MODIFICATION OF AIR FLOWS WITHIN AN INDUSTRIAL CARCASS CHILLER USING DELTA WING VORTEX GENERATORS

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ABSTRACT

The chilling of carcasses after slaughter has a considerable bearing on process costs and quality of the meat. Uniform air distribution is essential for the optimal operation of carcass chillers, yet many existing chillers have highly variable and ineffective air flow. This directly affects the uniformity of evaporative weight loss and carcass cooling rates within the chiller.

Delta plan aerofoils are known to convert a unidirectional air stream, progressively into a rotational and then turbulent multidirectional fragments of moving air. The aim of this research was to evaluate the use of delta wings to improve air flows inside a venison carcass chiller of typical design used in the New Zealand meat industry.

Air flow patterns within the chiller were characterised by measuring mean air speeds with a hot-wire anemometer over 61 grid points at 4 levels in height. Air speeds were found to be highly time-variable so the mean, standard deviation and range of 60 one second air speed measurements were used to represent the air flow at each point on the grid. The measurement of air velocity (speed and direction) using three othoganally mounted propeller anemometers had limited success, as air speeds within the chiller were often below the threshold of the anemometer.

Measurements before the installation of the delta wings indicated that a poor air flow distribution existed within the chiller as the majority of air was found to circulate around the walls and floor, producing near stagnant conditions between the carcasses.

Delta wings were constructed in two sizes from thin aluminium sheets. Wings were installed into the chiller by suspending them from the ceiling within the evaporator fan delivery air stream. Two wing configurations were trialed: The first wing configuration utilised 3 large delta wings mounted in front of the evaporator fans followed by a row of 6 small wings then a row of 7 small wings (3,6,7). The second delta wing configuration utilised a row of 6 large wings closest to the evaporator fans followed by a row of 9 small wings then a row of 13 small wings (6,9,13).

The second delta wing configuration showed superior performance over the first. In comparison to the unmodified chiller without wings, the mean air speeds in the critical region amongst the carcasses increased from 0.4 m/s to 0.6 m/s; the standard deviation of mean air speeds decreased from 0.33 m/s to 0.22 m/s and the percentage of mean air speeds between half and twice the mean increased from 84% to 95%. The second configuration of delta wings also produced a 14% increase in the mean air turbulence intensity (measure of the time-variability in air speed) and reduced the variability of evaporative weight loss within the chiller.

Overall, the delta wings were found to be an economic way to improve the performance of a chiller by providing a more uniform and effective air distribution without increasing fan power. This can result in a reduction in chilling times and less potential for weight loss. Their use in both new and existing chillers is recommended.

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Chapter 1

INTRODUCTION

The New Zealand meat industry continues to be a major contributor to New Zealand's economy. Since the 1880's it has been responsible for a large proportion of New Zealand's gross domestic product and foreign exchange earnings; in 1996 contributing 16.3 percent to the total value of exports (Beattie, 1996).

New Zealand produces around 1 million tonnes of meat per year, most of which is destined for overseas markets. Although, this makes up only 0.4 percent of the worlds total meat protein output, it equates to approximately 17 percent of all internationally traded meat. This can be broken down into a 7 percent share of world beef and veal exports and a 44 percent share of world sheep meat exports (Willis, 1992).

New Zealand still faces strong tariff and non-tariff barriers to free trade of agricultural products. These have restricted the volume growth of exports and real increases in prices. Subsidised returns to farmers in the US and OECD countries encourages excess production. This surplus competes directly with New Zealand's exports. When this occurs, New Zealand farmers receive artificially low returns for their produce. The significant cost of long distance transportation to many of New Zealand's major markets and barriers to free trade means that New Zealand's agricultural products must be produced at a lower cost, more efficiently and be of superior quality to compete with those of its competitors.

The refrigeration of meat makes up a significant proportion of the products final cost, as it is used extensively in the processing, transport and storage of meat. Capital investment, fan power, compressor energy and product weight loss all contribute to the cost of refrigeration. Refrigeration also has a significant impact on the final quality characteristics of the product. The microbial condition, tenderness and appearance are all affected by the environment, prior to and throughout the "cold-chain".

Increased competition has led to a larger range of product choice for the overseas consumer. The market for frozen meat is declining as more consumers demand chilled "fresh meat" cuts. This trend has forced a change in the meat industry towards the further processing of meat before it reaches the point of sale. Higher prices due to increased demand for further processed chilled meat have driven this shift which has resulted in dramatic changes in the export of sheep and beef.

In the year ended June 1992, 3 percent of New Zealand's sheep meat was exported in the unfrozen form. Since 1992 the quantity of chilled, fresh lamb exports has doubled, contributing to 7 percent of the total sheep meat exports in 1996. The volume of chilled lamb exports is expected to continue to grow and command premium prices (Lynch, 1996). These shifts have also been evident in beef processing where the export of traditional frozen beef quarters have been replaced by chilled, boneless, plastic wrapped primal cuts.

Such changes have been made possible by developments in the technology associated with the commercial refrigeration of meat. In particular, developments to better control the environment in refrigerated shipping facilities has enabled the transport of chilled meat cuts to distant markets, replacing the need to transport whole frozen carcasses. The introduction of vacuum and modified atmosphere packaging has also contributed to this change by extending the products shelf life.

Temperature, relative humidity, air velocity and air distribution make up the environmental conditions inside a refrigerated space. The effects of temperature and relative humidity on product characteristics are well understood and both can be controlled relatively easily. In contrast, the effects of air velocity over the product and air distribution within the room are less well understood and tend to be more difficult to control. However, adequate air velocity and a uniform air distribution are crucial to effective chilling and the holding of product in a chilled state. The products microbial quality, chilling rate, weight loss and uniformity of chilling are all directly affected.

The overall aim of this research is to consider meat carcass chiller design and operation from an air velocity and distribution perspective. In particular, the objective is to improve the uniformity of air flow across the product and increase chilling rates whilst minimising the rate of evaporative weight loss and fan energy requirements.

Chapter 2

LITERATURE REVIEW

This literature review is divided into seven sections. The first section considers the importance of air circulation to the effectiveness of carcass chilling. The second and third sections focus on the factors that influence air flow and ways that air circulation and distribution might be improved in chillers. The fourth and fifth sections cover the various methods used to visualise and measure air flow within chillers. The sixth section reviews the development and use of delta wing vortex generators and the effect these have on air movement. Lastly, the seventh section defines the specific objectives of this research.

2.1 IMPORTANCE OF AIR CIRCULATION IN CHILLING

The parameters which give rise to the physical environment in a chiller are of particular importance as they have a major effect on the product quality characteristics. Air velocity, humidity and temperature all effect ultimate meat quality. In particular, these parameters influence quality aspects such as the microbial status of the carcass, tenderness and appearance of the meat. They also affect processing aspects, such as the carcass weight loss, shrinkage, ease of cutting and the amount of condensation (produced on the chiller superstructure and on the carcass). Nottingham (1971) notes that as processing and quality requirements are often in conflict, optimal conditions for chilling must be a compromise.

In general, a fast chilling rate results in less evaporative weight loss and lower microbial growth (Taylor, 1972). However, it also results in a higher process cost and an increased susceptibility to toughness through cold shortening (Bendall, 1972). A slow rate of chilling leads to a lower process cost and is more conducive to tenderness, but increases evaporative weight loss and microbial load. Therefore, a "window of compromise" exists were there is an acceptable balance of process cost, toughness, microbial growth, and weight loss (Figure 2.1).

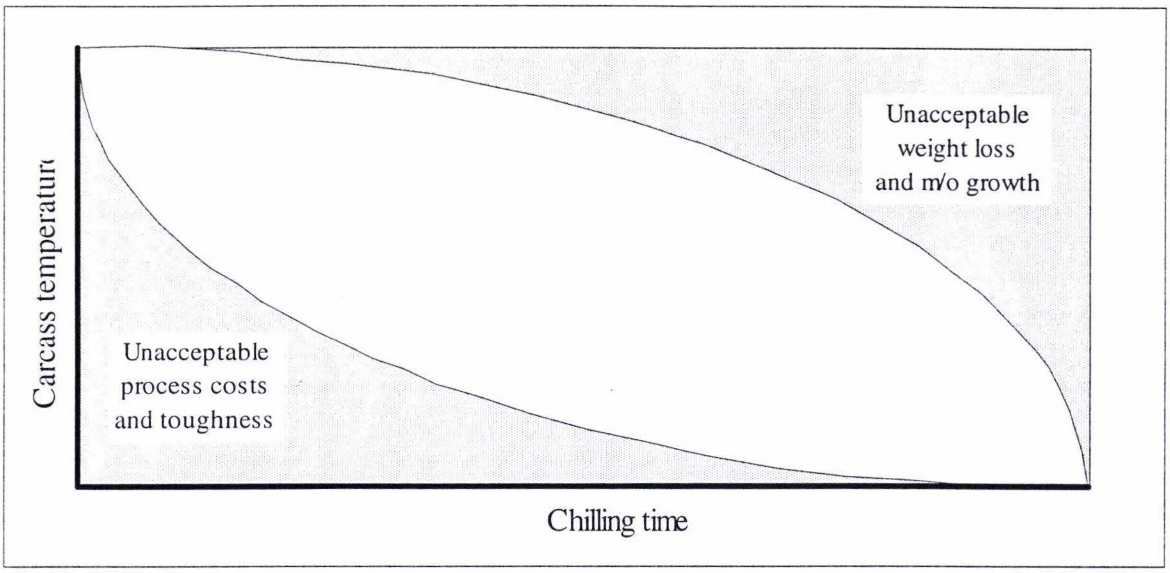


Figure 2.1: Compromise in the conditions for chilling

In many instances the chilling regime cannot be controlled within this 'window' due to poor uniformity of air flow across the refrigerated space. Localised zones of high air flow enable the fast removal of heat from carcasses within these areas, but this product is more susceptible to toughness. Conversely, zones of low air flow produce areas where the chilling rate is slow yet carcasses in these locations are more susceptible microbial spoilage.

In a batch situation, unloading of the chiller can only take place once the carcass with the slowest chilling rate has reached the required temperature. This situation produces conditions which are conducive to excessive weight loss. Carcasses which cool quickly, often must undergo a holding period in a location of high air flow as the required temperature is obtained much earlier than slowest cooling carcass.

Although chilling and freezing of meat has been carried out in New Zealand for over one hundred years, considerable differences of opinion still exist as to the optimal environmental conditions in regard to air velocity, relative humidity and temperature. Of these three variables, air velocity (and air movement in general) is the most poorly understood and gives rise to the most controversy in chilling and freezing. It is well established that air velocity strongly affects the chilling rate (Frazerhurst, 1971; Longdill, 1974; Daudin and Swain, 1990; Kondjoyan and Daudin, 1995). However, little is known about the distribution of the air flowing around the product (Daudin, 1992). In practice, air circulation is often only considered in a superficial manner in the design and operation of chillers despite the proven economic advantages obtained in systems where air flow is well managed.

2.1.1 CHILLING RATES

There is obvious economic incentive in the rapid chilling of product. Rapid chilling achieves a quick turnover, better hygiene, reduced drip and in many cases a lower weight loss (Taylor, 1972; Gigiel *et. al.*, 1989). However, the rapid chilling of carcasses can be detrimental to meat quality, for example, toughness induced by cold shortening of the meat (Bendall, 1972). This conflict between economic and quality aspects has given rise to two main processing specifications. The first is to slow chill, often with an initial delay stage at 10°C or above to maintain product quality. The second is to rapid chill in two stages: an initial period of low air temperatures and high air velocities to reduce the potential for drip and weight loss; followed by a less severe second stage of chilling to allow for temperature equilibration (Gigiel *et. al.*, 1989).

The rate of chilling is determined by a combination of air velocity over the product, the difference between the temperature of the air and product surface as well as the nature and variability of the product itself (Garnett, 1974). Although the nature and variability of the product does have a large bearing on chilling rates, carcass variations such as surface area to mass ratio, side thickness, fat cover and initial surface moisture are largely beyond the control of the processor. Therefore, the velocity of air as well as the temperature of air are the two main variables that can be manipulated to influence chilling rates.

Regulatory authorities require beef carcasses to be chilled to a deep bone temperature of 10°C or lower within 16 hours, otherwise carcasses are considered to be susceptible to spoilage during subsequent storage (Hodgson, 1970). Hodgson (1970) stated that air velocities of at least 0.75 m/s over the sides are required to reduce the deep bone temperature of a 100 kg beef side to 10°C within 16 hours in a room controlled at 0°C.

The Meat Industry Research Institute of New Zealand (MIRINZ) specifies that air velocities of 0.5 to 1.0 m/s with a minimum of 0.25 m/s over any surface should be used for chilling and aging of beef (Garnett, 1974). Garnett (1974) carried out tests in a number of different chillers and confirmed that air velocities of 1 m/s are required over the hind quarters of 135 kg prime beef sides if deep leg temperatures of 10°C are to be obtained over a 21 hour cycle in a chiller operating at 4°C. It was suggested that these velocities could be reduced to about 0.35 m/s between the sides because of smaller carcass cross-sectional areas at this level.

James and Bailey (1986) found that increasing air velocity during chilling produces a significant reduction in chilling times. Benefits were most pronounced at low air velocities. It was concluded that air velocities greater than 1 m/s over the product are unlikely to be justified as the power required to move air within a refrigerated room increases with the cube of velocity. For example, a four-fold increase in air velocity from 0.5 to 2 m/s may result in a 4 to 7 hour reduction in chilling time for a 140 kg beef side, but requires a 64 times increase in fan power.

2.1.2 WEIGHT LOSS

Weight loss is critical in determining profitability in the meat industry. Currently, profit margins in the industry are small, so every gram of water retained within the meat before it is sold becomes an important transaction.

Since evaporation is one of the mechanisms by which the carcass loses heat during chilling, some moisture loss is inevitable. Weight loss is effectively a slow low temperature drying process which is mass transfer limited (Daudin and Swain 1990). When air flows around a wet permeable body, mass transfer takes place both inside the body by diffusion and through the boundary layer which develops at the air-body interface. In the boundary layer, air flow is laminar and water vapour transfers to and from the surface by diffusion. This process depends on water vapour diffusivity in air and the thickness of the boundary layer. Thickness of the boundary layer is determined by shape, size and surface roughness of the body as well as air velocity and viscosity. Since the thickness of the boundary layer cannot be easily measured, its resistance to mass transfer is usually represented by an average mass transfer coefficient which has to be determined experimentally.

The mass transfer rate dM/dt at the air-body interface can be represented by:

$$dM/dt = k\,A\,(P_{wp}\,a_{w,s} - P_a) \tag{2.1}$$

$$\text{Where } P_a = H_r\,P_{wa}/100 \tag{2.2}$$

M	Mass of product (kg)
t	Time (s)
$a_{w,s}$	Water activity at the surface
P_a	Partial pressure of water vapour in bulk air (Pa)
P_{wp}	Vapour pressure of water at product temperature T_p (Pa)
P_{wa}	Vapour pressure of water at air temperature T_a (Pa)
k	Mass transfer coefficient (kg/m^{2}sPa)
A	Transfer surface area (m^2)
H_r	Relative Humidity (%)

As equation 2.1 shows, the rate of weight loss is a function of the mass transfer coefficient, the area available for mass transfer and the partial pressure driving force for mass transfer.

The mass transfer coefficient is a measure of the "ease" with which water can break free from the product surface and move through the boundary layer into the bulk air (Cleland & Cleland, 1996). It depends on how readily moisture is transferred from the product surface to the air (interphase resistance), and from the air at the surface to the bulk air (transport resistance). Interphase resistance is a function of product characteristics. For example, a carcass with thick fat cover generally has a large interphase resistance, whereas lean meat has a low interphase resistance. Transport resistance is a function of air velocity over the product. Once the air velocity is increased above a critical level, the transport resistance becomes small compared to air resistance, so any further increases in velocity will hardly change the mass transfer coefficient.

Partial pressure driving force is dependent on the products surface temperature, as well as the bulk air temperature and its relative humidity (Cleland & Cleland, 1996). Relative humidity has very little effect on the rate of weight loss early in the chill cycle as the impact on the partial pressure diving force is small while the temperature difference is large. Initially, the partial pressure driving force varies directly with temperature difference between the product surface and air.

As the products surface area is usually fixed and the mass transfer coefficient only varies slightly in a adequate air flow (as the interphase resistant is large in comparison to the transport resistance), the partial pressure driving force is the dominant variable in the chilling phase. As the partial pressure driving force varies directly with the temperature difference between the product surface and the air, the product is most susceptible to weight loss in the early stages of the chilling process because the product surface temperature is large, the partial pressure driving force will also be large.

Higher air velocities reduce the length of chilling time by increasing the rate at which the product surface temperature drops. While product temperature is above the required chilled temperature, an increase in air velocity will reduce the total weight loss but increase the rate at which weight loss occurs (Cleland & Cleland, 1996).

As the temperature of the product stabilises, the product can no longer be considered as being actively chilled. Under these conditions the partial pressure driving force is small and the 'drying power' of the air becomes dominant (Longdill, 1974). The drying power of the air is its ability to remove moisture from a wet surface at the same temperature. It is a function of air relative humidity and air velocity. Hence, once the carcass temperature is reduced, it is important to maintain a high relative humidity and a low air velocity in order to minimise weight loss.

The basis, on which weight loss is measured by, is vital in determining whether a change in air velocity increases or decreases weight loss. Weight loss measurements can be taken over a fixed time interval or by chilling to a fixed final temperature (Lovett *et. al,* 1978).

By conducting wind tunnel tests over a fixed time interval, Lovett *et. al.* (1978) concluded that in the initial stages of chilling, weight loss was not significantly affected by air velocity in the ranges from 0.56 to 3.7 m/s. After 22 hours of chilling, however, there were significantly higher evaporative losses from the meat samples exposed to the higher air velocities. Alternative results were presented as a function of the temperature of the meat and air velocity, instead of a function of chilling time and air velocity. For the same meat temperature, a higher air velocity increased the rate of weight loss, but also gave a faster rate of cooling. Higher air velocities were found to reduce total evaporative losses at final meat temperatures between 4 and 13° C.

Joseph and Smith (1984) also used a a fixed chilling time to investigate the effects of air velocity on weight loss. It was found that when air speed over the surface of the cooling beef carcass was increased from 0.5 to 1.0 m/s then evaporative weight loss decreased, but if the speed is increased further, weight loss increased again.

To study the degree of weight loss caused by using conventional chilling or forced chilling techniques, van der Wal *et. al.* (1995) carried out experiments by chilling pigs to a fixed final temperature. Conventional chilling was carried out with an air temperature of 4°C and air velocity of 0.5 m/s, whereas forced chilling was carried out using an air temperature of -5°C for 120 minutes or -30°C for 30 minutes with air velocities of 1, 2 or 4 m/s. Results showed that losses in carcass weight were about 2% for conventional chilling and forced chilling at -5°C, but were reduced to 1.3% by 'ultra' rapid, forced chilling at -30° C with an air velocity of 4 m/s.

Cooper (1970) also carried out studies on the weight loss of pig carcasses during quick and rapid chilling. Quick chilling of 60 kg dressed carcasses, using an air velocity of 0.25 m/s and temperature of 0.5° C, resulted in a weight loss of 1.9%. Rapid chilling, using an air velocity of 2 m/s and temperature of -7° C, resulted in a lower weight loss of 1.4% for the same degree of cooling (final temperature).

James and Bailey (1986) compared weight loss of beef carcasses over a fixed interval of 18 hours and found that changing the air velocity from 0.75 to 3 m/s had only a small effect on weight loss. Similar results were obtained by Kerens (1976) where small increases in weight loss were detected when increasing the air velocity from 0.25 to 1.5 m/s.

Longdill and Pham (1981) found that when chilling over a fixed time interval, weight losses increased proportionally with increasing air velocities for average air velocities under 0.6 m/s. They concluded that the velocity of air flowing over the carcass was the most significant variable affecting weight loss in chilled lambs.

Hodgson (1970) and Levy (1972) both recommended low air velocities for minimum weight loss when chilling over a fixed period of time. Hodgson (1970) stated that carcass chilling rooms should be controlled at the minimum value that is necessary to give the required product temperature at the terminal stage of the chilling process.

In general, research suggests that increasing air velocities while chilling over a fixed time interval will increase weight loss. Whereas increasing air velocities while chilling to a fixed final temperature will reduce the overall weight loss, but a higher rate of weight loss will occur. Therefore, the most widely accepted process is to use a fast chilling rate initially to reduce the product surface temperature rapidly, followed by conditions of low air velocity and high relative humidity once the carcass is close to the required temperature. These conditions theoretically give the lowest overall weight loss (Longdill, 1974).

2.1.3 MICROBIAL GROWTH

Refrigeration of meat is principally concerned with the inhibition of microbial spoilage It is inevitable that bacteria will be transferred to the meat surface during slaughter. Many of these bacteria are psychotropic (ie. capable of growth at chill temperatures). Since microbial growth mainly occurs on the carcass surface, it is common to express the microbial condition of meat in terms of the number of viable organisms on a given surface area of meat (Shaw, 1972).

The rate of microbial growth on the carcass surface is influenced by a number of factors such as the rate of fall in temperature, changes in the physiological factors (eg. decreasing pH within the tissue after slaughter) and the availability of water. The term used for physiologically available water is 'water activity'. The water activity for chilled lean meat is approximately 0.993 (Scott, 1936). This availability of water offers ideal conditions for microorganisms to grow.

Air velocity affects the available water on the carcass surface by contributing to surface drying and thus affects the rate of bacterial growth. Scott and Vickery (1939) found that provided the rate of air movement was sufficiently high (above 0.7 m/s) bacterial growth could be prevented even if the air was relatively warm. If the air flow was halved bacterial numbers increased 26-fold in 72 hours. It was therefore concluded in this study that the rate of desiccation was likely to be more important than the rate of chilling in restricting microbial growth.

MacFarlane (1973) took bacterial counts on the neck, loin and leg positions on beef sides during chilling in order to find the relationship between air velocity and bacterial growth. The data confirmed that where air flows tended to be low and consequently drying was minimal (eg. the neck region), bacterial loads tended to be high.

2.1.4 UNIFORMITY OF CHILLING

The heterogeneity of air flow causes major problems in the control of batch chillers due to the resulting variation in chilling times, surface temperatures and unfavourable changes to the quality of the product.

During chilling, the surface temperature of the product is largely determined by the surrounding air temperature and its velocity (Kondjoyan and Daudin, 1995). A long initial period in which the surface temperature is above 10°C must be avoided to reduce the risk of bacterial growth, especially that of pathogenic bacteria. However, significant risks only exist when air velocities are low (below 0.5 m/s) and chilling times are long. The risk of surface freezing is much more common. The temperature at the surface must not drop below the freezing temperature of the product as this will give rise to thawing drip which is detrimental to the appearance of the product, increases overall weight loss and promotes bacterial growth. For lean meat the freezing temperature is about -1°C. However, Kondjoyan and Daudin (1995) suggest that in practice it is best to avoid surface temperatures below 0°C.

For satisfactory operation, a carcass chilling room air distribution system should maintain a reasonably uniform air velocity distribution across the whole of the product. Localised recirculation patterns or free convection of warm air should be avoided, (as this can lead to inadequate cooling or condensation on the chiller superstructure) and an adequate flow of air across the thickest part of the carcass is needed to ensure a satisfactory chilling rate is achieved without increasing process costs unduly.

Surveys on air flow characteristics of a number of industrial chillers have shown that the distribution of air velocities and air circulation are often far from an ideal in regards to uniform flow. (Macfarlane, 1974; Daudin *et. al.*, 1992). The same situation has also been found in industrial cool stores and freezers (Falconer, 1993; Oliver, 1986; Edwards, 1979).

Studies of air flow characteristics in a chiller for pork offals by Daudin *et. al.* (1992) exemplified the large variation of air flow that exists in industrial plants. The air velocity was found to vary between 0.3 m/s and 9 m/s and had an average velocity of 2.3 m/s with a standard deviation of 1.5 m/s.

Wootton (1986) investigated a number of carcass chilling rooms in Northern Ireland. So much variation in air velocity was found that the location of the carcass in the chill room had almost as much effect on its cooling rate as did carcass weight, which was expected to be the most important variable.

Edwards (1979) suggested that if 95% of the measured air velocity readings adjacent to the product were between ½ to 2 times the average air velocity, then there was an acceptably uniform air flow within the refrigerated room. Oliver (1986) carried out studies on three types of carton blast freezers and found that the best configuration studied only gave 88% of the air velocity readings between ½ and 2 times the mean velocity.

Edwards (1979) showed that the basic multi-story vertical air flow carcass freezer was also unsatisfactory in terms of the uniformity of air flow. Only 91% of the air velocity readings adjacent to the carcass were within the specified range.

In conventional batch chillers with ceiling mounted evaporator fans, much of the air tends to bypass the carcass hanging area completely and recirculate back to the inlet of the evaporator. Test results on conventional batch chillers obtained by Murray (1972) indicated that air velocities near the walls and along the floor can be six times the velocities through the carcasses.

Amraie (1993) carried out extensive air flow measurements in a pig pre-chiller. The room operated with a ceiling mounted evaporator unit which housed 3 continuous fans operating with a total volumetric flow rate of 11370 m^3/h (3.16 m^3/s). The room had a volume of 87.7 m^3 and contained 5 rails mounted perpendicular to the air flow direction. The room could hold a maximum of 50 pigs. Air flow testing was undertaken in the empty room and again when the room was $^2/_3$ full. Air velocity measurements were taken at the leg, loin and head positions of the carcasses (9 around each carcass). Measurements in the empty chiller were performed at intervals of 1 meter across 4 different heights in the room. A total of 279 air velocity measurements were taken in the full chiller and 130 air velocity measurements were taken when the room was empty. In both cases results showed regions of high air movement located along the ceiling, walls and floor, whereas in the middle if the chiller, beneath the rails, the air movement was very slow. It was concluded that the area of high air movement can be considered turbulent and experiences only small velocity gradients. The area of low air movement could be considered to be non-turbulent with widely varying velocity gradients.

At South Bank University the behaviour of thin delta plan aerofoils in air streams has been investigated. This was achieved by assessing the influence of strong leading edge vortices produced by the aerofoils on room air mixing (Missenden, 1987; Amraie, 1993). The influence of the vortices was examined experimentally using dummy carcasses to simulate the actual conditions inside a chill room. Air movement was investigated using the response of temperature sensors to rapid temperature changes of the inlet air stream. Visualisation of the air flow was achieved by using soap bubble generators. Experiments showed that these delta wings improved air movement between carcasses in conventional carcass meat chilling rooms and hence product quality was also improved (Missenden *et. al.*, 1995).

2.2 FACTORS AFFECTING AIR FLOW

Air is a compressible fluid which when acted upon by a fan or other energy impelling means, flows from a region of higher absolute total pressure to one of lower absolute total pressure. The difference in pressures determine the characteristics of the flow.

2.2.1 FLOW ALONG A FIXED SURFACE

When a fluid flows over a fixed surface, layers next to the surface are held back by the viscous forces and "stick" to the surface (John, 1969). This causes the velocity of the fluid at the fixed wall to be zero. Moving out from the wall, the velocity increases to its free stream value, and a velocity distribution is built up. The effects of viscosity are dominant in the region near the surface. Air viscosity is small, so the viscous effects are confined to a very thin layer at the surface called the 'boundary layer'. In the boundary layer, the velocity components are zero both normal and tangential to the wall surface. In many cases the boundary layer effects can be neglected in the analysis of air flows. However in cases such as the calculation of mass and heat transfer coefficients, the boundary layer effects are important.

Air that flows along a fixed surface such as a wall or ceiling generates attraction forces between the surface and air. This phenomenon is known as the 'Coanda effect' (Amraie, 1993). The Coanda effect contributes to the problem of air circulating around the walls of a chiller, giving rise to stagnant zones in the centre where good air movement is needed the most.

2.2.2 FLOW OVER BAFFLES

In chillers, baffles can be used to introduce an extra pressure drop into air pathways which would otherwise have less resistance to air flow. They disrupt the air flow and create turbulence, thereby enhancing air flow through pathways that the air does not preferentially move. In this way, baffles can be used to reduce the short circuiting of the air within a chiller (Cleland & Cleland, 1996).

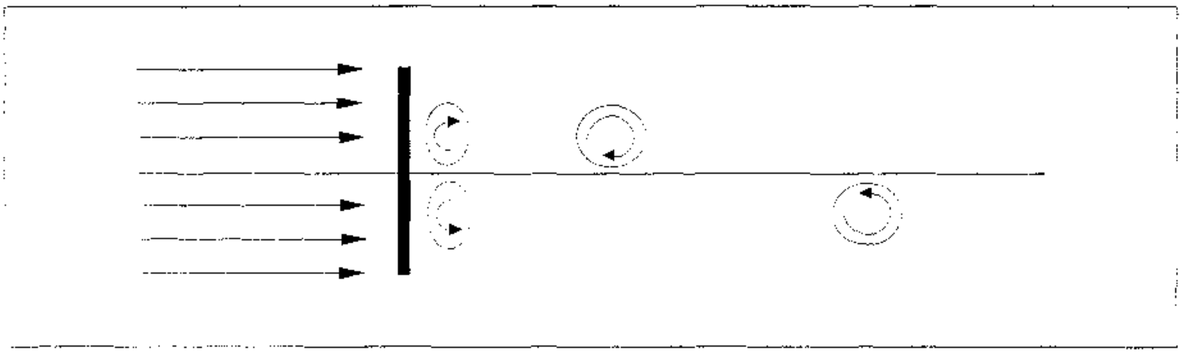


Figure 2.2: Flow over a fixed plate

Laminar flow over an fixed object such as a baffle causes a three dimensional separated turbulent flow pattern as shown in Figure 2.2. Flow separation occurs at the sharp edges. The adverse static pressure gradient slows the air to a standstill and then reverses its direction. The separation of the flow causes a stream of detached vortices known as a "vortex sheet". These vortices are known to expand and decay under viscous action until they dissipate into random turbulence (Missenden, 1987).

When the air flow is turbulent and there are many objects present, as in a loaded chiller, the detailed flow patterns that arise from air flowing over a baffle are difficult to describe (Bradshaw, 1971).

2.2.3 FLOW OVER AEROFOILS

If a flat plate is inclined at an angle to a moving stream of air there will be a net force exerted on the plate by the fluid due to a region of low pressure developing above the plate and a region of high pressure forming below the plate. The vertical component of the force exerted on the plate is called the lift whereas, the horizontal component is known as the drag.

The pressure difference between the surfaces causes an outward expansion over the lower surface which is balanced by an inward compression over the upper surface. This forces a lateral and upward circulation to occur at the tips where the upper and lower boundary layers meet (Figure 2.3). A trailing surface of discontinuity is formed as the extremities are rolled up. The resulting air flow pattern is called a Lanchester's vortex pair

(Missenden, 1987). The vorticies are known to create high turbulence and a strong air mixing effect (Kuethe & Schetzer, 1961).

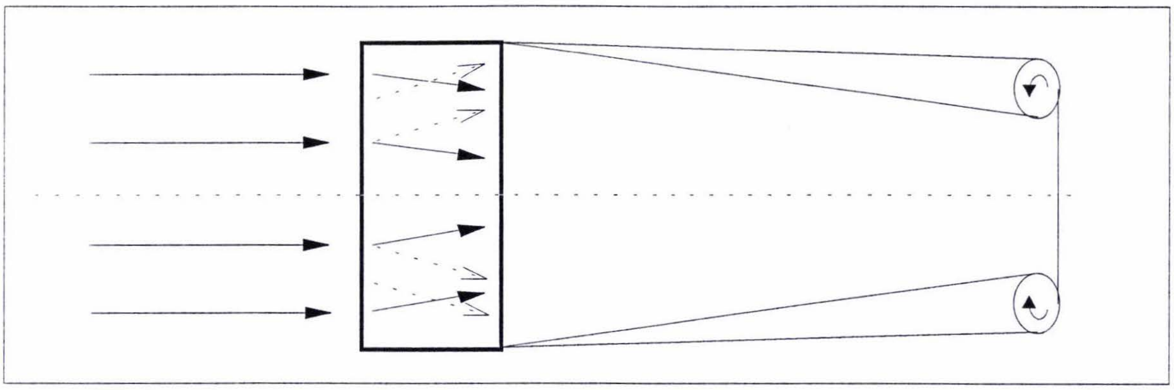


Figure 2.3: Flow over a inclined plate

2.2.4 FANS

In a chiller, air movement is required to transport heat from the product to the evaporators. For chillers and freezers, in particular, the amount of air movement is highly influential on the rate of heat removal from the product. Higher air movement allows chillers and freezers to be more compact and capital costs to be decreased, although at the expense of higher operating costs. However, there exists a limit where increasing the air velocity further leads to little benefit. Therefore, the amount of fan power used represents a compromise between capital and operating costs. As fans can typically provide over 30 % of the total heat load in chillers and freezers, optimisation of air flowrate is crucial (Cleland & Cleland, 1996).

Fans move air by the rotation of a number of aerofoils. Propeller fans are typically used for air circulation in chillers (Osbourne, 1977). These fans enable large volumes of air to be moved through the evaporator fins relatively economically and have a low capital cost. Air enters a propeller fan from all directions and is discharged mainly axially, but there is also some radial discharge. The velocity of the air stream drops rapidly as it leaves the outlet and spreads out at an angle between 15 and 20 degrees. When a resistance is imposed, such as ice formation on the evaporator, the air tends to flow back through the impeller. Because of this, propeller fans are not suitable for working against any substantial air flow resistance.

2.3 IMPROVING AIR DISTRIBUTION WITHIN CHILLERS

Improvement of air flow distribution within chillers tends to be situation specific because of the large number of variations in design and operating conditions. Careful consideration should be taken in the early stages of design since retrofitting devices to chillers is often difficult and expensive.

2.3.1 CHILLER DESIGN

In general, the poorest air distribution is found in long chillers in which the rails and the air flow are aligned with the length of the room (Figure 2.4a). Air velocities of less than 0.1 m/s have often been found between carcass sides in these circumstances (Garnett, 1974). This design is considered to be outdated and is almost non-existent in the modern meat industry.

In modern chillers, the most common design has the rails positioned along the length of the room and air is directed at right angles to the rails (Figure 2.4b). This design has the advantage of the air maintaining its momentum across the chiller as the air only has to travel the width of the chiller. Also air deflection is reduced as carcasses present their narrowest profiles to the air flow. Although this design offers some advantages, the overall air distribution still tends to be poor. In most cases the air flow pattern becomes a circular one, with the greatest proportion of air passing between the rails and ceiling in one direction and back between the floor and necks in the other. This gives rise to a 'dead' central area where there is little air flow over the carcasses. In addition, it is the neck, not the heavy hindquarter which experiences the highest air flows (Garnett, 1974).

A common method used to improve the air flow pattern produced from the standard design, is to use a false wall or duct (Figure 2.4c). This prevents air short circuiting from the evaporator outlet to the inlet, thus bypassing the carcasses. However, the problem still exists in that the bulk of fast moving air follows the path of least resistance around the outside of the carcass stack.

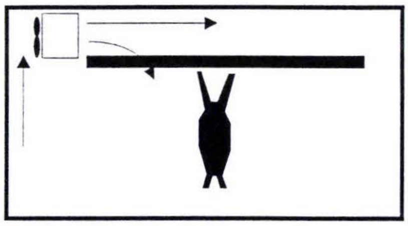


Fig. 2.4a: Wall Mounted units
Air flow along rails

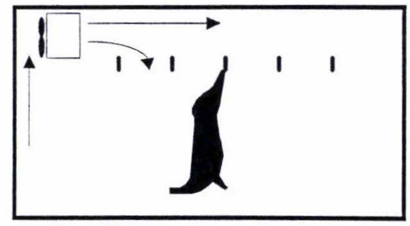


Fig. 2.4b: Wall Mounted units
Air flow across rails

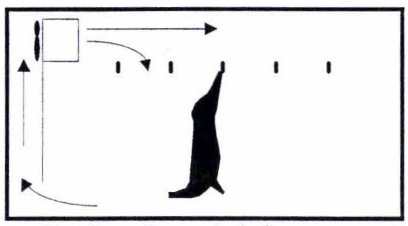


Fig. 2.4c: Ducted air flow system

Figure 2.4: Design configurations of chillers

Systems which guide air down onto the rails usually employ a plenum ceiling with slots above the rails (Figure 2.5a, 2.5b), or have a series of turning vanes (Figure 2.5c). Both systems can lead to hygiene problems and difficulties in ensuring the system is delivering an even distribution of air down between all the carcasses, however, these problems are not insurmountable (Garnett, 1974). The advantages of such systems is that the heavy hindquarter of the carcass is exposed to the fast moving air flow near the ceiling of the chiller giving faster chilling rates and also, when fine tuned, a more relatively air distribution can be achieved.

A recent approach is to reverse the flow of air in a ducted system (Figure 2.5d). Air is discharged across the floor and flows up between the carcasses (Willix, 1993). This system can produce a substantially more uniform air flow compared to the standard design as carcasses create a plenum effect at floor level enabling very even air distribution between carcasses. Willix (1993) suggests that a potential problem with this configuration could be condensation on the chiller rails and superstructure caused by moist, warm air coming off the carcasses.

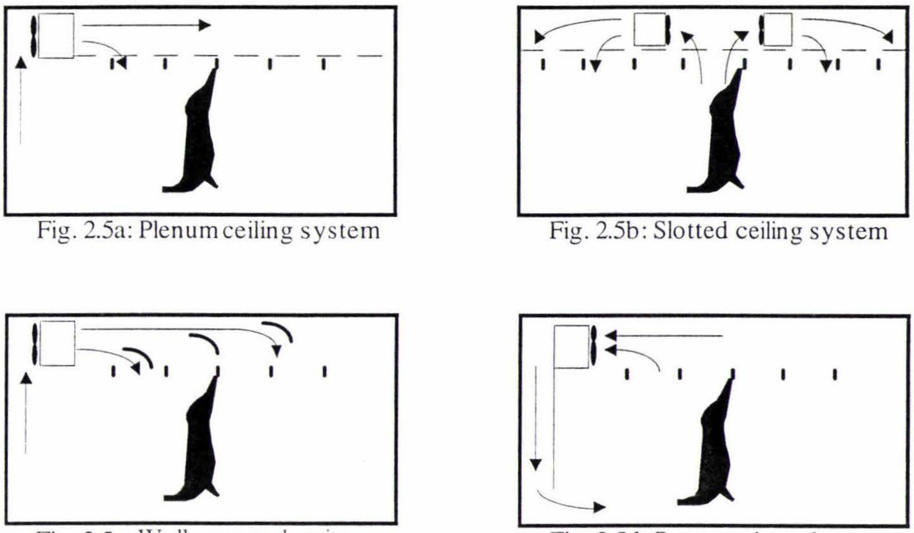


Fig. 2.5a: Plenum ceiling system

Fig. 2.5b: Slotted ceiling system

Fig. 2.5c: Wall mounted units with turning vanes

Fig. 2.5d: Reverse ducted system

Figure 2.5: Design configurations of chillers

Willix (1993) used a scale model to test a number of different chiller design configurations (details of this model are outlined in Section *2.4.1*). Results suggested that the basic design with wall mounted evaporators and no air deflectors gave the poorest air distribution of the configurations tested, regardless of room size or room loading. Extensive by-passing of air from evaporator inlet to outlet occurred, causing warm air to be drawn up through the product instead of the cold air being forced downwards. At ceiling level, the air was observed to be drawn back towards the evaporator inlet due to the high velocity by-pass effect. This caused considerable recirculation patterns and poor air movement between carcasses.

Willix (1993) found that the ducted air flow system, where the air inlet is at floor level and air is discharged at ceiling level, showed some improvement to the standard chiller configuration. In this case less by-passing of the air from inlet to outlet was evident. However, even with this configuration the high velocity by-pass effect was still visible, giving rise to poor air circulation between carcasses.

The plenum system gave the most uniform air distribution in a large 10 rail room of the configurations that were tested. However, the standard configuration fitted with turning vanes gave the most uniform air distribution in a smaller 6 rail room.

The model showed that a reverse ducted air flow system produced an air flow pattern of superior uniformity in comparison to patterns resulting from the standard design with wall mounted evaporators and the ducted system.

Early tests performed by Garnett (1974) at MIRINZ compared a standard chiller beef chiller with wall mounted evaporators and a chiller which directed air vertically downwards onto the hocks of carcasses using ceiling baffles. Results indicated that the average air flow over the carcasses for the vertical air flow configuration was 2-3 times as great at hock level and lifted by $^1/_3$ between the middle of the sides. The average deep leg temperature was reduced by a further 4°C after 16 hours of chilling and the average weight loss was reduced by 5% of the total weight loss.

Hodgson (1971) assumed that a linear relationship existed between the air circulation rate and the average air velocity at rump height. Chillers were compared by considering the rate of air circulation required to give an air velocity at rump height of 0.75 m/s per unit floor area. Hodgson found that a slotted ceiling system performed the best of all the configurations tested and required an air circulation rate of only 0.166 m^3/s per m^2, whereas, the plenum ceiling system, needed a high air circulation rate of 0.53 m^3/s per m^2. Both the standard configuration fitted with turning vanes and the ducted configuration, had an air circulation rate of about half of the plenum ceiling system with 0.257 and 0.248 m^3/s per m^2 respectively. Hodgson concluded that, in general, air circulation rates above 0.25 m^3/s per m^2 of floor area are required to keep the air temperature values below 5°C during peak load conditions.

2.3.2 AIR TURBULENCE IN CHILLERS

Measurement of air velocities in industrial chillers taken by Kondjoyan and Daudin (1995), demonstrated that mean air speed is only a very rough description of the flow. The air flow was found to include very rapid and large fluctuations spread over a few milliseconds which were superimposed on slow fluctuations spread over some minutes. Kondjoyan and Daudin (1995) found that if the flow contains only rapid fluctuations, turbulence is best described by the term turbulence intensity which is the standard deviation of the air speed fluctuations divided by the mean air speed. Turbulence intensity was found to affect the values of the heat transfer coefficients as much as the mean air speed. Increasing the air turbulence intensity from 6% to 31% had the same effect on the chilling rate as increasing the air speed from 0.5 m/s to 1.5 m/s on a 90 kg pork carcass hindquarter. Both of these variations reduced chilling times by one hour, for an air temperature of 1°C and a relative humidity of 80%. They concluded that as fan power is roughly proportional to the cube of air speed, it would be more profitable from an energy point of view to promote air turbulence rather than increase air velocity.

2.4 VISUALISING AIR FLOW PATTERNS

It is important to have a good insight into air flow within existing industrial chillers to be able either to modify operating conditions or to later improve the design of new chillers.

Air flows in refrigerated rooms can be examined in a number of ways. The main methods used are: scale modelling (Edwards, 1979; Lovatt *et. al.,* 1993), computational fluid dynamics (van Gerwen & van Oort, 1989; Wang & Visser, 1991), smoke or bubble generation, (Mueller, 1983; Amos, 1993; Missenden *et. al.*, 1995), ribbons (Winstanley, 1983) and anemometers (Hodgson, 1971; Oliver, 1986; Falconer, 1993; Daudin, 1992; Baleo, 1995).

2.4.1 SCALE MODELLING

The purpose of using small scale models is to be able to determine the effect of modifications in design or major changes to operating conditions without incurring unnecessary expense or risk. Scale models enable simple and accurate prediction of important criteria for the correct design of a full-scale installation.

Edwards (1979) used the technique of dimensional analysis scale modelling to study air flow patterns in carcass freezers. This technique meant that when using one-quarter scale models, air velocity had to be four times the full scale speed to maintain dynamic similarity with full-size freezers.

Willix (1993) and Lovatt *et. al.* (1993) used a 1/10, 2-dimensional scale model, with water as the flow medium, to investigate air flows in beef chillers. The model represented the cross-section of a chiller up to 10 m wide and 4.5 m high. Visualisation was achieved by using water as the flow medium and electrodes to generate hydrogen bubbles which were swept along by the flow. The model could be altered to represent a standard forced draft chiller with or without air deflectors, ducted and reverse ducted systems with or without air deflectors, as well as a plenum ceiling design, each with either six or ten rails. Results demonstrated that the model could provide a quick and inexpensive way of evaluating a wide range of alternative chiller configurations with a high degree of visual impact.

2.4.2 COMPUTATIONAL FLUID DYNAMICS

Computational Fluid Dynamics (CFD) is essentially the use of computers to solve the relevant fluid flow equations (Navier-Stokes equations) (Gigiel *et. al.,* 1994). Part of all CFD packages are graphic visual displays of the flow data. These are made up from information about the velocity, temperature and pressure of the fluid at every point in a computational mesh. Although this information can be obtained by measurement on a physical model, it would take a very long time and the measurements must be repeated for each change in external conditions. Although it is time consuming to set up the initial model, once a CFD model is obtained for one set of conditions, little effort is required to change the model to generate another set of data for different physical conditions. This makes CFD a very powerful mathematical tool for the modelling of fluid flows. However, difficulties arise in modelling flow around irregular shaped, 3-dimensional objects such as carcasses. In many cases complex objects must be approximated as a spheres, cylinders or boxes. Also, CFD is expensive due to the cost of the equipment, the software package, training courses and the large number of hours that are needed to develop expertise. The computing power needed is also relatively expensive. PC's can be used but are slow in many real applications.

van Gerwen and van Oort (1989) produced a advanced computer model using CFD which simulated the flow and heat transfer phenomena in cold stores for seasonal storage of fruit. The model was able to calculate the air velocities and product temperatures, based on the cooler air flow rate, product properties and the geometry of the cold store.

Wang and Visser (1991) simulated air flows in closed refrigerated rooms using CFD. The model described the flow in a closed room without air inlet and outlet openings, including detailed modelling of evaporators with circulating fans and various configurations of room loadings with boxes of produce.

Amraie (1993) carried out a small CFD study for a loaded test room which simulated conditions inside a chiller. This was a two dimensional model with rectangular sections to represent carcasses. Predictions from the model showed that (i) about half the air stream short circuited back to the evaporator inlet, (ii) short circuiting took place for the evaporator if there was only a short distance between outlet and inlet and (iii) air movement amongst the carcasses was small but there was high air movement along floors and return walls. These predictions agreed with experimental air flow data obtained in a pig pre-chiller.

2.4.3 SMOKE OR BUBBLE TECHNIQUE

A common way of monitoring air flow in a system is to use smoke trails. Visualisation of air flows by the use of 'smoke' includes methods which make use of a variety of smoke-like materials such as vapours, fumes and mists. Smoke flow visualisation techniques have evolved to a point where quantitative information can be obtained from the images of the smoke patterns using computers for image processing and lasers to illuminate the smoke (Mueller 1983). Less popular agents such as using bubbles for flow visualisation can also be effective (Missenden *et. al.* 1995).

Amos *et. al.* (1993) carried out smoke tests to ascertain air flow patterns in a large horticultural coolstore. The tests were carried out when the coolstore was empty, the doors were closed and all fans were operating at low speed. Results of the tests indicated significant back mixing and short-circuiting of air.

Missenden *et. al.* (1995) investigated room air mixing in a laboratory test chamber by using a bubble generator to visualise air flow patterns (as described in 2.2.3). The test room was fitted with bubble generators that had a capacity of 800 bubbles per second and produced bubbles of about 0.003 m in diameter with neutral buoyancy.

2.4.4 RIBBON OR TAPE TECHNIQUE

Use of smoke or bubble generators is often impractical in premises used for foodstuffs so alternative methods must be employed. Attaching tapes or ribbons at strategic positions within the chiller makes it possible to build up a picture of overall air movement.

Winstanley (1983) used tapes to detect ventilation deficiencies in a refrigerated room. It was found that a 2-3 inch strip of opaque polyethylene, quarter of an inch wide and the thickness used in a typical retailers' polybags, are suitable on most occasions. The tapes enable operators to see at a glance what is happening to air flow.

A number of difficulties arise when using this technique. Firstly, the air speed must be greater than a threshold value to overcome the gravity force acting on the tape, which depends on the thickness of the tape and the type of material used. Secondly, the mean position of the tape is often difficult to assess due to the air flow fluctuations commonly found in chillers (Daudin and van Gerwen, 1996).

2.4.5 ANEMOMETRY

Anemometry is concerned with velocity measurement of fluid flow. There are many types of anemometers available for the measurement of air speed such as those employing hot-wire, vane, cup, laser or sonic techniques. However, of these types, the hot-wire or thermal anemometer has traditionally been the most accepted method for measuring the detailed movements of air flow (Fingerson 1994). Hodgson (1971), Oliver (1986), Daudin (1992), and Falconer (1993) all successfully used hot-wire anemometers to measure air flows in refrigerated rooms in order to obtain an overall picture air flow patterns.

For many years the hot-wire anemometer has been successfully used to measure turbulent fluctuations, because it can handle fast fluctuations with ease. In its simplest form, a hot wire anemometer consists of a small metallic wire, usually of platinum or tungsten, which is heated by an electric current that flows through it. If the wire is cooled by air flowing around it, its electrical resistance is reduced and this reduction in resistance can be related to the air velocity.

The major limitation of most thermal anemometers (which is common to all devices that aim for point measurements) is their inability to measure the directional component of velocity. Thermal anemometers which can give a directional reading, utilise an array of six hot-wires and are thus expensive and cumbersome (Fingerson 1994).

Three orthogonally mounted vane or propeller anemometers (x-y-z arrangement), can be used effectively to measure the speed and direction of air flows (Jamieson, 1996). This method requires the use of vectors to calculate the magnitude and direction of the resultant, giving the overall air velocity. The main advantage of this technique is its low cost.

Since its introduction in 1964, the use of the laser velocimeter to measure the details of flowing fluids has expanded rapidly and has been used to visualise air flow patterns in refrigerated rooms. Baleo *et. al.* (1995) visualised the trajectories of injected particles in a refrigerated display case air curtain using a laser lighting system.

The laser velocimeter uses Doppler-shifted light scattered from particles in the flow to deduce the velocity of those particles. The laser velocimeter can resolve directional components and with frequency shifting, can detect flow reversals (Fingerson 1994). However, this method of air flow measurement has a high capital cost.

2.5 MEASURING AIR VELOCITIES IN CHILLERS

Measuring air flow within an industrial chiller is often difficult for a number of reasons (Daudin & van Gerwen, 1996). Firstly, the air flow is very turbulent due to fans and obstacles. This means that the airs direction and speed fluctuates rapidly with time and therefore their mean values at one location is difficult to measure. Secondly, the mean flow direction varies in space and consequently anemometers that are directionally dependent cannot be used. The mean air velocity also varies widely in space, so that a known value at one or several points have little meaning, particularly if they are not averaged over a long period of time. Thirdly, air speeds within chillers are often very low and in some places below the threshold of many anemometers.

2.5.1 MEASUREMENT DURATION

Daudin and van Gerwen (1996) carried out tests in chillers and dryers to evaluate how an average air velocity can be measured in turbulent and unsteady flows. Results suggested that if an accuracy of about 0.1 m/s is to be obtained, measurements performed at a frequency of 1 Hz must be averaged at least over a 5 minute period of time (Figure 2.6). It was therefore concluded that obtaining an air flow profile in a chillroom using a standard averaging procedure will be a tedious and time consuming process.

Daudin and van Gerwen (1996) suggest a different approach to assess air velocity distributions where the anemometers are moved slowly and measurements are recorded at regular intervals. The movement is achieved using either the conveyor in mechanical chillers or an independently operated truck. A discrete Fourier Transform is applied to the data in order to eliminate time-fluctuations and obtain the mean air velocity versus spatial co-ordinates. In this way air velocity can be measured at several thousands of points.

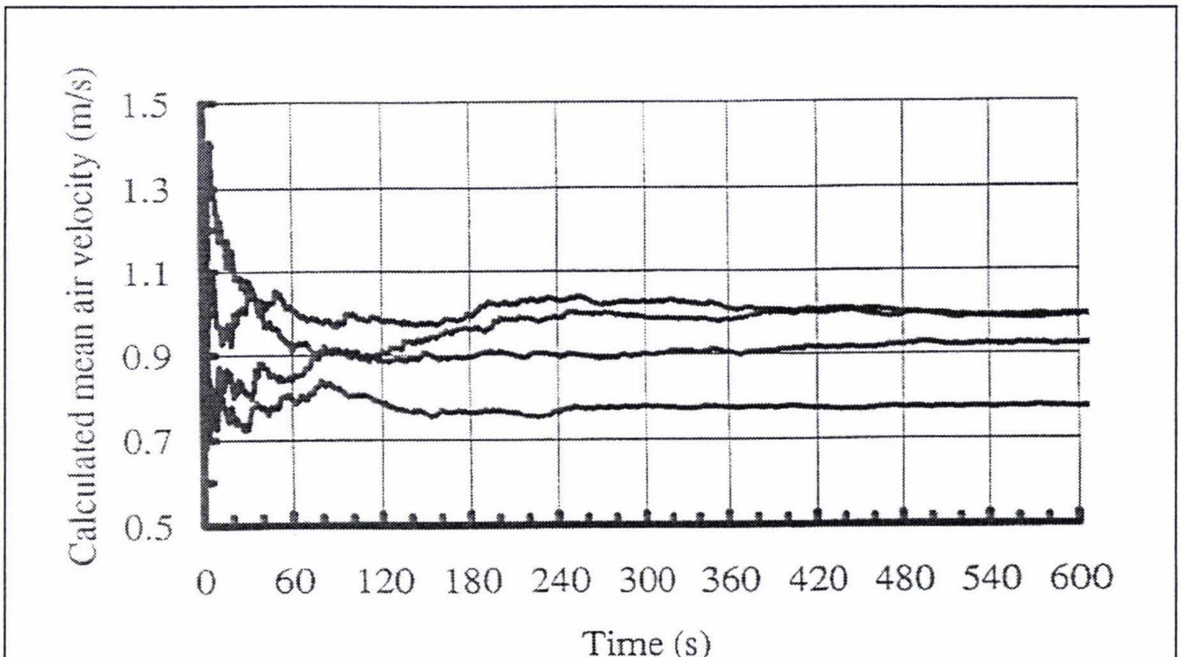


Figure 2.6: Variation of the calculated average air velocity with time at 4 locations in the chiller where the air flow was turbulent and unsteady (Daudin and van Gerwen, 1996)

Missenden (1987) used a similar approach to measure air movement within a test room. A remotely controlled vehicle was used to carry a pole on which thermistor probes were mounted. Air flows were measured at various positions on the track by controlling the vehicle and anemometers from outside the room. In this way any disruption to the air flow caused by moving in and out of the room was avoided. Unfortunately, it would be difficult to implement this technique in an industrial situation where chillers are constantly being loaded and unloaded, as fixtures needed to enable a tracked vehicle to operate would cause process problems. Also, industrial chillers are often tightly packed, making it difficult for a mechanical vehicle to move freely between carcasses.

2.5.2 NUMBER OF MEASUREMENTS

In an industrial batch chilling situation, measurements of air flow are usually performed over a fixed chilling period. Once the length of each measurement is decided, the period of the chill cycle largely dictates the maximum number of measurements that can be obtained.

Amraie (1993) measured air flows in an industrial pig pre-chiller which had a volume of 87.7 m^3. A total of 279 point measurements were taken in the full pre-chiller and 130 point measurements were taken in the empty pre-chiller to produce an air flow profile of the room.

2.6 DELTA WING VORTEX GENERATORS

2.6.1 VORTEX GENERATION

A highly swept, thin delta wing shaped aerofoil produces strong vortex interactions off the leading edges of the wing. These vortices are used as a form of direct lift control in aerodynamics, enabling an aircraft to manoeuvre at high angles of attack without stalling (Rom, 1992). The most favourable case for vortex generation is where the axis is nearly parallel to the translational motion and the diameter is large. This occurs over the surface of a highly swept wing at incidence to a flow field. Vortices are formed by the separation of the flow from the leading edge as the angle of attack is increased, as illustrated in Figure 2.7

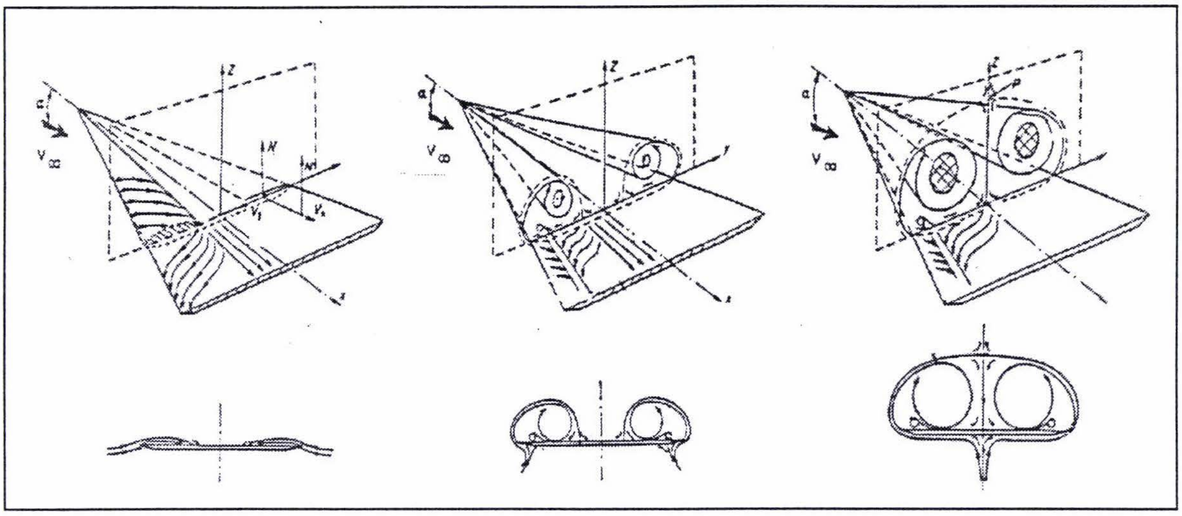


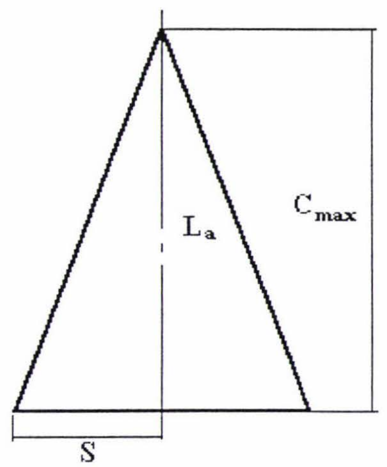
Figure 2.7: Structure of flows over delta wings with sharp leading edges (Rom, 1992)

As with a flat plate inclined to the air flow (Section *2.2.3*), the low pressure above the wing draws the separated sheet down towards the surface and rotation commences (Missenden *et. al.* 1995). A stagnation point occurs where the vortex loses its structure and breaks up, or bursts into large scale turbulence of considerable characteristic length and penetration. This creates a strong mixing effect which can be applied to enhance heat and mass transfer rates. The position of the burst depends on the angle of incidence, a figure below 30° provides bursts beyond the leading edge.

2.6.2 DELTA WING VORTEX GENERATORS FOR IMPROVED AIR MIXING

Missenden (1987) investigated the use of thin delta plan aerofoils of small semi angles (degree of sweep) at large angles of incidence in an artificially ventilated room to assess the influence of strong leading edge vortices upon air movement (Figure 2.8).

It was determined by computer modelling that the optimum wing position within a ventilated room was within the fast moving diffuser outlet air stream. The model also showed that the conversion of the air stream to vortices increased dramatically as the wings approached the diffuser. Smaller wings allowed more intensive use of the thin fast moving part of the air stream but reduced the bursting and penetration distance of the vortex fragments.



L_a = Semi angle (degree of sweep)

S = Trailing edge semi span (m)

C_{max} = Maximum chord length (m)

Mean Chord length (m), $C_m = {}^2/_3 C_{max}$

Aspect Ratio = $\frac{2S}{C_m}$

Figure 2.8: Delta wing geometry (Missenden, 1987)

Test results from a ventilated room showed that the vortex generators reduced the overall measured room air movement, whether assessed as mean air speed, momentum rate or power. At the same time, fragments of the vortex were in the order of 3-4 maximum cord lengths (0.9-1.2 m) and directed downwards and downstream of the wings trailing edges. This effect was maximised with large numbers of small wings situated within the fast moving plug flow region of the air stream, close to the ceiling and to the diffuser outlet. Larger wings reduced the effect but provided a longer distance spread of the vortex fragments.

Missenden concluded that experimentation together with computer models indicated that vortex generators could be expected to reduce the overall room momentum and kinetic energy. This would allow for higher air supply rates in air conditioned spaces before a condition of discomfort is reached. Also, locally perceived air movement is increased due to the fragments of fast moving burst vortices penetrating many cord lengths beyond the wings edges.

Amraie (1993) considered improving room air movement and velocity distribution within meat chilling rooms by using delta wing vortex generators. He investigated the local air velocities inside a commercial chilling room both empty and filled with pig carcasses. Results showed that some of the local air velocities around the carcasses were very low and were considered to be detrimental to the quality of the meat, indicating substantial room for improving air distribution. It was concluded from this set of experiments that the use of delta wings as baffles to convert the air flow from a unidirectional air stream, progressively into rotational and then turbulent multidirectional fragments of moving air directed into the occupied part of the room, could substantially reduce chilling times.

An experimental simulation of the pig carcass chiller was carried out in a laboratory test room. The room had similar dimensions to the pig pre-chilling room which was 4.5 m wide, 5.5 m long and 3.0 m high. A dummy evaporator produced uniform air flow into the room through a baffled diffuser mounted high on one wall. The diffuser was constructed from plywood with 348 equally spaced holes and it produced a face velocity of 1.57 m/s. A total of 40 'dummy' foam pig carcasses were hung in the test room at various positions to represent a fully loaded chiller. Air speed and temperature measurements were taken by thermistor probes positioned strategically in the test room. Two different sizes of wings were used, a small wing with a maximum cord length of 395 mm and a semi-span of 20° and a larger wing with a maximum cord length of 1000 mm and a semi-span of 20°. Wings were trialed in two different configurations. The first configuration involved placing 4 small delta wings close to the diffuser, followed by 2 large wings, then this was followed by two rows of 5 small wings (4, 2, 5, 5). The second configuration utilised 2 large wings mounted close to the diffuser, then a row of 4 small wings which was followed by two further rows of 5 small wings (2, 4, 5, 5). Different positioning of the delta wings indicated that the most effective configuration in room air mixing was the latter. Amraie concluded that the delta wings gave quantifiable increases in room air movement.

2.7 RESEARCH OBJECTIVES

It is evident from this literature survey that differences in opinion still exist regarding the optimum conditions required within chillers. However, researchers generally agree on the importance of reducing carcass temperatures rapidly once the slaughtering and dressing operations have been completed. It is also accepted that velocity and turbulence of air within a chillroom have a large influence on overall carcass chilling rates. Studies have shown that velocity distributions within chillrooms are generally far from the ideal situation of uniform air flow and, in contrast, there are often stagnant areas between carcasses where good air circulation is needed most.

Low or stagnant local air velocities around carcasses are considered to be detrimental to the quality of meat. Air distribution systems that have been developed in the past have only been partially successful in that they have tended to cause hygiene problems which result from difficulties in cleaning or have involved a high capital cost. Therefore, further development of simple, low cost air distribution systems is required to prevent zones of low air flow and recirculation of air.

The potential of delta wings as vortex generators has been shown by Missenden (1987), and Amraie (1993). However, delta wings have not been tested in industrial meat carcass chillers and the effect on rates of chilling and weight loss have not been examined.

Therefore, the aim of this research is to further extend the work carried out by Amraie (1993) in improving environmental conditions within chillrooms. This will be achieved by using delta wings to convert the unidirectional air stream produced by the evaporator fans, into turbulent, multidirectional fragments of moving air directed into the occupied part of the chiller. These fragments of fast moving air should increase air movement between carcasses and thus make the local environment more representative of the average room conditions, and in doing so improve the quality of the final product, as well as providing energy savings.

The specific objectives were to:

(i) Characterise air flow patterns in an empty industrial meat carcass chiller without delta wings.

(ii) Characterise air flow patterns in the fully loaded meat carcass chiller without delta wings.

(iii) Characterise air flow patterns in an empty industrial meat carcass chiller with delta wings installed and compare results to those found without delta wings.

(iv) Characterise air flow patterns in the fully loaded meat carcass chiller with delta wings installed and compare results to those found without delta wings..

(v) Determine the effect of pitch, size and spacing of delta wings on the air flow pattern.

Chapter 3

MATERIALS AND METHODS

3.1 INTRODUCTION

The aim of this study was to trial delta-wing vortex generators within an industrial meat carcass chiller and assess their performance in improving the air flow uniformity and its effectiveness adjacent to the product.

Initial chiller characterisation was achieved by taking extensive air flow measurements while the chiller was both empty and fully loaded with carcasses. Delta wings were then installed and the modified chiller was re-characterised. Air flow data from the modified chiller was compared to data from the initial characterisation to determine if the delta wings induced any changes in air flow characteristics.

3.2 CHILLER SPECIFICATIONS

3.2.1 CHILLER CONSTRUCTION

Due to project time constraints only one chiller was studied in this research. The chiller was chosen to have a design typical of that used in the New Zealand meat industry with wall mounted evaporators and sandwich panel for walls and ceiling. The chiller is situated at Venison Packers Trading Limited, Fielding and had been constructed in May, 1992.

The basic dimensions of the chiller are shown in Figure 3.1. The overall dimensions are 10 metres long by 5 metres wide and 3.53 metres high. Loading and unloading doors are located at opposite ends of the chiller and each are 1.2 metres wide by 2.48 metres high.

