4 Methods for Achieving Objective Four

EnviroAg were instructed to provide administration and enquiry assistance for LATSA 2.0 over a twelve (12) month period. With direction from DAFF and LiveCorp, enquiries were made to Data Info Tech or redirected from EnviroAg.

In cases, Assistance evolved in to software updates to either make processes more reliable or simpler to navigate.

Example of this are;

- Placement of dropdown boxes relevant to the order they are to be used without error
- Restricting available data in dropdown boxes to data that will not cause errors.
- Provision of administrative assistance contact details on the LATSA web based platform.
- Provision of an in-page tutorial for filling out consignment details.
- Alterations to reports to suit loading as suggested by users.

All contacts and their enquiries were to be dealt with at the time of enquiry or at a time suited to the contact. A log of all enquiries and LATSA issues and updates were continuously recorded.

5. Results

5.1 Results of Objective One

Collation and analysis of real time data provided four (4) major areas of interest.

5.1.1 Temperature and Humidity Trends

Optimal conditions for the transport of animals via aircraft can vary, and final hold conditions will be dependent on such variables as ground conditions pre-flight, temperature settings (controlled from the cockpit by the pilots), the total number and type of consignment (in this case cattle, sheep and goats) as well as their placement and positioning within the hold. Conditions viewed by the primary and export industries as 'optimal' range from a dry bulb temperature of 10°C to 20°C and humidity's of 40% to 80%. Conditions where animals become stressed will occur at temperatures (wet bulb and dry bulb) above 30°C and humidity's above 90%.

Throughout the flights, average dry bulb temperatures ranged from 16°C to 23°C in the main hold and 19°C to 25°C in the bottom holds. Overall, temperatures were on average 2°C warmer in the bottom holds. It can also be noted that a trend in increasing temperatures can be observed in the main hold, moving down the hold from nose to aft. This is mainly due to higher stocking densities occurring towards the aft of the hold due to availability of space.

Temperature was observed to be holding at constant levels in the main hold throughout the flight (see Figure 2 below). This would indicate that the on-board Environmental Control System (ECS) was maintaining an adequate turnover of air in the main hold by successfully removing the temperatures being generated by the livestock. This was not the case for the bottom holds during three flights, where visible trends of temperature increase could be observed (see Figure 3 below).

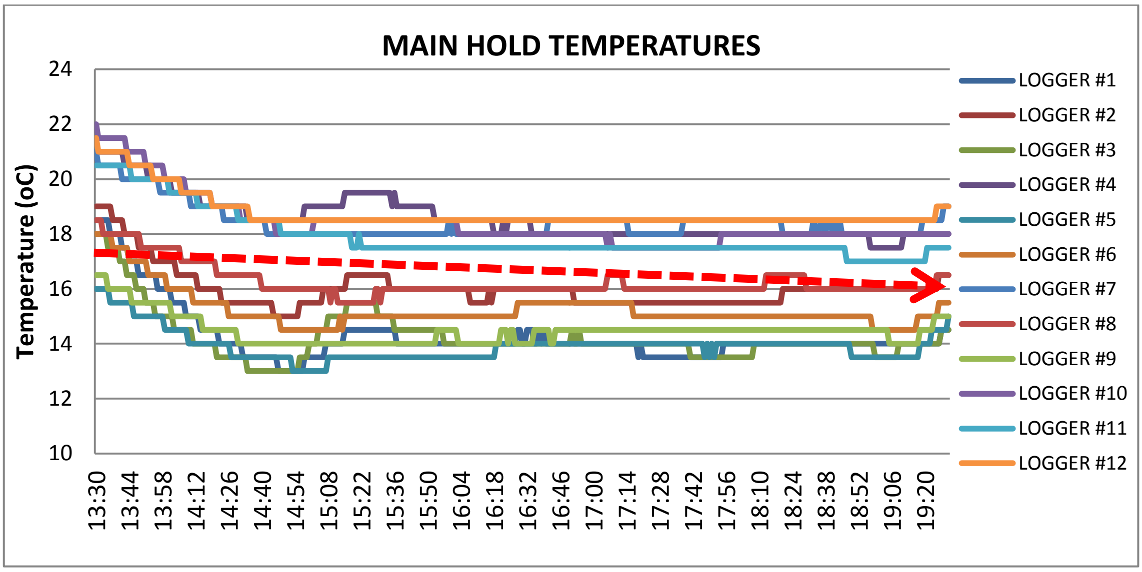


Figure 2: Main hold temperatures for flight number 6. Temperatures being held constant would indicate that the on-board ECS is operating sufficiently in the turning over of produced temperature and humidity.

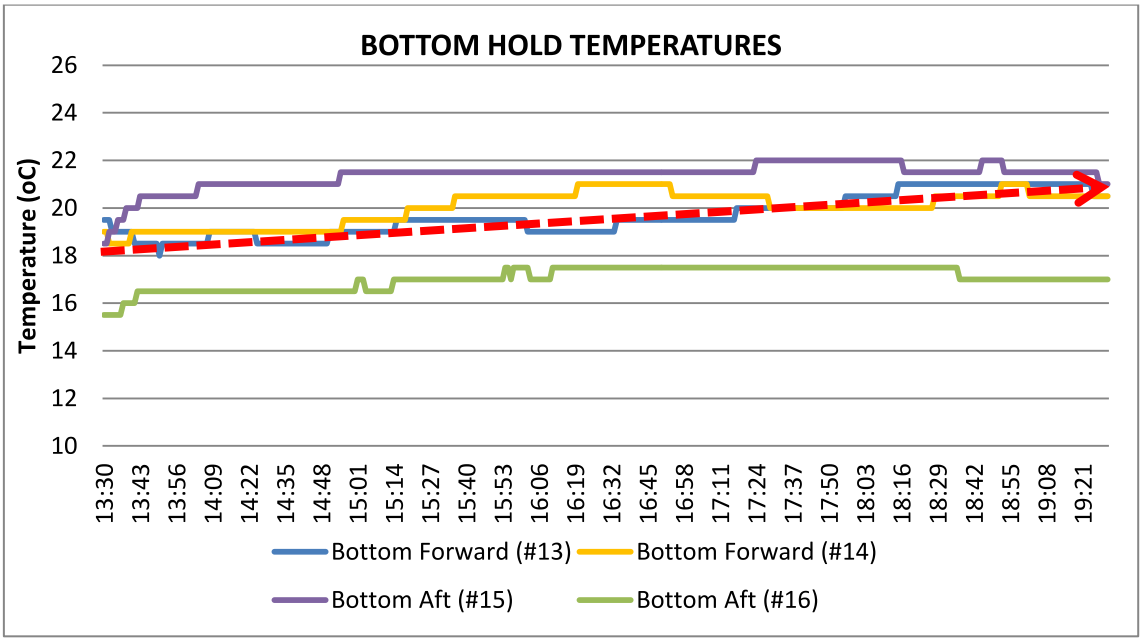


Figure 3: Bottom hold temperatures for flight number 6. Data shows a gradual increase in temperatures indicating an underperformance of the ECS.

Average relative humidity's across the main hold ranged from 53% to 77% and 33% to 72% in the bottom holds. Lower relative humidity's were experienced in the bottom holds due mainly to lower stocking densities.

Relative humidity's were held fairly constant throughout the flights. Humidity varied between species. Fluctuations within each flight were dependent on stocking densities, waste production and atmospheric conditions during loading.

A trend of slight increases in humidity throughout the holds can be observed. These increases are mainly due to moisture production through animal respiration and waste production (moisture loss from manure and urea). Figure 4 provides real time relative humidity's during flight number 3.

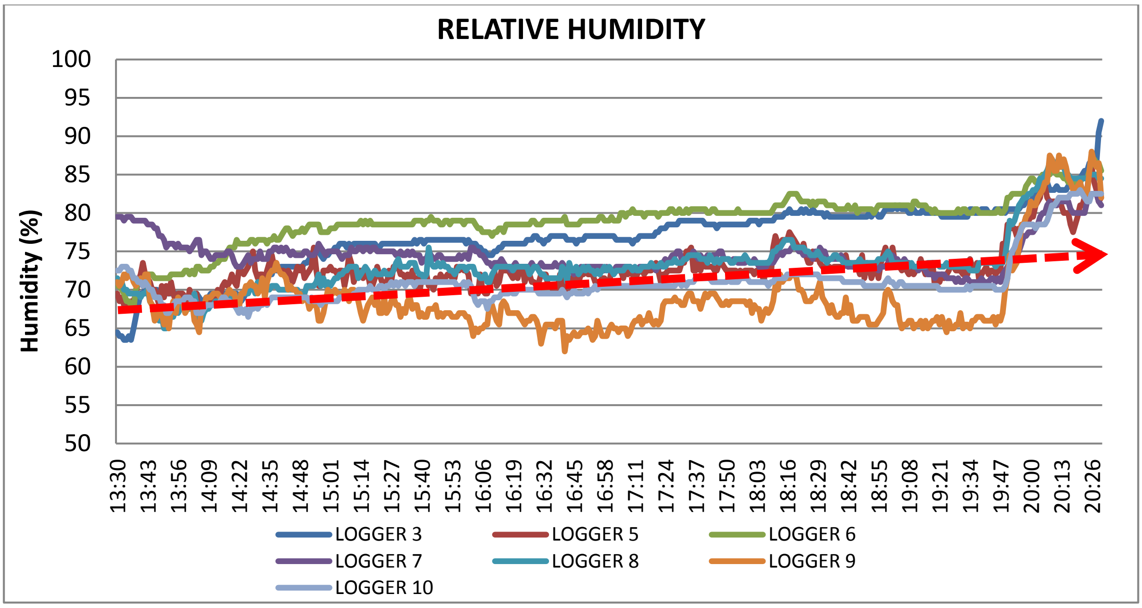


Figure 4: Relative humidity during flight number 3. A trend of slight increase in humidity can be observed.

5.1.2 Stopovers

Stopovers during flight were observed for two of the eight flights (flights number 1 and number 4). At both stopovers, the on-board ECS was turned off removing any turnover of air. Cargo doors were also opened exposing the consignment to external conditions. During stopover for flight number 4, dry bulb temperatures were observed to reach a maximum of 32.5°C, relative humidity 97.5% and a wet bulb temperature of 31.6°C, conditions that fall within the critical limits for animal discomfort. Stopover time was approximately one (1) hour (see Figure 5). Dry and wet bulb temperatures for flight number 1 reached a maximum of 26.5°C and 26.0°C respectively. Relative humidity achieved a maximum of 94.5%. Stopover time was approximately thirty (30) minutes, yielding lower maximums.

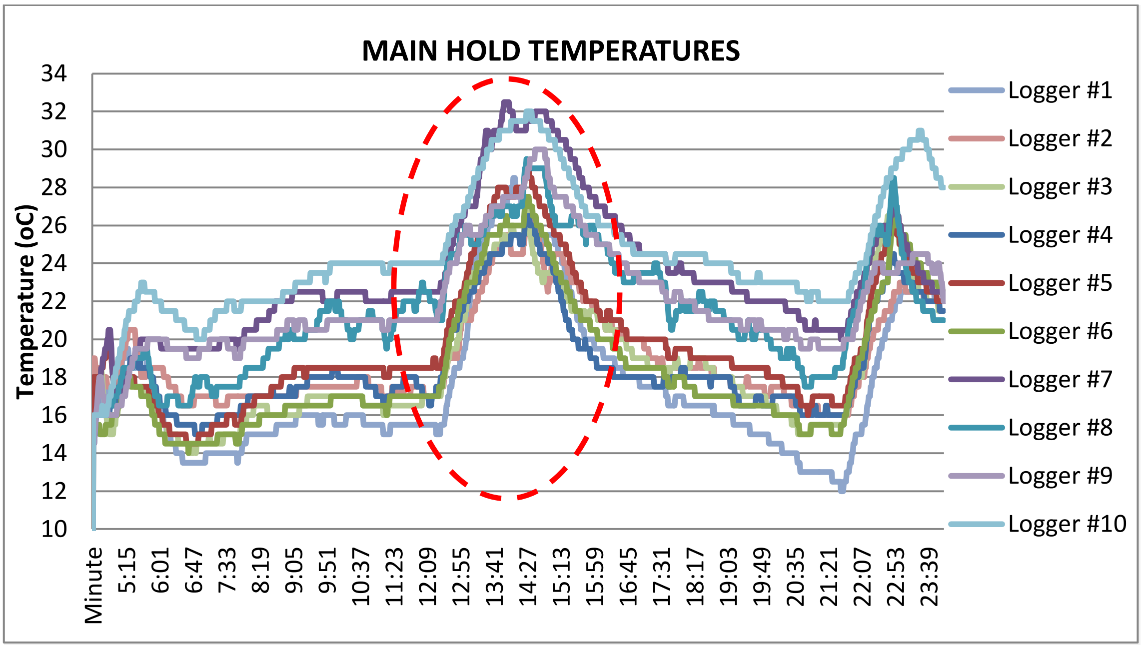


Figure 5: Main hold temperatures for flight number 4. The spike represents the stopover in Singapore where critical conditions were observed.

The stopovers also created a lag in the time taken for optimal conditions to be recovered in the aircraft inflight. 'Normal' air conditioned air quality conditions were not reached until arrival at the destination approximately six (6) hours later.

5.1.3 Crate Influences

Preliminary observations from collated data show dry bulb temperatures recorded internally of the crates to be 10°C to 13°C warmer than externally. Wet bulb temperatures were 12°C to 16°C warmer. These observations were recorded during flight number 2 when discussion arose as to the conditions occurring within the crate. The graph of main hold temperatures shown in Figure 6 below indicates the difference between internal and external conditions. Dry and wet bulb temperatures internally averaged 28.5°C and 27°C respectively while relative humidity averaged 84%. This was assumed to be due to a decrease in ventilation reaching the inside of the crates due to low crate permeability, and the added microclimates being produced.

Only one (1) data set exists for conditions being produced internally. Further data shall be obtained during project LIV.0289 to improve on the understanding of how crate permeability, size and positioning will affect air flow ventilation and the resulting internal conditions.

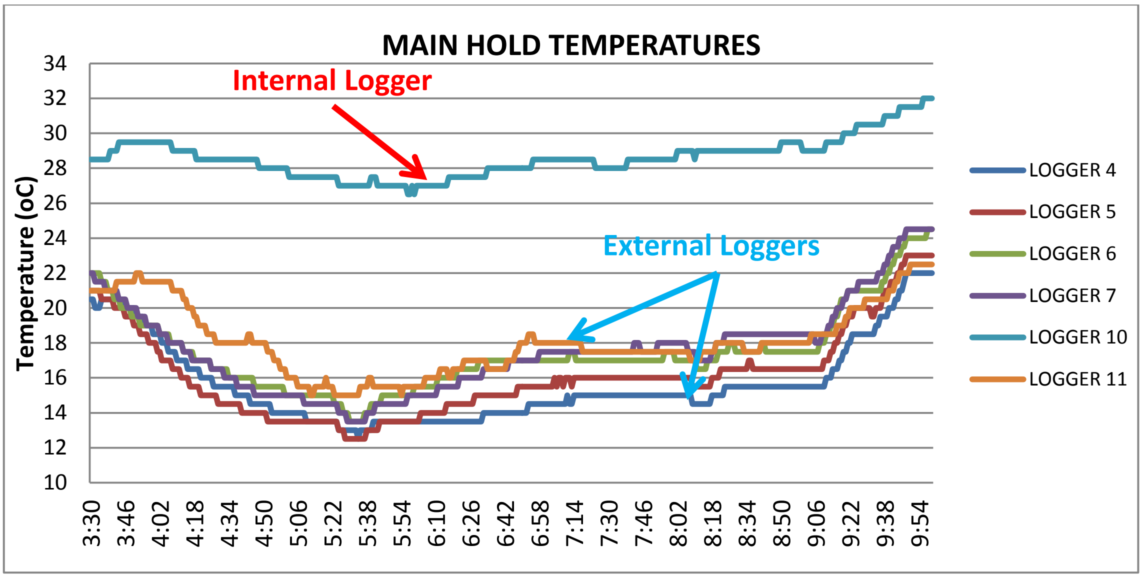


Figure 6: Graph of main hold temperatures showing the difference in temperatures being generated within the crate.

Data for conditions occurring between rows of crates were also obtained. Loggers were placed at positions of assumed 'hot spots', where air flow, and therefore heat flux, would be restricted. These were to occur between rows of crates, running down the hold centre parallel with the ventilation shafts.

At these identified hot spots, a marked increase in average dry and wet bulb temperatures of around 4.5oC and 3oC respectively were observed. The difference between temperatures during flight can be seen in Figure 7 below.

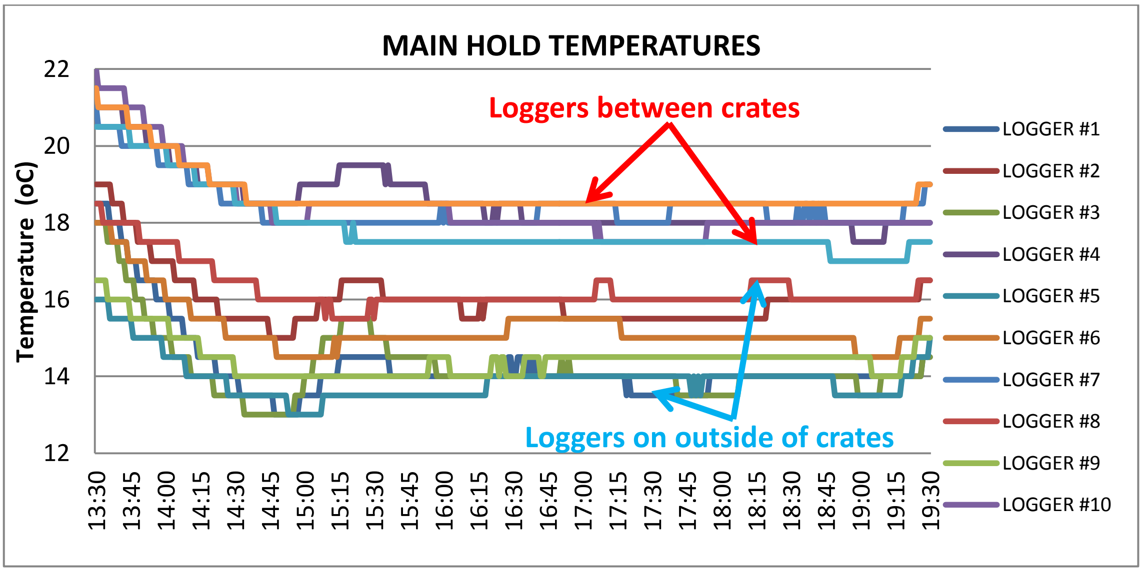


Figure 7: Temperature differentiation between identified hot spots during flight number 6.

5.1.4 Carbon Dioxide

Carbon dioxide (CO_2) measurements could not be recorded on all flights due to delays in airline approvals and limitations in CO_2 recording capabilities. Limitations included constraints in the recording of high concentrations, periodic data recording and power issues associated with travel time. As such, a modified sensor was designed and manufactured to overcome the limitations. Due to these issues, there was a delay in the application of the sensor during the procurement of flights.

Of the eight (8) flights, the final two (2) flights had the CO_2 sensor recording concentrations. Average CO_2 concentrations were observed around 1500 ppm (5x normal atmospheric concentrations). At no time did concentrations reach the upper limits for animal stress at 5000 ppm (16x normal atmospheric concentrations). It was observed that CO_2 gradually increased in concentrations on both flights (see graph of CO_2 concentrations for flight number 8 in Figure 8 below). This would indicate that the ECS is underperforming in the ventilation of CO_2 and most probable, other noxious gases.

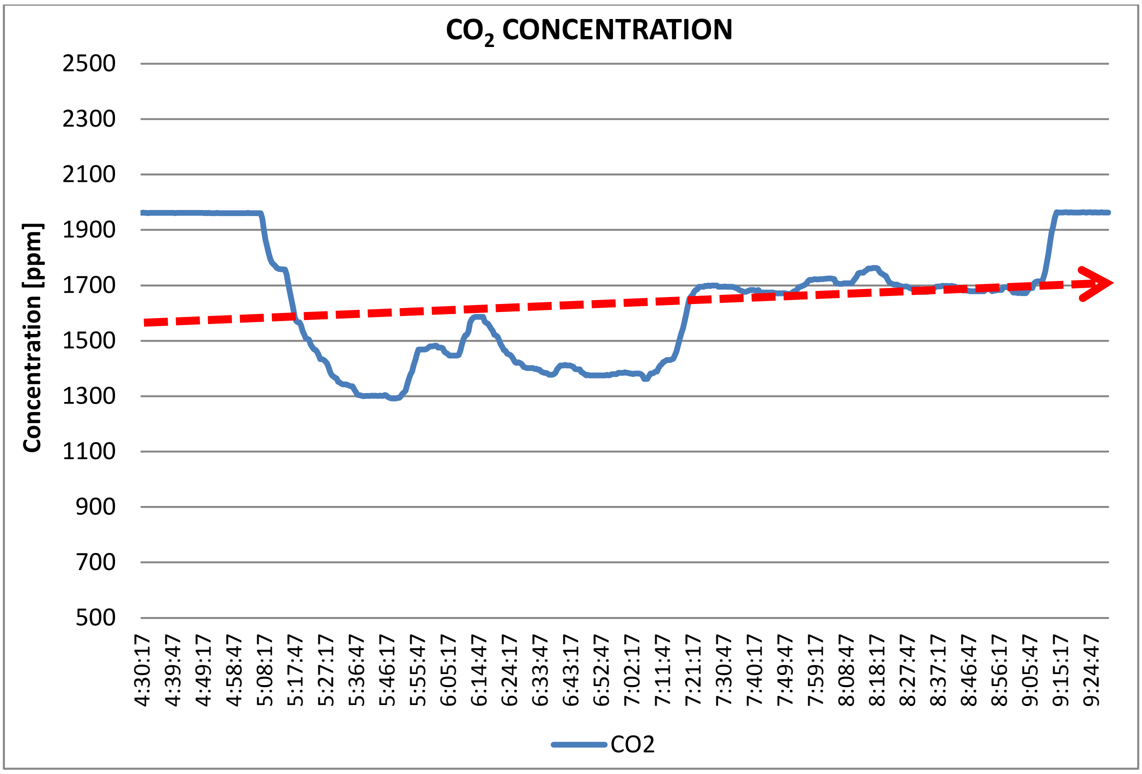


Figure 8: CO_2 concentrations for flight number 8. A gradual increase in concentrations can be observed indicating an underperformance of the ECS to successfully vent noxious gases.

Due to the limited data collected and the initial findings, it is recommended that more CO_2 data are recorded, and especially on longer duration flights, to better estimate gaseous conditions being generated during flight. We plan to include the CO_2 sensor on all future flights as part of W.LIV.0289 to complete this part of objective one.

5.2 Results of Objective Two

Each flight was run in LATSA to compare model conditions with real time data. The most notable variations when comparing model data with real time data include:

- Calculated relative humidity is too low within the LATSA model. Across all flights, the relative humidity was approximately 20% lower in the main hold and 29% lower in the bottom holds;
- Modelled dry bulb and wet bulb temperatures were in error by about 5^{o}C in the main hold and 7^{o}C in the bottom holds; and
- Modelled dry bulb temperatures are too high the main hold, and always too low in the bottom holds. This indicates that the model is over-predicting temperature in the main hold, and under-predicting them in the bottom holds.

The results of altering the three parameters explained in section 3.2 are detailed below. Tables showing the comparisons between modelled and real time data and the parameters associated with the validation process can be viewed in Appendix C.

5.2.1 Excitement Factor

The equations that model animal heat production and moisture losses assume that the animals are calm and are in a state of rest. Energy expenditure associated with increased animal activity is, however, going to affect the total heat produced. A need to compensate for aircraft movement or behavioural responses to any stress associated with handling and transport can cause increased levels of physical or metabolic activity and a resulting increase in total heat production and moisture losses through sweating.

The potential for an increase in total heat production due to situations described above has been accommodated into the LATSA software by the incorporation of a 'behaviour factor'. This factor, or coefficient, is designated the excitement factor, and it is applied to estimates of total heat production (ϕ_{tot}) and moisture losses. Given industry comments in regard to on-board animal handling practices, a value of 10% has been used (i.e. actual ϕ_{tot} = 1.1 x resting ϕ_{tot}) as a preliminary condition.

The excitement factor was changed from 10% (0.1) to 20% (0.2) in the validation process. The increase was due to lower temperatures being calculated in the bottom holds and the low relative humidity's being calculated throughout the entire aircraft. The increase in the excitement factor would model an increase in both metabolic heat production and moisture losses through sweating.

Little change was observed with increase in the excitement factor of 10% during comparisons. Dry bulb and wet bulb temperatures increased by only 1^{o}C throughout all holds. Relative humidity only increased by 4% in the main hold and 1% in the bottom holds.

A 10% increase in excitement factor creates little change. It was therefore concluded that any alteration of this parameter will do little to bring the data sets closer to alignment. Further, first hand observations as well as industry feedback reveal an overall calmness in animals during transport on these flights. In the studied cases it is not justifiable to increase the excitement factor any further as it was considered unrepresentative of real conditions.

5.2.2 Evaporation Coefficient (a_o)

Relative humidity is too low within the model calculations. Across all flights, the relative humidity was approximately 20% lower in the main hold and 29% lower in the bottom holds.

Evaporation from voided animal faeces and urine, collectively termed 'manure', can make a significant contribution to atmospheric moisture levels in a confined environment.

The evaporative rate of moisture will depend in part on the manure temperature and moisture content, as well as the ambient temperature, air speed and humidity or vapour pressure. As part of a large, integrated, animal housing model, the following equation provides the following relationship for estimating evaporative losses from manure:

$$\omega_{manure} = S_d \times a_0 \times R \times \Delta pw$$

Where:

ω_{manure} = evaporation from manure (kg/s);
S_d = manure surface area (m^2);
a_o = evaporation coefficient (7.12 – 26.6 kg/m^2.hr.Pa);
R = ventilation rate (m^3/s); and
Δpw = vapour pressure differential (Pa) between the air and evaporative surface.

The above equation is used in LATSA to model changes in humidity due to moisture losses to the hold atmosphere.

The evaporation coefficient (a_o) was identified as a potentially 'sensitive' parameter and was modified to alter calculated relative humidity's.

It was noted that the evaporative coefficient was initially set to a minimum of 7.12 kg/m2.hr.Pa when it came to readjusting the parameter. The evaporation coefficient was (re) set to its maximum of 26.6 kg/m2.hr.Pa. This was justified due to the large error in relative humidity being a calculated outcome and the fact that it would have no impact on dry bulb temperatures. It will however have an indirect, but small, impact on wet bulb temperatures.

Increasing the evaporative coefficient to its maximum made little change to the calculated relative humidity's. An increase of 7% was observed in the main hold, with a 2% and 1% increase in the bottom forward and aft holds respectively. Differences between main hold and bottom holds are due to higher numbers of animals occupying the main hold, and therefore an increased production of manure. Although changes in relative humidity did occur, they were not enough to lower the variance in humidity's to a confident range.

LATSA incorporates an equation for the direct loss of moisture from animals due to sweating. This equation is summarised below:

$$\omega_{animal} = \frac{\phi_{lat}}{\lambda} \times 3600$$

Where:

ω_{animal} = moisture loss (g/hr.animal);
Ø_{lat} = latent heat loss (W/animal); and
λ = latent heat of vaporisation at temperature t°C (kJ/kg)
= 2501 – 2.36 x t (kJ/kg)

It was identified that this equation may be under-predicting the humidity being produced during flight. This equation however is embedded in the software algorithm. Further changes in the computer code would have to be undertaken to indicate whether the equation is under-predicting.

Other reasons for the relative humidity being lower than the real time data may be due to the microclimatic conditions being produced within the crates. On one flight, conditions inside the crate revealed temperatures to be 10^{o}C to 13^{o}C higher. Stock inside the crates will be hotter than that indicated by the recorded out of crate data and thus their moisture loss will be higher. The model does not accommodate this temperature difference.

It is recommended in-crate data be pursued to better understand the conditions being produced during flight and to improve the predictions of LATSA.

5.2.3 Ventilation Rate

Due to variation in ventilation rates between different makes and models of aircraft, and the fact that rates can be automatically altered, constant values are implemented into the LATSA software. These values are sourced from manufactures specifications and are based upon effective ventilation of empty holds. Manufactures specifications for the ventilation rates of a Boeing 747-400 Freighter are described in Table 2 below:

Table 2: Set ventilation rates for a Boeing 747-400 Freighter. Values sourced from manufactures specifications.

Boeing 747-400 Freighter		
Hold	**Ventilation Rate [m3/hr]**	**Percentage**
Main	11 880	70%
Bottom Forward	2 988	17%
Bottom Aft	2 268	13%
Total	17 136	100%

Initial observations of the variance in data revealed a calculated dry bulb temperature being higher in the main hold, and always lower in the bottom holds. This would indicate that the model is over-predicting conditions in the main hold, and under-predicting in the bottom holds. Ventilation was redirected from the bottom holds to the main hold. Increasing the ventilation to the main holds would decrease overall temperatures. Reducing the ventilation rates to the bottom holds would increase temperatures. Through an iterative process, ventilation rates were altered, increasing the percentage of ventilation to the main hold.

The iterative process was concluded at a re-direction of 85% ventilation to the main hold. The final rates are summarised in Table 3 below:

Table 3: Iteration of ventilation rates.

Boeing 747-400 Freighter		
Hold	**Ventilation Rate [m^3/hr]**	**Percentage**
Main	14 566	85%
Bottom Forward	1 714	10%
Bottom Aft	856	5%
Total	17 136	100%

At the rates described in Table 3 above, temperature variances were bought to within an average of 2^{o}C throughout the holds. Redirecting the ventilation rates decreased the temperatures in the main hold by 5^{o}C, and increased temperatures in the forward and aft hold by 6^{o}C and 11^{o}C respectively.

Although findings suggest a modification of ventilation rates may be a solution, it is not feasible to implement. Ventilation rates very between makes and models of aircraft. Also, variations in data may not be necessarily due to a lack of, or an excess of ventilation. Crate size, permeability and positioning within the hold may also be hindering the effects that ventilation has upon hold conditions.

Further study into crate permeability and the microclimates that are being produced within the crates is recommended. This will be undertaken as part of W.LIV.0289. With more data obtained, a factor, or a “permeability” coefficient may be introduced alongside ventilation rates to alter the overall impact that air flow has on hold conditions. This factor would alternate with change in crate permeability, crate size and position. This factor would be incorporated into every model aircraft and hence, no ventilation rates would need to be modified. All rates would remain constant as per the manufacturer’s specifications.

5.3 Results of Objective Three

The following results describe the first instalment of LATSA 2.1 variation updates. It presents initial issues identified by MLA, EnviroAg and industry, their respective updates and how they are implemented within the web based software.

5.3.1 Requirement: 1

Heavily loaded consignments result in humidity levels above 100%. This leads to excessive wet bulb temperatures and very high Temperature Humidity Index (THI) values. Reassess relative humidity calculations so as not to exceed 100%.

Implementation

A 100% humidity correction was made when levels were beyond 100%. This correction is made before all other calculations use humidity.

5.3.2 Requirement: 2

Reduce the outcome of the Environmental Control System (ECS) results to an effective “one-liner” which determines the acceptability of the desired consignment of the aircraft.

Implementation

Within the consignment the status of the hold environment being displayed is a “one-liner” indicating the wet bulb result (see Figure 9 below).

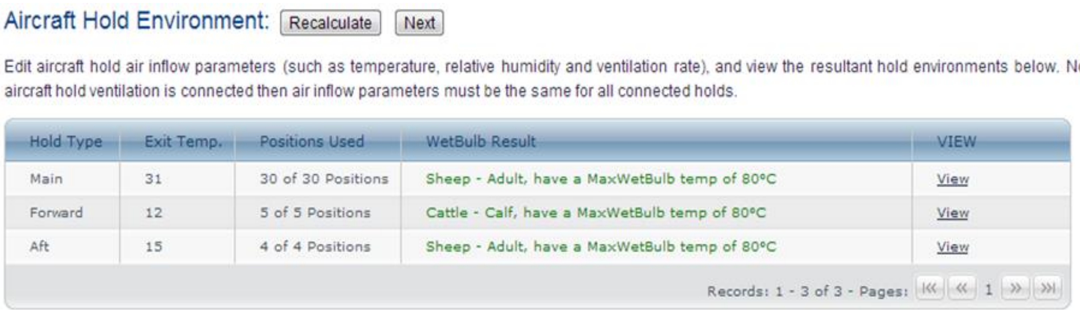


Figure 9: Within the consignment the status of the hold environment being displayed is the wet bulb result.

Further inspection of the hold environment will reveal other decision factors as in the example below following on from the main hold form above.

Figure 10: Hold environment, revealing other decision factors.

5.3.3 Requirement: 3

Include a manually entered field in the consignment header for "Agreed Max Payload" or similar.

Implementation

Agreed maximum payload has been created as a field of the consignment. When the calculated gross consignment weight is calculated it will display red if it is above the agreed maximum payload of the consignment.

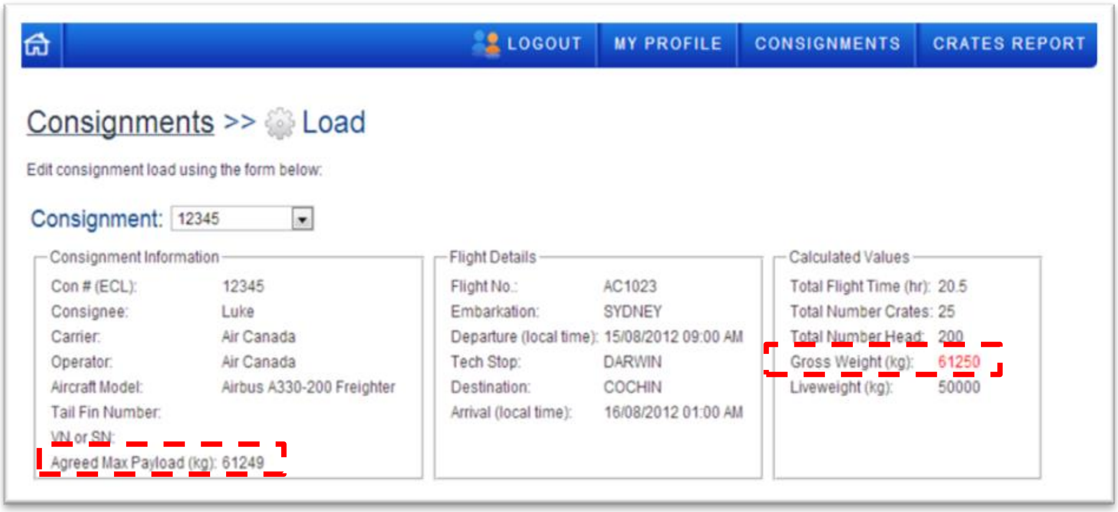


Figure 11: Maximum payload and gross weight fields.

5.3.4 Requirement: 4

Add a manually entered field in each load line for “Animal Height”. Use this field to check against the nominated (minimum) tier height in the specified crate. Provide a warning to select a more appropriate crate if: Animal Height > Minimum Tier Height - 3cm.

Implementation

A slight variation was made to this requirement. Rather than entering an animal height for each load line, an animal height property has been added to the animal, configured in the administration section.

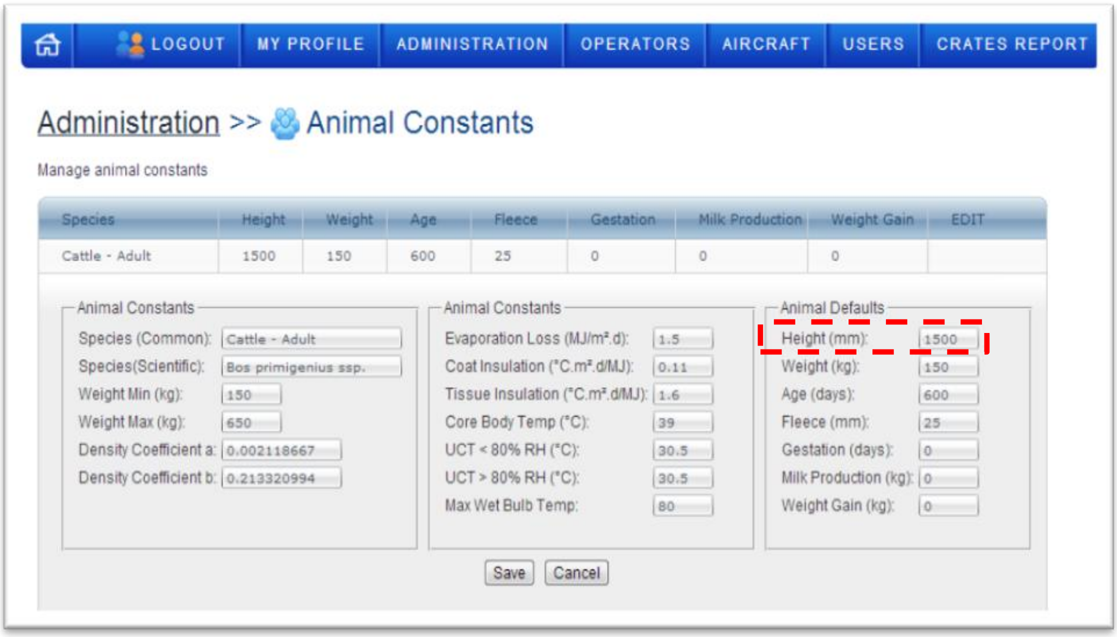


Figure 12: Within administration of animal height.