The chiller utilises three evaporator units mounted along the length of the room at ceiling height with a distance of 510 mm to the wall on the suction side. Each unit is 360 x 3000 mm long by 470 mm high with a 240 mm spacing between the units.

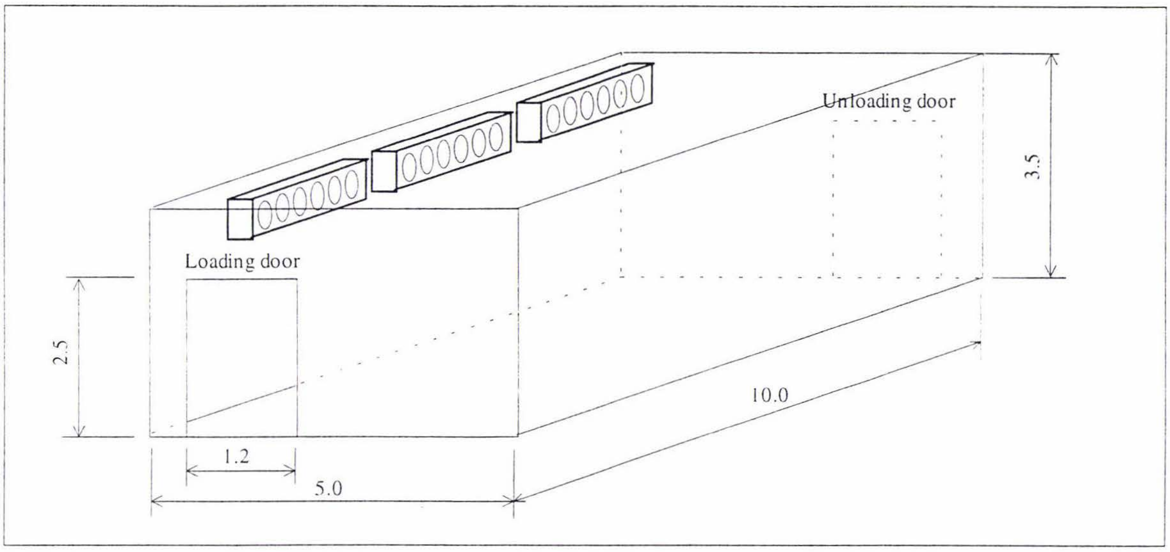


Figure 3.1: Basic chiller dimensions

The chiller contains six carcass rails. Rails are suspended from steel H-beams directed across the width of the chiller. The H-beams are supported on perpendicular steel beams mounted onto the walls. Full detailed dimensions of the chiller are shown in Appendix A, Figure A.1.

3.2.2 CHILLER EVAPORATOR SPECIFICATIONS

The chiller houses three SP8/4/HG/S comprex evaporator units supplied by Comprex Industries Limited, Feilding, New Zealand (Figure 3.2). The units employ six Ziell EBM A350 fans for air circulation which are constructed from four 175 mm blades at a 30° pitch. The volumetric flowrate through each unit is 12,200 m^3/hr with fans operating with a face velocity of approximately 5 m/s and rotation speed of 1350 rpm. The power requirement for each fans motor is 650 watts.

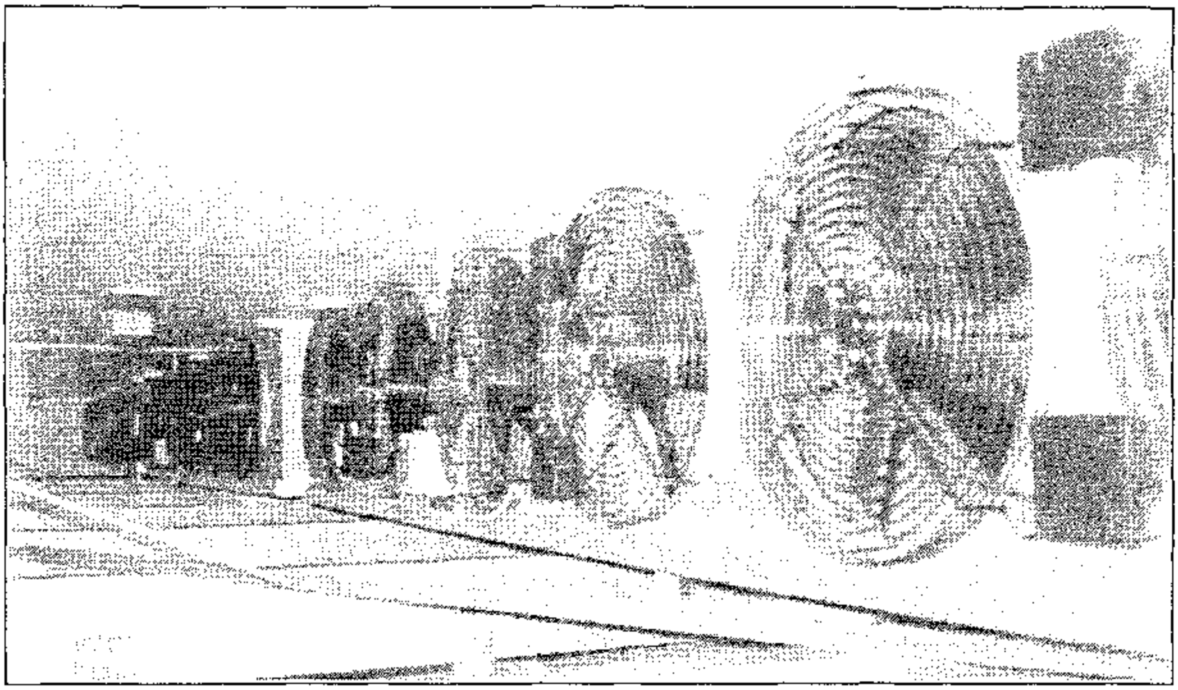


Figure 3.2: Evaporator Units

3.2.3 CHILLER OPERATION

Slaughtering is usually carried out between the hours of 6 a.m and 4 p.m. according to demand. Hot carcasses are weighed and loaded into the chiller after being slaughtered and dressed. During loading, refrigeration is turned off and doors are left open, but fans operate, circulating warm air at 10-15°C around the chiller.

Dressed carcasses can exhibit large weight variations. The dressed weight of red deer carcasses range from 35 to 160 kg, whereas fallow deer carcasses range from 17 to 25 kg. The maximum capacity of the chiller is 150 medium sized red deer with an approximate dressed weight of 50-60 kg or 170 fallow deer with an approximate dressed weight of 20 kg. However, the chiller can be loaded with a combination of red and fallow deer.

Once slaughtering is finished, the chiller doors are shut and refrigeration is turned on. Under normal operating conditions carcasses are chilled for 14 hours, however in special circumstances carcasses might be left in the chiller for up to 62 hours.

During chilling air temperature in the room is controlled to 2°C which is measured at the evaporator air-on position. Fans and refrigerant are turned off for 30 minutes at regular 4 hour intervals for evaporator defrost. Under normal operation, humidity levels are initially about 90% relative humidity (RH) at the start of the chill cycle and fall to approximately 83% before carcass unloading commences. During defrost periods, relative humidity rises to about 90% for a short time.

After chilling is complete the cold carcasses are re-weighed and then boned out. Carcasses are removed in the same order that they were loaded into the chiller, starting from the first rail and working back to the sixth rail. Fans and refrigeration remain on while unloading takes place.

3.3 AIR FLOW MEASUREMENTS

To measure air flow, two types of anemometers were used in this study: A Dantec FlowMaster 54N60 hot-wire anemometer was used for the purposes of measuring the mean, standard deviation, and range of the air speed over a set period; while three orthogonally mounted Gill propeller anemometers were used to measure air velocity (speed and direction).

3.3.1 MEASUREMENT METHODS

Air speed measurements made using the hot-wire anemometer were performed by two different methods:

Method 1: Air speed could be measured over a set integration period of 10, 60 or 180 seconds and the mean and range of the air speed was read directly from the anemometers display.

Method 2: The anemometer could be connected to a Grant 1200 series data logger via a RS232 cable which continuously records air speed data as a voltage at a frequency of 1 Hz over any measurement period greater than 1 second. The mean, range and standard deviation of the air speed was then calculated from this data.

In using the first method, standard deviations for each integrated measurement was estimated from the range using tables from Kramer and Twigg (1970) (Section *3.3.2.8*). For the second method, logged voltage data was firstly converted to air speeds, then the mean, range and standard deviation of the air speed for each measurement could be calculated directly from this data. All instrument testing was performed using the second method of data recording. The first method was used for some of the initial work performed in the chiller but was later substituted for the second method.

The method used for measuring air velocity using the orthoganally mounted propeller anemometers was to connect each transducer to a Grant 1200 series datalogger. Voltage outputs from the anemometers were continuously recorded by the datalogger at a frequency of 1 Hz over the duration of each measurement. Voltage data was converted to air speeds which was then used to obtain a time-averaged value of the air velocity (direction and magnitude).

For all air speed and velocity measurements taken between the heights of 1.0 m and 3.0 m, both the hot-wire and orthoganally mounted propeller anemometers were attached to a 2.0 m long stainless steel rod mounted on top of a camera tripod. Height adjustment was achieved by clamping the anemometers at different positions along the rod. For measurements below 1.0 m, anemometers were attached to a small laboratory clampstand. The hot-wire anemometer was positioned to the side of the propeller anemometers to avoid interference from the blades, but kept at the same height. Both the hot-wire and orthogonally mounted propeller anemometers attached to the clampstand are shown in Appendix A, Figure A.5.

3.3.2 AIR SPEED MEASUREMENTS - INSTRUMENT CALIBRATION AND TESTING

Before the hot-wire was used to characterise air flows within the chiller, a number of tests were carried out to assess its performance.

3.3.2.1 Calibration

The Dantec FlowMaster 54N60 hot-wire anemometer was calibrated against a micromanometre (traceable to national standards) at the Meat Industry Research Institute of New Zealand (MIRINZ) in the range of 0-8 m/s. The anemometer was found to have an R^2 value of 0.9998 and an offset of +0.002 m/s over this range.

3.3.2.2 Correlation of Voltage Signal With Displayed Air Speed Reading

In using the second method for the measurement of air speeds (described in Section *3.3.1*), logged voltages needed to be converted to time averaged air speed readings. The relationship between the continuous voltage output produced by the anemometer and the time averaged values was determined by taking replicate measurements at a range of air flow rates in a variable air speed tunnel (Figure 3.3). Measurements were performed using a frequency of 1 Hz over a duration of 1 minute. Data from this experiment is tabulated in Appendix B, Table B.1. Additional photos of the air tunnel are shown in Appendix A, Figures A.6 and A.7.

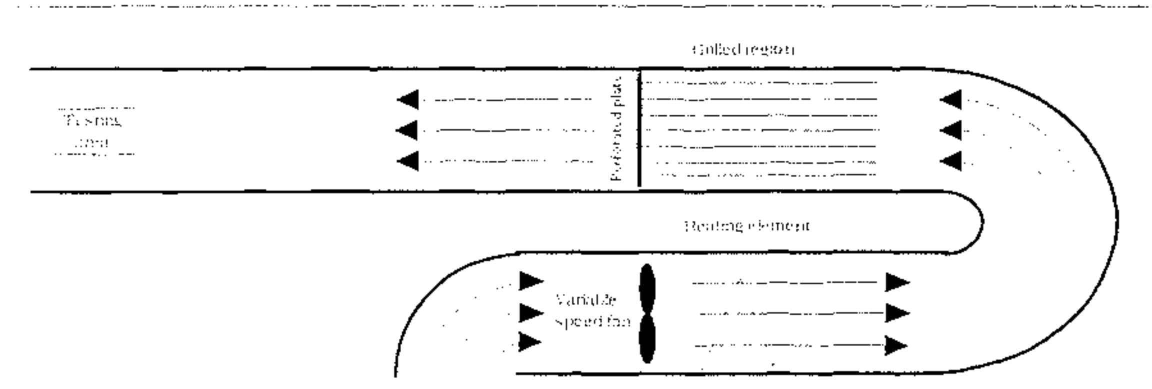


Figure 3.3: Variable air speed tunnel

Figure 3.4 shows that the voltage signal was found to be directly proportional to the displayed air speed reading according to:

$$V\ (\text{m/s}) = 10.145(\text{millivolts}) \tag{3.1}$$

Voltages recorded from the hot-wire anemometer by the Grant 1200 series data logger were converted to air speed readings using equation 3.1.

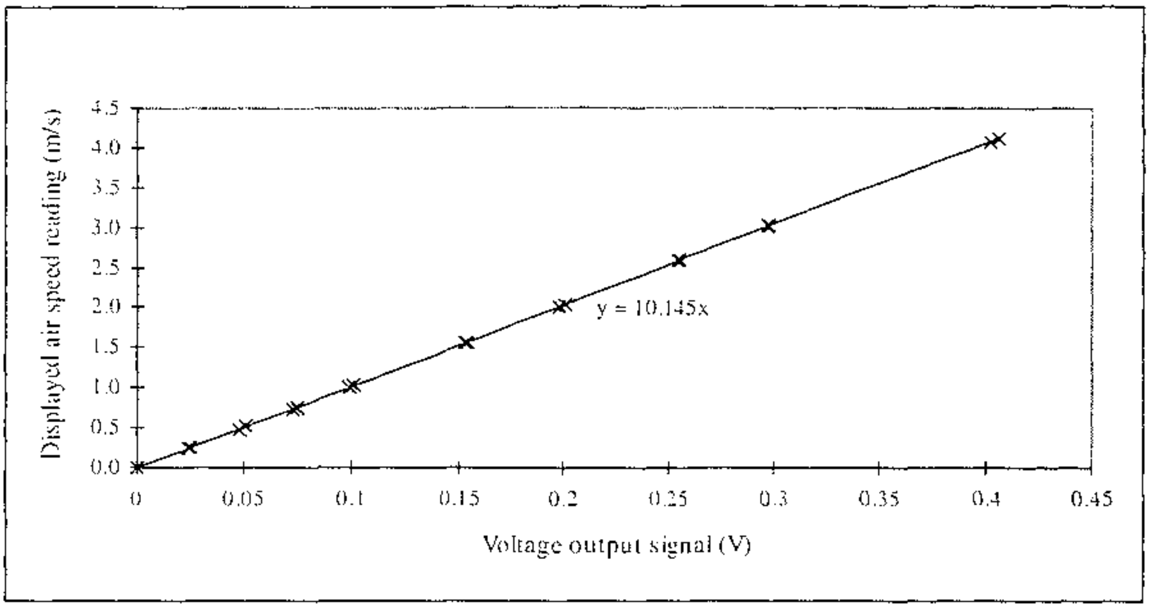


Figure 3.4: Correlation of hot-wire anemometers displayed air speed reading with time averaged values

3.3.2.3 Transducer Housing Interference

Air speed measurement errors caused by the protective housing around the anemometer sensors were investigated. The hot-wire anemometer transducer contains a velocity sensor and a temperature compensator made of nickel wire coils on the end of a 40 cm long shaft. Both the temperature compensator and the velocity sensor are encased in the framework of a protective metal housing (Figure 3.5).

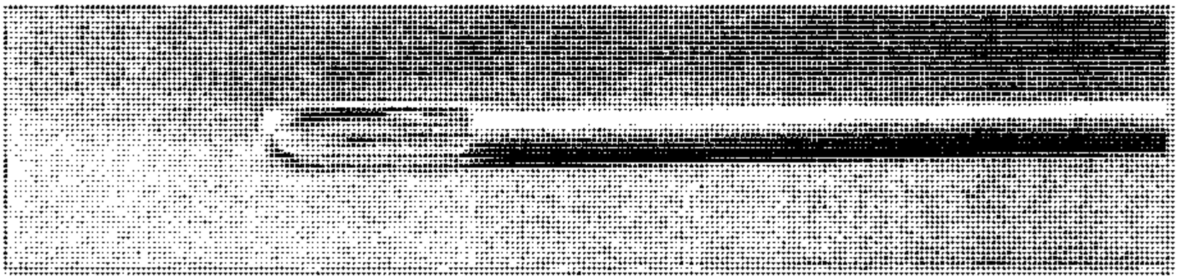


Figure 3.5 Hot-wire anemometer transducer

Tests were carried out in the variable speed air tunnel using a constant air flow of approximately 1 m/s (Figure 3.3). The transducer housing was rotated through 180 degrees with the shaft perpendicular to the direction of the flow. At each change in angle, the mean air speed reading was measured over a duration of 1 minute.

As the housing shape is symmetrical there were two possible orientation angles where the housing area presented to the air stream was at a minimum. These occurred 180 degrees apart from each other. One of these positions was used as an initial starting point and was arbitrarily chosen to be at a 0 degree orientation angle. By assuming a 'true' air speed reading was obtained when the hot-wire filament was perpendicular to the air flow and the housing area presented to the air stream was at its least, errors associated with each angle of rotation could be determined. Experimental data from these tests is tabulated in Appendix B, Table B.2.

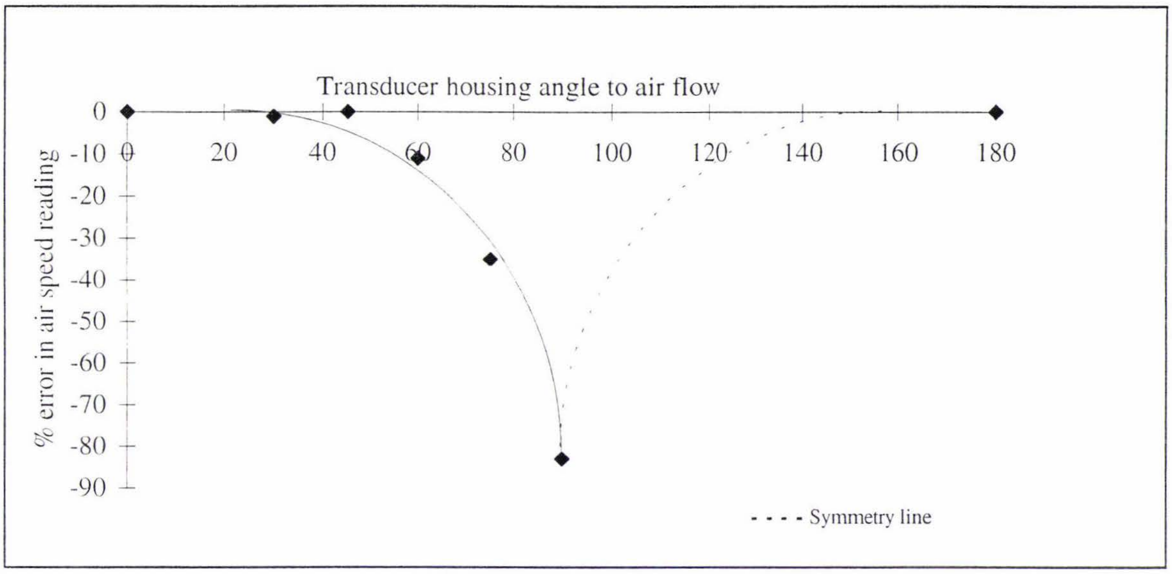


Figure 3.6: Anemometer air speed reading interference at various transducer housing angles to air flow.

Figure 3.6 shows that as the housing is turned past an angle of 45 degrees, measurement errors become obvious due to the filament being sheltered by the metal housing. Results indicate that significant errors in the air speed reading occur between housing angles of 45 and 135 degrees to the air flow. Similar errors can be expected between angles of 225 and 315 degrees due to the housing symmetry. These results were consistent with those of Daudin and van Gerwen (1996).

To eliminate this potential source of measurement error within the chiller, all measurements were performed by orientating the anemometer according to a red cotton tread attached to the end of the transducer. The thread gave an indication of the air flow direction around the sensors. This enabled the housing to be rotated to a position of least interference. Although, this method was relatively subjective it was adequate to enable the transducers housing to be kept within the critical range of ±45 degrees to the air flow.

3.3.2.4 Measurement Time

Air flow within a chiller is often turbulent and unsteady. In order to gain a better representation of air speed at any one position within a chiller, readings can be integrated over a set period of time. The longer the duration of the measurement the closer the mean air speed reading should be to the true mean air speed.

Tests were carried out to determine the measurement duration required to obtain an accurate estimate of the mean air speed in a fluctuating air stream. Four positions within the chiller with turbulent air flow were chosen and at each of these positions air speed readings were taken over a measurement duration of 5 minutes. Air speed data from these tests is tabulated in Appendix B, Table B.3 and the mean, range and standard deviation of the air speed calculated at various time intervals for each position is given in Appendix B, Tables B.4-B.7.

Figures 3.7 to 3.10 indicate that the air flow in the chiller is made up of very rapid, large fluctuations. This agrees with work performed by Kondjoyan and Daudin (1995) in the chilling and storage of foodstuffs (Section *2.5.1 Literature Review*). These fluctuations in the air flow cause the calculated mean air speed value to vary with time. The longer the duration of measurement time, the less impact each fluctuation in air speed has on the calculated mean.

When considering the duration of measurement time for taking mean air speed measurements, a 'trade-off' has to be made between the length of time for each measurement and the quantity of measurements taken. According to results shown in Figures 3.7 to 3.10, the ideal measurement period should be at least three minutes in order to obtain an accurate representation of the true mean air speed at any one position within the chiller. However, a 3 minute measurement period would significantly reduce the number of readings able to be taken over a chill cycle. Therefore, a compromise had to be made. A measurement period of 1 minute was chosen to enable a satisfactory quantity of readings to be completed over the limited time available.

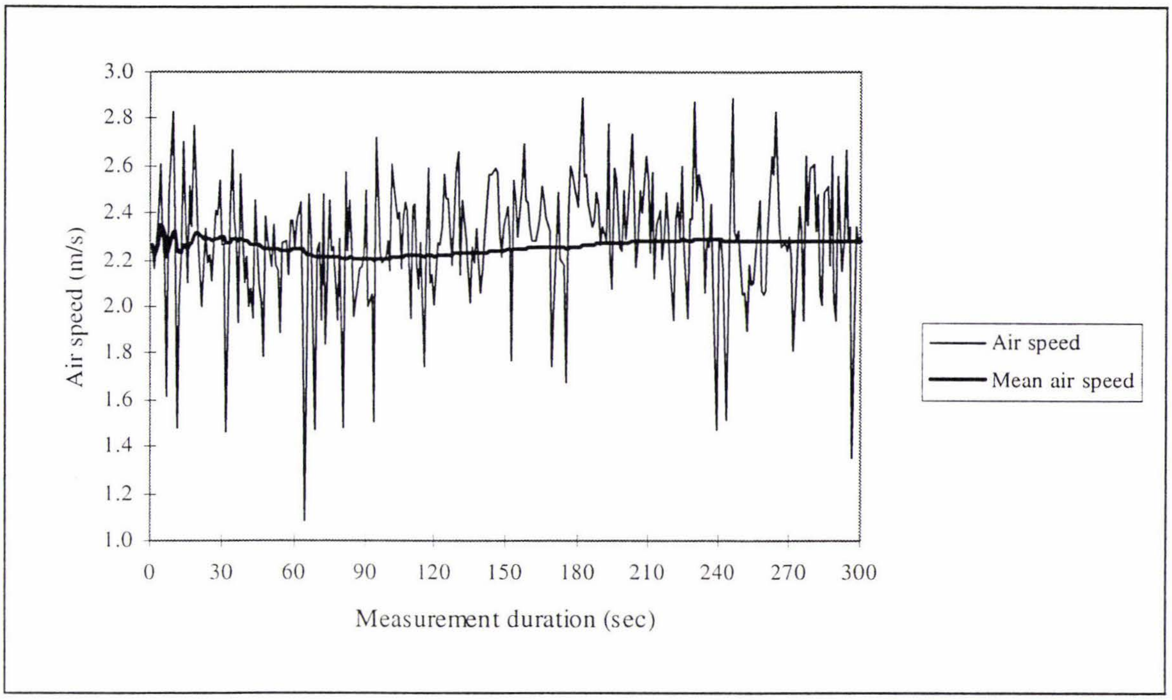


Figure 3.7: Variation of the calculated average air speed and actual air speed with time for position 1.

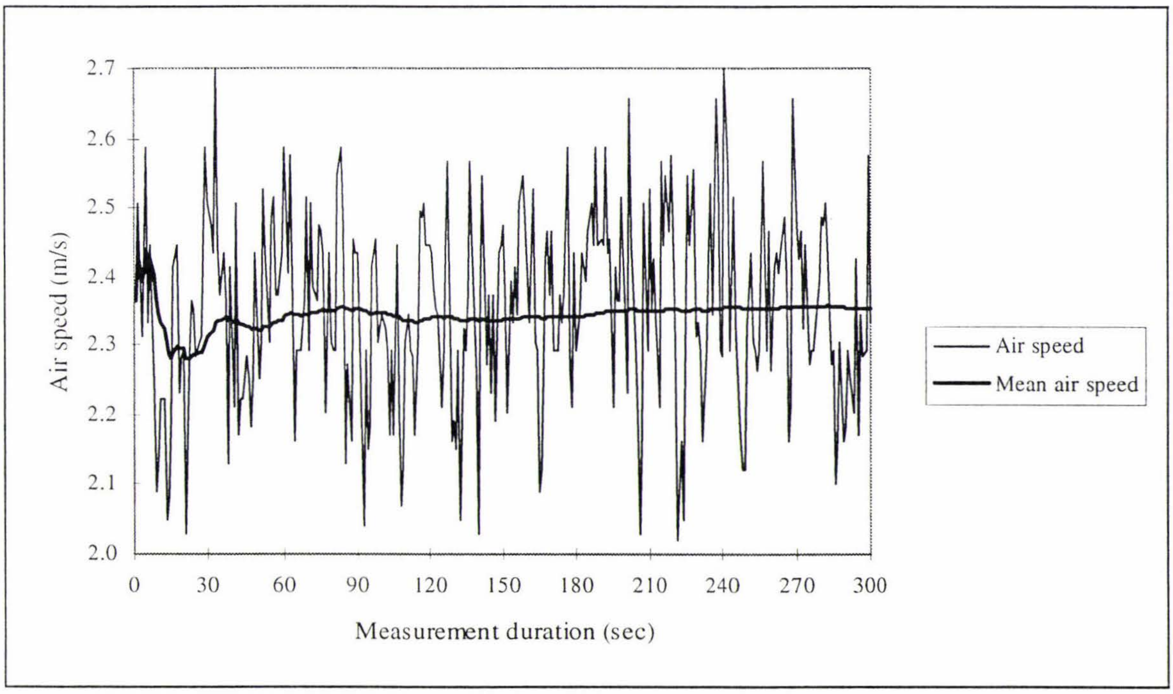


Figure 3.8: Variation of the calculated average air speed and actual air speed with time for position 2.

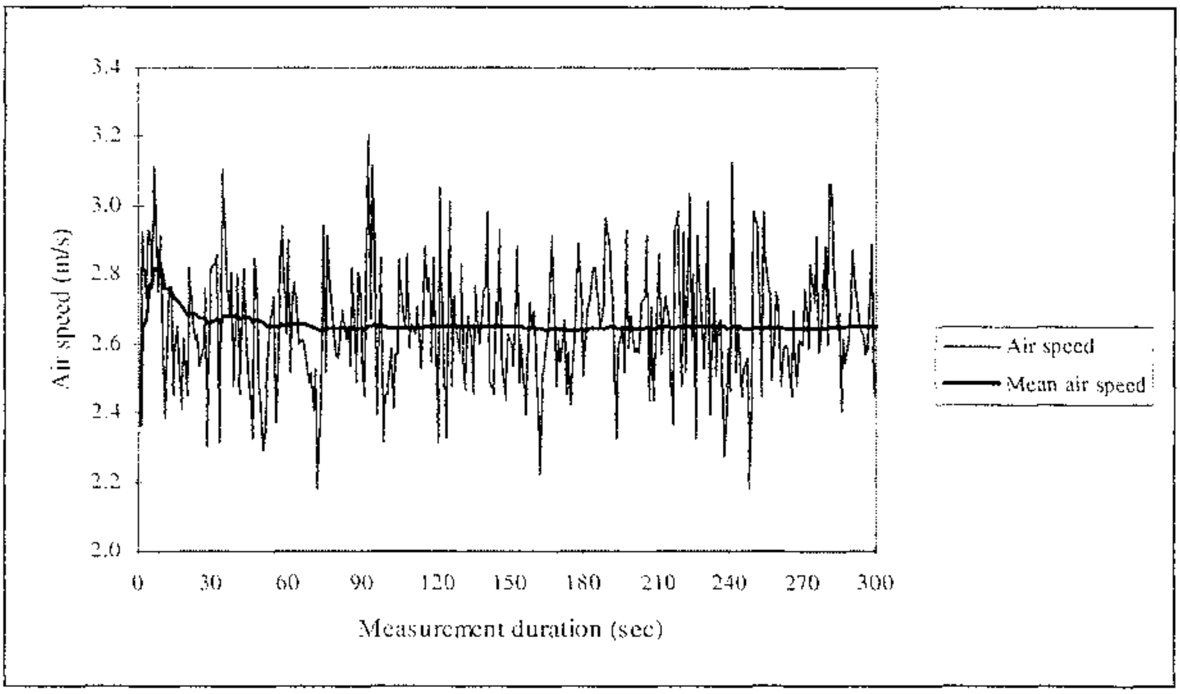


Figure 3.9: Variation of the calculated average air speed and actual air speed with time for position 3.

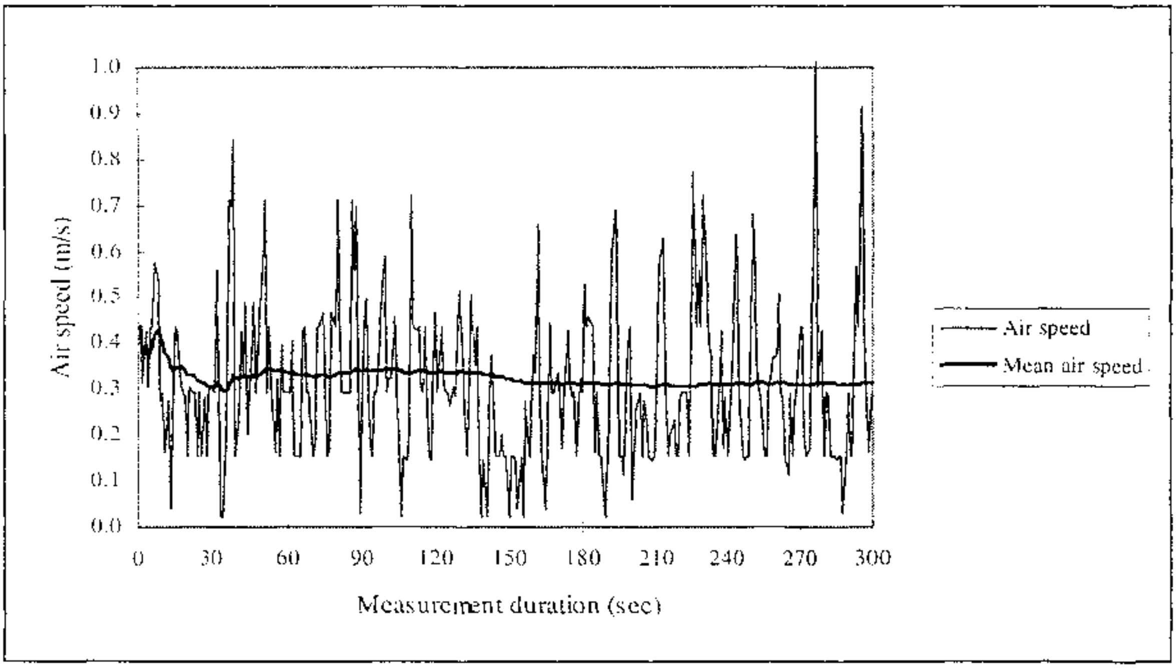


Figure 3.10: Variation of the calculated average air speed and actual air speed with time for position 4.

Figure 3.11 shows the maximum errors obtained for the mean, standard deviation and range of the air flow for different measurement periods over the four positions (Data is given Appendix B, Table B.9).

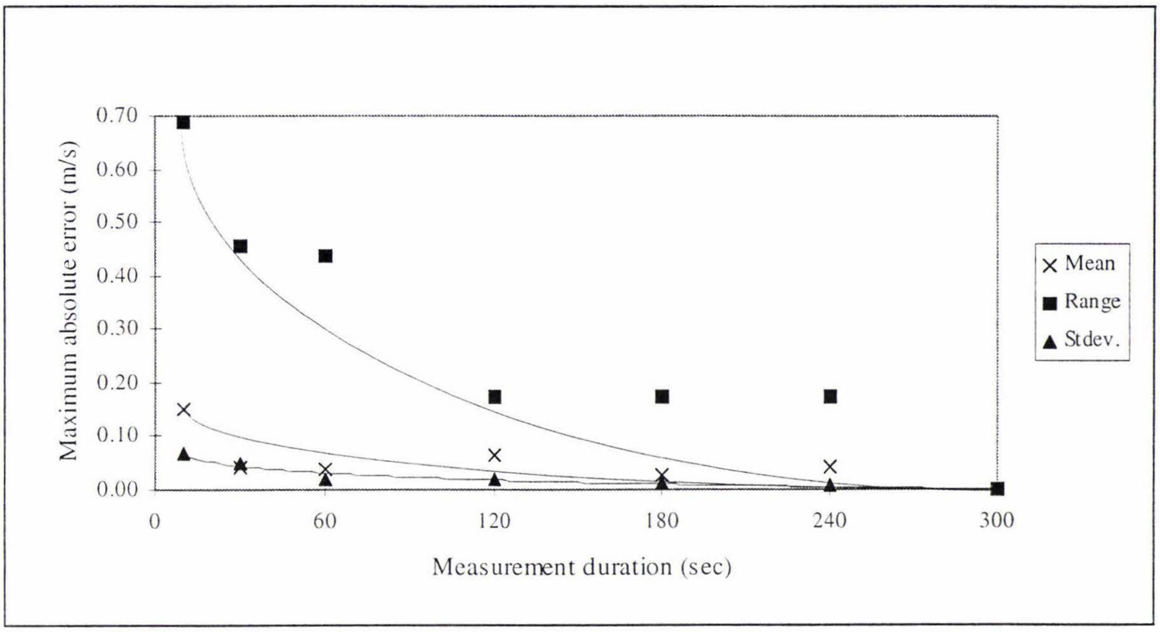


Figure 3.11: Maximum errors in mean estimates of statistical parametres for 4 positions within the chiller with turbulent air flow.

For a measurement duration of 1 minute, the maximum errors for the mean and standard deviation were considered to be acceptable at 0.038 m/s and 0.017 m/s respectively. However, the estimated average error for the range over this time was significant at 0.436 m/s.

3.3.2.5 Estimation of Measurement Error Caused By Random Fluctuations in Air Flow

Random air flow fluctuations within the chiller cause slightly different estimates of the mean, range and standard deviation of air speed to be obtained for replicate measurements. The uncertainty associated with each reading was estimated by comparing a number of air speed measurements taken in the same location within the chiller.

Using the same data collected for the estimation of measurement time, the mean, range and standard deviation of the air speed were calculated over a 1 minute measurement duration for the four positions discussed in Section *3.3.2.4*. This resulted in five 1 minute readings being obtained for the three parametres at each position. The range of these five replicate readings was used as an estimate of the uncertainty associated in the air speed measurements. The data from this experiment is tabulated in Appendix B, Table B.9 and B.10 and is summarised in Table 3.1.

	Position 1			Position 2			Position 3			Position 4		
	Mean (m/s)	Range (m/s)	Stdev. (m/s)	Mean (m/s)	Range (m/s)	Stdev. (m/s)	Mean (m/s)	Range (m/s)	Stdev. (m/s)	Mean (m/s)	Range (m/s)	Stdev. (m/s)
Range	0.182	0.619	0.094	0.051	0.122	0.024	0.040	0.304	0.040	0.078	0.345	0.072

Table 3.1: Range between statistical parametres for 5 air speed readings taken in 4 different positions within the chiller.

Table 3.1 shows that the maximum range over the 5 replicate mean air speeds readings was 0.18 m/s which was considered to be acceptable. It should be noted that this does not take into account errors associated with deviations in probe placement.

3.3.2.6 Attainment of Steady State Conditions

The major concern with the attainment of steady state air flow conditions is not the length of time that the chiller is left before measurements commence, since air flow steady state conditions are attained very rapidly. Instead the main problem is to ensure that steady state is re-established before each measurement is taken, as the air flow is disturbed each time the anemometer is re-positioned.

There are four distinct steps (phases) in taking a measurement in the chiller:

Step 1 (phase 1): Entering the chiller to position transducer (opening and closing chiller door). (15 seconds approx.)

Step 2 (phase 2): Positioning the transducer at the correct measurement site within the chiller. (30 seconds approx.)

Step 3 (phase 3): Exiting the chiller (opening and closing chiller door). (15 seconds approx.)

Step 4 (phase 4): Operating the anemometer from outside the chiller (taking the measurement). (60 seconds)

Every time the chiller door is opened or the transducer is re-positioned to a new measurement site, there is a substantial disruption of the air flow within the chiller. If steady state conditions are not quickly re-established again after the disruption, an inaccurate estimate of the air flow parameters at the next measurement position will result. Therefore, it is critical that air speed measurements are taken while the chiller is under steady state conditions. Tests were performed to assess whether steady state conditions are re-established before the next measurement commences. Air speed data was continuously logged while performing five air flow measurements of 1 minute duration at different positions within the chiller. Air speed data is tabulated in Appendix B, Table B.11.

Figure 3.12 indicates that as soon as the transducer is in position and the vicinity around the probe is vacated, steady state conditions are almost immediately re-established. The opening and closing of the chiller door does not seem to greatly disrupt the air flow amongst the carcasses, as the carcasses buffer any disturbance.

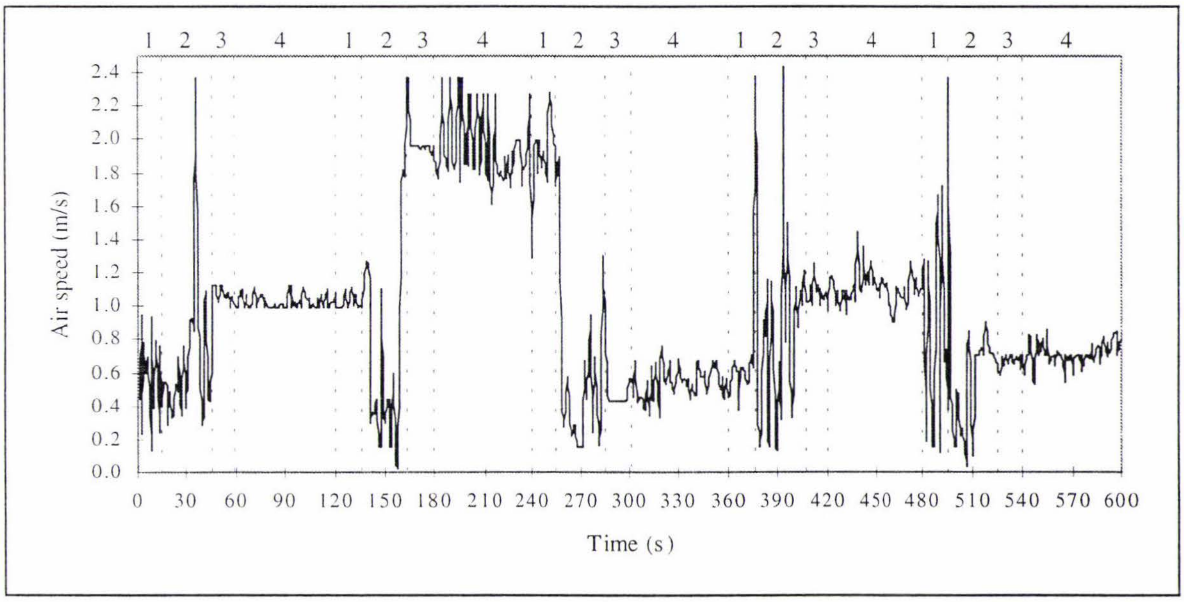


Figure 3.12: Continuous logging over 5 measurements of air flow at different positions within the chiller

1. - Phase 1: Entering chiller (opening and closing door) (~15 sec.)
2. - Phase 2: Positioning of anemometers transducer (~30 sec.)
3. - Phase 3: Exiting chiller (opening and closing door) (~15 sec.)
4. - Phase 4: Measurement time (60 sec.)

3.3.2.7 Estimation of the Air Speed Standard Deviation

For air speed data recorded by the first method (described in Section *3.3.1*) the standard deviation needed to be estimated from the range by:

$$s = R/d_2 \tag{3.2}$$

s = standard deviation
R = Range
d_2 = Factor for estimating s from R

The factor d_2, depends on the sample size. Using a measurement duration of 1 minute at a frequency of 1 Hz produces a sample size of 60 data values. The factor d_2, for a sample size of 60 is 4.639 (Kramer and Twigg, 1970).

This approximation assumes that the air speed data is normally distributed about the mean. This assumption can be tested by investigating the distribution of a number of air speed measurements. The distributions of the 60 air speed readings for 4 measurements are presented in Appendix B, Figures B.1-B.4. The data for these distributions is taken from Appendix B, Table B.3.

Distribution plots indicate that the air speed readings approximate a normal curve thus validating the use of Equation 3.2. However, it was shown in Section *3.3.2.4* that there are significant measurement errors involved in estimating the air speed range over a 1 minute period. Therefore, estimations of the standard deviation by this method should be treated with caution.

3.3.3 DIRECTIONAL AIR FLOW MEASUREMENTS - INSTRUMENT CALIBRATION AND TESTING

3.3.3.1 Calibration

The three Gill propeller anemometers used in this study were acquired from Works Consultancy Services, Wellington. Each anemometer consisted of a 4 bladed, polystyrene propeller with a diametre of 22 cm attached to a 30 cm long, slim generator.

Anemometers were individually calibrated at Works Consultancy Services Limited in the range of 0.5 to 5 m/s before use. Each anemometer was adjusted to produce an output voltage signal proportional to the speed of the propeller according to:

$$V_{true}\,(m/s) = 17.54 \text{ Volts} + 0.14 \qquad (R^2 = 0.9999) \qquad (3.3)$$

For values below 0.5 m/s air speeds were approximated by:

$$V(m/s) \approx 17.82 \text{ Volts} \qquad (3.4)$$

3.3.3.2 Response of a Single Anemometer at Various Orientation Angles to the Air Flow

A series of tests were performed to assess whether three orthogonally mounted propeller anemometers could be used as a reliable directional air flow indicator. Firstly, the response of a single anemometer output signal was investigated at different blade angles to the air flow. Ideally, the output response from the anemometer will be equal to the true air speed multiplied by the sine of the angle at which the air stream meets the anemometers blade.

$$\text{Ideal response (m/s)} = (\text{Air speed}) \sin(\text{blade angle to air flow}) \qquad (3.5)$$

The closer the anemometer response follows the ideal response, the more accurately the air flow direction can be calculated by the use of air velocity vectors.

One of the propeller anemometers was chosen arbitrarily and tested in an air tunnel to assess the response of the blades at various angles to an air stream. It was assumed that the results of these tests would be applicable to the other two anemometers. The anemometer was positioned in the air tunnel and the blade tilted in 10 degree increments through 90 degrees. At every change of angle of the blade, the response from the anemometer was recorded over a duration of 1 minute. The converted air speed readings were checked against the 'ideal' air speed reading that should be obtained at that particular blade angle (Equation 3.5). Six experimental runs were done using different tunnel air flow rates for each run. Tunnel air speed was adjusted from approximately 0.3 m/s through to 2.0 m/s by a variable speed fan. This corresponded to the range of air flow rates expected to be found in the chiller. The results from these tests are tabulated in Appendix C, Tables C.1-C.6 and plotted in Appendix C, Figures C.1-C.6.

From Figures C.1-C.6, Appendix C, it is evident that the output response of the anemometer follows the ideal response more closely at the higher air flow rates. As the angle of air flow onto the propellers blade becomes too acute, the response of the anemometer drops away sharply. This occurs at below an angle of 50 degrees for a 0.3 m/s air flow, below 40 degrees for a 0.5 m/s flow rate, below 30 degrees for a 0.7 m/s flow rate and below 20 degrees for a 1.0 m/s flow rate. Separate tests indicated that the propeller anemometers could not read air flow rates below 0.1 m/s. This suggests that at the above angles the resultant air speed perpendicular to the blade approaches 0.1 m/s and eventually becomes too low to overcome the propellers static friction. Overall, these results suggest that there will be a significant error associated with directional measurements at low air flow rates.

3.3.3.3 Response of Orthogonally Mounted Propeller Anemometers at Various Orientation Angles to the Air Flow

The next step in testing whether the propeller anemometers could be used as a reliable 3-dimensional directional air flow indicator was to investigate the responses from the three orthogonally mounted anemometers at different orientations to an air stream. This was carried out in a small, variable speed blast freezer with uniform air distribution (Figure 3.13 and Appendix A, Figures A.8 and A.9). All testing was performed in a 1 m x 1.5 m x 1 m chamber enclosed by two perforated plates which uniformly distributed air across the testing area. The blast freezer was controlled at 0°C to simulate operating conditions inside an industrial meat carcass chiller.

The orthogonally mounted propeller anemometers, set in the x, y, z arrangement, were attached to a laboratory clamp-stand via an aluminum housing (Section *3.3.1*). Anemometers were positioned in the middle of the test area inside the freezer and rotated in increments through 360 degrees in the horizontal (x,y) plane. With each change in angle, air speed measurements were taken from the three anemometers over a one minute duration enabling the resultant mean air speed to be calculated by vector summation using Equation 3.6, whereas, the mean air flow direction in the horizontal plane was calculated by Equation 3.7.

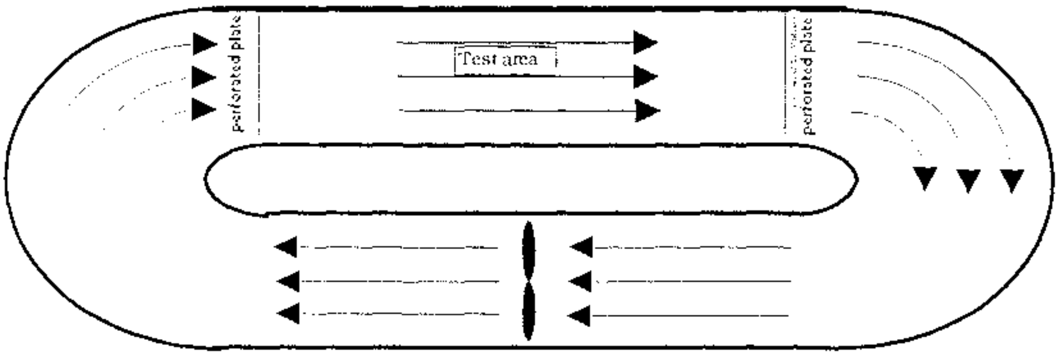


Figure 3.13: Blast freezer air flow pattern.

$$V_{x,y,z} = (V_x^2 + V_y^2 + V_z^2)^{1/2} \tag{3.6}$$

$$\theta = \tan^{-1}(V_y / V_x) \tag{3.7}$$

The resultant mean air speed was compared with the mean air speed obtained by the hot-wire anemometer over the same duration, whereas the calculated mean air flow direction was compared to the known angle of the anemometers orientation to the air flow. Three runs were carried out using this procedure with air flows set at 2.0, 1.0 and 0.6 m/s (0.6 m/s corresponded to the lowest possible fan speed in the blast freezer).

This procedure was then repeated by moving the anemometer arrangement in increments through 360 degrees in the horizontal (x,y) plane as well as tilting the arrangement at various angles in the vertical (x,z) plane. The resultant mean air speed and its direction in the horizontal plane were calculated as previously, whereas the mean air flow direction in the vertical plane (degree of tilt) was calculated by:

$$\theta = \tan^{-1}((V_x^2 + V_y^2)^{1/2} / V_z) \tag{3.8}$$

The data from this experiment is presented in Appendix C, Tables C.5-C.9 and Appendix C, Figures C.7-C.11. These figures indicate good agreement between the true angle and the calculated angle of anemometer orientation for the range of 0.6-2.0 m/s. At an air flow rate of 0.6 m/s the maximum error obtained was -19.7°. Therefore it is reasonable to assume that an uncertainty of ±20° can be expected for directional air flow readings taken at an air flow rate above 0.6 m/s. At low air flows, directional errors are likely to be significantly larger.

Unfortunately, the orthogonally mounted anemometers could not be tested at air flow rates below 0.6 m/s, as the blast freezer was not able to operate at these air speeds. However, assumptions can be made in order to estimate these errors. At low air flow rates, the maximum error in either the vertical or horizontal plane will occur when the air stream approaches the two blades at an angle close to 45° to each, so that one blade will remain still and the other will rotate. Therefore, theoretically, the maximum possible error that can occur in the vertical or horizontal plane is ±45°, providing the air flow rate is high enough to turn a single blade.

It was proposed that the error in the directional reading is related to the difference in the resultant mean air speed from the true mean air speed. By using the measurements obtained by the hot-wire as the true mean air speed, the percentage error in the mean air speed readings, could be compared with the directional errors (Figure 3.14). This data is tabulated in Appendix C, tables C.5-C.9.

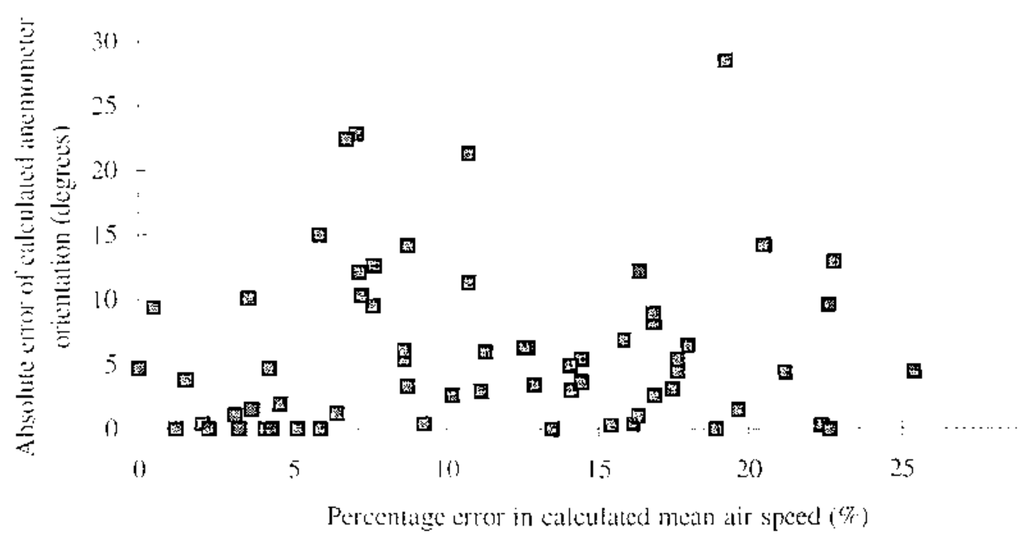


Figure 3.14: Relationship between errors in the resultant and directional reading errors

Figure 3.14 shows no obvious relationship between the resultant and directional errors, so the difference in the mean air speed readings given by the propeller and hot-wire anemometers cannot be used as an indication of the accuracy of the directional readings.

3.4 DELTA WING CONSTRUCTION

Construction of the prototype delta wing vortex generators followed work carried out by Amraie (1993). Six sets of large wings and twenty two sets of small wings with mounting brackets were made to specification at Steelfort New Zealand Limited. All wings were constructed from 2 mm aluminum sheeting. Large wings had a semi angle (degree of sweep) of 20 degrees and a maximum chord length of 1 metre, whereas the small wings had a semi angle of 20 degrees and a maximum chord length of 400 mm (Figure 3.15).

Mounting brackets were designed so that both the large and small wings could be interchangeable. The brackets also enabled the vertical height adjustment of the wings by 180 mm and the angle of attack (pitch) to be adjusted through 35 degrees.

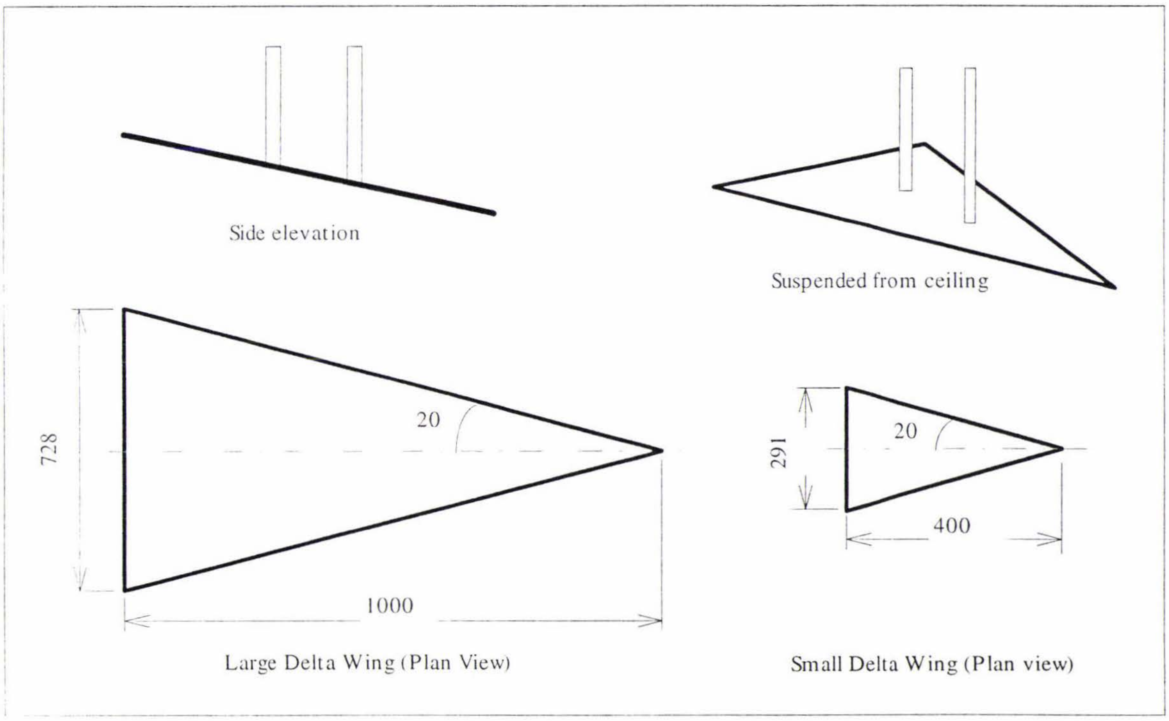


Figure 3.15: Delta wing vortex generators

Full dimensions of the delta wings and mounting bracket are given in Appendix A, Figures A.2-A.4.

3.5 DELTA WING INSTALLATION

Delta wings were installed in two different configurations according to guidelines suggested by Amraie (1993). For both configurations, a row of large wings was placed closest to the evaporator fans, followed by 2 rows of smaller wings. All wings were suspended 250 mm from the ceiling by adjustable mounting brackets. At this level the centre of the wing was in the fastest flowing air stream from the evaporator fans.

3.5.1 FIRST DELTA WING CONFIGURATION

The strategy used in the installation of the first configuration of delta wings was to minimise installation costs by positioning the wings as sparsely as possible while still maintaining an even distribution of turbulence over the whole of the chiller. To achieve this, the overlap of the turbulence zones created around each wing must be as small as possible.

Large wings were mounted so the nose of the wing was positioned 0.4 metres from the front of the evaporator fans as suggested by Amraie (1993). The position of the second row of wings was determined by measuring the length of the zone of turbulence created behind this first row of wings. Turbulence was measured according to Kondjoyan and Daudin (1995) where the turbulence can be described by the term turbulence intensity (Tu) if the air flow is made up of very rapid fluctuations. Turbulence intensity is related to the mean air speed and the standard deviation of the air speed fluctuations with time by:

$$Tu = 100(\sigma/v) \tag{3.9}$$

where,

Tu = Turbulence intensity (%)

v = Mean air speed (m/s)

σ = Standard deviation of air speed fluctuations over time

Large and small delta wings were temporarily installed within the chiller in front of the evaporator fans. Average air speeds and the standard deviation of the air speed fluctuations were measured using the hot-wire anemometer over a duration of 1 minute around both the large and small delta wings. Zones of turbulence around the wings were defined as areas where the turbulence intensity was significantly higher than the normal levels within the chiller (normal turbulence intensity levels were 15-25%).

The turbulence measurements suggest that the vortices created by the wings are directed behind the wings at approximately the angle of the wing semi-span (degree of sweep). The vortices produce distinct zones of air turbulence until vortex breakdown occurs and the turbulence effect is dissipated. Missenden (1987) claimed that the vortex fragments are in the order of 3-4 maximum chord lengths (0.8-1.2 m) for the small delta wings. This is consistent with the turbulence data obtained for the small wing, where it was found the turbulence effect was carried on approximately 0.8 metres downstream from the tail of the wing (Figure 3.17). The large wings produced a turbulence zone of approximately 1.4 metres in length (Figure 3.16).

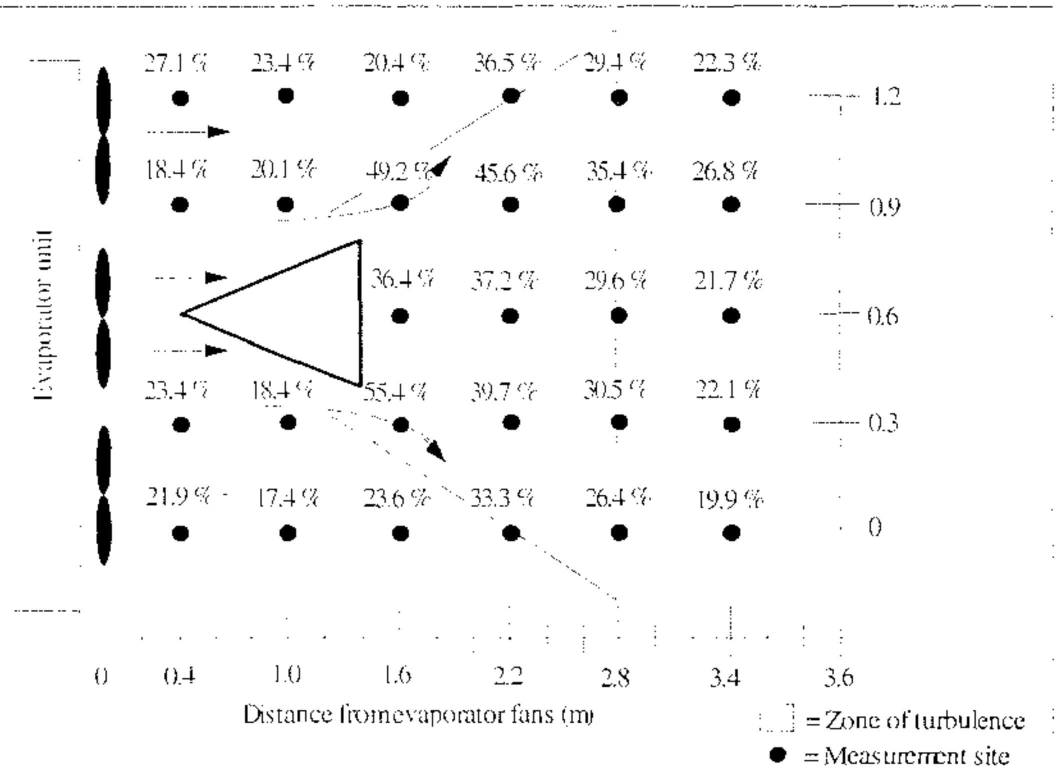


Figure 3.16 Measurements of the turbulence intensity around a large delta wing

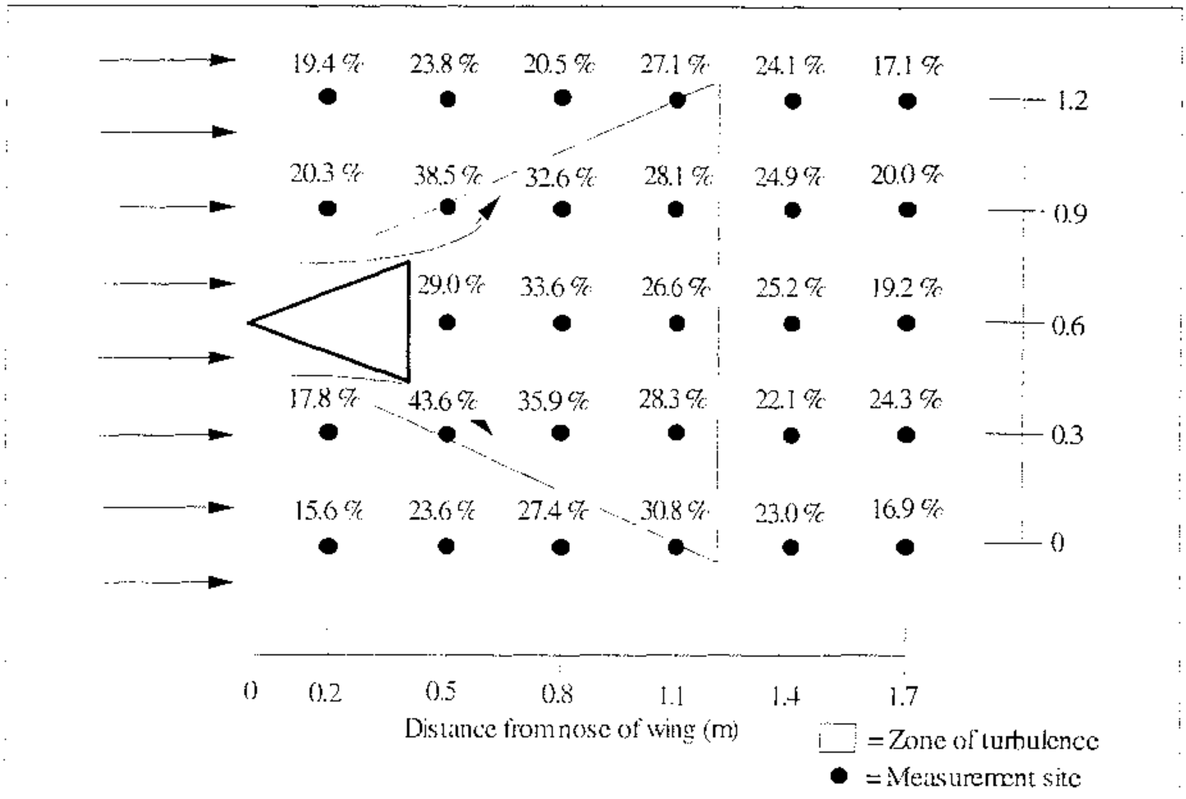


Figure 3.17 Measurements of the turbulence intensity around a small delta wing

The zone of turbulence behind the first row of large wings indicated that the centre of the second row of wings should be mounted about 950 mm behind the centre of the first row. At this distance, the second row of wings would be inside the tail of the turbulence zone caused by the first row. Similarly, the centre of the third row of wings should be about 730 mm behind the centre of the second row.

Figure 3.18 illustrates the installation pattern used for the first configuration of delta wings. The nose of each wing in the second row was positioned in line with the tip of the wing in the first row. Similarly, the nose of each wing in the third row was placed between the wing tips of those in the second row.

Additional wings in each row were also mounted outside the test zone area, using the same pattern. This was to ensure the turbulence effect caused by the wings would be carried on past the bounds of the test zone (centre line of chiller). Hence a true measurement of air turbulence caused by the wings could be obtained in the middle of the chiller.

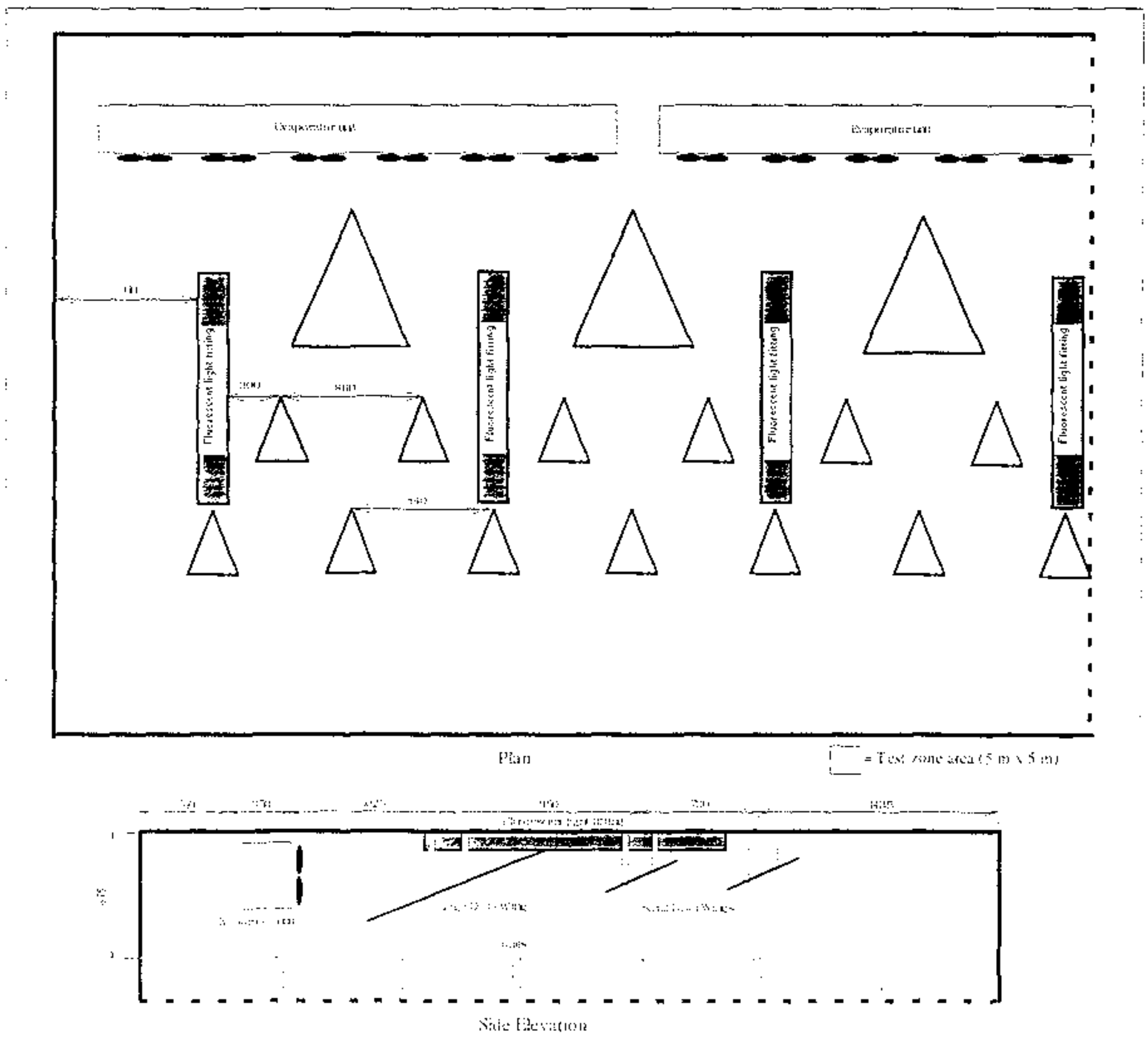


Figure 3.18: First Delta Wing Configuration

3.5.2 SECOND DELTA WING CONFIGURATION

A second wing configuration was investigated after full air flow characterisation of the first wing configuration was complete. Additional wings were placed between each of the small wings mounted in the first configuration. An additional large wing was also positioned between each fluorescent light fitting (Figure 3.19). Otherwise the second configuration was identical to the first.