When creating a load line, and selecting an animal, the manufacturer and crate drop down boxes are limited to options that link to crate tiers that are above the height of the animal selected.

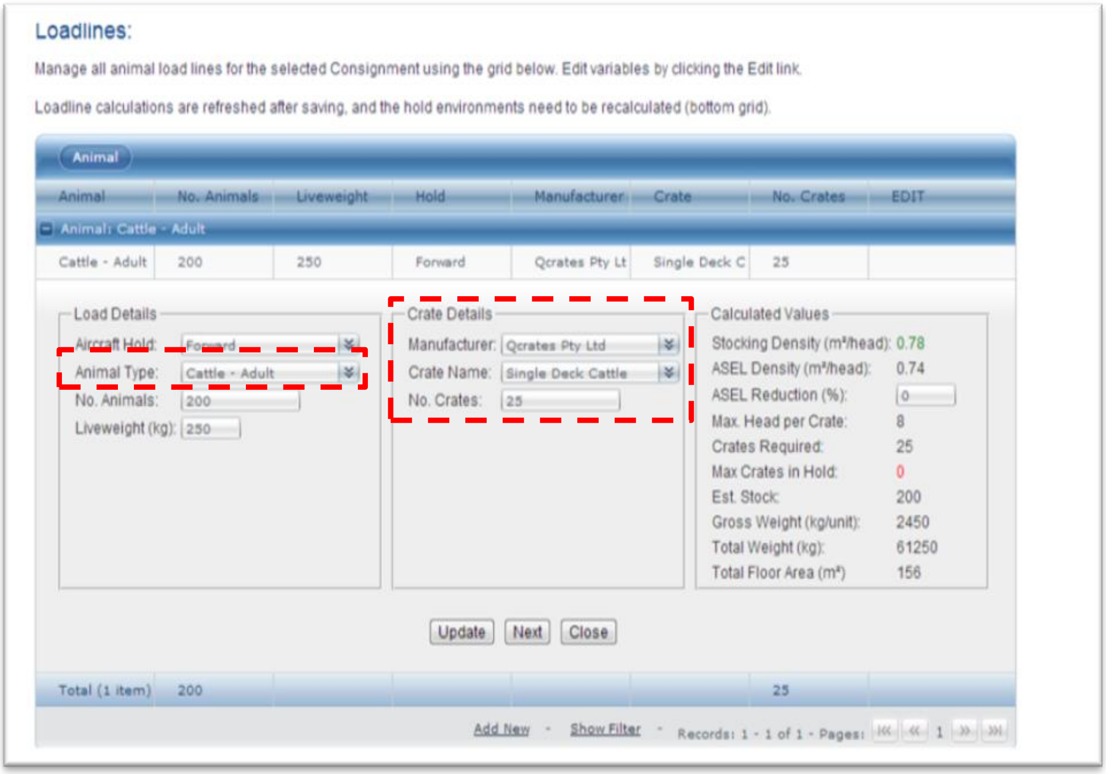


Figure 13: Available creates are determined by the height of the selected animal.

Note that initially the animal height values provided are of a software developer's best guess.

5.3.5 Requirement: 5

Consult with manufacturers so that all existing crate data is entered into LATSA and make it available for exporters use. Allow scrutiny of crate data (dimensions used in LATSA) by exporters through the "Exporters Report" or similar "Crate Report".

Implementation

There is a new tab in both the participant and administrator areas titles "Crates Report". This report details all the available crates for use in LATSA. It is ordered from the smallest tier height to the highest.

The "Crates Report" details are as follows:

- Manufacturer;
- Crate Name;
- Crate Weight (Tare);
- Crate Width;
- Crate Width;
- Crate Length;

- Crate Height;
- Crate Volume;
- Crate Area;
- Crate Tier's Height; and
- Individual Tier Heights.

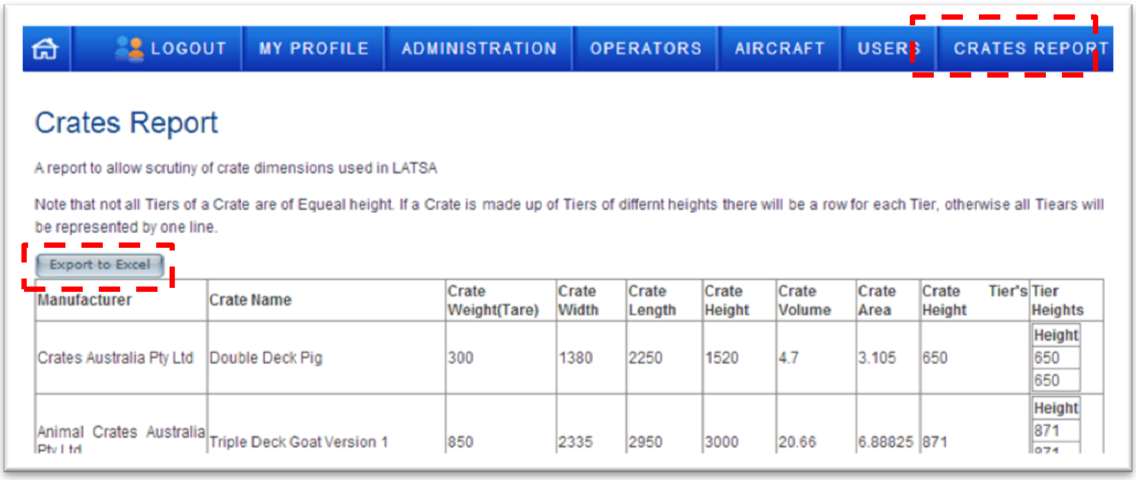


Figure 14: Creates report, exporting to excel.

The "Export to Excel" button will download an excel file with the following table format.

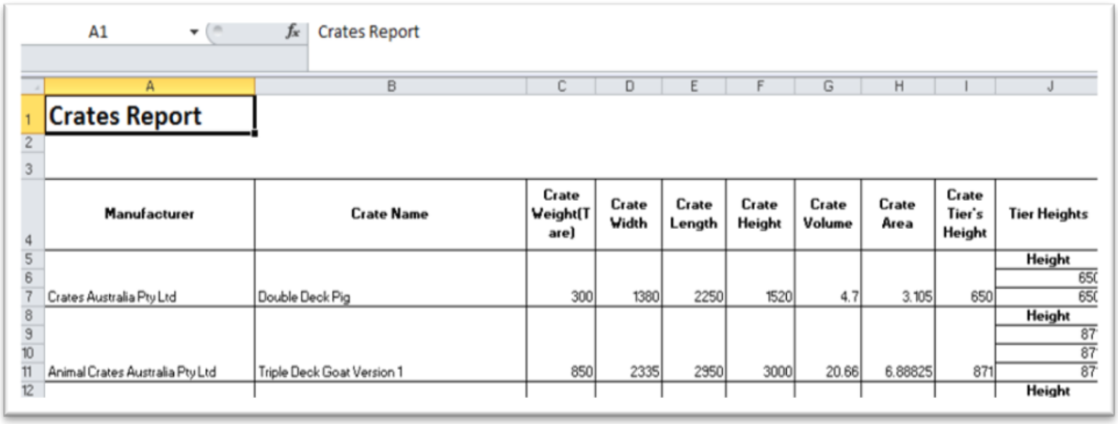


Figure 15: "Crates Report" in excel.

5.3.6 Requirement: 6

On advice from industry, provide and mechanism to incorporate animal height into the calculation of available floor space for upper decks of multi-tiered crates.

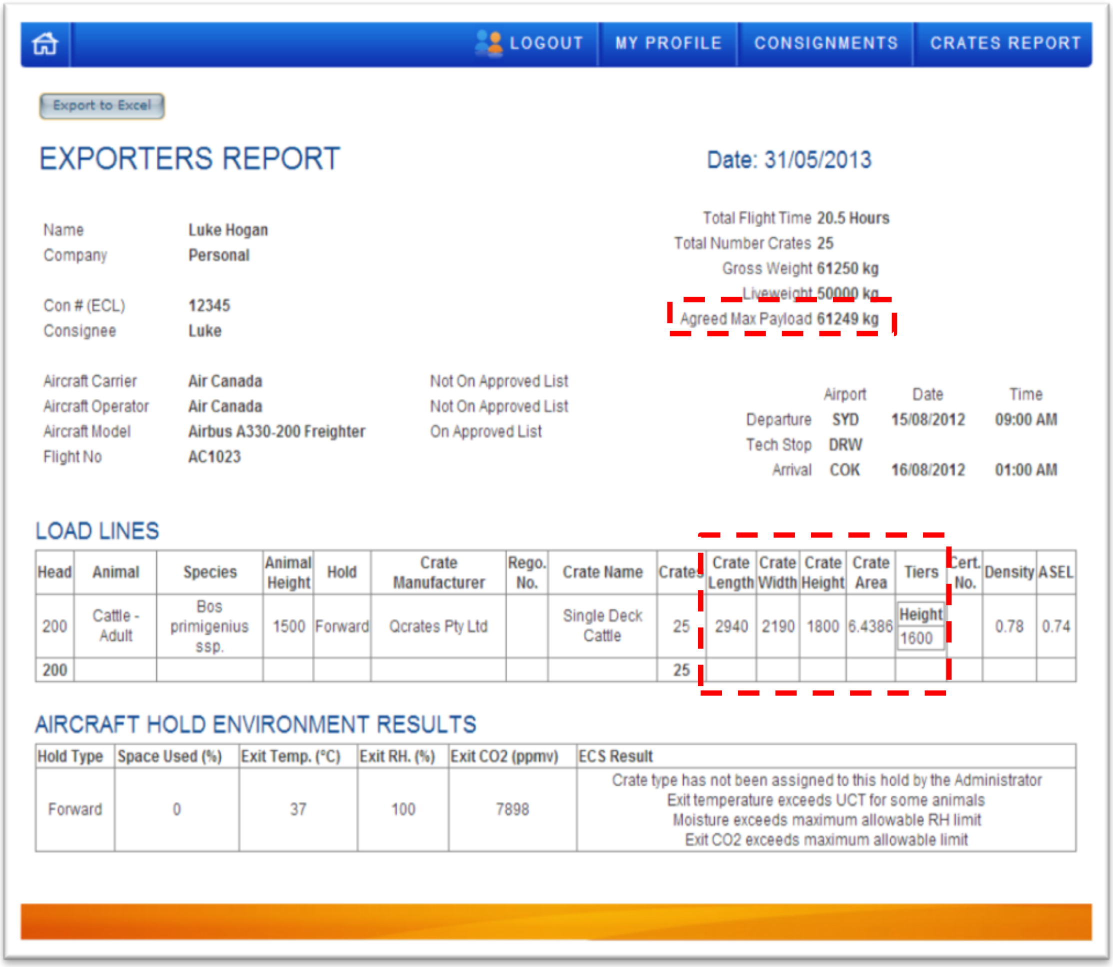
Implementation

With the update of animal height in requirement 4, this is successfully addressed. The available crates are based on the tiers of that crate and the selected animal, including the upper tier. The calculation of the available floor space within a crate is calculated over all tiers belonging to a specific crate.

5.3.7 Requirement: 7

Adjust the ground handling and "Exporters Report" to include a minimum of floor area of tiers, tier height, animal height and agreed payload.

Implementation


LOGOUT | MY PROFILE | CONSIGNMENTS | CRATES REPORT

Export to Excel

EXPORTERS REPORT

Date: 31/05/2013

Name	Luke Hogan
Company	Personal
Con # (ECL)	12345
Consignee	Luke

Total Flight Time 20.5 Hours
Total Number Crates 25
Gross Weight 61250 kg
Liveweight 50000 kg
Agreed Max Payload 61249 kg

Aircraft Carrier	Air Canada	Not On Approved List
Aircraft Operator	Air Canada	Not On Approved List
Aircraft Model	Airbus A330-200 Freighter	On Approved List
Flight No	AC1023	

	Airport	Date	Time
Departure	SYD	15/08/2012	09:00 AM
Tech Stop	DRW		
Arrival	COK	16/08/2012	01:00 AM

LOAD LINES

Head	Animal	Species	Animal Height	Hold	Crate Manufacturer	Rego. No.	Crate Name	Crates	Crate Length	Crate Width	Crate Height	Crate Area	Tiers	Cert. No.	Density	ASEL
200	Cattle - Adult	Bos primigenius ssp.	1500	Forward	Qcrates Pty Ltd		Single Deck Cattle	25	2940	2190	1800	6.4386	Height 1600		0.78	0.74
200								25								

AIRCRAFT HOLD ENVIRONMENT RESULTS

Hold Type	Space Used (%)	Exit Temp. (°C)	Exit RH. (%)	Exit CO2 (ppmv)	ECS Result
Forward	0	37	100	7898	Crate type has not been assigned to this hold by the Administrator Exit temperature exceeds UCT for some animals Moisture exceeds maximum allowable RH limit Exit CO2 exceeds maximum allowable limit

Figure 16: Additions to the exporters report.


Aircraft Ground Handling Checklist
LiveCorp Nov 2010
Carriage of Livestock by Aircraft

Figure 17: Aircraft Ground Handling Checklist Report header.

Additional sections (not entire report).

Figure 18: Aircraft Ground Handling Checklist Report consignment details.

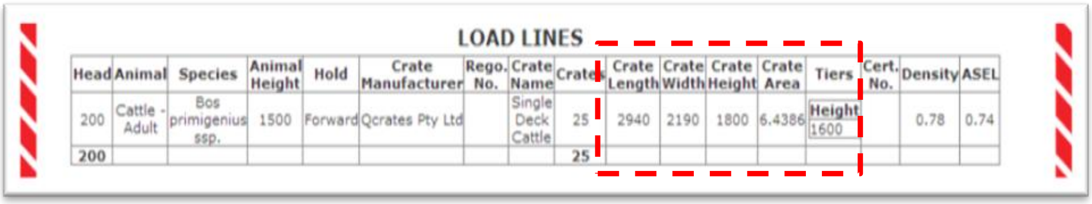


Figure 19: Aircraft Ground Handling Checklist Report load Line details.

5.3.8 Requirement: 8

Adjust the “space used” calculation to reflect the correct result for each hold. This is proposed to be based on “Positions Used” unless a more appropriate methodology is recommended following investigation and discussion with exporters.

Implementation

Each aircraft hold now has an additional parameter, “Positions”, to identify the number of positions that can be used in each hold.

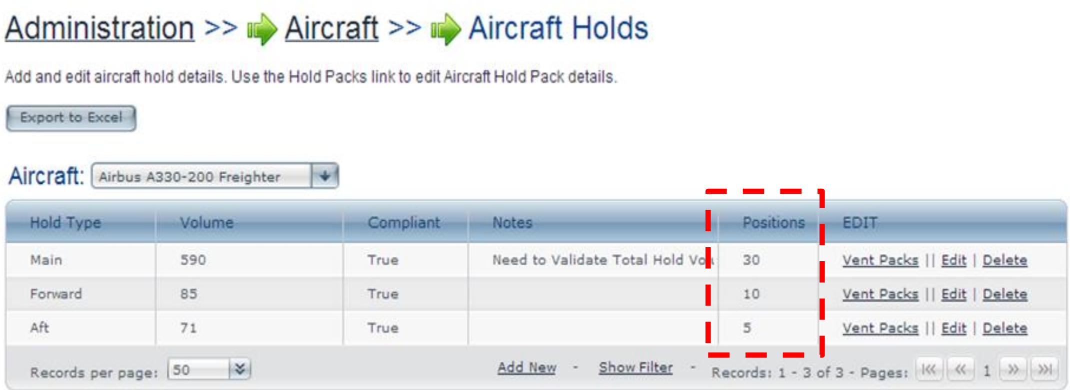


Figure 20: Aircraft hold positions.

Within the calculated hold environment of the consignment, the number of positions used is calculated from the crates used by the line items for that hold. This value and the number of available positions for the hold are displayed.

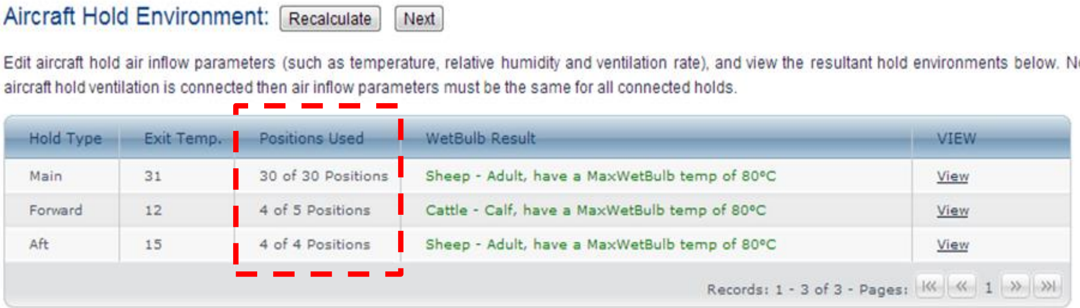


Figure 21: Positions used in an aircraft hold for a consignment.

5.3.9 Requirement: 9

Addition variations included the Introduction of a new field to the animal data table called "Maximum Wet Bulb Temperature" (Max Wet Bulb Temp (^{o}C)). Make this accessible via the "Animals Page" in the administration area.

Implementation

Maximum wet bulb temperature is administered within "Animal Constants".

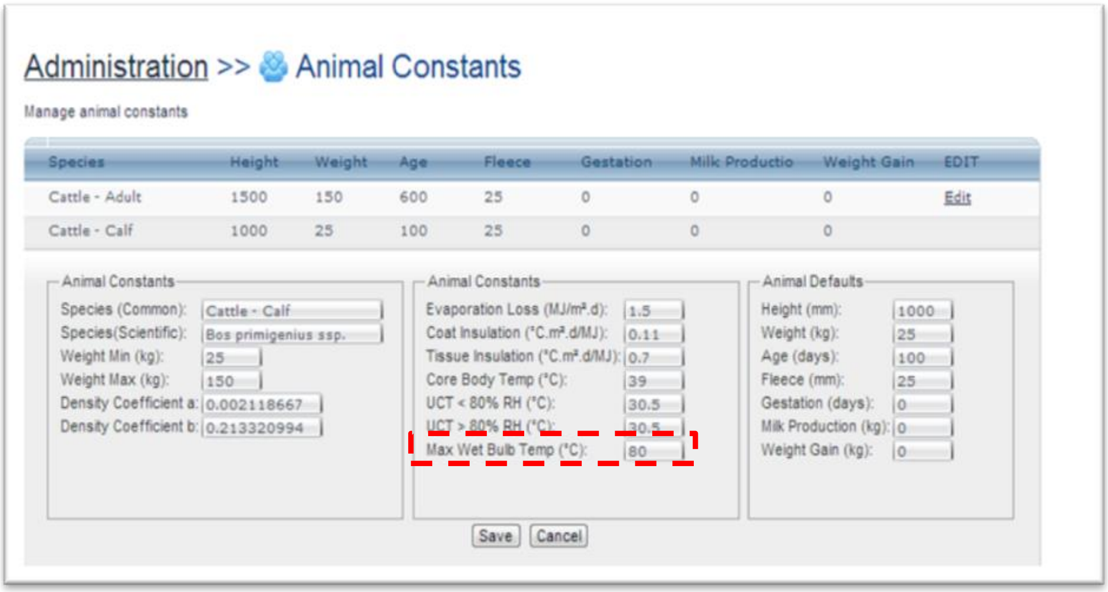


Figure 22: Administration of maximum wet bulb temperature.

On the participant side, the hold environment table displays the result, comparing that holds calculated temperature against all the animal types contained in that hold, comparing the animal with the lowest maximum bulb temperature. Green indicates a positive result and red indicates a negative result.

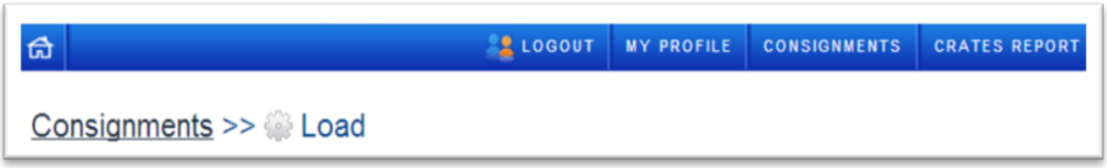


Figure 23: Consignment load page header.

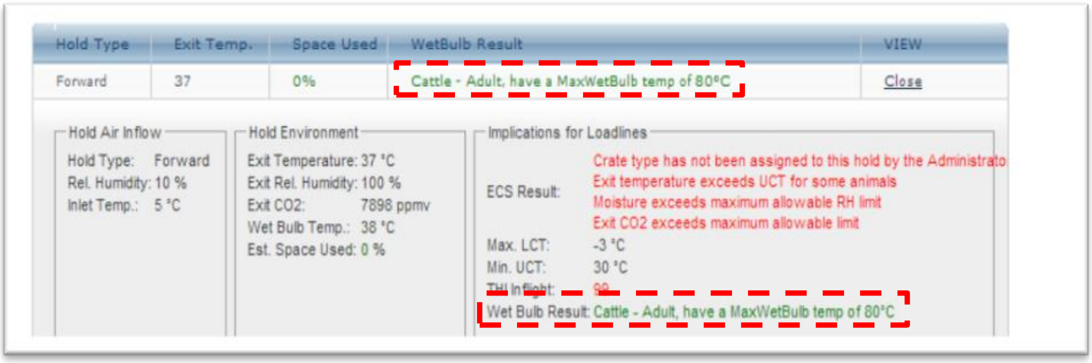


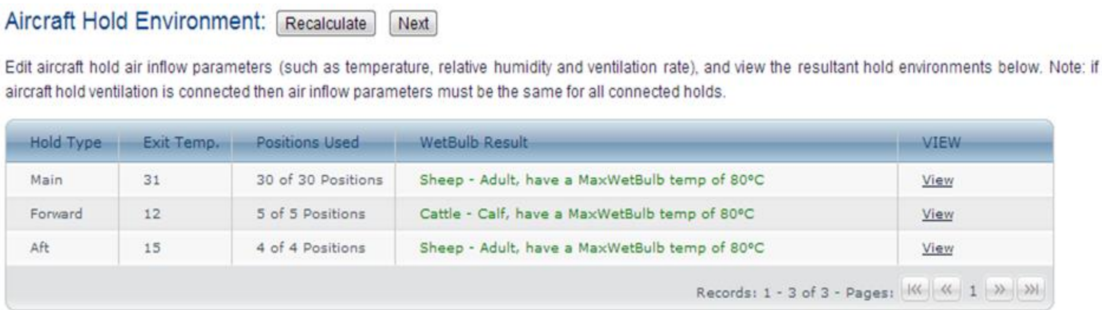
Figure 24: Consignment with wet bulb temperature message.

5.3.10 Requirement: 10

Adjust the consignment acceptance flag to use wet bulb temperature as the primary decision factor. Present all other data in a "View Detailed Results" page/section.

Implementation

Within the consignment the status of the hold environment being displayed is the wet bulb result.



Hold Type	Exit Temp.	Positions Used	WetBulb Result	VIEW
Main	31	30 of 30 Positions	Sheep - Adult, have a MaxWetBulb temp of 80°C	View
Forward	12	5 of 5 Positions	Cattle - Calf, have a MaxWetBulb temp of 80°C	View
Aft	15	4 of 4 Positions	Sheep - Adult, have a MaxWetBulb temp of 80°C	View

Figure 25: Consignments displaying wet bulb temperature prompt.

Further inspection of the hold environment will reveal other decision factors as in the example below following on from the main hold form above.

Figure 26: Expanded consignment view showing all consignment prompts.

5.3.11 Requirement: 11

Replace manually entered sections of the "Ground Handling Report" with data drawn from the LATSA database i.e. animal height and floor area.

Implementation

To accommodate a growing report, the "Ground Handling Report" now spans over two pages. The second page contains the consignment load information. The crate area of each load Line is calculated and a total is provided for the consignment. Animal height is also present in this report.

LOAD LINES

Head	Animal	Species	Animal Height	Hold	Crate Manufacturer	Rego. No.	Crate Name	Crates	Crate Length	Crate Width	Crate Height	Crate Area	Tiers	Cert. No.	Density	ASEL
145	Cattle - Calf	Bos primigenius ssp.	1000	Forward	CMTP Pty Ltd (VIC)	02	Double Deck Cattle	5	3000	2300	3000	6.9	Height 1400 1400		0.43	0.29
124	Sheep - Adult	Ovis aries	850	Aft	Animal Crates Australia Pty Ltd	01	Single Deck Cattle Series Version B - 1480	4	2950	2335	1605	6.88825	Height 1480	01/1480	0.2	0.2
915	Sheep - Adult	Ovis aries	850	Main	Animal Crates Australia Pty Ltd	01	Double Deck Cattle Version 1	15	3000	2335	3000	7.005	Height 1400 1362		0.21	0.21
1425	Sheep - Adult	Ovis aries	850	Main	Animal Crates Australia Pty Ltd	01	Triple Deck Goat Version 1	15	2950	2335	3000	6.88825	Height 871 871 871		0.2	0.2
2609								**39**				**27.6815**				

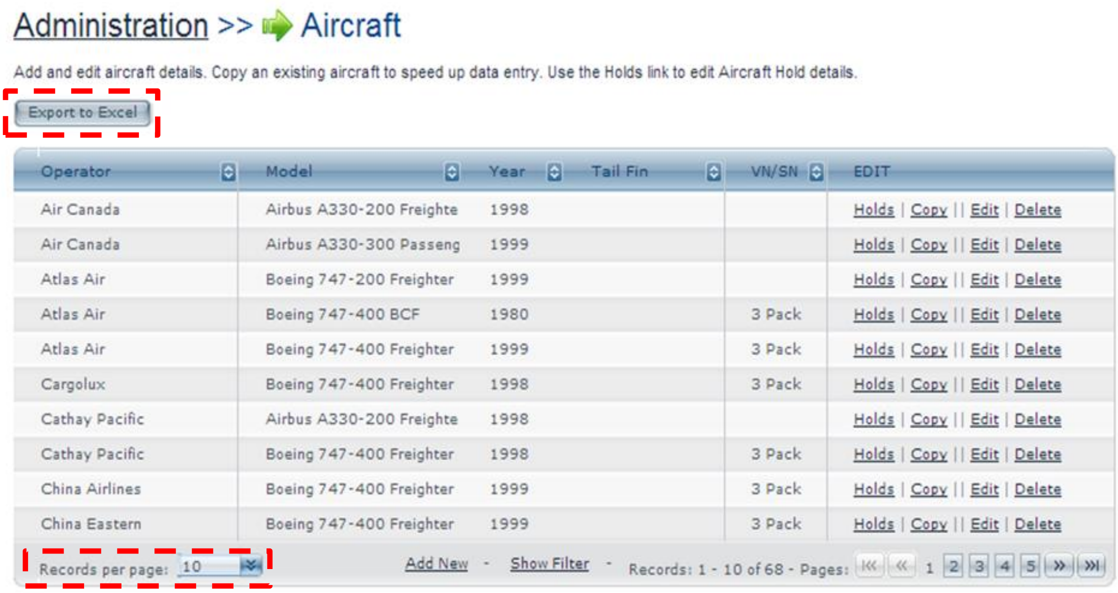
Figure 27: Ground Handling Report with additional fields.

5.3.12 Requirement: 12

Include the ability to export all administrative tables to excel.

Implementation

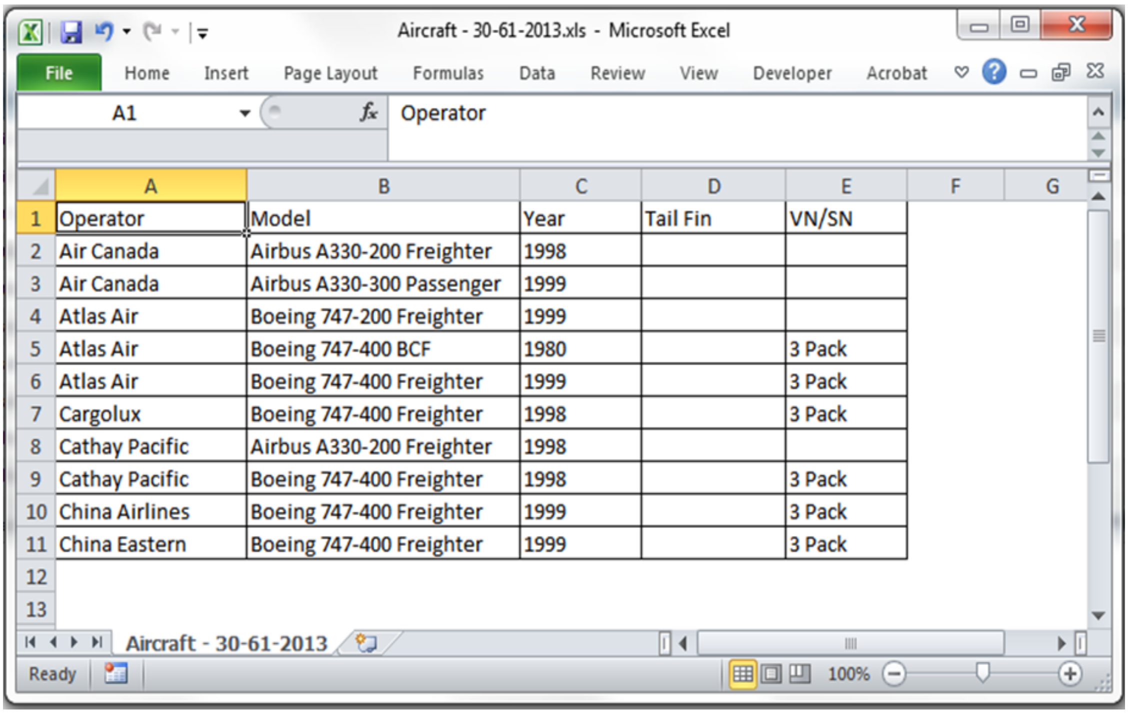
“Export to Excel” buttons have been placed above every administration table. Exporting to excel will transfer the visible information of the table. This required the addition of the “Records per Page” option being provided at the bottom of each table to allow the presentation of all records for that table for exporting.



Operator	Model	Year	Tail Fin	VN/SN	EDIT
Air Canada	Airbus A330-200 Freighte	1998			Holds | Copy || Edit | Delete
Air Canada	Airbus A330-300 Passeng	1999			Holds | Copy || Edit | Delete
Atlas Air	Boeing 747-200 Freighter	1999			Holds | Copy || Edit | Delete
Atlas Air	Boeing 747-400 BCF	1980		3 Pack	Holds | Copy || Edit | Delete
Atlas Air	Boeing 747-400 Freighter	1999		3 Pack	Holds | Copy || Edit | Delete
Cargolux	Boeing 747-400 Freighter	1998		3 Pack	Holds | Copy || Edit | Delete
Cathay Pacific	Airbus A330-200 Freighte	1998			Holds | Copy || Edit | Delete
Cathay Pacific	Boeing 747-400 Freighter	1998		3 Pack	Holds | Copy || Edit | Delete
China Airlines	Boeing 747-400 Freighter	1999		3 Pack	Holds | Copy || Edit | Delete
China Eastern	Boeing 747-400 Freighter	1999		3 Pack	Holds | Copy || Edit | Delete

Figure 28: Grid options for exporting to Excel.

Below is the above table exported to MS excel. The export will display columns hidden by the tables ‘preview’ of data. More records could have been exported by increasing the “Records per Page” value of the table.



Operator	Model	Year	Tail Fin	VN/SN
Air Canada	Airbus A330-200 Freighter	1998		
Air Canada	Airbus A330-300 Passenger	1999		
Atlas Air	Boeing 747-200 Freighter	1999		
Atlas Air	Boeing 747-400 BCF	1980		3 Pack
Atlas Air	Boeing 747-400 Freighter	1999		3 Pack
Cargolux	Boeing 747-400 Freighter	1998		3 Pack
Cathay Pacific	Airbus A330-200 Freighter	1998		
Cathay Pacific	Boeing 747-400 Freighter	1998		3 Pack
China Airlines	Boeing 747-400 Freighter	1999		3 Pack
China Eastern	Boeing 747-400 Freighter	1999		3 Pack

Figure 29: Example administration table in excel.

5.3.13 Requirement: 13

Include the ability for Users to export single consignments to excel.

Implementation

There is now a button on the exporter's report which will export all the consignment information.

Figure 30: Exporters report with 'Export to Excel' button.

In excel;

EXPORTERS REPORT

Name	Luke Hogan		Total Flight Time	12.5 Hours		
Company	Personal		Total Number			39
			Gross Weight	112858 kg		
Con # (ECL)	1234		Liveweight	85753 kg		
Consignee	AQIS		Agreed Max	112858 kg		
Aircraft Carrier	Qantas	On Approved				
Aircraft	Atlas Air	On Approved		Airport	Date	Time
Aircraft Model	Boeing 747-400	On Approved	Departure	MEL	13/09/2011	#####
Flight No	QFXXXXX		Tech Stop	DRW		
			Arrival	TSN	14/09/2011	#####

LOAD LINES

Head	Animal	Species	Animal Height	Hold	Crate Manufacturer	Rego.	Crate Name	Crat	Crate	Crate	Crate	Crate	Tiers	Cert.	Densi	AS
145	Sheep - Adult	Ovis aries	850	Forward	Animal Crates Australia Pty Ltd	1	Single Deck Cattle Series Version B - 1480	5	2950	2335	1605	6.88825	Heig 1480	01/1480	0.21	0.2
145	Sheep - Adult	Ovis aries	850	Forward	Animal Crates Australia Pty Ltd	1	Single Deck Cattle Series Version B - 1480	5	2950	2335	1605	6.88825	Heig 1480	01/1480	0.21	0.2
124	Sheep - Adult	Ovis aries	850	Aft	Animal Crates Australia Pty Ltd	1	Single Deck Cattle Series Version B - 1480	4	2950	2335	1605	6.88825	Heig 1480	01/1480	0.2	0.2
915	Sheep - Adult	Ovis aries	850	Main	Animal Crates Australia Pty Ltd	1	Double Deck Cattle Version 1	15	3000	2335	3000	7.005	Heig 1400 1362		0.21	0.2
1425	Sheep - Adult	Ovis aries	850	Main	Animal Crates Australia Pty Ltd	1	Triple Deck Goat Version 1	15	2950	2335	3000	6.88825	Heig 871 871 871		0.2	0.2
2754								**44**								

AIRCRAFT HOLD ENVIRONMENT RESULTS

Hold Type	Space Used (%)	Exit Temp.	Exit RH. (%)	Exit CO2	ECS Result
Main	130	31	98	5136	Exit CO2 exceeds maximum allowable limit
Forward	100	14	20	947	Acceptable ventilation conditions in this hold
Aft	100	15	20	984	Acceptable ventilation conditions in this hold

Figure 31: Exporters report in excel.

6. Discussion

EnviroAg Australia has been working with industry to develop and improve the live export business. It has engaged and is actively working in partnership with exporters to gain scientific data and industry knowledge to help improve the overall understanding of the live air export process.

The model itself is a complicated piece of software. Configuration, placement and size of crates, animal type, pre-husbandry handling, consignment densities, aircraft holds and ventilation all affect the microclimatic conditions occurring within the aircraft. Initial findings have been encouraging. The data collected to date indicates that further studies into the environmental conditions being produced on-board during the freighting process need to be carried out. This will ensure a continual development of not only the LATSA predictions, but an overall enhancement in industry standards and an improvement in animal welfare during transportation.

Most of the updates to LATSA have been implemented. Apart from the 100% relative humidity limitation implementation, no other fundamental changes were made to the core calculation function of LATSA.

The part of the model that surrounds crate manufactures, where crates can be placed in an aircraft and with what animal, is burdensome at an administrative level. This has a follow on affect, hindering the efficiency of LATSA by keeping the software up to date with all possible new configurations. Permutations between these objects needs to be pre-defined and currently is not effective, thus causing inconsistencies in the user's experience.

The LATSA software core algorithms predict an average temperature and humidity that would exist at a particular point during the flight. This limits the availability of known conditions that could occur. However if LATSA was redesigned to not just predict set conditions at a particular point in time, but identify the range at which conditions may fluctuate, a better idea of what may occur on-board can be identified. Knowing the boundary conditions that are produced may help the exporter to identify critical conditions thus reducing the risks associated with transport. Evolution of this predictive method could allow determination of the range at which ventilation needs to be achieved. Having a known ventilation rate would ensure that optimal air flow is continually achieved, reducing the risk of critical conditions being met during flight.