Fluorescent light fixtures influenced the patten of the second configuration to a degree as fewer delta wings were able to be mounted in the second row than in the third row.

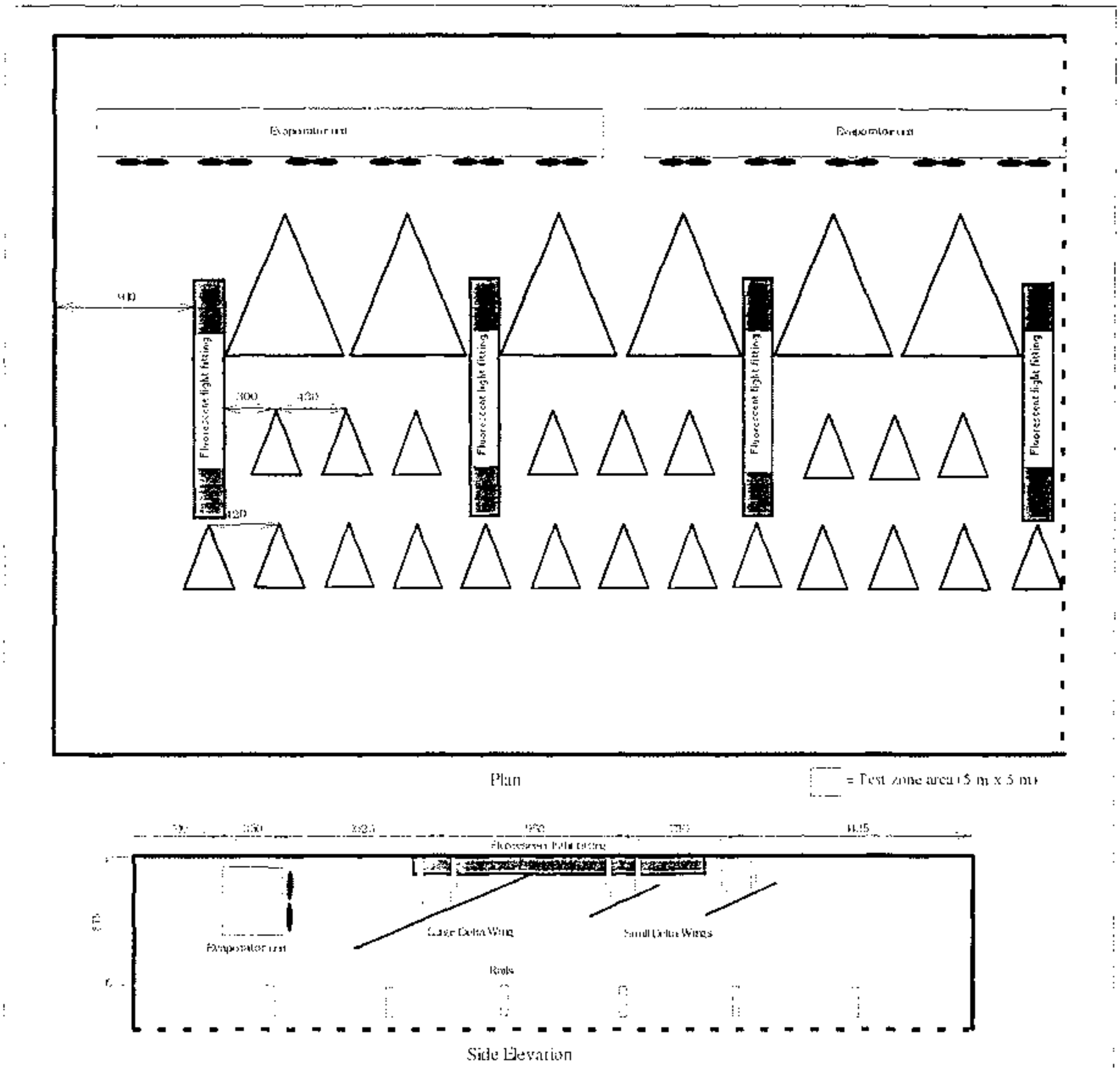


Figure 3.19: Second Delta Wing Configuration

The mounted delta wings are also shown in Appendix A, Figures A.10-A.13.

3.6 CHILLER AIR FLOW CHARACTERISATION

3.6.1 CHILLER MEASUREMENT SITES

The selection of air speed measurement sites involved a compromise between the time taken to obtain a full set of measurements and the increased information from a larger number of measurement sites (Section *3.3.2.4*). Although protective clothing was worn, the maximum amount of time able to be endured within the chiller was 8 hours. To minimise any temperature effects on measurement accuracy, the first 6 hours of a normal 14 hour chill cycle was used to allow the chiller to reach a relatively stable temperature. The last 8 hours of the chill cycle was used to characterise air flow within the chiller. As each air speed measurement took a total of 2 minutes to perform (1 minute to enter the chiller, position the transducer and exit the chiller, plus 1 minute to log the necessary air flow data), approximately 244 measurements of 2 minutes in length could be completed over this 8 hour period.

It was proposed that the testing area could be reduced to a more manageable size by dividing the chiller into two symmetrical halves. In this way an increased number of measurements could be taken as measurements would only need to be performed in one half of the chiller. In order for this to be possible, air flow must be symmetrical about the chillers centre line. To verify this, preliminary air speed measurements were taken at 1 metre intervals for heights of 0.5, 1.0, 1.5 and 2.0 metres over the whole of the fully loaded chiller. Data from these tests are tabulated in Appendix E Table E.1. A contour plot of the air speed profile is shown in Appendix E, Figure E.1.

The contour plot indicates that air flow either side of the centre line is symmetrical. Therefore, the loading end of the chiller was arbitrarily chosen for the test zone, in which air flow measurements would be taken. This 5 by 5 metre area was horizontally sectioned into 0.5 m intervals and the resulting grid pattern was marked on the floor. Measurement sites were marked at every second intersection of the grid. This produced 61 sites for air flow measurement (Figure 3.20).

Measurement heights of 0.5, 1.0, 1.5, 2.0 and 3.0 metres above the floor were chosen. The first four heights represented important positions relative to a hanging carcass (Figure 3.21), whereas the last height was chosen to represent the air flow above the rails and was only used in the characterisation of the empty chiller.

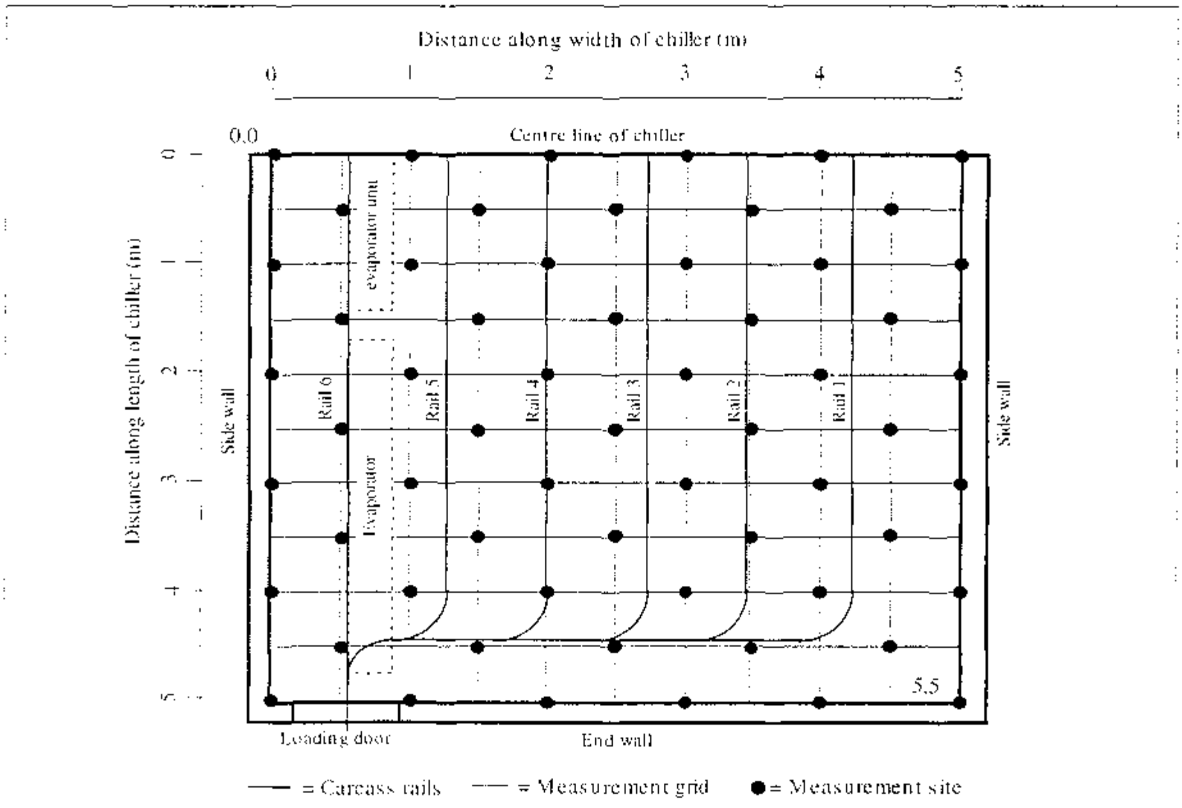


Figure 3.20: Plan view of measurement sites in test zone

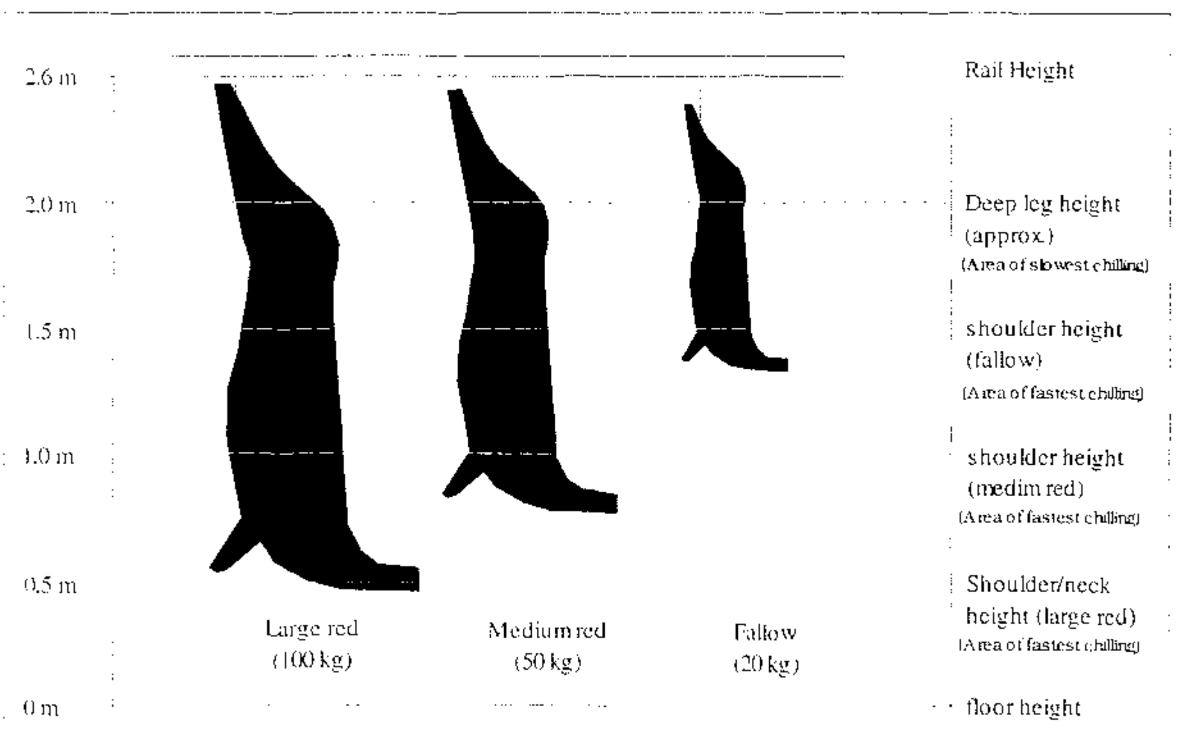


Figure 3.21: Measurement positions relative to carcass size

3.6.2 EMPTY CHILLER AIR FLOW MEASUREMENTS

For air flow measurements performed in the empty chiller, both the hot-wire anemometer and the orthoganally mounted propeller anemometers were used simultaneously.

The chiller was left for six hours after the chiller was turned on before measurements commenced (Section *3.6.1*). Measurements were carried out by moving the tripod or clampstand with the propeller and hot-wire anemometers attached at fixed heights, and placing it over each of the 61 grid marks on the chiller floor in turn. Measurements were taken in systematic order starting at grid position 0,0 and finishing at the grid position 5,5 for each of the five levels in height (0.5, 1.0, 1.5, 2.0 and 3.0 metres). Randomised order was not used because the constant height and positional adjustment involved was too time consuming.

The propeller anemometers were positioned at the same orientation for each reading whereas, the hot-wire was rotated according to the cotton thread (as described in Section *3.3.2.3*). Measurement positions adjacent to walls were taken at a distance of 10 cm out from the wall. Once anemometers had been set at the correct grid position, the chiller was exited and the air flow data from the anemometers was recorded from outside the chiller.

Two trials were carried out in the empty chiller without delta wings. Delta wings were then installed in the first configuration (Section *3.5.1*) and 4 trials were then performed using wing pitch angles of 20°, 25°, 30° and 35°. Delta wings were then re-installed in the second configuration (Section *3.5.2*) and another 4 trials were carried with wings set at the same pitch angles. These angles were specifically chosen to test whether the delta wing angle of 25° used in work performed by Amraie (1993) was close to the optimum. Air speed data was recorded by the second hot-wire anemometer method for all trials (Section *3.3.1*).

3.6.3 FULL CHILLER AIR FLOW MEASUREMENTS

Air speed measurements in the full chiller were performed using the same methods as in the characterisation of the empty chiller with the exception that no measurements were taken above the rails and the propeller anemometers were not used as their size prevented them from being maneuvered between carcasses.

The chiller was again left for six hours after the chill cycle was initialised to avoid the temperature pull-down phase (Section *3.6.1*). Carcasses were positioned a hands width apart according to marks on the rails which ensured the same loading configuration was used for each trial and that measurement sites always occurred between carcasses. The spacing of these marks differed according to whether the chiller was loaded with fallow or red deer. The number of carcasses along each rail varied slightly from run to run according to slight variations in the number of carcasses loaded into the chiller. To cope with this discrepancy, the first eleven red deer carcasses or fifteen fallow deer carcasses from the centre line of the chiller, were positioned according to the rail marks. Any extra carcasses were placed on the end of each of the rails. Measurement sites occurred between carcasses on rails 1, 3 and 5 and around carcasses on rails 2, 4, and 6 (Figure 3.16).

Characterisation of the fully loaded chiller was achieved by carrying out 5 experimental trials with no delta wings. For trials 1 and 3 the chiller contained both red and fallow deer whereas, for trials 2, 4 and 5 the chiller contained only red deer. Air speed data was recorded by the first hot-wire anemometer method for all 5 trials (Section *3.3.1*). Delta wings were then installed in the first configuration (Section *3.5.1*) and three trials were performed using a pitch of 25°. Delta wings were then re-installed in the second configuration (Section *3.5.2*) and another 3 trials were repeated using the same delta wing angle. Finally, an additional trial was performed using the second delta wing configuration at a pitch of 35°. For all trials carried out with delta wings, the chiller was loaded with only red deer and air speed data was recorded by the second method (Section *3.3.1*).

Carcasses were weighed before they were loaded into the chiller and also as they were unloaded from the chiller. The initial and final weights of each carcass and it's position within the chiller were recorded for all experimental trials except the first two trials performed without delta wings..

3.7 DATA ANALYSIS

In this study, aspects of air flow such as the speed, direction, uniformity and degree of turbulence within the chiller were all considered important. The data generated from air flow measurements can be analysed by a variety of different techniques. As each technique shows some aspects of air movement but not others, it was decided to use a number of these techniques in the data analysis. The techniques used are outlined below.

3.7.1. AIR SPEED

3.7.1.1 Contour Plots

Air speed data can be displayed on a 2-dimensional contour plot. Contour lines bound areas where a given range of speeds occur. A colour scale can also be used to highlight magnitude differences.

All contour plots were drawn using a Windows based programme sold under the brand name Surfer® (V6) which was developed by Golden Software, Inc.. Surfer® creates a grid file from an XYZ data file by interpolating the data by a chosen interpolation method. Once the grid file is made, the interpolated data is converted into a contour map. The Kriging interpolation method was chosen for all contour plotting performed in this study as this is the recommended method for most types of data (Keckler, 1997)

Contour plots have advantages for displaying large quantities of data but often tend to show the data subjectively, presenting the general trends but concealing detail.

3.7.1.2 Mean Air Speed Plots

In order to investigate how the air speeds are distributed around the chiller, mean air speed readings averaged along the length of the chiller can be examined on a cross sectional diagram. This technique is useful in making quantitative comparisons of the averaged mean air speed readings taken in different regions or the chiller. Three regions were identified as being particularly important. These were: across the whole of the chiller; amongst the carcasses and within the area of the lowest air flow between rails 2 and 5 called the 'critical zone'.

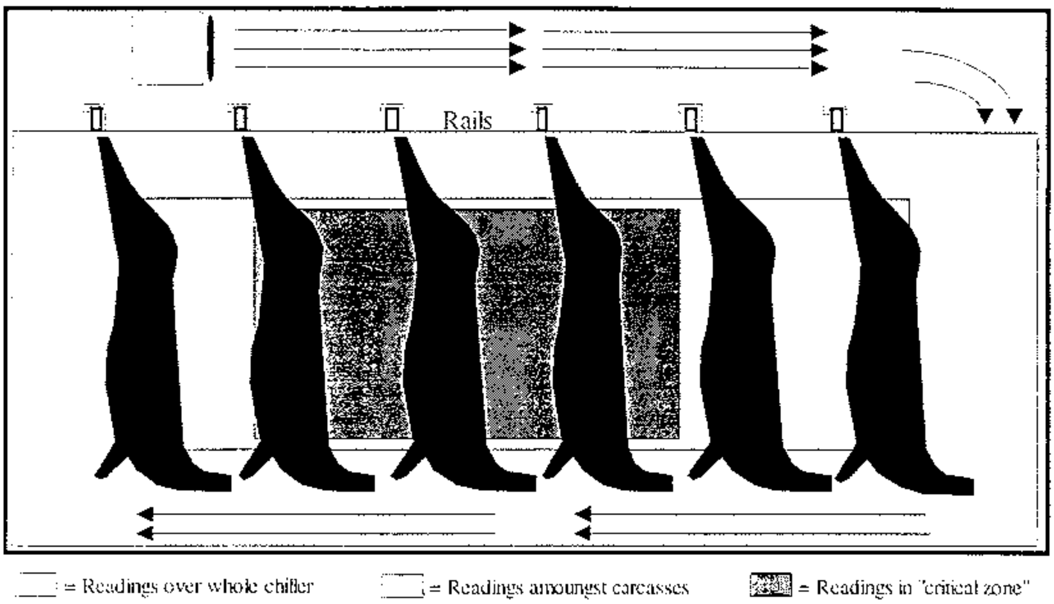


Figure 3.22: Important regions for air flow comparison

3.7.1.3 Difference in Mean Air Speed Plots

The difference in the mean air speed for two sets of air flow data can be displayed in the same way as the mean air speeds. By using one set of air flow data as a basis in which to compare another, differences in the mean air speed, averaged along the length of the chiller are calculated and displayed on a cross-sectional diagram of the chiller, with data positioned according to where measurements were taken. Net changes in air speed are presented rather than individual air speed measurements. This method is a useful way of comparing two sets of air speed data but it does not allow lengthwise comparisons to be made.

3.7.2 AIR FLOW DIRECTION

3.7.2.1 Vector Plots

Three-dimensional directional air flow data can be displayed on a 2-dimensional plot using vectors to represent the direction and the magnitude of the air velocity at corresponding measurement positions. This was done by separating the directional data obtained from the othoganally mounted anemometers into its horizontal and vertical components and then calculating the direction and magnitude for each component.

The air speed magnitude in the horizontal plane was calculated by:

$$V_{x,y} = (V_x + V_y)^{1/2} \qquad (3.10)$$

Whereas, the air flow direction in the horizontal plane was calculated by Equation 3.7.

The air speed magnitude in the vertical plane was calculated by:

$$V = (V_{x,y} + V_z)^{1/2} \qquad (3.11)$$

And the air flow direction in the vertical plane was calculated by Equation 3.8.

Vectors were plotted using Surfer for Windows. Plots of the horizontal data component could be used to represent a plan view of the air movement, whereas, plots of the vertical data component could be used to represent a side view.

As it is difficult to distinguish small changes in the magnitude or direction by the size and angles of the vectors, this technique again only gives a subjective representation of the data.

3.7.3 DISTRIBUTION OF AIR SPEEDS

3.7.3.1 Histograms and Standard Deviations

In an ideal chiller the air speeds over all the carcasses should be identical. In practice this is not possible and a range of flow rates are obtained which depend on the design. Obviously, a chiller in which the range of air flow rates is small will perform better, enabling considerably more uniform chilling than one with a wide range of air flow rates. To quantitatively assess air flow distribution, mean air speeds at each measurement position can be displayed on a histogram where the height of each bar represents the total readings falling within a defined segment of the total air speed range.

The shape of air speed histograms can be used as a guide to the uniformity of air speeds within a refrigerated room (Edwards, 1979). The smaller the spread of data values about the mean (measured by the standard deviation of the mean air speeds) and the closer the distribution is to a normal curve, the nearer the air flow distribution is to the optimum.

Although it is useful to examine the overall air speed distributions in the chiller, it is perhaps more important to investigate the distribution of air speeds amongst the carcasses (Figure 3.22). This was achieved by removing the first and last two rows of air speed readings which were taken close to the front and back walls of the chiller as well as all measurements performed at a height of 0.5 m.

3.7.3.2 MIRINZ Indicator

The percentage of air speed readings between ½ and 2 times the mean air speed give an indication of the variability of air flow (Edwards, 1979). MIRINZ formulated a rule that if 95 % of the measured air velocity readings adjacent to the product, are between ½ and 2 times the mean velocity, then there is an acceptably uniform air flow distribution. This technique has been used extensively in the past for assessing the uniformity of air flows within industrial chillers and freezers, it can therefore be used as a useful indicator against which to compare changes in air flow distributions.

3.7.3.3 Weight Loss

Indirectly, weight loss data can be used to indicate the degree of air flow uniformity within a chiller. In a batch chilling situation where the uniformity of air flow tends to be poor, the uniformity of weight loss also tends to be poor. This is because outside carcasses, which are exposed to higher air flows, tend to cool more rapidly than the centre carcasses. As the fast cooling carcasses reach the required temperature earlier, they must be held in the chiller until the slower cooling carcasses are ready to be removed. This holding period in locations of high air flow causes excessive weight loss. Therefore, by improving in the uniformity of air flow within the chiller can lead to an improvement in the uniformity of carcass weight loss.

3.7.4 TURBULENCE

3.7.4.1 Turbulence Intensity

Under conditions of rapid fluctuations, mean air speed only gives a rough description of the air flow. In this situation air turbulence can mainly be described by the term turbulence intensity (Kondjoyan and Daudin, 1995). The turbulence intensity (Tu) is related to the standard deviation of the air speed fluctuations and the mean air speed by Equation 3.8. In Section *3.3.2.4* it was shown that air flow within the chiller had rapid fluctuations. Therefore, this parameter was used to determine if any changes in air turbulence occur due to the presence of the delta wings.

3.8 DATA CONFIDENCE

3.8.1 NUMBER OF MEASUREMENTS

A total of 244 air speed measurements were taken for each trial carried out in the fully loaded chiller (61 measurements at heights of 0.5, 1.0, 1.5, and 2.0 m). The total number of measurements taken could not be significantly increased due to the chilling time constraints (Section *3.6.1*). In the same context, the time period over which measurements were taken could not be reduced without introducing an unacceptable amount of uncertainty into the data (Section *3.3.2.4*). However, it was still important to determine whether the 61 measurements taken at each height level was adequate to gain sufficient information on the air flow in the 5 by 5 metre test zone.

It was proposed that if no significant additional information about the air flow was obtained by doubling the number of air speed measurements in the test zone, it can be assumed that the number of measurements taken was sufficient. A total of 121 air flow measurements were taken at an arbitrary height of 1.5 metres over the test zone in the fully loaded chiller in order to investigate whether the 61 measurements gave an adequate representation of the air flow. The locations of the 121 measurement sites within the chiller are represented by every intersection on the grid shown in Figure 3.20. The data from this experiment is tabulated in Appendix E, Table E.17 and the resulting air speed contour plots are shown in Figure 3.23.

Figure 3.23 shows that both contour plots display the same general air flow pattern. The zones of high air flow near the front and back walls and the three zones of low flow (below 0.5 m/s) are present on each. The extra measurements show some additional information in the air flow by the slightly larger areas of low air speed (below 0.5 m/s) and a small zone in the centre of the chiller where air flow exceeds 1 m/s. However, the good agreement suggests that 61 measurements was sufficient.

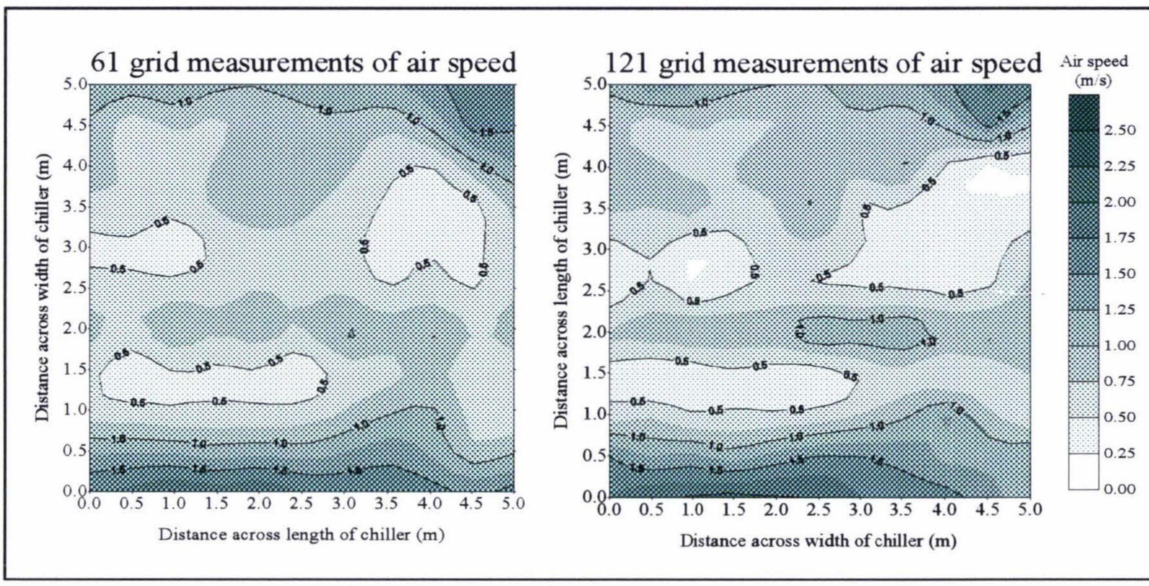


Figure 3.23 Comparison of a contour plot at a height of 1.5 m with double the number of air flow measurements

3.8.2 DATA REPRODUCIBILITY

3.8.2.1 Air Speed Measurements

To assess the reproducibility of the air speed data, measurements were repeated at a height of 1.5 m using the second delta wing configuration. The replicate measurements were carried out independently but under exactly the same conditions as the initial measurements. This resulted in two sets of air speed data being obtained at a height of 1.5 m. Air speed data is tabulated in Appendix E, Table E.18. Contour plots are shown in Figure 3.24.

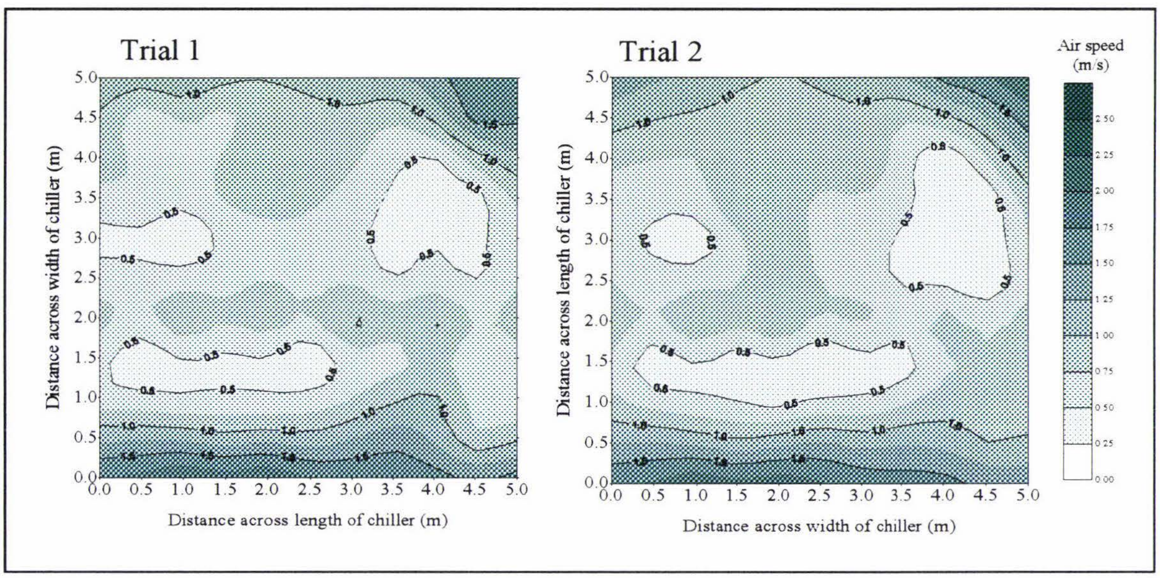


Figure 3.24: Comparison of air speed contour plots between two sets of data carried out under exactly the same conditions at a height of 1.5 m.

The comparison of contour plots shown in Figure 3.24 indicates that similar air flow patterns were obtained for the two sets of data. The three zones of low air flow below 0.5 m/s all occur in the same positions and are roughly the same shape. Both profiles indicate the zones of high air flow occurring close to the walls and along the length of the chiller.

Information on the variation in the air speed readings can be obtained by plotting the absolute difference of the air speed reading for each measurement. This data is presented in Figure 3.25.

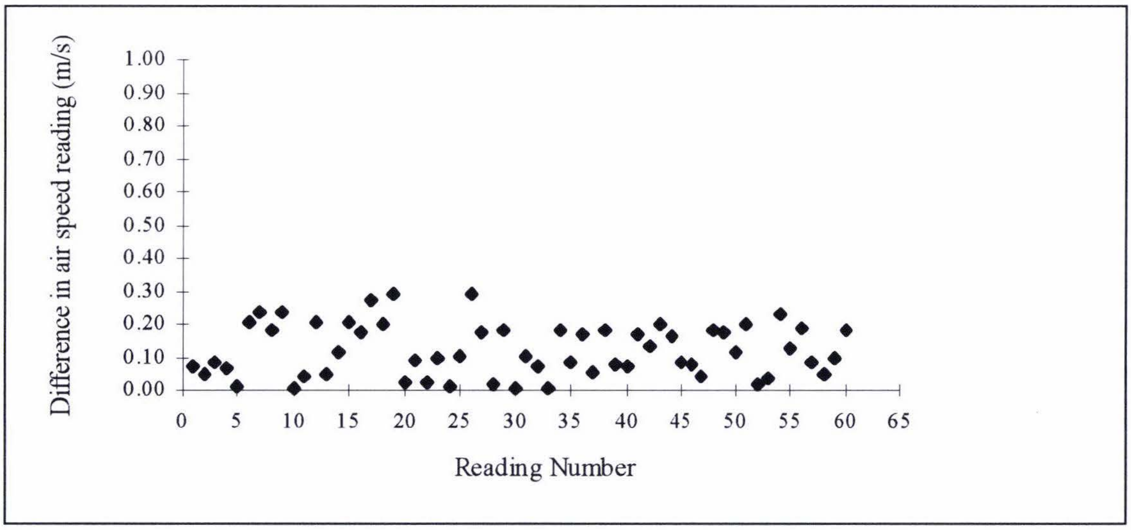


Figure 3.25: Absolute difference in air speed measurements for two trials carried out under the same conditions.

In Section *3.3.2.5*, the maximum variation between two air speed readings taken in the same position was found to be 0.18 m/s. However, with the additional errors caused by the deviations in transducer positioning, Figure 3.25 shows that the maximum variation between replicate readings is approximately 0.30 m/s. Therefore, the uncertainty in the air speed readings taken in the fully loaded chiller was assumed to be less than 0.30 m/s.

3.8.2.2 Directional Measurements

The first two trials performed in the empty chiller were used to assess the reproducibility of the directional measurements. The data from these two runs is tabulated in Appendix D, Tables D.1 and D.2.

The difference in the directional readings taken at the same positions within the chiller is presented in Figure 3.26.

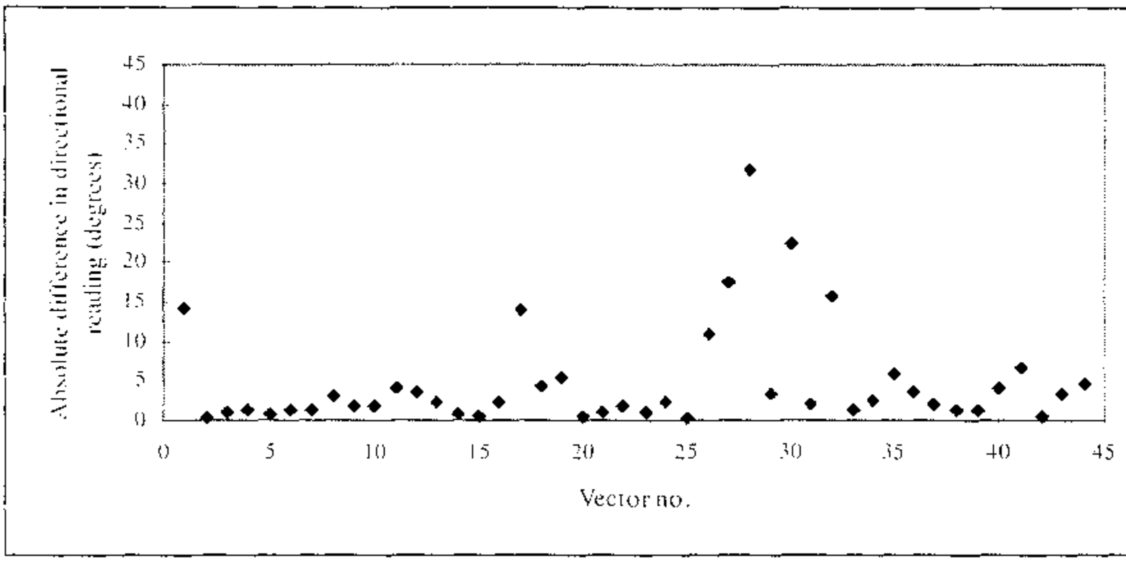


Figure 3.26: Absolute difference in the angle of vectors for empty chiller - Trials 1 & 2

The absolute difference in the angle of vectors for the two sets of data, shown in Figure 3.26, indicate that variation between the majority of directional readings was less than 5 degrees. Vectors that varied by more than 5 degrees corresponded to measurement positions of low air flow (below 0.6 m/s). The maximum variation in angle found was 32 degrees which is below the theoretical maximum error of 45 degrees (Section *3.3.3.3*). Therefore, the uncertainty in the directional readings taken in the empty chiller was assumed to be less than ±35 degrees.

Chapter 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

Dimensioned drawings and photographs of equipment used in this study are presented in Appendix A. All experimental data relating to the calibration and testing of the instruments are presented in Appendices B andpassword C. Air flow data collected in the empty chiller is tabulated in Appendix D. Air flow measurements taken in the full chiller is tabulated in Appendix E. Weight loss data is presented in Appendix F.

4.2 EMPTY CHILLER CHARACTERISATION

Figures 4.1 and 4.2 summarise the air speed and directional data for the two trials performed in the empty chiller without delta wings installed. Details of the experimental procedures are described in Section *3.6.2 Materials and Methods*. Data from these two trials are tabulated in Appendix D, Tables D.1 and D.2.

Figures 4.3 to 4.6 summarise the air speed and directional data for the four trials performed in the empty chiller with delta wings installed in the first configuration. Details of the experimental procedures are described in Section *3.6.2 Materials and Methods*. Experimental data from these trials are tabulated in Appendix 3, Tables D.3-D.6.

Figures 4.7 to 4.10 summarise the air speed and directional data for the four trials performed in the empty chiller with delta wings installed in the second configuration. Details of the experimental procedures are described in Section *3.6.2 Materials and Methods*. Experimental data from these trials are tabulated in Appendix 3, Tables D.7-D.10.

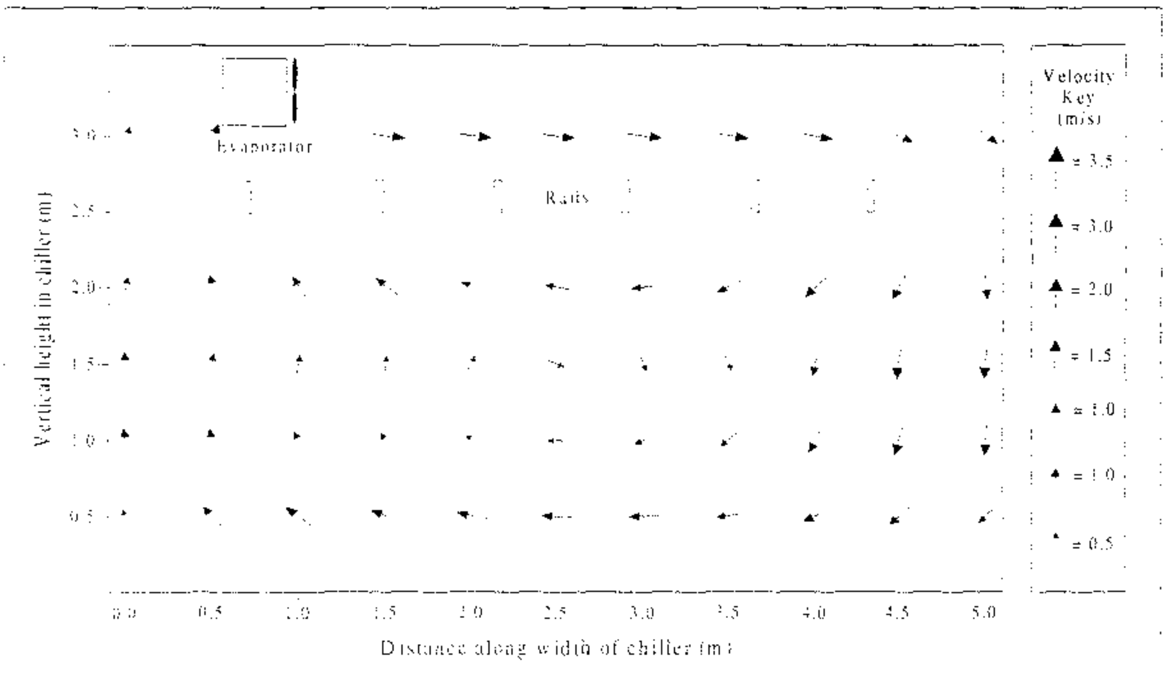


Figure 4.1: Cross-sectional view of mean air velocities in the empty chiller
Trial 1 - No delta wings

(Each vector is an average of 4-5 measurements across the length of the chiller)

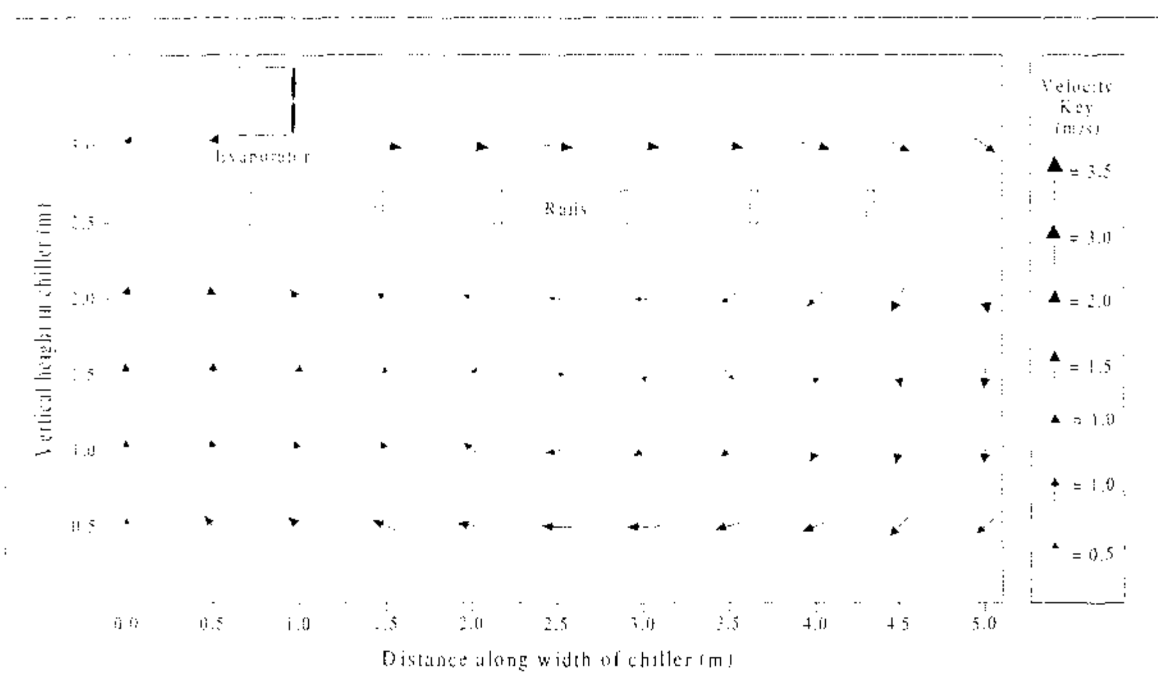


Figure 4.2: Cross-sectional view of mean air velocities in the empty chiller
Trial 2 - No delta wings

(Each vector is an average of 4-5 measurements across the length of the chiller)

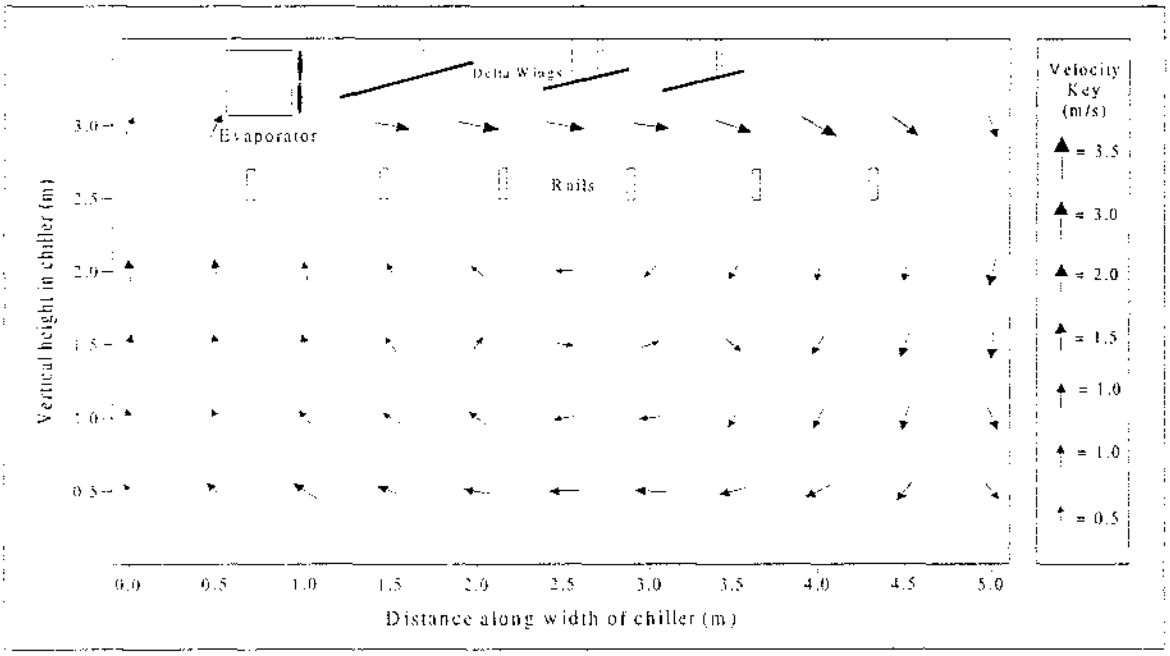


Figure 4.3: Cross-sectional view of mean air velocities in the empty chiller
Trial 1 - First configuration of delta wings, 20° pitch
(Each vector is an average of 4-5 measurements across the length of the chiller)

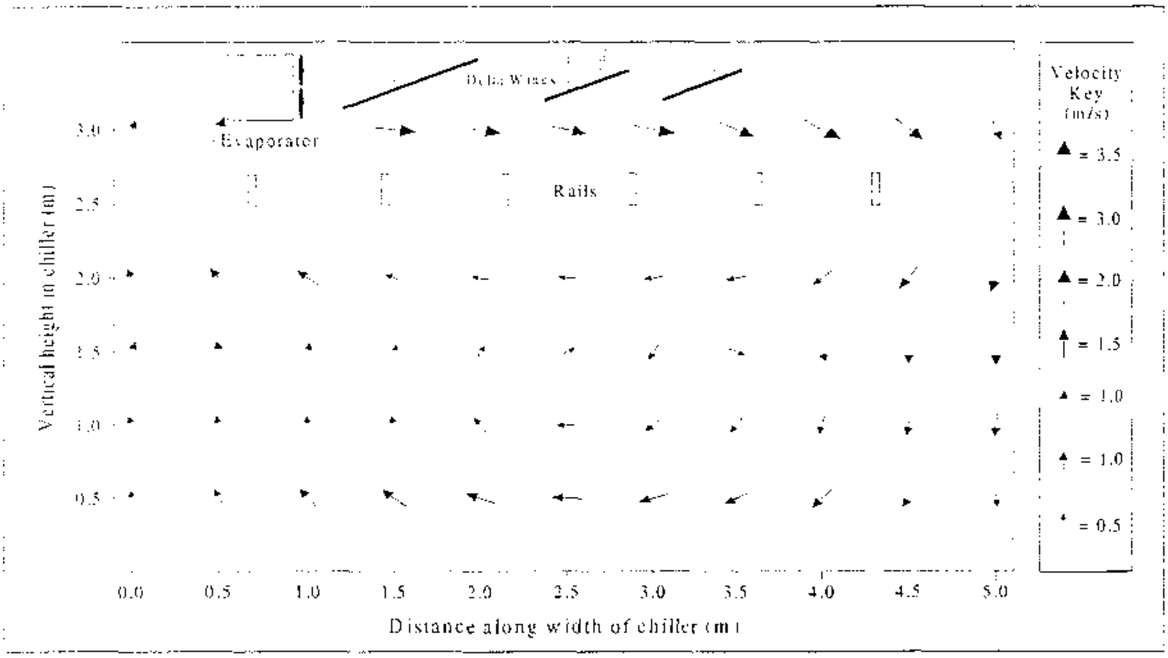


Figure 4.4: Cross-sectional view of mean air velocities in the empty chiller
Trial 2 - First configuration of delta wings, 25° pitch
(Each vector is an average of 4-5 measurements across the length of the chiller)

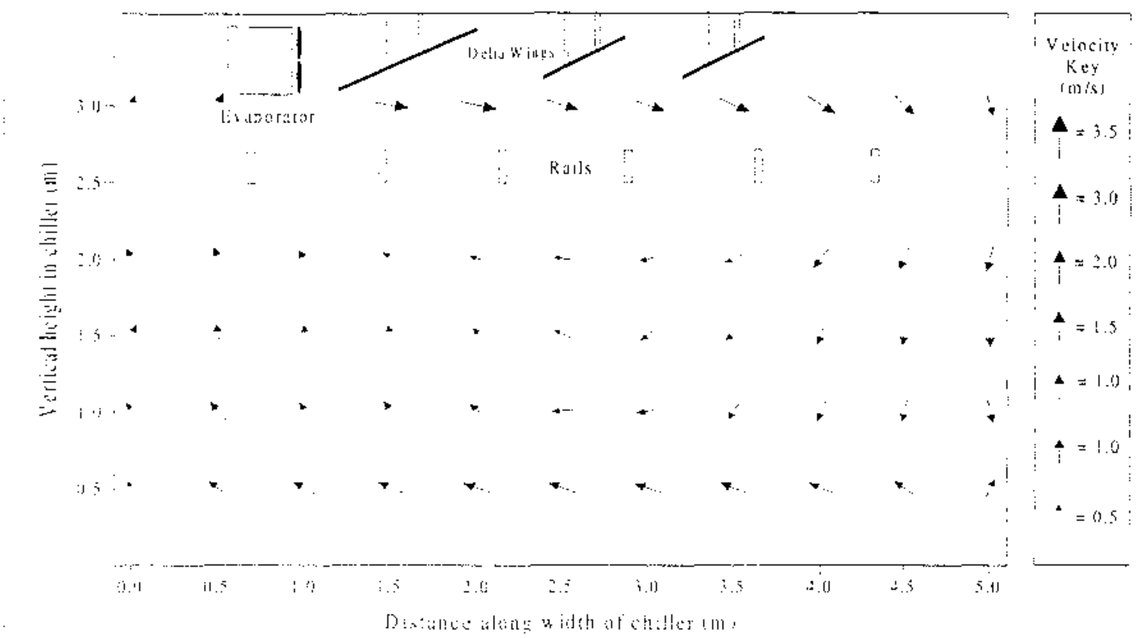


Figure 4.5: Cross-sectional view of mean air velocities in the empty chiller
Trial 3 - First configuration of delta wings, 30° pitch
(Each vector is an average of 4-5 measurements across the length of the chiller)

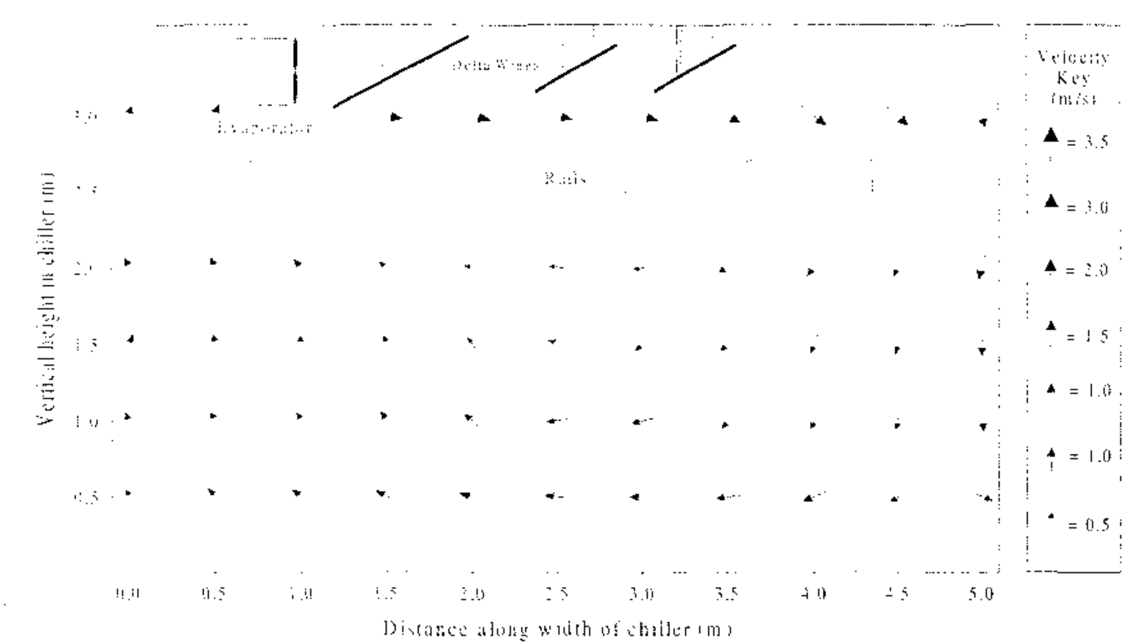


Figure 4.6: Cross-sectional view of mean air velocities in the empty chiller
Trial 4 - First configuration of delta wings, 35° pitch
(Each vector is an average of 4-5 measurements across the length of the chiller)

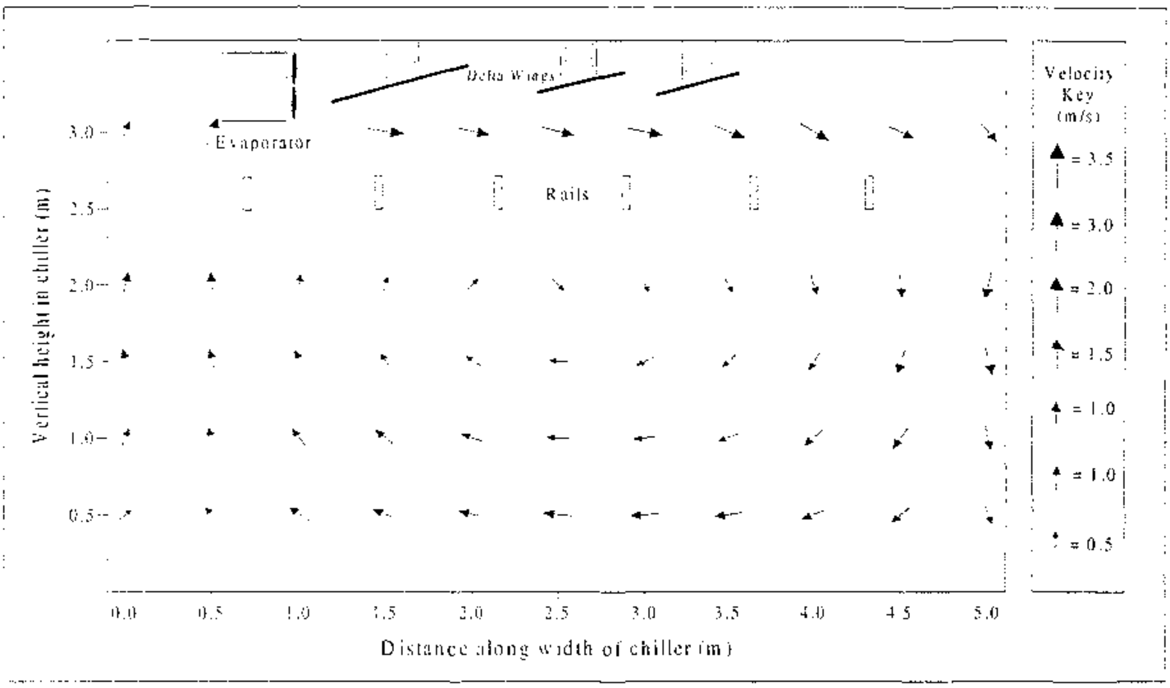


Figure 4.7: Cross-sectional view of mean air velocities in the empty chiller
Trial 1 - Second configuration of delta wings, 20° pitch
(Each vector is an average of 4-5 measurements across the length of the chiller)

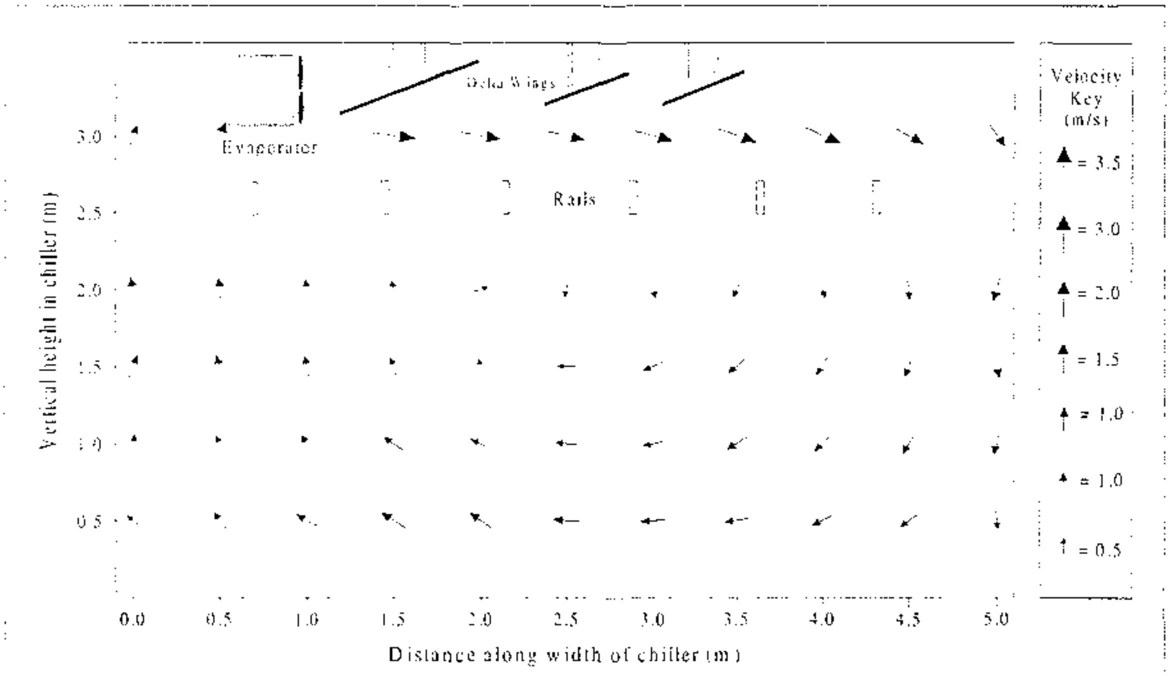


Figure 4.8: Cross-sectional view of mean air velocities in the empty chiller
Trial 2 - Second configuration of delta wings, 25° pitch
(Each vector is an average of 4-5 measurements across the length of the chiller)

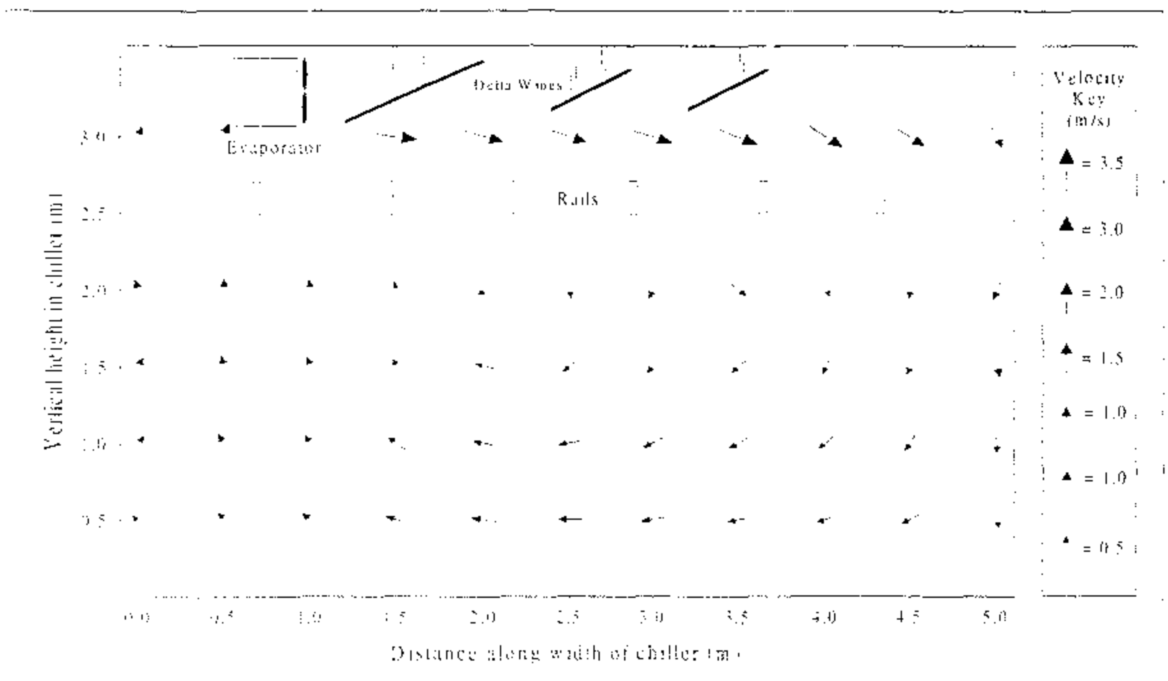


Figure 4.9 Cross-sectional view of mean air velocities in the empty chiller
Trial 3 - Second configuration of delta wings, 30° pitch
(Each vector is an average of 4-5 measurements across the length of the chiller)

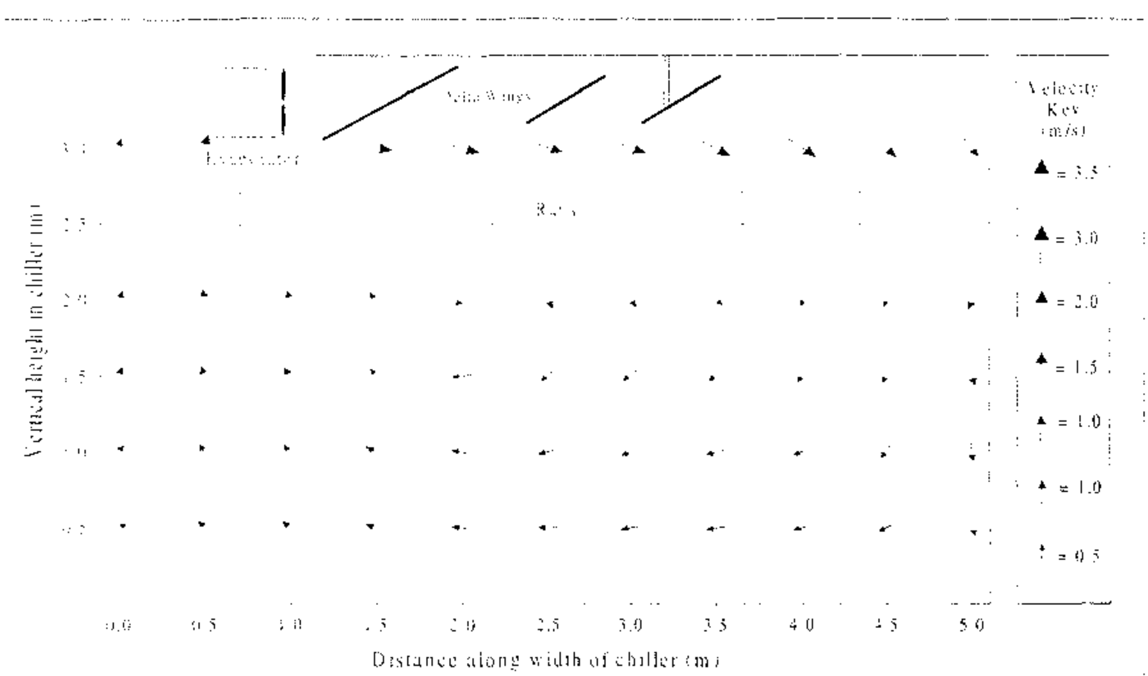


Figure 4.10: Cross-sectional view of mean air velocities in the empty chiller
Trial 4 - Second configuration of delta wings, 35° pitch
(Each vector is an average of 4-5 measurements across the length of the chiller)

4.3 FULL CHILLER CHARACTERISATION

4.3.1 AIR SPEED

Experimental data for the five trials that were carried out in the fully loaded chiller without delta wings installed is tabulated in Appendix E, Tables E.2-E.6. Averaged data is tabulated in Appendix E, Table E.7. Procedures used for these trials are described in Section *3.6.3 Materials and Methods.* Contour plots of air speed for each trial are presented in Appendix E, Figures E.2-E.6. The contour plot for the averaged air speed data is shown in Figure 4.11.