With completion of project LIV.0283, it is recommended that:

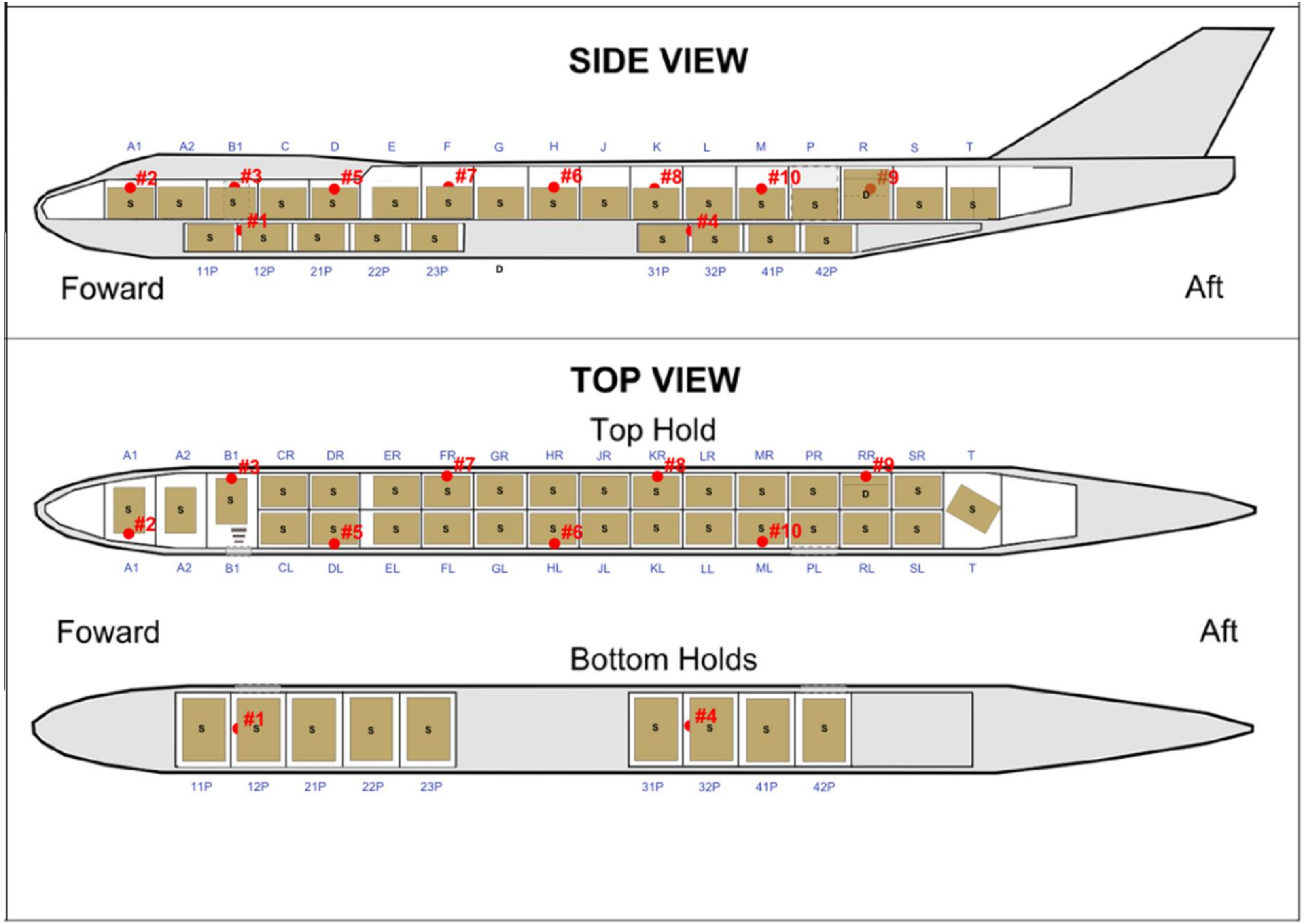
- Data for inside crates be collected to better understand the microclimates being produced. This will improve the understanding of how crate permeability, size and positioning will affect air flow. The overall goal would be to improve animal welfare conditions and understanding, as well as providing data for the calibration of the LATSA software;
- Obtain more inflight CO_2 data to better identify the gaseous conditions being produced during flight;
- To investigate the equations and algorithm associated with relative humidity, and to identify and modify any parameters associated with them;
- The removal of the "preconfigured" nature of LATSA to allow for the user to more freely choose any combination of crate-animal hold detail; and
- Investigate the possibility for the redesign of LATSA, to find boundary conditions that indicate the environmental range and the optimal ventilation rate for the safe transport of animals.

7. Appendices

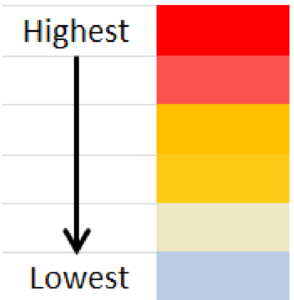
Appendix A. Flight information and Real Time Data

Appendix A1. Flight Number 1 Information:

Flight Number 1	
Flight Info	
Date	12/03/2013
Type of Aircraft	Boeing 747-400 Freighter
Departure	Sydney, Australia
Destination	Kita Kyushu, Japan
Departure Time	11:00pm [2300] (AEST)
Arrival Time	7:30am [0730] (AEST) / 5:30am [0530] (local time)
Flight Time	8.5hrs
Stop Over	Singapore
Set Temperatures	Main = N/A
	Bottom Forward = N/A
	Bottom Aft = N/A
Holds Utilised	Main = 100%
	Bottom Forward = 100%
	Bottom Aft = 100%
Period of Loading	08:30pm - 10:10pm
Aircraft Doors Closed	10:30pm (cargo doors)
Consignment Info	
Total Number of Animals	345
Type of Animal	Cattle
Average Age of Animals	18 months
Average Live Weight	280 kg
Crate Info	
Total Number of Crates	39
Single Tiered	38
Double Tiered	1
Triple Tiered	0
Average Number of Head per Tier	8
Logging Info	
Number of Loggers Used	10
Top Hold Loggers	8 [#2, #3, #5, #6, #7, #8, #9, #10]
Bottom Forward Loggers	1 [#1]
Bottom Aft Loggers	1 [#4]
CO_2 Logger	N/A


SIDE VIEW
A1 A2 B1 C D E F G H J K L M P R S T
#2 #3 #5 #7 #6 #8 #10 #9
#1 #4
11P 12P 21P 22P 23P D 31P 32P 41P 42P
Foward
Aft
TOP VIEW
Top Hold
A1 A2 B1 CR DR ER FR GR HR JR KR LR MR PR RR SR T
A1 A2 B1 CL DL EL FL GL HL JL KL LL ML PL RL SL T
Foward
Aft
Bottom Holds
11P 12P 21P 22P 23P 31P 32P 41P 42P

Max, Min and Averages per Logger (Main Hold)									
		LOGGER #2	LOGGER #3	LOGGER #5	LOGGER #6	LOGGER #7	LOGGER #8	LOGGER #9	LOGGER #10
Temperature [°C]	MAX	26.50	26.00	25.50	26.50	26.00	26.50	24.50	25.50
	MIN	20.50	20.50	19.00	19.50	19.50	20.50	16.50	18.50
	Average	23.30	22.87	21.90	22.31	22.21	22.85	19.09	21.37
Relative Humidity [%]	MAX	83.5	84.5	89.0	89.0	91.0	88.5	94.5	85.5
	MIN	64.5	69.0	72.5	73.0	73.0	73.5	78.5	72.0
	Average	72.0	73.9	76.7	77.6	78.8	77.8	83.4	77.3
Dew Point [°C]	MAX	23.5	23.2	23.1	24.4	24.3	23.9	23.4	22.8
	MIN	13.6	14.6	13.9	14.5	14.7	15.6	12.8	13.7
	Average	18.0	18.0	17.6	18.2	18.3	18.8	16.2	17.2
Wet Bulb [°C]	MAX	24.9	24.6	24.5	25.8	25.7	25.3	24.8	24.2
	MIN	15.0	16.1	15.4	16.0	16.2	17.1	14.3	15.1
	Average	19.4	19.5	19.1	19.7	19.8	20.3	17.7	18.7

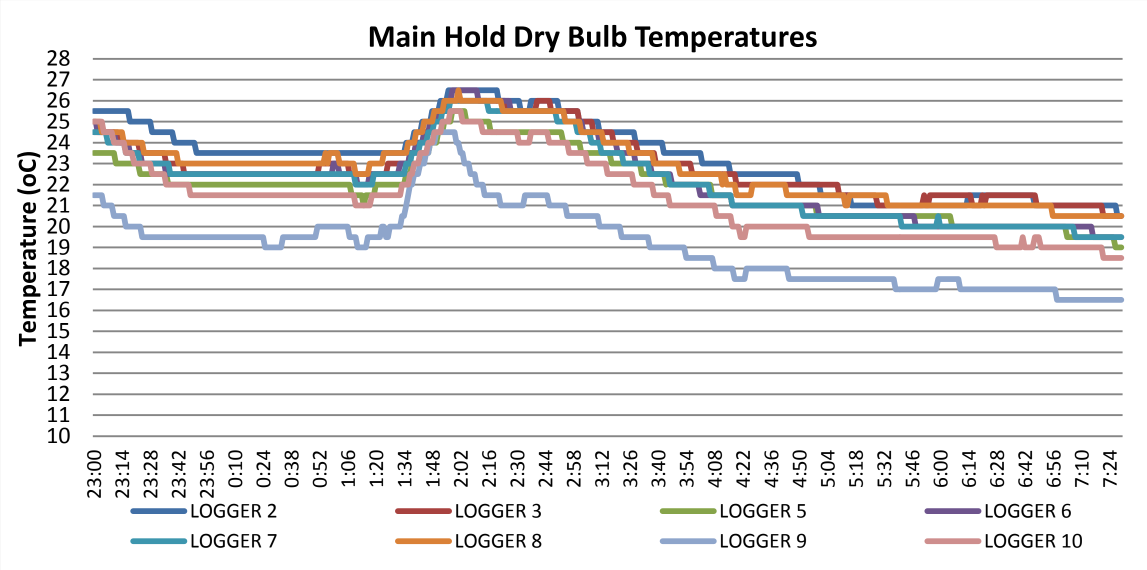


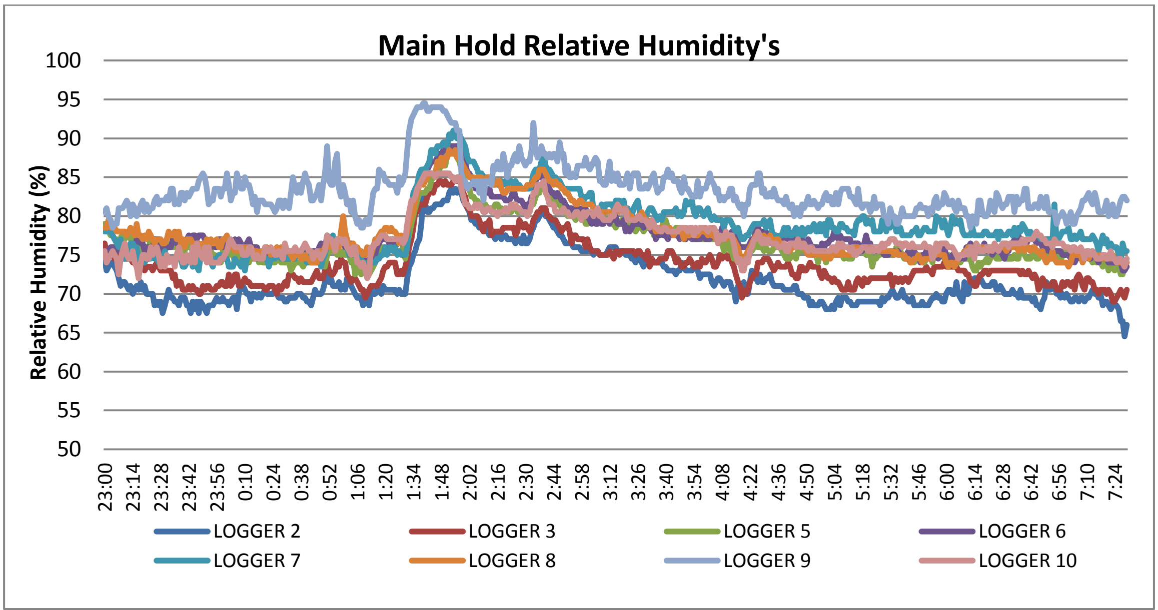
Max, Min and Averages per Logger (Bottom Holds)			
		LOGGER #1	LOGGER #4
Temperature [°C]	MAX	26.00	27.00
	MIN	18.50	25.00
	Average	22.66	25.31
Relative Humidity [%]	MAX	66.50	69.00
	MIN	40.50	48.00
	Average	49.68	56.51
`Dew Point [°C]	MAX	18.80	20.80
	MIN	4.80	13.20
	Average	11.55	16.02
Wet Bulb [°C]	MAX	20.32	22.31
	MIN	5.39	14.66
	Average	12.80	17.52

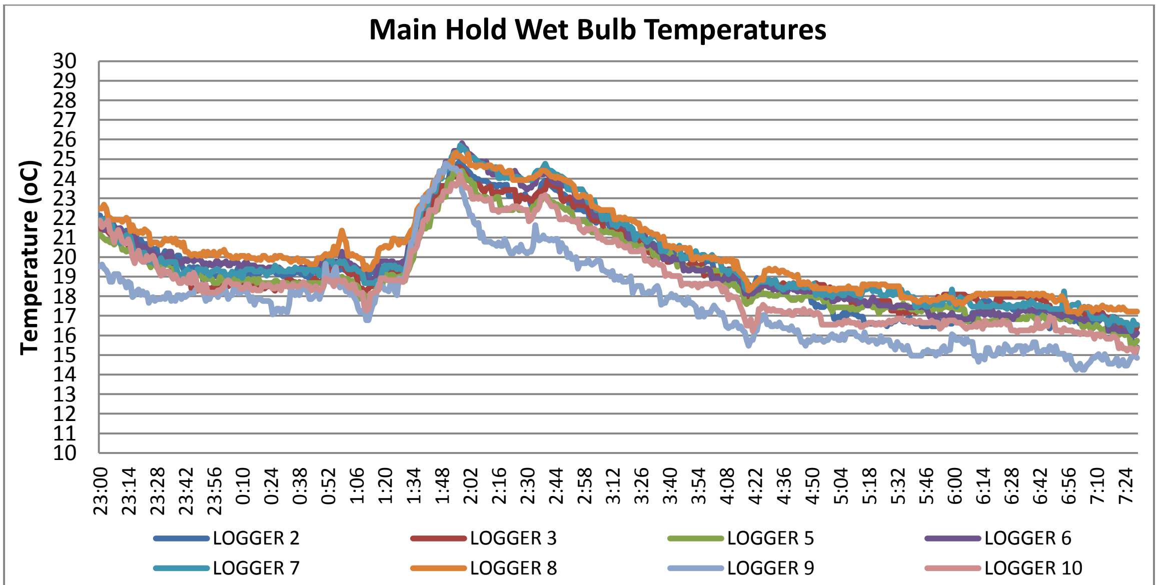
Main Hold Totals (8 loggers)				
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	26.50	94.50	24.40	25.81
LOWEST	16.50	64.50	12.80	17.11
AVERAGE	21.99	77.18	17.78	19.28
ST. DEVIATION	1.76	3.37	2.25	2.23

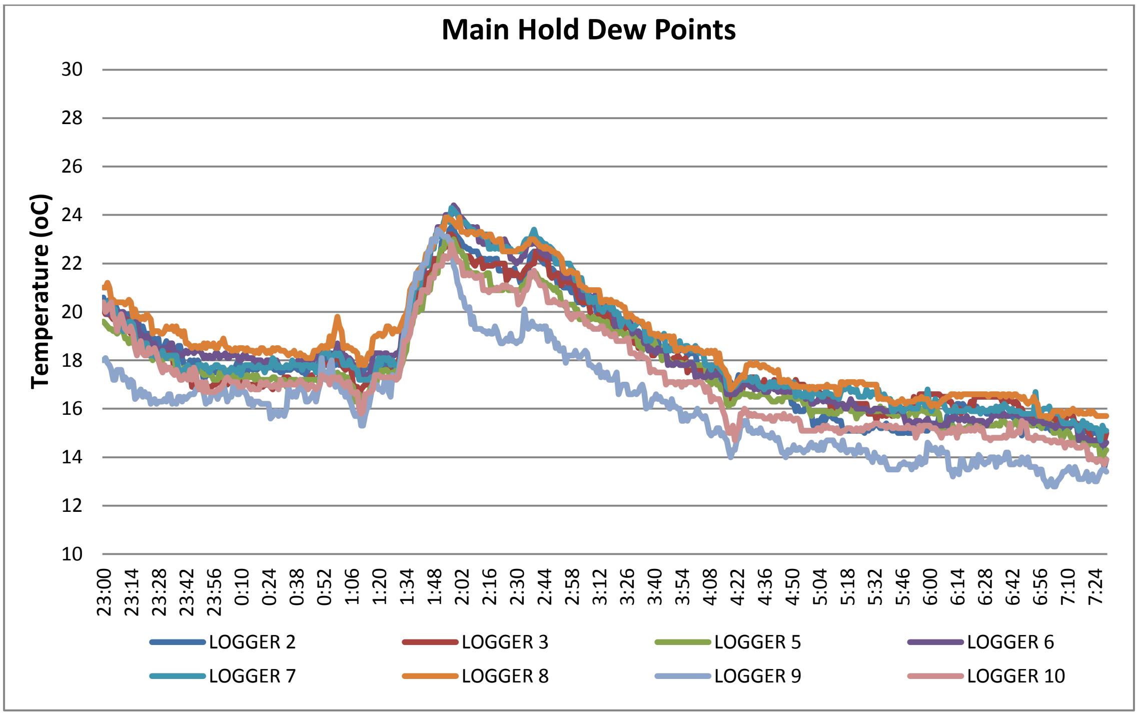
Bottom Hold Totals (2 loggers)				
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	27.00	69.00	20.80	22.31
LOWEST	18.50	40.50	4.80	5.39
AVERAGE	23.99	53.10	13.78	15.16
ST. DEVIATION	1.23	4.75	2.27	2.39

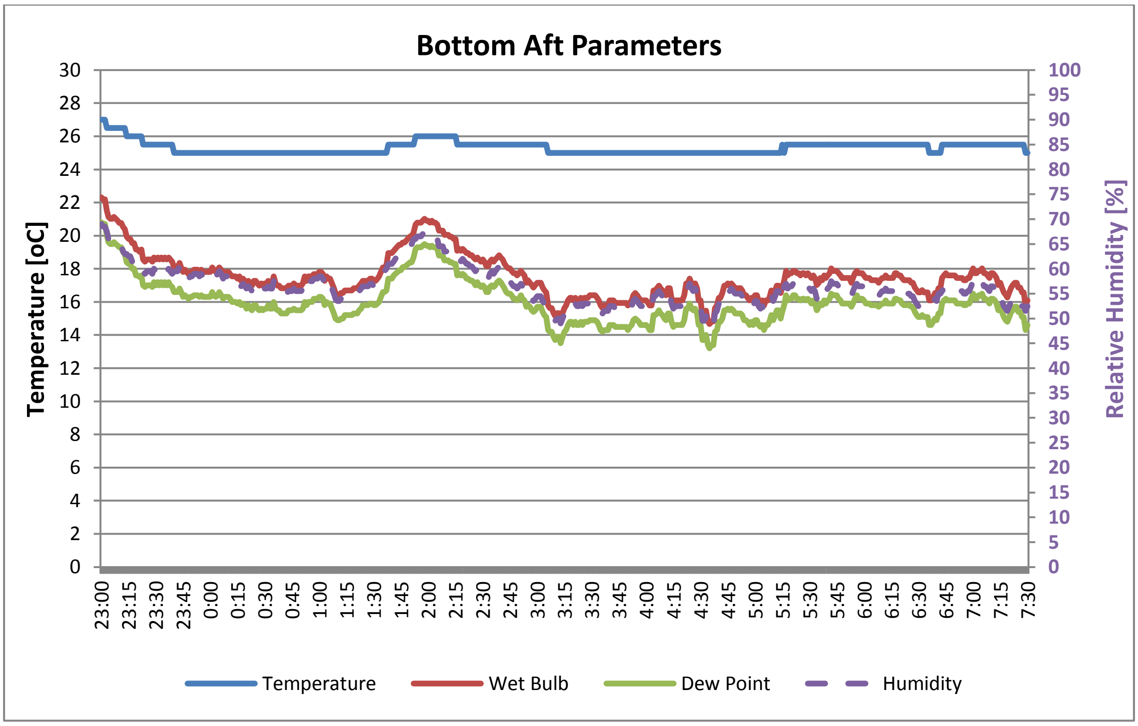
CO_2 Logger CO_2 Concentration [ppm]	
HIGHEST	N/A
LOWEST	N/A
AVERAGE	N/A
ST. DEVIATION	N/A
TREND EQUATION	N/A
TREND	**N/A**


Main Hold Dry Bulb Temperatures
Temperature (oC)
LOGGER 2
LOGGER 3
LOGGER 5
LOGGER 6
LOGGER 7
LOGGER 8
LOGGER 9
LOGGER 10


Main Hold Relative Humidity's
Relative Humidity (%)
LOGGER 2
LOGGER 3
LOGGER 5
LOGGER 6
LOGGER 7
LOGGER 8
LOGGER 9
LOGGER 10

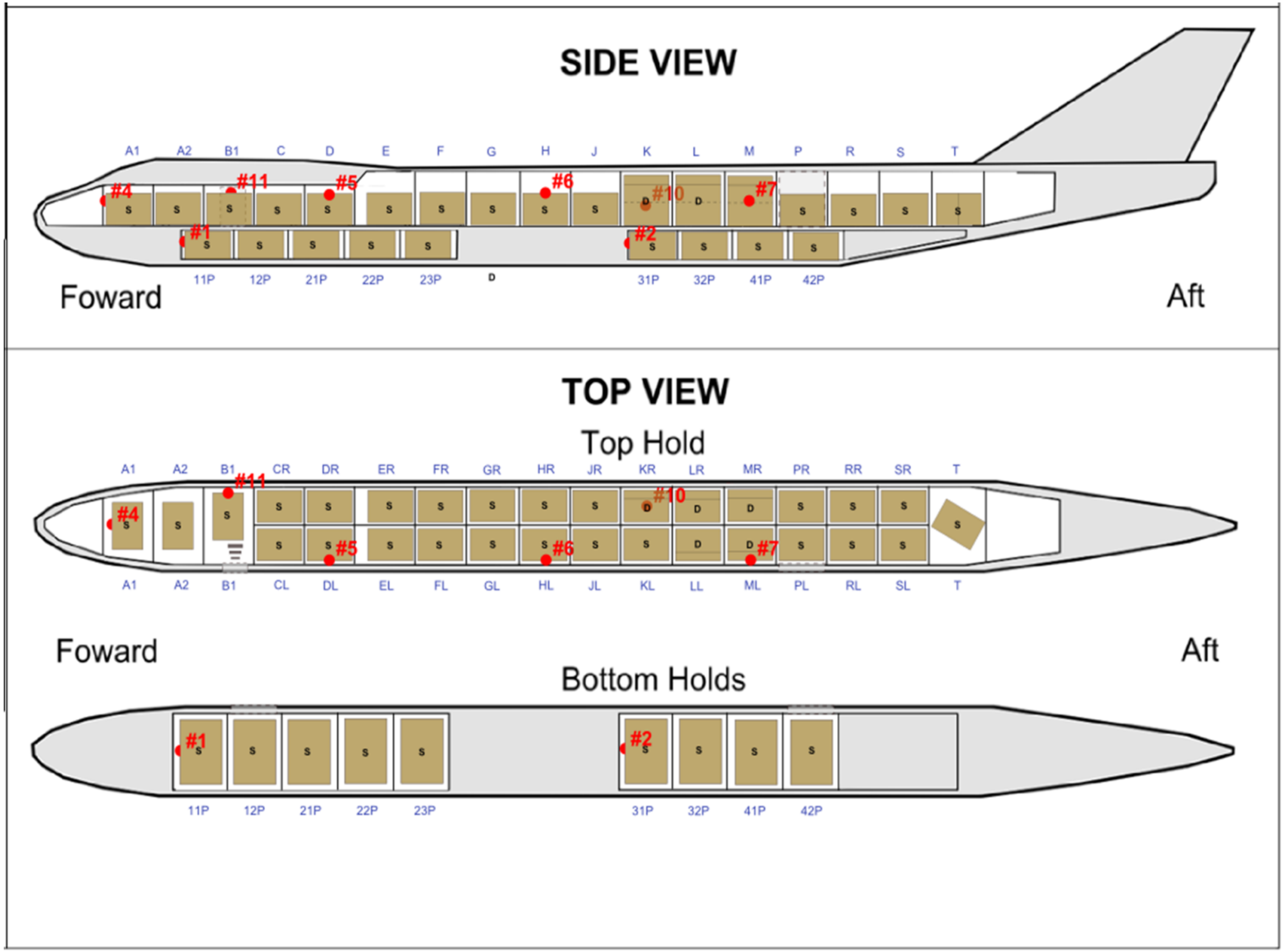

Main Hold Wet Bulb Temperatures
Temperature (oC)
LOGGER 2
LOGGER 3
LOGGER 5
LOGGER 6
LOGGER 7
LOGGER 8
LOGGER 9
LOGGER 10


Main Hold Dew Points
Temperature (oC)
30
28
26
24
22
20
18
16
14
12
10
23:00 23:14 23:28 23:42 23:56 0:10 0:24 0:38 0:52 1:06 1:20 1:34 1:48 2:02 2:16 2:30 2:44 2:58 3:12 3:26 3:40 3:54 4:08 4:22 4:36 4:50 5:04 5:18 5:32 5:46 6:00 6:14 6:28 6:42 6:56 7:10 7:24
LOGGER 2
LOGGER 3
LOGGER 5
LOGGER 6
LOGGER 7
LOGGER 8
LOGGER 9
LOGGER 10


Bottom Aft Parameters
Temperature [oC]
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Relative Humidity [%]
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
23:00 23:15 23:30 23:45 0:00 0:15 0:30 0:45 1:00 1:15 1:30 1:45 2:00 2:15 2:30 2:45 3:00 3:15 3:30 3:45 4:00 4:15 4:30 4:45 5:00 5:15 5:30 5:45 6:00 6:15 6:30 6:45 7:00 7:15 7:30
Temperature
Wet Bulb
Dew Point
Humidity

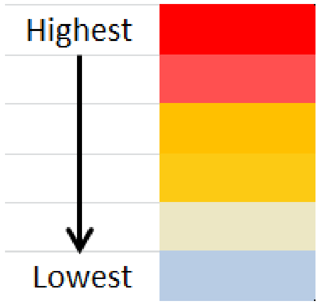
Appendix A2. Flight Number 2 Information:

Flight Number 2	
Flight Info	
Date	14/05/2013
Type of Aircraft	Boeing 747-400 Freighter
Departure	Melbourne, Australia
Destination	Jakarta, Indonesia
Departure Time	3:30am [0330] (AEST)
Arrival Time	10:00am [1000] (AEST) / 6:30am [0630] (local time)
Flight Time	6.5 hrs
Stop Over	N/A
Set Temperatures	Main = N/A
	Bottom Forward = N/A
	Bottom Aft = N/A
Holds Utilised	Main = 100%
	Bottom Forward = 100%
	Bottom Aft = 100%
Period of Loading	11:30pm - 2:45am
Aircraft Doors Closed	3:00am (cargo doors)
Consignment Info	
Total Number of Animals	308
Type of Animal	Cattle
Average Age of Animals	12 months
Average Live Weight	290 kg
Crate Info	
Total Number of Crates	39
Single Tiered	34
Double Tiered	5
Triple Tiered	0
Average Number of Head per Tier	7
Logging Info	
Number of Loggers Used	8
Main Hold Loggers	6 [#4, #5, #6, #7, #10, #11]
Bottom Forward Loggers	1 [#1]
Bottom Aft Loggers	1 [#2]
CO_2 Logger	N/A


SIDE VIEW
A1
A2
B1
C
D
E
F
G
H
J
K
L
M
P
R
S
T
#4
#11
#5
#6
#10
#7
#1
#2
11P
12P
21P
22P
23P
31P
32P
41P
42P
Foward
Aft
TOP VIEW
Top Hold
A1
A2
B1
CR
DR
ER
FR
GR
HR
JR
KR
LR
MR
PR
RR
SR
T
CL
DL
EL
FL
GL
HL
JL
KL
LL
ML
PL
RL
SL
Foward
Aft
Bottom Holds

Max, Min and Averages per Logger (Main Hold)							
		LOGGER #4	LOGGER #5	LOGGER #6	LOGGER #7	LOGGER #10	LOGGER #11
Temperature [°C]	MAX	22.00	23.00	24.50	24.50	32.00	22.50
	MIN	12.5	12.5	13.5	13.5	26.5	15.0
	Average	15.7	16.2	17.5	17.6	28.6	18.1
Relative Humidity [%]	MAX	95.5	93.5	94.0	97.0	90.0	94.0
	MIN	71.5	57.0	54.5	66.5	79.5	59.0
	Average	79.9	68.1	69.3	79.3	84.2	72.9
Dew Point [°C]	MAX	21.0	21.8	23.3	23.7	30.0	21.5
	MIN	8.4	4.2	4.5	7.5	22.7	7.8
	Average	12.2	10.2	11.7	14.0	25.7	13.1
Wet Bulb [°C]	MAX	22.0	21.0	24.0	27.5	25.0	27.5
	MIN	8.5	11.5	16.0	18.5	16.5	23.0
	Average	13.5	11.3	13.0	15.4	27.0	14.4

Max, Min and Averages per Logger (Bottom Holds)			
		LOGGER #1	LOGGER #2
Temperature [°C]	MAX	31.00	26.00
	MIN	20.00	21.50
	Average	22.41	23.25
Relative Humidity [%]	MAX	93.50	88.50
	MIN	53.50	40.00
	Average	71.93	56.24
Dew Point [°C]	MAX	26.70	23.90
	MIN	10.70	9.40
	Average	16.99	13.78
Wet Bulb [°C]	MAX	27.98	25.33
	MIN	12.00	12.00
	Average	18.48	15.18

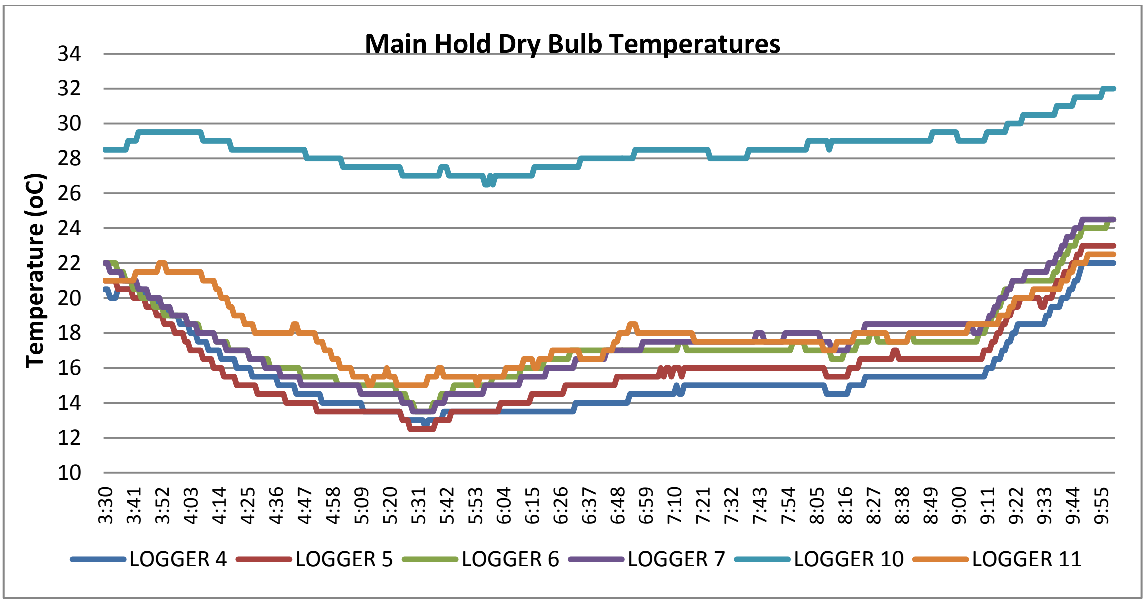


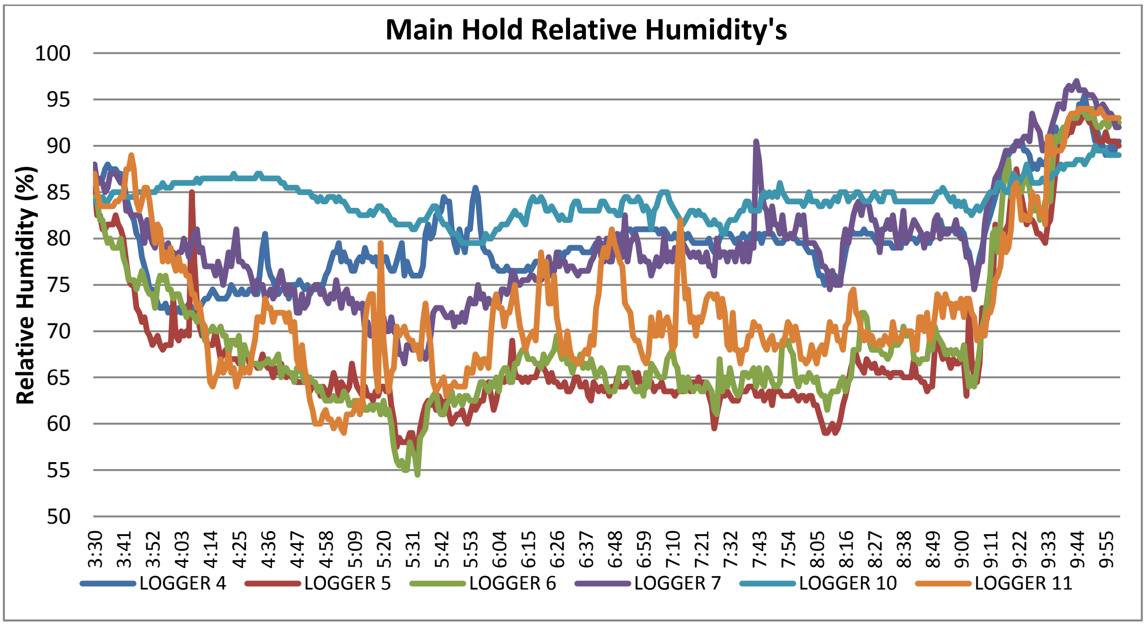
Main Hold Totals (5 loggers) (excluding #10)

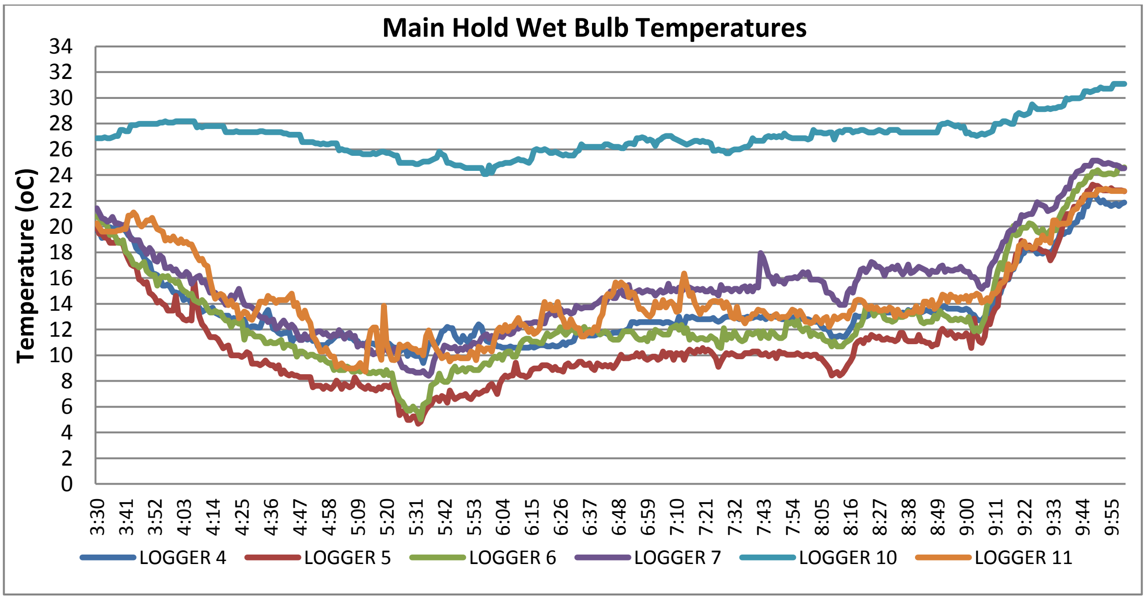
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	24.50	97.00	23.70	27.50
LOWEST	15.00	54.50	4.20	8.50
AVERAGE	17.01	73.89	12.24	13.52
ST. DEVIATION	2.34	7.30	3.58	3.72

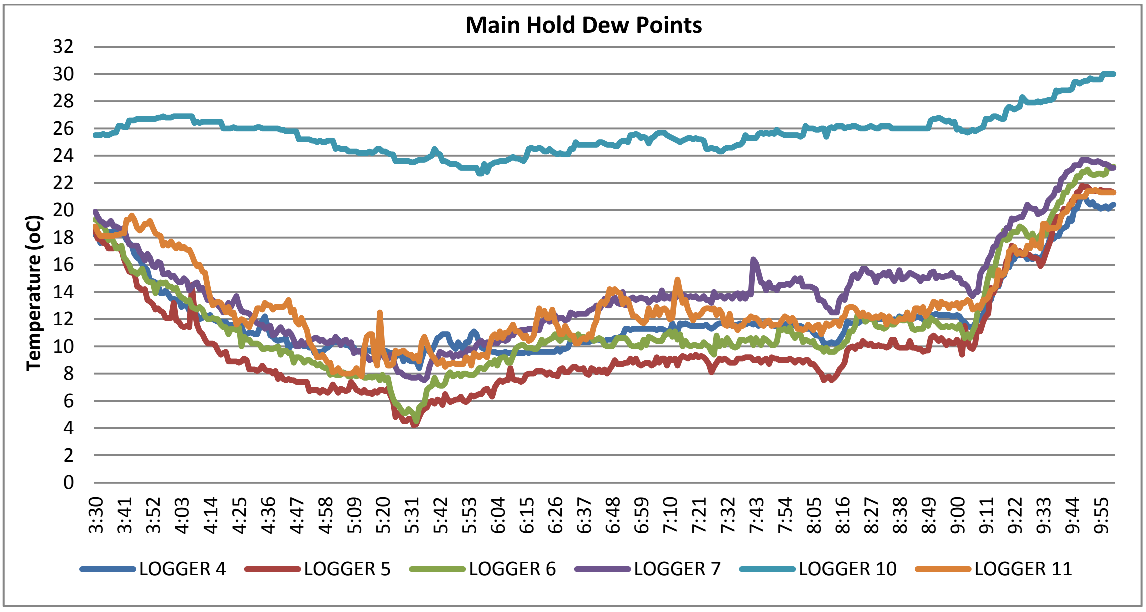
Bottom Hold Totals (2 loggers)				
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	31.00	93.50	26.70	27.98
LOWEST	20.00	40.00	9.40	10.54
AVERAGE	22.83	64.09	15.39	16.83
ST. DEVIATION	1.24	10.53	3.02	3.05

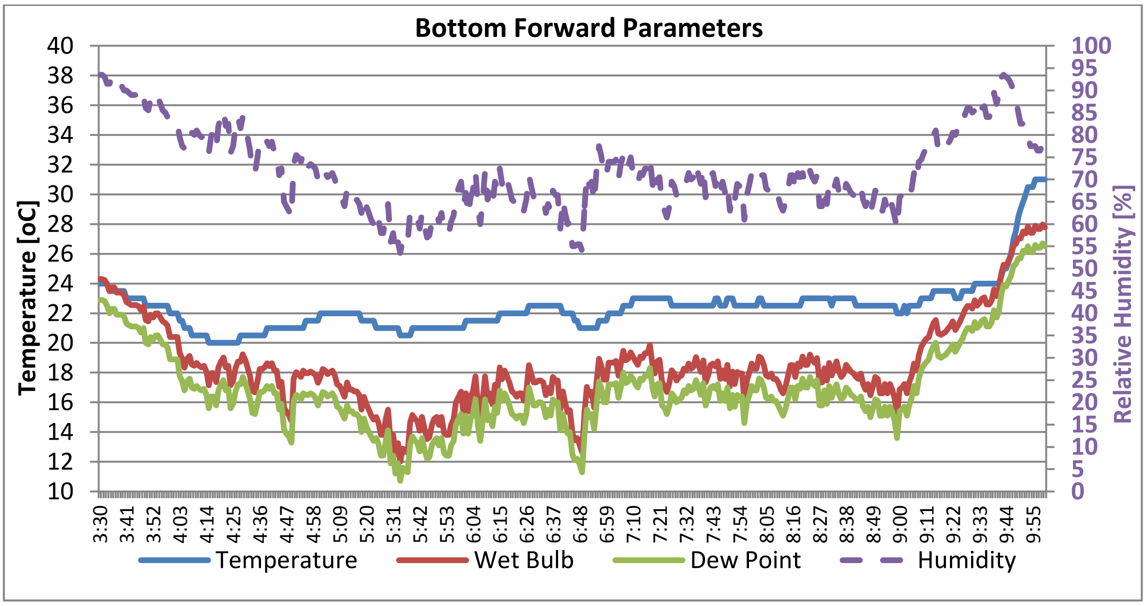
Logger #10 (Placed internally in crate at position KR)				
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	32.00	90.00	30.00	25.00
LOWEST	29.50	79.50	22.70	16.50
AVERAGE	28.60	84.21	25.66	26.98
ST. DEVIATION	1.13	2.05	1.47	1.40
AVERAGE DIFF.	11.60	10.32	13.41	13.47

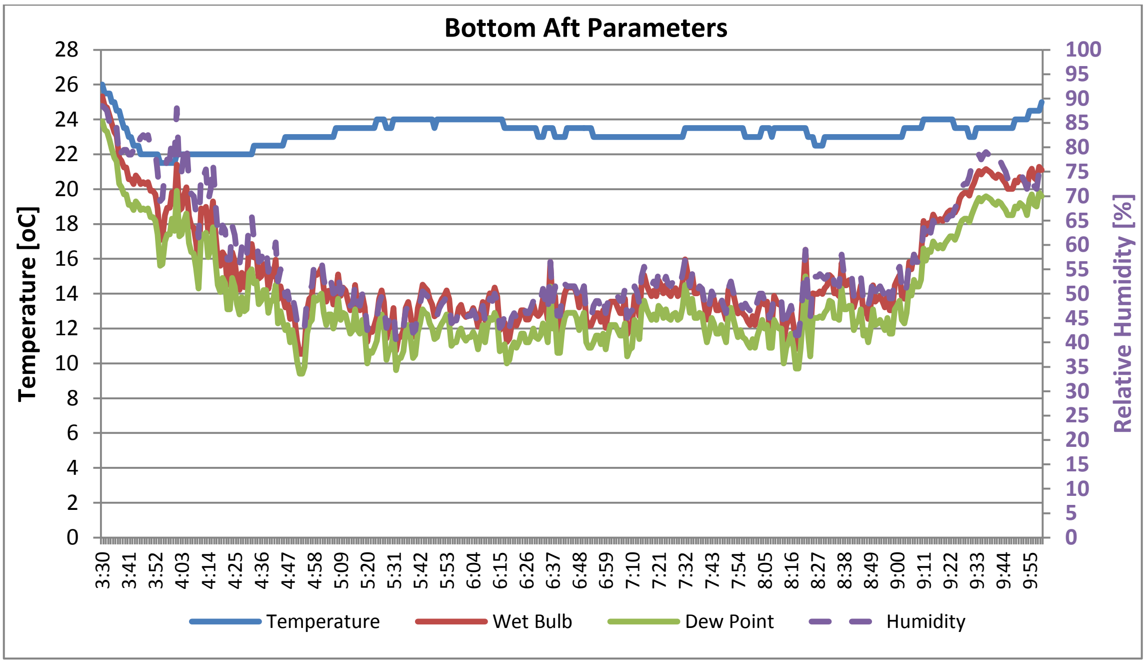

Main Hold Dry Bulb Temperatures
Temperature (oC)
34
32
30
28
26
24
22
20
18
16
14
12
10
3:30 3:41 3:52 4:03 4:14 4:25 4:36 4:47 4:58 5:09 5:20 5:31 5:42 5:53 6:04 6:15 6:26 6:37 6:48 6:59 7:10 7:21 7:32 7:43 7:54 8:05 8:16 8:27 8:38 8:49 9:00 9:11 9:22 9:33 9:44 9:55
LOGGER 4
LOGGER 5
LOGGER 6
LOGGER 7
LOGGER 10
LOGGER 11


Main Hold Relative Humidity's
Relative Humidity (%)
100
95
90
85
80
75
70
65
60
55
50
3:30 3:41 3:52 4:03 4:14 4:25 4:36 4:47 4:58 5:09 5:20 5:31 5:42 5:53 6:04 6:15 6:26 6:37 6:48 6:59 7:10 7:21 7:32 7:43 7:54 8:05 8:16 8:27 8:38 8:49 9:00 9:11 9:22 9:33 9:44 9:55
LOGGER 4
LOGGER 5
LOGGER 6
LOGGER 7
LOGGER 10
LOGGER 11


Main Hold Wet Bulb Temperatures
Temperature (oC)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
3:30 3:41 3:52 4:03 4:14 4:25 4:36 4:47 4:58 5:09 5:20 5:31 5:42 5:53 6:04 6:15 6:26 6:37 6:48 6:59 7:10 7:21 7:32 7:43 7:54 8:05 8:16 8:27 8:38 8:49 9:00 9:11 9:22 9:33 9:44 9:55
LOGGER 4
LOGGER 5
LOGGER 6
LOGGER 7
LOGGER 10
LOGGER 11

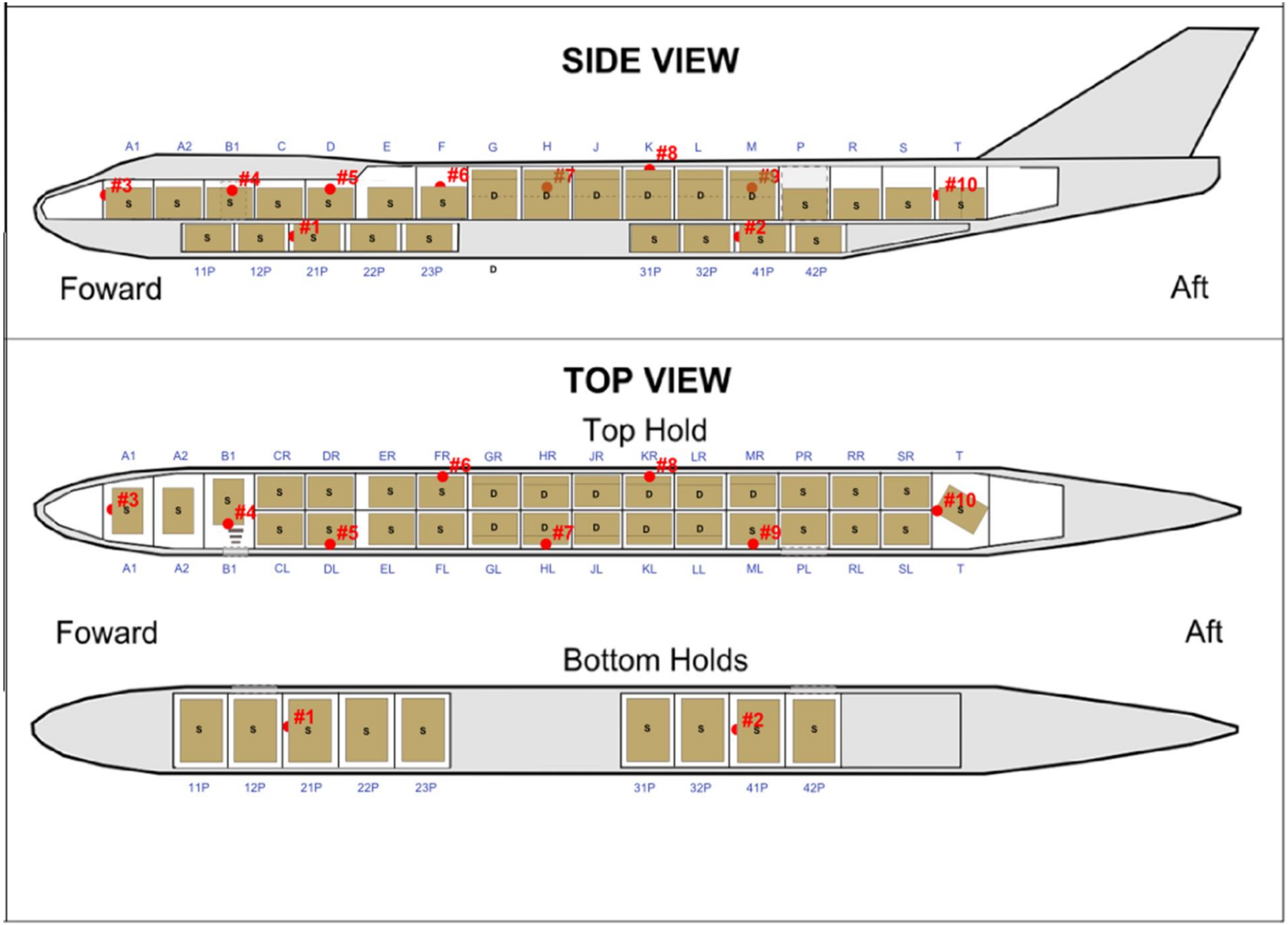

Main Hold Dew Points
Temperature (oC)
LOGGER 4
LOGGER 5
LOGGER 6
LOGGER 7
LOGGER 10
LOGGER 11


Bottom Forward Parameters
Temperature [oC]
Relative Humidity [%]
Temperature
Wet Bulb
Dew Point
Humidity


Bottom Aft Parameters
Temperature [oC]
Relative Humidity [%]
Temperature
Wet Bulb
Dew Point
Humidity

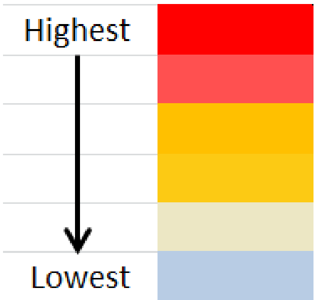
Appendix A3. Flight Number 3 Information:

Flight Number 3	
Flight Info	
Date	28/05/2013
Type of Aircraft	Boeing 747-400 Freighter
Departure	Sydney, Australia
Destination	Kota Kinabalu, Malaysia
Departure Time	1:30pm [1330] (AEST)
Arrival Time	9:00pm [2100] (AEST) / 7:00pm [1900] (local time)
Flight Time	7.5 hrs
Stop Over	N/A
Set Temperatures	Main = N/A
	Bottom Forward = N/A
	Bottom Aft = N/A
Holds Utilised	Main = 100%
	Bottom Forward = 100%
	Bottom Aft = 100%
Period of Loading	11:00am - 12:30pm
Aircraft Doors Closed	12:40pm (cargo doors); 1:10pm (entrance door)
Consignment Info	
Total Number of Animals	452
Type of Animal	Cattle
Average Age of Animals	8 months
Average Live Weight	193 kg
Crate Info	
Total Number of Crates	39
Single Tiered	28
Double Tiered	11
Triple Tiered	0
Average Number of Head per Tier	9
Logging Info	
Number of Loggers Used	10
Main Hold Loggers	8 [#3, #4, #5, #6, #7, #8, #9, #10]
Bottom Forward Loggers	1 [#1]
Bottom Aft Loggers	1 [#2]
CO_2 Logger	N/A


SIDE VIEW
A1 A2 B1 C D E F G H J K L M P R S T
#1 #2 #3 #4 #5 #6 #7 #8 #9 #10
11P 12P 21P 22P 23P 31P 32P 41P 42P
Foward
Aft
TOP VIEW
Top Hold
A1 A2 B1 CR DR ER FR GR HR JR KR LR MR PR RR SR T
A1 A2 B1 CL DL EL FL GL HL JL KL LL ML PL RL SL T
Foward
Aft
Bottom Holds
11P 12P 21P 22P 23P 31P 32P 41P 42P

Max, Min and Averages per Logger (Main Hold)								
		LOGGER #3	LOGGER #5	LOGGER #6	LOGGER #7	LOGGER #8	LOGGER #9	LOGGER #10
Temperature [°C]	MAX	24.00	23.50	25.00	24.50	24.00	22.50	23.00
	MIN	19.00	18.00	21.00	20.50	18.50	15.50	17.00
	Average	19.73	19.42	21.62	21.21	19.72	17.07	18.32
Relative Humidity [%]	MAX	92.00	86.00	87.00	82.50	87.00	88.00	83.00
	MIN	63.50	66.00	67.50	71.00	65.00	62.00	66.50
	Average	76.81	72.90	78.97	74.58	73.35	69.00	71.05
Dew Point [°C]	MAX	21.10	20.60	22.10	21.10	20.20	20.10	18.40
	MIN	13.50	12.80	16.60	15.30	13.30	9.00	11.50
	Average	15.54	14.43	17.78	16.52	14.80	11.32	12.98
Wet Bulb [°C]	MAX	22.60	22.12	23.54	22.60	21.74	21.63	19.91
	MIN	14.95	14.17	18.13	16.78	14.72	10.04	12.81
	Average	17.01	15.89	19.31	18.02	16.27	12.59	14.36

Max, Min and Averages per Logger (Bottom Holds)			
		LOGGER #1	LOGGER #2
Temperature [°C]	MAX	25.50	27.50
	MIN	17.00	22.00
	Average	19.12	22.08
Relative Humidity [%]	MAX	71.50	83.50
	MIN	36.00	34.00
	Average	48.72	41.96
Dew Point [°C]	MAX	19.60	21.30
	MIN	3.20	5.40
	Average	7.92	8.42
Wet Bulb [°C]	MAX	21.13	22.79
	MIN	3.51	6.07
	Average	8.80	9.39

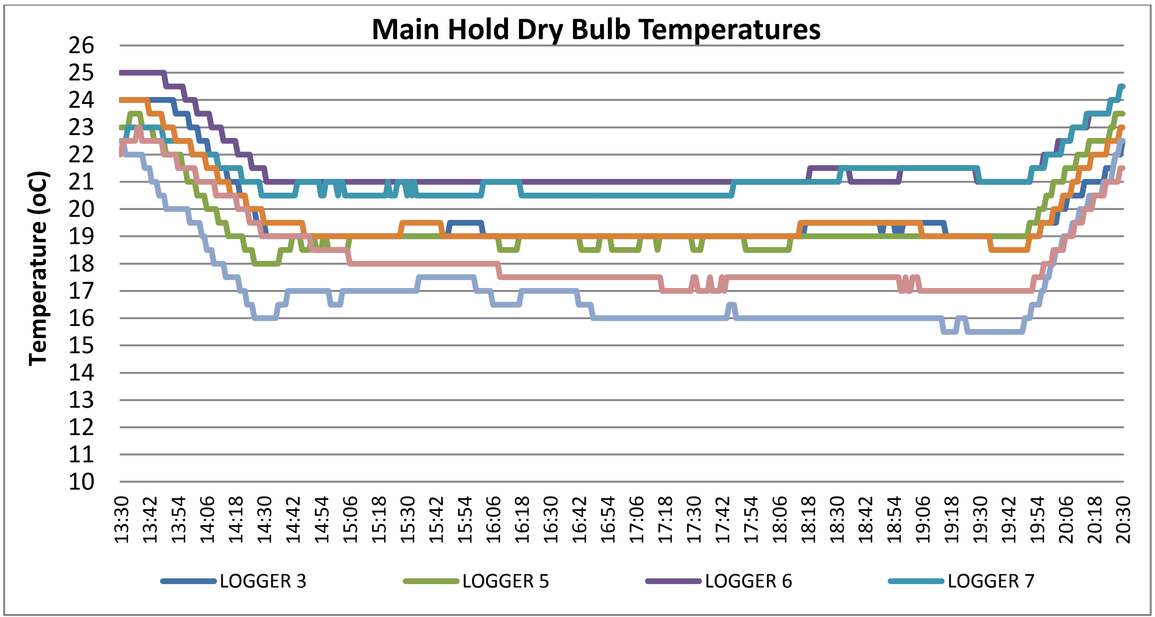


Main Hold Totals (7 loggers)

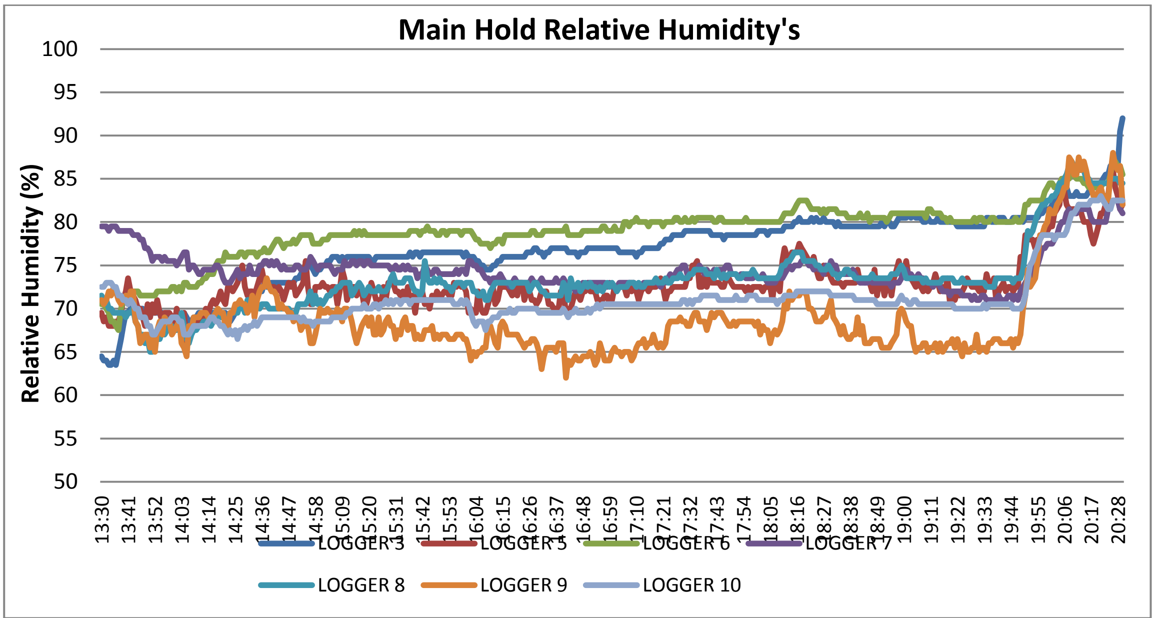
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	25.00	92.00	22.10	23.54
LOWEST	15.50	62.00	9.00	10.04
AVERAGE	19.58	73.81	14.77	16.21
ST. DEVIATION	1.31	3.63	1.49	1.52

Bottom Hold Totals (2 loggers)				
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	27.50	83.50	21.30	22.79
LOWEST	17.00	34.00	3.20	3.51
AVERAGE	20.60	45.34	8.17	9.10
ST. DEVIATION	1.48	7.71	3.28	3.55

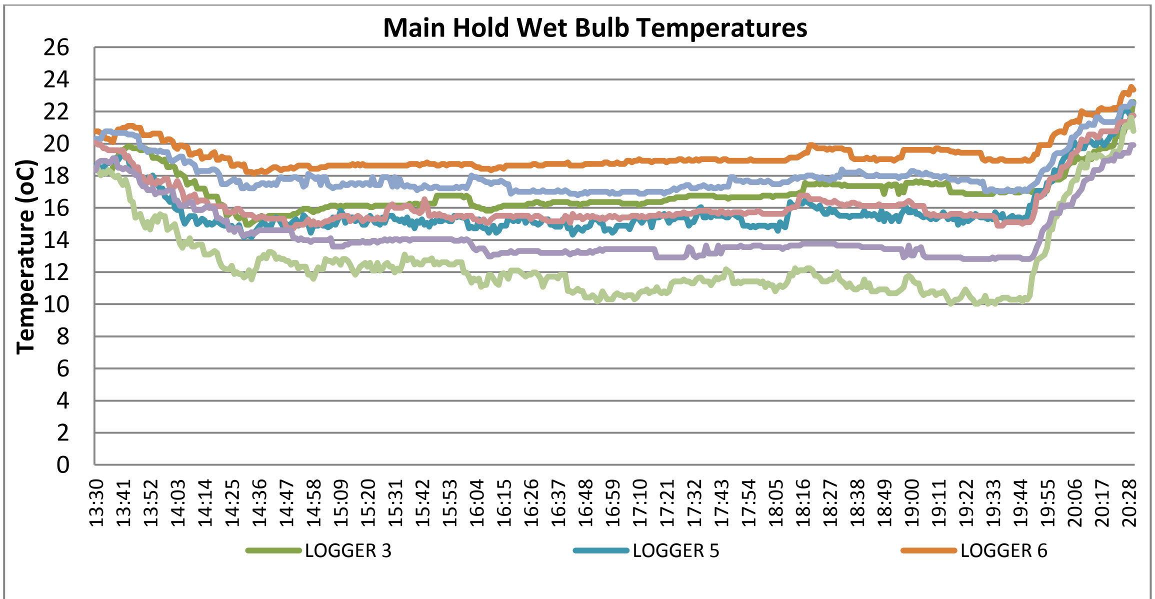
CO_2 Logger CO_2 Concentration [ppm]	
HIGHEST	N/A
LOWEST	N/A
AVERAGE	N/A
ST. DEVIATION	N/A
TREND EQUATION	N/A
TREND	**N/A**



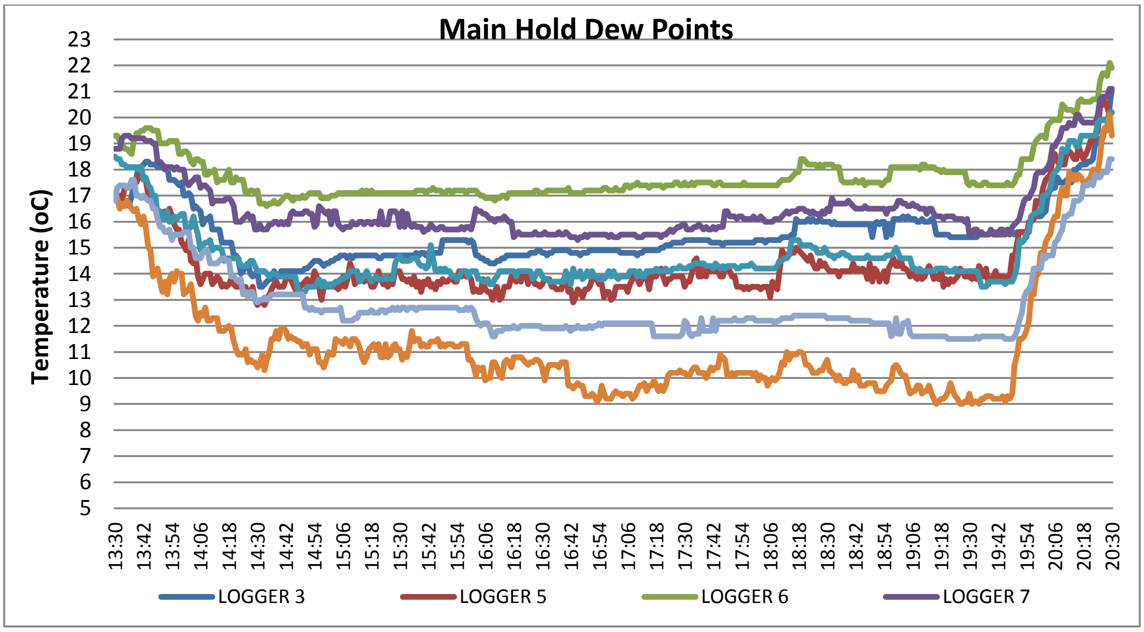
Main Hold Dry Bulb Temperatures
Temperature (oC)
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
13:30
13:42
13:54
14:06
14:18
14:30
14:42
14:54
15:06
15:18
15:30
15:42
15:54
16:06
16:18
16:30
16:42
16:54
17:06
17:18
17:30
17:42
17:54
18:06
18:18
18:30
18:42
18:54
19:06
19:18
19:30
19:42
19:54
20:06
20:18
20:30
LOGGER 3
LOGGER 5
LOGGER 6
LOGGER 7

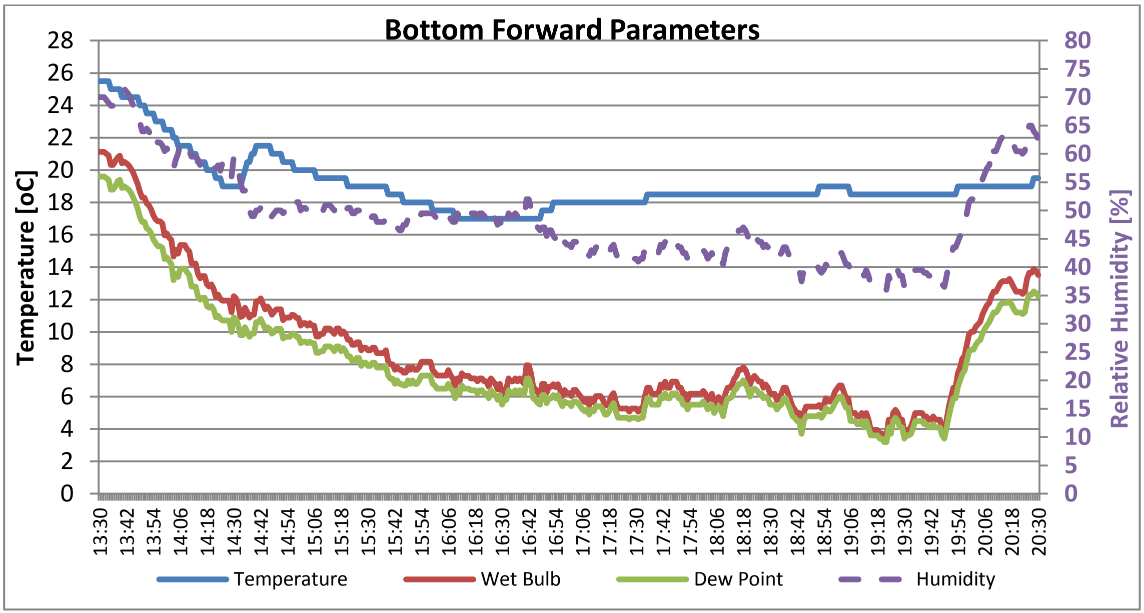


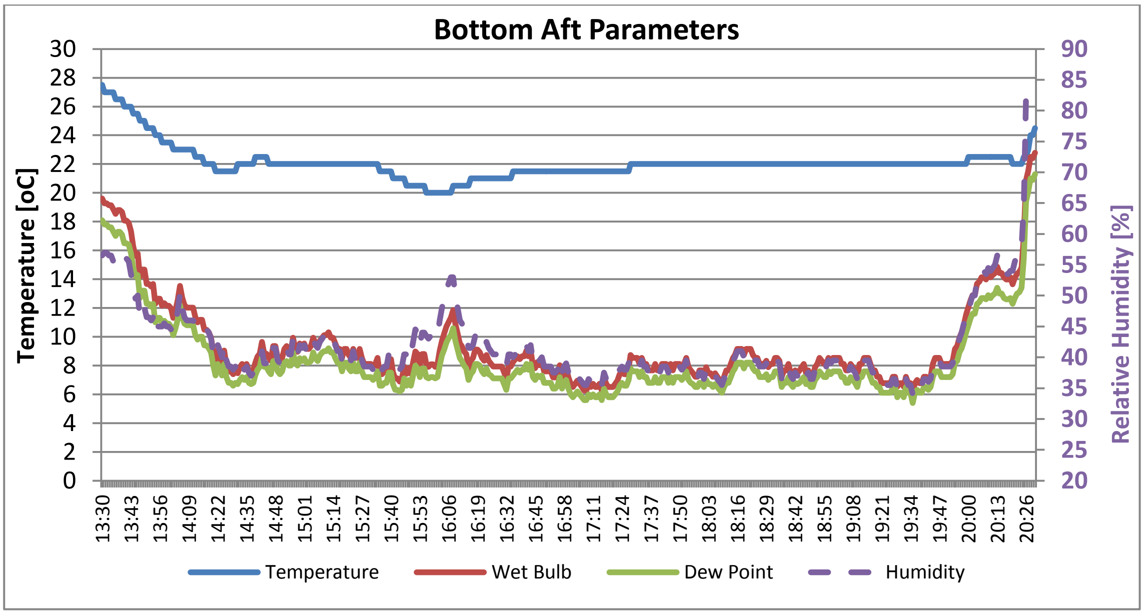
Main Hold Relative Humidity's
Relative Humidity (%)
100
95
90
85
80
75
70
65
60
55
50
13:30
13:41
13:52
14:03
14:14
14:25
14:36
14:47
14:58
15:09
15:20
15:31
15:42
15:53
16:04
16:15
16:26
16:37
16:48
16:59
17:10
17:21
17:32
17:43
17:54
18:05
18:16
18:27
18:38
18:49
19:00
19:11
19:22
19:33
19:44
19:55
20:06
20:17
20:28
LOGGER 3
LOGGER 5
LOGGER 6
LOGGER 7
LOGGER 8
LOGGER 9
LOGGER 10



Main Hold Wet Bulb Temperatures
Temperature (oC)
26
24
22
20
18
16
14
12
10
8
6
4
2
0
13:30
13:41
13:52
14:03
14:14
14:25
14:36
14:47
14:58
15:09
15:20
15:31
15:42
15:53
16:04
16:15
16:26
16:37
16:48
16:59
17:10
17:21
17:32
17:43
17:54
18:05
18:16
18:27
18:38
18:49
19:00
19:11
19:22
19:33
19:44
19:55
20:06
20:17
20:28
LOGGER 3
LOGGER 5
LOGGER 6

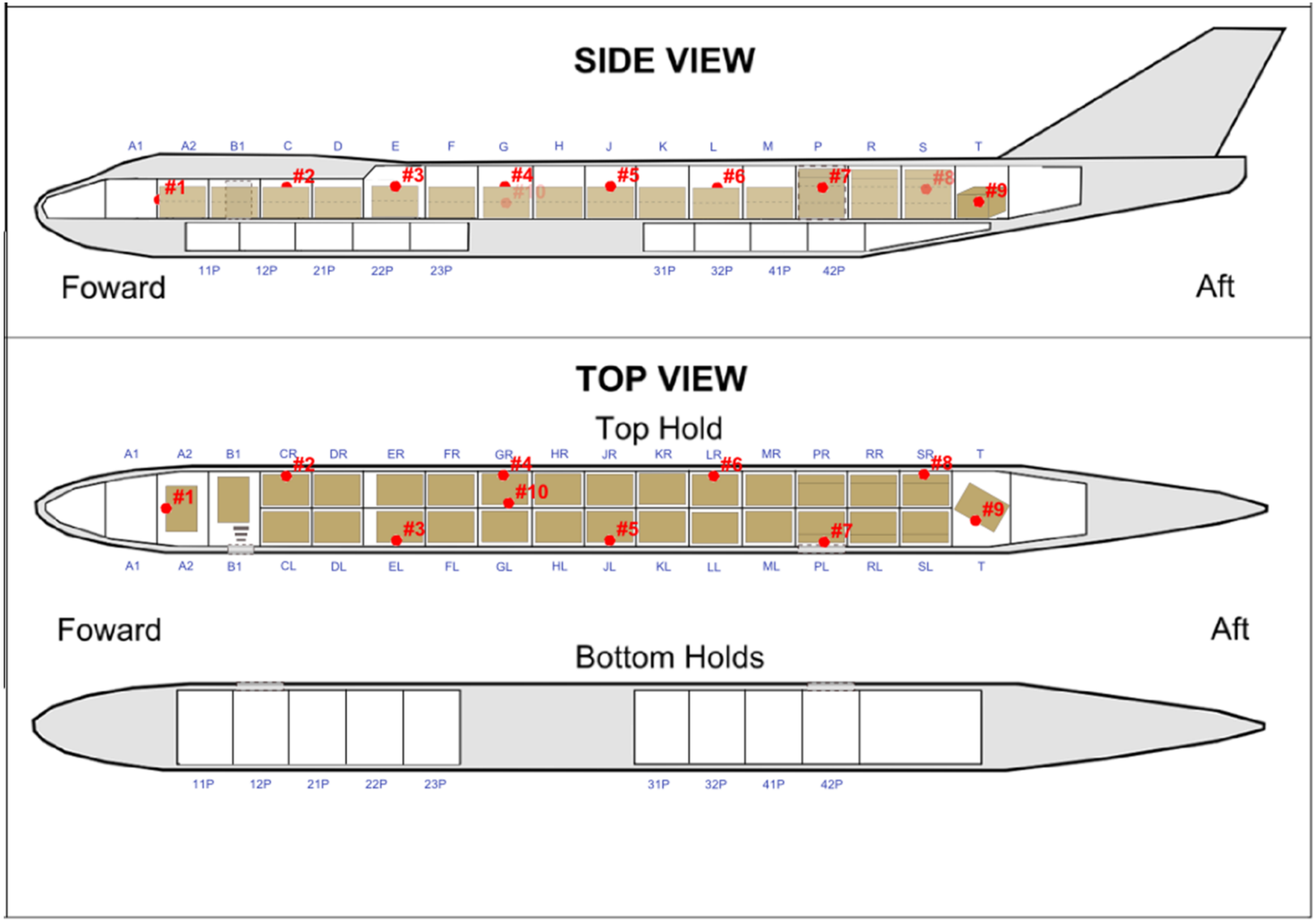

Main Hold Dew Points
Temperature (oC)
LOGGER 3
LOGGER 5
LOGGER 6
LOGGER 7


Bottom Forward Parameters
Temperature [oC]
Relative Humidity [%]
Temperature
Wet Bulb
Dew Point
Humidity


Bottom Aft Parameters
Temperature [oC]
Relative Humidity [%]
Temperature
Wet Bulb
Dew Point
Humidity

Appendix A4. Flight Number 4 Information:

Flight Number 4	
Flight Info	
Date	28/05/2013
Type of Aircraft	Boeing 747-400 Freighter
Departure	Melbourne, Australia
Destination	North China
Departure Time	5:00am [0500] (AEST)
Arrival Time	10:00pm [2200] (AEST) / 6:05pm [1805] (local time)
Flight Time	15 hrs
Stop Over	N/A
Set Temperatures	Main = 12^{o}C
	Bottom Forward = 12^{o}C
	Bottom Aft = 12^{o}C
Holds Utilised	Main = 96%
	Bottom Forward = 100%
	Bottom Aft = 100%
Period of Loading	2:30am -4:45am
Aircraft Doors Closed	Bottom: 3:00am / Top: 4:50am
Consignment Info	
Total Number of Animals	1345
Type of Animal	Sheep
Average Age of Animals	8-14 months
Average Live Weight	58 kg
Crate Info	
Total Number of Crates	38
Single Tiered	10
Double Tiered	22
Triple Tiered	6
Average Number of Head per Tier	18
Logging Info	
Number of Loggers Used	10
Main Hold Loggers	10 [#1, #2, #3, #4, #5, #6, #7, #8, #9, #10]
Bottom Forward Loggers	0
Bottom Aft Loggers	0
CO_2 Logger	N/A