Experimental data for the three trials that were performed in the fully loaded chiller with the delta wings in the first configuration is tabulated in Appendix E, Tables E.8-E.10. Averaged data is tabulated in Appendix E, Table E.11. Air speed measurements were carried out according to procedures described in Section *3.6.3 Materials and Methods.* The contour plot for the averaged air speed data is shown in Figure 4.12.

Experimental data for the three trials that were performed in the fully loaded chiller with the delta wings in the second configuration is tabulated in Appendix E, Tables E.12-E14. Averaged data is tabulated in Appendix E, Table E.15. Air speed measurements were carried out according to procedures described in Section *3.6.3 Materials and Methods.* The contour plot for the averaged air speed data is shown in Figure 4.13.

Figure 4.14 shows the cross-sectional profile of mean air speed data averaged along the length of the chiller without wings installed.

Cross-sectional diagrams shown in Figure 4.15 and 4.16 display the average differences in mean air speeds for the first and second delta wing configurations with that obtained without wings. Net changes in the average air speed are displayed in their respective measurement positions.

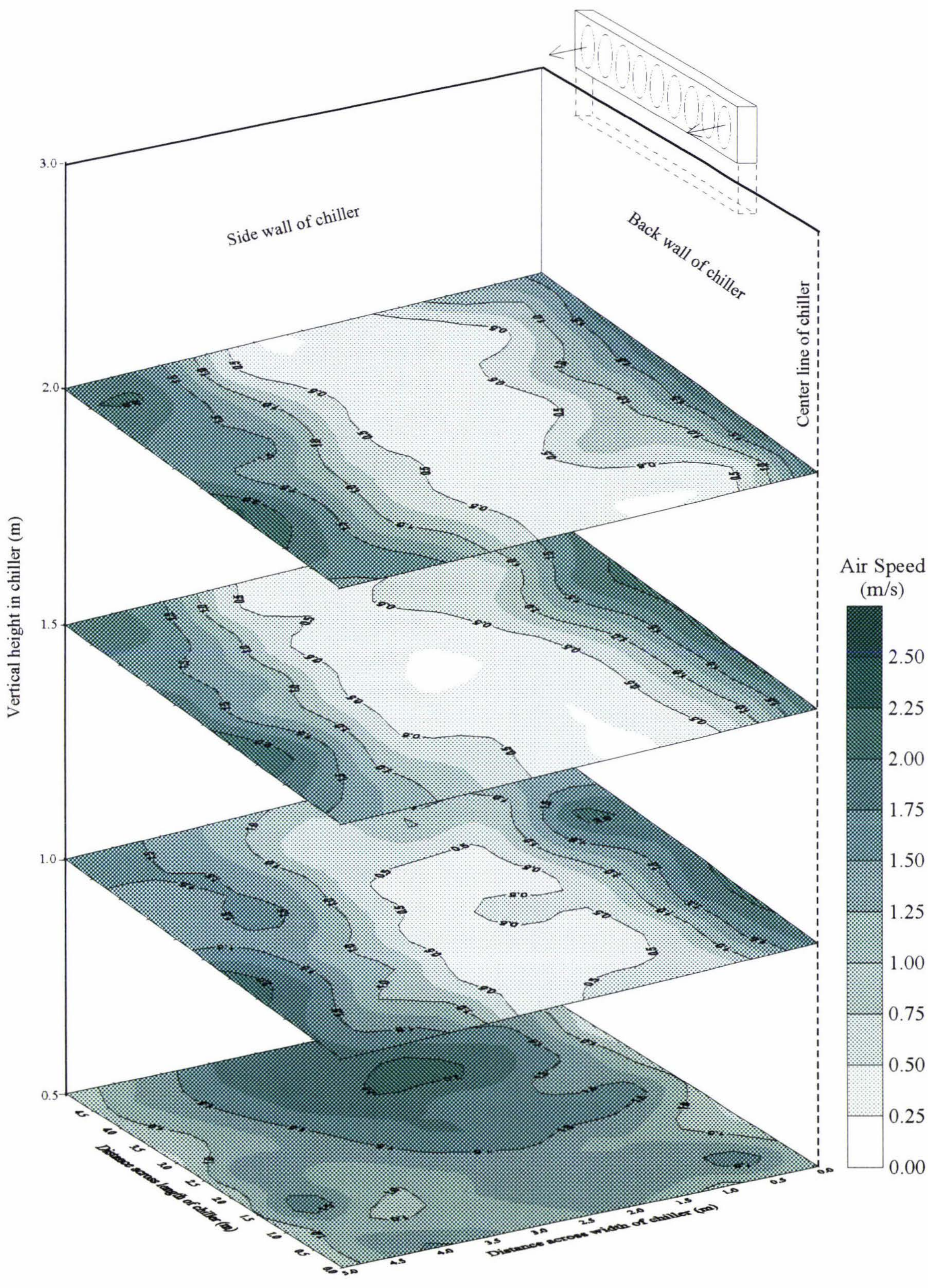


Figure 4.11: Average air flow profile of full chiller without wings

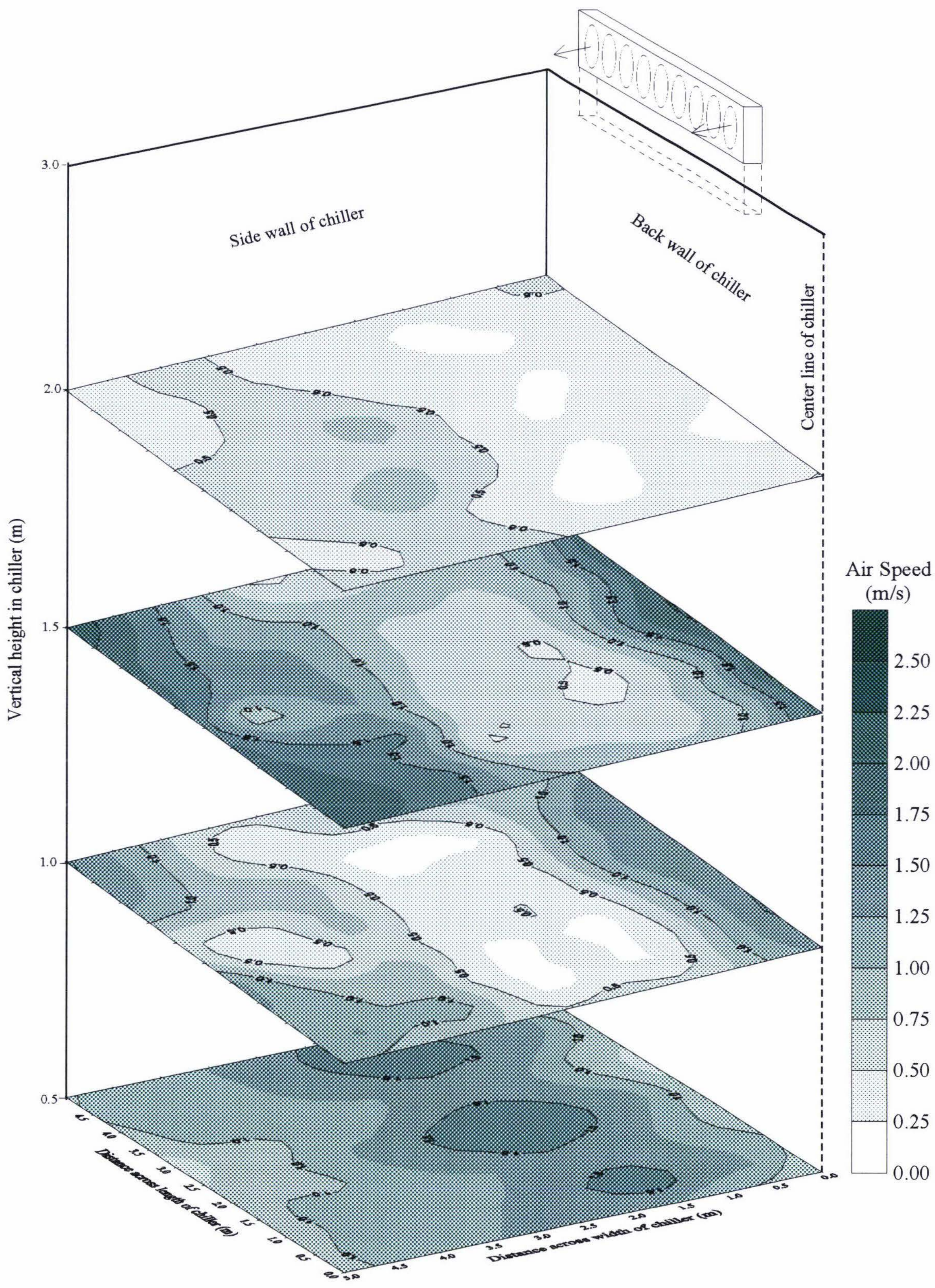


Figure 4.12: Average air flow profile of full chiller with delta wings in first configuration

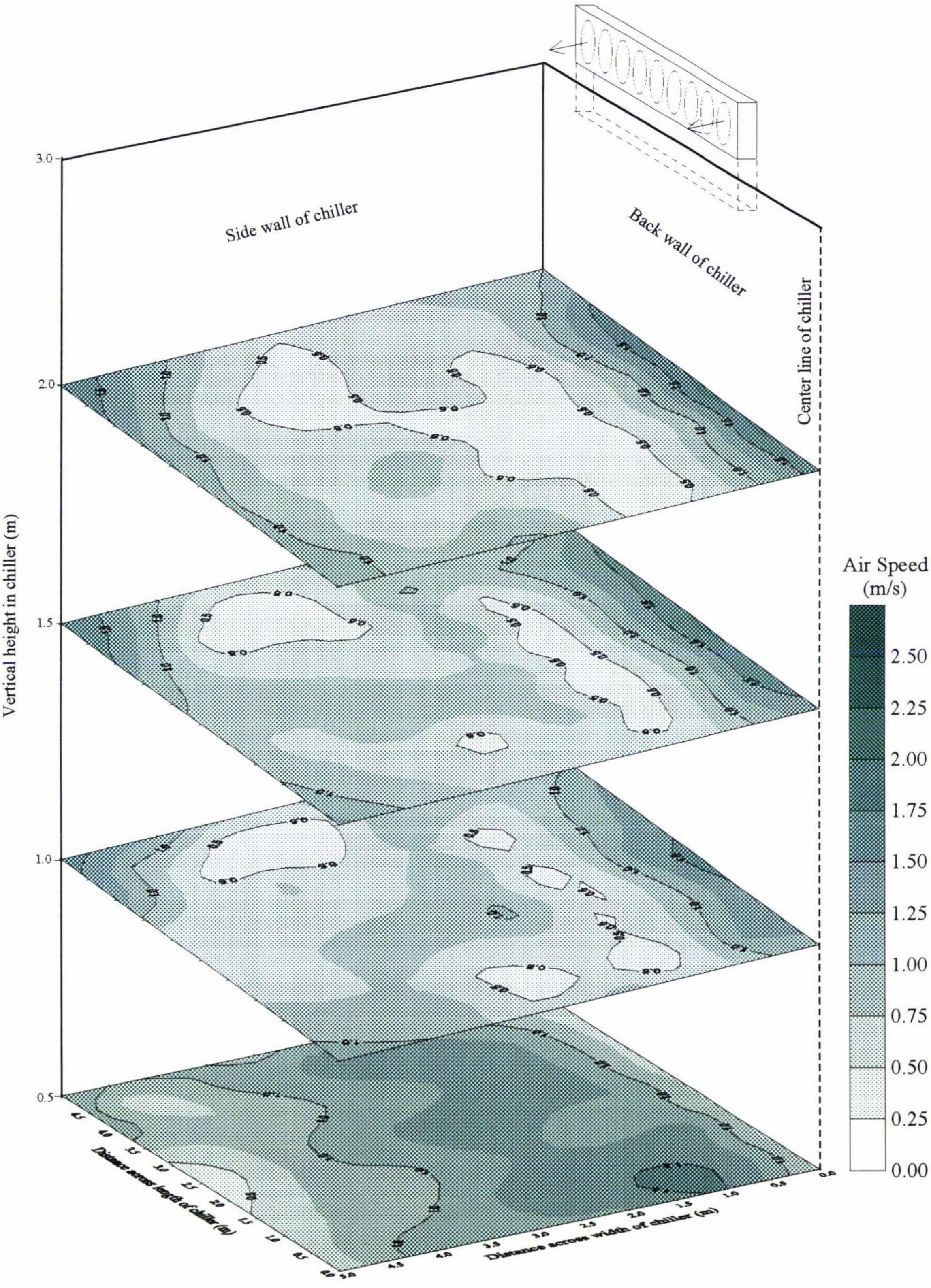


Figure 4.13: Average air flow profile of full chiller with delta wings in second configuration

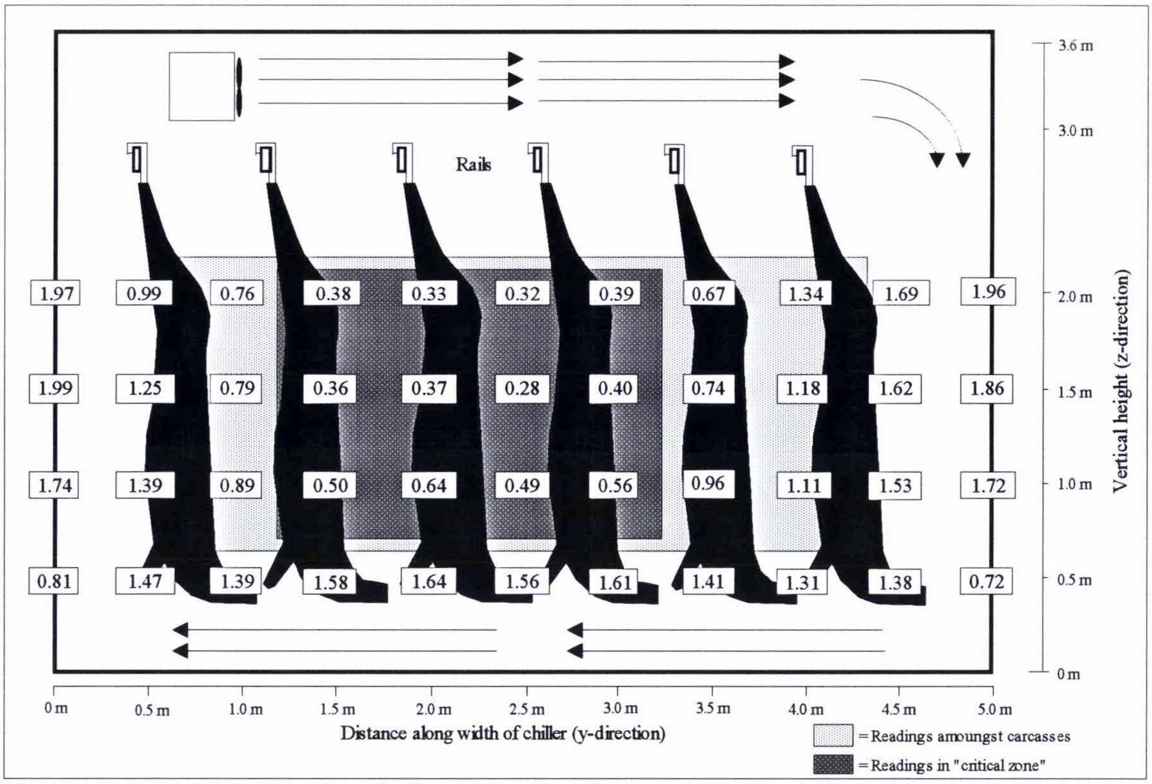


Figure 4.14: Cross-sectional view of mean air speeds in the full chiller
(Each reading is an average of 4-5 mean air speed readings across the length of the chiller)

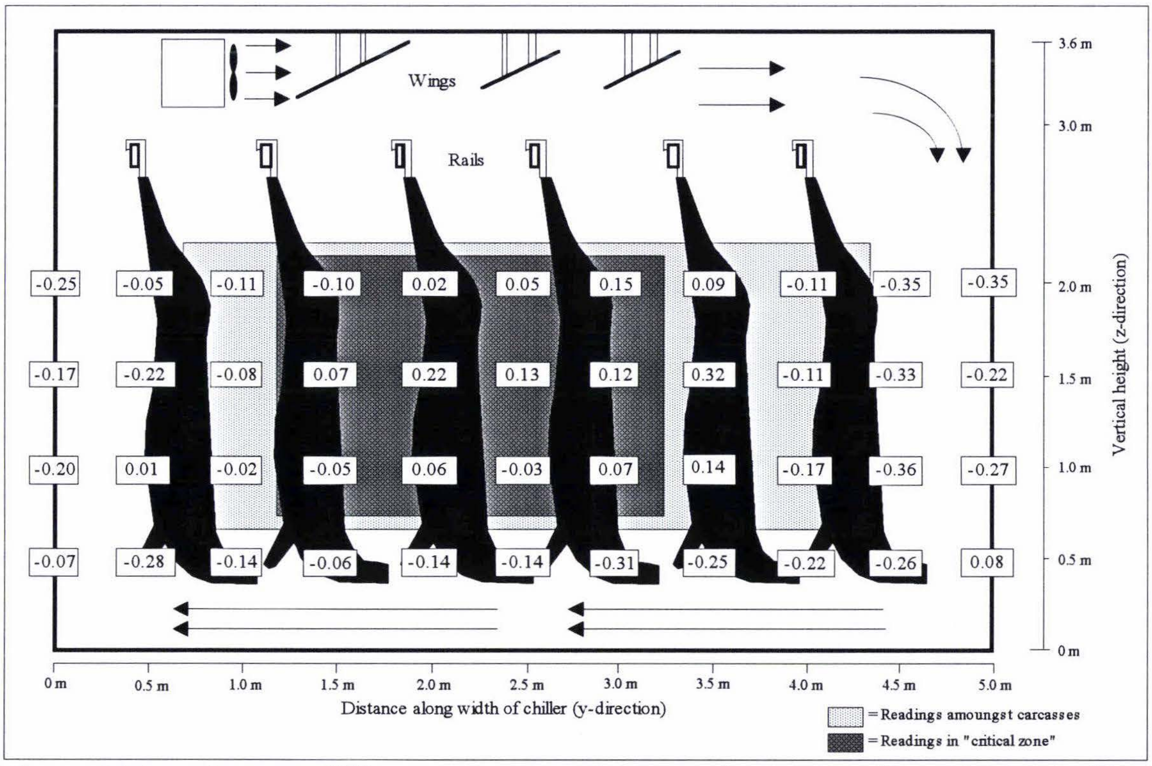


Figure 4.15: Average differences between the mean air speed readings obtained without delta wings and for the first configuration.
(Each value is an average difference of 4-5 mean air speed readings across the length of the chiller)

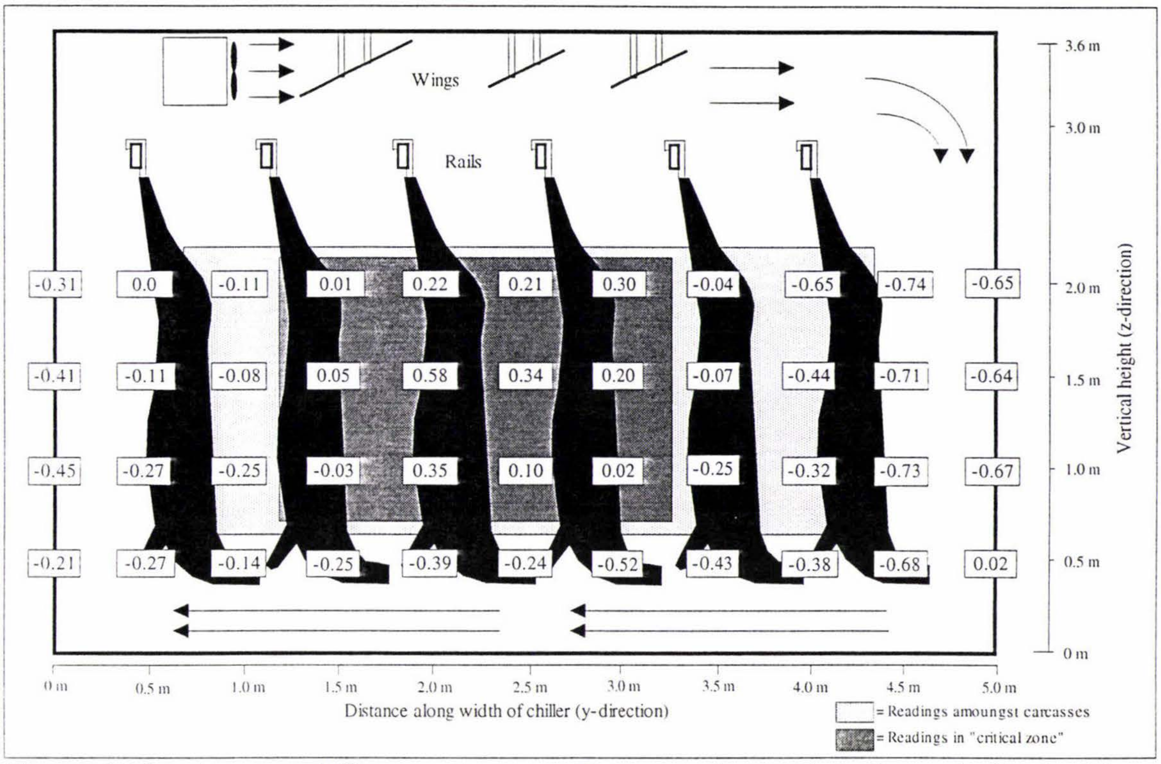


Figure 4.16: Average differences between the mean air speed readings obtained without delta wings and for the second configuration
(Each value is an average difference of 4-5 mean air speed readings across the length of the chiller)

4.3.2 AIR FLOW DISTRIBUTION

Figures 4.17, 4.18 and 4.19 show the mean air speed distributions for the fully loaded chiller without delta wings, and with wings installed in the first and second configurations. Data is taken from averaged air speed readings tabulated in Appendix E, Tables E.7, E.11 and E.15.

Figures 4.20, 4.21 and 4.22 show the mean air speed distributions amongst the carcasses for the fully loaded chiller without delta wings, and with wings installed in the first and second configurations. Data is taken from averaged air speed readings tabulated in Appendix E, Tables E.7, E.11 and E.15.

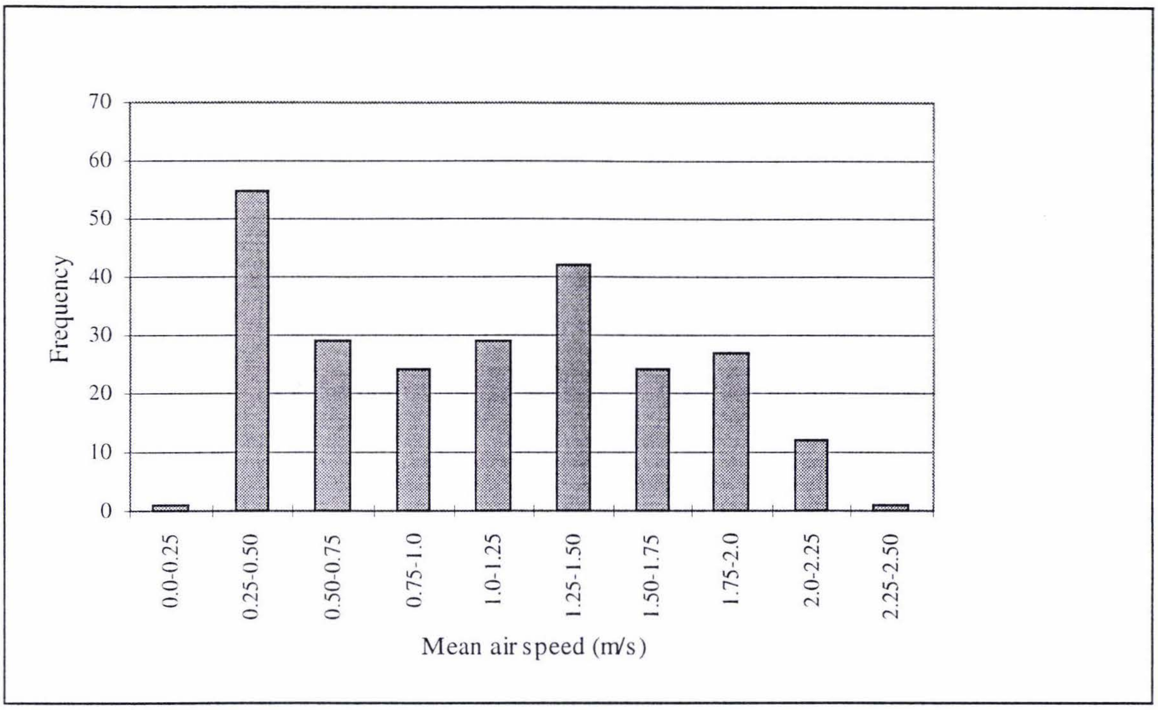


Figure 4.17: Mean air speed distribution in full chiller without delta wings. Distribution mean = 1.10 m/s and standard deviation = 0.564 m/s.

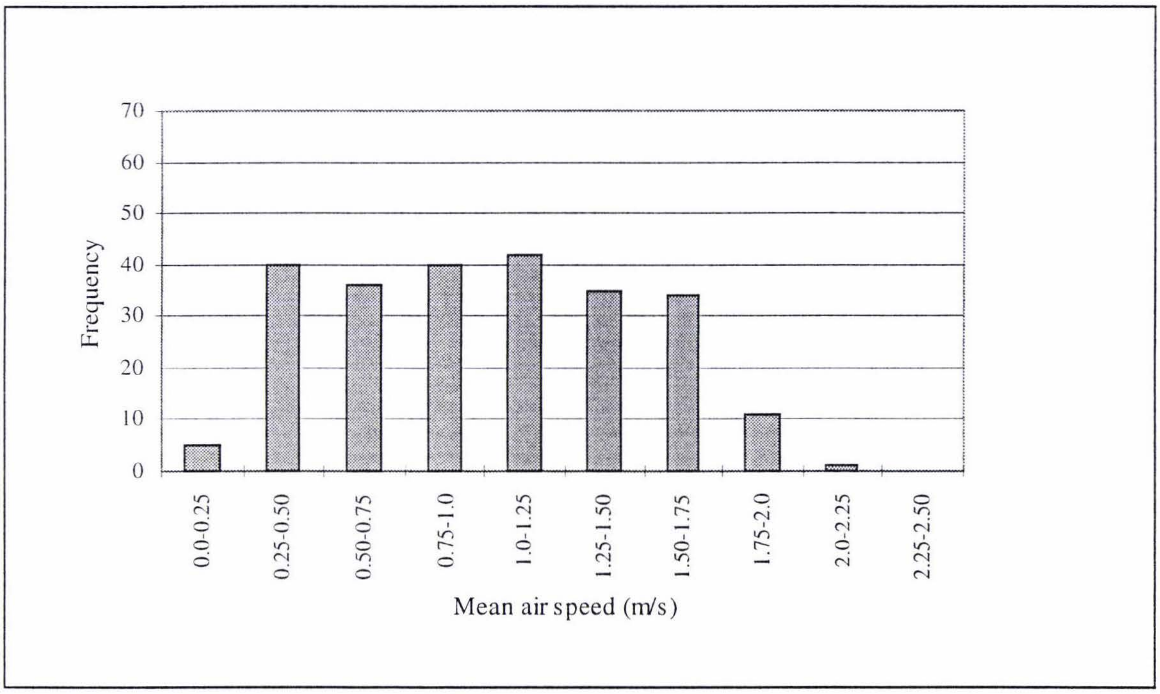


Figure 4.18: Mean air speed distribution for the first delta wing configuration. Distribution mean = 1.01 m/s and standard deviation = 0.466 m/s

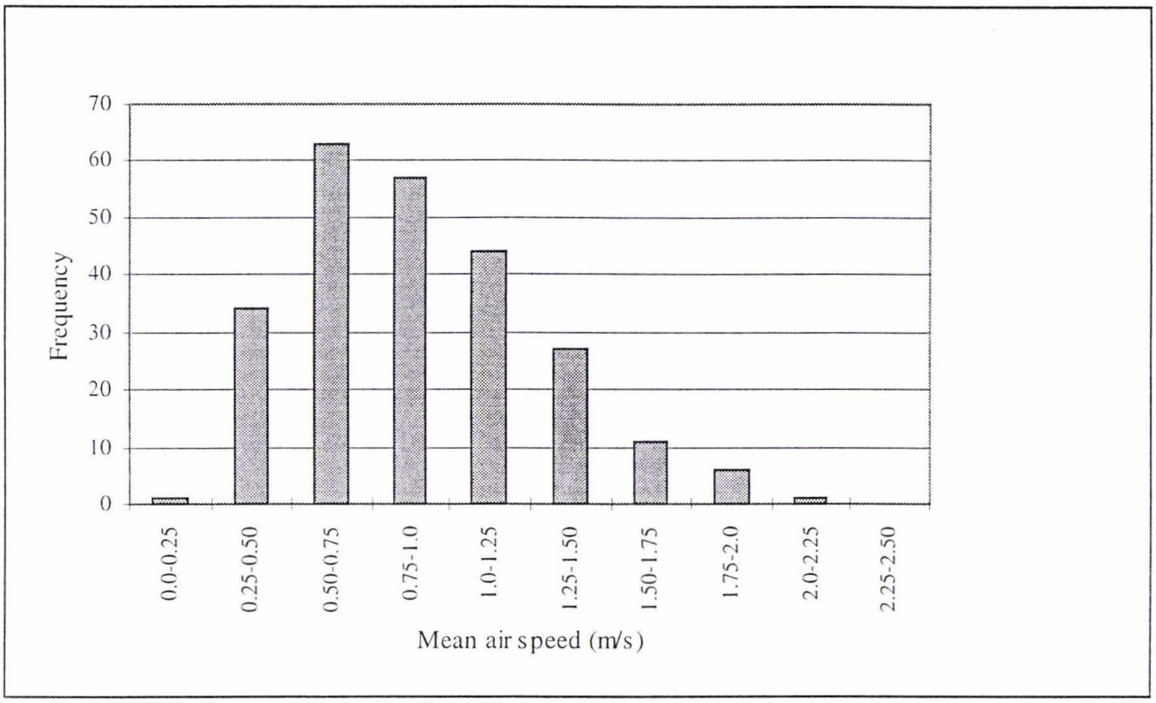


Figure 4.19: Mean air speed distribution for the second delta wing configuration. Distribution mean = 0.89 m/s and standard deviation = 0.377 m/s.

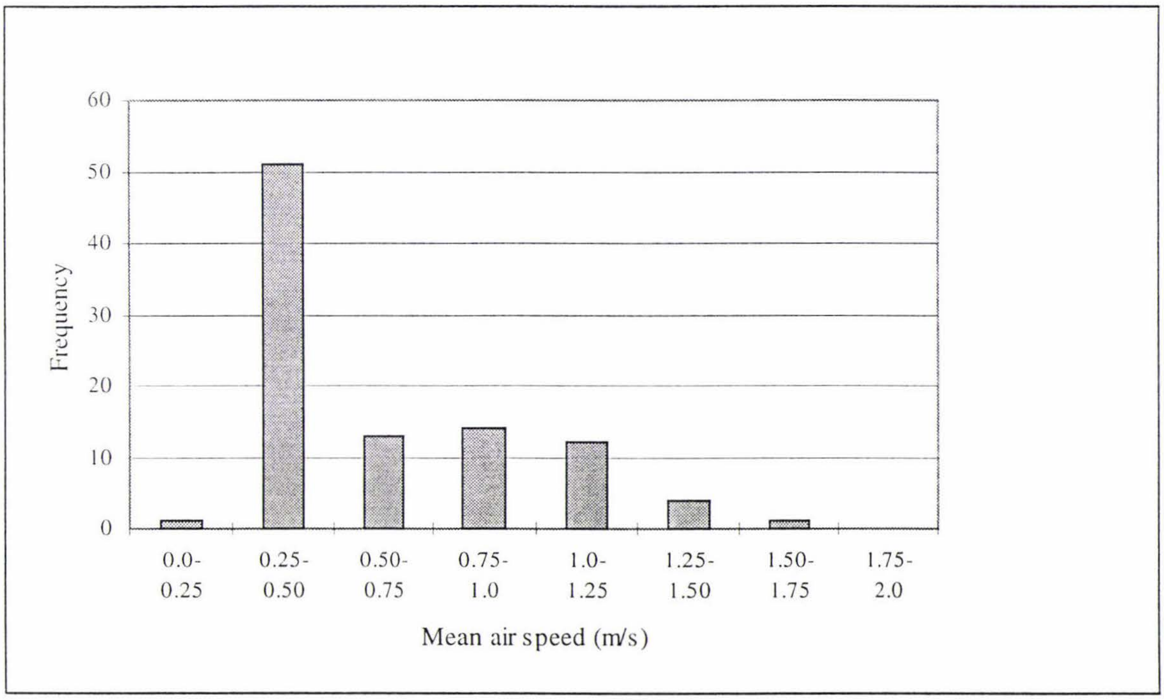


Figure 4.20: Mean air speed distribution amongst the carcasses without delta wings. Mean = 0.644 m/s, standard deviation = 0.325 m/s, MIRINZ indicator = 84%

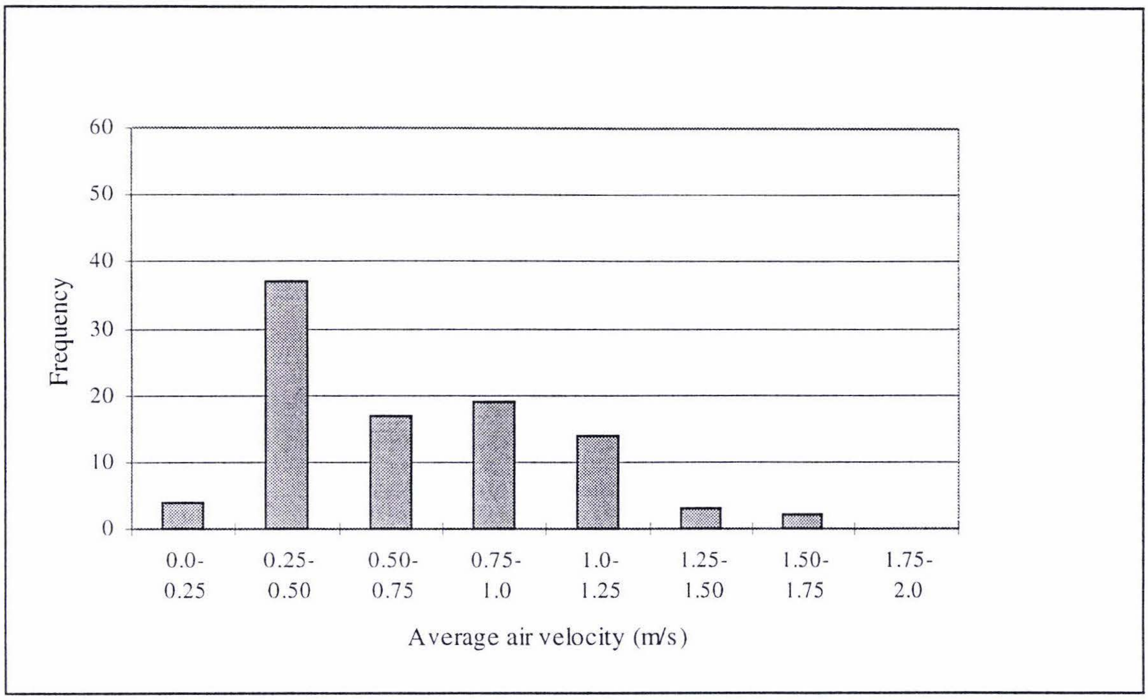


Figure 4.21: Mean air speed distribution amongst the carcasses for the first delta wing configuration.
Mean = 0.644 m/s, standard deviation = 0.325 m/s, MIRINZ indicator = 84%

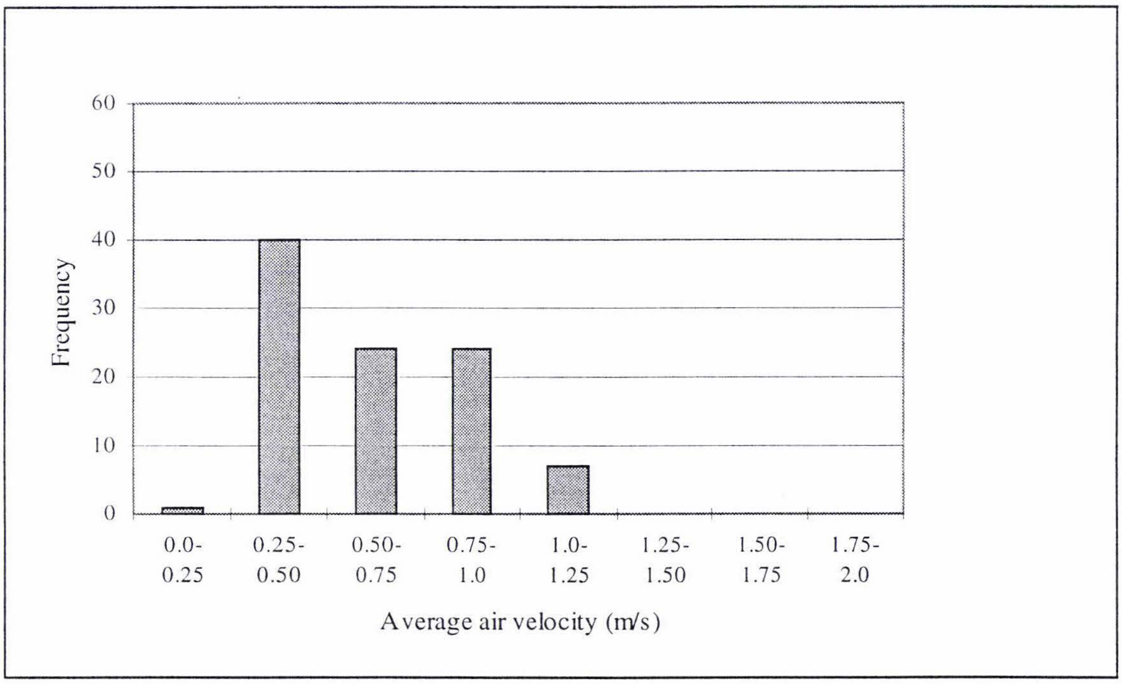


Figure 4.22: Mean air speed distribution amongst the carcasses for the second delta wing configuration.
Mean = 0.644 m/s, standard deviation = 0.325 m/s, MIRINZ indicator = 84%

4.3.3 WEIGHT LOSS

Weight loss data for the first three trials performed without wings installed is tabulated in Appendix F, Tables F.1-F.6. Percentages of the mean carcass weight loss, averaged along each rail, are presented in Figure 4.23.

Weight loss data for the trials carried out with the delta wings in the first configuration are tabulated in Appendix F, Tables F.7-F.12. Percentages of the mean carcass weight loss, averaged along each rail, are shown in Figure 4.24.

Weight loss data for the trials performed with the delta wings in the second configuration are tabulated in Appendix F, Tables F.13-F.18. Percentages of carcass weight loss, averaged along each rail, are displayed in Figure 4.25.

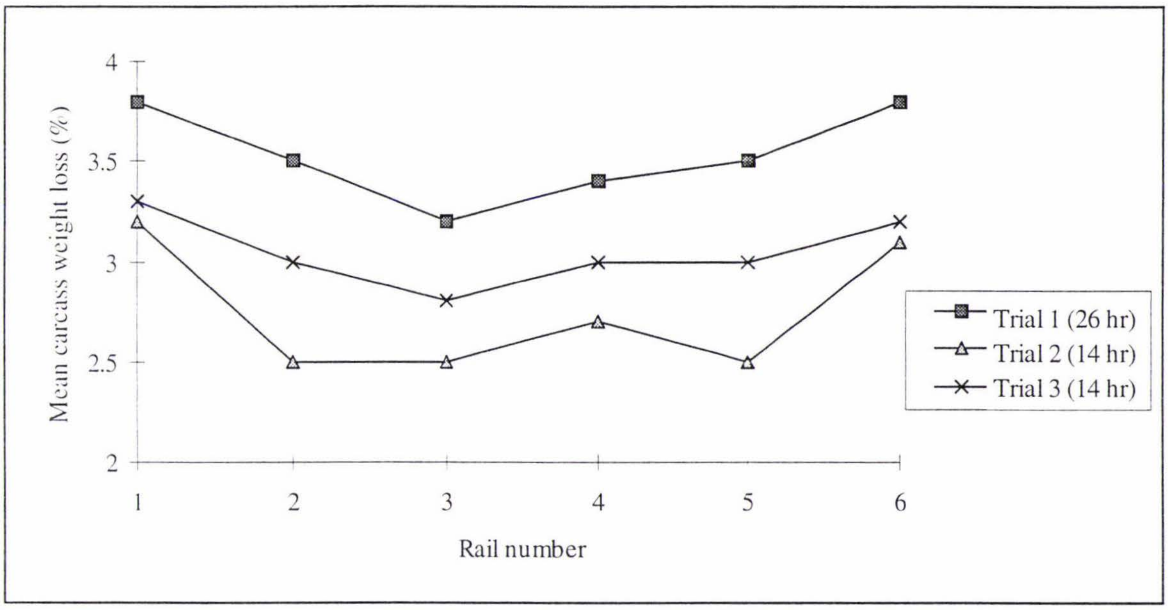


Figure 4.23: Variation in the average carcass weight loss along each rail without delta wings - Trials 1-3

The overall mean carcass weight loss in the test zone without delta wings installed was 2.91% for a 14 hour chill cycle.

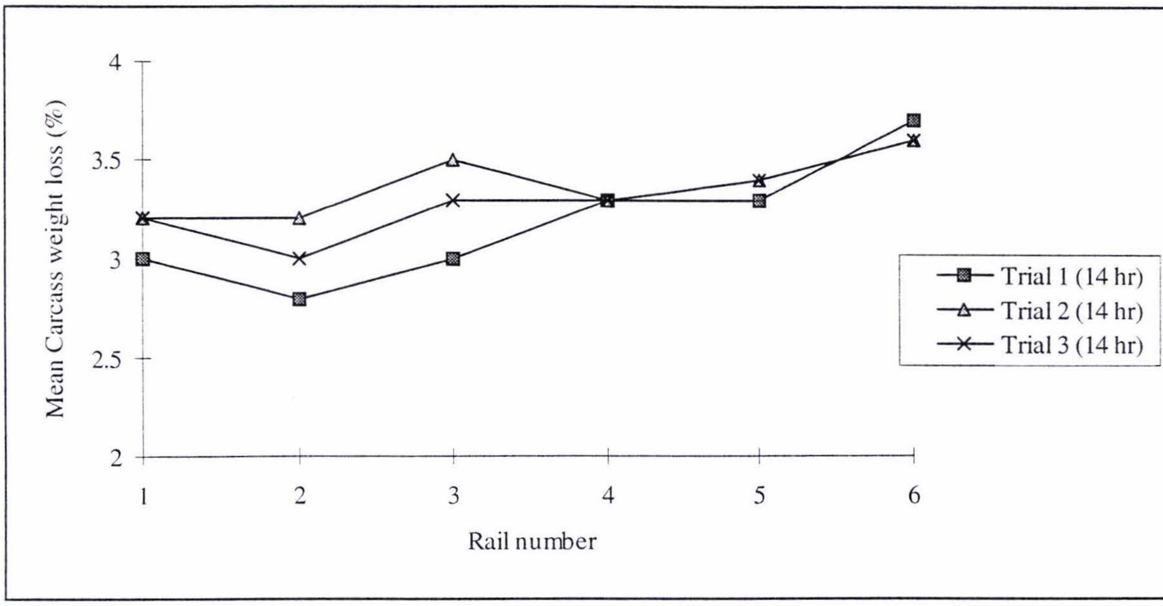


Figure 4.24: Variation in the average carcass weight loss along each rail
Delta wings in first configuration - Trials 1-3

The overall mean carcass weight loss in the test zone with delta wings installed in the first configuration was 3.29% for a 14 hour chill cycle.

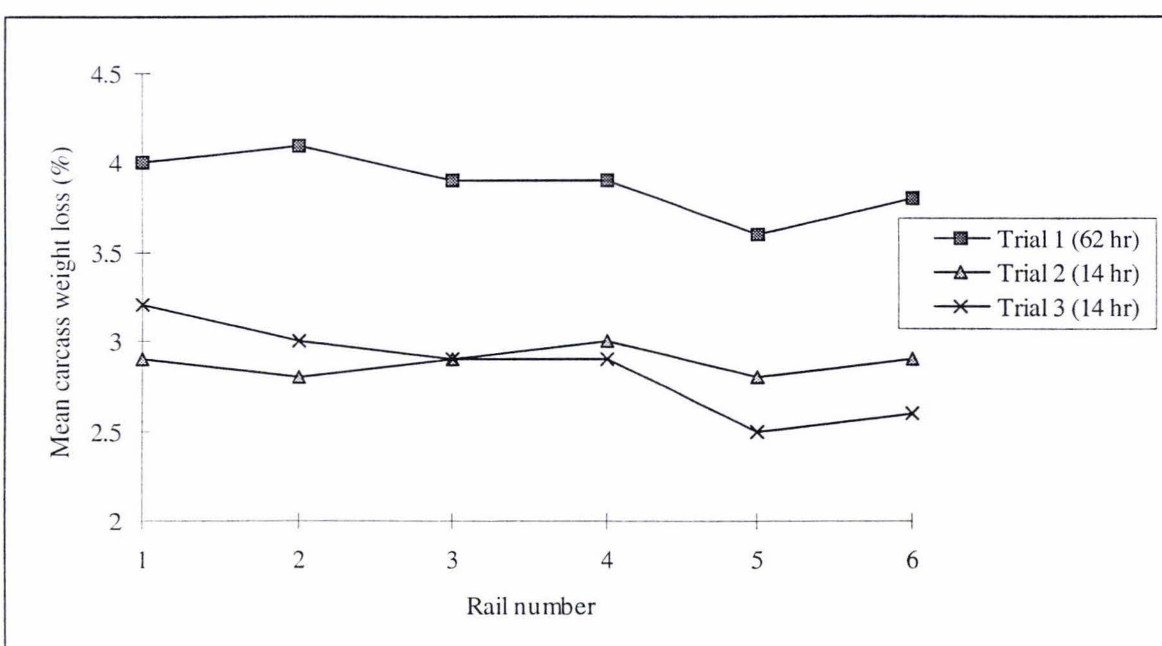


Figure 4.25: Variation in the average carcass weight loss along each rail
Delta wings in second configuration - Trials 1-3

The overall mean carcass weight loss in the test zone with delta wings installed in the second configuration was 2.94% for a 14 hour chill cycle.

4.3.4 AIR TURBULENCE

The mean turbulence intensity was calculated for ten positions amongst the carcasses for each trial carried out in the fully loaded chiller. Details of the calculation methods is given in Section *3.5.1 Materials and Methods.* Averaged data is presented in Appendix E, Table E.19.

The mean turbulence intensity averaged over the ten positions within the chiller was 22.3% without delta wings, 27.4% for the first configuration of delta wings and 36.5% for the second configuration.

4.3.4 ADDITIONAL TESTING

All previous tests carried out in the full chiller were performed with delta wings mounted at 25°. This wing angle was chosen to allow direct comparison with past work by Amraie (1993). However, experiments performed in the empty chiller indicated that the most favourable directional air flow profile was obtained with a delta wing pitch of 35°. Therefore, an additional trial was carried out in the full chiller with the delta wings adjusted to an angle of 35° in the second configuration. The experimental procedure was identical to those used in previous trials and is outlined in Section *3.5.3 Materials and Methods*. The data from this trial is presented in Appendix E, Table E.16 and displayed on a contour plot in Figure 4.26.

4.4 DISCUSSION

4.4.1 EMPTY CHILLER CHARACTERISATION

4.4.1.1 Without Delta Wings

Both Figures 4.1 and 4.2 show that high air flows occur at a height level with the evaporator, and close to the walls and floor. Air exiting the evaporators tends to travel horizontally until it reaches the far wall. Upon hitting the wall, air is deflected downwards towards the floor. This sets up a high velocity air stream which stays within 1.0 m from the wall. The zone of high air flow continues along the floor and back up behind the evaporator units. Regions of high air flow circulating around the walls and floor produce an area of slow, re-circulating air in the centre of the chiller.

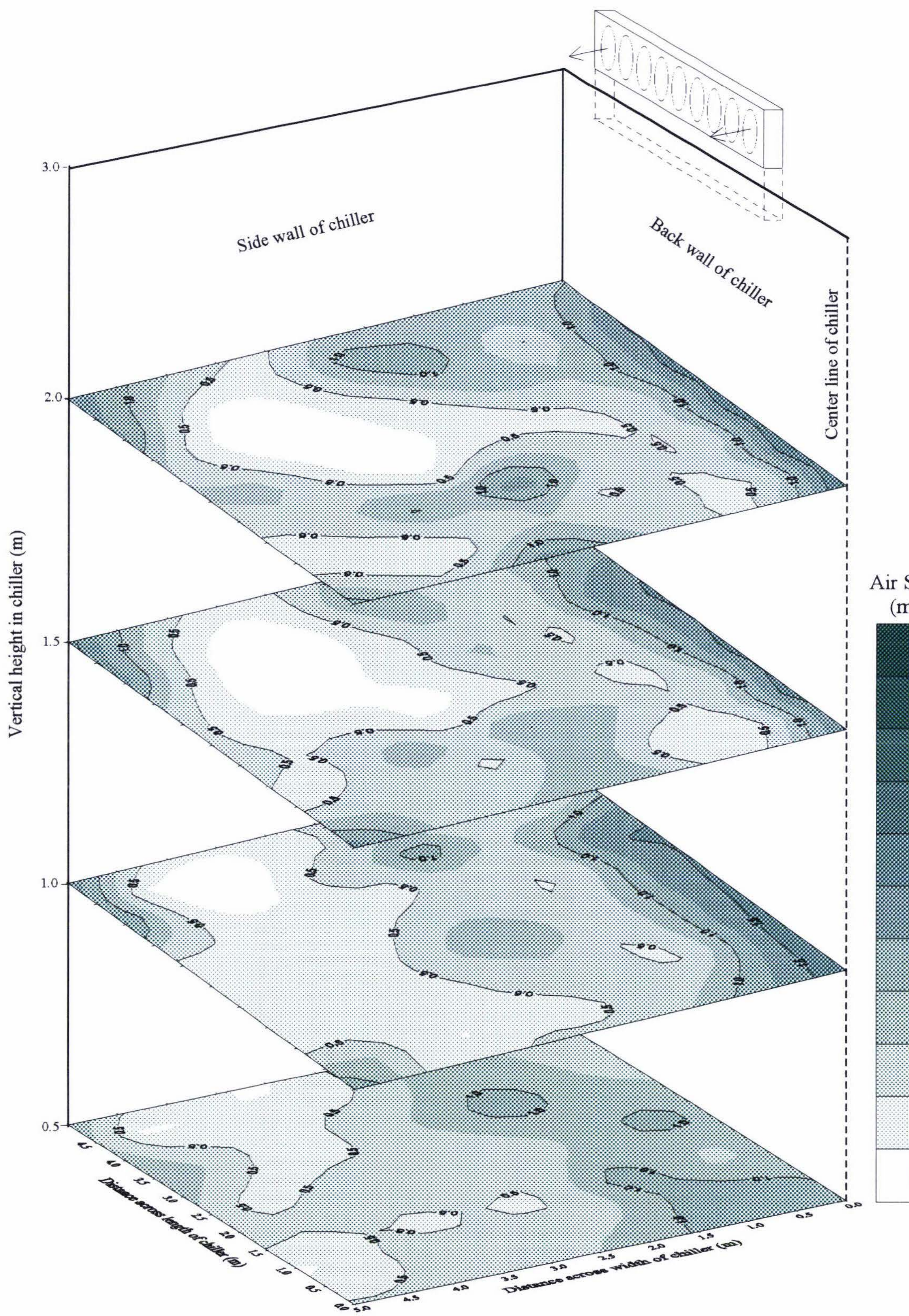


Figure 4.26: Average air flow profile of full chiller with delta wings at 35° in second configuration

This pattern of air circulation can be attributed to the walls guiding the fast moving air back to the evaporator inlet causing it to by-pass the centre of the room. The attractive forces set up by flow along a fixed surface (Coanda effect) also contribute to this effect (Section *2.2.1*). This phenomenon is common in batch chillers with ceiling mounted evaporators, and is also described by Murray (1974) and Amraie (1993) (Section *2.1.4*). Zones of low air flow also occur in the corners of the chiller, near the floor, as the fast moving air by-passes these areas. The overall air flow pattern is shown schematically in Figure 4.27.

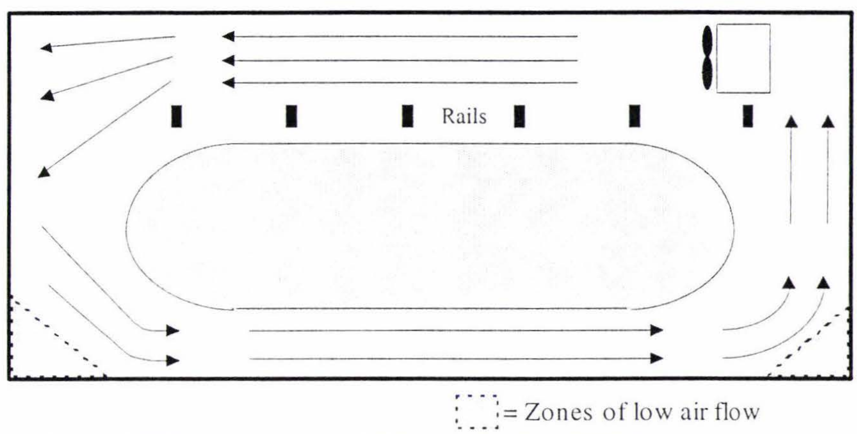


Figure 4.27: Zones of high and low air flow in empty chiller.

Figure 4.27 indicates that the overall air flow pattern is poor. The area where the product is to be located in the chiller is also the area of slowest air movement.

4.4.1.2 First Delta Wing Configuration

Figure 4.3 shows that with the delta wings set at a 20° pitch the resulting air velocity pattern closely resembles those found for the empty chiller with no wings installed (Figures 4.1 and 4.2). High air velocities are shown to occur at evaporator level, along the walls and across the floor. A zone of slow, recirculating air is again apparent in the centre of the chiller. A slight downwards tilt to the velocity vectors is evident at a height of 3.0 metres. This suggests that the delta wings are causing some air deflection close to the ceiling.

With the delta wings set at a 25° pitch there is still evidence of a high velocity air stream circulating close to the walls and floor (Figure 4.4), but this is less pronounced than that found with delta wings set at an angle of 20° (Figure 4.3). Recirculation of air can be seen occurring in the zone of low flow in the centre of the chiller. Again, a slight vertical air deflection is apparent from the exit air leaving the evaporator units. This downward deflection becomes more prominent with increasing distance from the fans.

Figure 4.5 shows a significant improvement on the uniformity of air velocities within the chiller using a delta wing pitch of 30°. The high velocity air stream around the walls has been dispersed toward the centre. Air flow at evaporator height and along the floor is directed more towards the middle of the room.

Figure 4.6 suggests further improvements in air flow uniformity have resulted in using a delta wing pitch of 35°. Below rail height, air flow is uniform right across the width of the chiller. No evidence of any zones of low air flow or air recirculation are apparent in the centre of the chiller.

4.4.1.3 Second Delta Wing Configuration

Figure 4.7 displays a similar velocity profile using a wing pitch of 20° in the second configuration, to that found under the same conditions for the first delta wing configuration (Figure 4.3). Zones of high air flow are still noticeable close to the walls an along the floor, although these are not as prominent as those obtained with no delta wings present (Figures 4.1 and 4.2). Some evidence of the air recirculating can be seen in the centre or the chiller, close to the rails.

Figure 4.8 shows that some improvement in air flow uniformity has occured with delta wings set at an angle of 25° in the second configuration in comparison to the first configuration with the same delta wing angle (Figure 4.4). The zone of high air flow around the walls and along the floor is less pronounced and air velocities seem to be unidirectional at the different levels up to rail height. Air seems to be flowing down through the rails rather than flowing horizontally underneath the rails. The large zone of recirculating air in the centre of the chiller, found using the first wing configuration, has become a small area close to the rails.

For delta wings set at 30° in the second configuration, the air velocity profile shown in Figure 4.9 suggests a slight improvement to that found for the first configuration using the same wing angle (Figure 4.5). A more uniform air flow pattern is achieved with fairly even air velocities occurring up to rail height. Again, air seems to be flowing vertically down through the rails rather than horizontally. No evidence of any air recirculation patterns are noticeable.

Figure 4.10 shows that with delta wings set in the second configuration at a pitch of 35° there has once again been an improvement in air velocity distribution compared to the profile obtained from the first configuration with identical wing angles (Figure 4.6). Below rail height, air velocities are more evenly distributed across the width of the chiller. Also, vectors at a height of 2.0 metres suggest air is flowing vertically down through the rails rather than across horizontally. No evidence of any air recirculation pattern is apparent. Of the various combinations of conditions tested, the second configuration with delta wings at 35° gives the most favourable air flow pattern in the empty chiller.

4.4.1.4 Summary of Results in Empty Chiller

		First delta wing configuration				Second delta wing configuration			
	No Wings	20°	25°	30°	35°	20°	25°	30°	35°
Distribution	poor	poor	poor	good	good	avg.	avg.	good	good
Re-circulation	yes	yes	yes	no	no	yes	no	no	no
Direction at 2 m	Hori.	Hori.	Hori.	Hori.	Hori.	vert.	vert.	vert.	vert.

Table 4.1: Summary of the air velocity profiles obtained in the empty chiller.

A summary of results is presented in Table 4.1. Overall, the profiles obtained with delta wings installed show much improved air distribution patterns in comparison to those obtained without wings. The second delta wing configuration performed better than the first configuration with superior air flow uniformity, less evidence of air re-circulation and a more vertical air flow at a height of 2.0 m. Also, the larger wing angles produced better air flow pattterns than smaller wing angles.

4.4.2 FULL CHILLER CHARACTERISATION

4.4.2.1 Air Speed

With each trial carried out in the full chiller, conditions within the chiller differed slightly. Variation occurred in carcass size, shape and quantity with each loading

(Section *3.2.3 Materials and Methods*). In order to obtain an average air speed profile for the five trials performed without wings, it must be shown that the variability in conditions had a negligible effect on air flow. Statistical *t*-tests showed differences in the mean air speed readings between each trial were not significant at the 95% level. Therefore, the conclusion was that the variation in carcass, size, shape and quantity that occurred had little effect on the measured air speeds within the chiller.

The average air flow profile for trials performed in the full chiller without wings (Figure 4.11) shows two distinct zones of slow air movement at a vertical height of 0.5 m. One of these zones occurs close to the back wall of the chiller, behind the evaporator fans and the other occurs close to the front wall, opposite the evaporator units. These zones of slow moving air at the foot of the walls were also found in the empty chiller and are discussed in Section *4.4.1.1*.

Zones of fast moving air occur close to the front and back walls down to a height of 1.0 m and close to the floor, in the centre of the chiller, at a height of 0.5 m. These zones of fast moving air also occur in the empty chiller, although, this effect is more pronounced in the fully loaded chiller due to the presence of the carcasses. The carcasses form a semi-impenetrable barrier to air flow causing air to be drawn down the front wall, under the hanging carcasses and back up the wall under the evaporator inlets. As the bulk of fast moving air from the evaporator fans follows the path of least resistance around the carcasses, a large area with low air movement is formed in the centre of the chiller. This is indicated by the well defined section in the middle of the profiles at heights of 1, 1.5 and 2 metres. This area of very low air flow is again more prominent than in the empty chiller situation.

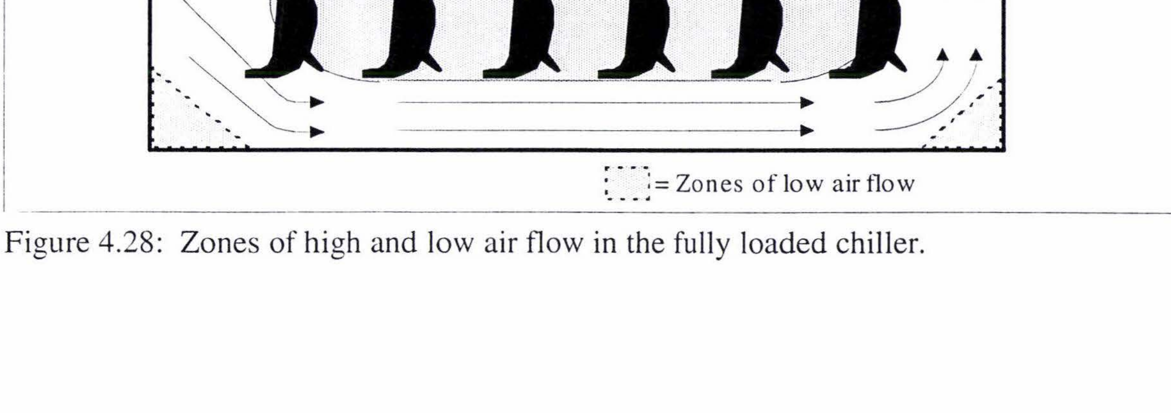


Figure 4.28: Zones of high and low air flow in the fully loaded chiller.

Figure 4.28 shows the general air flow pattern in the fully loaded chiller. As with the empty chiller (Figure 4.27), the overall pattern is poor, with little air movement occurring in the vicinity of the carcasses.

Figure 4.12 indicates an improvement in the uniformity of the air flow has occured over the four measurement heights with delta wings installed in the first configuration. The areas of high air flow rates, close to the floor and near the front wall, that were prominent when no wings were installed (Figure 4.11), are now less noticeable. However, an increased number of areas with near stagnant conditions (with air flow below 0.25 m/s) have appeared. These mainly occur at positions amongst the carcasses at heights of 1 and 2 metres. These localised zones of low air flow may indicate that the first configuration has an insufficient number of wings mounted over the test area. Too few wings could create stagnant areas in positions where the turbulent, fast moving air, flowing off adjacent wings, does not overlap.

Figure 4.13 shows a distinct improvement in air flow uniformity with delta wings in the second configuration in comparison to profiles obtained with delta wings mounted in the first configuration (Figure 4.12) and without delta wings (Figure 4.11). The second wing configuration has caused a large reduction in air speeds close to the floor and near the front and back walls. The area of low air flow in the centre of the chiller, amongst the carcasses, is no longer well defined. Also, there is no longer any evidence of localised zones of air flow near stagnant conditions (below 0.25 m/s). This suggests that with an increased number of wings, the zones of high air flow off the wings are now overlapping each other, creating a much more even air speed distribution across the chiller.

An alternative way of viewing the same air speed data is to display the mean air speeds on a cross-sectional diagram of the chiller allowing a quantitative assessment to be made. Figure 4.14 highlights the poor uniformity of air flow across the width of the full chiller without delta wings. This is caused by fast moving air circulating close to the walls and floor. Amongst the carcasses there are still relatively high mean air flow rates close to the end carcasses. However, there is a area of very low mean air speeds, in the "critical zone", where air flow is almost stagnant. The overall average air speed in this zone is only 0.42 m/s.

To illustrate how the air speeds have been redistributed with delta wings installed, the difference in mean air speeds were plotted on a cross-sectional diagram of the chiller.

Ideally, the delta wings should redistribute the air flow so there is a reduction in the mean air flow at positions where air speeds were relatively high (namely, along the floor and walls), and increase air flow in positions where air speeds were relatively low (amongst the carcasses). This redistribution of air flow within the chiller is apparent with wings installed in the first configuration (Figure 4.15). In general, areas of high air flow around the outside of the chiller, have been reduced, whereas air speed in areas of dominantly low air flow amongst the carcasses, has increased. The average increase in air speed for each position amongst the carcasses was 0.031 m/s (4.8%). In the "critical zone" zone the average increase was slightly higher at 0.059 m/s (14.1%).

Figure 4.16 indicates that the second delta wing configuration has caused further reductions in the air flow close to the walls and floor. There is no significant gain in the overall average air speed for positions amongst the carcasses. However, the average air flow rates at positions within the "critical zone" have been increased dramatically. On average the air speeds within this area have increased by 0.196 m/s (30.6%) over the air speeds obtained without delta wings.

4.4.2.2 Air Flow Distribution

The mean air speed distribution obtained without delta wings, shown in Figure 4.16, suggests poor air uniformity. The shape of the distribution is far from a normal curve with peaks occurring between air speeds of 0.25-0.5 m/s and 1.25-1.5 m/s. Air speeds also fall over a wide range of values (0-2.5 m/s).

The resulting mean air speed distribution obtained with delta wings in the first configuration, presented in Figure 4.18, indicates a marked improvement in the uniformity of the air flow. The distribution shape is closer to that of normal distribution, as the peaks which occurred at extreme air speed values, have been significantly reduced. The range of the distribution is smaller and values are centreed closer to the mean.

Figure 4.19 suggests that the second delta wing configuration produces the best mean air speed distribution of the three situations tested. Good air flow uniformity is indicated by a close approximation to a normal distribution and from the majority of the air speed readings occurring around the distribution mean. This gives rise to a comparatively lower standard deviation.