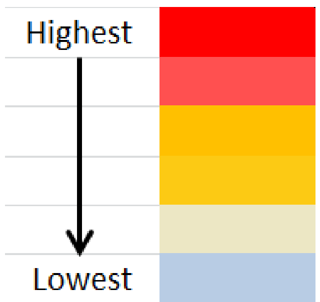

SIDE VIEW
A1 A2 B1 C D E F G H J K L M P R S T
#1 #2 #3 #4 #10 #5 #6 #7 #8 #9
11P 12P 21P 22P 23P 31P 32P 41P 42P
Foward
Aft
TOP VIEW
Top Hold
A1 A2 B1 CR DR ER FR GR HR JR KR LR MR PR RR SR T
#1 #2 #3 #4 #10 #5 #6 #7 #8 #9
A1 A2 B1 CL DL EL FL GL HL JL KL LL ML PL RL SL T
Foward
Aft
Bottom Holds
11P 12P 21P 22P 23P 31P 32P 41P 42P

Max, Min and Averages per Logger (Main Hold)

		LOGGER #1	LOGGER #2	LOGGER #3	LOGGER #4	LOGGER #5	LOGGER #6	LOGGER #7	LOGGER #8	LOGGER #9	LOGGER #10
Dry Bulb [°C]	MAX	28.5	26.5	27	26.5	29	27.5	32.5	29.5	30	32
	MIN	12	16	14	15	14.5	14	14.5	14.5	14.5	16
	Average	17.61	19.08	18.59	18.69	19.79	18.50	23.41	21.55	22.02	24.51
Relative Humidity [%]	MAX	89.00	89.50	91.00	97.50	92.00	93.50	92.50	95.50	93.00	85.00
	MIN	39.50	46.50	38.00	37.50	36.50	43.00	42.50	35.50	49.00	46.00
	Average	59.19	62.13	53.21	63.12	64.94	69.79	75.69	70.69	80.12	58.04
Dew Point [°C]	MAX	25.50	24.60	25.40	26.00	27.60	26.40	30.50	28.20	28.20	27.60
	MIN	2.10	6.30	1.60	5.40	5.40	6.30	5.80	5.20	6.00	8.50
	Average	9.40	11.54	8.60	11.31	12.84	12.75	18.76	15.79	18.39	15.61
Wet Bulb [°C]	MAX	26.85	25.99	26.73	27.28	28.80	27.64	31.65	29.41	29.39	28.86
	MIN	2.36	7.04	1.83	5.99	6.08	7.10	6.52	5.77	6.67	9.52
	Average	10.36	12.74	9.45	12.46	14.08	14.01	20.18	17.15	19.85	17.00

Max, Min and Averages per Logger (Bottom Holds)

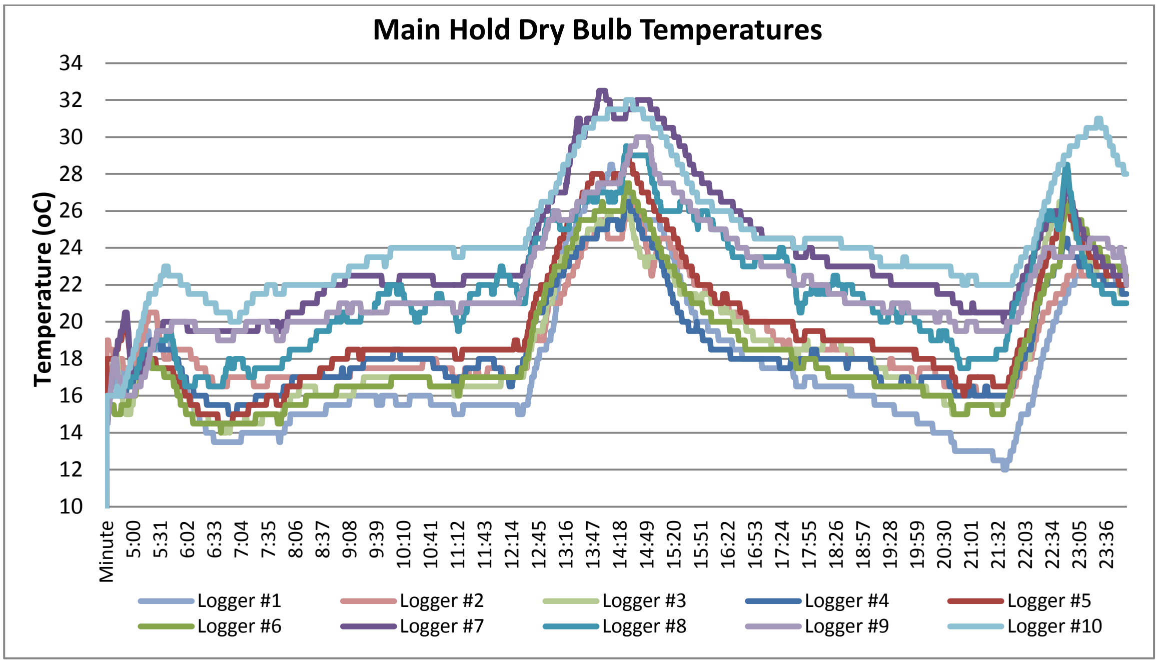
		N/A	N/A
Temperature [°C]	MAX	-	-
	MIN	-	-
	Average	-	-
Relative Humidity [%]	MAX	-	-
	MIN	-	-
	Average	-	-
Dew Point [°C]	MAX	-	-
	MIN	-	-
	Average	-	-
Wet Bulb [°C]	MAX	-	-
	MIN	-	-
	Average	-	-

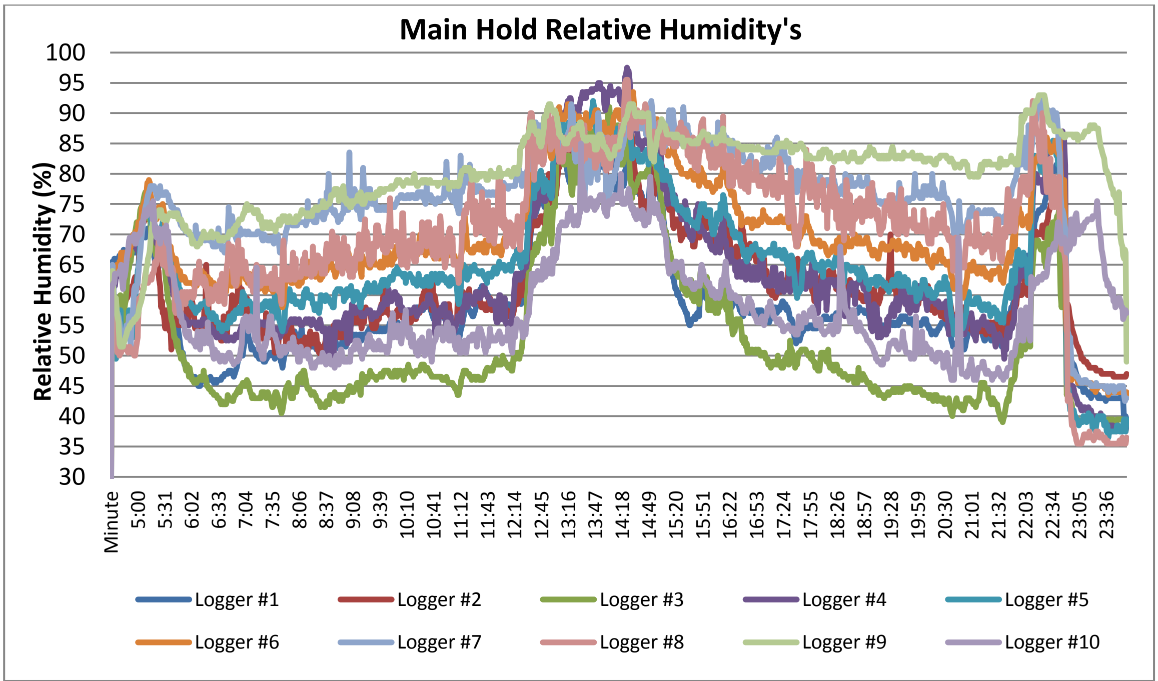


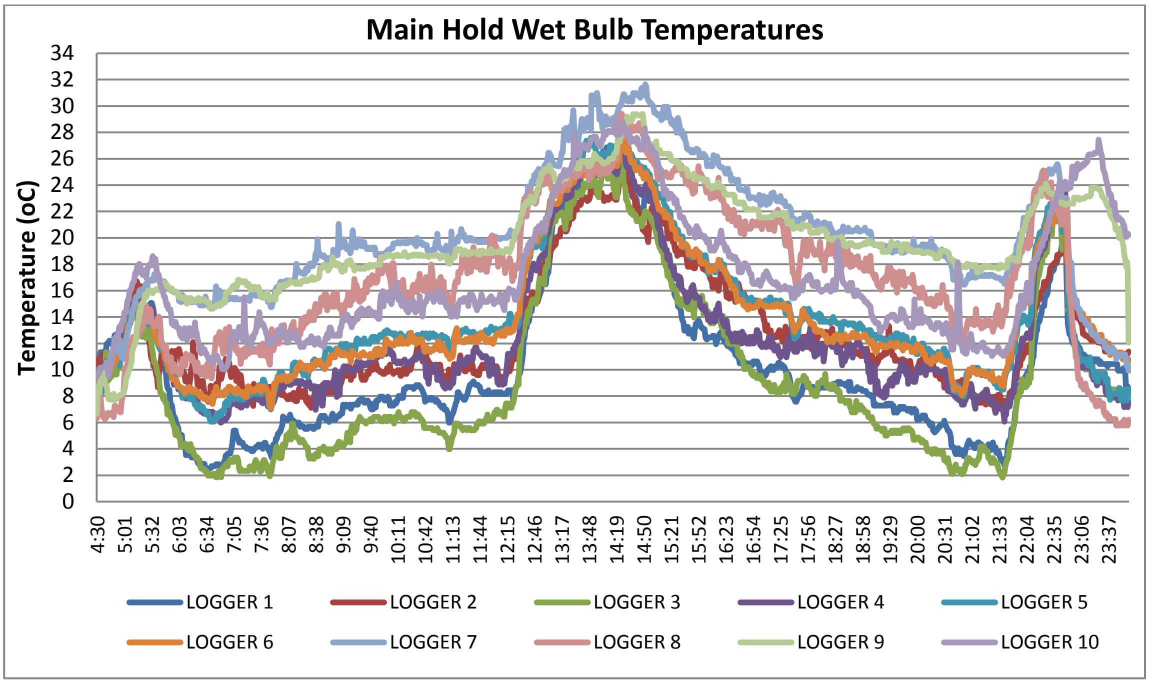
Main Hold Totals (10 loggers)				
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	32.50	97.50	30.50	31.65
LOWEST	12.00	35.50	1.60	1.83
AVERAGE	20.38	65.69	13.50	14.73
ST. DEVIATION	3.25	10.63	4.99	5.14

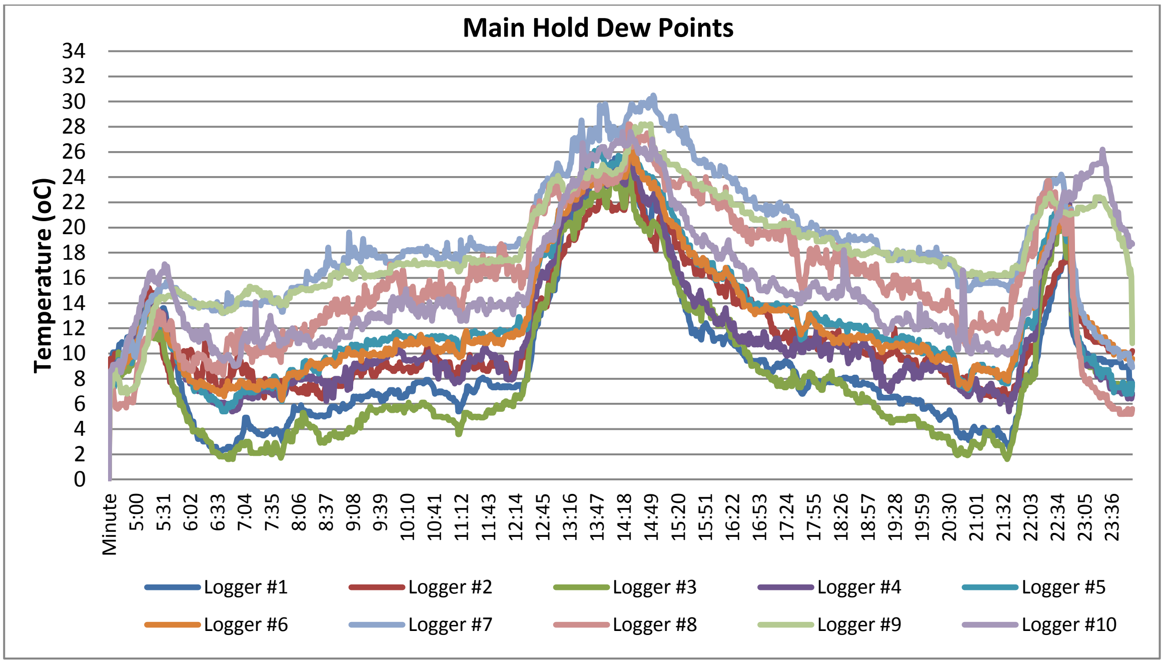
Bottom Hold Totals (0 loggers)				
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	-	-	-	-
LOWEST	-	-	-	-
AVERAGE	-	-	-	-
ST. DEVIATION	-	-	-	-

CO_2 Logger CO_2 Concentration [ppm]	
HIGHEST	N/A
LOWEST	N/A
AVERAGE	N/A
ST. DEVIATION	N/A
TREND EQUATION	N/A
TREND	**N/A**


Main Hold Dry Bulb Temperatures
Temperature (oC)
34
32
30
28
26
24
22
20
18
16
14
12
10
Minute
5:00
5:31
6:02
6:33
7:04
7:35
8:06
8:37
9:08
9:39
10:10
10:41
11:12
11:43
12:14
12:45
13:16
13:47
14:18
14:49
15:20
15:51
16:22
16:53
17:24
17:55
18:26
18:57
19:28
19:59
20:30
21:01
21:32
22:03
22:34
23:05
23:36
Logger #1
Logger #2
Logger #3
Logger #4
Logger #5
Logger #6
Logger #7
Logger #8
Logger #9
Logger #10

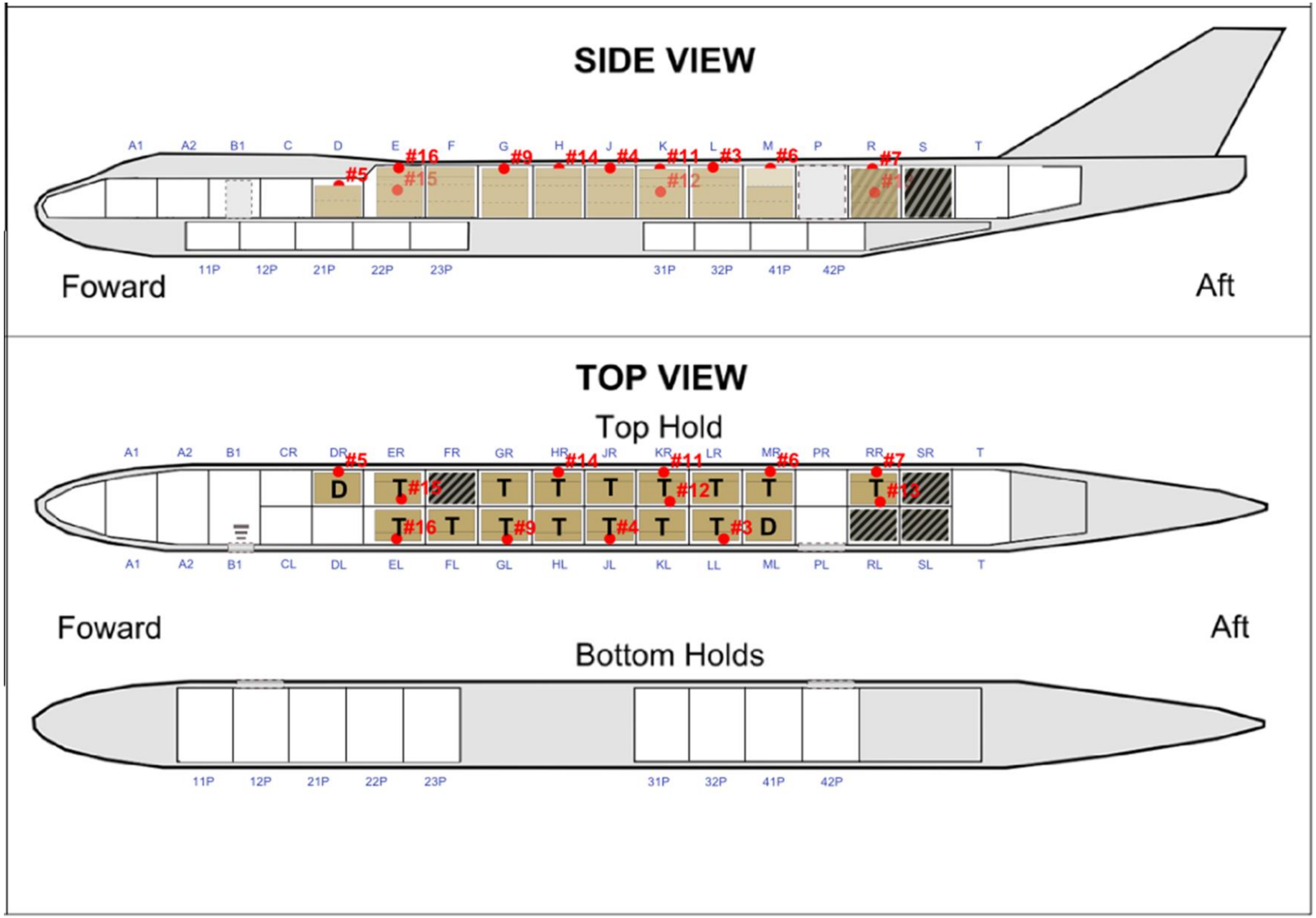

Main Hold Relative Humidity's
Relative Humidity (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
Minute
5:00
5:31
6:02
6:33
7:04
7:35
8:06
8:37
9:08
9:39
10:10
10:41
11:12
11:43
12:14
12:45
13:16
13:47
14:18
14:49
15:20
15:51
16:22
16:53
17:24
17:55
18:26
18:57
19:28
19:59
20:30
21:01
21:32
22:03
22:34
23:05
23:36
Logger #1
Logger #2
Logger #3
Logger #4
Logger #5
Logger #6
Logger #7
Logger #8
Logger #9
Logger #10


Main Hold Wet Bulb Temperatures
Temperature (oC)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
4:30
5:01
5:32
6:03
6:34
7:05
7:36
8:07
8:38
9:09
9:40
10:11
10:42
11:13
11:44
12:15
12:46
13:17
13:48
14:19
14:50
15:21
15:52
16:23
16:54
17:25
17:56
18:27
18:58
19:29
20:00
20:31
21:02
21:33
22:04
22:35
23:06
23:37
LOGGER 1
LOGGER 2
LOGGER 3
LOGGER 4
LOGGER 5
LOGGER 6
LOGGER 7
LOGGER 8
LOGGER 9
LOGGER 10


Main Hold Dew Points
Temperature (oC)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Minute
5:00
5:31
6:02
6:33
7:04
7:35
8:06
8:37
9:08
9:39
10:10
10:41
11:12
11:43
12:14
12:45
13:16
13:47
14:18
14:49
15:20
15:51
16:22
16:53
17:24
17:55
18:26
18:57
19:28
19:59
20:30
21:01
21:32
22:03
22:34
23:05
23:36
Logger #1
Logger #2
Logger #3
Logger #4
Logger #5
Logger #6
Logger #7
Logger #8
Logger #9
Logger #10

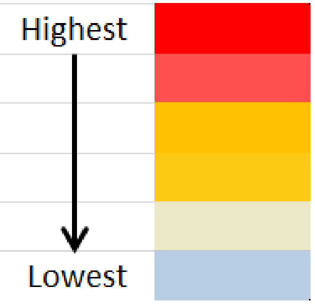
Appendix A5. Flight Number 5 Information:

Flight Number 5	
Flight Info	
Date	13/11/2013
Type of Aircraft	Boeing 747-400 Freighter
Departure	Sydney, Australia
Destination	Kuala Lumpa, Malaysia
Departure Time	12:10pm [1210] (EADT)
Arrival Time	9:00pm (AEDT) / 6:00pm [1800] (local time)
Flight Time	9 hrs
Stop Over	N/A
Set Temperatures	Main = 15^{o}C
	Bottom Forward = 15^{o}C
	Bottom Aft = 15^{o}C
Holds Utilised	Main = 56%
	Bottom Forward = 0%
	Bottom Aft = 0%
Period of Loading	10:30am – 12:00pm
Aircraft Doors Closed	12:15pm
Consignment Info	
Total Number of Animals	980
Type of Animal	Goats
Average Age of Animals	12 months
Average Live Weight	50 kg
Crate Info	
Total Number of Crates	17
Single Tiered	0
Double Tiered	2
Triple Tiered	15
Average Number of Head per Tier	20
Logging Info	
Number of Loggers Used	12
Main Hold Loggers	12 [#3, #4, #5, #6, #7, #9, #11, #12, #13, #14, #15, #16]
Bottom Forward Loggers	0
Bottom Aft Loggers	0
CO_2 Logger	N/A


SIDE VIEW
A1 A2 B1 C D E F G H J K L M P R S T
#16
#15
#5
#9
#14
#4
#11
#12
#3
#6
#7
11P 12P 21P 22P 23P 31P 32P 41P 42P
Foward
Aft
TOP VIEW
Top Hold
A1 A2 B1 CR DR ER FR GR HR JR KR LR MR PR RR SR T
A1 A2 B1 CL DL EL FL GL HL JL KL LL ML PL RL SL T
D
T
#16
#9
#4
#3
#12
Foward
Aft
Bottom Holds
11P 12P 21P 22P 23P 31P 32P 41P 42P

Max, Min and Averages per Logger (Main Hold)												
		LOGGER #3	LOGGER #4	LOGGER #5	LOGGER #6	LOGGER #7	LOGGER #9	LOGGER #11	LOGGER #12	LOGGER #13	LOGGER #14	LOGGER #15
Dry Bulb [°C]	MAX	27.00	25.50	21.50	27.50	24.50	25.00	26.50	29.50	28.00	24.50	27.00
	MIN	15.00	14.00	7.00	16.00	14.50	14.00	15.50	21.00	16.00	13.00	16.00
	Average	18.18	17.06	10.27	19.18	17.63	17.47	18.86	24.11	19.97	16.17	19.04
Relative Humidity [%]	MAX	81.00	79.50	87.00	80.50	80.50	73.00	80.00	62.50	71.50	76.50	62.00
	MIN	39.50	44.00	31.50	38.50	39.50	45.50	44.00	43.00	43.50	48.50	40.00
	Average	62.16	62.66	50.56	65.09	61.25	57.14	64.94	52.51	56.19	59.70	47.80
Dew Point [°C]	MAX	15.80	16.00	12.90	16.30	15.40	15.80	18.00	19.00	17.30	15.70	16.40
	MIN	8.10	6.20	-4.10	9.30	7.00	5.00	8.70	10.50	7.40	4.80	4.70
	Average	10.71	9.80	0.39	12.39	10.02	8.85	12.06	13.77	10.92	8.29	7.70
Wet Bulb [°C]	MAX	17.27	17.54	14.27	17.81	16.87	17.27	19.50	20.56	18.86	17.18	17.88
	MIN	9.12	6.98	-3.38	10.43	7.79	5.55	9.78	11.72	8.25	5.36	5.24
	Average	11.95	10.96	0.71	13.76	11.19	9.89	13.40	15.20	12.16	9.26	8.58

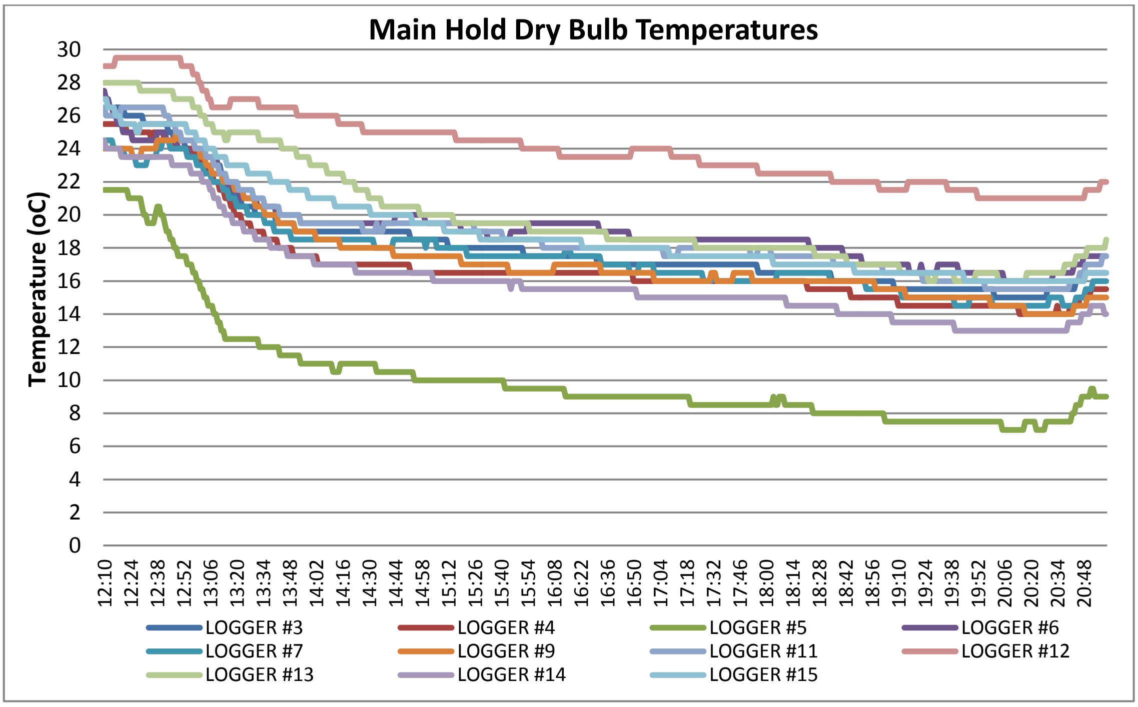
Max, Min and Averages per Logger (Bottom Holds)			
		N/A	**N/A**
Temperature [°C]	MAX	-	-
	MIN	-	-
	Average	-	-
Relative Humidity [%]	MAX	-	-
	MIN	-	-
	Average	-	-
Dew Point [°C]	MAX	-	-
	MIN	-	-
	Average	-	-
Wet Bulb [°C]	MAX	-	-
	MIN	-	-
	Average	-	-



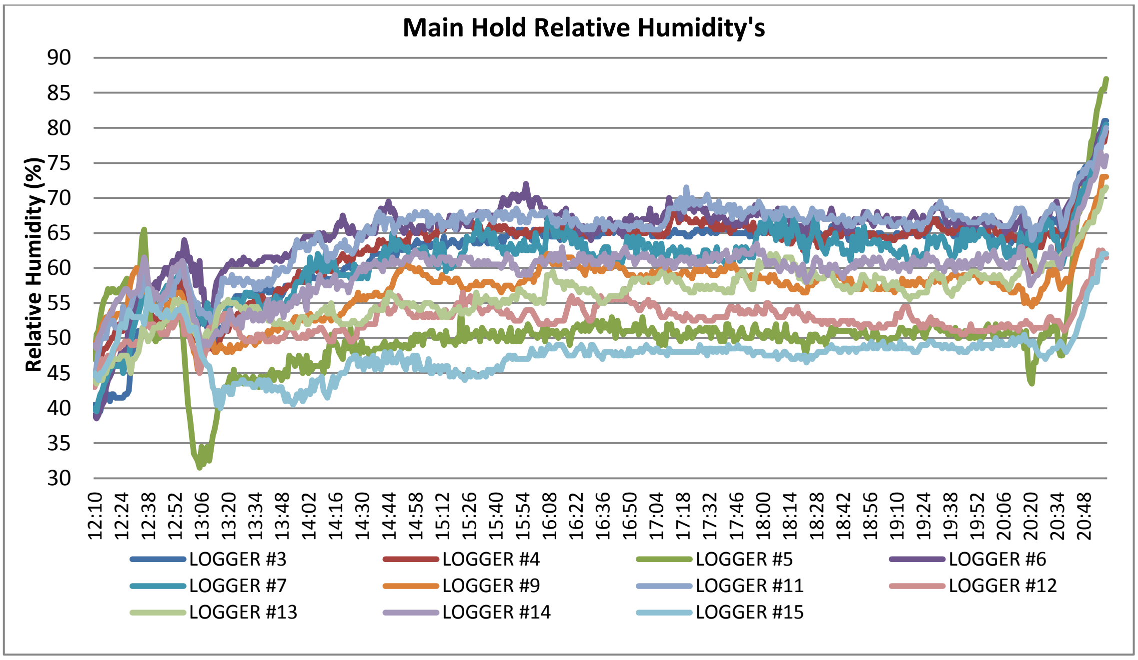
Main Hold Totals (11 loggers)				
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	29.50	87.00	19.00	20.56
LOWEST	7.00	31.50	-4.10	-3.38
AVERAGE	17.99	58.18	9.54	10.64
ST. DEVIATION	2.89	4.67	2.11	2.27

Bottom Hold Totals (0 loggers)				
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	-	-	-	-
LOWEST	-	-	-	-
AVERAGE	-	-	-	-
ST. DEVIATION	-	-	-	-

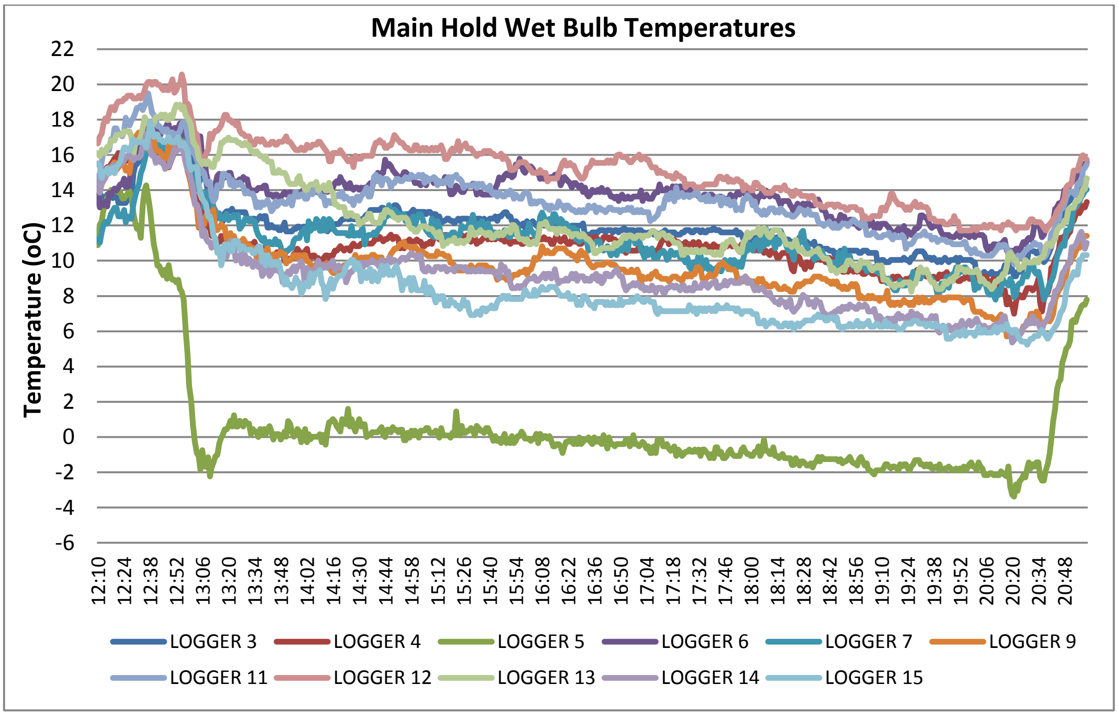
CO_2 Logger CO_2 Concentration [ppm]	
HIGHEST	N/A
LOWEST	N/A
AVERAGE	N/A
ST. DEVIATION	N/A
TREND EQUATION	N/A
TREND	**N/A**

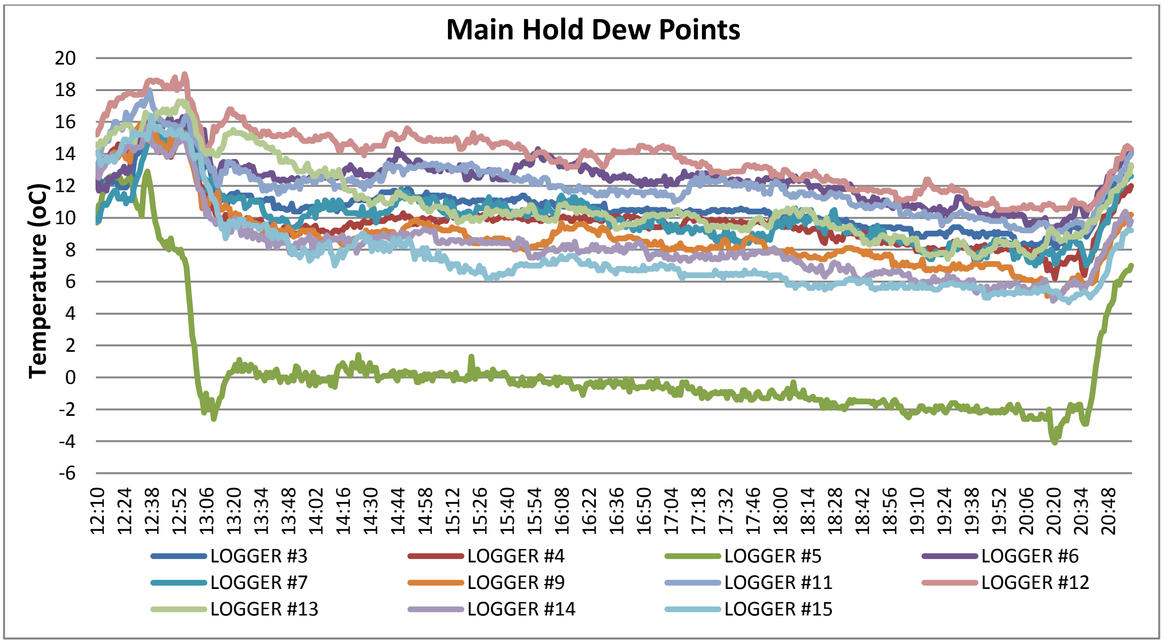


Main Hold Dry Bulb Temperatures
Temperature (oC)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
12:10
12:24
12:38
12:52
13:06
13:20
13:34
13:48
14:02
14:16
14:30
14:44
14:58
15:12
15:26
15:40
15:54
16:08
16:22
16:36
16:50
17:04
17:18
17:32
17:46
18:00
18:14
18:28
18:42
18:56
19:10
19:24
19:38
19:52
20:06
20:20
20:34
20:48
LOGGER #3
LOGGER #4
LOGGER #5
LOGGER #6
LOGGER #7
LOGGER #9
LOGGER #11
LOGGER #12
LOGGER #13
LOGGER #14
LOGGER #15



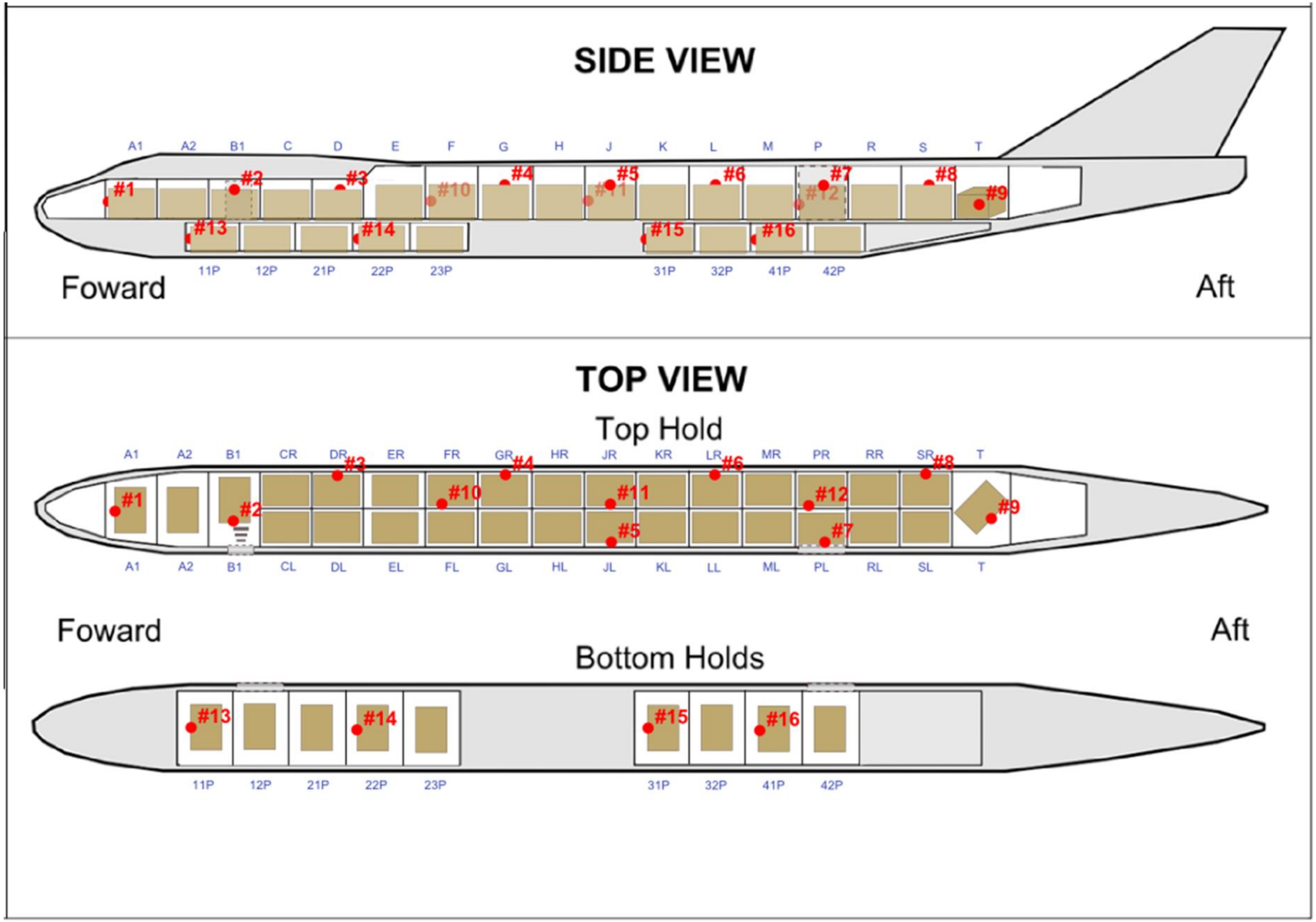
Main Hold Relative Humidity's
Relative Humidity (%)
90
85
80
75
70
65
60
55
50
45
40
35
30
12:10
12:24
12:38
12:52
13:06
13:20
13:34
13:48
14:02
14:16
14:30
14:44
14:58
15:12
15:26
15:40
15:54
16:08
16:22
16:36
16:50
17:04
17:18
17:32
17:46
18:00
18:14
18:28
18:42
18:56
19:10
19:24
19:38
19:52
20:06
20:20
20:34
20:48
LOGGER #3
LOGGER #4
LOGGER #5
LOGGER #6
LOGGER #7
LOGGER #9
LOGGER #11
LOGGER #12
LOGGER #13
LOGGER #14
LOGGER #15


Main Hold Wet Bulb Temperatures
Temperature (oC)
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
12:10
12:24
12:38
12:52
13:06
13:20
13:34
13:48
14:02
14:16
14:30
14:44
14:58
15:12
15:26
15:40
15:54
16:08
16:22
16:36
16:50
17:04
17:18
17:32
17:46
18:00
18:14
18:28
18:42
18:56
19:10
19:24
19:38
19:52
20:06
20:20
20:34
20:48
LOGGER 3
LOGGER 4
LOGGER 5
LOGGER 6
LOGGER 7
LOGGER 9
LOGGER 11
LOGGER 12
LOGGER 13
LOGGER 14
LOGGER 15


Main Hold Dew Points
Temperature (oC)
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
12:10
12:24
12:38
12:52
13:06
13:20
13:34
13:48
14:02
14:16
14:30
14:44
14:58
15:12
15:26
15:40
15:54
16:08
16:22
16:36
16:50
17:04
17:18
17:32
17:46
18:00
18:14
18:28
18:42
18:56
19:10
19:24
19:38
19:52
20:06
20:20
20:34
20:48
LOGGER #3
LOGGER #4
LOGGER #5
LOGGER #6
LOGGER #7
LOGGER #9
LOGGER #11
LOGGER #12
LOGGER #13
LOGGER #14
LOGGER #15

Appendix A6. Flight Number 6 Information:

Flight Number 6	
Flight Info	
Date	23/11/2013
Type of Aircraft	Boeing 747-400 Freighter
Departure	Sydney, Australia
Destination	Jakarta, Indonesia
Departure Time	1:30pm [1330] (EADT)
Arrival Time	7:30pm [1930] (AEDT) / 4:30pm [1630] (local time)
Flight Time	6 hrs
Stop Over	N/A
Set Temperatures	Main = 18^{o}C
	Bottom Forward = 18^{o}C
	Bottom Aft = 18^{o}C
Holds Utilised	Main = 100%
	Bottom Forward = 100%
	Bottom Aft = 100%
Period of Loading	10:30am - 1:00pm
Aircraft Doors Closed	1:15pm
Consignment Info	
Total Number of Animals	200
Type of Animal	Cattle
Average Age of Animals	12-24 months
Average Live Weight	400 kg
Crate Info	
Total Number of Crates	39
Single Tiered	39
Double Tiered	0
Triple Tiered	0
Average Number of Head per Tier	5
Logging Info	
Number of Loggers Used	16
Main Hold Loggers	12 [#1, #2, #3, #4, #5, #6, #7, #8, #9, #10, #11, #12]
Bottom Forward Loggers	2 [#13, #14]
Bottom Aft Loggers	2 [#15, #16]
CO_2 Logger	N/A

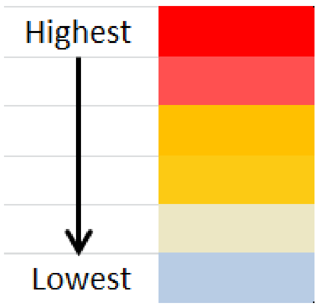

SIDE VIEW
A1 A2 B1 C D E F G H J K L M P R S T
#1 #2 #3 #4 #5 #6 #7 #8 #9 #10 #11 #12
#13 #14 #15 #16
11P 12P 21P 22P 23P 31P 32P 41P 42P
Foward
Aft
TOP VIEW
Top Hold
A1 A2 B1 CR DR ER FR GR HR JR KR LR MR PR RR SR T
#1 #2 #3 #4 #5 #6 #7 #8 #9 #10 #11 #12
A1 A2 B1 CL DL EL FL GL HL JL KL LL ML PL RL SL T
Foward
Aft
Bottom Holds
#13 #14 #15 #16
11P 12P 21P 22P 23P 31P 32P 41P 42P

Max, Min and Averages per Logger (Main Hold)

		LOGGER #1	LOGGER #2	LOGGER #3	LOGGER #4	LOGGER #5	LOGGER #6	LOGGER #7	LOGGER #8	LOGGER #9	LOGGER #10	LOGGER #11	LOGGER #12
Dry Bulb [°C]	MAX	18.50	19.00	18.00	21.00	16.00	18.00	21.00	18.50	16.50	22.00	20.50	21.50
	MIN	13.00	15.00	13.00	17.50	13.00	14.50	18.00	15.50	14.00	17.50	17.00	18.50
	Average	14.27	16.01	14.23	18.57	13.92	15.25	18.42	16.26	14.47	18.42	17.92	18.77
Relative Humidity [%]	MAX	62.50	55.00	62.00	53.50	61.00	63.50	61.50	68.50	64.50	57.50	63.00	59.00
	MIN	50.50	43.50	46.50	39.00	48.00	53.00	52.50	56.50	56.00	42.50	48.50	49.50
	Average	57.07	48.53	52.41	44.72	52.27	56.12	54.97	61.35	59.78	45.09	52.43	52.55
Dew Point [°C]	MAX	10.20	9.80	10.60	11.20	8.50	11.00	13.30	12.40	9.70	13.20	13.20	13.20
	MIN	3.00	3.20	2.50	4.70	2.50	5.00	8.10	7.40	5.60	5.00	6.10	7.70
	Average	5.87	5.16	4.62	6.31	4.30	6.56	9.21	8.81	6.75	6.30	8.04	8.87
Wet Bulb [°C]	MAX	11.43	10.93	11.86	12.50	9.52	12.25	14.75	13.75	10.83	14.65	14.64	14.58
	MIN	3.29	3.52	2.83	5.28	2.83	5.62	9.13	8.25	6.28	5.53	6.79	8.68
	Average	6.55	5.76	5.14	7.06	4.77	7.34	10.31	9.87	7.56	7.04	9.00	9.93

Max, Min and Averages per Logger (Bottom Holds)

		LOGGER #13	LOGGER #14	LOGGER #15	LOGGER #16
Temperature [°C]	MAX	21	21	22	17.5
	MIN	18	18.5	18.5	15.5
	Average	19.65	20.02	21.38	17.05
Relative Humidity [%]	MAX	54.00	56.50	45.50	37.00
	MIN	35.00	29.00	32.00	27.00
	Average	41.88	35.59	35.28	30.14
Dew Point [°C]	MAX	9.50	9.70	7.10	1.20
	MIN	3.20	1.40	4.10	-2.10
	Average	6.30	4.24	5.38	-0.60
Wet Bulb [°C]	MAX	10.63	10.86	7.96	1.43
	MIN	3.56	1.65	4.59	-1.78
	Average	7.05	4.72	6.01	-0.40

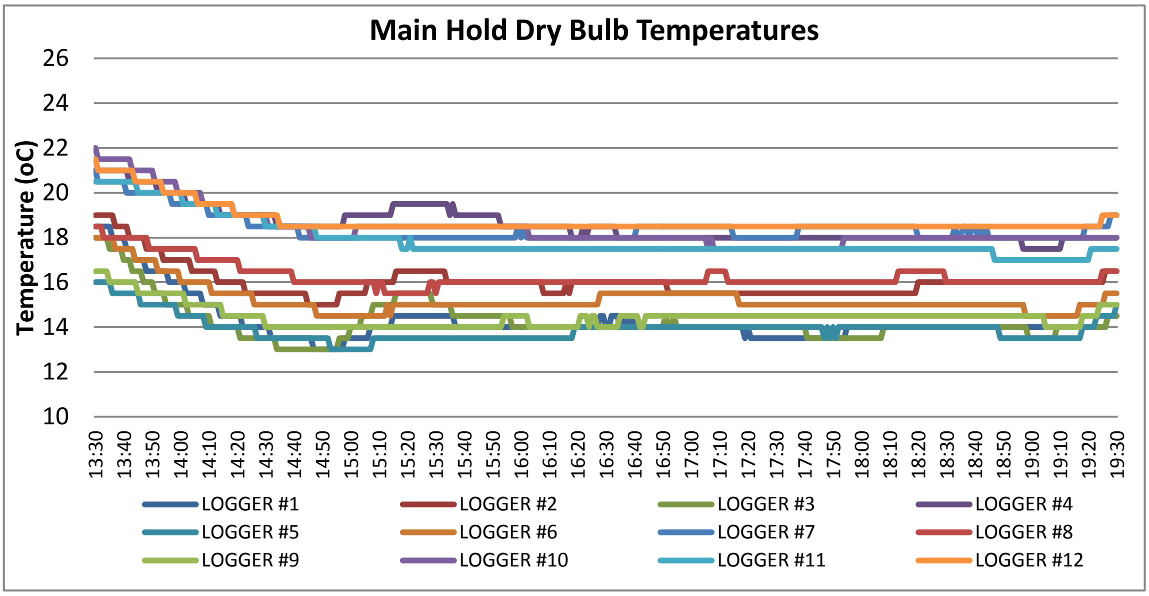


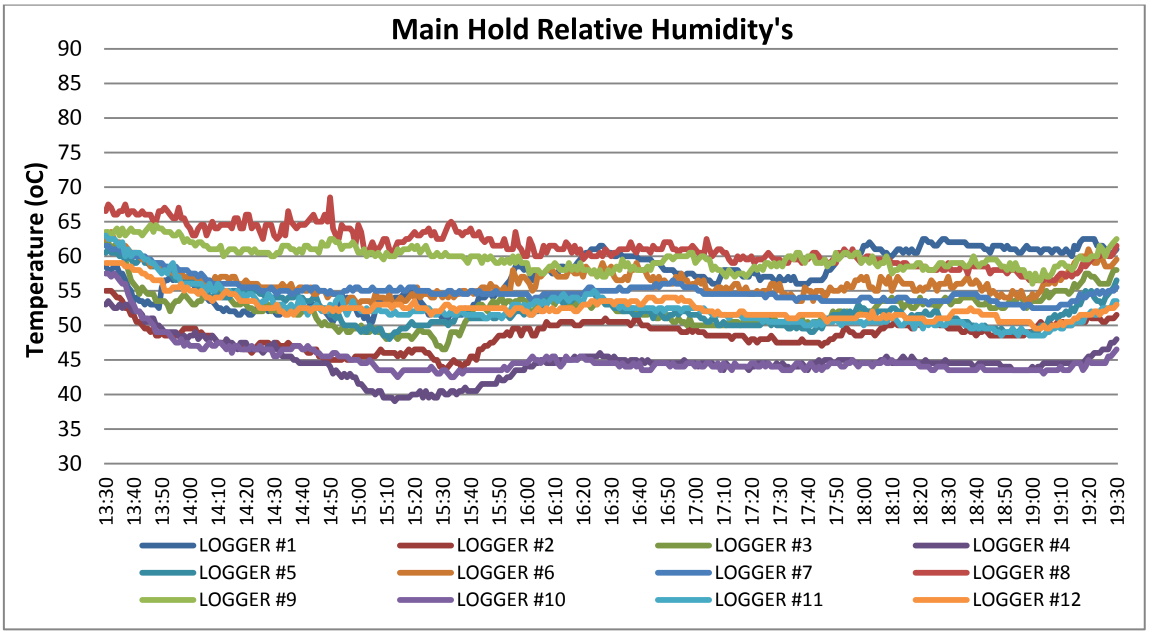
Main Hold Totals (12 loggers)				
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	22.00	68.50	13.30	14.75
LOWEST	13.00	39.00	2.50	2.83
AVERAGE	16.38	53.11	6.73	7.53
ST. DEVIATION	0.75	2.36	1.17	1.31

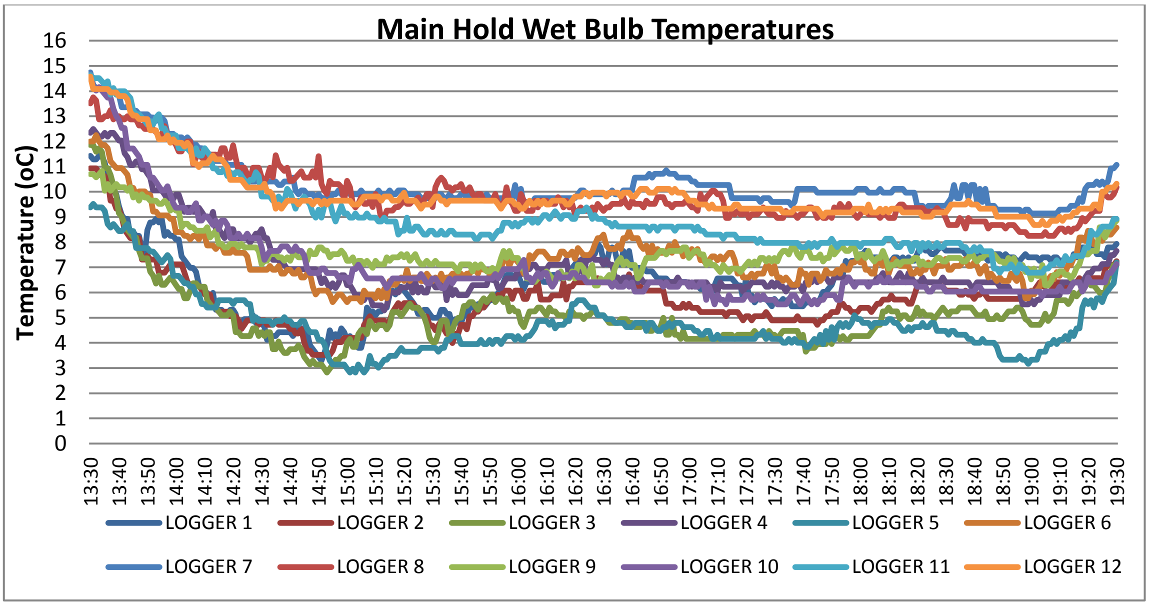
Bottom Hold Totals (4 loggers)				
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	22.00	56.50	9.70	10.86
LOWEST	15.50	27.00	-2.10	-1.78
AVERAGE	19.52	35.72	3.83	4.35
ST. DEVIATION	0.64	3.21	0.97	1.07

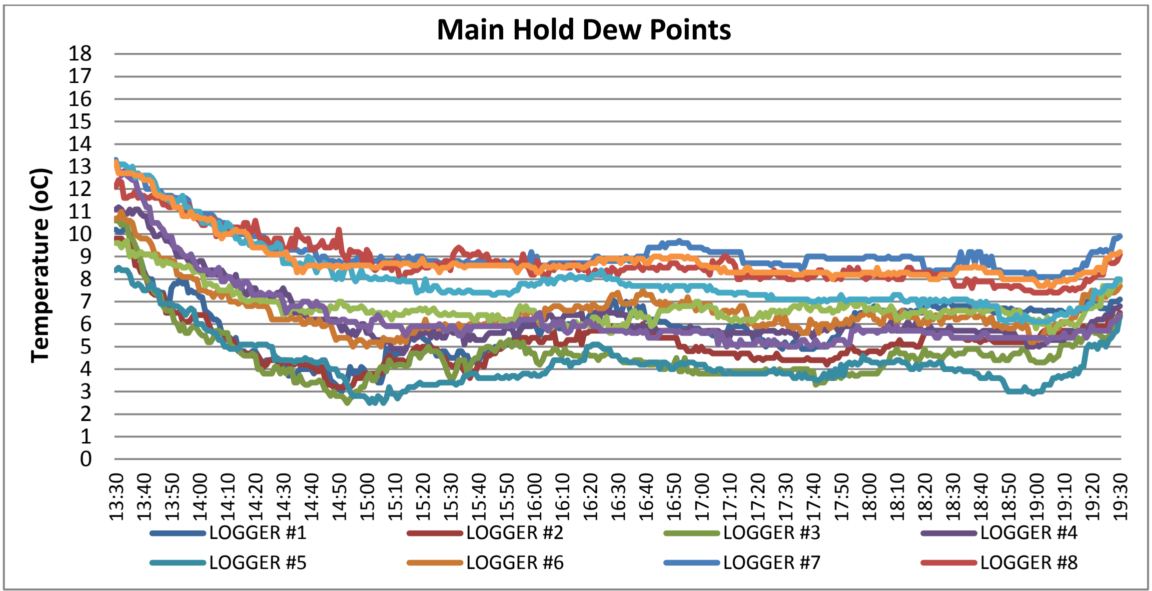
CO_2 Logger CO_2 Concentration [ppm]	
HIGHEST	N/A
LOWEST	N/A
AVERAGE	N/A
ST. DEVIATION	N/A
TREND EQUATION	N/A

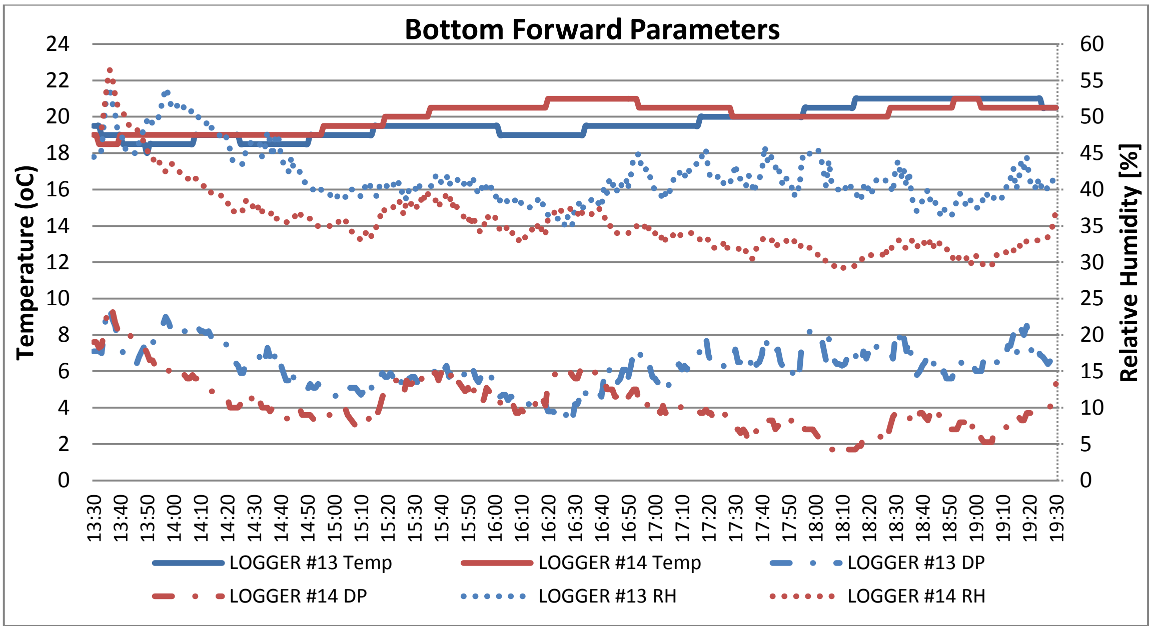
TREND	N/A

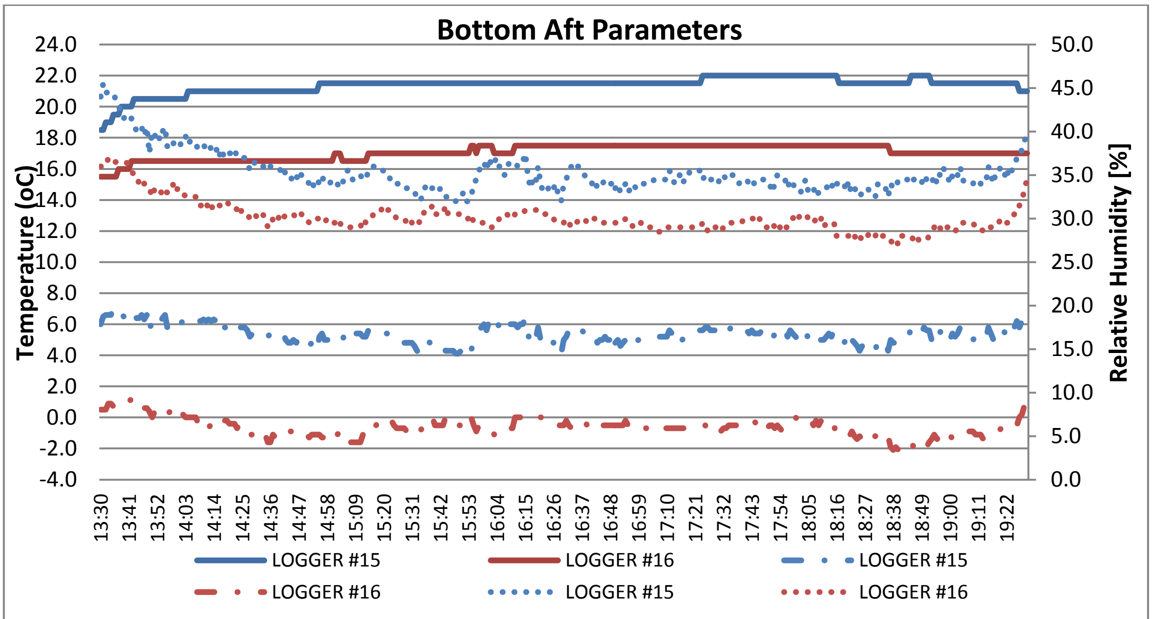

Main Hold Dry Bulb Temperatures
Temperature (oC)
26
24
22
20
18
16
14
12
10
13:30
13:40
13:50
14:00
14:10
14:20
14:30
14:40
14:50
15:00
15:10
15:20
15:30
15:40
15:50
16:00
16:10
16:20
16:30
16:40
16:50
17:00
17:10
17:20
17:30
17:40
17:50
18:00
18:10
18:20
18:30
18:40
18:50
19:00
19:10
19:20
19:30
LOGGER #1
LOGGER #2
LOGGER #3
LOGGER #4
LOGGER #5
LOGGER #6
LOGGER #7
LOGGER #8
LOGGER #9
LOGGER #10
LOGGER #11
LOGGER #12


Main Hold Relative Humidity's
Temperature (oC)
90
85
80
75
70
65
60
55
50
45
40
35
30
13:30
13:40
13:50
14:00
14:10
14:20
14:30
14:40
14:50
15:00
15:10
15:20
15:30
15:40
15:50
16:00
16:10
16:20
16:30
16:40
16:50
17:00
17:10
17:20
17:30
17:40
17:50
18:00
18:10
18:20
18:30
18:40
18:50
19:00
19:10
19:20
19:30
LOGGER #1
LOGGER #2
LOGGER #3
LOGGER #4
LOGGER #5
LOGGER #6
LOGGER #7
LOGGER #8
LOGGER #9
LOGGER #10
LOGGER #11
LOGGER #12


Main Hold Wet Bulb Temperatures
Temperature (oC)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
13:30
13:40
13:50
14:00
14:10
14:20
14:30
14:40
14:50
15:00
15:10
15:20
15:30
15:40
15:50
16:00
16:10
16:20
16:30
16:40
16:50
17:00
17:10
17:20
17:30
17:40
17:50
18:00
18:10
18:20
18:30
18:40
18:50
19:00
19:10
19:20
19:30
LOGGER 1
LOGGER 2
LOGGER 3
LOGGER 4
LOGGER 5
LOGGER 6
LOGGER 7
LOGGER 8
LOGGER 9
LOGGER 10
LOGGER 11
LOGGER 12

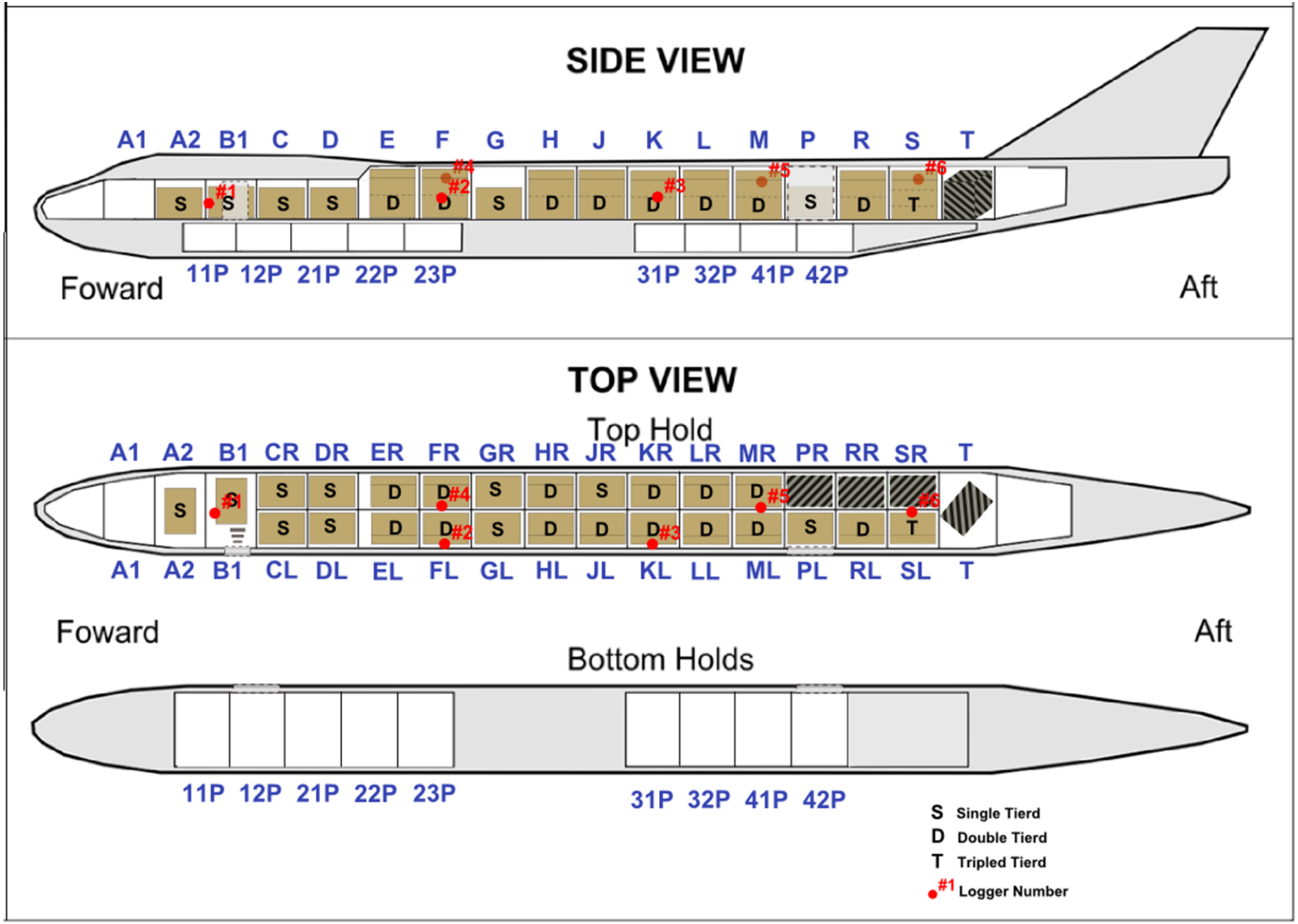

Main Hold Dew Points
Temperature (oC)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
13:30
13:40
13:50
14:00
14:10
14:20
14:30
14:40
14:50
15:00
15:10
15:20
15:30
15:40
15:50
16:00
16:10
16:20
16:30
16:40
16:50
17:00
17:10
17:20
17:30
17:40
17:50
18:00
18:10
18:20
18:30
18:40
18:50
19:00
19:10
19:20
19:30
LOGGER #1
LOGGER #2
LOGGER #3
LOGGER #4
LOGGER #5
LOGGER #6
LOGGER #7
LOGGER #8


Bottom Forward Parameters
Temperature (oC)
24
22
20
18
16
14
12
10
8
6
4
2
0
Relative Humidity [%]
60
55
50
45
40
35
30
25
20
15
10
5
0
13:30
13:40
13:50
14:00
14:10
14:20
14:30
14:40
14:50
15:00
15:10
15:20
15:30
15:40
15:50
16:00
16:10
16:20
16:30
16:40
16:50
17:00
17:10
17:20
17:30
17:40
17:50
18:00
18:10
18:20
18:30
18:40
18:50
19:00
19:10
19:20
19:30
LOGGER #13 Temp
LOGGER #14 Temp
LOGGER #13 DP
LOGGER #14 DP
LOGGER #13 RH
LOGGER #14 RH


Bottom Aft Parameters
Temperature (oC)
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
Relative Humidity [%]
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
13:30
13:41
13:52
14:03
14:14
14:25
14:36
14:47
14:58
15:09
15:20
15:31
15:42
15:53
16:04
16:15
16:26
16:37
16:48
16:59
17:10
17:21
17:32
17:43
17:54
18:05
18:16
18:27
18:38
18:49
19:00
19:11
19:22
LOGGER #15
LOGGER #16
LOGGER #15
LOGGER #16
LOGGER #15
LOGGER #16

Appendix A7. Flight Number 7 information:

Flight Number 7	
Flight Info	
Date	30/11/2013
Type of Aircraft	Boeing 747-400 Freighter
Departure	Sydney, Australia
Destination	Kuala Lumpur, Malaysia
Departure Time	12:30pm [1230] (EADT)
Arrival Time	8:15pm [2015] (EADT) / 5:15pm [1715] (local time)
Flight Time	8 hrs
Stop Over	N/A
Set Temperatures	Main = 17^{o}C
	Bottom Forward = 17^{o}C
	Bottom Aft = 17^{o}C
Holds Utilised	Main = 83%
	Bottom Forward = 0%
	Bottom Aft = 0%
Period of Loading	11:00am – 12:00pm
Aircraft Doors Closed	12:15pm
Consignment Info	
Total Number of Animals	256
Type of Animal	Cattle – 196
	Goats – 60
Average Age of Animals	Cattle - 18 months
	Goats - 12 months
Average Live Weight	Cattle - 200 kg
	Goats - 50 kg
Crate Info	
Total Number of Crates	25
Single Tiered	10
Double Tiered	14
Triple Tiered	1
Average Number of Head per Tier	Cattle - 5
	Goats - 20
Logging Info	
Number of Loggers Used	6
Top Hold Loggers	6 [#1, #2, #3, #4, #5, #6]
Bottom Forward Loggers	0
Bottom Aft Loggers	0
CO_2 Logger	Main Hold; alternating positions (HL, LL, SL, LR, HR, DR)

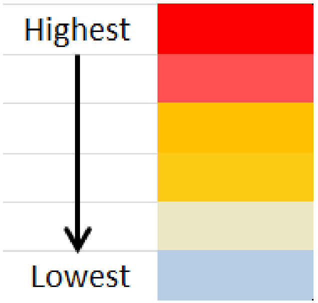

SIDE VIEW
A1 A2 B1 C D E F G H J K L M P R S T
S S S S D D S D D D D D S D T
#1 #2 #3 #4 #5 #6
11P 12P 21P 22P 23P 31P 32P 41P 42P
Foward
Aft
TOP VIEW
Top Hold
A1 A2 B1 CR DR ER FR GR HR JR KR LR MR PR RR SR T
A1 A2 B1 CL DL EL FL GL HL JL KL LL ML PL RL SL T
Foward
Aft
Bottom Holds
11P 12P 21P 22P 23P 31P 32P 41P 42P
S Single Tierd
D Double Tierd
T Tripled Tierd
#1 Logger Number

Max, Min and Averages per Logger (Main Hold)

		LOGGER #1	LOGGER #2	LOGGER #3	LOGGER #4	LOGGER #5	LOGGER #6
Dry Bulb [°C]	MAX	26.00	28.50	26.00	25.50	25.00	22.00
	MIN	15.50	15.00	17.00	21.00	19.00	14.00
	Average	17.44	17.85	18.38	22.31	22.13	14.95
Relative Humidity [%]	MAX	72.50	81.50	74.50	69.00	73.00	77.50
	MIN	26.50	22.50	25.00	49.00	53.00	53.00
	Average	45.48	55.45	53.18	53.69	58.19	57.82
Dew Point [°C]	MAX	15.10	17.70	14.80	19.00	19.80	14.50
	MIN	2.90	2.60	4.00	10.30	9.80	4.60
	Average	5.36	8.51	8.49	12.44	13.52	6.71
Wet Bulb [°C]	MAX	16.57	19.18	16.33	20.55	21.32	15.99
	MIN	3.16	2.85	4.50	11.57	10.93	5.09
	Average	5.97	9.52	9.51	13.80	14.93	7.48

Max, Min and Averages per Logger (Bottom Holds)

		N/A	N/A	N/A	N/A
Dry Bulb [°C]	MAX	-	-	-	-
	MIN	-	-	-	-
	Average	-	-	-	-
Relative Humidity [%]	MAX	-	-	-	-
	MIN	-	-	-	-
	Average	-	-	-	-
Dew Point [°C]	MAX	-	-	-	-
	MIN	-	-	-	-
	Average	-	-	-	-
Wet Bulb [°C]	MAX	-	-	-	-
	MIN	-	-	-	-
	Average	-	-	-	-