Amongst the carcasses, poor air flow uniformity is also evident without delta wings installed (Figure 4.20). The shape of the histogram deviates greatly from a normal distribution, indicating poor air flow uniformity. The MIRINZ indicator confirms there is unacceptable uniformity of air flow, with only 84% of values between ½ and 2 times the mean air speed.

Figure 4.21 displays a slight improvement in the air flow amongst the carcasses for the first configuration of delta wings. The distribution approximates a normal distribution more closely. However, the standard deviation of the distribution remains largely unchanged at 0.327 m/s (0.325 m/s without wings). Whereas, mean air speed amongst the carcasses is marginally higher at 0.675 m/s (0.644 m/s without wings). The MIRINZ indicator suggests there is still a poor uniformity of air flow as only 82 % of the air speed values are between ½ and 2 times the mean.

Figure 4.21 demonstrates a marked improvement in the uniformity of the air flow for the second delta wing configuration. The distribution closely approximates a normal distribution and range and standard deviation of the distribution have been significantly reduced. The MIRINZ indicator suggests there is acceptable uniform air flow with 95 % of air speed values between ½ and 2 times the mean air speed.

4.4.2.3 Weight Loss

Figure 4.23 indicates a general trend of higher weight losses occurring from carcasses positioned on the first rail (furthest from the evaporators) and the sixth rail (closest to the evaporators). These results are supported by the corresponding air speed profiles (Section *4.4.2.1*) where high air flows were found to occur along the floor and walls producing a zone of fast moving air close to the outside carcasses on rails 1 and 6, and low air flow around the centre carcasses on rails 2, 3, 4 and 5. As chilling was carried out over a fixed duration of time needed to reduce the slowest cooling carcass to the required temperature, this air flow pattern is conducive to high weight loss. The outside carcasses are brought down to the required temperature rapidly and are then held in a high velocity air stream until the chilling of the slower cooling carcasses is complete. These carcasses are prone to higher weight losses than those positioned in the centre of the chiller where there is relatively low air flow and hence slower chilling rates.

Figure 4.24 suggests an improvement in weight loss uniformity has occurred across the chiller by comparison with trends displayed without delta wings (Figure 4.23). The plots gradient indicates less moisture was lost from carcasses positioned on the 1st rail, compared to those on the 6th rail. This trend is supported by data showing difference in air speeds (Figure 4.15), where larger reductions in air speeds occurred adjacent to carcasses located furthest from the evaporators. The reduction in air speeds on the far side of the chiller has resulted in comparatively lower weight losses for carcasses on the 1st rail. However, the mean carcass weight loss for a 14 hour chill cycle increased from 2.91% without delta wings, to 3.29%.

Weight loss trends displayed in Figure 4.25 show a drastic improvement in uniformity of weight loss for the second delta wing configuration compared to the previous two situations. Again this result is supported by the corresponding air speed data which suggests a more uniform air flow distribution has also arisen from the second delta wing configuration (Section *4.4.2.1*). The mean carcass weight loss for a 14 hour chill cycle remained largely unchanged at 2.94% compared to 2.91% without delta wings.

4.4.2.4 Additional Testing

Figure 4.26 shows the air flow profile obtained with wings set at 35° in the second configuration. An increased number of areas near stagnant conditions have appeared over the test zone in comparison to the profile obtained using a delta wing pitch of 25° (Figure 4.13). Although, a delta wing angle of 35° produced the most favourable air flow pattern in the empty chiller, results suggest that the delta wings perform better at an angle of 25° in the full chiller.

4.4.2.5 Characterisation Summary

	Overall mean air speed (m/s)	Overall air speed stdev. (m/s)	Mean air speed amongst carcasses (m/s)	Air speed stdev. amongst carcasses (m/s)	Mean air speed in 'critical zone' (m/s)	MIRINZ indicator (%)	Turbulence intensity (%)	Weight loss Uniformity
Without DW's	1.12	0.564	0.644	0.325	0.418	84	22.3	poor
DW config. 1	1.01	0.466	0.675	0.327	0.477	82	27.4	average
DW config. 2	0.89	0.377	0.638	0.222	0.614	95	36.5	good

Table 4.2: Summary of the air flow distribution without delta wings and with delta wings in the first and second configurations.

A summary of results is presented in Table 4.2. Overall, delta wings reduce the mean air speed in the chiller. A likely explanation for this is that the added pressure drop from the delta wings causes a slight reduction in the total air flow rate.
Although delta wings decreased the overall mean air speed, they did not significantly alter mean air speed amongst the carcasses, whereas, mean air speed in the 'critical zone' increased.

The reduction in the mean air speed standard deviation over the whole chiller and amongst the carcasses shows that uniformity of air flow has improved with the installation of delta wings. The second delta wing configuration produced the lowest mean air speed standard deviation in both cases, suggesting that its performance was superior to the first configuration. This conclusion is also supported by the increase in the percentage of readings between half and double the mean air speed (MIRINZ indicator)

Both delta wing configurations give rise to increases in the turbulence intensity within the chiller. The first configuration increased mean turbulence intensity by 5.1%, whereas, the second configuration increased mean turbulence intensity by 14.2% over the ten position tested.

Delta wings improved uniformity of weight loss across each rail. Without delta wings, higher weight loss occurred from carcasses on the outside rails. With delta wings installed, the variability of mean carcass moisture loss across the rails was significantly reduced.

In general, the first delta wing configuration increased air uniformity across the whole of the chiller, however little improvement shown to occur amongst the carcasses. The second delta wing configuration improved air uniformity across the whole of chiller as well as amongst the carcasses.

4.5 COMPARISON WITH PREVIOUS WORK

Amraie (1993) characterised the flow of air in an empty and fully loaded pig pre-chiller (Section *2.1.4 Literature Review*). In the empty room, two regions of air movement were prominent. High air flow occurred close to the ceiling, walls and floor whereas low air flow occurred in the centre where the carcasses were hung. Results were consistent with those found in this study (Section *4.4.1.1*)

In the full pig pre-chiller, the overall air flow pattern was found to closely resemble those found in the full deer chiller with zones of high air movement occurring around the outside of the carcasses and a zone of low air movement among the carcasses. These results are consistent with those discussed in Section *4.4.2.1*.

Amraie (1993) also performed air flow measurements in a laboratory test room to investigate the room air mixing effect produced by delta wings. Thermistors were placed in nine positions around the test room to be used as anemometres. The room air mixing was tested by instantaneously heating the supply air and recording the lag time from the response of the thermistors. With instantaneous heating of the supply air and perfect mixing the room would behave as a stirred tank with minimum first order lag.

Comparing the time constants recorded by each of the thermistors for the situations with and without the delta wings, Amraie found that the wings improved air mixing between the dummy carcasses by a factor of 2-3. Results indicated that the mean air speed among the dummy carcasses increased by 0.22 m/s upon the installation of the delta wings. This increase is comparable those found in this study where a gain of 0.20 m/s was found to occur in the critical zone using the second delta wing configuration (Section *4.4.2.1*). Amraie (1993) also found that the delta wings greatly increased the thickness of the air jet from the diffuser but reduced the main velocity contour. Results from this study support this claim, where the turbulence zone behind the wings was found to widen as the distance behind the wing increased, until the turbulence effect was dissipated (Section *3.4.2.1 Materials and Methods*).

4.6 IMPLICATIONS FOR INDUSTRY

Although no investigation into the effect on chilling rate was carried out in this study an analysis of the imact can still be made. As the delta wings increased the air velocity and turbulence around the carcasses while also producing a more uniform air flow, it can be assumed that this will have an direct influence on the rate and uniformity of chilling. The second wing configuration increased the mean air speed by 0.2 m/s in the 'critical zone' (area of lowest air flow) while lifting the mean turbulence intensity by 14.2%. Based on the work performed by Kondjoyan and Daudin (1995), an increase in the turbulence intensity of this size equates to an equivalent rise in air speed of 0.6 m/s. Therefore, for the same amount of fan power, the wings have on average increased effective air speed by 0.8 m/s in the area of lowest air flow.

This increase in mean air speed will lead to significant reductions in chilling times. For example, by approximating a large red deer carcass with a 100 kg lean side of beef, a carcass in the 'critical zone', before the installation of delta wings, would take approximately 13.5 hours to chill to a deep leg temperature of 10°C, in 4°C air (MIRINZ beef chilling charts). This is just within the normal 14 hour chilling period. However, with an equivalent air flow increase of 0.8 m/s, the same carcass would take 11.5 hours to chill to 10°C with the same air temperature (MIRINZ beef chilling charts). This 2 hour reduction in chilling time can give rise to real benefits.

As a chill cycle now only takes approximately 12 hours to perform instead of the normal 14 hours, it may mean that the chiller could be loaded twice a day. This would lead to improved efficiencies and substantial savings in process costs, especially if it is possible to operate with the same throughput using one less chiller. Energy costs will also be reduced as the chiller can be operated for a shorter duration. There are implications for weight loss as well. If chilling is achieved more rapidly, carcasses can be removed from the chiller earlier, reducing the potential for weight loss.

The same reduction in chilling times could be induced by increasing the evaporator fan speed in order to obtain higher air flow rates in the 'critical zone'. However, as the fan power increases by the cube of the air velocity, in order to obtain the equivalent increase in effective air speed (from 0.4 m/s to 1.2 m/s), the amount of fan power needed would increase by a factor of 27. This would lead to a significant increase in chilling costs while also causing excessive moisture loss from carcasses which are subjected to the high velocity air stream close to the walls, as it is unlikely that any significant improvements in air uniformity will occur.

Another benefit from the delta wings is that the installation of spray chilling mechanisms becomes more feasible. Retrofitting simple spraying devices into chillers to reduce weight loss is often financially desirable (Hall, 1975). However, if the chiller has poor air uniformity, the majority of moisture will circulate around the areas of high air flow. This leads to the outside carcasses becoming saturated as they are subjected to most of the moist air, while centre carcasses still tend to dry out as they receive little moisture. A potential problem is that some carcasses register a weight gain while others register a weight loss. With improved air uniformity from the installation of delta wings, this weight variation would be significantly reduced as moisture will be more evenly distributed around the chiller.

Chapter 5

CONCLUSIONS

The importance of air movement in relation to carcass quality, moisture loss, chilling rate and cost of chilling was discussed in Section *2.1* of the *Literature Review*. It was stressed that a "window of compromise" exists were the chilling rate produces an acceptable balance of process costs, product toughness, microbial growth, and product weight loss. In order to be able to control chilling rates within this 'window', uniform air speed distribution over the carcasses is highly desirable so each carcass experiences similar conditions.

The deer carcass chiller chosen for this study was shown to have a poor air distribution while empty and fully loaded. Air speed readings indicated that the bulk of the air was flowing around the walls, floor and ceiling, producing near stagnant conditions in the center of the chiller. This suggested that a large scope existed for the improvement of air uniformity within the chiller.

Air speeds in the full chiller had an overall mean of 1.12 m/s and a standard deviation of 0.564 m/s. Amongst the carcasses the mean air speed was significantly lower at 0.644 m/s with a standard deviation of 0.325 m/s. In the 'critical zone', the mean air speed was only 0.418 m/s. The MIRINZ indicator suggested poor air uniformity as only 84% of the air speed measurements around the carcasses were between ½ and 2 times the mean. Carcass weight loss was also non-uniform across the chiller with the outside carcasses showed relatively high weight losses, whereas, the centre carcasses displayed comparatively lower weight losses. The mean turbulence intensity over the ten positions tested was found to be 22.3%.

With delta wings installed in the first configuration, there was a significant reduction in the flow of air close to the walls, ceiling and floor. As a result of the extra pressure drop from the delta wings, the overall mean air speed decreased slightly to 1.01 m/s but the overall air speed standard deviation also decreased to 0.466 m/s which indicated an improvement in air flow uniformity across the chiller. However, the mean and standard deviation of the air speed amongst the carcasses and the mean air speed in the 'critical zone', remained largely unchanged. This suggested that there had been no significant improvements in air flow and its uniformity around the product. The MIRINZ indicator supported this result as only 82% of the air speed measurements amongst the carcasses were between ½ and 2 times the mean. Trends in the mean carcass weight loss along each rail indicated a slight improvement in the uniformity of moisture loss across the chiller. The mean turbulence intensity over the ten positions tested increased by 5.1% which is equivalent to a mean air speed increase of 0.20 m/s

The second configuration of wings trialed showed further reductions the flow of air around the walls, ceiling and floor. Overall the mean air speed in the chiller decreased slightly to 0.89 m/s. However, the air speed amongst the carcasses was not significantly altered and the air speeds in the 'critical zone' showed an average gain of 0.20 m/s. The standard deviation of the mean air speeds over the whole chiller and amongst the carcasses were dramatically reduced to 0.377 and 0.222 m/s respectively. This pointed to much less variation occurring in air flow. This was confirmed by the MIRINZ indicator, where 95 % of the readings around the product were between ½ and 2 times the mean, which suggests that air flow uniformity is adequate with the second wing configuration. The mean turbulence intensity at the ten positions increased by 14.2 % from the those obtained with no wings present. This equates to an equivalent air speed increase of 0.6 m/s.

Varying wing pitch between 20° and 35° in the characterisation of the empty chiller suggested that the most favourable air flow pattern was obtained with delta wings set at an angle of 35°. However, when delta wings were trialed in the full chiller at 35° they did not perform as well as when they were set at 25°. Therefore, it was concluded that there is no evidence to suggest that the optimum delta wing angle was not 25° as recommended by Amraie (1993).

The delta wing vortex generators have been shown to quantitatively improve the uniformity of the air flow by reducing the velocities close to the walls and floor and increasing the velocities in the centre of the chiller where higher air flow is needed most. They have also been shown to create additional turbulence amongst the carcasses and reduce the variability of weight loss across the chiller. These benefits translate to real savings in power and efficiencies. Increases in the air speed, turbulence and air uniformity amongst the carcasses lead to faster, more even chilling rates. Carcasses can be removed from the chiller earlier, thus reducing the potential for weight loss and saving in energy requirements.

Chapter 6

RECOMMENDATIONS FOR FURTHER WORK

The combinations of parameters used in this study were largely chosen on the basis of previous work carried out by Missenden (1987) and Amraie (1993). However, an almost an infinite number of combinations of the configuration, size, pitch and shape of the delta wings exist. The parameters chosen in this study may not be optimal. The technique of using site measurements to find the best possible set of conditions becomes unfeasible, as new trials would have to be carried out for each change in external conditions. Therefore, other techniques, such computational fluid dynamics (CFD) or scale modelling, must be used to investigate the flow patterns resulting from changes to the delta wing parameters.

The effects of delta wings on the air flow for partial loading of the chiller were not determined. As industrial chillers are often not fully loaded, it is important to characterise the effects of the delta wings while the chiller is in a partially loaded state. Further work needs to be performed in this area.

In order to assess whether the installation of delta wings is economic, a full cost-benefit analysis must first be carried out. Although quantifiable benefits in the operation of chillers have been shown to occur from the installation of delta wings, retrofitting delta wings into existing chillers can be difficult. The installation and production costs of the delta wings must be compared to the savings in energy and efficiency.

A potential problem with the delta wings is the collection of dust and other particulate material on the surface of the wings from the air discharged by the evaporator fans. Although, the delta wings were robust enough to enable cleaning with a high pressure hose, the top surface of the delta wings proved difficult to access.

The appearance of the wings is also a potential problem. The material used in the construction of delta wings was 2mm aluminum sheets. This provided the required rigidity to remain stationary in the fast moving air and lightness for easy installation. However, aluminum quickly tarnishes and appears dirty, thus failing inspection requirements. Therefore, it is recommended that additional work be performed in the investigation of alternative construction materials.

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APPENDIX A

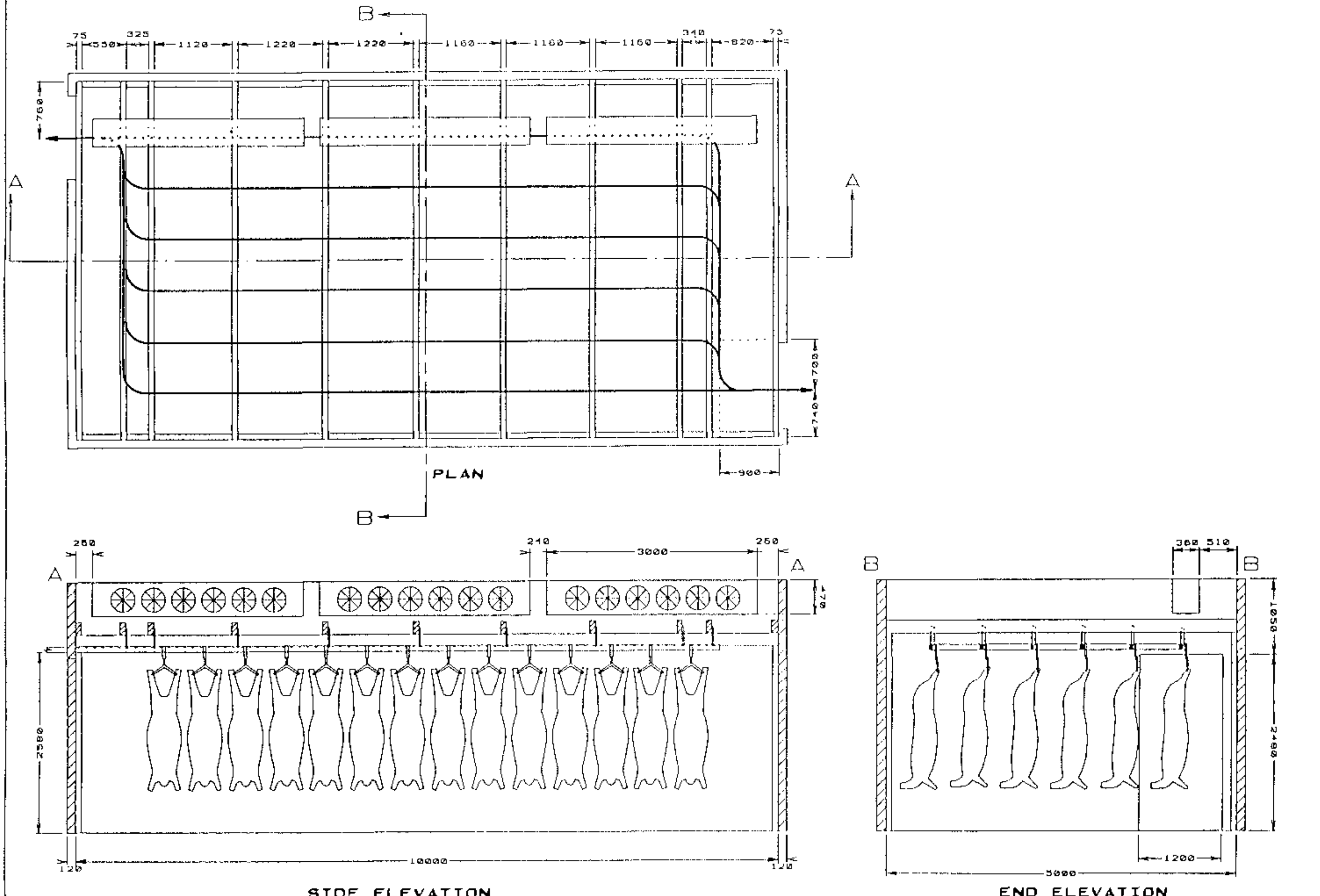

FIGURE A.1	CHILLER No. 4 VENISON PACKERS - FEILDING	SCALE 1:75

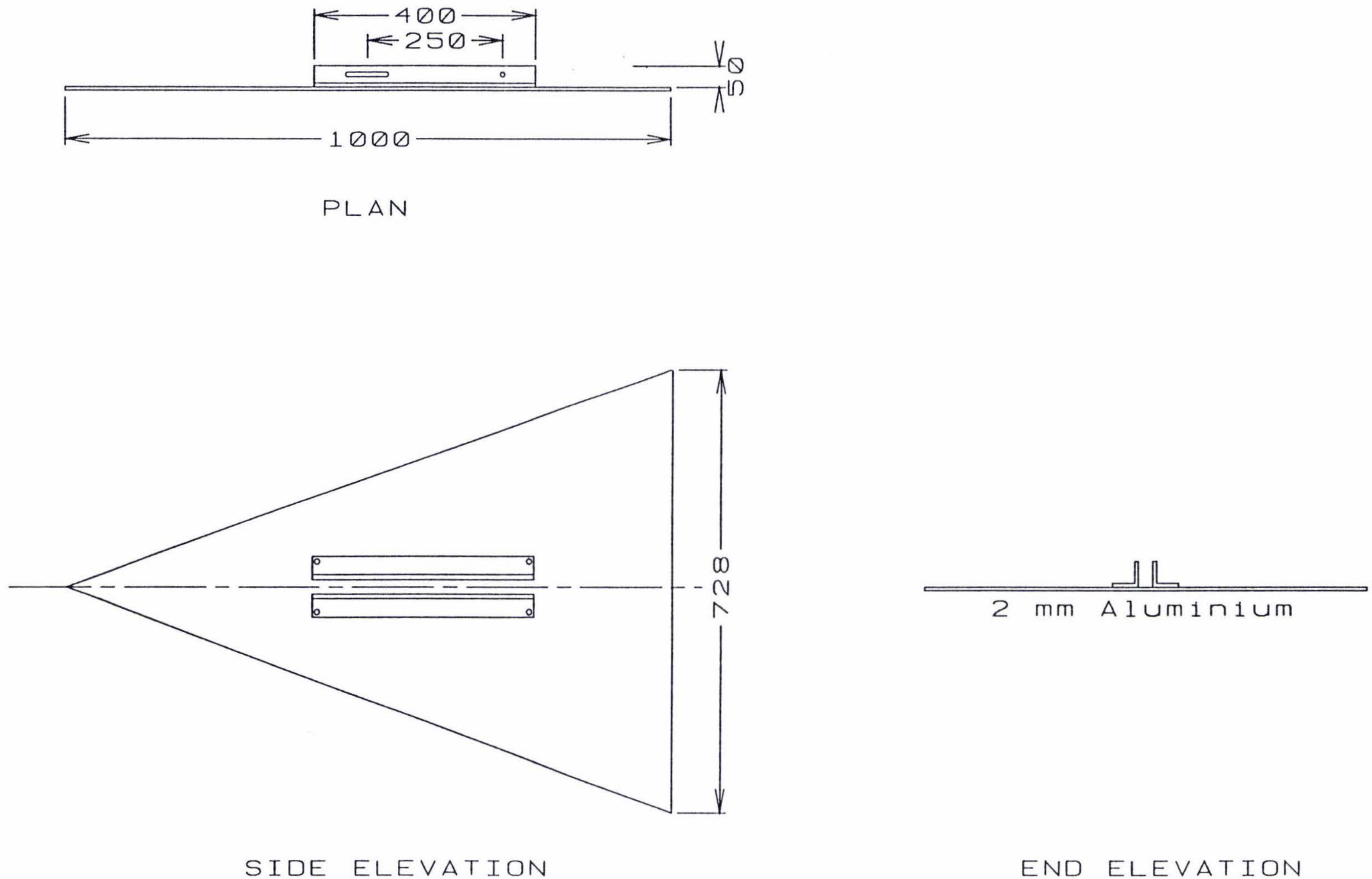

FIGURE A.2 | LARGE DELTA WING | SCALE 1:6

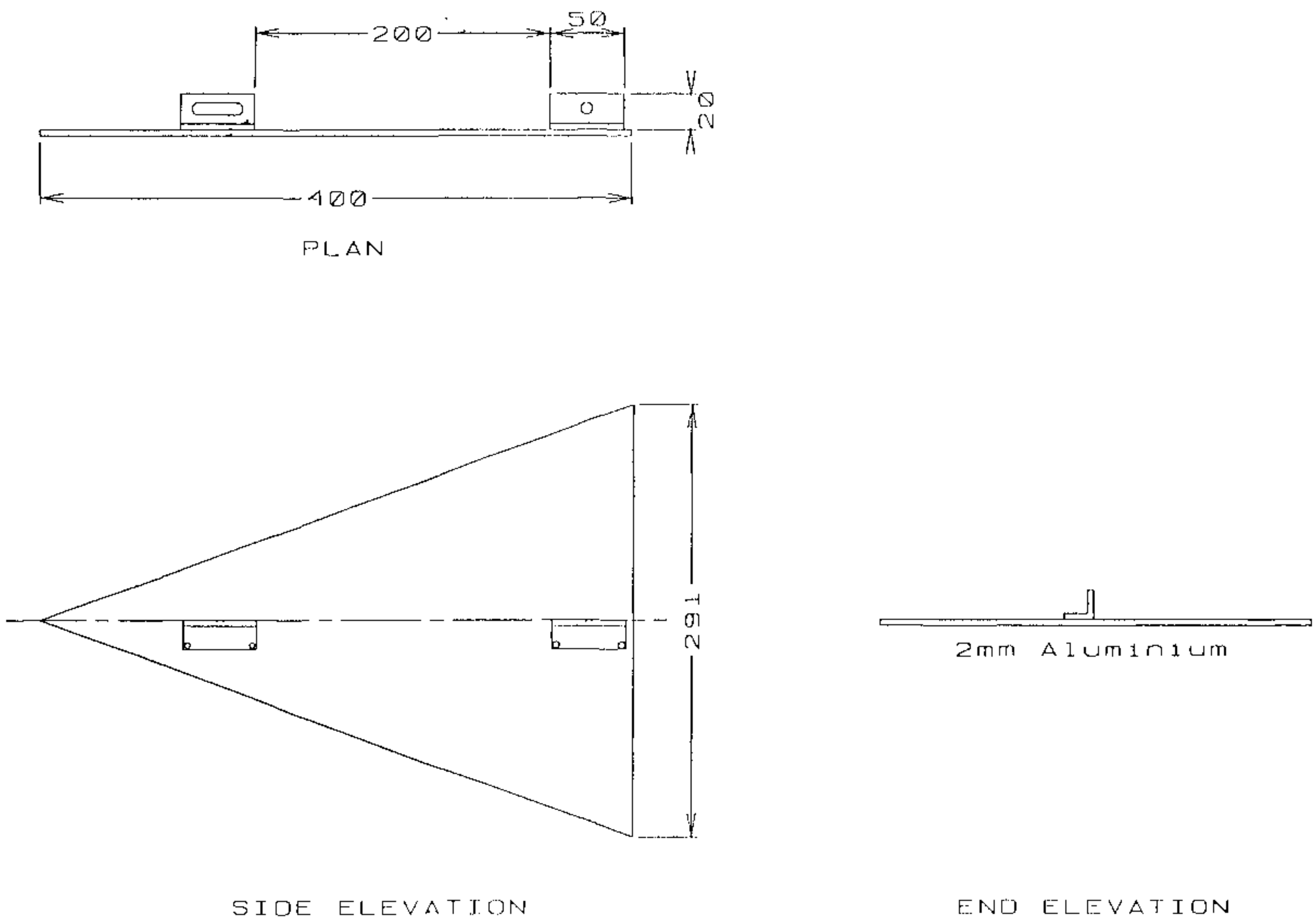

FIGURE A.3	SMALL DELTA WING	SCALE 1:6

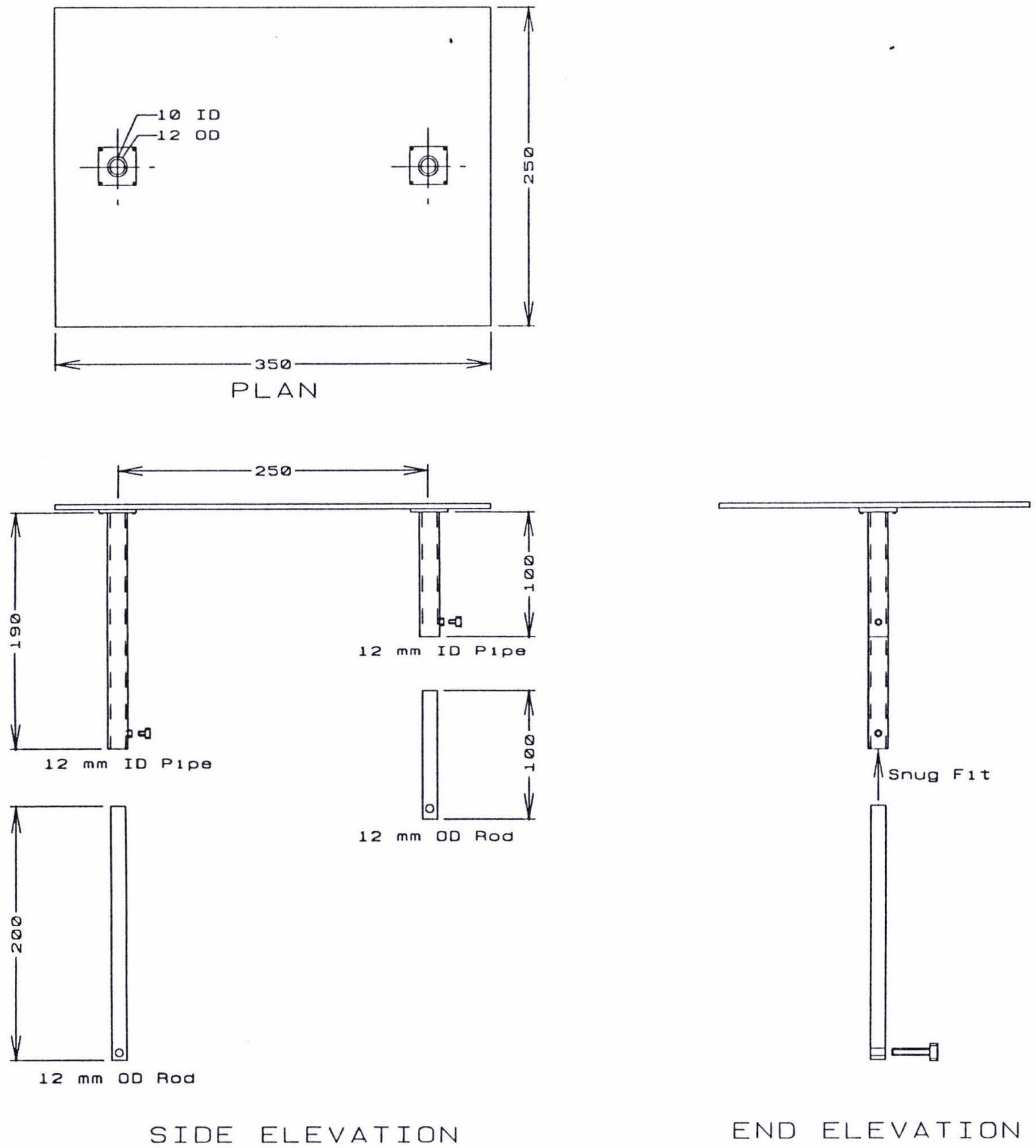

FIGURE A.4	DELTA WING BRACKET	SCALE 1:6

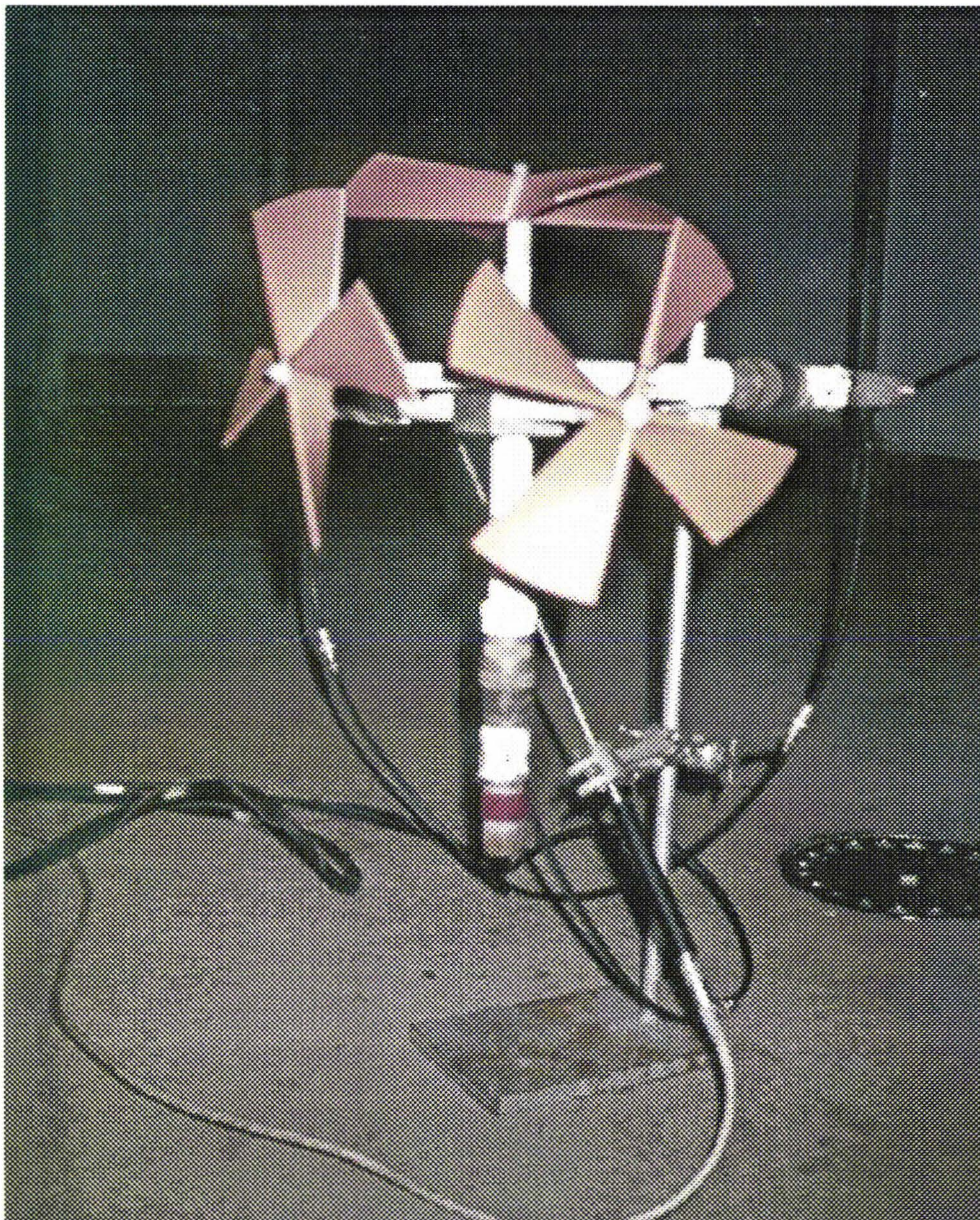

Figure A.5: Orthogonally mounted propeller anemometers and hot-wire

Figure A.6: Variable speed air tunnel

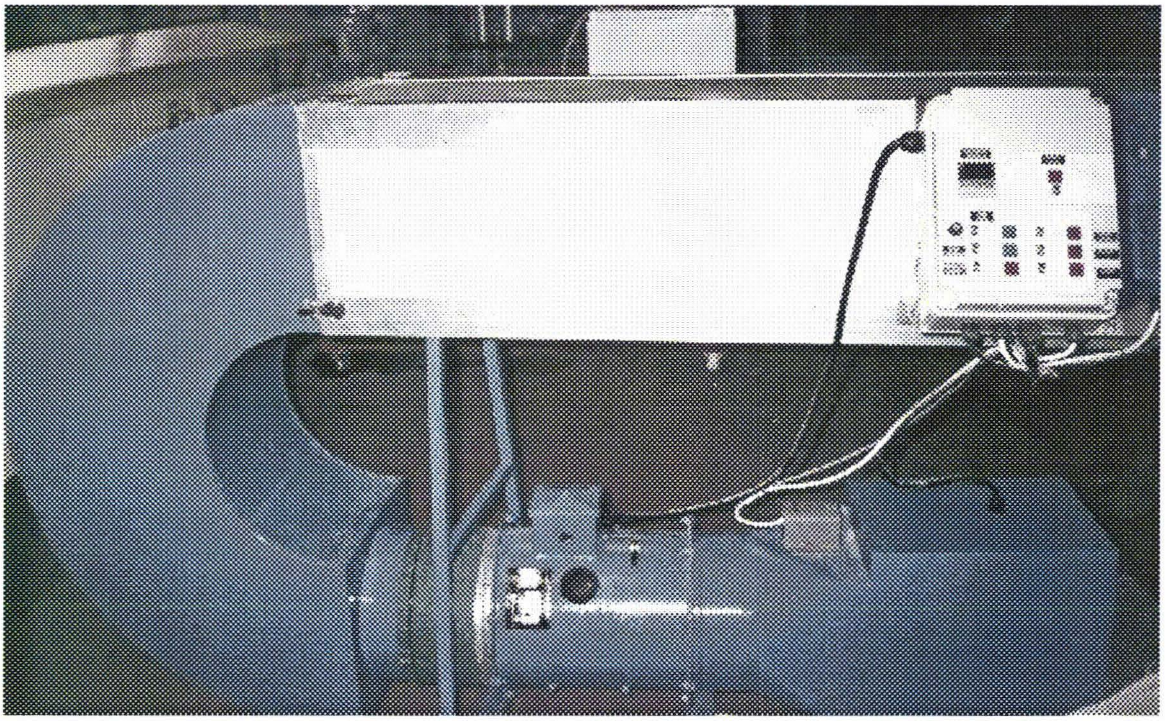

Figure A.7: Variable speed air tunnel

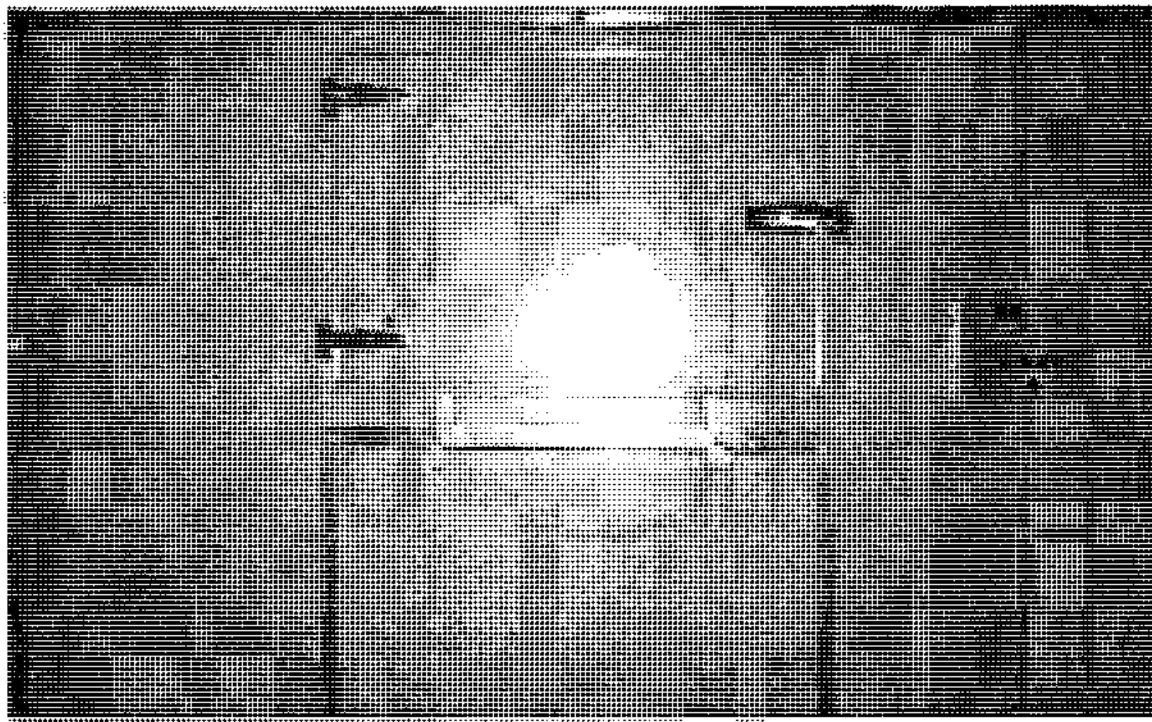
Figure A.8: Blast freezer

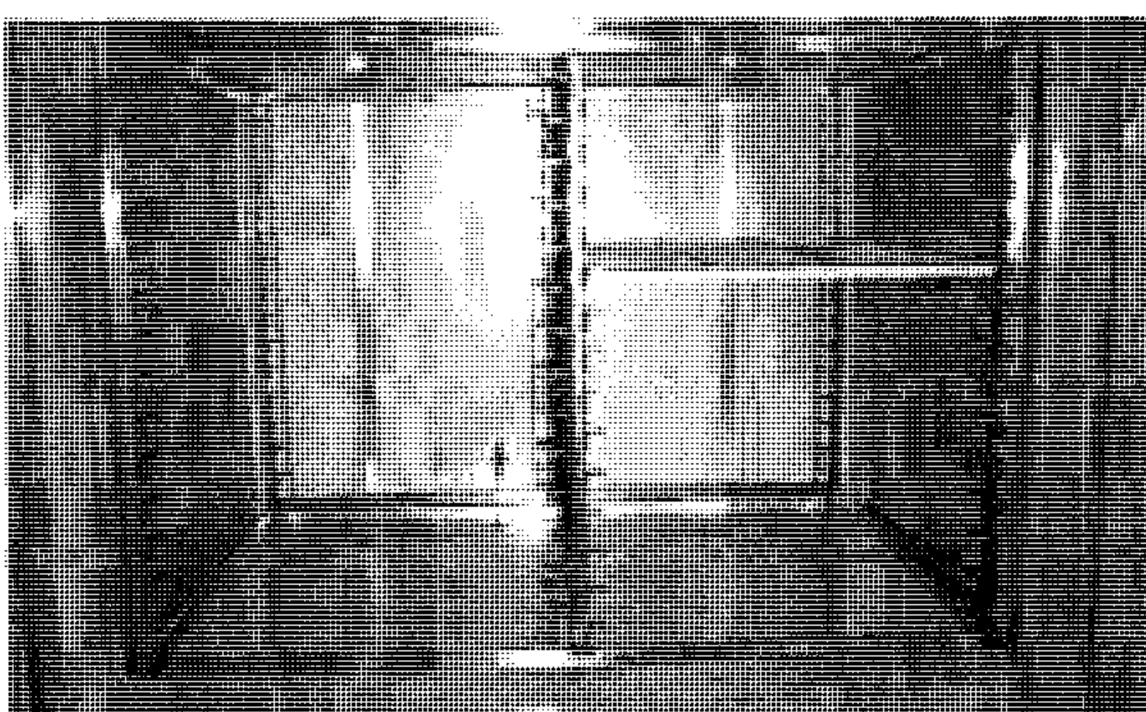
Figure A.9: Blast freezer chamber

Figure A.10: Delta wings

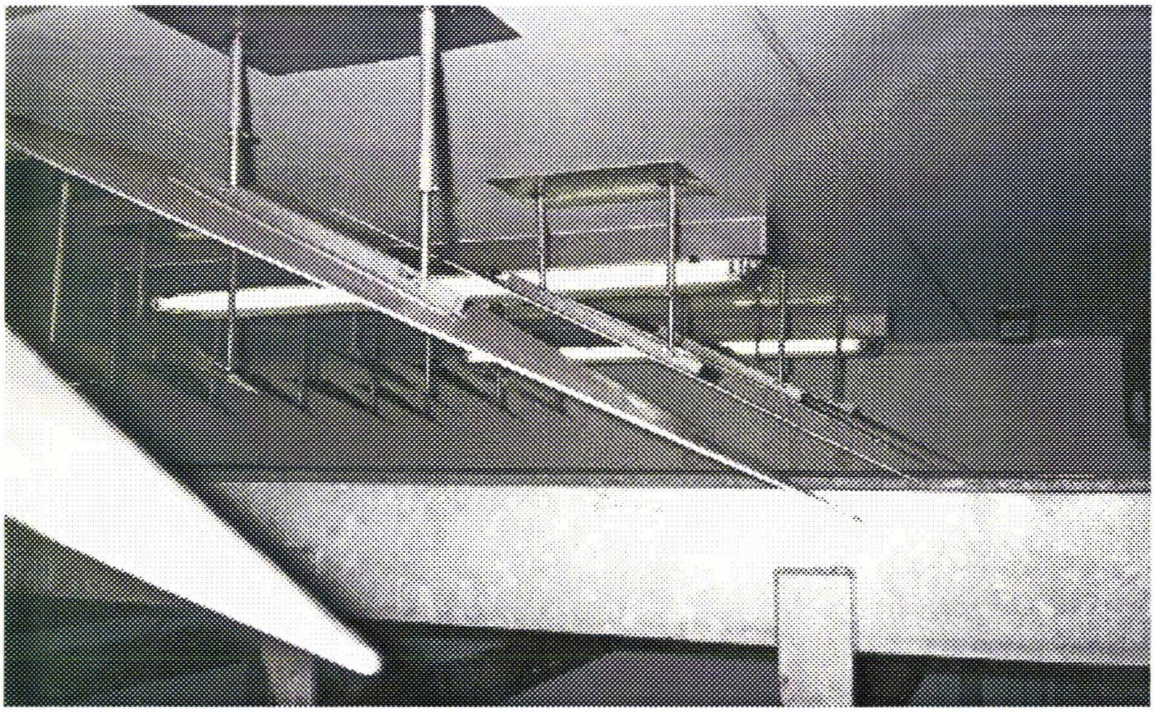

Figure A.11: Delta wings

APPENDIX B

Table B.1: Hot-wire anemometer electronics voltage signal and displayed air speed reading correlation data

Approx. tunnel air speed (m/s)	measurement 1		measurement 2	
	output signal (V)	displayed Reading (m/s)	output signal (V)	displayed Reading (m/s)
0.00	0.000	0.000	0.000	0.000
0.25	0.024	0.250	0.025	0.255
0.50	0.051	0.518	0.048	0.486
0.75	0.073	0.741	0.075	0.760
1.00	0.101	1.02	0.099	1.00
1.50	0.153	1.55	0.154	1.56
2.00	0.201	2.04	0.198	2.01
2.50	0.255	2.59	0.256	2.60
3.00	0.298	3.02	0.297	3.01
4.00	0.406	4.12	0.402	4.08

Note: All readings are integrated measurements over a one minute interval

Table B.2: Interference to hot wire anemometer air speed readings from transducer housing

Time (S)	Angle of rotation of housing (Degrees)						
	0	30	45	60	75	90	180
	Air speed reading (m/s)						
1	1.00	1.01	1.01	0.87	0.58	0.16	0.87
2	0.93	1.01	0.96	0.81	0.64	0.15	0.99
3	0.90	1.01	1.01	0.87	0.61	0.15	0.88
4	1.00	0.96	1.01	0.87	0.59	0.23	0.98
5	1.01	0.93	1.01	0.87	0.65	0.15	0.87
6	0.88	0.89	1.01	0.75	0.58	0.15	0.96
7	1.00	1.01	1.01	0.87	0.59	0.20	0.87
8	0.97	1.01	1.01	0.87	0.60	0.28	1.01
9	1.01	0.95	1.01	0.87	0.61	0.15	1.01
10	1.01	1.01	1.00	0.87	0.58	0.15	1.01
11	0.96	0.99	1.01	0.87	0.62	0.19	0.89
12	0.87	1.01	0.93	0.87	0.67	0.15	0.87
13	0.99	0.95	1.01	0.87	0.60	0.15	1.01
14	1.01	1.01	0.88	0.87	0.62	0.15	0.94
15	0.87	1.01	1.01	0.74	0.59	0.16	0.98
16	0.88	0.87	1.01	0.87	0.64	0.15	1.01
17	1.00	1.01	0.87	0.87	0.66	0.15	1.01
18	0.90	0.90	0.99	0.87	0.59	0.16	1.01
19	0.99	0.99	1.00	0.87	0.65	0.15	1.01
20	0.93	0.99	1.00	0.87	0.67	0.18	0.89

Table B.2: Interference to hot wire anemometer air speed readings from transducer housing (cont.)

Time (S)	Angle of rotation of housing (Degrees)						
	0	30	45	60	75	90	180
	Air speed reading (m/s)						
21	1.00	0.99	1.01	0.82	0.58	0.15	1.00
22	1.01	0.95	0.96	0.87	0.60	0.15	0.98
23	0.98	1.01	1.00	0.87	0.63	0.15	0.97
24	1.01	1.01	0.87	0.87	0.65	0.15	1.01
25	1.01	1.01	0.91	0.87	0.58	0.15	0.87
26	0.96	1.01	0.88	0.87	0.60	0.15	0.87
27	1.01	1.01	1.01	0.86	0.58	0.16	0.91
28	0.87	0.96	1.01	0.87	0.60	0.16	1.01
29	0.88	0.96	1.00	0.73	0.57	0.15	1.01
30	0.95	0.94	0.87	0.87	0.60	0.15	1.01
31	0.87	0.90	0.93	0.87	0.60	0.16	1.01
32	0.96	0.95	0.87	0.87	0.65	0.15	0.95
33	0.90	0.90	1.01	0.87	0.61	0.15	0.92
34	1.01	0.98	1.01	0.87	0.59	0.15	1.01
35	1.01	1.01	1.01	0.87	0.63	0.15	0.97
36	1.01	1.01	1.01	0.87	0.60	0.15	1.01
37	0.98	1.01	0.89	0.87	0.63	0.15	1.01
38	0.95	1.01	1.01	0.84	0.64	0.16	1.01
39	0.88	0.88	1.01	0.87	0.65	0.16	1.00
40	1.00	0.92	0.92	0.87	0.65	0.16	1.01
41	1.01	0.94	1.01	0.87	0.62	0.16	0.89
42	0.95	0.88	0.92	0.87	0.60	0.15	0.87
43	0.88	0.93	1.01	0.87	0.67	0.15	0.93
44	1.01	1.01	0.88	0.87	0.63	0.29	1.01
45	1.01	1.01	1.01	0.84	0.57	0.16	1.01
46	1.01	1.01	1.01	0.87	0.67	0.16	1.01
47	1.01	1.01	1.01	0.81	0.62	0.15	1.01
48	1.00	1.01	1.01	0.87	0.66	0.15	0.93
49	1.01	1.01	1.01	0.87	0.64	0.15	0.89
50	1.01	1.01	0.93	0.87	0.67	0.15	0.87
51	1.01	0.93	1.01	0.86	0.59	0.15	0.98
52	0.90	0.94	1.00	0.87	0.64	0.15	1.01
53	1.01	0.90	0.88	0.87	0.62	0.16	1.01
54	1.01	0.94	0.87	0.87	0.58	0.18	0.87
55	1.01	1.01	0.96	0.87	0.66	0.25	1.01
56	1.01	0.91	0.93	0.87	0.66	0.16	1.00
57	1.01	1.01	0.90	0.82	0.60	0.16	1.01
58	0.87	1.01	0.93	0.86	0.67	0.16	1.00
59	1.00	1.00	0.92	0.87	0.61	0.16	0.87
60	0.95	1.01	0.88	0.86	0.64	0.16	1.01
Avg. (m/s)	0.97	0.98	0.97	0.86	0.62	0.17	0.97
% error	0	1	0	-11	-36	-83	0
Range (m/s)	0.14	0.14	0.14	0.14	0.10	0.14	0.14
Stdev. (m/s)	0.05	0.05	0.05	0.03	0.03	0.03	0.06

Variation in the calculated average air speed with time for hot-wire anemometer at 4 locations in the chiller where the air flow was turbulent and unsteady

Table B.3: Data of air speed and average air speed for 4 positions in the chiller over 5 minutes

Time (s)	Position 1		Position 2		Position 3		Position 4	
	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)
1	2.26	2.26	2.36	2.36	2.36	2.36	0.44	0.44
2	2.16	2.21	2.51	2.43	2.92	2.64	0.31	0.38
3	2.37	2.27	2.31	2.39	2.73	2.67	0.43	0.39
4	2.61	2.35	2.43	2.40	2.93	2.74	0.30	0.37
5	2.30	2.34	2.59	2.44	2.92	2.77	0.44	0.38
6	2.20	2.32	2.33	2.42	2.76	2.77	0.44	0.39
7	1.61	2.22	2.44	2.43	3.11	2.82	0.58	0.42
8	2.48	2.25	2.23	2.40	2.75	2.81	0.54	0.43
9	2.83	2.31	2.09	2.37	2.91	2.82	0.27	0.42
10	2.40	2.32	2.14	2.34	2.60	2.80	0.29	0.40
11	1.48	2.25	2.22	2.33	2.38	2.76	0.16	0.38
12	2.04	2.23	2.22	2.32	2.75	2.76	0.27	0.37
13	2.22	2.23	2.05	2.30	2.77	2.76	0.04	0.35
14	2.70	2.26	2.08	2.29	2.46	2.74	0.24	0.34
15	2.10	2.25	2.19	2.28	2.61	2.73	0.44	0.35
16	2.52	2.27	2.41	2.29	2.65	2.73	0.43	0.35
17	2.34	2.27	2.44	2.30	2.40	2.71	0.30	0.35
18	2.77	2.30	2.23	2.29	2.62	2.70	0.29	0.35
19	2.58	2.31	2.28	2.29	2.55	2.69	0.28	0.34
20	2.33	2.32	2.29	2.29	2.44	2.68	0.15	0.33
21	2.00	2.30	2.03	2.28	2.82	2.69	0.30	0.33
22	2.16	2.29	2.28	2.28	2.65	2.69	0.29	0.33
23	2.33	2.30	2.36	2.28	2.61	2.68	0.29	0.33
24	2.19	2.29	2.35	2.29	2.63	2.68	0.15	0.32
25	2.22	2.29	2.28	2.29	2.54	2.67	0.29	0.32
26	2.11	2.28	2.30	2.29	2.59	2.67	0.15	0.31
27	2.41	2.29	2.31	2.29	2.76	2.67	0.28	0.31
28	2.39	2.29	2.46	2.29	2.30	2.66	0.15	0.31
29	2.54	2.30	2.59	2.31	2.58	2.66	0.29	0.31
30	2.26	2.30	2.51	2.31	2.82	2.66	0.30	0.31
31	2.26	2.30	2.48	2.32	2.83	2.67	0.29	0.31
32	1.46	2.27	2.43	2.32	2.86	2.68	0.56	0.31
33	2.42	2.28	2.70	2.33	2.31	2.66	0.33	0.31
34	2.67	2.29	2.44	2.34	2.69	2.66	0.02	0.31
35	2.38	2.29	2.37	2.34	3.10	2.68	0.02	0.30
36	2.27	2.29	2.43	2.34	2.77	2.68	0.24	0.30
37	1.93	2.28	2.36	2.34	2.68	2.68	0.71	0.31
38	2.57	2.29	2.13	2.33	2.81	2.68	0.70	0.32
39	2.10	2.28	2.41	2.34	2.48	2.68	0.84	0.33
40	2.21	2.28	2.21	2.33	2.80	2.68	0.15	0.33
41	2.00	2.27	2.51	2.34	2.46	2.68	0.25	0.32
42	2.08	2.27	2.17	2.33	2.66	2.68	0.43	0.33
43	1.95	2.26	2.22	2.33	2.82	2.68	0.33	0.33
44	2.46	2.27	2.22	2.33	2.61	2.68	0.49	0.33

Time	Position 1		Position 2		Position 3		Position 4	
(s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)
45	2.10	2.26	2.28	2.33	2.44	2.67	0.20	0.33
46	2.02	2.26	2.25	2.33	2.32	2.66	0.39	0.33
47	1.79	2.25	2.18	2.32	2.85	2.67	0.49	0.33
48	2.38	2.25	2.25	2.32	2.80	2.67	0.29	0.33
49	2.29	2.25	2.43	2.32	2.50	2.67	0.40	0.33
50	2.17	2.25	2.25	2.32	2.29	2.66	0.58	0.34
51	2.35	2.25	2.30	2.32	2.34	2.65	0.71	0.35
52	2.18	2.25	2.53	2.33	2.54	2.65	0.29	0.34
53	2.15	2.25	2.42	2.33	2.65	2.65	0.44	0.35
54	1.89	2.24	2.30	2.33	2.74	2.65	0.32	0.35
55	2.27	2.24	2.49	2.33	2.37	2.65	0.16	0.34
56	2.28	2.24	2.52	2.33	2.52	2.65	0.32	0.34
57	2.14	2.24	2.37	2.33	2.83	2.65	0.15	0.34
58	2.36	2.24	2.37	2.33	2.94	2.65	0.40	0.34
59	2.36	2.24	2.43	2.34	2.63	2.65	0.29	0.34
60	2.25	2.24	2.59	2.34	2.90	2.66	0.29	0.34
61	2.36	2.25	2.51	2.34	2.52	2.66	0.29	0.34
62	2.44	2.25	2.40	2.34	2.74	2.66	0.41	0.34
63	1.92	2.24	2.58	2.35	2.78	2.66	0.15	0.34
64	1.09	2.23	2.16	2.35	2.60	2.66	0.15	0.33
65	1.82	2.22	2.29	2.34	2.61	2.66	0.15	0.33
66	2.48	2.22	2.29	2.34	2.61	2.66	0.43	0.33
67	2.30	2.23	2.29	2.34	2.58	2.65	0.44	0.33
68	1.47	2.21	2.36	2.34	2.49	2.65	0.29	0.33
69	2.24	2.21	2.52	2.35	2.52	2.65	0.29	0.33
70	2.27	2.22	2.29	2.34	2.40	2.65	0.15	0.33
71	1.94	2.21	2.51	2.35	2.53	2.65	0.18	0.33
72	2.48	2.22	2.38	2.35	2.18	2.64	0.44	0.33
73	1.84	2.21	2.36	2.35	2.52	2.64	0.44	0.33
74	2.46	2.21	2.48	2.35	2.94	2.64	0.47	0.33
75	2.24	2.21	2.47	2.35	2.52	2.64	0.29	0.33
76	2.25	2.21	2.43	2.35	2.91	2.64	0.15	0.33
77	2.12	2.21	2.20	2.35	2.78	2.64	0.17	0.33
78	1.94	2.21	2.43	2.35	2.63	2.64	0.47	0.33
79	2.29	2.21	2.30	2.35	2.57	2.64	0.44	0.33
80	1.48	2.20	2.29	2.35	2.56	2.64	0.71	0.34
81	2.58	2.21	2.29	2.35	2.64	2.64	0.44	0.34
82	2.24	2.21	2.55	2.35	2.70	2.64	0.29	0.34
83	2.46	2.21	2.59	2.35	2.61	2.64	0.29	0.34
84	2.28	2.21	2.48	2.36	2.65	2.64	0.29	0.33
85	1.96	2.21	2.13	2.35	2.54	2.64	0.29	0.33
86	2.09	2.21	2.27	2.35	2.82	2.64	0.71	0.34
87	2.16	2.21	2.16	2.35	2.49	2.64	0.56	0.34
88	2.17	2.21	2.46	2.35	2.81	2.64	0.70	0.35
89	2.22	2.21	2.43	2.35	2.79	2.65	0.03	0.34
90	2.50	2.21	2.43	2.35	2.53	2.64	0.25	0.34
91	2.00	2.21	2.30	2.35	2.44	2.64	0.43	0.34
92	2.05	2.20	2.04	2.35	3.21	2.65	0.50	0.34
93	1.50	2.20	2.29	2.35	2.67	2.65	0.18	0.34
94	2.72	2.20	2.15	2.35	3.11	2.65	0.15	0.34

Time	Position 1		Position 2		Position 3		Position 4	
(s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)
95	2.50	2.21	2.18	2.34	2.88	2.66	0.29	0.34
96	2.24	2.21	2.41	2.35	2.39	2.65	0.29	0.34
97	2.19	2.21	2.46	2.35	2.85	2.65	0.36	0.34
98	2.21	2.21	2.30	2.35	2.31	2.65	0.56	0.34
99	2.28	2.21	2.32	2.35	2.46	2.65	0.59	0.34
100	2.15	2.21	2.34	2.35	2.46	2.65	0.29	0.34
101	2.61	2.21	2.32	2.35	2.59	2.65	0.32	0.34
102	2.52	2.21	2.29	2.35	2.41	2.64	0.32	0.34
103	2.37	2.21	2.17	2.34	2.57	2.64	0.46	0.34
104	2.40	2.22	2.29	2.34	2.57	2.64	0.29	0.34
105	2.16	2.22	2.17	2.34	2.84	2.64	0.15	0.34
106	2.38	2.22	2.44	2.34	2.67	2.65	0.02	0.34
107	2.44	2.22	2.20	2.34	2.65	2.65	0.15	0.34
108	2.41	2.22	2.07	2.34	2.86	2.65	0.14	0.33
109	1.95	2.22	2.12	2.34	2.59	2.65	0.21	0.33
110	2.42	2.22	2.30	2.34	2.66	2.65	0.72	0.34
111	2.43	2.22	2.34	2.34	2.63	2.65	0.44	0.34
112	2.17	2.22	2.29	2.34	2.71	2.65	0.43	0.34
113	2.08	2.22	2.28	2.34	2.61	2.65	0.44	0.34
114	2.27	2.22	2.17	2.33	2.53	2.65	0.30	0.34
115	1.74	2.22	2.31	2.33	2.88	2.65	0.29	0.34
116	2.30	2.22	2.50	2.34	2.75	2.65	0.44	0.34
117	2.59	2.22	2.49	2.34	2.79	2.65	0.15	0.34
118	2.10	2.22	2.51	2.34	2.55	2.65	0.14	0.34
119	2.14	2.22	2.44	2.34	2.85	2.65	0.36	0.34
120	2.01	2.22	2.44	2.34	2.31	2.65	0.47	0.34
121	2.27	2.22	2.43	2.34	3.05	2.65	0.29	0.34
122	2.26	2.22	2.38	2.34	2.74	2.65	0.44	0.34
123	2.34	2.22	2.35	2.34	2.49	2.65	0.31	0.34
124	2.57	2.22	2.34	2.34	2.32	2.65	0.29	0.34
125	2.47	2.22	2.21	2.34	3.01	2.65	0.29	0.34
126	2.47	2.23	2.29	2.34	2.48	2.65	0.26	0.34
127	2.18	2.23	2.46	2.34	2.74	2.65	0.30	0.34
128	2.37	2.23	2.57	2.34	2.65	2.65	0.28	0.34
129	2.59	2.23	2.16	2.34	2.58	2.65	0.44	0.34
130	2.66	2.23	2.19	2.34	2.83	2.65	0.52	0.34
131	2.14	2.23	2.15	2.34	2.53	2.65	0.36	0.34
132	2.46	2.23	2.29	2.34	2.47	2.65	0.21	0.34
133	2.28	2.23	2.05	2.34	2.68	2.65	0.15	0.34
134	2.14	2.23	2.32	2.34	2.61	2.65	0.28	0.34
135	2.02	2.23	2.29	2.34	2.46	2.65	0.51	0.34
136	2.25	2.23	2.37	2.34	2.77	2.65	0.36	0.34
137	2.19	2.23	2.57	2.34	2.66	2.65	0.44	0.34
138	2.33	2.23	2.46	2.34	2.60	2.65	0.17	0.34
139	2.06	2.23	2.26	2.34	2.75	2.65	0.02	0.33
140	2.16	2.23	2.03	2.34	2.76	2.65	0.14	0.33
141	2.32	2.23	2.36	2.34	2.98	2.65	0.02	0.33
142	2.44	2.23	2.55	2.34	2.50	2.65	0.28	0.33
143	2.57	2.24	2.27	2.34	2.46	2.65	0.38	0.33
144	2.57	2.24	2.37	2.34	2.72	2.65	0.29	0.33

Time	Position 1		Position 2		Position 3		Position 4	
(s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)
145	2.59	2.24	2.23	2.34	2.66	2.65	0.15	0.33
146	2.58	2.24	2.37	2.34	2.93	2.65	0.15	0.33
147	2.31	2.24	2.19	2.34	2.56	2.65	0.20	0.33
148	2.21	2.24	2.43	2.34	2.43	2.65	0.15	0.33
149	2.34	2.24	2.44	2.34	2.63	2.65	0.15	0.32
150	2.42	2.24	2.48	2.34	2.62	2.65	0.02	0.32
151	2.30	2.25	2.36	2.34	2.60	2.65	0.15	0.32
152	1.77	2.24	2.20	2.34	2.54	2.65	0.15	0.32
153	2.54	2.24	2.39	2.34	2.88	2.65	0.14	0.32
154	2.46	2.25	2.33	2.34	2.49	2.65	0.04	0.32
155	2.30	2.25	2.41	2.34	2.60	2.65	0.15	0.32
156	2.50	2.25	2.34	2.34	2.50	2.65	0.02	0.31
157	2.69	2.25	2.51	2.34	2.39	2.65	0.27	0.31
158	2.46	2.25	2.55	2.34	2.72	2.65	0.20	0.31
159	2.44	2.25	2.48	2.34	2.65	2.65	0.15	0.31
160	2.34	2.25	2.40	2.34	2.70	2.65	0.38	0.31
161	2.28	2.25	2.33	2.34	2.58	2.65	0.33	0.31
162	2.28	2.25	2.53	2.34	2.22	2.64	0.66	0.32
163	2.32	2.25	2.30	2.34	2.51	2.64	0.30	0.32
164	2.37	2.25	2.29	2.34	2.54	2.64	0.15	0.31
165	2.52	2.26	2.09	2.34	2.60	2.64	0.04	0.31
166	2.47	2.26	2.12	2.34	2.66	2.64	0.24	0.31
167	2.38	2.26	2.42	2.34	2.91	2.64	0.45	0.31
168	2.32	2.26	2.47	2.34	2.70	2.64	0.29	0.31
169	1.74	2.26	2.37	2.34	2.48	2.64	0.29	0.31
170	2.00	2.25	2.47	2.34	2.61	2.64	0.33	0.31
171	2.20	2.25	2.29	2.34	2.55	2.64	0.29	0.31
172	2.49	2.26	2.29	2.34	2.67	2.64	0.17	0.31
173	2.20	2.25	2.37	2.34	2.46	2.64	0.28	0.31
174	2.18	2.25	2.33	2.34	2.58	2.64	0.43	0.31
175	1.67	2.25	2.37	2.34	2.42	2.64	0.31	0.31
176	2.37	2.25	2.59	2.34	2.64	2.64	0.28	0.31
177	2.60	2.25	2.26	2.34	2.78	2.64	0.29	0.31
178	2.58	2.26	2.21	2.34	2.89	2.64	0.15	0.31
179	2.52	2.26	2.43	2.34	2.76	2.64	0.32	0.31
180	2.42	2.26	2.29	2.34	2.51	2.64	0.29	0.31
181	2.68	2.26	2.34	2.34	2.70	2.64	0.53	0.31
182	2.89	2.26	2.43	2.34	2.73	2.64	0.44	0.31
183	2.56	2.27	2.41	2.34	2.76	2.64	0.46	0.31
184	2.57	2.27	2.39	2.34	2.82	2.64	0.44	0.31
185	2.43	2.27	2.47	2.34	2.82	2.64	0.16	0.31
186	2.34	2.27	2.51	2.34	2.65	2.64	0.29	0.31
187	2.36	2.27	2.44	2.34	2.67	2.64	0.15	0.31
188	2.49	2.27	2.59	2.35	2.72	2.65	0.15	0.31
189	2.43	2.27	2.44	2.35	2.96	2.65	0.02	0.31
190	2.26	2.27	2.46	2.35	2.88	2.65	0.14	0.31
191	2.34	2.27	2.44	2.35	2.76	2.65	0.26	0.31
192	2.28	2.27	2.59	2.35	2.60	2.65	0.60	0.31
193	2.78	2.27	2.43	2.35	2.32	2.65	0.69	0.31
194	2.19	2.27	2.46	2.35	2.59	2.65	0.44	0.31