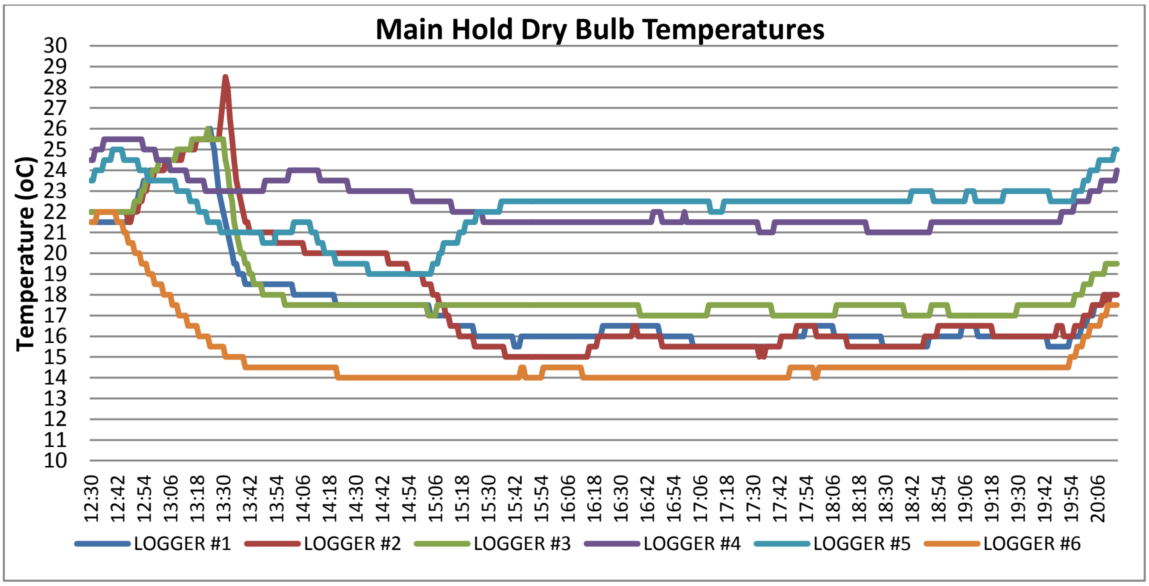


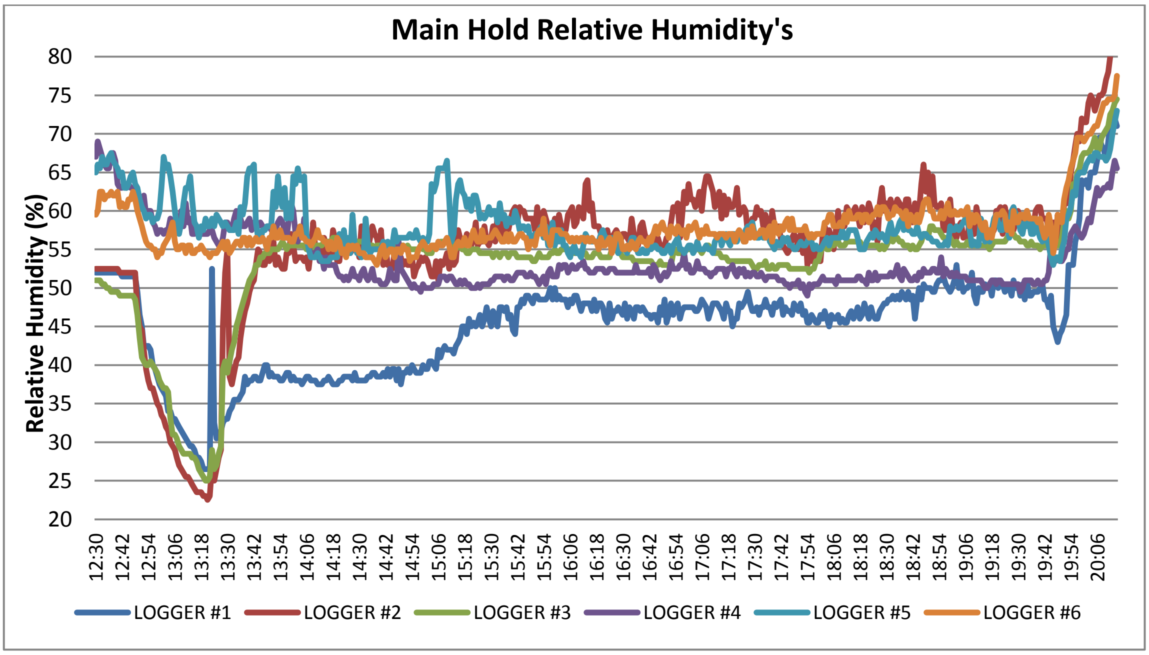
Main Hold Totals (6 loggers)

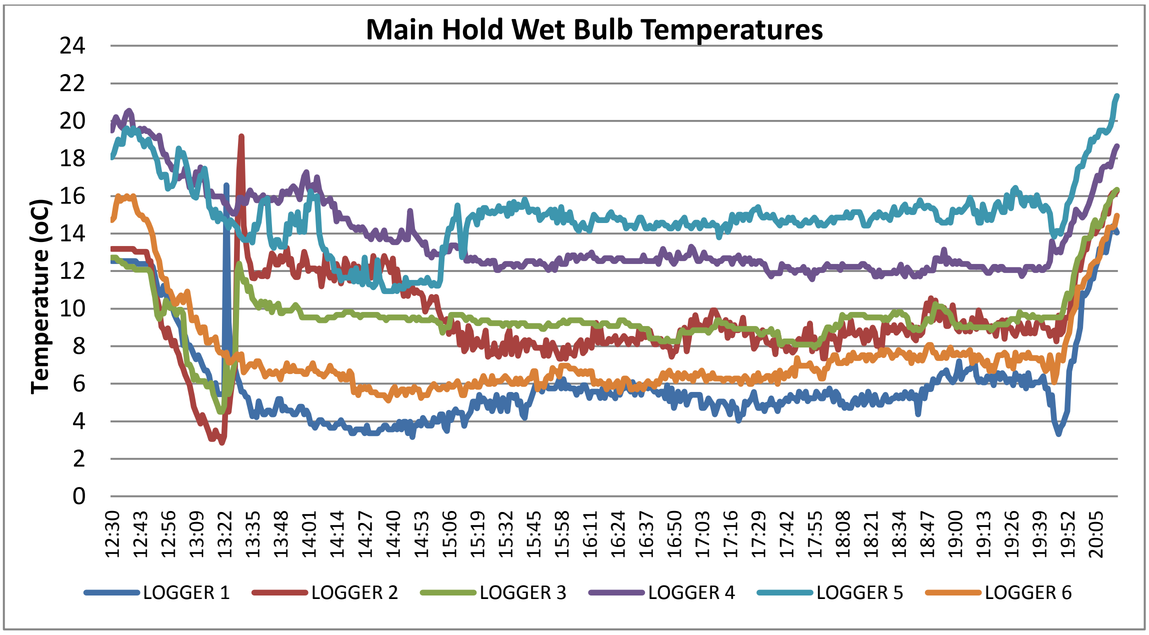
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	28.5	81.50	19.80	21.32
LOWEST	14.00	22.50	2.60	2.85
AVERAGE	18.84	53.97	9.17	10.20
ST. DEVIATION	2.05	5.88	1.94	2.10

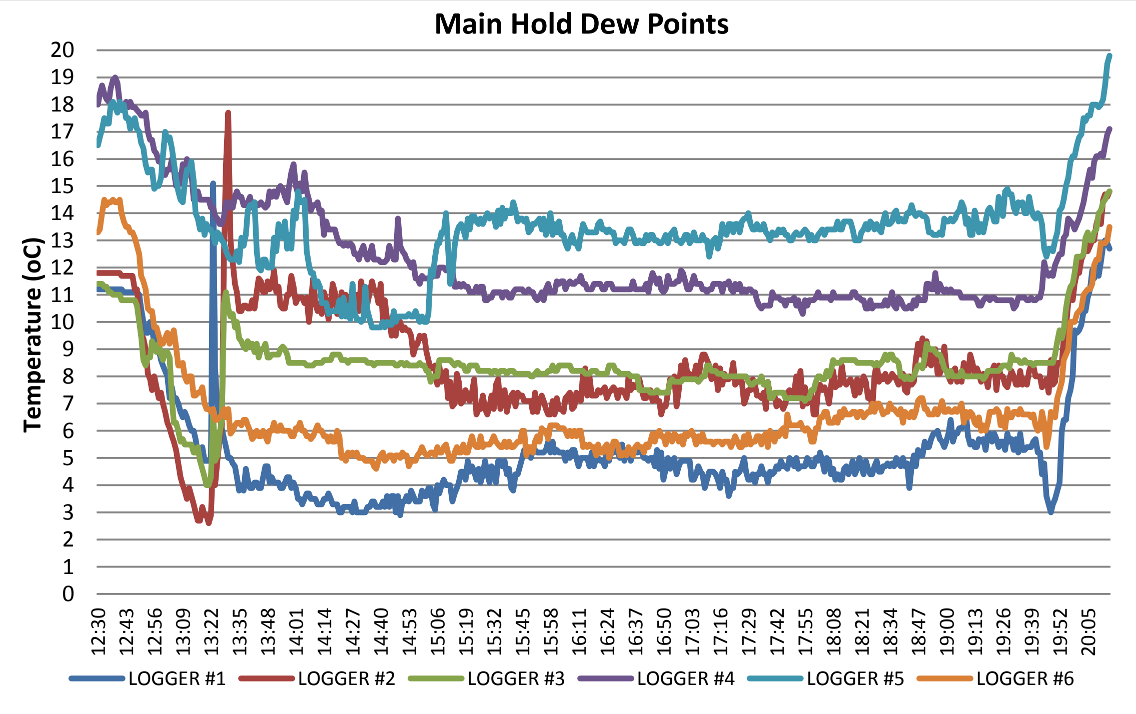
Bottom Hold Totals (0 loggers)				
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	-	-	-	-
LOWEST	-	-	-	-
AVERAGE	-	-	-	-
ST. DEVIATION	-	-	-	-

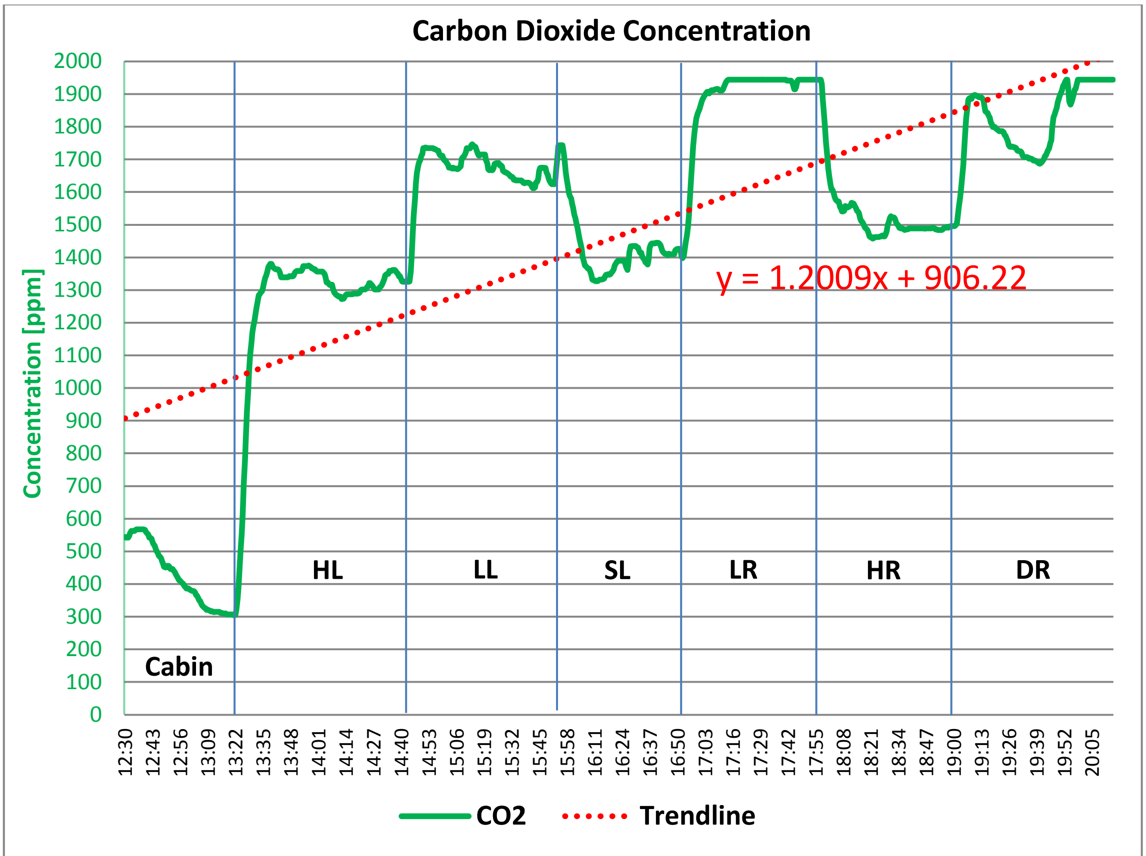
CO_2 Logger **CO_2 Concentration [ppm]**	
HIGHEST	1944.40
LOWEST	304.60
AVERAGE	1465.83
ST. DEVIATION	443.82
TREND EQUATION	y = 1.2009x + 906.22
TREND	**Positive**


Main Hold Dry Bulb Temperatures
Temperature (oC)
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
12:30
12:42
12:54
13:06
13:18
13:30
13:42
13:54
14:06
14:18
14:30
14:42
14:54
15:06
15:18
15:30
15:42
15:54
16:06
16:18
16:30
16:42
16:54
17:06
17:18
17:30
17:42
17:54
18:06
18:18
18:30
18:42
18:54
19:06
19:18
19:30
19:42
19:54
20:06
LOGGER #1
LOGGER #2
LOGGER #3
LOGGER #4
LOGGER #5
LOGGER #6


Main Hold Relative Humidity's
Relative Humidity (%)
80
75
70
65
60
55
50
45
40
35
30
25
20
12:30
12:42
12:54
13:06
13:18
13:30
13:42
13:54
14:06
14:18
14:30
14:42
14:54
15:06
15:18
15:30
15:42
15:54
16:06
16:18
16:30
16:42
16:54
17:06
17:18
17:30
17:42
17:54
18:06
18:18
18:30
18:42
18:54
19:06
19:18
19:30
19:42
19:54
20:06
LOGGER #1
LOGGER #2
LOGGER #3
LOGGER #4
LOGGER #5
LOGGER #6

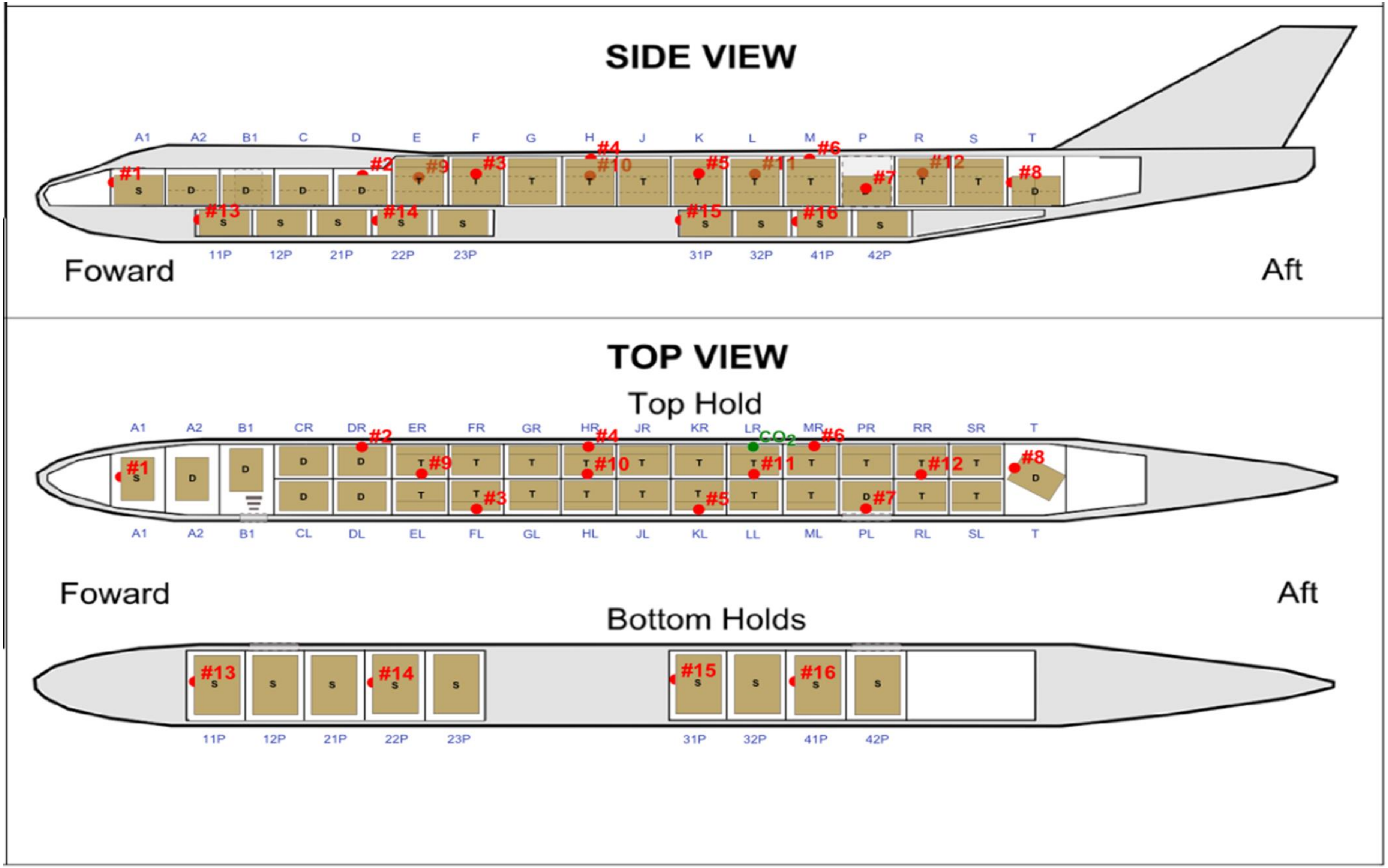

Main Hold Wet Bulb Temperatures
Temperature (oC)
24
22
20
18
16
14
12
10
8
6
4
2
0
12:30
12:43
12:56
13:09
13:22
13:35
13:48
14:01
14:14
14:27
14:40
14:53
15:06
15:19
15:32
15:45
15:58
16:11
16:24
16:37
16:50
17:03
17:16
17:29
17:42
17:55
18:08
18:21
18:34
18:47
19:00
19:13
19:26
19:39
19:52
20:05
LOGGER 1
LOGGER 2
LOGGER 3
LOGGER 4
LOGGER 5
LOGGER 6


Main Hold Dew Points
Temperature (oC)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
12:30 12:43 12:56 13:09 13:22 13:35 13:48 14:01 14:14 14:27 14:40 14:53 15:06 15:19 15:32 15:45 15:58 16:11 16:24 16:37 16:50 17:03 17:16 17:29 17:42 17:55 18:08 18:21 18:34 18:47 19:00 19:13 19:26 19:39 19:52 20:05
LOGGER #1
LOGGER #2
LOGGER #3
LOGGER #4
LOGGER #5
LOGGER #6


Carbon Dioxide Concentration
Concentration [ppm]
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
y = 1.2009x + 906.22
Cabin
HL
LL
SL
LR
HR
DR
12:30 12:43 12:56 13:09 13:22 13:35 13:48 14:01 14:14 14:27 14:40 14:53 15:06 15:19 15:32 15:45 15:58 16:11 16:24 16:37 16:50 17:03 17:16 17:29 17:42 17:55 18:08 18:21 18:34 18:47 19:00 19:13 19:26 19:39 19:52 20:05
CO2
Trendline

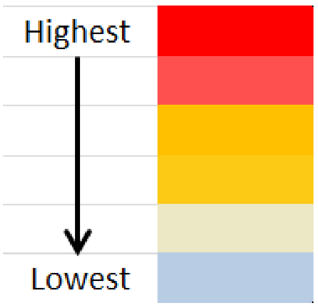
Appendix A8. Flight Number 8 Information:

Flight Number 8	
Flight Info	
Date	20/12/2013
Type of Aircraft	Boeing 747-400 Freighter
Departure	Perth, Australia
Destination	Kuala Lumpur, Malaysia
Departure Time	5:30am [0530] (WST)
Arrival Time	10:30am [1030] (WST)
Flight Time	5hrs
Stop Over	N/A
Set Temperatures	Main = 18^{o}C
	Bottom Forward = 18^{o}C
	Bottom Aft = 18^{o}C
Holds Utilised	Main = 100%
	Bottom Forward = 100%
	Bottom Aft = 100%
Period of Loading	12:00am – 5:00am
Aircraft Doors Closed	5:15am
Consignment Info	
Total Number of Animals	2492
Type of Animal	Sheep – 1480
	Goats – 1012
Average Age of Animals	Sheep - 24 months
	Goats - 24 months
Average Live Weight	Sheep - 34 kg
	Goats - 34 kg
Crate Info	
Total Number of Crates	39
Single Tiered	10
Double Tiered	8
Triple Tiered	21
Average Number of Head per Tier	Sheep - 27
	Goats - 30
Logging Info	
Number of Loggers Used	16
Top Hold Loggers	12 [#1, #2, #3, #4, #5, #6, #7, #8, #9, #10, #11, #12]
Bottom Forward Loggers	2 [#13, #14]
Bottom Aft Loggers	2 [#15, #16]
CO_2 Logger	Main Hold; position LR


SIDE VIEW
A1 A2 B1 C D E F G H J K L M P R S T
#1 #2 #3 #4 #5 #6 #7 #8 #9 #10 #11 #12 #13 #14 #15 #16
11P 12P 21P 22P 23P 31P 32P 41P 42P
Foward
Aft
TOP VIEW
Top Hold
A1 A2 B1 CR DR ER FR GR HR JR KR LR MR PR RR SR T
CO_2
A1 A2 B1 CL DL EL FL GL HL JL KL LL ML PL RL SL T
Foward
Aft
Bottom Holds
11P 12P 21P 22P 23P 31P 32P 41P 42P

Max, Min and Averages per Logger (Main Hold)													
		LOGGER #1	LOGGER #2	LOGGER #4	LOGGER #5	CO_2 LOGGER	LOGGER #6	LOGGER #7	LOGGER #8	LOGGER #9	LOGGER #10	LOGGER #11	LOGGER #12
Dry Bulb [°C]	MAX	22.00	21.00	24.00	27.50	27.28	25.00	27.50	26.50	28.00	28.50	29.00	28.00
	MIN	8.50	11.50	16.00	18.50	20.79	16.50	23.00	19.00	19.50	22.00	23.00	24.50
	Average	11.71	13.50	18.32	20.86	23.13	18.02	24.55	21.17	22.00	24.44	25.30	25.91
Relative Humidity [%]	MAX	76.00	87.00	88.00	79.50	77.88	88.00	73.50	82.00	68.00	71.00	70.00	72.00
	MIN	42.00	50.00	61.00	60.50	51.84	63.50	54.00	64.00	49.00	53.50	50.50	54.00
	Average	50.31	57.82	68.80	67.05	59.37	68.73	58.66	68.11	54.73	59.19	55.55	58.25
Dew Point [°C]	MAX	16.40	17.60	21.90	22.20	22.67	21.20	22.30	21.70	21.40	22.70	23.00	22.50
	MIN	-2.60	1.70	9.60	11.30	11.94	9.60	13.20	12.30	9.00	13.40	12.60	14.70
	Average	1.62	5.26	12.46	14.50	14.98	12.17	15.89	15.04	12.44	15.93	15.72	17.04
Wet Bulb [°C]	MAX	17.91	19.14	23.34	23.67	23.76	22.68	23.78	23.11	22.89	24.15	24.39	23.91
	MIN	-2.19	1.94	10.70	12.62	12.52	10.70	14.62	13.65	10.05	14.79	14.01	16.22
	Average	2.03	5.83	13.79	15.93	15.89	13.48	17.37	16.51	13.75	17.42	17.20	18.55

Max, Min and Averages per Logger (Bottom Holds)					
		LOGGER #13	LOGGER #14	LOGGER #15	LOGGER #16
Dry Bulb [°C]	MAX	23.5	24	24.5	24.5
	MIN	19	21	20	17.5
	Average	22.63	22.00	22.42	22.83
Relative Humidity [%]	MAX	68.00	62.50	56.00	65.00
	MIN	43.00	29.00	32.50	39.50
	Average	49.58	35.40	42.74	51.45
Dew Point [°C]	MAX	14.90	15.00	12.40	15.00
	MIN	9.60	3.20	5.60	4.00
	Average	11.46	5.71	9.00	12.26
Wet Bulb [°C]	MAX	16.39	16.47	13.74	16.47
	MIN	10.78	3.57	6.30	4.48
	Average	12.77	6.36	10.07	13.61

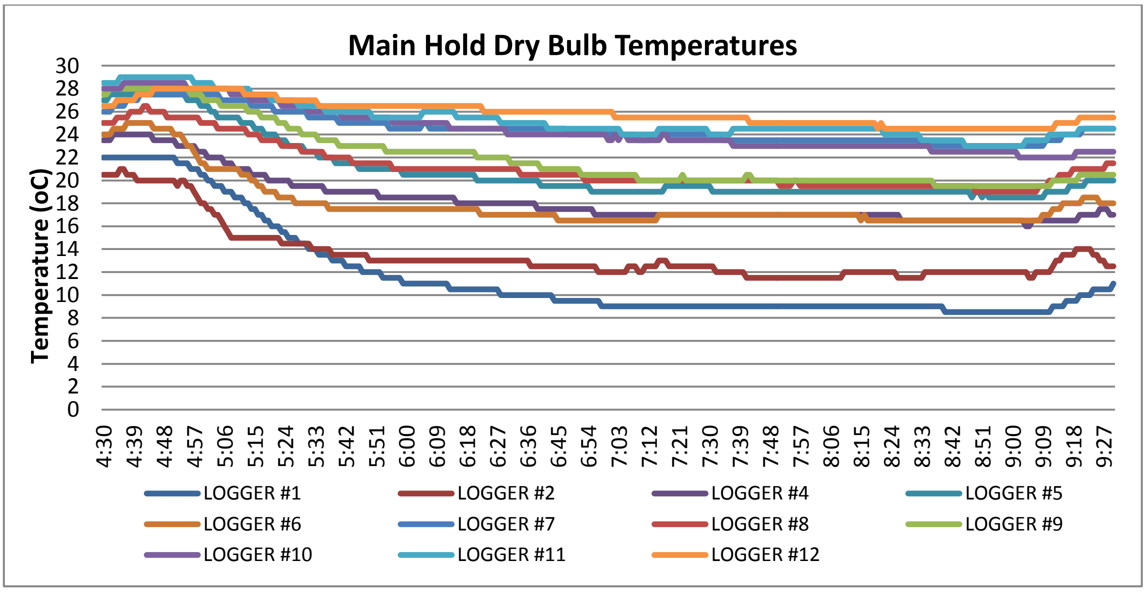


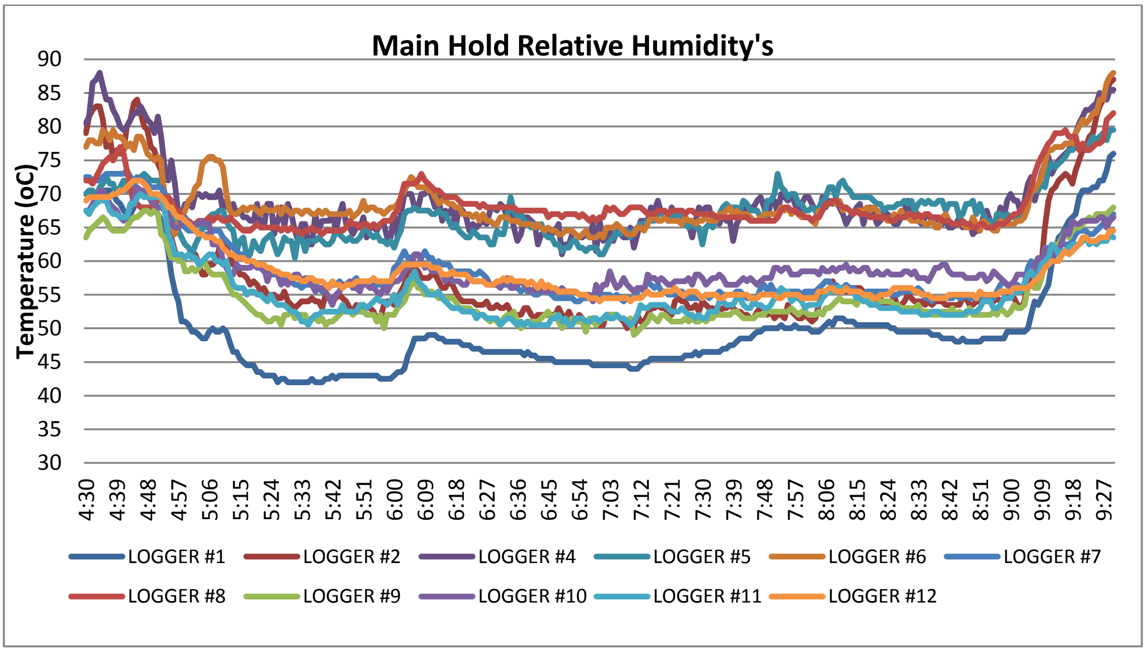
Main Hold Totals (11 loggers)

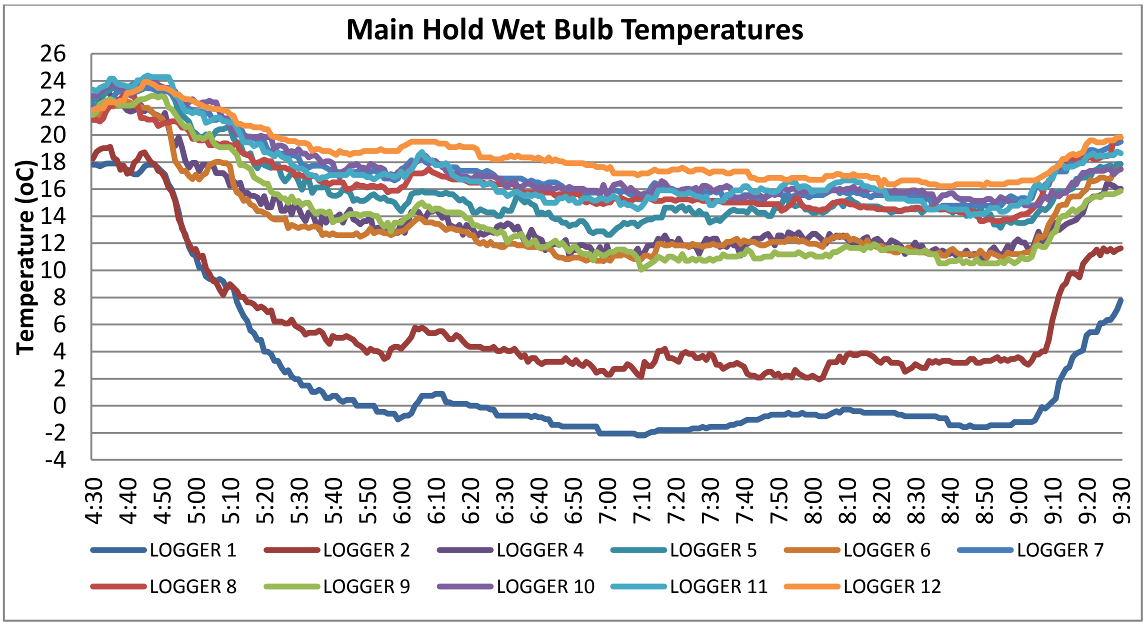
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	29.00	88.00	23.00	24.39
LOWEST	8.50	42.00	-2.60	-2.19
AVERAGE	20.74	60.55	12.75	13.98
ST. DEVIATION	2.24	5.44	3.00	3.11

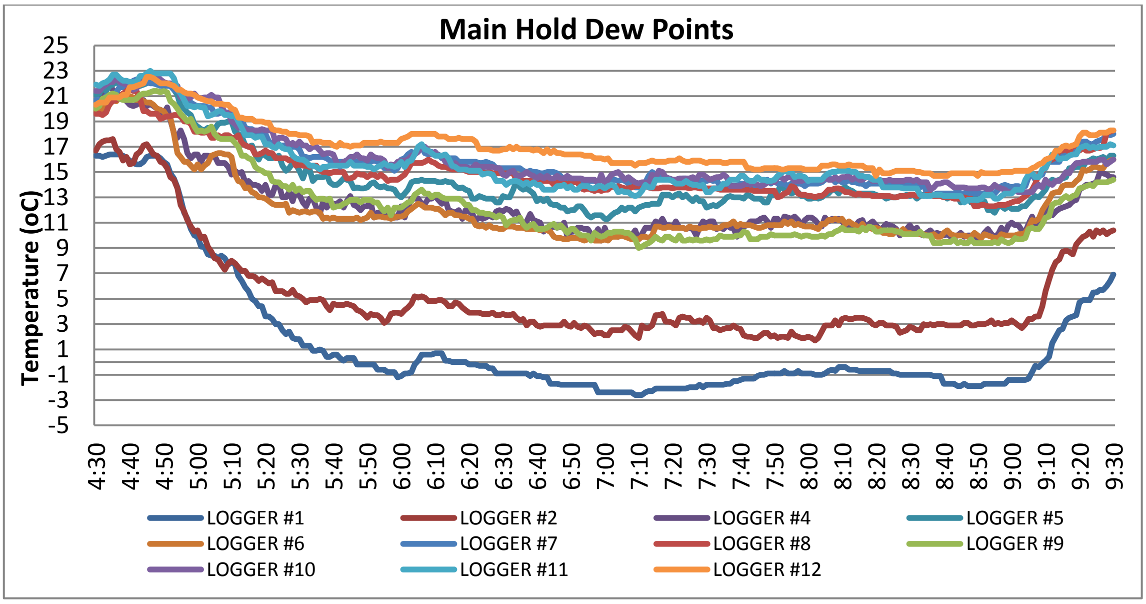
Bottom Hold Totals (4 loggers)				
	Temperature (°C)	Humidity (%rh)	dew point (°C)	Wet Bulb (°C)
HIGHEST	24.50	68.00	15.00	16.47
LOWEST	17.50	29.00	3.20	3.57
AVERAGE	22.47	44.79	9.61	10.70
ST. DEVIATION	1.18	6.11	1.88	2.07

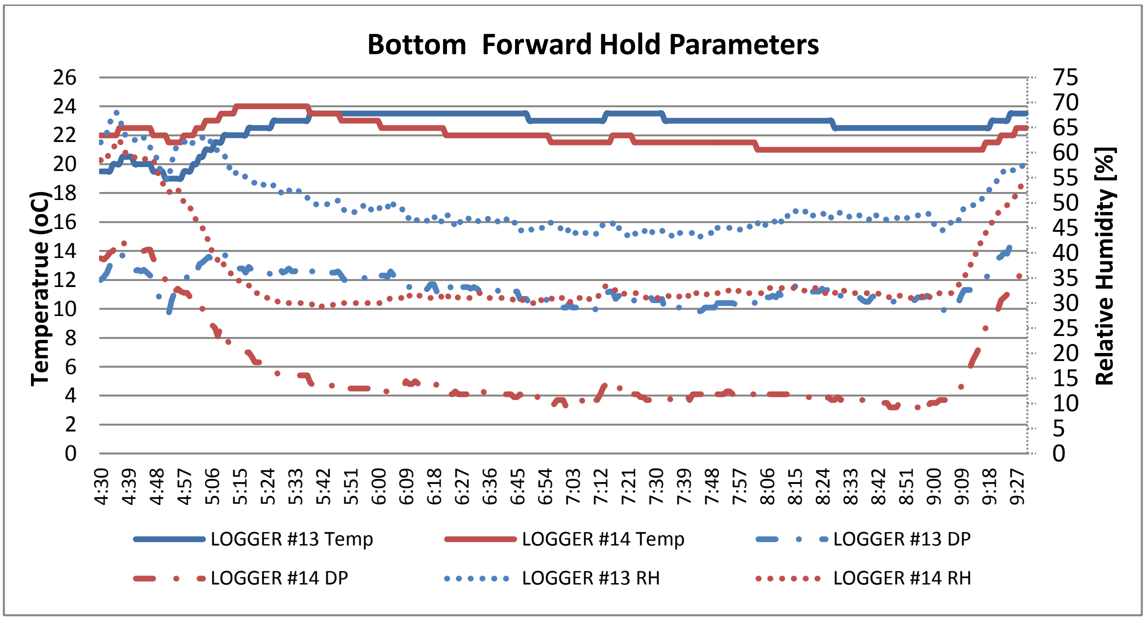
CO_2 Logger CO_2 Concentration [ppm]	
HIGHEST	1963.50
LOWEST	1292.12
AVERAGE	1634.77
ST. DEVIATION	209.76
TREND EQUATION	y = 0.1642x + 1585.4
TREND	**Positive**

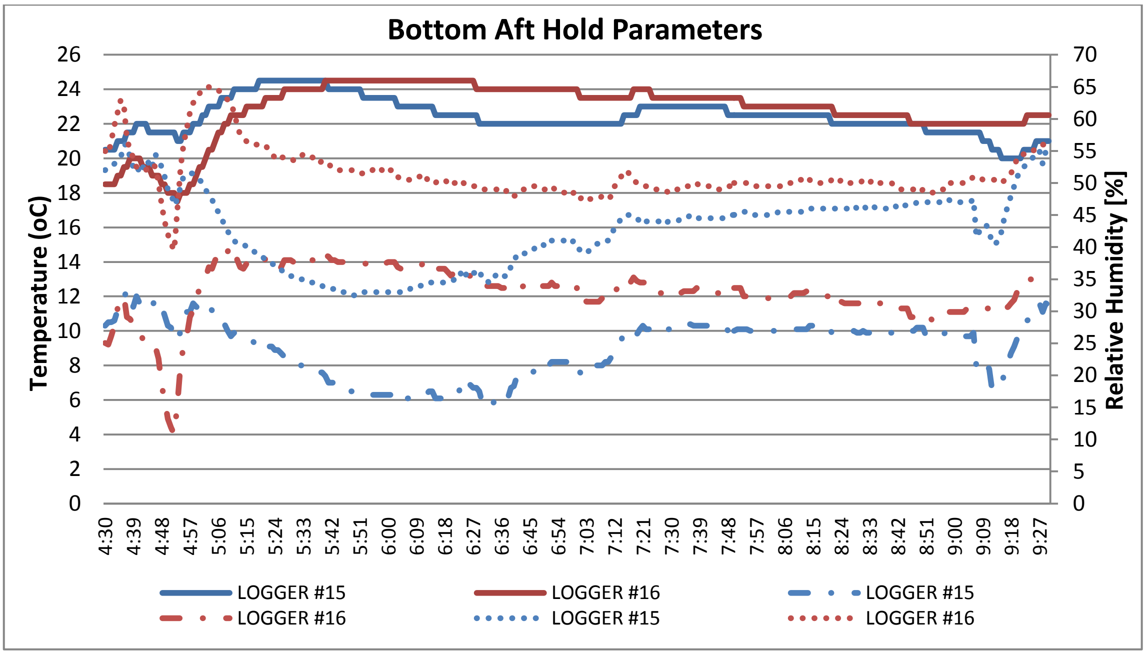

Main Hold Dry Bulb Temperatures
Temperature (oC)
LOGGER #1
LOGGER #2
LOGGER #4
LOGGER #5
LOGGER #6
LOGGER #7
LOGGER #8
LOGGER #9
LOGGER #10
LOGGER #11
LOGGER #12