Time (s)	Position 1 Air speed (m/s)	Average air speed (m/s)	Position 2 Air speed (m/s)	Average air speed (m/s)	Position 3 Air speed (m/s)	Average air speed (m/s)	Position 4 Air speed (m/s)	Average air speed (m/s)
195	2.08	2.27	2.21	2.35	2.65	2.65	0.15	0.31
196	2.59	2.27	2.41	2.35	2.52	2.65	0.15	0.31
197	2.55	2.28	2.36	2.35	2.93	2.65	0.11	0.31
198	2.25	2.28	2.36	2.35	2.59	2.65	0.40	0.31
199	2.24	2.28	2.52	2.35	2.68	2.65	0.44	0.31
200	2.50	2.28	2.34	2.35	2.58	2.65	0.06	0.31
201	2.29	2.28	2.23	2.35	2.59	2.65	0.15	0.31
202	2.39	2.28	2.66	2.35	2.58	2.65	0.25	0.31
203	2.74	2.28	2.44	2.35	2.72	2.65	0.29	0.31
204	2.49	2.28	2.30	2.35	2.74	2.65	0.15	0.31
205	2.17	2.28	2.20	2.35	2.91	2.65	0.27	0.31
206	2.26	2.28	2.03	2.35	2.43	2.65	0.24	0.31
207	2.50	2.28	2.17	2.35	2.71	2.65	0.15	0.31
208	2.40	2.28	2.51	2.35	2.43	2.65	0.14	0.31
209	2.64	2.28	2.29	2.35	2.72	2.65	0.15	0.31
210	2.54	2.28	2.53	2.35	2.86	2.65	0.29	0.31
211	2.23	2.28	2.35	2.35	2.57	2.65	0.57	0.31
212	2.58	2.29	2.42	2.35	2.67	2.65	0.63	0.31
213	2.12	2.28	2.33	2.35	2.74	2.65	0.44	0.31
214	2.35	2.28	2.21	2.35	2.67	2.65	0.24	0.31
215	2.41	2.29	2.57	2.35	2.48	2.65	0.15	0.31
216	2.20	2.28	2.44	2.35	2.36	2.65	0.20	0.31
217	2.29	2.29	2.55	2.35	2.92	2.65	0.23	0.31
218	2.49	2.29	2.47	2.35	2.98	2.65	0.15	0.31
219	2.36	2.29	2.58	2.35	2.58	2.65	0.15	0.31
220	2.19	2.29	2.47	2.35	2.48	2.65	0.27	0.31
221	1.94	2.28	2.31	2.35	2.92	2.65	0.29	0.31
222	2.37	2.28	2.02	2.35	2.52	2.65	0.29	0.31
223	2.44	2.29	2.16	2.35	3.03	2.65	0.29	0.31
224	2.29	2.29	2.05	2.35	2.61	2.65	0.15	0.30
225	2.60	2.29	2.29	2.35	2.80	2.65	0.36	0.31
226	2.28	2.29	2.55	2.35	2.32	2.65	0.77	0.31
227	1.95	2.29	2.44	2.35	2.91	2.65	0.44	0.31
228	2.37	2.29	2.56	2.35	2.67	2.65	0.56	0.31
229	2.37	2.29	2.31	2.35	2.53	2.65	0.44	0.31
230	2.87	2.29	2.33	2.35	2.69	2.65	0.72	0.31
231	2.46	2.29	2.29	2.35	3.01	2.65	0.53	0.31
232	2.57	2.29	2.16	2.35	2.39	2.65	0.41	0.31
233	2.47	2.29	2.29	2.35	2.76	2.65	0.38	0.31
234	2.06	2.29	2.42	2.35	2.51	2.65	0.15	0.31
235	2.29	2.29	2.54	2.35	2.66	2.65	0.15	0.31
236	2.25	2.29	2.34	2.35	2.67	2.65	0.29	0.31
237	2.43	2.29	2.66	2.35	2.27	2.65	0.43	0.31
238	2.06	2.29	2.58	2.35	2.37	2.65	0.17	0.31
239	1.47	2.29	2.29	2.35	2.59	2.65	0.28	0.31
240	2.28	2.29	2.28	2.35	2.47	2.65	0.15	0.31
241	2.28	2.29	2.70	2.35	3.12	2.65	0.29	0.31
242	2.16	2.29	2.57	2.36	2.52	2.65	0.41	0.31
243	1.85	2.28	2.29	2.36	2.65	2.65	0.64	0.31
244	1.51	2.28	2.39	2.36	2.58	2.65	0.58	0.31

Time	Position 1		Position 2		Position 3		Position 4	
(s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)
245	2.54	2.28	2.52	2.36	2.44	2.65	0.29	0.31
246	2.89	2.28	2.31	2.36	2.53	2.65	0.15	0.31
247	2.32	2.28	2.17	2.36	2.56	2.65	0.14	0.31
248	2.29	2.28	2.12	2.35	2.18	2.64	0.15	0.31
249	2.32	2.28	2.12	2.35	2.46	2.64	0.15	0.31
250	2.05	2.28	2.32	2.35	2.98	2.64	0.68	0.31
251	2.06	2.28	2.43	2.35	2.94	2.65	0.57	0.31
252	1.90	2.28	2.30	2.35	2.70	2.65	0.37	0.31
253	2.18	2.28	2.29	2.35	2.44	2.65	0.30	0.31
254	2.09	2.28	2.26	2.35	2.98	2.65	0.28	0.31
255	2.10	2.28	2.29	2.35	2.84	2.65	0.15	0.31
256	2.35	2.28	2.57	2.35	2.75	2.65	0.15	0.31
257	2.46	2.28	2.43	2.35	2.50	2.65	0.30	0.31
258	2.07	2.28	2.29	2.35	2.58	2.65	0.32	0.31
259	2.05	2.28	2.47	2.35	2.75	2.65	0.37	0.31
260	2.07	2.28	2.26	2.35	2.73	2.65	0.38	0.31
261	2.32	2.28	2.41	2.35	2.48	2.65	0.51	0.31
262	2.64	2.28	2.43	2.35	2.59	2.65	0.29	0.31
263	2.57	2.28	2.40	2.35	2.60	2.65	0.28	0.31
264	2.83	2.28	2.43	2.35	2.59	2.65	0.15	0.31
265	2.59	2.28	2.49	2.35	2.44	2.65	0.11	0.31
266	2.33	2.28	2.40	2.36	2.70	2.65	0.29	0.31
267	2.25	2.28	2.16	2.35	2.55	2.65	0.15	0.31
268	2.27	2.28	2.21	2.35	2.48	2.64	0.26	0.31
269	2.24	2.28	2.66	2.35	2.61	2.64	0.29	0.31
270	2.30	2.28	2.48	2.36	2.60	2.64	0.44	0.31
271	2.21	2.28	2.42	2.36	2.76	2.64	0.44	0.31
272	1.82	2.28	2.47	2.36	2.70	2.65	0.20	0.31
273	2.03	2.28	2.32	2.36	2.59	2.64	0.15	0.31
274	2.42	2.28	2.44	2.36	2.83	2.65	0.17	0.31
275	2.32	2.28	2.27	2.36	2.72	2.65	0.43	0.31
276	1.94	2.28	2.29	2.36	2.91	2.65	0.66	0.31
277	2.64	2.28	2.29	2.36	2.58	2.65	1.01	0.31
278	2.35	2.28	2.32	2.36	2.63	2.65	0.30	0.31
279	2.59	2.28	2.39	2.36	2.88	2.65	0.43	0.31
280	2.61	2.28	2.49	2.36	2.60	2.65	0.15	0.31
281	2.32	2.28	2.48	2.36	3.06	2.65	0.29	0.31
282	2.48	2.28	2.51	2.36	3.06	2.65	0.28	0.31
283	2.05	2.28	2.44	2.36	2.84	2.65	0.15	0.31
284	2.01	2.28	2.27	2.36	2.64	2.65	0.15	0.31
285	2.49	2.28	2.29	2.36	2.69	2.65	0.14	0.31
286	2.52	2.28	2.10	2.36	2.40	2.65	0.15	0.31
287	2.18	2.28	2.16	2.36	2.62	2.65	0.15	0.31
288	2.64	2.29	2.30	2.36	2.55	2.65	0.03	0.31
289	2.03	2.28	2.16	2.35	2.62	2.65	0.15	0.31
290	1.94	2.28	2.18	2.35	2.72	2.65	0.29	0.31
291	2.56	2.28	2.29	2.35	2.87	2.65	0.15	0.31
292	2.15	2.28	2.25	2.35	2.78	2.65	0.15	0.31
293	2.27	2.28	2.20	2.35	2.67	2.65	0.57	0.31
294	2.67	2.29	2.42	2.35	2.64	2.65	0.44	0.31

Time (s)	Position 1		Position 2		Position 3		Position 4	
	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)	Air speed (m/s)	Average air speed (m/s)
295	2.29	2.29	2.17	2.35	2.63	2.65	0.69	0.31
296	2.34	2.29	2.34	2.35	2.57	2.65	0.91	0.31
297	1.35	2.28	2.28	2.35	2.59	2.65	0.43	0.31
298	2.34	2.28	2.29	2.35	2.89	2.65	0.16	0.31
299	2.27	2.28	2.58	2.35	2.44	2.65	0.24	0.31
300	2.30	2.28	2.33	2.35	2.52	2.65	0.29	0.31

Variation in the calculated average air speed, range and standard deviation with time for hot-wire anemometer at 4 locations in the chiller where the air flow was turbulent and unsteady

Table B.4: Position 1 - Center of chiller - 0.5 meters vertical height

Time (sec)	Avg. Vel. (m/s)	error (m/s)	min. (m/s)	max. (m/s)	Range (m/s)	error (m/s)	stdev (m/s)	error (m/s)
10	2.323	0.041	1.613	2.830	1.217	-0.588	0.320	0.050
30	2.298	0.015	1.481	2.830	1.349	-0.456	0.291	0.021
60	2.245	-0.038	1.461	2.830	1.369	-0.436	0.271	0.001
120	2.218	-0.065	1.085	2.830	1.745	-0.061	0.289	0.019
180	2.258	-0.025	1.085	2.830	1.745	-0.061	0.271	0.001
240	2.286	0.004	1.085	2.891	1.806	0.000	0.266	-0.004
300	2.282	0.000	1.085	2.891	1.806	0.000	0.270	0.000

Table B.5: Position 2 - Chiller wall - 1.5 meters vertical height

Time (sec)	Avg. Vel. (m/s)	error (m/s)	min. (m/s)	max. (m/s)	Range (m/s)	error (m/s)	stdev (m/s)	error (m/s)
10	2.344	-0.008	2.090	2.587	0.497	-0.183	0.158	0.020
30	2.311	-0.041	2.029	2.587	0.558	-0.122	0.149	0.011
60	2.340	-0.012	2.029	2.698	0.670	-0.010	0.144	0.006
120	2.339	-0.013	2.029	2.698	0.670	-0.010	0.137	0.000
180	2.341	-0.011	2.029	2.698	0.670	-0.010	0.134	-0.004
240	2.353	0.001	2.019	2.698	0.680	0.000	0.139	0.001
300	2.352	0.000	2.019	2.698	0.680	0.000	0.138	0.000

Table B.6: Position 3 - Chiller wall - 1.0 meters vertical height

Time (sec)	Avg. Vel. (m/s)	error (m/s)	min. (m/s)	max. (m/s)	Range (m/s)	error (m/s)	stdev (m/s)	error (m/s)
10	2.800	0.150	2.364	3.114	0.751	-0.274	0.211	0.026
30	2.663	0.014	2.303	3.114	0.812	-0.213	0.193	0.009
60	2.657	0.007	2.293	3.114	0.822	-0.203	0.202	0.017
120	2.648	-0.002	2.181	3.206	1.025	0.000	0.194	0.010
180	2.641	-0.009	2.181	3.206	1.025	0.000	0.186	0.001
240	2.646	-0.003	2.181	3.206	1.025	0.000	0.185	0.001
300	2.650	0.000	2.181	3.206	1.025	0.000	0.184	0.000

Table B.7: Position 4 - Center of chiller - 2.0 meters vertical height

Time (sec)	Avg. Vel. (m/s)	error (m/s)	min. (m/s)	max. (m/s)	Range (m/s)	error (m/s)	stdev (m/s)	error (m/s)
10	0.404	0.091	0.274	0.578	0.304	-0.690	0.105	-0.066
30	0.306	-0.007	0.041	0.578	0.538	-0.456	0.120	-0.050
60	0.338	0.025	0.020	0.842	0.822	-0.172	0.166	-0.004
120	0.338	0.025	0.020	0.842	0.822	-0.172	0.165	-0.005
180	0.311	-0.001	0.020	0.842	0.822	-0.172	0.159	-0.011
240	0.311	-0.002	0.020	0.842	0.822	-0.172	0.163	-0.008
300	0.313	0.000	0.020	1.014	0.994	0.000	0.170	0.000

Table B.8: Absolute error averages (runs 1-4)

Time (sec)	Maximum Mean Error (m/s)	Maximum Range Error (m/s)	Maximum stdev. Error (m/s)
10	0.150	0.690	0.066
30	0.041	0.456	0.050
60	0.038	0.436	0.017
120	0.065	0.172	0.019
180	0.025	0.172	0.011
240	0.004	0.172	0.008
300	0.000	0.000	0.000

Variation in the measured average, range and standard deviation of the air speed taken over a 1 minute interval at 4 locations in the chiller where the air flow was turbulent and unsteady

Table B.9

		Position 1			Position 2	
	Avg. (m/s)	Range (m/s)	Stdev. (m/s)	Avg. (m/s)	Range (m/s)	Stdev. (m/s)
Reading 1	2.245	1.370	0.271	2.341	0.670	0.144
Reading 2	2.191	1.633	0.305	2.339	0.548	0.132
Reading 3	2.334	1.015	0.211	2.347	0.558	0.129
Reading 4	2.372	1.420	0.237	2.390	0.639	0.153
Reading 5	2.271	1.481	0.290	2.364	0.599	0.134
Spread	0.182	0.619	0.094	0.051	0.122	0.024

Table B.10

		Position 3			Position 4	
	Avg. (m/s)	Range (m/s)	Stdev. (m/s)	Avg. (m/s)	Range (m/s)	Stdev. (m/s)
Reading 1	2.657	0.822	0.202	0.338	0.822	0.166
Reading 2	2.638	1.025	0.188	0.338	0.700	0.166
Reading 3	2.628	0.832	0.169	0.260	0.639	0.133
Reading 4	2.663	0.761	0.188	0.318	0.751	0.175
Reading 5	2.669	0.720	0.162	0.327	0.984	0.205
Spread	0.040	0.304	0.040	0.078	0.345	0.072

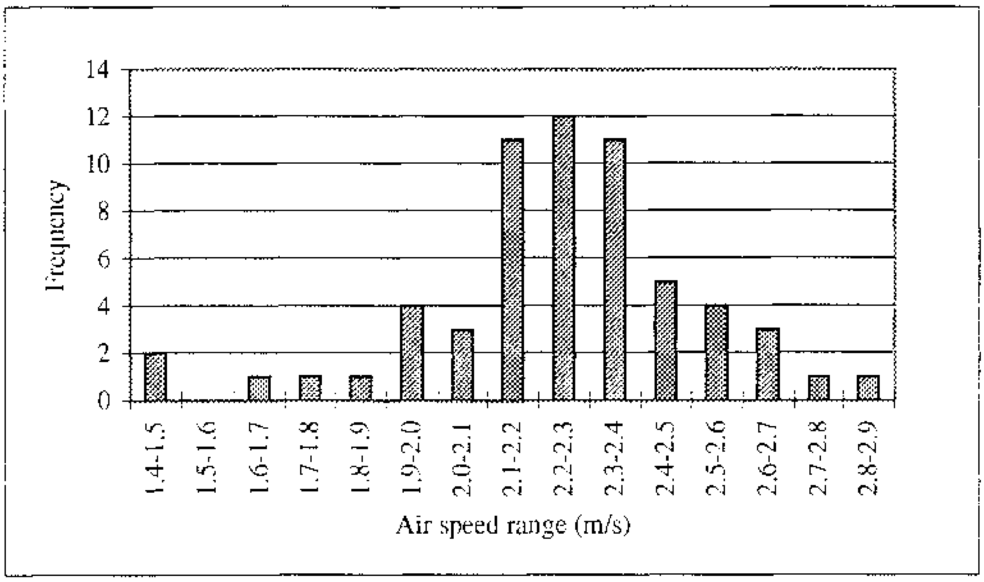

Figure B.1: Distribution of data values taken over a 1 minute period
Measurement 1

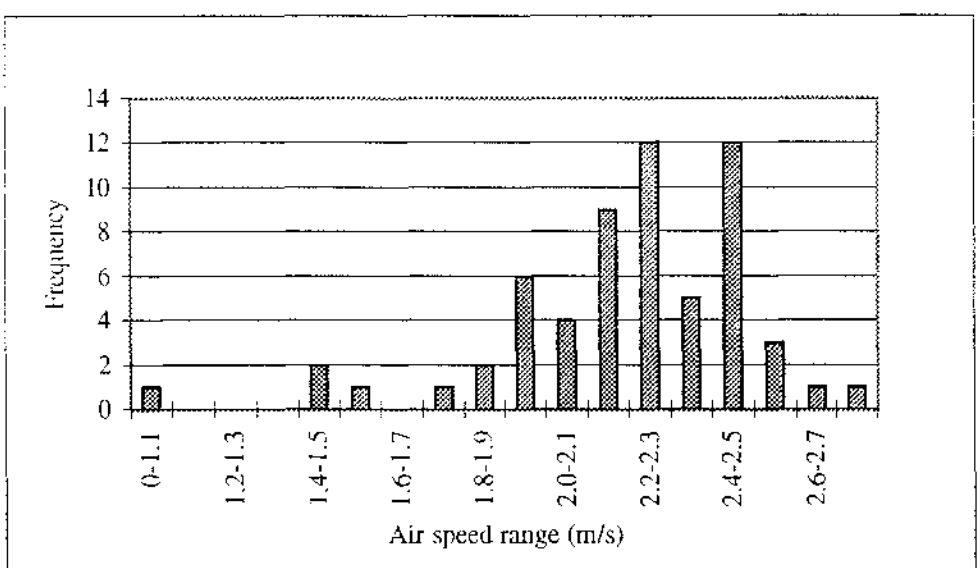

Figure B.2: Distribution of data values taken over a 1 minute period
Measurement 2

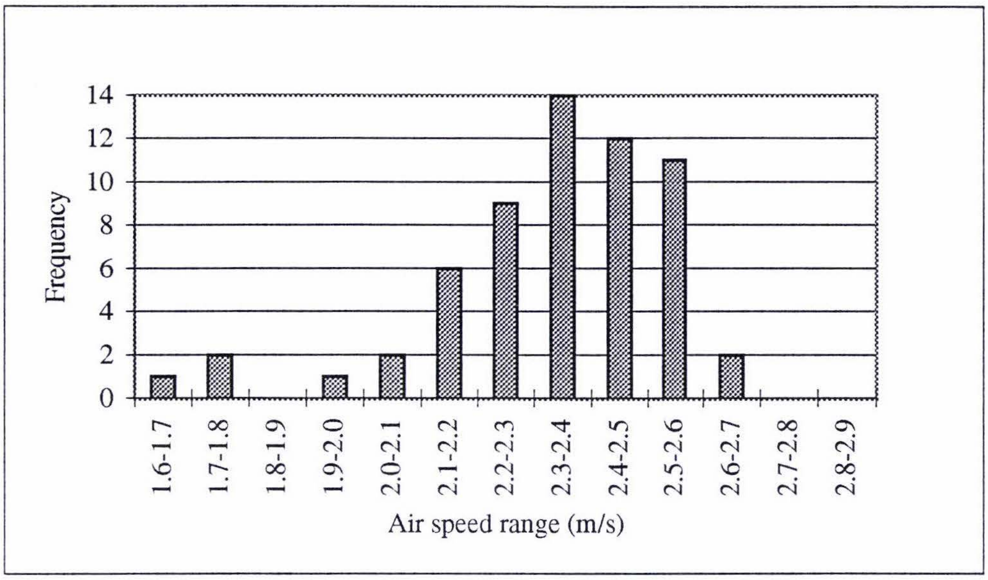

Figure B.3: Distribution of data values taken over a 1 minute period
Measurement 3

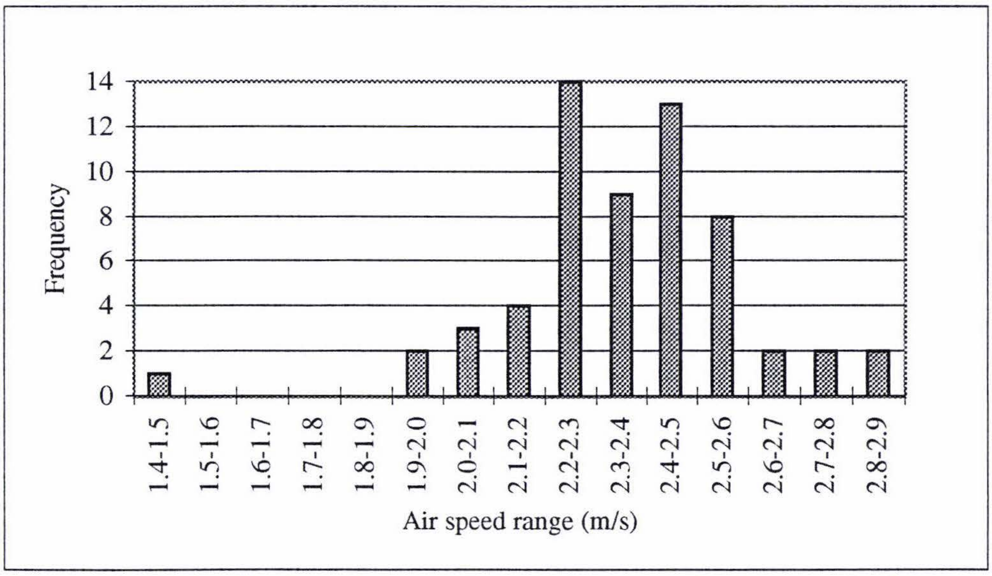

Figure B.4: Distribution of data values taken over a 1 minute period
Measurement 4

Air speed data to investigate whether steady state conditions are obtained before each measurement

Table B.11: Data of air speed during the 4 phases in measurement taking

measurement 1		measurement 2		measurement 3		measurement 4		measurement 5	
Time (s)	Air speed (m/s)	Time (s)	Air speed (m/s)	Time (s)	Air speed (m/s)	Time (s)	Air speed (m/s)	Time (s)	Air speed (m/s)
1	0.44	121	0.99	241	1.88	361	0.48	481	1.27
2	0.94	122	0.99	242	1.99	362	0.52	482	0.19
3	0.24	123	0.99	243	1.98	363	0.56	483	1.26
4	0.78	124	0.99	244	1.79	364	0.67	484	0.69
5	0.59	125	1.03	245	2.00	365	0.61	485	0.84
6	0.69	126	1.01	246	1.82	366	0.60	486	0.17
7	0.44	127	1.10	247	1.92	367	0.38	487	0.15
8	0.14	128	0.99	248	1.82	368	0.63	488	1.10
9	0.93	129	1.02	249	1.75	369	0.63	489	1.65
10	0.38	130	1.11	250	1.99	370	0.60	490	0.76
11	0.79	131	1.00	251	2.27	371	0.53	491	0.15
12	0.55	132	1.07	252	2.17	372	0.56	492	1.72
13	0.24	133	1.07	253	2.00	373	0.59	493	0.67
14	0.76	134	0.99	254	1.92	374	0.70	494	0.74
15	0.39	135	1.00	255	1.72	375	0.64	495	0.41
16	0.54	136	0.99	256	1.82	376	2.37	496	2.37
17	0.54	137	0.99	257	1.89	377	1.27	497	0.60
18	0.48	138	1.11	258	0.41	378	0.53	498	0.37
19	0.29	139	1.27	259	0.30	379	0.16	499	0.15
20	0.49	140	1.26	260	0.28	380	0.28	500	0.15
21	0.34	141	1.02	261	0.36	381	0.90	501	0.50
22	0.34	142	0.31	262	0.58	382	0.82	502	0.45
23	0.53	143	0.37	263	0.40	383	1.14	503	0.22
24	0.48	144	0.35	264	0.22	384	0.32	504	0.27
25	0.69	145	0.44	265	0.28	385	0.16	505	0.15
26	0.55	146	0.18	266	0.25	386	1.12	506	0.05
27	0.34	147	0.16	267	0.29	387	0.76	507	0.59
28	0.76	148	1.10	268	0.15	388	0.21	508	0.85
29	0.39	149	0.40	269	0.15	389	0.15	509	0.57
30	0.46	150	0.29	270	0.15	390	0.13	510	0.10
31	0.49	151	0.43	271	0.15	391	0.67	511	0.64
32	0.89	152	0.44	272	0.15	392	0.36	512	0.71
33	0.93	153	0.15	273	0.68	393	2.37	513	0.71
34	0.84	154	0.15	274	0.44	394	1.89	514	0.71
35	0.98	155	0.59	275	0.78	395	0.78	515	0.74
36	2.37	156	0.16	276	0.58	396	1.50	516	0.71
37	1.04	157	0.04	277	0.94	397	0.89	517	0.71
38	0.76	158	0.71	278	0.25	398	0.33	518	0.90
39	0.30	159	0.42	279	0.69	399	0.67	519	0.82
40	0.46	160	1.60	280	0.43	400	0.80	520	0.73
41	0.86	161	1.82	281	0.17	401	1.12	521	0.71
42	1.08	162	1.77	282	0.16	402	0.87	522	0.69
43	0.48	163	2.37	283	0.30	403	1.09	523	0.71
44	0.43	164	2.37	284	1.29	404	1.00	524	0.68
45	0.80	165	2.37	285	0.79	405	1.03	525	0.65

measurement 1		measurement 2		measurement 3		measurement 4		measurement 5	
Time (s)	Air speed (m/s)	Time (s)	Air speed (m/s)	Time (s)	Air speed (m/s)	Time (s)	Air speed (m/s)	Time (s)	Air speed (m/s)
46	1.12	166	1.97	286	0.58	406	1.21	526	0.58
47	1.12	167	1.96	287	0.49	407	1.02	527	0.69
48	1.12	168	1.96	288	0.43	408	1.02	528	0.70
49	1.02	169	1.96	289	0.43	409	1.05	529	0.63
50	1.12	170	1.96	290	0.43	410	1.12	530	0.71
51	1.12	171	1.96	291	0.43	411	1.01	531	0.65
52	1.12	172	1.94	292	0.43	412	1.26	532	0.70
53	1.07	173	1.96	293	0.43	413	1.08	533	0.71
54	1.04	174	1.94	294	0.43	414	1.12	534	0.68
55	1.08	175	1.96	295	0.43	415	1.01	535	0.65
56	0.99	176	1.96	296	0.43	416	1.10	536	0.69
57	1.03	177	1.96	297	0.43	417	1.06	537	0.68
58	1.06	178	1.90	298	0.43	418	1.03	538	0.71
59	1.01	179	1.96	299	0.44	419	1.07	539	0.62
60	0.99	180	1.87	300	0.57	420	0.99	540	0.71
61	1.00	181	1.86	301	0.57	421	0.97	541	0.58
62	1.05	182	1.76	302	0.48	422	1.15	542	0.70
63	1.06	183	1.92	303	0.45	423	1.18	543	0.71
64	1.10	184	2.37	304	0.68	424	1.15	544	0.83
65	0.99	185	2.37	305	0.42	425	1.00	545	0.82
66	1.07	186	1.94	306	0.46	426	1.04	546	0.63
67	1.04	187	1.88	307	0.45	427	1.09	547	0.54
68	0.99	188	1.81	308	0.44	428	0.97	548	0.83
69	0.99	189	2.37	309	0.43	429	1.06	549	0.70
70	1.01	190	1.93	310	0.37	430	1.09	550	0.71
71	1.11	191	1.92	311	0.55	431	0.95	551	0.72
72	0.99	192	1.82	312	0.34	432	1.09	552	0.80
73	0.99	193	1.87	313	0.64	433	1.03	553	0.71
74	1.04	194	2.37	314	0.50	434	1.03	554	0.73
75	1.05	195	2.37	315	0.43	435	1.11	555	0.85
76	1.06	196	1.74	316	0.66	436	1.14	556	0.64
77	0.99	197	2.37	317	0.47	437	1.04	557	0.69
78	1.05	198	1.89	318	0.34	438	1.45	558	0.69
79	1.01	199	1.85	319	0.56	439	1.18	559	0.71
80	0.99	200	2.27	320	0.76	440	1.08	560	0.64
81	0.99	201	1.84	321	0.60	441	1.26	561	0.73
82	0.99	202	2.27	322	0.53	442	1.35	562	0.70
83	1.01	203	1.81	323	0.59	443	1.12	563	0.71
84	0.99	204	1.82	324	0.67	444	1.20	564	0.67
85	0.99	205	2.27	325	0.55	445	1.12	565	0.54
86	0.99	206	1.91	326	0.54	446	1.27	566	0.70
87	1.01	207	1.79	327	0.48	447	1.12	567	0.69
88	1.01	208	1.92	328	0.54	448	1.13	568	0.67
89	0.99	209	2.27	329	0.66	449	1.17	569	0.71
90	0.99	210	1.80	330	0.68	450	1.12	570	0.58
91	0.99	211	1.75	331	0.62	451	1.09	571	0.67
92	1.12	212	2.27	332	0.54	452	1.14	572	0.70
93	0.99	213	1.93	333	0.57	453	1.04	573	0.71
94	1.12	214	1.61	334	0.55	454	1.17	574	0.71
95	1.01	215	1.80	335	0.52	455	1.16	575	0.60

measurement 1		measurement 2		measurement 3		measurement 4		measurement 5	
Time (s)	Air speed (m/s)	Time (s)	Air speed (m/s)	Time (s)	Air speed (m/s)	Time (s)	Air speed (m/s)	Time (s)	Air speed (m/s)
96	1.03	216	2.27	336	0.56	456	1.12	576	0.71
97	0.99	217	1.93	337	0.44	457	1.13	577	0.64
98	1.04	218	1.83	338	0.53	458	1.00	578	0.71
99	0.99	219	1.77	339	0.46	459	1.06	579	0.71
100	1.03	220	1.81	340	0.47	460	0.97	580	0.68
101	1.12	221	1.75	341	0.62	461	0.92	581	0.77
102	1.08	222	1.78	342	0.67	462	0.91	582	0.72
103	1.03	223	1.89	343	0.58	463	1.11	583	0.66
104	1.05	224	1.77	344	0.58	464	1.05	584	0.71
105	1.00	225	1.90	345	0.59	465	1.10	585	0.76
106	0.99	226	1.70	346	0.61	466	1.07	586	0.74
107	1.01	227	1.93	347	0.47	467	1.05	587	0.65
108	0.99	228	1.80	348	0.51	468	1.06	588	0.73
109	1.01	229	1.89	349	0.61	469	1.11	589	0.82
110	1.05	230	1.98	350	0.68	470	0.98	590	0.73
111	0.99	231	1.99	351	0.65	471	1.01	591	0.70
112	1.07	232	2.00	352	0.63	472	1.26	592	0.79
113	1.00	233	1.72	353	0.67	473	1.18	593	0.71
114	1.06	234	1.82	354	0.57	474	1.11	594	0.74
115	1.10	235	1.82	355	0.50	475	1.07	595	0.84
116	0.99	236	1.85	356	0.57	476	1.17	596	0.84
117	0.99	237	1.99	357	0.50	477	1.06	597	0.85
118	1.02	238	2.27	358	0.44	478	1.11	598	0.71
119	1.02	239	2.27	359	0.56	479	1.10	599	0.76
120	1.08	240	1.29	360	0.45	480	1.12	600	0.79
Avg.	1.02	Avg.	1.95	Avg.	0.54	Avg.	1.10	Avg.	0.71

= Phase 1: Entering chiller in order to position transducer for measurement (15 sec. approx)

= Phase 2: Transducer placement and adjustment within the chiller (30 sec. approx.)

= Phase 3: Exiting chiller and shutting door (15 sec. approx.)

= Phase 4: Operation of the anemometer from outside the chiller / Measurement time (60 sec.)

APPENDIX C

Air Tunnel data for single propeller anemometer
Generator output signal response at various blade orientation angles to air flow

Table C.1: Propeller anemometer resonse at various angles to the air flow using a tunnel air speed of approx. 0.3 m/s

Blade angle (degrees)	Anemometer voltage readings			Converted air flow readings			Ideal response (m/s)	error (m/s)
	Average (m/v)	Minimum (m/v)	Maximum (m/v)	Average (m/s)	Minimum (m/s)	Maximum (m/s)		
90	11.93	11.20	12.60	0.35	0.34	0.36	0.35	0.00
80	11.39	10.80	12.10	0.34	0.33	0.35	0.34	0.00
70	10.00	9.30	10.60	0.32	0.30	0.33	0.33	-0.01
60	8.08	7.30	8.50	0.27	0.24	0.28	0.30	-0.04
50	4.89	4.10	5.80	0.16	0.13	0.19	0.27	-0.11
40	2.49	1.50	3.60	0.08	0.05	0.12	0.22	-0.14
30	0.00	0.00	0.00	0.00	0.00	0.00	0.17	-0.17
20	0.00	0.00	0.00	0.00	0.00	0.00	0.12	-0.12
10	0.00	0.00	0.00	0.00	0.00	0.00	0.06	-0.06
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: All readings are integrated measurements over a one minute interval

Table C.2: Propeller anemometer resonse at various angles to the air flow using a tunnel air speed of approx. 0.5 m/s

Blade angle (degrees)	Anemometer voltage readings			Converted air flow readings			Ideal response (m/s)	error (m/s)
	Average (m/v)	Minimum (m/v)	Maximum (m/v)	Average (m/s)	Minimum (m/s)	Maximum (m/s)		
90	22.45	21.30	23.70	0.53	0.51	0.56	0.53	0.00
80	21.25	20.20	22.20	0.51	0.49	0.53	0.53	-0.01
70	19.68	18.40	20.60	0.49	0.46	0.50	0.50	-0.02
60	17.14	16.20	17.80	0.44	0.42	0.45	0.46	-0.02
50	12.43	11.40	13.60	0.36	0.34	0.38	0.41	-0.05
40	9.24	8.60	10.00	0.30	0.28	0.32	0.34	-0.04
30	4.75	3.90	5.50	0.16	0.13	0.18	0.27	-0.11
20	1.21	-0.10	2.80	0.04	0.00	0.09	0.18	-0.14
10	0.00	0.00	0.00	0.00	0.00	0.00	0.09	-0.09
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: All readings are integrated measurements over a one minute interval

Table C.3: Propeller anemometer resonse at various angles to the air flow using a tunnel air speed of approx. 0.7 m/s

Blade angle (degrees)	Anemometer voltage readings			Converted air flow readings			Ideal response (m/s)	error (m/s)
	Average (m/v)	Minimum (m/v)	Maximum (m/v)	Average (m/s)	Minimum (m/s)	Maximum (m/s)		
90	31.20	29.60	32.60	0.69	0.66	0.71	0.69	0.00
80	29.80	28.30	33.10	0.66	0.64	0.72	0.68	-0.01
70	27.30	25.20	29.20	0.62	0.58	0.65	0.65	-0.03
60	24.10	22.10	26.80	0.56	0.53	0.61	0.60	-0.03
50	19.00	17.30	21.20	0.47	0.44	0.51	0.53	-0.05
40	13.60	12.40	14.90	0.38	0.36	0.40	0.44	-0.06
30	7.70	6.40	8.70	0.25	0.21	0.29	0.34	-0.09
20	0.00	-0.10	0.00	0.00	0.00	0.00	0.24	-0.24
10	0.00	-0.10	0.00	0.00	0.00	0.00	0.12	-0.12
0	0.00	-0.20	0.00	0.00	-0.01	0.00	0.00	0.00

Note: All readings are integrated measurements over a one minute interval

Table C.4: Propeller anemometer resonse at various angles to the air flow using a tunnel air speed of approx. 1.0 m/s

Blade angle (degrees)	Anemometer voltage readings			Converted air flow readings			Ideal response (m/s)	error (m/s)
	Average (m/v)	Minimum (m/v)	Maximum (m/v)	Average (m/s)	Minimum (m/s)	Maximum (m/s)		
90	50.90	48.30	54.10	1.03	0.99	1.09	1.03	0.00
80	48.60	45.50	50.70	0.99	0.94	1.03	1.02	-0.02
70	44.70	43.00	48.20	0.92	0.89	0.99	0.97	-0.05
60	39.40	37.70	41.80	0.83	0.80	0.87	0.89	-0.06
50	32.10	30.40	33.90	0.70	0.67	0.73	0.79	-0.09
40	23.60	21.50	24.70	0.55	0.52	0.57	0.66	-0.11
30	14.40	13.10	15.20	0.39	0.37	0.41	0.52	-0.12
20	7.20	6.50	8.20	0.24	0.21	0.27	0.35	-0.12
10	0.00	-0.10	0.00	0.00	0.00	0.00	0.18	-0.18
0	0.00	-4.10	-1.90	0.00	-0.13	-0.06	0.00	0.00

Note: All readings are integrated measurements over a one minute interval

Table C.5: Propeller anemometer resonse at various angles to the air flow using a tunnel air speed of approx. 1.4 m/s

Blade angle (degrees)	Anemometer voltage readings			Converted air flow readings			Ideal response (m/s)	error (m/s)
	Average (m/v)	Minimum (m/v)	Maximum (m/v)	Average (m/s)	Minimum (m/s)	Maximum (m/s)		
90	71.9	70.7	74.9	1.40	1.38	1.45	1.40	0.00
80	67.9	66.3	69.7	1.33	1.30	1.36	1.38	-0.05
70	62.1	60.9	63.6	1.23	1.21	1.26	1.32	-0.09
60	55.3	53.6	56.9	1.11	1.08	1.14	1.21	-0.10
50	44.7	43.5	46.2	0.92	0.90	0.95	1.07	-0.15
40	32.8	31.3	34.2	0.72	0.69	0.74	0.90	-0.19
30	21.4	20.5	22.2	0.52	0.50	0.53	0.70	-0.19
20	9.9	8.9	10.8	0.31	0.29	0.33	0.48	-0.17
10	-0.1	-0.4	0.2	0.00	-0.01	0.01	0.24	-0.25
0	-4.3	-5.4	-3	-0.14	-0.18	-0.10	0.00	-0.14

Note: All readings are integrated measurements over a one minute interval

Table C.6: Propeller anemometer resonse at various angles to the air flow using a tunnel air speed of approx. 1.7 m/s

Blade angle (degrees)	Anemometer voltage readings			Converted air flow readings			Ideal response (m/s)	error (m/s)
	Average (m/v)	Minimum (m/v)	Maximum (m/v)	Average (m/s)	Minimum (m/s)	Maximum (m/s)		
90	86.3	83.2	88.9	1.65	1.60	1.70	1.65	0.00
80	83.7	81.2	86.4	1.61	1.56	1.66	1.63	-0.02
70	78.6	76.7	82.4	1.52	1.49	1.59	1.55	-0.04
60	68.7	66.7	71.5	1.34	1.31	1.39	1.43	-0.09
50	58.7	56.6	61.4	1.17	1.13	1.22	1.27	-0.10
40	44.6	42.2	46.7	0.92	0.88	0.96	1.06	-0.14
30	30.1	28.3	32.5	0.67	0.64	0.71	0.83	-0.16
20	15.7	14	17.6	0.42	0.39	0.45	0.57	-0.15
10	5.9	3.9	7.3	0.19	0.13	0.24	0.29	-0.09
0	-4.5	-5.9	-2.9	-0.15	-0.19	-0.10	0.00	-0.15

Note: All readings are integrated measurements over a one minute interval

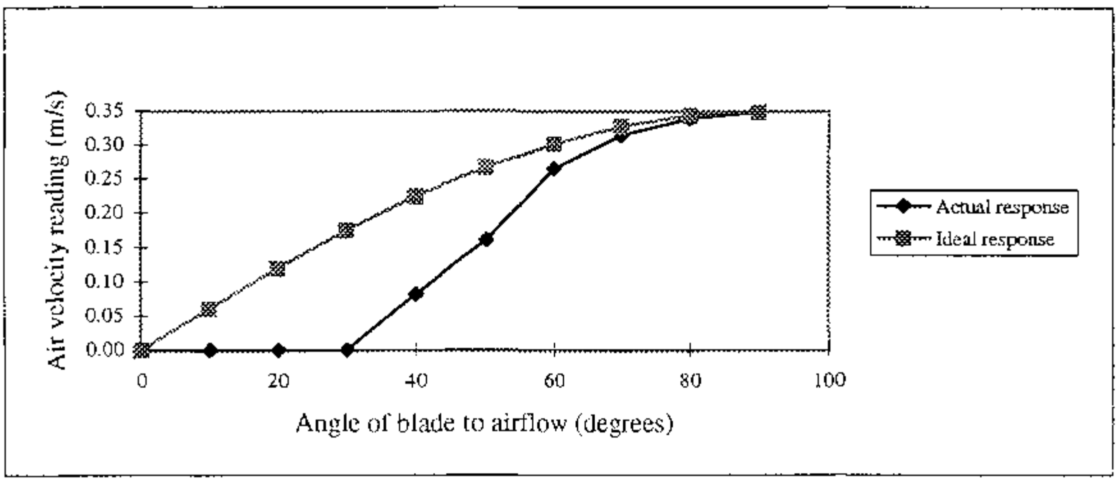

Figure C.1: Anemometer response at various blade angles to air stream
Tunnel air flow = 0.3 m/s

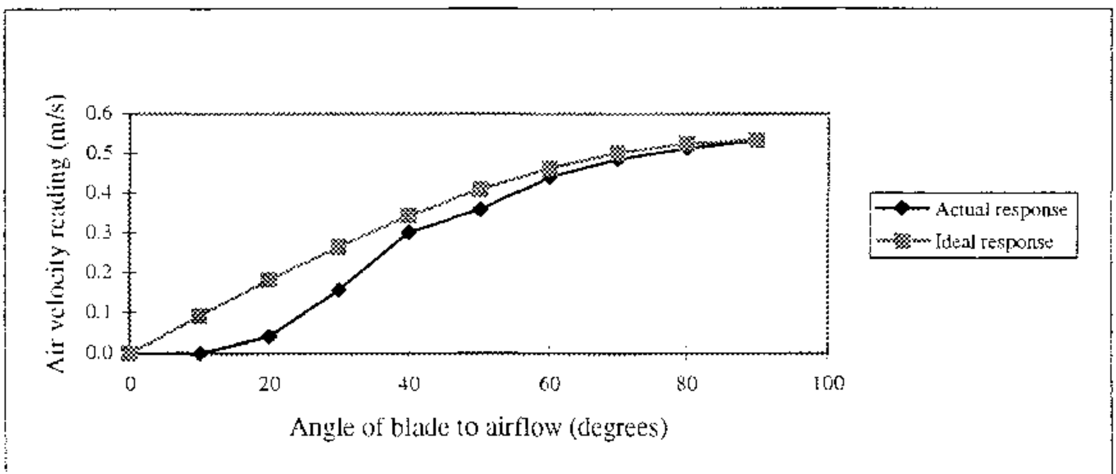

Figure C.2: Anemometer response at various blade angles to air stream
Tunnel air flow = 0.5 m/s

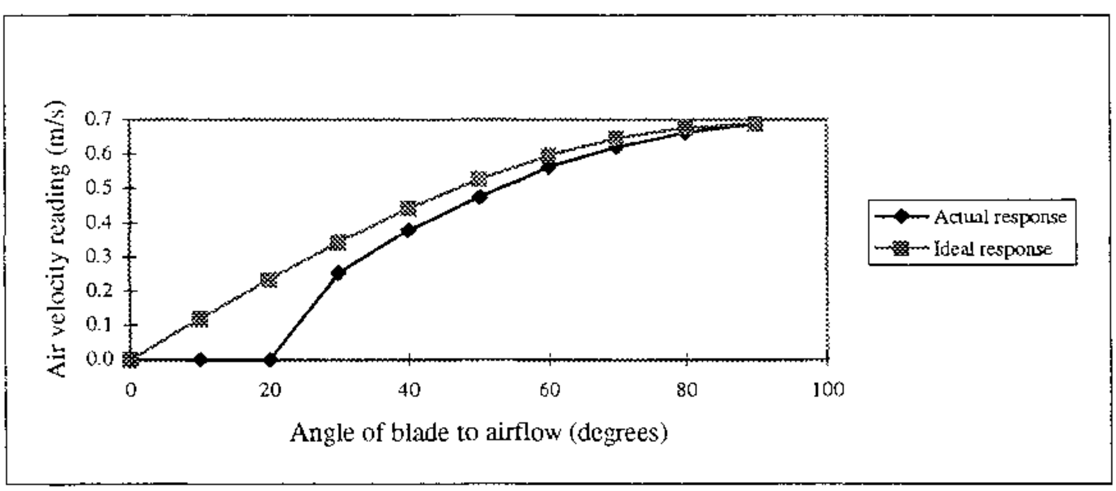

Figure C.3: Anemometer response at various blade angles to air stream
Tunnel air flow = 0.7 m/s

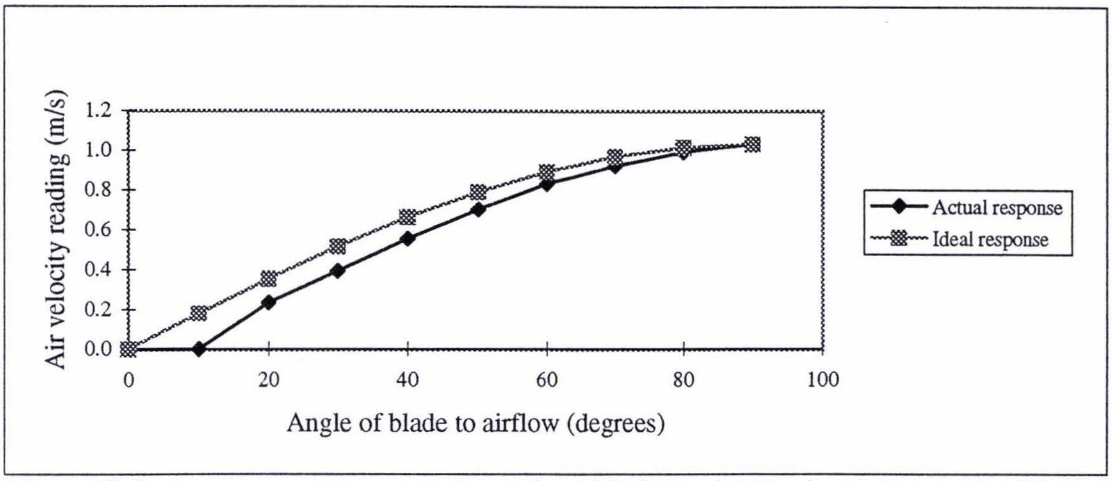

Figure C.4: Anemometer response at various blade angles to air stream
Tunnel air flow = 1.0 m/s

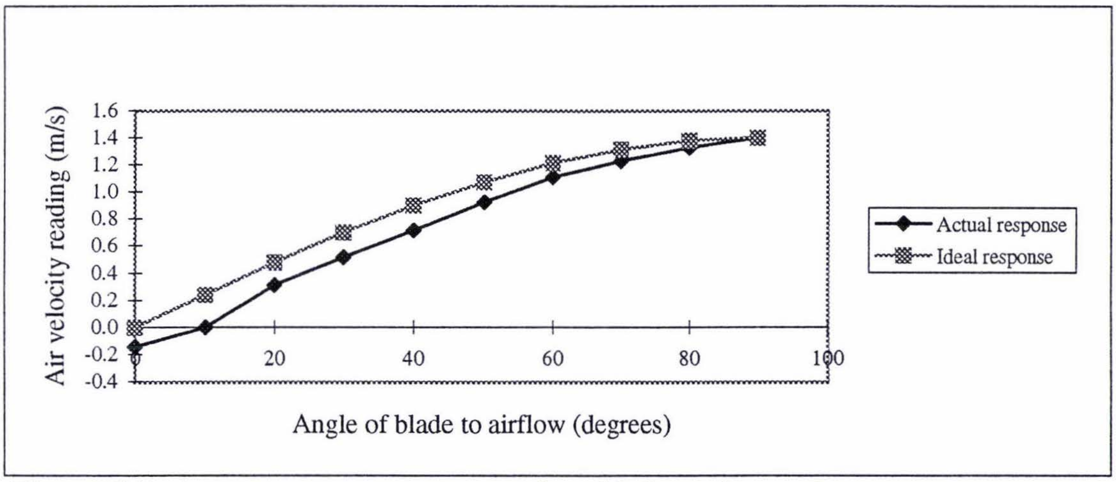

Figure C.5: Anemometer response at various blade angles to air stream
Tunnel air flow = 1.4 m/s

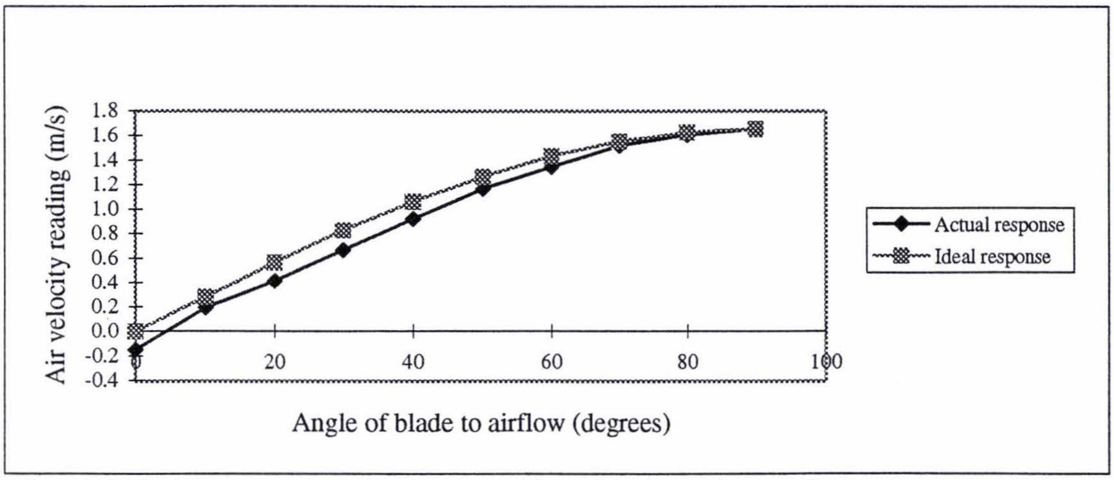

Figure C.6: Anemometer response at various blade angles to air stream
Tunnel air flow = 1.7 m/s

Blast freezer air tunnel data for orthonganlly mounted propeller anemometers.
Response at various blade orientations to air flow

Table C.7: Anemometer resonses at various angles to the air flow using a tunnel air speed of approx. 2.0 m/s
(Anemometers rotated in x-y plane)

Angle to air flow (degrees)	Hot wire readings Mean (m/s)	Min. (m/s)	Max (m/s)	Propeller anemometer readings: Voltage Readings z avg. (mV)	y avg. (mV)	x avg. (mV)	Converted airflow readings z avg. (m/s)	y avg. (m/s)	x avg. (m/s)	Calculations resultant (m/s)	Direction (degrees)	Direction Error (degrees)
0	1.95	1.87	2.04	-11.70	0.00	110.80	-0.35	0.00	2.08	2.11	9.5	9.5
19	1.93	1.86	2.04	-35.10	-0.10	95.00	-0.76	0.00	1.81	1.96	22.8	3.8
38	1.94	1.83	2.02	-55.70	-0.20	65.40	-1.12	-0.01	1.29	1.70	41	3.0
56	1.94	1.88	2.04	-77.10	-0.20	33.30	-1.49	-0.01	0.72	1.66	64.2	8.2
75	1.97	1.92	2.04	-80.90	-0.40	15.30	-1.56	-0.01	0.41	1.61	75.3	0.3
95	1.94	1.87	2.01	-86.40	-0.40	-2.00	-1.66	-0.01	-0.07	1.66	92.4	-2.6
119	1.89	1.81	1.97	-78.10	-0.20	-40.70	-1.51	-0.01	-0.85	1.73	119.4	0.4
139	1.84	1.78	1.92	-60.50	-0.20	-65.30	-1.20	-0.01	-1.29	1.76	137.1	-1.9
159	1.95	1.84	2.02	-27.60	-0.20	-77.80	-0.62	-0.01	-1.50	1.63	157.5	-1.5
180	1.95	1.87	2.00	-0.10	0.00	-85.30	0.00	0.00	-1.64	1.64	180	0.0
200	1.94	1.86	2.01	25.20	-0.10	-81.20	0.58	0.00	-1.56	1.67	200.4	0.4
218	1.95	1.84	2.02	57.60	-0.10	-68.60	1.15	0.00	-1.34	1.77	220.6	2.6
237	2.01	1.94	2.08	85.70	-0.20	-53.50	1.64	-0.01	-1.08	1.97	236.6	-0.4
253	1.99	1.94	2.05	112.00	-0.20	-35.60	2.10	-0.01	-0.76	2.24	250.1	-2.9
275	1.99	1.91	2.06	100.70	0.00	-0.30	1.91	0.00	-0.01	1.91	270.3	-4.7
296	2.00	1.94	2.07	75.30	-0.10	41.30	1.46	0.00	0.86	1.70	300.5	4.5
317	1.99	1.93	2.06	42.10	-0.10	83.30	0.88	0.00	1.60	1.83	331.2	14.2
337	1.94	1.88	2.03	13.70	-0.10	109.80	0.38	0.00	2.07	2.10	349.6	12.6

Note: All readings are integrated measurements over a one minute interval

Table C.8: Anemometer resonses at various angles to the air flow using a tunnel air speed of approx. 1.0 m/s
(Anemometers rotated in x-y plane)

Angle to air flow (degrees)	Hot wire readings Mean (m/s)	Min. (m/s)	Max (m/s)	Propellor anemometer readings: Voltage Readings z avg. (mV)	y avg. (mV)	x avg. (mV)	Converted airflow readings z avg. (m/s)	y avg. (m/s)	x avg. (m/s)	Calculations resultant (m/s)	Direction (degrees)	Direction Error (degrees)
0	1.00	0.932	1.050	-0.60	45.70	-0.10	-0.02	0.94	0.00	0.94	1.2	1.2
30	1.00	0.953	1.040	-20.10	31.50	-0.10	-0.49	0.69	0.00	0.85	35.4	5.4
60	1.03	0.990	1.070	-36.70	8.80	-0.10	-0.78	0.29	0.00	0.84	69.6	9.6
90	1.01	0.955	1.070	-43.00	-0.10	-0.10	-0.89	0.00	0.00	0.89	90.0	0.0
120	1.03	0.993	1.090	-32.10	19.60	-0.10	-0.70	0.48	0.00	0.85	124.4	4.4
150	1.05	1.000	1.100	-17.80	-36.90	-0.10	-0.45	-0.79	0.00	0.91	150.3	0.3
180	1.03	0.977	1.090	-0.10	-40.00	-0.10	0.00	-0.84	0.00	0.84	180.0	0.0
210	1.01	0.972	1.070	22.80	-35.20	0.00	0.54	-0.76	0.00	0.93	215.4	5.4
240	1.05	1.000	1.090	46.00	-17.50	-0.10	0.95	-0.45	0.00	1.05	244.7	4.7
270	1.03	0.950	1.080	48.30	-0.10	-0.10	0.99	0.00	0.00	0.99	270.0	0.0
300	1.03	0.953	1.060	34.80	20.70	-0.10	0.75	0.50	0.00	0.90	303.7	3.7
330	1.04	0.997	1.070	10.60	44.30	-0.10	0.33	0.92	0.00	0.97	340.3	10.3

Note: All readings are integrated measurements over a one minute interval

Table C.9: Anemometer resonses at various angles to the air flow using a tunnel air speed of approx. 1.0 m/s
(Anemometers rotated in x-y plane with a 30 degree tilt)

Anemometer Orientation		Hot wire readings			Propellor anemometer readings						Directional Errors	
					Converted airflow readings			Calculated parameters				
x-y plane (degrees)	x-z plane (degrees)	Mean (m/s)	Min. (m/s)	Max. (m/s)	z avg. (m/s)	x avg. (m/s)	y avg. (m/s)	resultant (m/s)	x-y plane (degrees)	x-z plane (degrees)	x-y plane (degrees)	x-z plane (degrees)
0	30.0	1.00	0.945	1.000	0.00	0.83	-0.50	0.97	0.0	31.1	0.0	-1.1
30	25.7	1.00	1.050	1.080	-0.51	0.57	-0.33	0.83	41.8	23.3	-11.8	2.4
60	14.5	1.03	0.975	1.010	-0.82	0.25	-0.36	0.93	73.0	22.8	-13.0	-8.3
90	0.0	1.01	1.060	1.100	-0.93	-0.10	0.00	0.93	96.1	0.0	-6.1	0.0
120	345.5	1.03	0.985	1.030	-0.76	-0.44	0.32	0.93	123.3	337.5	-3.3	8.0
150	334.3	1.05	0.985	1.020	-0.44	-0.72	0.37	0.93	148.6	336.3	1.4	-2.0
180	330.0	1.03	0.985	1.020	0.00	-0.81	0.37	0.90	180.0	335.4	0.0	-5.4
210	334.3	1.01	0.987	1.030	0.53	-0.59	0.33	0.86	227.9	337.4	168.1	-3.1
240	345.5	1.05	1.010	1.050	0.84	-0.39	0.31	0.98	248.1	341.5	-8.1	4.0
270	0.0	1.03	0.960	0.995	0.98	0.00	0.00	0.98	270.0	0.0	0.0	0.0
300	14.5	1.03	0.912	0.960	0.74	0.44	-0.27	0.90	300.7	17.4	-0.7	-2.9
330	25.7	1.04	0.938	0.979	0.34	0.76	-0.29	0.89	335.9	22.7	-5.9	3.0

Note: All readings are integrated measurements over a one minute interval

Table 10c: Anemometer resonses at various angles to the air flow using a tunnel air speed of approx. 0.6 m/s
(Anemometers rotated in x-y plane)

Angle to air flow (degrees)	Hot wire readings			Propellor anemometer readings								Direction Error (degrees)
				Voltage Readings			Converted airflow readings			Calculations		
	Mean (m/s)	Min. (m/s)	Max (m/s)	z avg. (mV)	y avg. (mV)	x avg. (mV)	z avg. (m/s)	y avg. (m/s)	x avg. (m/s)	resultant (m/s)	Direction (degrees)	
0	0.599	0.565	0.632	-0.10	24.50	-0.10	0.00	0.57	0.00	0.57	0.0	0.0
30	0.601	0.555	0.624	-10.10	16.90	-0.10	-0.32	0.44	0.00	0.54	36.0	6.0
60	0.616	0.567	0.655	-20.00	7.00	-0.10	-0.49	0.23	0.00	0.54	64.9	4.9
90	0.614	0.587	0.637	-25.00	0.00	-0.10	-0.58	0.00	0.00	0.58	90.0	0.0
120	0.590	0.559	0.670	-18.40	-6.00	-0.10	-0.46	-0.20	0.00	0.50	113.5	-6.5
150	0.605	0.570	0.638	-8.10	-17.70	-0.10	-0.27	-0.45	0.00	0.52	149.0	-1.0
180	0.593	0.567	0.616	-0.10	-25.20	-0.10	0.00	-0.58	0.00	0.58	180.0	0.0
210	0.620	0.596	0.643	10.70	-17.50	-0.10	0.33	-0.45	0.00	0.55	216.3	6.3
240	0.598	0.571	0.628	25.20	-6.30	-0.10	0.58	-0.21	0.00	0.62	250.1	10.1
270	0.587	0.560	0.609	24.80	-0.10	-0.10	0.57	0.00	0.00	0.58	270.0	0.0
300	0.608	0.574	0.658	20.40	6.60	-0.10	0.50	0.22	0.00	0.54	293.7	-6.3
330	0.614	0.576	0.658	4.60	23.80	-0.10	0.15	0.56	0.00	0.58	345.0	15.0

Note: All readings are integrated measurements over a one minute interval

Table 11c: Anemometer resonses at various angles to the air flow using a tunnel air speed of approx. 0.6 m/s
(Anemometers rotated in x-y plane with a 30 degree tilt)

Anemometer Orientation		Hot wire readings			Propellor anemometer readings						Directional Errors	
					Converted airflow readings			Calculated parameters				
x-y plane (degrees)	x-z plane (degrees)	Mean (m/s)	Min. (m/s)	Max (m/s)	z avg. (m/s)	x avg. (m/s)	y avg. (m/s)	resultant (m/s)	x-y plane (degrees)	x-z plane (degrees)	x-y plane (degrees)	x-z plane (degrees)
0	30.0	0.601	0.572	0.630	0.00	0.49	-0.30	0.58	0.0	31.5	0.0	-1.5
30	25.7	0.578	0.536	0.603	-0.31	0.32	-0.31	0.54	45.9	32.6	-15.9	-6.9
60	14.5	0.589	0.557	0.618	-0.62	0.27	-0.17	0.70	66.5	14.1	-6.5	0.4
90	0.0	0.609	0.583	0.639	-0.59	0.00	0.00	0.59	90.0	0.0	0.0	0.0
120	345.5	0.587	0.560	0.609	-0.46	-0.26	-0.11	0.54	119.4	348.2	0.6	-2.7
150	334.3	0.614	0.587	0.637	-0.27	-0.39	0.15	0.50	145.3	342.5	4.7	-8.2
180	330.0	0.627	0.609	0.653	0.00	-0.46	0.22	0.50	180.0	334.4	0.0	-4.4
210	334.3	0.620	0.590	0.640	0.36	-0.36	0.11	0.52	225.0	347.8	-15.0	-13.5
240	345.5	0.597	0.567	0.616	0.61	-0.11	-0.13	0.64	259.7	348.2	-19.7	-2.7
270	0.0	0.584	0.540	0.614	0.61	0.00	0.00	0.61	270.0	0.0	0.0	0.0
300	14.5	0.593	0.552	0.628	0.49	0.25	-0.21	0.59	297.0	20.9	3.0	-6.4
330	25.7	0.617	0.574	0.646	0.17	0.46	-0.21	0.53	339.7	23.2	-9.7	2.5

Note: All readings are integrated measurements over a one minute interval

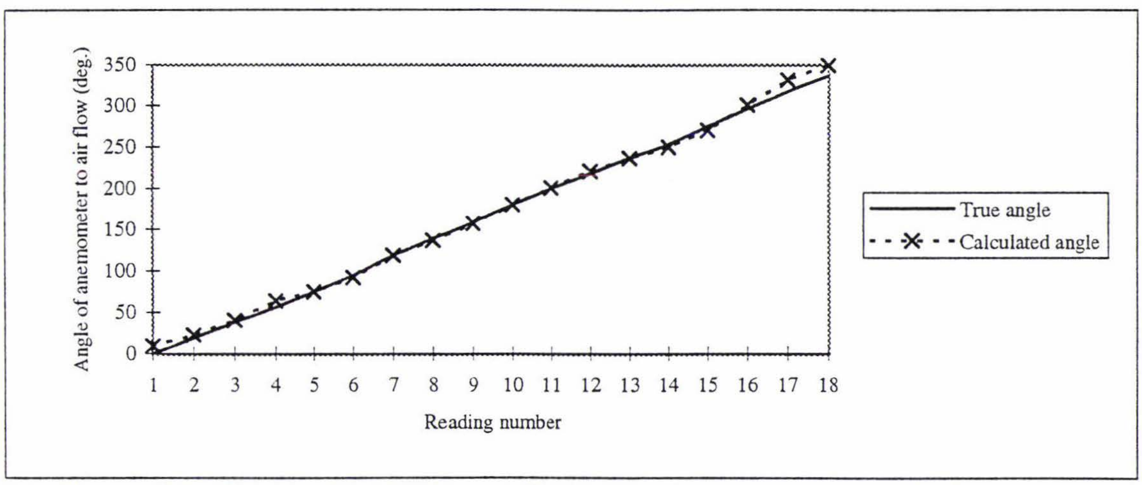

Figure C.7: True angle of orthoganally mounted anemometers to air flow compared to calculated orientation - Tunnel air speed = 2.0 m/s

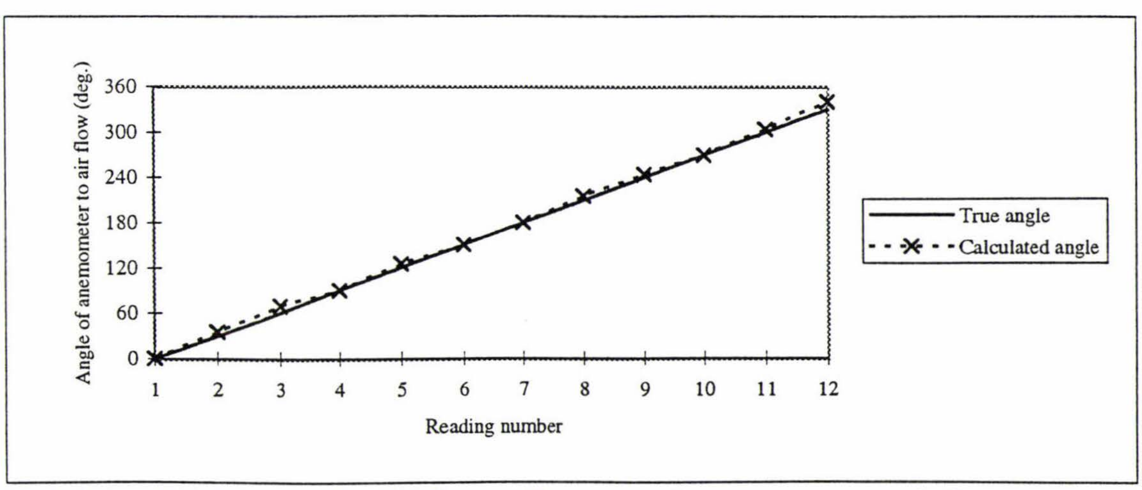

Figure C.8: True angle of orthoganally mounted anemometers to air flow compared to calculated orientation - Tunnel air speed = 1.0 m/s

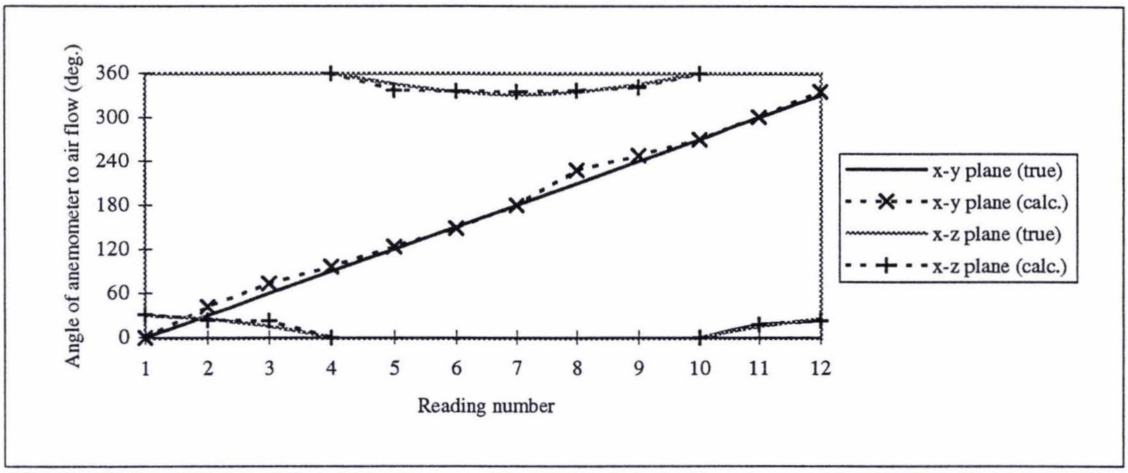

Figure C.9: True angle of orthoganally mounted anemometers to air flow compared to calculated orientation -30 deg. tilt - Tunnel air speed = 1.0 m/s

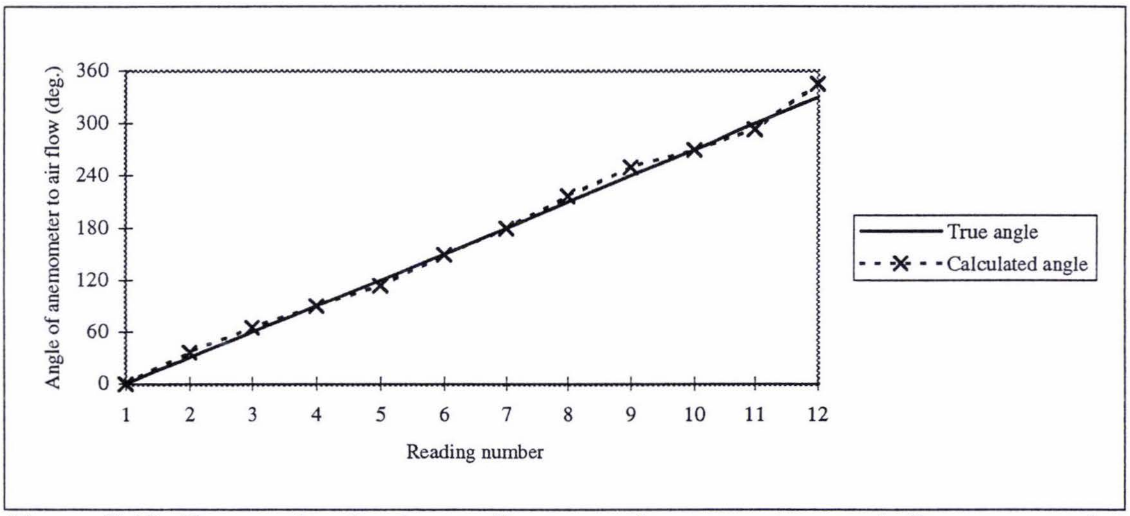

Figure C.10: True angle of orthoganally mounted anemometers to air flow compared to calculated orientation - Tunnel air speed = 0.7 m/s

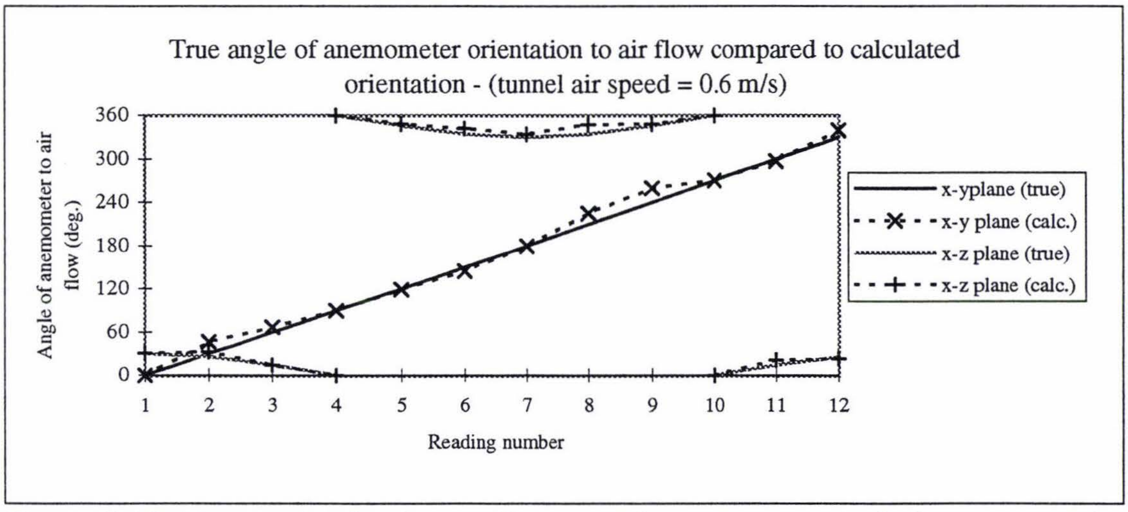

Figure C.11: True angle of orthoganally mounted anemometers to air flow compared to calculated orientation -30 deg. tilt - Tunnel air speed = 0.7 m/s

APPENDIX E

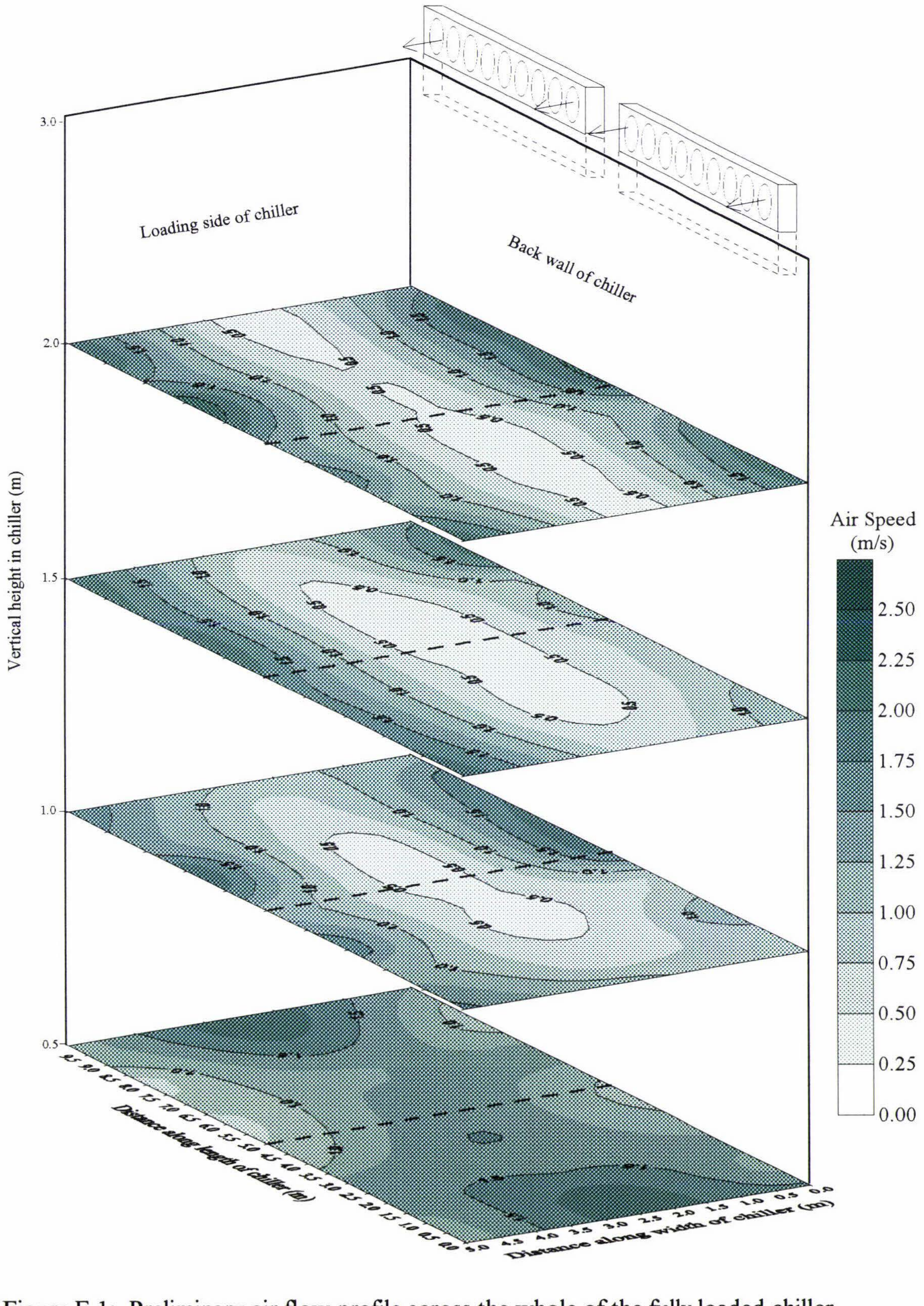

Figure E.1: Preliminary air flow profile across the whole of the fully loaded chiller

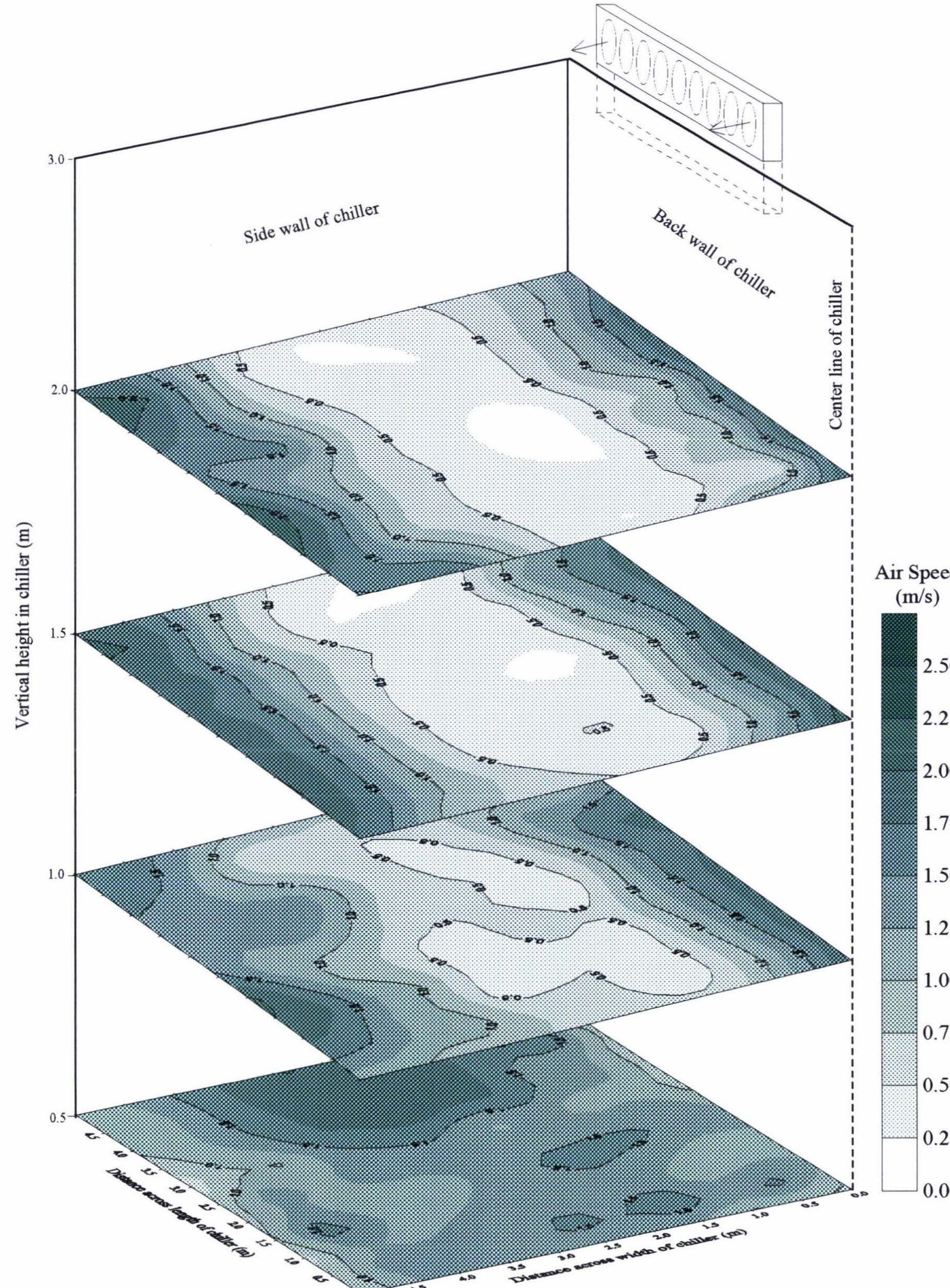

Figure E.2: Air flow profile of full chiller without delta wings - Trial 1

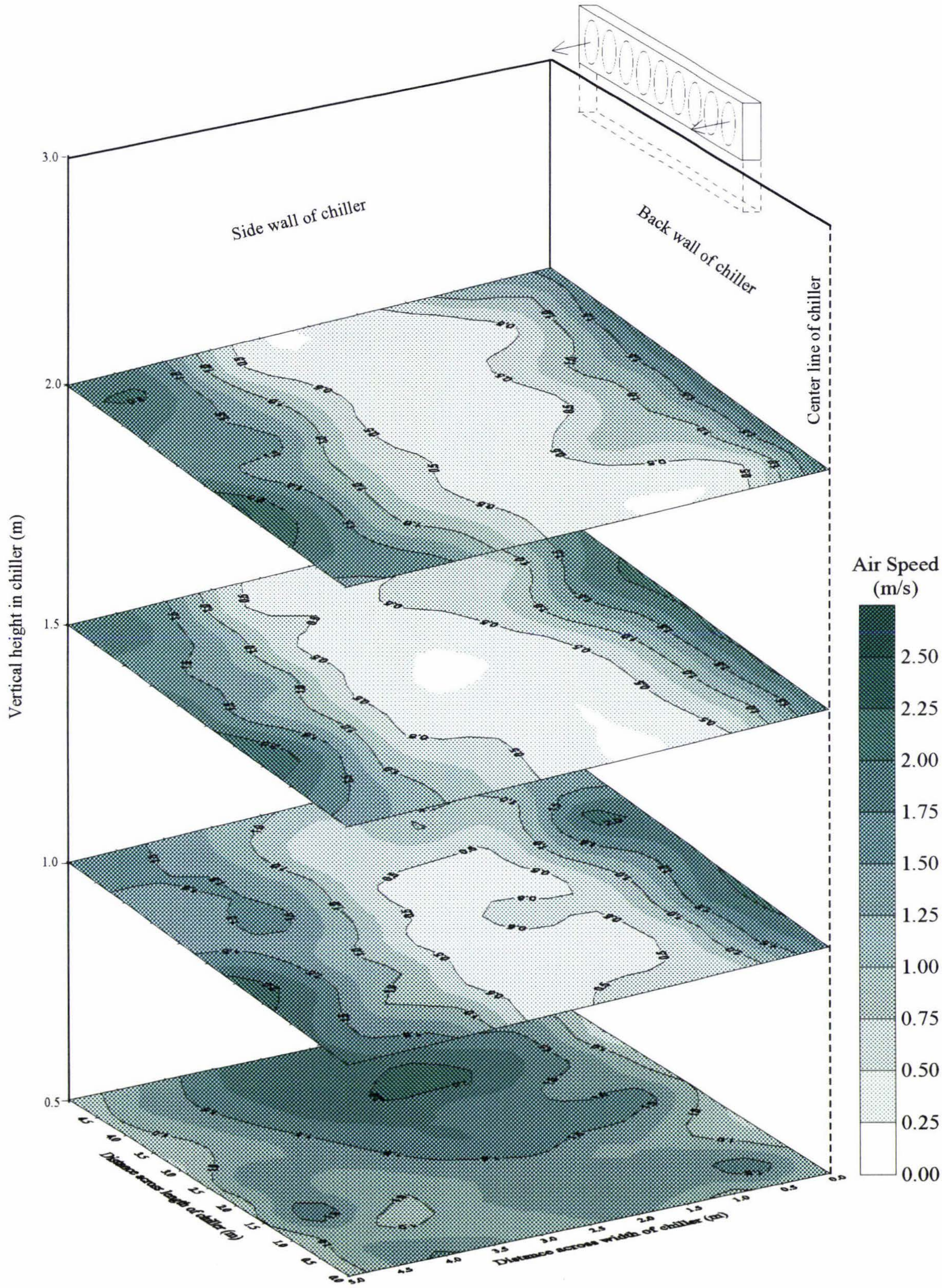

Figure E.3: Air flow profile of full chiller without delta wings - Trial 2

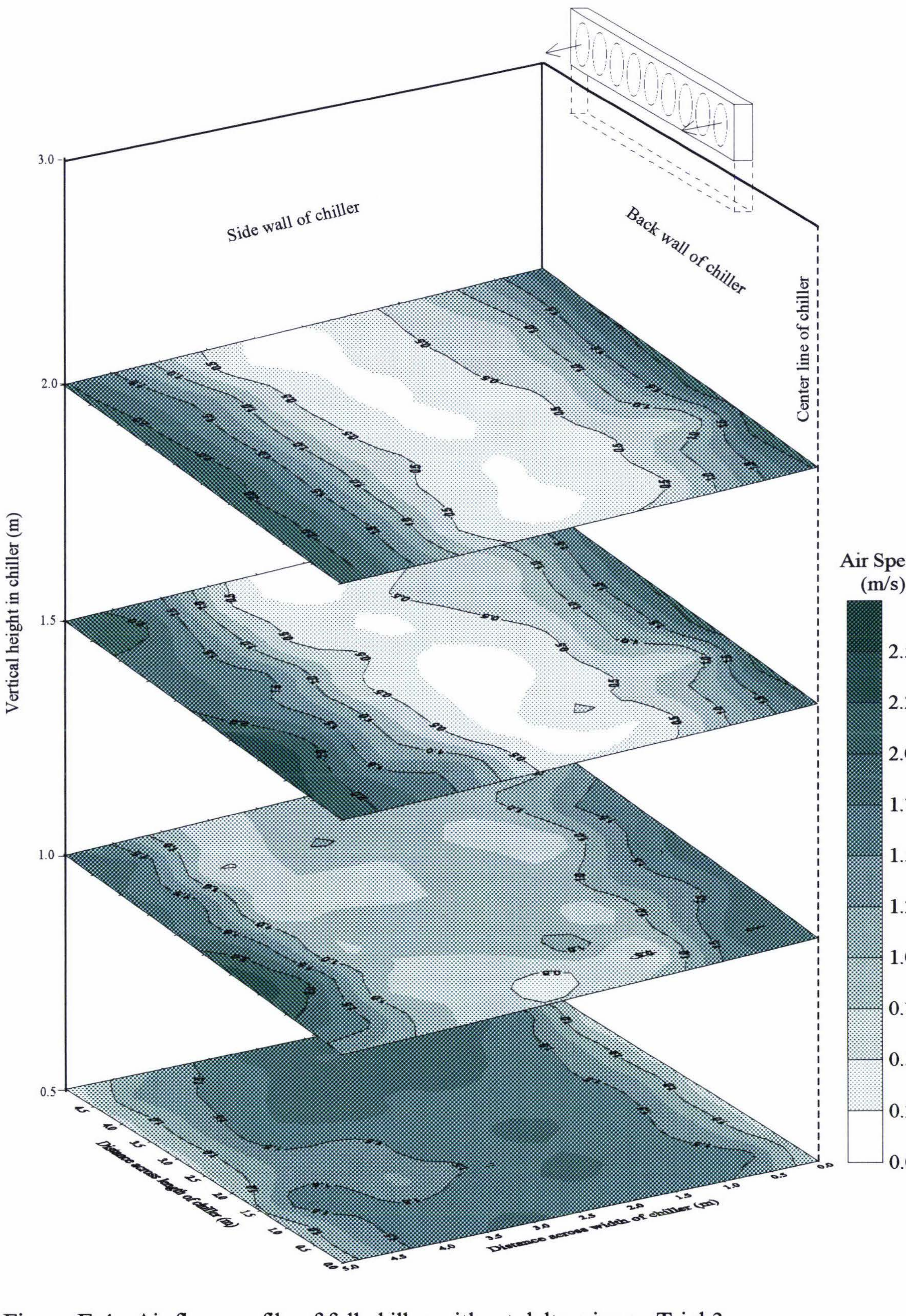

Figure E.4: Air flow profile of full chiller without delta wings - Trial 3

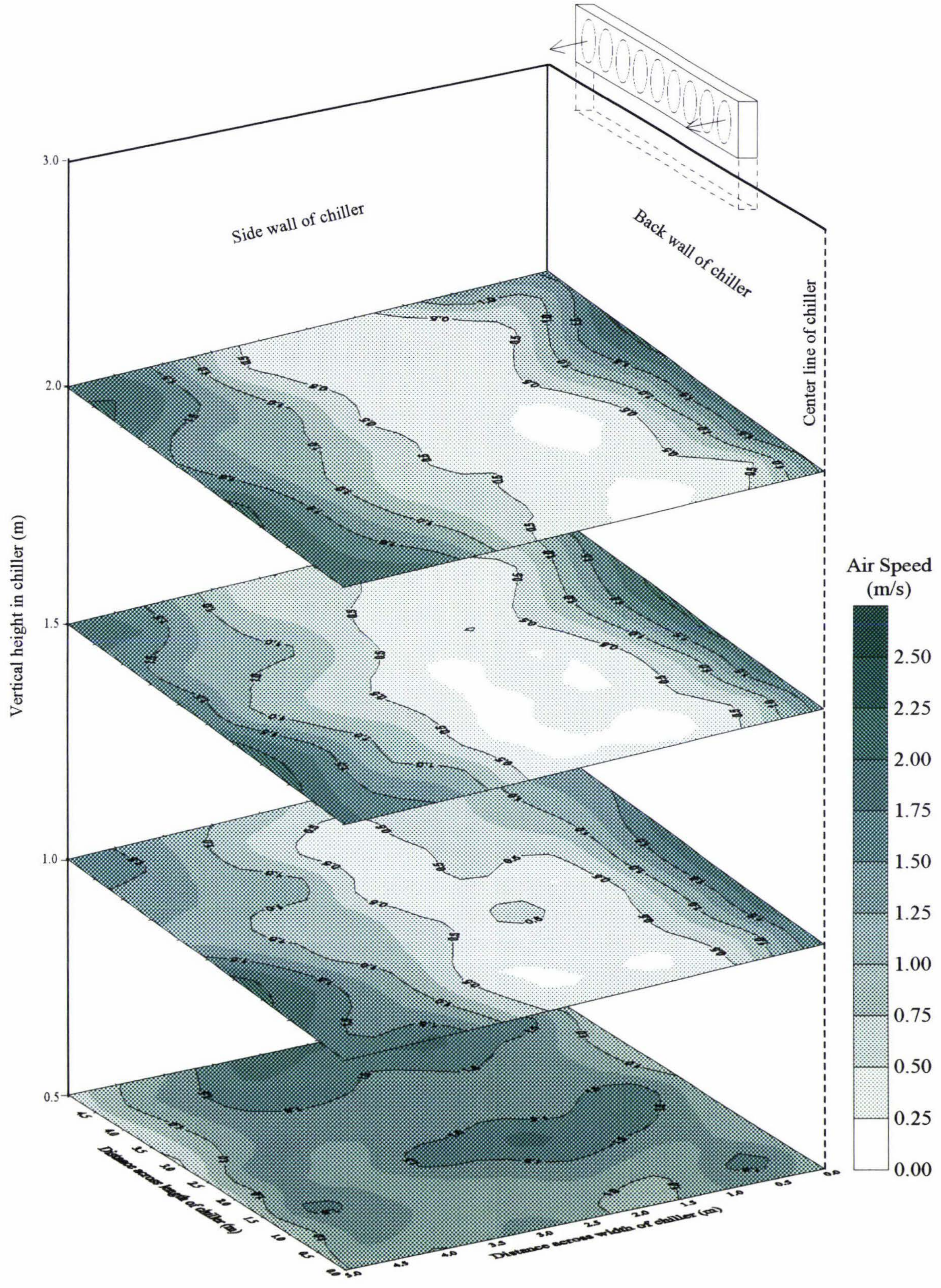

Figure E.5: Air flow profile of full chiller without delta wings - Trial 4

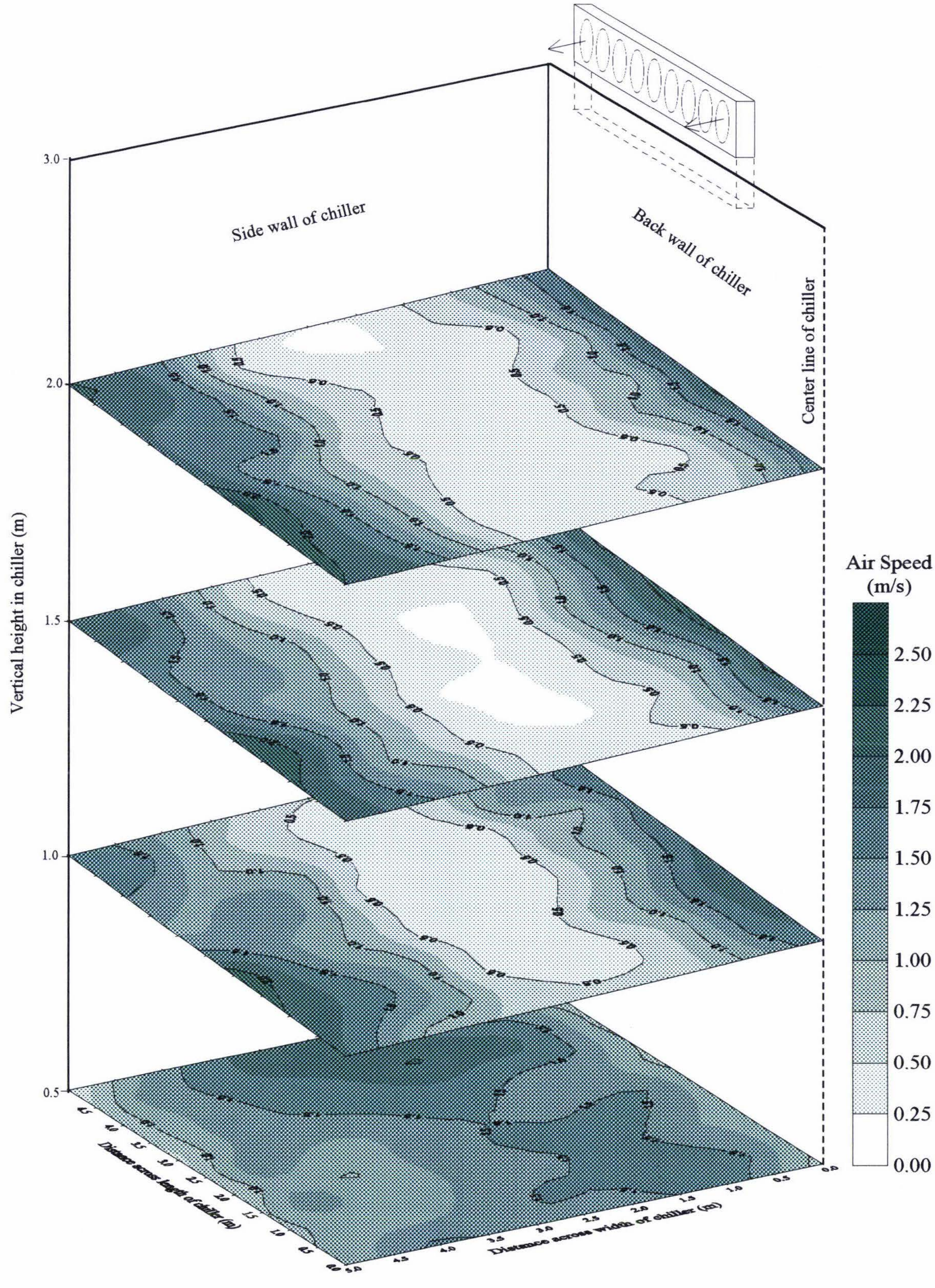

Figure E.6: Air flow profile of full chiller without delta wings - Trial 5

Table E.1: Preliminary air speed data from fully loaded chiller

Coordinates					
y - dir. (with) (m)	x - dir. (length) (m)	mean air speed (m/s)	mean air speed (m/s)	mean air speed (m/s)	mean air speed (m/s)
0.0	0.00	1.56	0.97	2..03	1.86
1.0	0.00	1.07	0.77	1.23	1.96
2.0	0.00	1.33	1.37	0.95	1.79
3.0	0.00	1.16	0.90	1.01	1.67
4.0	0.00	0.95	0.75	0.88	1.08
5.0	0.00	0.89	1.99	1.02	2.05
6.0	0.00	1.24	1.98	1.26	2.10
7.0	0.00	1.34	1.88	0.90	1.89
8.0	0.00	0.85	1.73	1.82	2.03
9.0	0.00	0.92	1.66	1.84	1.93
10.0	0.00	1.26	1.08	1.47	1.39
0.0	2.50	1.89	1.12	0.62	0.23
1.0	2.50	1.96	0.54	0.52	0.47
2.0	2.50	1.48	0.52	0.29	0.27
3.0	2.50	1.42	0.29	0.36	0.38
4.0	2.50	1.56	0.49	0.44	0.29
5.0	2.50	1.39	0.33	0.31	0.47
6.0	2.50	1.41	0.29	0.27	0.42
7.0	2.50	1.14	0.30	0.30	0.48
8.0	2.50	1.49	0.65	0.43	0.41
9.0	2.50	1.85	0.63	0.53	0.35
10.0	2.50	2.03	0.96	0.75	0.27
0.0	5.00	1.10	1.58	1.98	2.01
1.0	5.00	1.12	1.38	1.82	1.65
2.0	5.00	1.43	1.03	1.75	1.21
3.0	5.00	1.40	1.82	1.70	1.76
4.0	5.00	0.85	1.46	1.62	1.50
5.0	5.00	0.75	1.11	1.75	1.45
6.0	5.00	0.60	1.84	2.03	2.04
7.0	5.00	0.87	2.09	1.98	2.33
8.0	5.00	0.55	1.35	1.78	1.46
9.0	5.00	1.05	1.51	1.90	2.03
10.0	5.00	1.12	1.76	1.98	1.95

Table E.2: Fully loaded chiller without delta wings - Air speed data for trial 1
Breed type loaded: Red deer - rails 1 & 3-6, Fallow deer - rail 2

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)
0.0	0.0	0.89	0.55	1.39	0.84	0.182	1.99	1.67	2.31	0.64	0.138	2.23	1.97	2.15	0.18	0.039	2.05	1.71	2.33	0.62	0.134
1.0	0.0	1.24	0.89	1.53	0.65	0.139	1.98	1.78	2.16	0.38	0.082	1.96	1.69	2.18	0.49	0.106	2.10	1.89	2.38	0.49	0.106
2.0	0.0	1.34	0.74	1.60	0.87	0.186	1.88	1.60	2.13	0.53	0.114	2.04	1.80	2.29	0.49	0.106	1.89	1.66	2.15	0.49	0.106
3.0	0.0	0.85	0.34	1.30	0.96	0.207	1.73	1.42	2.06	0.64	0.138	1.82	1.52	2.03	0.51	0.110	2.03	1.77	2.20	0.43	0.093
4.0	0.0	0.82	0.42	1.16	0.74	0.159	1.66	1.31	1.96	0.65	0.140	1.84	1.56	2.07	0.51	0.110	1.93	1.73	2.18	0.45	0.097
5.0	0.0	0.53	0.39	0.75	0.36	0.078	1.08	0.74	1.30	0.57	0.122	1.47	1.05	1.69	0.64	0.138	1.39	1.07	1.64	0.57	0.123
4.5	0.5	1.72	1.41	1.79	0.38	0.082	0.85	0.62	1.08	0.46	0.100	1.42	1.17	1.61	0.44	0.095	1.01	0.46	1.38	0.92	0.198
3.5	0.5	1.33	0.74	1.65	0.91	0.196	1.76	1.53	2.08	0.55	0.119	1.50	1.25	1.77	0.52	0.112	1.23	0.77	1.64	0.87	0.187
2.5	0.5	1.50	0.98	1.78	0.80	0.173	1.51	1.15	1.76	0.61	0.131	1.15	0.95	1.33	0.38	0.081	0.76	0.47	1.11	0.64	0.138
1.5	0.5	1.04	0.56	1.44	0.88	0.189	1.42	1.20	1.63	0.43	0.093	1.39	1.17	1.56	0.39	0.084	0.84	0.58	1.16	0.58	0.125
0.5	0.5	1.62	1.04	1.97	0.93	0.200	1.21	1.03	1.41	0.38	0.082	1.20	1.03	1.57	0.54	0.116	0.45	0.21	0.68	0.47	0.101
0.0	1.0	0.95	0.35	1.62	1.27	0.274	0.75	0.50	1.10	0.60	0.129	1.02	0.62	1.50	0.88	0.189	1.08	0.52	1.51	0.99	0.213
1.0	1.0	1.05	0.42	1.51	1.09	0.236	0.74	0.40	1.10	0.70	0.152	0.77	0.48	1.03	0.55	0.119	0.87	0.62	1.23	0.62	0.133
2.0	1.0	1.56	1.14	1.89	0.75	0.162	0.97	0.78	1.20	0.42	0.091	0.64	0.38	0.90	0.53	0.114	0.86	0.59	1.16	0.57	0.123
3.0	1.0	1.07	0.66	1.74	1.08	0.233	0.77	0.59	1.10	0.51	0.110	0.95	0.69	1.18	0.49	0.106	0.96	0.62	1.38	0.76	0.164
4.0	1.0	1.33	1.03	1.61	0.58	0.125	1.37	1.19	1.63	0.44	0.095	1.35	1.10	1.62	0.52	0.112	0.79	0.29	1.27	0.98	0.210
5.0	1.0	1.16	0.64	1.84	1.20	0.258	0.90	0.66	1.20	0.54	0.116	0.88	0.47	1.24	0.77	0.166	0.67	0.31	1.03	0.72	0.156
4.5	1.5	1.77	1.42	2.06	0.64	0.138	0.82	0.34	1.70	1.36	0.294	0.32	0.22	0.42	0.21	0.044	0.43	0.26	0.62	0.36	0.078
3.5	1.5	1.77	1.31	2.10	0.79	0.170	0.48	0.28	0.87	0.59	0.127	0.33	0.16	5.73	5.58	1.202	0.46	0.10	0.65	0.55	0.119
2.5	1.5	1.45	1.15	1.78	0.63	0.136	0.22	0.12	0.36	0.24	0.051	0.17	0.08	0.27	0.19	0.041	0.24	0.12	0.33	0.21	0.046
1.5	1.5	1.49	1.22	1.97	0.75	0.162	0.23	0.14	0.35	0.20	0.044	0.32	0.13	0.49	0.36	0.078	0.22	0.13	0.38	0.26	0.056
0.5	1.5	1.75	1.09	2.43	1.34	0.289	0.19	0.08	0.43	0.35	0.075	0.17	0.07	0.30	0.24	0.051	0.24	0.14	0.31	0.17	0.037
0.0	2.0	1.22	0.94	1.91	0.97	0.209	0.67	0.54	0.78	0.24	0.052	0.46	0.25	0.83	0.58	0.125	0.27	0.13	0.46	0.33	0.072
1.0	2.0	1.35	1.02	1.71	0.69	0.149	0.53	0.38	0.75	0.37	0.080	0.59	0.48	0.76	0.28	0.060	0.43	0.17	0.63	0.46	0.099
2.0	2.0	1.53	1.24	1.94	0.70	0.151	0.78	0.62	0.98	0.36	0.078	0.28	0.17	0.48	0.31	0.067	0.10	0.05	0.29	0.24	0.052
3.0	2.0	1.13	0.78	1.51	0.73	0.158	0.53	0.41	0.84	0.42	0.091	0.38	0.19	0.55	0.36	0.077	0.25	0.14	0.41	0.27	0.058
4.0	2.0	1.98	1.74	2.27	0.53	0.114	0.46	0.30	1.00	0.70	0.151	0.28	0.12	0.43	0.31	0.067	0.23	0.12	0.38	0.27	0.057
5.0	2.0	1.94	1.56	2.20	0.64	0.138	0.86	0.71	1.05	0.34	0.074	0.25	0.16	0.39	0.23	0.050	0.39	0.19	0.59	0.41	0.088
4.5	2.5	1.89	1.55	2.27	0.72	0.155	0.51	0.26	0.73	0.47	0.100	0.23	0.07	0.48	0.41	0.089	0.23	0.10	0.43	0.33	0.072
3.5	2.5	1.96	1.72	2.32	0.60	0.129	0.54	0.33	0.90	0.57	0.124	0.52	0.26	0.83	0.57	0.123	0.47	0.30	0.61	0.31	0.066
2.5	2.5	1.48	1.29	1.71	0.42	0.091	0.52	0.37	0.81	0.44	0.094	0.29	0.16	0.55	0.39	0.083	0.27	0.13	0.45	0.32	0.069
1.5	2.5	1.42	1.19	1.65	0.46	0.099	0.29	0.17	0.42	0.25	0.055	0.36	0.20	0.60	0.40	0.086	0.38	0.21	0.67	0.47	0.101
0.5	2.5	1.56	1.02	2.14	1.12	0.241	0.69	0.50	0.71	0.21	0.045	0.44	0.26	0.63	0.37	0.080	0.29	0.16	0.44	0.28	0.059
0.0	3.0	1.39	1.08	1.73	0.65	0.140	0.73	0.35	0.97	0.62	0.133	0.61	0.33	1.02	0.69	0.149	0.47	0.26	0.71	0.45	0.096
1.0	3.0	1.41	1.25	1.57	0.32	0.069	0.29	0.16	0.44	0.28	0.061	0.27	0.13	0.58	0.44	0.096	0.42	0.18	0.62	0.44	0.095
2.0	3.0	1.14	0.97	1.42	0.45	0.097	0.30	0.15	0.47	0.32	0.068	0.30	0.15	0.52	0.38	0.081	0.48	0.23	1.37	1.14	0.246
3.0	3.0	1.49	1.26	1.80	0.54	0.116	0.65	0.43	0.92	0.49	0.106	0.43	0.18	0.87	0.69	0.149	0.41	0.24	0.62	0.37	0.081
4.0	3.0	1.85	1.61	2.20	0.59	0.127	0.63	0.45	0.89	0.45	0.096	0.23	0.12	0.49	0.37	0.080	0.35	0.21	0.57	0.36	0.077
5.0	3.0	2.03	1.86	2.24	0.38	0.082	0.96	0.77	1.15	0.38	0.081	0.45	0.27	0.67	0.40	0.086	0.27	0.11	0.48	0.37	0.080
4.5	3.5	1.79	1.48	2.03	0.55	0.119	0.49	0.22	0.82	0.60	0.129	0.61	0.45	0.78	0.33	0.070	0.40	0.19	0.78	0.58	0.125
3.5	3.5	1.70	1.37	2.05	0.68	0.147	1.39	0.99	1.63	0.65	0.139	0.85	0.43	1.32	0.89	0.193	0.65	0.37	1.04	0.68	0.146
2.5	3.5	1.42	1.25	1.58	0.33	0.071	0.87	0.60	1.07	0.47	0.100	0.62	0.46	0.99	0.53	0.114	0.65	0.35	1.05	0.70	0.151
1.5	3.5	1.13	0.95	1.33	0.38	0.081	1.00	0.70	1.30	0.60	0.130	0.61	0.44	0.89	0.46	0.099	0.60	0.28	1.07	0.79	0.171
0.5	3.5	1.38	1.14	1.87	0.73	0.157	1.15	0.84	1.42	0.59	0.126	0.87	0.26	1.50	1.24	0.268	0.86	0.51	1.37	0.86	0.185
0.0	4.0	1.45	1.00	1.80	0.80	0.172	0.84	0.53	1.20	0.67	0.144	0.80	0.31	1.33	1.02	0.220	1.85	1.42	2.16	0.74	0.160
1.0	4.0	1.16	0.72	1.46	0.74	0.160	1.15	0.78	1.57	0.79	0.171	1.09	0.57	1.44	0.87	0.187	0.78	0.24	1.50	1.26	0.271
2.0	4.0	1.01	0.56	1.36	0.80	0.172	0.86	0.62	1.09	0.48	0.102	1.10	0.60	1.61	1.01	0.219	0.99	0.51	1.29	0.78	0.168
3.0	4.0	0.92	1.06	1.74	0.68	0.147	1.50	1.11	1.77	0.66	0.142	1.13	0.69	1.53	0.84	0.181	1.65	1.17	2.13	0.96	0.207
4.0	4.0	1.49	0.67	1.48	0.81	0.175	1.10	0.70	1.39	0.69	0.148	0.99	0.33	1.46	1.13	0.244	1.00	0.52	1.29	0.78	0.167
5.0	4.0	1.53	0.77	1.32	0.55	0.119	1.40	1.16	1.66	0.50	0.108	1.36	1.07	1.67	0.60	0.129	1.16	0.90	1.48	0.59	0.126
4.5	4.5	1.10	0.77	1.32	0.55	0.119	1.58	1.39	1.92	0.53	0.114	1.98	1.77	2.13	0.36	0.078	2.01	1.80	2.18	0.38	0.082
3.5	4.5	1.12	0.67	1.48	0.81	0.175	1.38	0.91	1.72	0.81	0.174	1.82	0.80	1.91	1.11	0.239	1.65	1.32	1.98	0.66	0.142
2.5	4.5	1.43	1.06	1.74	0.68	0.147	1.03	0.72	1.40	0.69	0.148	1.75	1.00	2.04	1.04	0.224	1.21	0.78	1.60	0.82	0.177
1.5	4.5	1.74	1.37	2.00	0.63	0.136	1.82	1.56	2.02	0.46	0.099	1.70	1.11	2.00	0.89	0.192	1.76	1.51	1.98	0.47	0.101
0.5	4.5	1.34	1.09	1.61	0.52	0.112	1.46	0.89	1.81	0.93	0.199	1.62	1.17	1.99	0.82	0.177	1.50	0.73	2.19	1.46	0.315
0.0	5.0	0.75	0.39	1.12	0.73	0.158	1.11	0.54	1.60	1.06	0.228	1.75	1.33	2.05	0.72	0.155	1.45	0.98	1.09	0.11	0.024
1.0	5.0	0.60	0.28	1.06	0.78	0.168	1.84	1.46	2.20	0.74	0.160	2.03	1.70	2.31	0.61	0.131	2.04	1.71	2.35	0.64	0.138
2.0	5.0	0.87	0.53	1.33	0.81	0.174	2.09	1.66	2.31	0.65	0.140	1.98	1.58	2.33	0.75	0.162	2.33	1.84	2.45	0.61	0.131
3.0	5.0	0.55	0.29	1.04	0.75	0.162	1.35	0.99	1.64	0.66	0.141	1.78	1.27	2.15	0.88	0.190	1.46	0.85	1.88	1.03	0.222
4.0	5.0	1.05	0.55	1.41	0.86	0.185	1.51	1.02	1.87	0.85	0.183	1.90	1.52	2.21	0.69	0.149	2.03	1.47	2.51	1.04	0.224
5.0	5.0	1.12	0.52	1.61	1.09	0.236	1.76	1.53	1.94	0.41	0.088	1.98	1.78	2.18	0.40	0.086	1.95	1.65	2.19	0.54	0.116
Averages:		1.34	0.97	1.69	0.72	0.156	1.03	0.77	1.31	0.54	0.117	1.01	0.72	1.37	0.65	0.141	0.95	0.66	1.25	0.59	0.127

Table E.3: Fully loaded chiller without delta wings - Air speed data for trial 2
Breed type loaded: Red deer

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)
0.0	0.0	0.97	0.65	1.19	0.54	0.116	1.85	1.50	2.10	0.60	0.129	2.05	1.76	2.28	0.52	0.112	2.09	1.78	2.31	0.53	0.114
1.0	0.0	0.79	0.58	1.10	0.52	0.112	2.08	1.78	2.30	0.52	0.112	2.08	1.84	2.32	0.48	0.103	2.09	1.84	2.26	0.42	0.091
2.0	0.0	0.76	0.51	1.13	0.62	0.134	2.03	1.80	2.17	0.37	0.080	2.17	1.92	2.45	0.53	0.114	2.06	1.86	2.37	0.51	0.110
3.0	0.0	0.85	0.61	1.10	0.49	0.106	1.91	1.68	2.10	0.42	0.091	2.09	1.79	2.38	0.59	0.127	1.98	1.72	2.25	0.53	0.114
4.0	0.0	0.43	0.25	0.76	0.51	0.111	1.45	1.18	1.70	0.52	0.112	1.93	1.76	2.14	0.38	0.082	1.96	1.66	2.22	0.56	0.121
5.0	0.0	0.73	0.44	1.03	0.59	0.127	1.17	0.73	1.53	0.80	0.173	1.71	1.31	1.93	0.62	0.134	1.62	1.32	1.86	0.54	0.116
4.5	0.5	1.46	1.12	1.77	0.65	0.140	1.38	1.09	1.66	0.57	0.123	1.40	0.96	1.93	0.97	0.209	0.93	0.41	1.23	0.82	0.176
3.5	0.5	1.44	1.04	1.72	0.68	0.147	2.18	1.93	2.42	0.49	0.106	1.87	1.57	2.10	0.53	0.114	1.10	0.87	1.27	0.40	0.085
2.5	0.5	1.70	1.48	1.94	0.46	0.099	1.41	1.22	1.62	0.40	0.086	1.38	1.21	1.54	0.33	0.071	1.13	0.72	1.33	0.61	0.131
1.5	0.5	0.85	0.57	1.47	0.90	0.193	1.74	1.48	2.06	0.58	0.125	1.28	1.00	1.56	0.56	0.121	1.00	0.73	1.31	0.58	0.126
0.5	0.5	1.77	1.09	2.04	0.95	0.205	1.53	1.29	1.88	0.59	0.127	1.07	0.87	1.41	0.54	0.116	0.53	0.26	1.12	0.86	0.185
0.0	1.0	0.83	0.43	1.44	1.01	0.219	0.55	0.30	0.92	0.62	0.135	0.47	0.31	0.60	0.29	0.062	0.28	0.13	0.50	0.37	0.080
1.0	1.0	1.41	0.78	1.97	1.19	0.256	0.65	0.33	0.83	0.50	0.107	0.66	0.46	0.79	0.33	0.071	0.59	0.28	0.99	0.71	0.153
2.0	1.0	1.52	1.26	1.85	0.59	0.127	0.74	0.54	1.15	0.61	0.131	0.64	0.42	0.86	0.44	0.095	0.88	0.64	1.14	0.50	0.108
3.0	1.0	1.26	0.82	1.70	0.88	0.189	1.29	1.08	1.66	0.58	0.125	1.21	0.97	1.41	0.44	0.094	1.01	0.78	1.31	0.53	0.115
4.0	1.0	1.80	1.45	1.99	0.54	0.116	0.82	0.52	1.16	0.64	0.139	0.61	0.26	0.88	0.62	0.134	0.37	0.20	0.60	0.40	0.086
5.0	1.0	1.15	0.82	2.02	1.21	0.260	0.99	0.58	1.35	0.77	0.167	1.00	0.68	1.34	0.66	0.143	1.32	1.04	1.74	0.70	0.151
4.5	1.5	1.67	1.44	1.97	0.53	0.114	1.07	0.81	1.46	0.65	0.139	0.51	0.33	0.75	0.42	0.090	0.31	0.17	0.56	0.38	0.083
3.5	1.5	1.99	1.45	2.22	0.77	0.166	0.47	0.24	0.80	0.56	0.121	0.67	0.30	0.98	0.68	0.146	0.53	0.13	0.86	0.73	0.157
2.5	1.5	1.67	0.94	2.05	1.11	0.239	0.32	0.14	0.50	0.36	0.078	0.35	0.16	0.54	0.38	0.082	0.27	0.11	0.47	0.37	0.079
1.5	1.5	1.11	0.58	1.63	1.05	0.227	0.41	0.19	0.62	0.44	0.094	0.29	0.11	0.49	0.38	0.083	0.94	0.22	0.56	0.35	0.074
0.5	1.5	1.43	0.75	2.19	1.44	0.311	0.49	0.28	0.73	0.45	0.096	0.32	0.22	0.46	0.24	0.052	0.29	0.19	0.44	0.25	0.055
0.0	2.0	1.28	0.74	1.76	1.02	0.221	0.71	0.36	1.07	0.71	0.154	0.18	0.10	0.26	0.16	0.034	0.24	0.11	0.35	0.23	0.050
1.0	2.0	1.48	1.01	1.97	0.96	0.207	0.33	0.19	0.45	0.26	0.055	0.24	0.15	0.32	0.16	0.035	0.29	0.15	0.47	0.32	0.068
2.0	2.0	1.71	1.33	1.95	0.62	0.134	0.75	0.39	1.05	0.66	0.142	0.30	0.17	0.47	0.30	0.065	0.32	0.16	0.49	0.33	0.072
3.0	2.0	1.49	1.17	1.84	0.67	0.144	0.32	0.18	0.66	0.49	0.105	0.33	0.17	0.58	0.41	0.087	0.27	0.15	0.54	0.39	0.085
4.0	2.0	2.16	1.62	2.44	0.82	0.177	1.07	0.66	1.65	0.99	0.213	0.67	0.44	0.90	0.46	0.098	0.44	0.29	0.64	0.35	0.075
5.0	2.0	1.99	1.86	2.13	0.27	0.058	0.93	0.69	1.17	0.48	0.104	0.47	0.22	0.76	0.55	0.118	0.36	0.11	0.62	0.51	0.110
4.5	2.5	1.72	1.51	1.91	0.40	0.086	0.66	0.48	0.87	0.39	0.084	0.38	0.26	0.59	0.33	0.072	0.32	0.14	0.58	0.44	0.095
3.5	2.5	2.03	1.53	2.35	0.82	0.177	0.56	0.31	0.99	0.68	0.147	0.29	0.13	0.65	0.53	0.113	0.32	0.16	0.63	0.47	0.101
2.5	2.5	1.81	1.56	2.00	0.44	0.095	0.48	0.19	0.87	0.67	0.145	0.24	0.14	0.37	0.23	0.049	0.32	0.15	0.55	0.40	0.086
1.5	2.5	1.25	0.69	1.70	1.01	0.219	0.33	0.22	0.47	0.24	0.053	0.36	0.22	0.53	0.31	0.067	0.32	0.18	0.60	0.42	0.091
0.5	2.5	1.28	0.87	1.90	1.03	0.222	0.42	0.24	0.59	0.35	0.075	0.37	0.21	0.66	0.45	0.097	0.40	0.29	0.48	0.19	0.041
0.0	3.0	1.18	0.89	1.47	0.58	0.125	0.29	0.16	0.60	0.44	0.094	0.49	0.33	0.72	0.39	0.084	0.50	0.30	0.68	0.39	0.083
1.0	3.0	1.30	0.86	1.56	0.71	0.152	0.24	0.13	0.41	0.28	0.061	0.55	0.28	0.74	0.45	0.098	0.44	0.27	0.71	0.44	0.095
2.0	3.0	1.44	1.21	1.69	0.48	0.103	0.25	0.12	0.45	0.33	0.071	0.25	0.12	0.47	0.35	0.075	0.52	0.27	0.83	0.55	0.119
3.0	3.0	1.69	1.19	2.12	0.93	0.200	0.47	0.35	0.66	0.31	0.067	0.33	0.20	0.25	0.05	0.012	0.37	0.21	0.58	0.37	0.079
4.0	3.0	1.88	1.51	2.13	0.62	0.134	0.47	0.25	0.89	0.64	0.137	0.54	0.24	0.99	0.75	0.161	0.40	0.21	0.61	0.41	0.088
5.0	3.0	2.00	1.82	2.31	0.49	0.106	1.07	0.75	1.48	0.73	0.157	0.32	0.12	0.61	0.49	0.105	0.19	0.08	0.37	0.29	0.063
4.5	3.5	1.84	1.61	1.97	0.36	0.078	1.06	0.79	1.46	0.67	0.144	0.47	0.26	0.72	0.46	0.099	0.49	0.21	0.73	0.52	0.112
3.5	3.5	1.73	1.26	2.27	1.01	0.218	1.29	1.01	1.66	0.65	0.140	0.43	0.24	0.83	0.60	0.129	1.01	0.65	1.58	0.93	0.201
2.5	3.5	1.40	1.19	1.65	0.46	0.099	1.08	0.78	1.35	0.57	0.122	0.42	0.18	0.85	0.67	0.144	0.66	0.28	1.13	0.85	0.184
1.5	3.5	0.99	0.83	1.19	0.36	0.078	1.00	0.72	1.22	0.50	0.108	0.40	0.19	0.73	0.54	0.117	0.61	0.28	1.05	0.77	0.166
0.5	3.5	1.11	0.89	1.41	0.52	0.113	1.04	0.62	1.42	0.80	0.173	0.81	0.52	1.27	0.75	0.161	0.99	0.62	1.58	0.97	0.208
0.0	4.0	1.62	1.23	2.01	0.78	0.168	1.70	0.85	1.55	0.70	0.151	1.01	0.74	1.35	0.61	0.131	1.65	1.23	2.16	0.93	0.200
1.0	4.0	0.81	0.42	1.17	0.75	0.163	0.91	0.44	1.32	0.88	0.189	0.87	0.51	1.27	0.76	0.164	1.04	0.39	1.54	1.15	0.247
2.0	4.0	1.03	0.55	1.44	0.90	0.193	1.10	0.89	1.33	0.44	0.095	1.08	0.77	1.36	0.59	0.127	1.21	0.80	1.54	0.75	0.161
3.0	4.0	1.16	0.84	1.48	0.64	0.137	1.66	1.12	2.09	0.97	0.209	1.35	0.43	1.57	1.14	0.246	1.69	1.38	1.99	0.61	0.131
4.0	4.0	1.51	1.24	1.80	0.56	0.121	1.52	1.05	1.86	0.81	0.175	1.36	0.89	1.71	0.82	0.176	1.46	1.22	1.83	0.61	0.131
5.0	4.0	1.38	1.18	1.56	0.38	0.082	1.46	1.22	1.65	0.43	0.093	1.58	1.35	1.79	0.44	0.095	1.57	1.35	1.81	0.46	0.099
4.5	4.5	1.31	1.07	1.47	0.40	0.086	1.52	1.27	1.73	0.46	0.099	1.86	1.66	2.13	0.47	0.101	2.07	1.72	2.39	0.67	0.144
3.5	4.5	1.00	0.60	1.55	0.95	0.204	1.41	1.06	1.78	0.72	0.155	1.42	0.90	1.85	0.95	0.205	1.52	0.87	2.02	1.15	0.247
2.5	4.5	1.61	1.08	1.90	0.82	0.177	1.46	0.86	1.92	1.06	0.229	1.20	0.90	1.59	0.69	0.149	1.40	0.95	1.68	0.73	0.156
1.5	4.5	1.89	1.58	2.19	0.61	0.131	1.85	1.63	2.12	0.49	0.106	1.97	1.76	2.22	0.46	0.099	1.89	1.66	2.11	0.45	0.097
0.5	4.5	1.33	0.89	1.78	0.89	0.192	1.41	0.81	1.85	1.04	0.225	1.41	0.82	2.16	1.34	0.290	1.67	0.66	2.19	1.53	0.329
0.0	5.0	0.81	0.35	1.14	0.79	0.170	1.89	1.60	2.24	0.64	0.138	1.35	0.93	1.72	0.79	0.171	1.31	1.00	1.67	0.67	0.145
1.0	5.0	0.69	0.41	0.92	0.50	0.109	1.88	1.64	2.13	0.49	0.106	1.91	1.51	2.19	0.68	0.147	2.03	1.60	2.33	0.73	0.157
2.0	5.0	0.73	0.57	1.14	0.58	0.124	2.21	1.92	2.40	0.48	0.103	2.29	1.97	2.55	0.58	0.125	2.37	2.18	2.76	0.58	0.125
3.0	5.0	0.66	0.45	0.95	0.50	0.108	1.27	0.80	1.72	0.92	0.198	1.94	1.67	2.26	0.59	0.127	1.65	1.41	1.89	0.48	0.103
4.0	5.0	0.88	0.52	1.12	0.60	0.129	1.44	1.14	1.72	0.58	0.125	1.66	1.34	1.92	0.58	0.125	1.90	1.55	2.17	0.62	0.134
5.0	5.0	0.74	0.43	1.00	0.58	0.124	1.62	1.27	1.87	0.60	0.129	1.90	1.67	2.13	0.46	0.099	1.85	1.57	2.08	0.51	0.110
Averages:		1.34	0.98	1.68	0.71	0.152	1.11	0.82	1.40	0.58	0.126	1.00	0.74	1.27	0.53	0.114	1.01	0.72	1.29	0.57	0.123

Table E.4: Fully loaded chiller without delta wings - Air speed data for trial 3
Breed type loaded: Red deer - rails 1-3, Fallow deer - rails 3-6