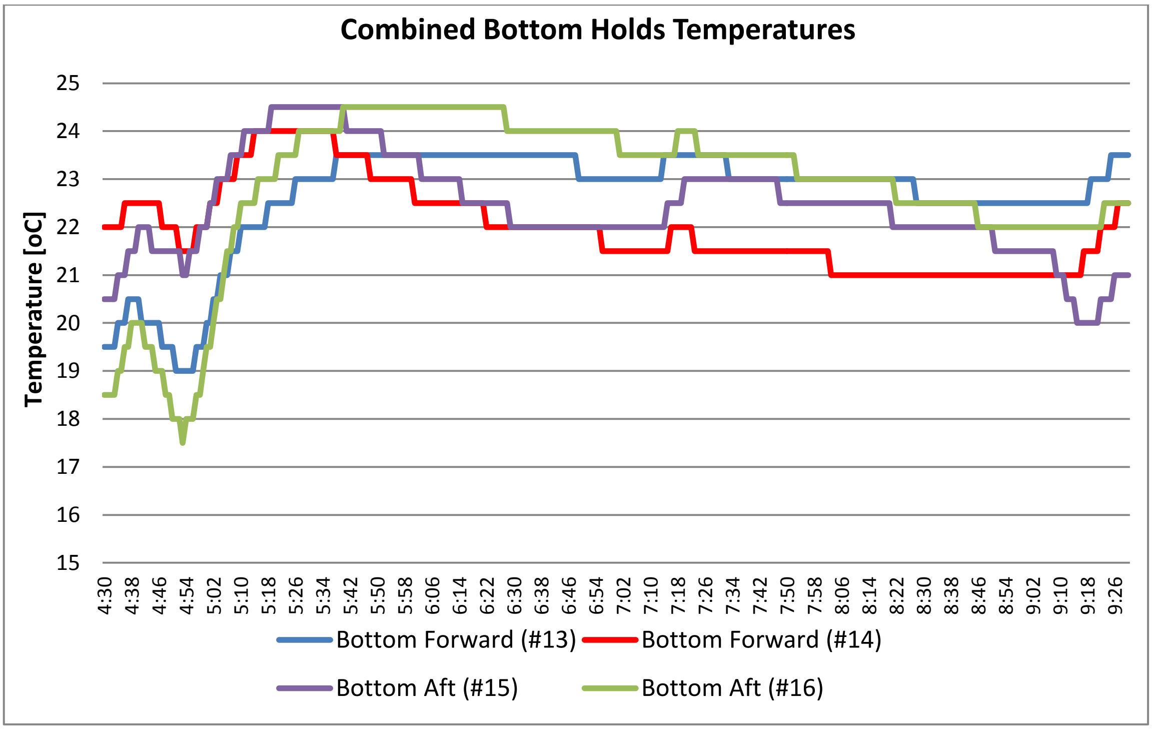

Main Hold Relative Humidity's
Temperature (oC)
LOGGER #1
LOGGER #2
LOGGER #4
LOGGER #5
LOGGER #6
LOGGER #7
LOGGER #8
LOGGER #9
LOGGER #10
LOGGER #11
LOGGER #12

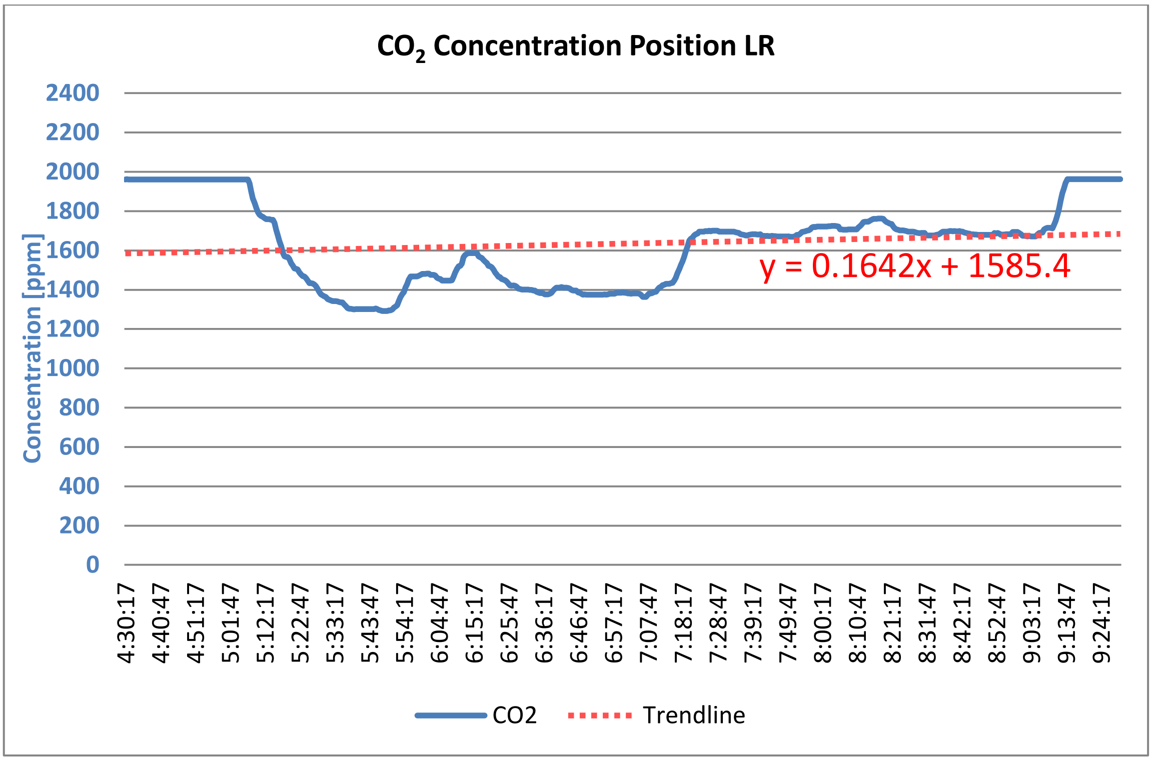

Main Hold Wet Bulb Temperatures
Temperature (oC)
LOGGER 1
LOGGER 2
LOGGER 4
LOGGER 5
LOGGER 6
LOGGER 7
LOGGER 8
LOGGER 9
LOGGER 10
LOGGER 11
LOGGER 12


Main Hold Dew Points
Temperature (oC)
25
23
21
19
17
15
13
11
9
7
5
3
1
-1
-3
-5
4:30
4:40
4:50
5:00
5:10
5:20
5:30
5:40
5:50
6:00
6:10
6:20
6:30
6:40
6:50
7:00
7:10
7:20
7:30
7:40
7:50
8:00
8:10
8:20
8:30
8:40
8:50
9:00
9:10
9:20
9:30
LOGGER #1
LOGGER #2
LOGGER #4
LOGGER #5
LOGGER #6
LOGGER #7
LOGGER #8
LOGGER #9
LOGGER #10
LOGGER #11
LOGGER #12


Bottom Forward Hold Parameters
Temperatrue (oC)
Relative Humidity [%]
26
24
22
20
18
16
14
12
10
8
6
4
2
0
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
4:30
4:39
4:48
4:57
5:06
5:15
5:24
5:33
5:42
5:51
6:00
6:09
6:18
6:27
6:36
6:45
6:54
7:03
7:12
7:21
7:30
7:39
7:48
7:57
8:06
8:15
8:24
8:33
8:42
8:51
9:00
9:09
9:18
9:27
LOGGER #13 Temp
LOGGER #14 Temp
LOGGER #13 DP
LOGGER #14 DP
LOGGER #13 RH
LOGGER #14 RH


Bottom Aft Hold Parameters
Temperature (oC)
Relative Humidity [%]
26
24
22
20
18
16
14
12
10
8
6
4
2
0
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
4:30
4:39
4:48
4:57
5:06
5:15
5:24
5:33
5:42
5:51
6:00
6:09
6:18
6:27
6:36
6:45
6:54
7:03
7:12
7:21
7:30
7:39
7:48
7:57
8:06
8:15
8:24
8:33
8:42
8:51
9:00
9:09
9:18
9:27
LOGGER #15
LOGGER #16
LOGGER #15
LOGGER #16
LOGGER #15
LOGGER #16

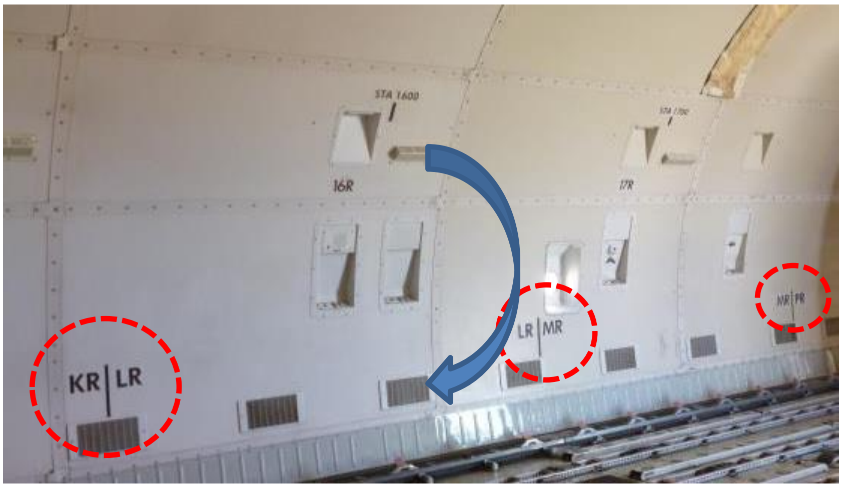

Combined Bottom Holds Temperatures
Temperature [oC]
25
24
23
22
21
20
19
18
17
16
15
4:30
4:38
4:46
4:54
5:02
5:10
5:18
5:26
5:34
5:42
5:50
5:58
6:06
6:14
6:22
6:30
6:38
6:46
6:54
7:02
7:10
7:18
7:26
7:34
7:42
7:50
7:58
8:06
8:14
8:22
8:30
8:38
8:46
8:54
9:02
9:10
9:18
9:26
Bottom Forward (#13)
Bottom Forward (#14)
Bottom Aft (#15)
Bottom Aft (#16)


CO2 Concentration Position LR
Concentration [ppm]
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
y = 0.1642x + 1585.4
4:30:17
4:40:47
4:51:17
5:01:47
5:12:17
5:22:47
5:33:17
5:43:47
5:54:17
6:04:47
6:15:17
6:25:47
6:36:17
6:46:47
6:57:17
7:07:47
7:18:17
7:28:47
7:39:17
7:49:47
8:00:17
8:10:47
8:21:17
8:31:47
8:42:17
8:52:47
9:03:17
9:13:47
9:24:17
CO2
Trendline

Appendix B. Photographs

Appendix B1: Temperature and humidity logger attached to the roof of a single tiered crate.

Appendix B2: Ventilation shaft next to a single tiered crate with a temperature and humidity logger attached.



Appendix B3: Fuselage of main hold showing direction of air flow from ventilation to exhaust shaft. Crate positioning's (KR-LR-MR-PR).

Appendix B4: Layout of single and double tiered crates. Note the space between crates down the centre of the hold. This area was identified as "Hot Spots", where air flow and therefore heat flux would be lower.

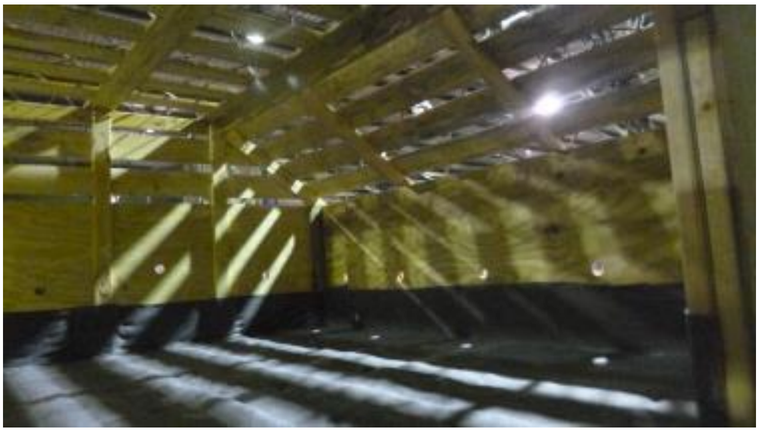
Appendix B5: Distance between crates and fuselage wall of the main hold. Exhaust vents run down the hold near the floor.

Appendix B6: Available head space for cattle in the bottom tier of a double tier crate.

Appendix B7: Available head space for goats in the bottom tier of a triple tier crate. Air flow through these bottom tiers will be reduced due to the enclosed area.

Appendix B8: Single, double and triple tiered crates awaiting use at the terminal.

Appendix B9: Internal area of a single tiered crate.



Appendix B10: Internal area of the top tier of a double tiered crate.

Appendix B11: Animals being loaded into a double tiered crate.

Appendix B12: Single tiered crate with attached logger waiting to be loaded onto aircraft.

Appendix B13: Double tiered crate waiting to be loaded onto the aircraft.

Appendix B14: Triple tier crate waiting to be loaded onto aircraft.

Appendix B15: Bottom aft hold cargo door opened for loading of single tiered crates.

Appendix B16: Loading of single tiered crates through the main hold cargo door at the aft of the aircraft.

Appendix B17: View of the aft of the main hold showing cargo door access.

Appendix B18: Loading of a triple tiered crate through the cargo door of the main hold.

Appendix B19: Positioning of a double tiered crate within the main hold.

Appendix B20: Positioning of triple tiered crates into the main hold.

Appendix C. Validation Comparison Tables

ORIGINAL SETTINGS

	MAIN						FORWARD						AFT					
FLIGHT	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]
		Model Output	26	45	18	2668		Model Output	15	20	5	1103		Model Output	16	21	5	1150
1. Syd-Jap - Cattle	100%	Real Time Data	22	77	19	N/A	100%	Real Time Data	23	50	13	N/A	100%	Real Time Data	25	57	18	N/A
		Difference	-4	32	1	N/A		Difference	8	30	8	N/A		Difference	9	36	13	N/A
		Model Output	27	49	20	2844		Model Output	15	20	4	1060		Model Output	15	20	5	1104
2. Mel-Ind - Cattle	100%	Real Time Data	23	64	27	N/A	100%	Real Time Data	22	72	18	N/A	100%	Real Time Data	23	56	15	N/A
		Difference	-4	15	7	N/A		Difference	7	52	14	N/A		Difference	8	36	10	N/A
		Model Output	28	55	22	2864		Model Output	14	19	4	927		Model Output	12	18	2	994
3. Syd-Mal - Cattle	100%	Real Time Data	20	74	16	N/A	100%	Real Time Data	19	49	9	N/A	100%	Real Time Data	22	42	9	N/A
		Difference	-8	19	-6	N/A		Difference	5	30	5	N/A		Difference	10	24	7	N/A
		Model Output	30	78	28	4041		Model Output	13	19	3	881		Model Output	14	19	4	916
4. Mel-Chi - Sheep	96%	Real Time Data	20	66	15	N/A	100%	Real Time Data	N/A	N/A	N/A	N/A	100%	Real Time Data	N/A	N/A	N/A	N/A
		Difference	-10	-12	-13	N/A		Difference	#VALUE!	#VALUE!	#VALUE!	N/A		Difference	#VALUE!	#VALUE!	#VALUE!	N/A
		Model Output	23	36	14	1787		Model Output	0	0	0	0		Model Output	0	0	0	0
5. Syd-Mal - Goats	56%	Real Time Data	18	58	11	N/A	0%	Real Time Data	0	0	0	0	0%	Real Time Data	0	0	0	0
		Difference	-5	22	-3	0		Difference	0	0	0	0		Difference	0	0	0	0
		Model Output	25	40	16	2335		Model Output	14	19	4	986		Model Output	14	19	4	1026
6. Syd-Ind - Cattle	100%	Real Time Data	16	53	8	N/A	100%	Real Time Data	20	39	6	N/A	100%	Real Time Data	19	33	3	N/A
		Difference	-9	13	-8	N/A		Difference	6	20	2	N/A		Difference	5	14	-1	N/A
		Model Output	17	26	7	1209		Model Output	0	0	0	0		Model Output	0	0	0	0
7. Syd-Mal - Mix	83%	Real Time Data	18	54	10	1466	0%	Real Time Data	0	0	0	0	0%	Real Time Data	0	0	0	0
		Difference	1	28	3	257		Difference	0	0	0	0		Difference	0	0	0	0
		Model Output	31	95	31	4955		Model Output	15	20	4	974		Model Output	16	21	5	1056
8. Per-Mal - Mix		Real Time Data	21	61	14	1635		Real Time Data	22	43	10	N/A		Real Time Data	23	47	12	N/A
		Difference	-10	-34	-17	-3320		Difference	7	23	6	N/A		Difference	7	26	7	N/A
AVERAGE DIFFERENCE			-6	10	-5	-1532			7	31	7	N/A			8	27	7	N/A

Excitement Factor = 0.2

	MAIN						FORWARD						AFT					
FLIGHT	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]
		Model Output	27	49	20	2890		Model Output	16	21	6	1182		Model Output	17	21	6	1233
1. Syd-Jap - Cattle	100%	Real Time Data	22	77	19	N/A	100%	Real Time Data	23	50	13	N/A	100%	Real Time Data	25	57	18	N/A
		Difference	-5	28	-1	N/A		Difference	7	29	7	N/A		Difference	8	36	12	N/A
		Model Output	27	53	21	3082		Model Output	16	21	5	1060		Model Output	16	21	6	1183
2. Mel-Ind - Cattle	100%	Real Time Data	23	64	27	N/A	100%	Real Time Data	22	72	18	N/A	100%	Real Time Data	23	56	15	N/A
		Difference	-4	11	6	N/A		Difference	6	51	13	N/A		Difference	7	35	9	N/A
		Model Output	28	60	23	3479		Model Output	15	20	5	1087		Model Output	13	18	3	935
3. Syd-Mal - Cattle	100%	Real Time Data	20	74	16	N/A	100%	Real Time Data	19	49	9	N/A	100%	Real Time Data	22	42	9	N/A
		Difference	-8	14	-7	N/A		Difference	4	29	4	N/A		Difference	9	24	6	N/A
		Model Output	30	84	29	4358		Model Output	14	19	4	939		Model Output	15	20	4	977
4. Mel-Chi - Sheep	96%	Real Time Data	20	66	15	N/A	100%	Real Time Data	N/A	N/A	N/A	N/A	100%	Real Time Data	N/A	N/A	N/A	N/A
		Difference	-10	-18	-14	N/A		Difference	#VALUE!	#VALUE!	#VALUE!	N/A		Difference	#VALUE!	#VALUE!	#VALUE!	N/A
		Model Output	24	39	15	1928		Model Output	0	0	0	0		Model Output	0	0	0	0
5. Syd-Mal - Goats	56%	Real Time Data	18	58	11	N/A	0%	Real Time Data	0	0	0	0	0%	Real Time Data	0	0	0	0
		Difference	-6	19	-4	0		Difference	0	0	0	0		Difference	0	0	0	0
		Model Output	26	43	18	2527		Model Output	14	20	4	1053		Model Output	15	20	4	1097
6. Syd-Ind - Cattle	100%	Real Time Data	16	53	8	N/A	100%	Real Time Data	20	39	6	N/A	100%	Real Time Data	19	33	3	N/A
		Difference	-10	10	-10	N/A		Difference	6	19	2	N/A		Difference	4	13	-1	N/A
		Model Output	18	27	8	1297		Model Output	0	0	0	0		Model Output	0	0	0	0
7. Syd-Mal - Mix	83%	Real Time Data	18	54	10	1466	0%	Real Time Data	0	0	0	0	0%	Real Time Data	0	0	0	0
		Difference	0	27	2	169		Difference	0	0	0	0		Difference	0	0	0	0
		Model Output	31	100	32	5383		Model Output	16	21	5	1041		Model Output	17	22	6	1130
8. Per-Mal - Mix		Real Time Data	21	61	14	1635		Real Time Data	22	43	10	N/A		Real Time Data	23	47	12	N/A
		Difference	-10	-39	-18	-3748		Difference	6	22	5	N/A		Difference	6	25	6	N/A
AVERAGE DIFFERENCE			-7	7	-6	-1790			6	30	6	N/A			7	27	6	N/A

DIFFERENCE BETWEEN EXCITEMENT FACTORS (E.F=0.1 vs E.F=0.2)

	MAIN						FORWARD						AFT					
FLIGHT	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]
		E.F = 0.1	26	45	18	2668		E.F = 0.1	15	20	5	1103		E.F = 0.1	16	21	5	1150
1. Syd-Jap - Cattle	100%	E.F = 0.2	27	49	20	2890	100%	E.F = 0.2	16	21	6	1182	100%	E.F = 0.2	17	21	6	1233
		Difference	1	4	2	222		Difference	1	1	1	79		Difference	1	0	1	83
		E.F = 0.1	27	49	20	2844		E.F = 0.1	15	20	4	1060		E.F = 0.1	15	20	5	1104
2. Mel-Ind - Cattle	100%	E.F = 0.2	27	53	21	3082	100%	E.F = 0.2	16	21	5	1060	100%	E.F = 0.2	16	21	6	1183
		Difference	0	4	1	238		Difference	1	1	1	0		Difference	1	1	1	79
		E.F = 0.1	28	55	22	2864		E.F = 0.1	14	19	4	927		E.F = 0.1	12	18	2	994
3. Syd-Mal - Cattle	100%	E.F = 0.2	28	60	23	3479	100%	E.F = 0.2	15	20	5	1087	100%	E.F = 0.2	13	18	3	935
		Difference	0	5	1	615		Difference	1	1	1	160		Difference	1	0	1	-59
		E.F = 0.1	30	78	28	4041		E.F = 0.1	13	19	3	881		E.F = 0.1	14	19	4	916
4. Mel-Chi - Sheep	96%	E.F = 0.2	30	84	29	4358	100%	E.F = 0.2	14	19	4	939	100%	E.F = 0.2	15	20	4	977
		Difference	0	6	1	317		Difference	1	0	1	58		Difference	1	1	0	61
		E.F = 0.1	23	36	14	1787		E.F = 0.1	0	0	0	0		E.F = 0.1	0	0	0	0
5. Syd-Mal - Goats	56%	E.F = 0.2	24	39	15	1928	0%	E.F = 0.2	0	0	0	0	0%	E.F = 0.2	0	0	0	0
		Difference	1	3	1	141		Difference	0	0	0	0		Difference	0	0	0	0
		E.F = 0.1	25	40	16	2335		E.F = 0.1	14	19	4	986		E.F = 0.1	14	19	4	1026
6. Syd-Ind - Cattle	100%	E.F = 0.2	26	43	18	2527	100%	E.F = 0.2	14	20	4	1053	100%	E.F = 0.2	15	20	4	1097
		Difference	1	3	2	192		Difference	0	1	0	67		Difference	1	1	0	71
		E.F = 0.1	17	26	7	1209		E.F = 0.1	0	0	0	0		E.F = 0.1	0	0	0	0
7. Syd-Mal - Mix	83%	E.F = 0.2	18	27	8	1297	0%	E.F = 0.2	0	0	0	0	0%	E.F = 0.2	0	0	0	0
		Difference	1	1	1	88		Difference	0	0	0	0		Difference	0	0	0	0
		E.F = 0.1	31	95	31	4955		E.F = 0.1	15	20	4	974		E.F = 0.1	16	21	5	1056
8. Per-Mal - Mix		E.F = 0.2	31	100	32	5383		E.F = 0.2	16	21	5	1041		E.F = 0.2	17	22	6	1130
		Difference	0	5	1	428		Difference	1	1	1	67		Difference	1	1	1	74
AVERAGE DIFFERENCE			1	4	1	259			1	1	1	75			1	1	1	50

Evaporation Coefficient = 26.6 (max)

			MAIN				FORWARD						AFT					
FLIGHT	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]
		Model Output	26	52	20	2668		Model Output	15	22	5	1103		Model Output	16	22	6	1150
1. Syd-Jap - Cattle	100%	Real Time Data	22	77	19	N/A	100%	Real Time Data	23	50	13	N/A	100%	Real Time Data	25	57	18	N/A
		Difference	-4	25	-1	N/A		Difference	8	28	8	N/A		Difference	9	35	12	N/A
		Model Output	27	55	21	2844		Model Output	15	21	5	1060		Model Output	15	21	5	1104
2. Mel-Ind - Cattle	100%	Real Time Data	23	64	27	N/A	100%	Real Time Data	22	72	18	N/A	100%	Real Time Data	23	56	15	N/A
		Difference	-4	9	6	N/A		Difference	7	51	13	N/A		Difference	8	35	10	N/A
		Model Output	28	61	23	3209		Model Output	14	21	4	1017		Model Output	12	19	3	878
3. Syd-Mal - Cattle	100%	Real Time Data	20	74	16	N/A	100%	Real Time Data	19	49	9	N/A	100%	Real Time Data	22	42	9	N/A
		Difference	-8	13	-7	N/A		Difference	5	28	5	N/A		Difference	10	23	6	N/A
		Model Output	30	82	28	4041		Model Output	13	21	4	881		Model Output	14	20	4	916
4. Mel-Chi - Sheep	96%	Real Time Data	20	66	15	N/A	100%	Real Time Data	N/A	N/A	N/A	N/A	100%	Real Time Data	N/A	N/A	N/A	N/A
		Difference	-10	-16	-13	N/A		Difference	#VALUE!	#VALUE!	#VALUE!	N/A		Difference	#VALUE!	#VALUE!	#VALUE!	N/A
		Model Output	23	47	16	1787		Model Output	0	0	0	0		Model Output	0	0	0	0
5. Syd-Mal - Goats	56%	Real Time Data	18	58	11	N/A	0%	Real Time Data	0	0	0	0	0%	Real Time Data	0	0	0	0
		Difference	-5	11	-5	0		Difference	0	0	0	0		Difference	0	0	0	0
		Model Output	25	47	18	2335		Model Output	14	21	4	986		Model Output	14	21	4	1026
6. Syd-Ind - Cattle	100%	Real Time Data	16	53	8	N/A	100%	Real Time Data	20	39	6	N/A	100%	Real Time Data	19	33	3	N/A
		Difference	-9	6	-10	N/A		Difference	6	18	2	N/A		Difference	5	12	-1	N/A
		Model Output	17	36	9	1209		Model Output	0	0	0	0		Model Output	0	0	0	0
7. Syd-Mal - Mix	83%	Real Time Data	18	54	10	1466	0%	Real Time Data	0	0	0	0	0%	Real Time Data	0	0	0	0
		Difference	1	18	1	257		Difference	0	0	0	0		Difference	0	0	0	0
		Model Output	31	96	32	4955		Model Output	15	22	5	974		Model Output	16	22	6	1056
8. Per-Mal - Mix		Real Time Data	21	61	14	1635		Real Time Data	22	43	10	N/A		Real Time Data	23	47	12	N/A
		Difference	-10	-35	-18	-3320		Difference	7	21	5	N/A		Difference	7	25	6	N/A
AVERAGE DIFFERENCE			-6	4	-6	-1532			7	29	7	N/A			8	26	7	N/A

DIFFERENCE BETWEEN Evaporation factors (ao = 7.12 vs ao = 26.6)

			MAIN				FORWARD						AFT					
FLIGHT	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]
		ao = 7.12	26	45	18	2668		Original	15	20	5	1103		Original	16	21	5	1150
1. Syd-Jap - Cattle	100%	ao = 26.6	26	52	20	2668	100%	New	15	22	5	1103	100%	New	16	22	6	1150
		Difference	0	7	2	0		Difference	0	2	0	0		Difference	0	1	1	0
		ao = 7.12	27	49	20	2844		Original	15	20	4	1060		Original	15	20	5	1104
2. Mel-Ind - Cattle	100%	ao = 26.6	27	55	21	2844	100%	New	15	21	5	1060	100%	New	15	21	5	1104
		Difference	0	6	1	0		Difference	0	1	1	0		Difference	0	1	0	0
		ao = 7.12	28	55	22	2864		Original	14	19	4	927		Original	12	18	2	994
3. Syd-Mal - Cattle	100%	ao = 26.6	28	61	23	3209	100%	New	14	21	4	1017	100%	New	12	19	3	878
		Difference	0	6	1	345		Difference	0	2	0	90		Difference	0	1	1	-116
		ao = 7.12	30	78	28	4041		Original	13	19	3	881		Original	14	19	4	916
4. Mel-Chi - Sheep	96%	ao = 26.6	30	82	28	4041	100%	New	13	21	4	881	100%	New	14	20	4	916
		Difference	0	4	0	0		Difference	0	2	1	0		Difference	0	1	0	0
		ao = 7.12	23	36	14	1787		Original	0	0	0	0		Original	0	0	0	0
5. Syd-Mal - Goats	56%	ao = 26.6	23	47	16	1787	0%	New	0	0	0	0	0%	New	0	0	0	0
		Difference	0	11	2	0		Difference	0	0	0	0		Difference	0	0	0	0
		ao = 7.12	25	40	16	2335		Original	14	19	4	986		Original	14	19	4	1026
6. Syd-Ind - Cattle	100%	ao = 26.6	25	47	18	2335	100%	New	14	21	4	986	100%	New	14	21	4	1026
		Difference	0	7	2	0		Difference	0	2	0	0		Difference	0	2	0	0
		ao = 7.12	17	26	7	1209		Original	0	0	0	0		Original	0	0	0	0
7. Syd-Mal - Mix	83%	ao = 26.6	17	36	9	1209	0%	New	0	0	0	0	0%	New	0	0	0	0
		Difference	0	10	2	0		Difference	0	0	0	0		Difference	0	0	0	0
		ao = 7.12	31	95	31	4955		Original	15	20	4	974		Original	16	21	5	1056
8. Per-Mal - Mix		ao = 26.6	31	96	32	4955		New	15	22	5	974		New	16	22	6	1056
		Difference	0	1	1	0		Difference	0	2	1	0		Difference	0	1	1	0
AVERAGE DIFFERENCE			0	7	1	49			0	2	0	18			0	1	1	-23

VENTILATION [m3/hr] - MAIN = 14 566 (85%) / FORWARD = 1 714 (10%) / AFT = 856 (5%)

	MAIN						FORWARD							AFT					
FLIGHT	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]
		Model Output	20	28	10	1576		Model Output	21	28	11	1750		Model Output	26	43	18	2665
1. Syd-Jap - Cattle	100%	Real Time Data	22	77	19	N/A	100%	Real Time Data	23	50	13	N/A	100%	Real Time Data	25	57	18	N/A
		Difference	2	49	9	N/A		Difference	2	22	2	N/A		Difference	-1	14	0	N/A
		Model Output	21	31	11	1673		Model Output	21	27	11	1673		Model Output	26	41	17	2542
2. Mel-Ind - Cattle	100%	Real Time Data	23	64	27	N/A	100%	Real Time Data	22	72	18	N/A	100%	Real Time Data	23	56	15	N/A
		Difference	2	33	16	N/A		Difference	1	45	7	N/A		Difference	-3	15	-2	N/A
		Model Output	22	34	13	1875		Model Output	20	26	10	1597		Model Output	23	31	13	1934
3. Syd-Mal - Cattle	100%	Real Time Data	20	74	16	N/A	100%	Real Time Data	19	49	9	N/A	100%	Real Time Data	22	42	9	N/A
		Difference	-2	40	3	N/A		Difference	-1	23	-1	N/A		Difference	-1	11	-4	N/A
		Model Output	26	47	19	2341		Model Output	19	25	9	1357		Model Output	25	36	15	2031
4. Mel-Chi - Sheep	96%	Real Time Data	20	66	15	N/A	100%	Real Time Data	N/A	N/A	N/A	N/A	100%	Real Time Data	N/A	N/A	N/A	N/A
		Difference	-6	19	-4	N/A		Difference	#VALUE!	#VALUE!	#VALUE!	N/A		Difference	#VALUE!	#VALUE!	#VALUE!	N/A
		Model Output	21	32	11	1501		Model Output	0	0	0	0		Model Output	0	0	0	0
5. Syd-Mal - Goats	56%	Real Time Data	18	58	11	N/A	0%	Real Time Data	0	0	0	0	0%	Real Time Data	0	0	0	0
		Difference	-3	26	0	0		Difference	0	0	0	0		Difference	0	0	0	0
		Model Output	18	26	8	1392		Model Output	20	26	9	1542		Model Output	25	38	16	2332
6. Syd-Ind - Cattle	100%	Real Time Data	16	53	8	N/A	100%	Real Time Data	20	39	6	N/A	100%	Real Time Data	19	33	3	N/A
		Difference	-2	27	0	N/A		Difference	0	13	-3	N/A		Difference	-6	-5	-13	N/A
		Model Output	14	24	5	1030		Model Output	0	0	0	0		Model Output	0	0	0	0
7. Syd-Mal - Mix	83%	Real Time Data	18	54	10	1466	0%	Real Time Data	0	0	0	0	0%	Real Time Data	0	0	0	0
		Difference	4	30	5	436		Difference	0	0	0	0		Difference	0	0	0	0
		Model Output	28	67	24	2848		Model Output	21	28	11	1520		Model Output	26	44	18	2406
8. Per-Mal - Mix		Real Time Data	21	61	14	1635		Real Time Data	22	43	10	N/A		Real Time Data	23	47	12	N/A
		Difference	-7	-6	-10	-1213		Difference	1	15	-1	N/A		Difference	-3	3	-6	N/A
AVERAGE DIFFERENCE			-2	27	2	-389			1	24	1	N/A			-3	8	-5	N/A

DIFFERENCE BETWEEN VENTILATION RATES (Main: 70%-85% / Forward: 17%-10% / Aft: 10%-5%)

	MAIN						FORWARD							AFT					
FLIGHT	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]	Space Used		Dry Bulb [°C]	Relative Humidity [%]	Wet Bulb [°C]	CO2 [ppm]
		Original (70%, 17%, 13%)	26	45	18	2668		Original	15	20	5	1103		Original	16	21	5	1150
1. Syd-Jap - Cattle	100%	New (85%, 10%, 5%)	20	28	10	1576	100%	New	21	28	11	1750	100%	New	26	43	18	2665
		Difference	-6	-17	-8	-1092		Difference	6	8	6	647		Difference	10	22	13	1515
		Original (70%, 17%, 13%)	27	49	20	2844		Original	15	20	4	1060		Original	15	20	5	1104
2. Mel-Ind - Cattle	100%	New (85%, 10%, 5%)	21	31	11	1673	100%	New	21	27	11	1673	100%	New	26	41	17	2542
		Difference	-6	-18	-9	-1171		Difference	6	7	7	613		Difference	11	21	12	1438
		Original (70%, 17%, 13%)	28	55	22	2864		Original	14	19	4	927		Original	12	18	2	994
3. Syd-Mal - Cattle	100%	New (85%, 10%, 5%)	22	34	13	1875	100%	New	20	26	10	1597	100%	New	23	31	13	1934
		Difference	-6	-21	-9	-989		Difference	6	7	6	670		Difference	11	13	11	940
		Original (70%, 17%, 13%)	30	78	28	4041		Original	13	19	3	881		Original	14	19	4	916
4. Mel-Chi - Sheep	96%	New (85%, 10%, 5%)	26	47	19	2341	100%	New	19	25	9	1357	100%	New	25	36	15	2031
		Difference	-4	-31	-9	-1700		Difference	6	6	6	476		Difference	11	17	11	1115
		Original (70%, 17%, 13%)	23	36	14	1787		Original	0	0	0	0		Original	0	0	0	0
5. Syd-Mal - Goats	56%	New (85%, 10%, 5%)	21	32	11	1501	0%	New	0	0	0	0	0%	New	0	0	0	0
		Difference	-2	-4	-3	-286		Difference	0	0	0	0		Difference	0	0	0	0
		Original (70%, 17%, 13%)	25	40	16	2335		Original	14	19	4	986		Original	14	19	4	1026
6. Syd-Ind - Cattle	100%	New (85%, 10%, 5%)	18	26	8	1392	100%	New	20	26	9	1542	100%	New	25	38	16	2332
		Difference	-7	-14	-8	-943		Difference	6	7	5	556		Difference	11	19	12	1306
		Original (70%, 17%, 13%)	17	26	7	1209		Original	0	0	0	0		Original	0	0	0	0
7. Syd-Mal - Mix	83%	New (85%, 10%, 5%)	14	24	5	1030	0%	New	0	0	0	0	0%	New	0	0	0	0
		Difference	-3	-2	-2	-179		Difference	0	0	0	0		Difference	0	0	0	0
		Original (70%, 17%, 13%)	31	95	31	4955		Original	15	20	4	974		Original	16	21	5	1056
8. Per-Mal - Mix		New (85%, 10%, 5%)	28	67	24	2848		New	21	28	11	1520		New	26	44	18	2406
		Difference	-3	-28	-7	-2107		Difference	6	8	7	546		Difference	10	23	13	1350
AVERAGE DIFFERENCE			-5	-17	-7	-909			6	7	6	606			11	20	12	1310