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)
0.0	0.0	0.68	0.39	1.12	0.73	0.158	1.80	1.53	2.09	0.56	0.121	1.99	1.55	2.35	0.80	0.172	2.06	1.73	2.38	0.65	0.140
1.0	0.0	0.63	0.47	1.03	0.56	0.120	1.96	1.62	2.20	0.58	0.125	2.28	2.05	2.52	0.47	0.101	2.40	1.96	2.66	0.70	0.151
2.0	0.0	0.56	0.41	0.79	0.38	0.082	1.96	1.73	2.11	0.38	0.082	2.29	2.80	3.20	0.40	0.086	2.35	2.01	2.58	0.57	0.123
3.0	0.0	0.65	0.37	1.00	0.63	0.135	1.73	1.52	1.90	0.38	0.082	2.10	1.88	2.25	0.37	0.080	2.15	1.87	2.39	0.52	0.112
4.0	0.0	0.50	0.27	0.74	0.47	0.101	1.52	1.30	1.76	0.46	0.099	1.88	1.57	2.08	0.51	0.110	2.05	1.75	2.28	0.53	0.114
5.0	0.0	0.55	0.36	0.85	0.48	0.104	1.15	0.76	1.40	0.64	0.138	1.78	1.38	1.98	0.60	0.129	1.97	1.77	2.31	0.54	0.116
4.5	0.5	1.67	1.40	1.98	0.58	0.125	0.82	0.42	1.64	1.22	0.263	1.27	0.89	1.47	0.58	0.124	1.34	1.09	1.58	0.49	0.106
3.5	0.5	1.36	0.60	1.66	1.06	0.228	1.53	1.13	1.83	0.70	0.151	1.39	1.04	1.77	0.73	0.157	1.42	1.24	1.71	0.47	0.101
2.5	0.5	1.42	1.11	1.87	0.76	0.164	1.56	1.15	1.89	0.74	0.160	1.34	1.01	1.71	0.70	0.151	1.39	1.20	1.62	0.42	0.091
1.5	0.5	1.27	0.83	1.67	0.84	0.182	1.38	1.03	1.58	0.55	0.119	0.51	0.31	0.83	0.52	0.113	0.62	0.51	0.72	0.21	0.046
0.5	0.5	1.64	0.95	1.95	1.00	0.216	2.02	1.68	2.52	0.84	0.181	1.34	1.04	1.58	0.54	0.116	1.48	1.21	1.74	0.53	0.114
0.0	1.0	1.53	1.03	1.99	0.96	0.207	1.54	1.13	2.09	0.96	0.207	0.93	0.53	1.24	0.71	0.154	1.07	0.70	1.31	0.61	0.132
1.0	1.0	1.57	1.09	2.03	0.94	0.203	1.24	0.96	1.68	0.72	0.154	0.93	0.67	1.12	0.45	0.097	0.95	0.74	1.25	0.51	0.110
2.0	1.0	1.75	1.32	2.02	0.70	0.151	1.29	0.96	1.61	0.65	0.140	0.98	0.75	1.28	0.53	0.115	0.89	0.67	1.08	0.41	0.088
3.0	1.0	1.57	1.09	1.85	0.76	0.164	0.56	0.32	0.84	0.52	0.112	0.83	0.58	1.14	0.56	0.122	0.72	0.58	0.98	0.41	0.088
4.0	1.0	1.68	1.32	1.94	0.62	0.134	1.05	0.82	1.29	0.47	0.100	0.54	0.38	0.87	0.49	0.106	0.63	0.40	0.81	0.41	0.088
5.0	1.0	1.80	1.42	2.12	0.70	0.151	1.05	0.83	1.28	0.45	0.097	1.07	0.67	1.32	0.66	0.141	0.92	0.76	1.24	0.48	0.103
4.5	1.5	1.75	1.46	1.96	0.50	0.108	0.91	0.75	1.09	0.34	0.073	0.56	0.25	0.89	0.64	0.137	0.63	0.37	0.96	0.59	0.127
3.5	1.5	1.75	1.29	2.20	0.91	0.196	0.52	0.28	0.71	0.43	0.092	0.63	0.36	1.01	0.65	0.139	0.57	0.28	0.82	0.54	0.116
2.5	1.5	1.63	1.28	1.96	0.68	0.147	0.77	0.56	1.32	0.76	0.164	0.35	0.14	0.59	0.45	0.097	0.42	0.22	0.65	0.43	0.092
1.5	1.5	1.56	1.15	1.79	0.64	0.138	0.50	0.26	0.75	0.49	0.105	0.37	0.16	0.63	0.47	0.102	0.35	0.12	0.51	0.39	0.085
0.5	1.5	1.48	0.95	1.99	1.04	0.225	0.34	0.14	0.61	0.47	0.101	0.21	0.10	0.74	0.64	0.139	0.28	0.12	0.42	0.29	0.063
0.0	2.0	1.62	1.06	2.18	1.12	0.241	0.74	0.44	1.12	0.68	0.147	0.29	0.17	0.48	0.31	0.066	0.48	0.26	0.77	0.51	0.110
1.0	2.0	1.95	1.63	2.28	0.65	0.140	1.24	0.83	1.57	0.74	0.159	0.61	0.28	1.04	0.76	0.163	0.41	0.21	0.62	0.41	0.088
2.0	2.0	1.89	1.53	2.26	0.73	0.157	0.92	0.48	1.23	0.75	0.162	0.20	0.12	0.35	0.23	0.050	0.37	0.16	0.50	0.35	0.074
3.0	2.0	1.72	1.24	2.12	0.88	0.190	1.11	0.67	1.75	1.08	0.233	0.39	0.24	0.73	0.49	0.106	0.46	0.25	0.74	0.49	0.105
4.0	2.0	1.98	1.64	2.25	0.61	0.131	0.86	0.53	1.11	0.58	0.125	0.66	0.37	1.01	0.64	0.138	0.47	0.21	0.53	0.32	0.068
5.0	2.0	1.95	1.44	2.25	0.81	0.175	0.57	0.33	0.79	0.46	0.099	0.24	0.07	0.66	0.60	0.128	0.35	0.16	0.47	0.31	0.067
4.5	2.5	1.67	1.28	1.96	0.68	0.147	1.00	0.65	1.42	0.77	0.165	0.17	0.00	0.38	0.38	0.081	0.23	0.02	0.50	0.48	0.104
3.5	2.5	1.72	1.36	2.13	0.77	0.166	0.74	0.49	0.99	0.50	0.108	0.14	0.05	0.30	0.25	0.054	0.18	0.02	0.38	0.36	0.078
2.5	2.5	1.58	1.31	1.86	0.55	0.119	0.76	0.56	1.05	0.49	0.105	0.14	0.06	0.24	0.18	0.038	0.14	0.08	0.30	0.22	0.048
1.5	2.5	1.44	1.19	1.64	0.45	0.097	0.91	0.50	1.14	0.64	0.138	0.17	0.09	0.56	0.47	0.100	0.20	0.03	0.42	0.39	0.083
0.5	2.5	1.64	1.34	1.97	0.63	0.136	0.38	0.14	0.71	0.57	0.123	0.13	0.00	0.35	0.35	0.076	0.14	0.02	0.42	0.40	0.087
0.0	3.0	1.80	1.50	2.33	0.83	0.179	0.52	0.30	0.78	0.48	0.104	0.50	0.22	0.75	0.53	0.114	0.36	0.12	0.56	0.45	0.097
1.0	3.0	1.75	1.36	2.00	0.64	0.138	0.61	0.25	1.04	0.79	0.169	0.25	0.12	0.49	0.37	0.080	0.32	0.14	0.55	0.41	0.089
2.0	3.0	1.64	1.43	1.90	0.47	0.101	1.00	0.65	1.31	0.66	0.143	0.32	0.11	0.68	0.57	0.123	0.49	0.12	0.75	0.64	0.137
3.0	3.0	1.79	1.43	2.20	0.77	0.166	0.49	0.31	0.69	0.38	0.082	0.54	0.24	0.83	0.59	0.127	0.31	0.15	0.47	0.32	0.068
4.0	3.0	1.88	1.58	2.06	0.48	0.103	1.07	0.77	1.34	0.57	0.122	0.33	0.15	0.65	0.50	0.108	0.27	0.19	0.39	0.20	0.044
5.0	3.0	1.97	1.66	2.39	0.73	0.157	0.77	0.39	1.11	0.72	0.156	0.17	0.09	0.29	0.21	0.045	0.20	0.12	0.49	0.37	0.080
4.5	3.5	1.61	1.34	1.89	0.55	0.119	0.63	0.34	0.82	0.47	0.102	0.39	0.22	0.60	0.38	0.081	0.31	0.10	0.52	0.42	0.091
3.5	3.5	1.83	1.52	2.08	0.56	0.121	0.77	0.59	0.98	0.39	0.084	0.46	0.07	0.90	0.83	0.178	0.55	0.20	0.81	0.61	0.131
2.5	3.5	1.35	1.00	1.77	0.77	0.166	0.97	0.73	1.23	0.51	0.109	0.55	0.31	0.93	0.63	0.135	0.63	0.31	0.94	0.63	0.135
1.5	3.5	1.11	0.90	1.35	0.45	0.096	0.74	0.32	1.02	0.70	0.150	0.72	0.40	1.03	0.63	0.135	0.57	0.29	0.79	0.50	0.108
0.5	3.5	1.67	1.46	1.95	0.49	0.106	0.71	0.65	1.03	0.38	0.081	1.48	0.86	1.96	1.10	0.238	0.43	0.23	0.67	0.44	0.096
0.0	4.0	1.72	1.11	2.07	0.96	0.207	0.82	0.42	1.31	0.89	0.192	1.64	1.05	1.97	0.92	0.198	1.26	1.00	1.51	0.51	0.110
1.0	4.0	1.53	1.30	1.80	0.50	0.108	0.69	0.44	0.93	0.49	0.106	1.16	0.80	1.48	0.68	0.147	1.35	1.19	1.57	0.38	0.082
2.0	4.0	1.36	1.05	1.81	0.76	0.164	0.66	0.45	1.00	0.56	0.120	1.46	1.11	1.81	0.70	0.151	1.28	1.05	1.56	0.51	0.110
3.0	4.0	1.72	1.16	2.18	1.02	0.220	0.46	0.26	0.82	0.56	0.121	1.63	1.37	1.88	0.51	0.110	1.20	1.01	1.43	0.42	0.091
4.0	4.0	1.54	1.20	1.76	0.56	0.121	0.38	0.22	0.57	0.36	0.077	1.28	1.02	1.68	0.66	0.142	1.35	1.12	1.57	0.45	0.097
5.0	4.0	1.29	1.00	1.52	0.52	0.113	0.79	0.62	1.07	0.45	0.097	1.53	1.14	1.81	0.67	0.144	0.88	0.64	1.03	0.39	0.083
4.5	4.5	1.38	1.10	1.63	0.53	0.114	1.78	1.60	1.97	0.37	0.080	2.13	1.83	2.35	0.52	0.112	1.65	1.39	1.93	0.54	0.116
3.5	4.5	1.26	0.63	1.70	1.08	0.232	1.67	1.17	2.02	0.85	0.183	1.71	1.36	2.09	0.73	0.157	1.74	1.55	2.05	0.50	0.108
2.5	4.5	1.16	0.82	2.14	1.32	0.285	1.65	1.23	1.93	0.70	0.151	1.58	1.37	1.91	0.54	0.116	1.95	1.75	2.38	0.63	0.136
1.5	4.5	1.90	1.45	2.19	0.74	0.160	2.12	1.87	2.37	0.50	0.108	2.21	1.96	2.52	0.56	0.121	1.89	1.74	2.15	0.41	0.088
0.5	4.5	1.39	1.03	1.69	0.66	0.142	1.62	0.96	1.95	0.99	0.213	1.92	1.44	2.27	0.83	0.179	1.84	1.53	2.18	0.65	0.140
0.0	5.0	0.83	0.46	1.02	0.56	0.120	1.21	0.67	1.73	1.06	0.229	2.21	1.70	2.58	0.88	0.190	2.21	1.99	2.38	0.39	0.084
1.0	5.0	0.69	0.47	1.20	0.73	0.157	2.10	1.81	2.50	0.69	0.149	2.39	2.13	2.63	0.50	0.108	2.18	1.89	2.41	0.52	0.112
2.0	5.0	0.69	0.29	1.05	0.76	0.163	2.46	2.20	2.69	0.49	0.106	2.46	2.20	2.68	0.48	0.103	2.09	1.95	2.23	0.28	0.060
3.0	5.0	0.62	0.28	1.18	0.90	0.195	1.77	1.25	1.72	0.47	0.101	1.94	1.62	2.19	0.57	0.123	2.28	2.01	2.59	0.58	0.125
4.0	5.0	0.61	0.39	1.05	0.67	0.143	1.77	1.22	2.09	0.87	0.188	1.94	1.47	2.27	0.80	0.172	2.15	1.91	2.45	0.54	0.116
5.0	5.0	0.53	0.33	0.85	0.52	0.112	1.87	1.72	2.09	0.37	0.080	2.12	1.86	2.34	0.48	0.103	2.06	1.76	2.28	0.52	0.112
Averages:		1.42	1.06	1.77	0.71	0.153	1.12	0.82	1.43	0.61	0.132	1.08	0.82	1.38	0.57	0.122	1.05	0.82	1.28	0.46	0.099

Table E.5: Fully loaded chiller without delta wings - Air speed data for trial 4
Breed type loaded: Red deer

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)
0.0	0.0	0.97	0.43	1.46	1.04	0.223	1.86	1.26	2.14	0.88	0.190	1.72	1.54	2.02	0.48	0.103	1.61	1.37	1.77	0.40	0.086
1.0	0.0	1.00	0.63	1.32	0.69	0.150	2.03	1.73	2.22	0.49	0.106	2.11	1.96	2.28	0.32	0.069	2.05	1.84	2.22	0.38	0.082
2.0	0.0	0.98	0.57	1.29	0.72	0.155	2.04	1.86	2.24	0.38	0.082	2.19	2.06	2.29	0.23	0.050	2.02	2.05	2.27	0.22	0.047
3.0	0.0	0.77	0.52	1.12	0.60	0.129	1.90	1.70	2.16	0.46	0.099	2.14	1.90	2.29	0.39	0.084	2.06	1.93	2.20	0.27	0.058
4.0	0.0	0.70	0.42	1.00	0.58	0.124	1.46	1.24	1.70	0.46	0.099	1.80	1.63	1.96	0.33	0.071	2.04	1.90	2.17	0.27	0.058
5.0	0.0	0.64	0.33	1.28	0.95	0.205	1.37	1.22	1.58	0.36	0.078	1.88	1.64	2.04	0.40	0.086	1.57	1.26	1.71	0.45	0.097
4.5	0.5	1.67	1.40	1.91	0.51	0.110	1.32	1.00	1.58	0.58	0.125	0.83	0.59	1.16	0.57	0.123	0.70	0.48	0.84	0.36	0.077
3.5	0.5	1.19	0.65	1.56	0.91	0.196	1.14	0.81	1.46	0.65	0.140	1.31	1.14	1.44	0.30	0.065	1.57	1.31	1.76	0.45	0.097
2.5	0.5	1.72	1.43	1.98	0.55	0.119	1.31	1.11	1.50	0.39	0.084	1.37	1.17	1.49	0.32	0.069	1.12	0.88	1.25	0.37	0.079
1.5	0.5	1.32	0.88	1.65	0.78	0.167	1.08	0.92	1.26	0.35	0.074	0.86	0.71	1.13	0.42	0.091	0.91	0.48	1.23	0.75	0.161
0.5	0.5	1.76	1.36	2.18	0.82	0.177	0.85	0.70	1.14	0.45	0.096	0.60	0.44	0.77	0.33	0.072	0.41	0.27	0.59	0.32	0.068
0.0	1.0	1.28	0.86	1.93	1.07	0.231	0.40	0.17	0.80	0.63	0.135	0.36	0.17	0.54	0.37	0.080	0.33	0.21	0.61	0.40	0.087
1.0	1.0	1.04	0.76	1.47	0.72	0.154	0.59	0.46	0.84	0.38	0.082	0.51	0.34	0.62	0.28	0.059	0.53	0.29	0.69	0.40	0.085
2.0	1.0	1.67	1.46	1.87	0.41	0.088	0.43	0.20	0.64	0.44	0.095	0.39	0.16	0.54	0.39	0.083	0.32	0.23	0.54	0.31	0.067
3.0	1.0	1.38	1.10	1.84	0.74	0.160	0.58	0.38	0.77	0.39	0.084	0.81	0.73	0.94	0.21	0.045	0.88	0.63	1.07	0.44	0.095
4.0	1.0	1.42	1.11	1.77	0.66	0.142	0.89	0.53	1.14	0.61	0.131	0.36	0.26	0.60	0.34	0.074	0.35	0.25	0.41	0.16	0.033
5.0	1.0	1.08	0.83	1.54	0.71	0.154	0.74	0.49	1.10	0.61	0.132	1.28	1.10	1.45	0.35	0.075	1.54	1.27	1.82	0.55	0.119
4.5	1.5	1.90	1.79	2.03	0.24	0.052	0.60	0.37	0.79	0.42	0.090	0.28	0.20	0.37	0.17	0.037	0.28	0.11	0.96	0.86	0.185
3.5	1.5	1.46	1.09	1.80	0.71	0.153	0.70	0.39	0.97	0.58	0.126	0.37	0.16	0.55	0.39	0.084	0.30	0.24	0.40	0.16	0.034
2.5	1.5	1.33	1.04	1.70	0.66	0.142	0.18	0.08	0.32	0.23	0.050	0.22	0.09	0.39	0.30	0.064	0.18	0.08	0.25	0.18	0.038
1.5	1.5	1.57	1.48	1.76	0.28	0.060	0.31	0.24	0.45	0.20	0.044	0.21	0.11	0.35	0.25	0.053	0.24	0.14	0.35	0.20	0.044
0.5	1.5	0.89	0.47	1.17	0.70	0.151	0.17	0.09	0.32	0.23	0.049	0.10	0.06	0.15	0.09	0.019	0.22	0.17	0.30	0.13	0.028
0.0	2.0	0.89	0.57	1.20	0.63	0.136	0.42	0.30	0.69	0.39	0.085	0.36	0.25	0.53	0.29	0.061	0.19	0.13	0.25	0.12	0.026
1.0	2.0	1.38	1.21	1.59	0.38	0.082	0.49	0.35	0.59	0.23	0.050	0.45	0.35	0.61	0.27	0.057	0.29	0.16	0.46	0.30	0.064
2.0	2.0	1.91	1.77	2.01	0.24	0.052	0.65	0.57	0.82	0.25	0.053	0.37	0.24	0.53	0.29	0.063	0.25	0.12	0.50	0.38	0.083
3.0	2.0	1.38	1.00	2.09	1.09	0.235	0.65	0.45	0.90	0.45	0.097	0.57	0.44	0.79	0.35	0.075	0.47	0.36	0.58	0.21	0.046
4.0	2.0	1.48	1.28	1.61	0.33	0.071	0.62	0.29	0.85	0.57	0.122	0.33	0.16	0.56	0.40	0.086	0.40	0.29	0.49	0.20	0.043
5.0	2.0	1.90	1.79	2.01	0.22	0.047	0.65	0.46	1.02	0.56	0.120	0.54	0.47	0.67	0.19	0.041	0.36	0.24	0.47	0.24	0.051
4.5	2.5	1.49	1.30	1.68	0.38	0.082	0.44	0.22	0.62	0.40	0.086	0.64	0.51	1.00	0.49	0.105	0.47	0.26	0.70	0.44	0.095
3.5	2.5	1.46	1.24	1.64	0.40	0.086	0.28	0.10	0.49	0.39	0.084	0.31	0.15	0.42	0.27	0.058	0.34	0.12	0.51	0.39	0.084
2.5	2.5	1.42	1.17	1.55	0.38	0.082	0.32	0.21	0.43	0.22	0.047	0.15	0.10	0.23	0.14	0.029	0.44	0.25	0.63	0.38	0.082
1.5	2.5	1.32	1.25	1.45	0.20	0.043	0.33	0.16	0.49	0.34	0.072	0.17	0.09	0.32	0.23	0.050	0.51	0.31	0.72	0.41	0.088
0.5	2.5	1.04	0.91	1.32	0.41	0.088	0.19	0.10	0.50	0.40	0.087	0.17	0.11	0.27	0.16	0.034	0.47	0.37	0.59	0.22	0.046
0.0	3.0	1.47	1.25	1.64	0.39	0.084	0.54	0.27	0.93	0.66	0.142	0.39	0.27	0.60	0.33	0.070	0.44	0.36	0.54	0.18	0.039
1.0	3.0	1.11	0.83	1.46	0.63	0.136	0.27	0.13	0.41	0.28	0.060	0.24	0.14	0.48	0.35	0.075	0.57	0.49	0.64	0.16	0.034
2.0	3.0	1.70	1.56	1.85	0.29	0.063	0.61	0.21	0.96	0.75	0.161	0.36	0.23	0.50	0.27	0.058	0.48	0.29	0.72	0.43	0.093
3.0	3.0	1.35	1.00	1.70	0.70	0.151	0.33	0.19	0.56	0.37	0.079	0.57	0.36	0.67	0.31	0.067	0.41	0.27	0.49	0.22	0.046
4.0	3.0	1.57	1.41	1.76	0.35	0.075	0.36	0.17	0.70	0.53	0.115	0.65	0.54	0.88	0.35	0.075	0.41	0.33	0.52	0.19	0.042
5.0	3.0	1.98	1.86	2.24	0.38	0.082	0.94	0.60	1.22	0.62	0.133	0.46	0.24	0.75	0.50	0.108	0.34	0.13	0.77	0.64	0.139
4.5	3.5	1.77	1.60	1.89	0.29	0.063	0.75	0.56	1.00	0.44	0.095	0.74	0.63	0.82	0.19	0.041	0.53	0.39	0.68	0.29	0.062
3.5	3.5	1.45	1.20	1.59	0.39	0.084	1.26	0.87	1.46	0.59	0.127	1.07	0.83	1.34	0.51	0.110	1.07	0.83	1.40	0.57	0.123
2.5	3.5	1.12	1.07	1.21	0.14	0.030	1.01	0.81	1.21	0.40	0.087	0.56	0.47	0.70	0.24	0.052	0.93	0.58	1.32	0.74	0.159
1.5	3.5	1.08	0.97	1.19	0.23	0.049	0.88	0.57	1.07	0.50	0.107	0.81	0.64	1.11	0.47	0.101	0.64	0.38	0.60	0.22	0.047
0.5	3.5	1.11	0.95	1.34	0.40	0.085	0.92	0.53	1.30	0.77	0.166	1.08	0.85	1.24	0.39	0.085	1.00	0.73	1.26	0.53	0.114
0.0	4.0	0.95	0.49	1.42	0.93	0.201	1.89	1.40	2.19	0.79	0.170	1.49	1.25	1.68	0.43	0.093	1.79	1.46	2.07	0.61	0.131
1.0	4.0	1.38	1.18	1.65	0.47	0.101	1.28	0.96	1.61	0.65	0.141	0.96	0.82	1.30	0.48	0.104	1.20	0.95	1.36	0.42	0.089
2.0	4.0	1.13	0.98	1.30	0.32	0.070	0.90	0.63	1.14	0.51	0.109	0.84	0.58	1.06	0.48	0.103	0.99	0.71	1.29	0.58	0.125
3.0	4.0	1.32	0.93	1.62	0.69	0.148	0.89	0.61	1.27	0.66	0.143	0.93	0.58	1.18	0.60	0.130	1.16	0.95	1.43	0.49	0.105
4.0	4.0	1.48	1.26	1.66	0.40	0.086	1.11	0.39	1.62	1.23	0.265	1.11	0.90	1.37	0.47	0.102	1.39	1.22	1.66	0.44	0.095
5.0	4.0	1.21	0.99	1.42	0.43	0.092	1.22	1.04	1.42	0.38	0.082	1.34	1.10	1.50	0.40	0.086	1.38	1.21	1.58	0.37	0.080
4.5	4.5	1.21	1.05	1.38	0.33	0.071	1.54	1.22	1.70	0.48	0.103	1.78	1.58	1.96	0.38	0.082	1.98	1.77	2.24	0.47	0.101
3.5	4.5	0.99	0.66	1.20	0.54	0.117	1.25	0.84	1.50	0.66	0.143	1.12	0.70	1.57	0.87	0.188	1.24	0.73	1.61	0.88	0.189
2.5	4.5	1.47	1.26	1.60	0.34	0.073	1.11	0.85	1.40	0.55	0.119	0.91	0.71	1.14	0.43	0.092	1.31	1.07	1.54	0.47	0.101
1.5	4.5	1.69	1.48	1.85	0.37	0.080	1.79	1.43	2.07	0.64	0.138	1.77	1.65	1.93	0.28	0.060	1.64	1.48	1.85	0.37	0.080
0.5	4.5	1.32	1.09	1.59	0.50	0.108	1.33	1.00	1.68	0.68	0.147	1.52	1.37	1.74	0.37	0.080	1.70	1.38	2.07	0.69	0.149
0.0	5.0	0.99	0.40	1.56	1.16	0.250	1.68	1.19	1.94	0.75	0.162	1.83	1.62	2.05	0.43	0.093	1.98	1.78	2.22	0.44	0.095
1.0	5.0	0.65	0.42	1.19	0.77	0.166	1.90	1.66	2.22	0.56	0.121	2.10	2.01	2.22	0.21	0.045	1.93	1.77	2.02	0.25	0.054
2.0	5.0	0.59	0.33	0.90	0.57	0.124	2.17	1.94	2.47	0.53	0.114	2.11	1.73	2.31	0.58	0.125	2.16	2.03	2.28	0.25	0.054
3.0	5.0	0.40	0.28	1.18	0.90	0.195	1.17	0.66	1.59	0.93	0.201	1.89	1.49	2.04	0.55	0.119	1.50	1.32	1.73	0.41	0.088
4.0	5.0	0.55	0.26	0.80	0.55	0.118	1.41	0.96	1.77	0.81	0.174	1.59	1.30	1.79	0.49	0.106	1.98	1.87	2.20	0.33	0.071
5.0	5.0	0.58	0.36	0.83	0.47	0.102	1.64	1.41	1.85	0.44	0.095	1.91	1.78	2.03	0.25	0.054	1.89	1.49	2.04	0.55	0.119
Averages:		1.26	1.00	1.55	0.55	0.119	0.97	0.71	1.23	0.52	0.111	0.95	0.78	1.14	0.36	0.077	0.97	0.79	1.17	0.38	0.083

Table E.6: Fully loaded chiller without delta wings - Air speed data for trial 5
Breed type loaded: Red deer

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)
0.0	0.0	0.85	0.66	1.07	0.41	0.089	1.64	1.44	1.81	0.37	0.080	1.77	1.54	2.01	0.47	0.101	1.77	1.56	1.96	0.40	0.086
1.0	0.0	1.13	0.91	1.38	0.47	0.101	1.95	1.84	2.11	0.27	0.058	2.12	2.05	2.20	0.15	0.032	1.76	1.57	2.02	0.45	0.097
2.0	0.0	1.14	0.85	1.39	0.54	0.116	1.95	1.86	2.11	0.25	0.054	2.14	2.00	2.27	0.27	0.058	2.12	1.94	2.22	0.28	0.060
3.0	0.0	0.88	0.62	1.11	0.49	0.106	1.80	1.72	2.04	0.32	0.069	2.09	1.93	2.21	0.28	0.060	2.09	1.90	2.18	0.28	0.060
4.0	0.0	0.90	0.66	1.12	0.46	0.099	1.74	1.60	1.95	0.35	0.075	2.07	1.96	2.24	0.28	0.060	2.03	1.93	2.20	0.27	0.058
5.0	0.0	0.55	0.31	0.88	0.57	0.123	1.39	1.27	1.59	0.32	0.069	2.00	1.71	2.16	0.45	0.097	1.77	1.47	1.96	0.49	0.106
4.5	0.5	1.50	1.17	1.72	0.55	0.119	1.41	1.24	1.53	0.29	0.063	1.37	1.03	1.62	0.59	0.127	1.21	0.96	1.40	0.44	0.095
3.5	0.5	1.51	1.32	1.70	0.38	0.082	0.88	0.53	1.19	0.66	0.142	1.32	1.12	1.49	0.37	0.080	0.84	0.63	1.10	0.47	0.101
2.5	0.5	1.55	1.27	1.85	0.58	0.125	1.17	1.01	1.31	0.30	0.065	1.61	1.49	1.78	0.29	0.063	0.89	0.80	1.02	0.22	0.048
1.5	0.5	1.25	1.08	1.62	0.54	0.116	1.66	1.57	1.75	0.18	0.039	1.03	0.82	1.17	0.35	0.076	1.08	0.97	1.24	0.27	0.059
0.5	0.5	1.54	0.89	1.99	1.10	0.237	1.52	1.00	1.92	0.92	0.198	1.41	1.18	1.64	0.46	0.099	0.87	0.65	1.27	0.62	0.134
0.0	1.0	1.64	1.21	1.93	0.72	0.155	0.84	0.61	1.08	0.47	0.102	0.46	0.27	0.73	0.46	0.098	0.61	0.39	0.88	0.49	0.106
1.0	1.0	1.54	1.25	2.10	0.85	0.183	0.84	0.76	0.93	0.18	0.038	0.55	0.40	0.66	0.25	0.054	0.39	0.22	0.54	0.33	0.070
2.0	1.0	1.65	1.14	1.97	0.83	0.179	0.93	0.89	1.06	0.18	0.038	0.81	0.70	0.96	0.26	0.056	0.98	0.81	1.19	0.38	0.081
3.0	1.0	1.19	0.75	1.38	0.63	0.135	0.99	0.88	1.22	0.34	0.074	1.02	0.85	1.17	0.32	0.070	0.86	0.66	1.00	0.34	0.074
4.0	1.0	1.87	1.43	2.00	0.57	0.123	1.42	1.18	1.73	0.55	0.119	0.54	0.38	0.69	0.31	0.066	0.44	0.27	0.49	0.22	0.048
5.0	1.0	1.08	0.71	1.37	0.67	0.143	0.85	0.66	0.99	0.32	0.070	1.17	0.99	1.38	0.39	0.085	0.78	0.62	0.88	0.25	0.055
4.5	1.5	1.78	1.66	1.94	0.28	0.060	0.66	0.50	0.95	0.45	0.097	0.55	0.38	0.68	0.30	0.065	0.52	0.43	0.59	0.16	0.034
3.5	1.5	1.63	1.04	2.12	1.08	0.233	0.32	0.27	0.41	0.14	0.030	0.28	0.17	0.41	0.24	0.051	0.40	0.18	0.60	0.42	0.089
2.5	1.5	1.39	1.25	1.57	0.32	0.069	0.40	0.24	0.57	0.33	0.070	0.38	0.26	0.54	0.29	0.061	0.39	0.32	0.47	0.15	0.032
1.5	1.5	1.49	1.20	1.76	0.56	0.121	0.86	0.71	1.00	0.29	0.062	0.48	0.42	0.53	0.12	0.025	0.31	0.17	0.40	0.23	0.050
0.5	1.5	1.78	1.53	2.06	0.53	0.114	0.52	0.46	0.70	0.25	0.053	0.56	0.39	0.74	0.35	0.076	0.60	0.51	0.65	0.14	0.031
0.0	2.0	1.21	0.94	1.66	0.72	0.156	0.59	0.41	0.77	0.36	0.077	0.33	0.29	0.40	0.11	0.023	0.26	0.16	0.37	0.21	0.044
1.0	2.0	1.49	1.38	1.62	0.24	0.052	0.24	0.14	0.37	0.23	0.049	0.17	0.15	0.23	0.08	0.018	0.43	0.34	0.57	0.23	0.049
2.0	2.0	1.54	1.33	1.77	0.44	0.095	0.27	0.20	0.35	0.14	0.031	0.24	0.15	0.32	0.17	0.037	0.30	0.16	0.40	0.24	0.051
3.0	2.0	1.60	1.37	1.98	0.61	0.131	0.29	0.21	0.38	0.17	0.037	0.20	0.15	0.28	0.13	0.027	0.31	0.24	0.44	0.20	0.043
4.0	2.0	2.06	1.90	2.29	0.39	0.084	0.38	0.22	0.58	0.37	0.079	0.34	0.27	0.45	0.18	0.039	0.24	0.18	0.31	0.14	0.030
5.0	2.0	1.85	1.63	2.13	0.50	0.108	0.54	0.47	0.60	0.14	0.029	0.42	0.35	0.60	0.25	0.054	0.26	0.16	0.36	0.20	0.044
4.5	2.5	1.77	1.60	1.97	0.37	0.080	0.30	0.21	0.36	0.15	0.032	0.24	0.14	0.35	0.20	0.044	0.23	0.15	0.33	0.18	0.040
3.5	2.5	1.65	1.11	2.11	1.00	0.216	0.35	0.19	0.49	0.30	0.065	0.26	0.15	0.38	0.23	0.049	0.48	0.36	0.58	0.22	0.048
2.5	2.5	1.46	1.31	1.60	0.29	0.063	0.35	0.16	0.54	0.38	0.082	0.33	0.23	0.44	0.20	0.044	0.36	0.22	0.53	0.31	0.067
1.5	2.5	1.45	1.28	1.57	0.29	0.063	0.39	0.29	0.51	0.23	0.049	0.21	0.13	0.26	0.13	0.027	0.26	0.16	0.33	0.18	0.038
0.5	2.5	1.55	1.38	1.70	0.32	0.069	0.49	0.35	0.72	0.37	0.079	0.40	0.27	0.56	0.29	0.063	0.35	0.19	0.47	0.28	0.060
0.0	3.0	1.47	1.30	1.59	0.29	0.063	0.56	0.42	0.75	0.33	0.072	0.46	0.27	0.68	0.41	0.088	0.36	0.36	0.54	0.18	0.039
1.0	3.0	1.38	1.17	1.52	0.35	0.075	0.44	0.34	0.71	0.37	0.080	0.33	0.25	0.41	0.16	0.033	0.28	0.19	0.37	0.18	0.039
2.0	3.0	1.44	1.30	1.60	0.30	0.065	0.32	0.23	0.48	0.25	0.054	0.24	0.18	0.36	0.17	0.038	0.51	0.35	0.70	0.35	0.076
3.0	3.0	1.45	1.33	1.58	0.25	0.054	0.29	0.25	0.38	0.14	0.029	0.45	0.27	0.66	0.39	0.084	0.51	0.37	0.63	0.26	0.056
4.0	3.0	1.70	1.53	1.82	0.29	0.063	0.53	0.28	0.78	0.49	0.106	0.44	0.24	0.71	0.47	0.101	0.47	0.31	0.70	0.38	0.083
5.0	3.0	1.91	1.76	2.15	0.39	0.084	0.66	0.57	0.80	0.24	0.051	0.38	0.29	0.49	0.20	0.044	0.29	0.17	0.39	0.22	0.048
4.5	3.5	1.73	1.65	1.85	0.20	0.043	0.65	0.53	0.78	0.24	0.053	0.68	0.58	0.84	0.26	0.056	0.43	0.32	0.57	0.25	0.053
3.5	3.5	1.52	1.23	1.75	0.52	0.112	1.23	1.10	1.36	0.26	0.056	1.08	0.99	1.17	0.18	0.039	0.91	0.75	1.19	0.44	0.094
2.5	3.5	1.10	1.00	1.23	0.23	0.050	0.95	0.77	1.10	0.33	0.071	0.89	0.68	1.12	0.44	0.094	0.59	0.25	0.92	0.67	0.144
1.5	3.5	1.04	0.94	1.15	0.21	0.046	1.13	0.90	1.31	0.41	0.088	0.80	0.58	1.05	0.47	0.101	0.67	0.52	0.90	0.38	0.081
0.5	3.5	1.30	1.07	1.69	0.62	0.134	1.16	0.87	1.39	0.53	0.113	0.99	0.76	1.14	0.39	0.083	0.64	0.39	0.87	0.48	0.104
0.0	4.0	1.60	1.37	1.74	0.37	0.080	0.78	0.62	0.93	0.31	0.067	1.48	1.09	1.84	0.75	0.162	1.68	1.45	2.13	0.68	0.147
1.0	4.0	0.97	0.76	1.19	0.43	0.093	1.59	1.39	1.80	0.41	0.088	0.93	0.81	1.11	0.30	0.064	1.30	1.14	1.58	0.44	0.095
2.0	4.0	0.93	0.59	1.10	0.51	0.111	1.69	0.91	1.20	0.29	0.063	1.08	0.86	1.26	0.40	0.087	1.07	0.77	1.31	0.54	0.116
3.0	4.0	1.38	1.16	1.53	0.37	0.080	1.53	1.28	1.82	0.54	0.116	1.35	1.27	1.49	0.22	0.047	1.69	1.46	2.09	0.63	0.136
4.0	4.0	1.40	1.23	1.68	0.45	0.097	0.97	0.49	1.44	0.96	0.206	1.28	1.19	1.36	0.17	0.037	1.56	1.37	1.77	0.40	0.086
5.0	4.0	1.40	1.28	1.45	0.17	0.037	1.17	0.96	1.35	0.39	0.084	1.40	1.12	1.52	0.40	0.086	1.50	1.25	1.70	0.45	0.097
4.5	4.5	1.36	1.12	1.47	0.35	0.075	1.66	1.48	1.79	0.31	0.067	1.86	1.74	1.94	0.20	0.043	2.06	1.87	2.11	0.24	0.052
3.5	4.5	1.23	0.96	1.52	0.56	0.120	1.20	0.94	1.48	0.54	0.116	1.33	1.03	1.59	0.56	0.121	1.59	1.32	1.90	0.58	0.125
2.5	4.5	1.52	1.18	1.75	0.57	0.123	1.28	1.16	1.39	0.23	0.050	1.23	1.07	1.51	0.44	0.095	1.33	1.10	1.56	0.46	0.099
1.5	4.5	1.54	1.63	2.15	0.52	0.112	1.73	1.48	1.93	0.45	0.097	1.96	1.70	2.06	0.36	0.078	1.88	1.70	2.06	0.36	0.078
0.5	4.5	1.21	0.93	1.39	0.46	0.100	1.60	1.43	1.71	0.28	0.060	1.61	1.40	1.81	0.41	0.088	1.86	1.58	2.20	0.62	0.134
0.0	5.0	1.09	0.85	1.46	0.61	0.132	1.80	1.39	1.97	0.58	0.125	2.00	1.74	2.14	0.40	0.086	2.00	1.78	2.15	0.37	0.080
1.0	5.0	0.90	0.75	1.09	0.34	0.072	1.98	1.80	2.18	0.38	0.082	2.06	1.90	2.20	0.30	0.065	2.08	1.92	2.35	0.43	0.093
2.0	5.0	0.65	0.44	0.99	0.55	0.119	2.26	2.04	2.44	0.40	0.086	2.25	2.06	2.34	0.28	0.060	2.48	2.13	2.69	0.56	0.121
3.0	5.0	0.61	0.42	0.74	0.32	0.069	1.18	0.91	1.45	0.55	0.117	1.65	1.48	1.88	0.40	0.086	1.80	1.63	2.06	0.43	0.093
4.0	5.0	0.81	0.63	1.05	0.42	0.090	1.53	1.25	1.74	0.49	0.106	1.70	1.51	1.94	0.43	0.093	1.79	1.58	2.03	0.45	0.097
5.0	5.0	0.48	0.33	0.61	0.28	0.060	1.61	1.51	1.74	0.23	0.050	1.99	1.86	2.11	0.31	0.067	2.01	1.89	2.15	0.26	0.056
Averages:		1.35	1.12	1.59	0.48	0.103	1.03	0.86	1.21	0.35	0.076	1.03	0.87	1.18	0.31	0.067	1.01	0.84	1.19	0.35	0.676

Table E.7: Fully loaded chiller without delta wings - Average air speed data for trials 1-5

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev est. (m/s)
0.0	0.0	0.87	0.53	1.25	0.71	0.153	1.83	1.48	2.09	0.61	0.131	1.95	1.67	2.16	0.49	0.106	1.92	1.63	2.15	0.52	0.112
1.0	0.0	0.96	0.70	1.27	0.58	0.124	2.00	1.75	2.20	0.45	0.097	2.11	1.92	2.30	0.38	0.082	2.08	1.82	2.31	0.49	0.105
2.0	0.0	0.96	0.61	1.24	0.62	0.135	1.97	1.77	2.15	0.38	0.082	2.17	2.12	2.50	0.38	0.083	2.09	1.90	2.32	0.41	0.089
3.0	0.0	0.80	0.49	1.13	0.63	0.137	1.81	1.61	2.05	0.44	0.096	2.05	1.80	2.23	0.43	0.092	2.06	1.84	2.24	0.41	0.088
4.0	0.0	0.67	0.40	0.96	0.55	0.119	1.57	1.33	1.81	0.49	0.105	1.90	1.70	2.10	0.40	0.087	2.00	1.79	2.21	0.42	0.090
5.0	0.0	0.60	0.37	0.96	0.59	0.127	1.23	0.94	1.48	0.54	0.116	1.77	1.42	1.96	0.54	0.117	1.66	1.38	1.90	0.52	0.112
4.5	0.5	1.60	1.30	1.83	0.53	0.115	1.16	0.87	1.50	0.62	0.135	1.26	0.93	1.56	0.63	0.136	1.04	0.68	1.29	0.60	0.130
3.5	0.5	1.37	0.87	1.66	0.79	0.170	1.50	1.19	1.80	0.61	0.131	1.48	1.22	1.71	0.49	0.106	1.23	0.97	1.50	0.53	0.114
2.5	0.5	1.58	1.25	1.88	0.63	0.136	1.39	1.13	1.62	0.49	0.105	1.37	1.17	1.57	0.40	0.087	1.06	0.81	1.27	0.45	0.097
1.5	0.5	1.15	0.78	1.57	0.79	0.170	1.46	1.24	1.66	0.42	0.090	1.01	0.80	1.25	0.45	0.097	0.89	0.65	1.13	0.48	0.103
0.5	0.5	1.67	1.07	2.03	0.96	0.207	1.43	1.14	1.77	0.64	0.137	1.12	0.91	1.39	0.48	0.104	0.75	0.52	1.08	0.56	0.121
0.0	1.0	1.25	0.77	1.78	1.01	0.217	0.82	0.54	1.20	0.66	0.141	0.65	0.38	0.92	0.54	0.116	0.67	0.39	0.96	0.57	0.123
1.0	1.0	1.32	0.86	1.82	0.96	0.206	0.81	0.58	1.08	0.49	0.107	0.68	0.47	0.84	0.37	0.080	0.66	0.43	0.94	0.51	0.110
2.0	1.0	1.63	1.26	1.92	0.66	0.141	0.87	0.67	1.13	0.46	0.099	0.69	0.48	0.91	0.43	0.092	0.79	0.59	1.02	0.43	0.093
3.0	1.0	1.29	0.89	1.70	0.82	0.176	0.84	0.65	1.12	0.47	0.101	0.96	0.76	1.17	0.41	0.087	0.89	0.65	1.15	0.50	0.107
4.0	1.0	1.62	1.27	1.86	0.59	0.128	1.11	0.85	1.39	0.54	0.117	0.68	0.48	0.93	0.46	0.098	0.51	0.28	0.72	0.43	0.093
5.0	1.0	1.25	0.88	1.78	0.90	0.193	0.90	0.64	1.18	0.54	0.116	1.08	0.78	1.35	0.57	0.122	1.05	0.80	1.34	0.54	0.117
4.5	1.5	1.77	1.55	1.99	0.44	0.094	0.81	0.55	1.20	0.64	0.139	0.44	0.28	0.62	0.35	0.075	0.43	0.27	0.74	0.47	0.101
3.5	1.5	1.72	1.24	2.09	0.85	0.184	0.50	0.29	0.75	0.46	0.099	0.46	0.23	1.74	1.51	0.325	0.45	0.19	0.67	0.48	0.103
2.5	1.5	1.49	1.13	1.81	0.68	0.147	0.38	0.23	0.61	0.38	0.083	0.29	0.15	0.47	0.32	0.069	0.30	0.17	0.43	0.27	0.057
1.5	1.5	1.44	1.13	1.78	0.66	0.142	0.46	0.31	0.63	0.32	0.070	0.33	0.18	0.50	0.32	0.068	0.41	0.16	0.44	0.29	0.062
0.5	1.5	1.47	0.96	1.97	1.01	0.218	0.34	0.21	0.56	0.35	0.075	0.27	0.17	0.48	0.31	0.067	0.33	0.22	0.42	0.20	0.043
0.0	2.0	1.24	0.85	1.74	0.89	0.193	0.62	0.41	0.89	0.48	0.103	0.32	0.21	0.50	0.29	0.062	0.29	0.16	0.44	0.28	0.060
1.0	2.0	1.53	1.25	1.83	0.58	0.126	0.57	0.38	0.74	0.36	0.079	0.41	0.28	0.59	0.31	0.067	0.37	0.21	0.55	0.34	0.074
2.0	2.0	1.72	1.44	1.99	0.55	0.118	0.68	0.45	0.88	0.43	0.093	0.28	0.17	0.43	0.26	0.056	0.27	0.13	0.44	0.31	0.066
3.0	2.0	1.46	1.11	1.91	0.80	0.172	0.58	0.38	0.90	0.52	0.113	0.37	0.24	0.59	0.35	0.075	0.35	0.23	0.54	0.31	0.067
4.0	2.0	1.93	1.64	2.17	0.54	0.116	0.68	0.40	1.04	0.64	0.138	0.46	0.27	0.67	0.40	0.086	0.35	0.22	0.47	0.25	0.055
5.0	2.0	1.93	1.65	2.14	0.49	0.105	0.71	0.53	0.93	0.39	0.085	0.39	0.25	0.62	0.36	0.078	0.34	0.17	0.50	0.33	0.072
4.5	2.5	1.71	1.45	1.96	0.51	0.110	0.58	0.37	0.80	0.43	0.094	0.33	0.20	0.56	0.36	0.078	0.30	0.13	0.51	0.38	0.081
3.5	2.5	1.76	1.39	2.11	0.72	0.155	0.49	0.28	0.77	0.49	0.105	0.30	0.15	0.52	0.37	0.079	0.35	0.19	0.54	0.35	0.075
2.5	2.5	1.55	1.33	1.74	0.42	0.090	0.49	0.30	0.74	0.44	0.094	0.23	0.14	0.36	0.23	0.049	0.30	0.17	0.49	0.33	0.070
1.5	2.5	1.38	1.12	1.60	0.48	0.104	0.45	0.27	0.61	0.34	0.073	0.25	0.15	0.45	0.31	0.066	0.33	0.18	0.55	0.37	0.080
0.5	2.5	1.41	1.10	1.81	0.70	0.151	0.43	0.26	0.64	0.38	0.082	0.33	0.17	0.49	0.32	0.070	0.33	0.21	0.48	0.27	0.059
0.0	3.0	1.46	1.20	1.75	0.55	0.118	0.53	0.30	0.81	0.51	0.109	0.49	0.28	0.75	0.47	0.101	0.42	0.28	0.61	0.33	0.071
1.0	3.0	1.39	1.09	1.62	0.53	0.114	0.37	0.20	0.60	0.40	0.086	0.33	0.19	0.54	0.35	0.076	0.41	0.25	0.58	0.33	0.070
2.0	3.0	1.47	1.29	1.69	0.40	0.086	0.50	0.27	0.73	0.46	0.100	0.32	0.16	0.51	0.35	0.075	0.49	0.25	0.88	0.62	0.134
3.0	3.0	1.55	1.24	1.88	0.64	0.138	0.45	0.30	0.64	0.34	0.073	0.46	0.25	0.66	0.41	0.088	0.40	0.25	0.56	0.31	0.066
4.0	3.0	1.78	1.53	1.99	0.47	0.100	0.61	0.38	0.92	0.53	0.115	0.44	0.26	0.74	0.49	0.105	0.38	0.25	0.56	0.31	0.067
5.0	3.0	1.98	1.79	2.27	0.47	0.102	0.88	0.62	1.15	0.54	0.115	0.36	0.20	0.56	0.36	0.078	0.26	0.12	0.50	0.38	0.082
4.5	3.5	1.75	1.54	1.93	0.39	0.084	0.72	0.49	0.97	0.48	0.105	0.58	0.43	0.75	0.32	0.069	0.43	0.24	0.65	0.41	0.089
3.5	3.5	1.65	1.32	1.95	0.63	0.136	1.19	0.91	1.42	0.51	0.109	0.78	0.51	1.11	0.60	0.130	0.84	0.56	1.20	0.64	0.139
2.5	3.5	1.28	1.10	1.49	0.39	0.083	0.98	0.74	1.19	0.45	0.098	0.61	0.42	0.92	0.50	0.108	0.69	0.36	1.07	0.72	0.155
1.5	3.5	1.07	0.92	1.24	0.32	0.070	0.95	0.64	1.18	0.54	0.117	0.67	0.45	0.96	0.51	0.110	0.62	0.35	0.88	0.53	0.115
0.5	3.5	1.31	1.10	1.65	0.55	0.119	1.00	0.70	1.31	0.61	0.132	1.04	0.65	1.42	0.77	0.167	0.79	0.50	1.15	0.66	0.141
0.0	4.0	1.47	1.04	1.81	0.77	0.166	1.21	0.76	1.44	0.67	0.145	1.28	0.89	1.63	0.75	0.161	1.65	1.31	2.01	0.69	0.150
1.0	4.0	1.17	0.87	1.45	0.58	0.125	1.12	0.80	1.45	0.65	0.139	1.09	0.70	1.32	0.62	0.133	1.13	0.78	1.51	0.73	0.157
2.0	4.0	1.09	0.74	1.40	0.66	0.142	0.92	0.70	1.15	0.45	0.098	1.11	0.78	1.42	0.64	0.137	1.11	0.77	1.40	0.63	0.136
3.0	4.0	1.30	1.03	1.71	0.68	0.146	1.21	0.88	1.55	0.68	0.146	1.28	0.87	1.53	0.66	0.143	1.48	1.19	1.81	0.62	0.134
4.0	4.0	1.48	1.12	1.68	0.56	0.120	1.02	0.57	1.38	0.81	0.174	1.20	0.87	1.52	0.65	0.140	1.35	1.09	1.62	0.54	0.115
5.0	4.0	1.36	1.04	1.45	0.41	0.089	1.21	1.00	1.43	0.43	0.093	1.44	1.16	1.66	0.50	0.108	1.30	1.07	1.52	0.45	0.097
4.5	4.5	1.27	1.02	1.45	0.43	0.093	1.62	1.39	1.82	0.43	0.093	1.92	1.72	2.10	0.39	0.083	1.94	1.71	2.17	0.46	0.099
3.5	4.5	1.12	0.70	1.49	0.79	0.170	1.38	0.98	1.70	0.72	0.154	1.48	0.96	1.80	0.84	0.182	1.55	1.16	1.91	0.75	0.162
2.5	4.5	1.44	1.08	1.83	0.75	0.161	1.31	0.96	1.61	0.65	0.139	1.33	1.01	1.64	0.63	0.135	1.44	1.13	1.75	0.62	0.134
1.5	4.5	1.75	1.50	2.08	0.57	0.124	1.86	1.59	2.10	0.51	0.110	1.92	1.64	2.15	0.51	0.110	1.81	1.62	2.03	0.41	0.089
0.5	4.5	1.32	1.01	1.61	0.61	0.131	1.48	1.02	1.80	0.78	0.169	1.62	1.24	1.99	0.75	0.163	1.71	1.18	2.17	0.99	0.213
0.0	5.0	0.89	0.49	1.26	0.77	0.166	1.54	1.08	1.90	0.82	0.176	1.83	1.46	2.11	0.64	0.139	1.79	1.51	1.90	0.40	0.086
1.0	5.0	0.70	0.47	1.09	0.62	0.134	1.94	1.67	2.25	0.57	0.123	2.10	1.85	2.31	0.46	0.099	2.05	1.78	2.29	0.51	0.111
2.0	5.0	0.71	0.43	1.08	0.65	0.141	2.24	1.95	2.46	0.51	0.110	2.22	1.91	2.44	0.53	0.115	2.29	2.03	2.48	0.46	0.098
3.0	5.0	0.57	0.34	1.02	0.67	0.145	1.35	0.92	1.62	0.70	0.152	1.84	1.51	2.10	0.60	0.129	1.74	1.44	2.03	0.59	0.126
4.0	5.0	0.78	0.47	1.09	0.62	0.133	1.53	1.12	1.84	0.72	0.155	1.76	1.43	2.03	0.60	0.129	1.97	1.68	2.27	0.60	0.128
5.0	5.0	0.69	0.39	0.98	0.59	0.127	1.70	1.49	1.90	0.41	0.088	1.98	1.78	2.16	0.38	0.082	1.95	1.67	2.15	0.48	0.103
Averages		1.34	1.03	1.66	0.63	0.137	1.05	0.79	1.32	0.52	0.112	1.01	0.78	1.27	0.48	0.104	1.00	0.76	1.24	0.47	0.102

Table E.8: Fully loaded chiller with delta wings set at 25 degrees in first configuration - Air speed data for trial 1
Breed type loaded: Red deer

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)
0.0	0.0	0.69	0.59	0.93	0.35	0.115	1.66	1.56	1.79	0.23	0.076	1.81	1.58	1.95	0.37	0.119	1.88	1.77	2.05	0.28	0.091
1.0	0.0	1.14	1.00	1.28	0.28	0.093	1.65	1.57	1.75	0.18	0.054	1.93	1.87	2.04	0.17	0.059	1.72	1.59	1.81	0.22	0.076
2.0	0.0	0.76	0.35	0.98	0.63	0.203	1.50	1.41	1.72	0.31	0.103	1.80	1.70	1.90	0.20	0.064	1.84	1.72	1.96	0.24	0.077
3.0	0.0	0.59	0.43	0.80	0.37	0.118	1.39	1.25	1.54	0.29	0.091	1.74	1.60	1.83	0.23	0.071	1.84	1.76	1.95	0.19	0.059
4.0	0.0	0.90	0.80	0.98	0.18	0.056	1.59	1.53	1.68	0.15	0.051	1.73	1.64	1.82	0.18	0.062	1.69	1.55	1.82	0.27	0.090
5.0	0.0	0.39	0.28	0.64	0.35	0.117	1.27	1.08	1.43	0.35	0.110	1.61	1.39	1.75	0.36	0.112	1.11	0.72	1.28	0.56	0.179
4.5	0.5	1.44	1.29	1.62	0.33	0.112	1.39	1.17	1.53	0.36	0.118	0.83	0.60	1.01	0.41	0.129	1.12	0.92	1.33	0.41	0.132
3.5	0.5	0.94	0.49	1.21	0.72	0.232	1.74	1.46	1.93	0.47	0.153	1.47	1.39	1.59	0.20	0.062	1.39	1.18	1.59	0.41	0.134
2.5	0.5	1.44	1.29	1.61	0.32	0.108	1.86	1.63	2.03	0.40	0.130	1.65	1.47	1.79	0.32	0.107	1.17	0.94	1.32	0.38	0.126
1.5	0.5	1.07	0.84	1.30	0.46	0.154	1.23	1.07	1.34	0.27	0.084	0.96	0.85	1.07	0.22	0.072	1.23	1.15	1.34	0.19	0.059
0.5	0.5	1.41	1.27	1.56	0.29	0.094	1.42	1.33	1.52	0.19	0.062	1.12	0.99	1.24	0.25	0.085	0.72	0.65	0.81	0.17	0.056
0.0	1.0	1.04	0.80	1.26	0.46	0.145	0.92	0.76	1.16	0.40	0.124	0.47	0.29	0.53	0.24	0.077	0.37	0.29	0.54	0.26	0.080
1.0	1.0	1.44	1.30	1.55	0.25	0.079	0.56	0.45	0.69	0.24	0.078	0.48	0.40	0.54	0.14	0.045	0.32	0.21	0.50	0.30	0.098
2.0	1.0	1.51	1.31	1.73	0.42	0.136	0.85	0.59	1.05	0.46	0.149	0.35	0.25	0.48	0.23	0.075	0.42	0.23	0.62	0.39	0.129
3.0	1.0	1.30	1.09	1.48	0.39	0.129	1.00	0.86	1.12	0.26	0.087	0.81	0.57	0.98	0.41	0.133	0.77	0.66	0.95	0.30	0.100
4.0	1.0	1.50	1.26	1.75	0.49	0.156	1.01	0.85	1.10	0.25	0.082	0.75	0.68	0.83	0.15	0.050	0.75	0.64	0.86	0.22	0.070
5.0	1.0	0.85	0.43	1.16	0.73	0.241	0.92	0.47	1.16	0.69	0.222	1.03	0.77	1.18	0.41	0.131	0.95	0.75	1.10	0.35	0.112
4.5	1.5	1.61	1.46	1.73	0.27	0.083	0.77	0.68	0.94	0.25	0.081	0.43	0.34	0.54	0.20	0.067	0.41	0.32	0.54	0.22	0.074
3.5	1.5	1.21	1.00	1.43	0.43	0.145	0.38	0.31	0.46	0.16	0.048	0.39	0.17	0.51	0.34	0.107	0.33	0.23	0.53	0.30	0.102
2.5	1.5	1.71	1.49	1.97	0.48	0.152	0.35	0.19	0.57	0.38	0.128	0.30	0.16	0.39	0.23	0.077	0.42	0.37	0.51	0.14	0.049
1.5	1.5	1.29	1.10	1.46	0.36	0.115	0.28	0.22	0.32	0.10	0.036	0.47	0.16	0.26	0.11	0.034	0.22	0.11	0.29	0.18	0.055
0.5	1.5	1.62	1.52	1.86	0.34	0.115	0.29	0.25	0.33	0.08	0.025	0.49	0.15	0.25	0.10	0.028	0.25	0.15	0.42	0.27	0.089
0.0	2.0	1.16	1.04	1.32	0.28	0.089	0.65	0.60	0.71	0.11	0.035	0.53	0.43	0.59	0.16	0.053	0.37	0.22	0.46	0.23	0.072
1.0	2.0	1.46	1.36	1.59	0.23	0.072	0.51	0.50	0.64	0.14	0.044	0.42	0.31	0.54	0.23	0.077	0.36	0.30	0.44	0.14	0.042
2.0	2.0	1.62	1.47	1.72	0.25	0.078	0.65	0.51	0.86	0.35	0.110	0.43	0.33	0.51	0.17	0.053	0.40	0.26	0.69	0.44	0.142
3.0	2.0	1.46	1.20	1.71	0.51	0.164	0.99	0.78	1.18	0.40	0.127	0.26	0.18	0.38	0.20	0.068	0.35	0.22	0.46	0.24	0.077
4.0	2.0	1.58	1.39	1.70	0.31	0.104	0.48	0.36	0.56	0.20	0.060	0.67	0.50	0.83	0.32	0.110	0.39	0.28	0.53	0.25	0.085
5.0	2.0	1.57	1.31	1.81	0.50	0.160	0.56	0.53	0.60	0.08	0.022	0.42	0.38	0.48	0.10	0.036	0.37	0.29	0.53	0.24	0.075
4.5	2.5	1.55	1.46	1.64	0.18	0.056	0.54	0.47	0.58	0.11	0.035	0.36	0.28	0.64	0.36	0.116	0.31	0.22	0.48	0.26	0.081
3.5	2.5	1.10	0.81	1.42	0.62	0.199	0.30	0.17	0.39	0.22	0.072	0.33	0.15	0.46	0.30	0.100	0.65	0.42	0.84	0.42	0.138
2.5	2.5	1.57	1.24	1.87	0.63	0.203	0.38	0.24	0.58	0.34	0.106	0.57	0.35	0.82	0.48	0.153	0.37	0.17	0.59	0.42	0.136
1.5	2.5	1.19	1.11	1.31	0.20	0.064	0.71	0.37	0.84	0.46	0.151	0.50	0.36	0.60	0.24	0.076	0.59	0.43	0.84	0.41	0.132
0.5	2.5	1.53	1.43	1.67	0.24	0.082	0.43	0.31	0.55	0.25	0.080	0.49	0.26	0.69	0.44	0.141	0.34	0.24	0.39	0.15	0.046
0.0	3.0	1.26	1.07	1.47	0.40	0.127	0.82	0.65	1.00	0.35	0.113	0.74	0.51	1.04	0.53	0.177	0.68	0.44	0.89	0.45	0.152
1.0	3.0	1.06	1.32	1.66	0.28	0.095	0.34	0.25	0.46	0.21	0.072	0.30	0.17	0.47	0.30	0.099	0.38	0.19	0.54	0.34	0.116
2.0	3.0	1.45	1.32	1.60	0.28	0.086	0.73	0.40	0.93	0.53	0.172	0.61	0.47	0.71	0.24	0.080	0.87	0.61	1.22	0.61	0.196
3.0	3.0	1.23	1.09	1.41	0.32	0.106	0.39	0.27	0.52	0.25	0.081	0.66	0.38	0.84	0.46	0.145	0.92	0.69	1.31	0.62	0.200
4.0	3.0	1.38	1.17	1.48	0.31	0.105	0.33	0.27	0.38	0.11	0.039	0.56	0.35	0.72	0.37	0.120	0.34	0.24	0.43	0.20	0.067
5.0	3.0	1.54	1.40	1.75	0.35	0.118	0.60	0.44	0.78	0.34	0.113	0.34	0.24	0.47	0.23	0.078	0.25	0.19	0.31	0.12	0.039
4.5	3.5	1.18	1.03	1.40	0.37	0.115	0.48	0.38	0.63	0.26	0.086	0.69	0.39	0.84	0.45	0.149	0.47	0.26	0.72	0.46	0.151
3.5	3.5	1.14	1.00	1.25	0.25	0.085	1.39	1.16	1.64	0.48	0.157	0.71	0.58	0.78	0.20	0.064	1.01	0.81	1.20	0.40	0.129
2.5	3.5	1.33	1.13	1.54	0.41	0.135	1.25	1.01	1.41	0.40	0.130	1.36	1.13	1.52	0.39	0.130	0.71	0.42	0.95	0.52	0.165
1.5	3.5	1.05	0.97	1.18	0.22	0.066	1.08	1.00	1.17	0.17	0.051	1.00	0.71	1.14	0.43	0.136	1.22	0.80	1.85	1.05	0.340
0.5	3.5	1.08	0.95	1.22	0.27	0.083	1.33	1.20	1.49	0.29	0.094	1.09	0.86	1.23	0.37	0.117	0.69	0.58	0.85	0.27	0.091
0.0	4.0	1.38	1.12	1.62	0.50	0.158	0.76	0.59	0.95	0.37	0.118	1.30	0.93	1.50	0.57	0.189	1.62	1.31	1.91	0.60	0.189
1.0	4.0	1.16	0.97	1.46	0.49	0.157	0.88	0.68	1.11	0.43	0.133	1.16	0.96	1.43	0.47	0.155	1.03	0.88	1.27	0.39	0.127
2.0	4.0	0.86	0.74	0.96	0.22	0.069	0.54	0.28	0.75	0.46	0.150	0.84	0.63	1.04	0.41	0.132	1.00	0.60	1.35	0.75	0.240
3.0	4.0	0.89	0.75	1.22	0.47	0.147	1.08	0.88	1.29	0.41	0.136	0.87	0.66	1.10	0.44	0.143	1.63	1.48	1.76	0.28	0.089
4.0	4.0	1.16	0.96	1.32	0.36	0.119	0.94	0.57	1.22	0.65	0.209	0.74	0.58	0.96	0.38	0.123	0.68	0.50	0.91	0.41	0.130
5.0	4.0	1.26	1.10	1.44	0.34	0.109	0.86	0.62	1.12	0.50	0.163	0.92	0.76	1.10	0.34	0.107	1.20	0.91	1.57	0.66	0.210
4.5	4.5	1.27	1.06	1.40	0.34	0.110	1.58	1.27	1.80	0.53	0.176	1.66	1.38	1.79	0.41	0.136	1.40	1.16	1.61	0.45	0.145
3.5	4.5	1.05	0.71	1.27	0.56	0.181	1.39	1.12	1.48	0.36	0.117	1.34	1.12	1.56	0.44	0.147	1.29	1.09	1.44	0.35	0.110
2.5	4.5	0.89	0.69	1.11	0.42	0.140	0.27	0.17	0.42	0.25	0.076	0.46	0.30	0.64	0.34	0.115	0.57	0.36	0.87	0.50	0.168
1.5	4.5	1.16	0.86	1.33	0.47	0.147	1.08	0.92	1.37	0.45	0.143	1.32	1.11	1.47	0.36	0.117	1.47	1.29	1.65	0.36	0.117
0.5	4.5	1.24	1.09	1.30	0.21	0.063	1.46	1.34	1.57	0.23	0.073	1.55	1.22	1.70	0.48	0.159	1.69	1.55	1.78	0.23	0.070
0.0	5.0	0.75	0.45	1.05	0.60	0.195	1.41	1.32	1.59	0.27	0.092	1.53	1.32	1.73	0.41	0.130	1.63	1.23	1.91	0.68	0.215
1.0	5.0	0.60	0.35	1.02	0.67	0.214	1.41	1.29	1.59	0.30	0.094	1.74	1.48	1.87	0.39	0.130	1.49	1.33	1.75	0.42	0.136
2.0	5.0	1.08	0.59	1.38	0.79	0.252	1.62	1.38	1.84	0.46	0.145	1.51	1.30	1.71	0.41	0.135	1.11	0.83	1.34	0.51	0.166
3.0	5.0	0.55	0.40	0.85	0.46	0.149	0.76	0.43	1.07	0.64	0.210	1.52	1.21	1.76	0.55	0.173	1.28	1.09	1.45	0.36	0.117
4.0	5.0	1.17	1.04	1.22	0.18	0.061	1.46	1.39	1.66	0.27	0.085	1.69	1.59	1.80	0.21	0.064	1.88	1.76	2.00	0.24	0.081
5.0	5.0	1.03	0.53	1.30	0.77	0.245	1.67	1.53	1.85	0.32	0.103	1.92	1.81	2.08	0.27	0.092	1.99	1.80	2.12	0.32	0.107
Averages:		1.19	1.00	1.40	0.40	0.128	0.95	0.79	1.11	0.32	0.103	0.95	0.77	1.08	0.32	0.103	0.92	0.74	1.10	0.36	0.117

Table E.9: Fully loaded chiller with delta wings set at 25 degrees in first configuration - Air speed data for trial 2
Breed type loaded: Red deer

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)
0.0	0.0	0.71	0.59	1.05	0.47	0.152	1.46	1.21	1.64	0.43	0.141	1.52	1.31	1.64	0.33	0.111	1.44	1.23	1.64	0.41	0.131
1.0	0.0	1.05	0.86	1.15	0.29	0.088	1.73	1.56	1.85	0.29	0.098	1.96	1.87	2.03	0.16	0.047	2.01	1.99	2.07	0.08	0.028
2.0	0.0	0.80	0.32	1.02	0.70	0.232	1.50	1.39	1.61	0.22	0.074	1.80	1.66	1.90	0.24	0.074	1.75	1.68	1.88	0.20	0.070
3.0	0.0	0.62	0.42	0.86	0.44	0.146	1.42	1.27	1.58	0.31	0.100	1.78	1.57	2.01	0.44	0.145	1.74	1.60	1.87	0.27	0.085
4.0	0.0	0.86	0.78	1.06	0.28	0.094	1.57	1.38	1.71	0.33	0.105	1.85	1.76	2.01	0.25	0.082	1.88	1.81	1.91	0.10	0.035
5.0	0.0	0.42	0.26	0.68	0.42	0.136	1.33	1.17	1.49	0.32	0.108	1.54	1.39	1.78	0.39	0.122	1.16	0.85	1.42	0.57	0.182
4.5	0.5	1.39	1.12	1.58	0.46	0.149	0.71	0.58	0.90	0.32	0.107	0.61	0.50	0.81	0.31	0.103	0.84	0.54	1.06	0.52	0.172
3.5	0.5	0.77	0.44	1.23	0.79	0.258	1.40	1.33	1.56	0.23	0.070	1.14	0.99	1.20	0.21	0.065	0.55	0.42	0.75	0.33	0.108
2.5	0.5	1.35	1.11	1.52	0.40	0.128	1.59	1.42	1.79	0.37	0.116	1.65	1.54	1.80	0.26	0.087	1.02	0.79	1.15	0.36	0.117
1.5	0.5	1.02	0.81	1.30	0.48	0.158	1.34	1.08	1.58	0.50	0.162	0.98	0.86	1.06	0.20	0.066	0.30	0.21	0.43	0.22	0.076
0.5	0.5	1.31	1.13	1.89	0.76	0.248	1.37	1.16	1.46	0.30	0.092	0.48	0.38	0.63	0.25	0.079	0.74	0.63	0.90	0.27	0.091
0.0	1.0	1.02	0.73	1.71	0.98	0.313	0.86	0.76	1.00	0.24	0.080	0.73	0.60	0.97	0.37	0.121	0.44	0.26	0.58	0.33	0.103
1.0	1.0	1.41	1.18	1.64	0.46	0.144	0.60	0.50	0.73	0.23	0.072	0.48	0.37	0.69	0.32	0.101	0.63	0.41	0.79	0.38	0.120
2.0	1.0	1.44	1.12	1.68	0.56	0.179	0.48	0.31	0.71	0.40	0.135	0.40	0.29	0.51	0.22	0.074	0.57	0.34	0.83	0.49	0.157
3.0	1.0	1.34	0.88	1.44	0.55	0.182	0.98	0.90	1.05	0.15	0.051	0.37	0.30	0.51	0.21	0.068	0.81	0.73	0.87	0.13	0.047
4.0	1.0	1.44	1.15	2.05	0.91	0.296	0.85	0.73	0.98	0.25	0.080	0.77	0.74	0.86	0.12	0.038	0.34	0.26	0.43	0.16	0.055
5.0	1.0	0.94	0.35	1.51	1.15	0.374	0.51	0.41	0.64	0.23	0.077	0.48	0.32	0.68	0.36	0.116	0.52	0.30	0.72	0.42	0.133
4.5	1.5	1.56	1.25	1.79	0.54	0.176	0.99	0.78	1.16	0.38	0.121	0.70	0.53	0.90	0.37	0.116	0.47	0.37	0.53	0.16	0.051
3.5	1.5	1.31	1.09	1.61	0.52	0.174	0.21	0.12	0.36	0.24	0.081	0.59	0.26	0.72	0.46	0.147	0.36	0.19	0.60	0.40	0.134
2.5	1.5	1.41	1.53	2.08	0.55	0.178	0.29	0.30	0.83	0.53	0.170	0.39	0.19	0.53	0.35	0.109	0.30	0.25	0.46	0.20	0.069
1.5	1.5	1.37	1.15	1.55	0.40	0.133	0.20	0.06	0.40	0.34	0.113	0.32	0.18	0.43	0.24	0.082	0.22	0.11	0.33	0.22	0.071
0.5	1.5	1.68	1.52	1.95	0.43	0.141	0.31	0.17	0.42	0.26	0.085	0.66	0.22	0.90	0.68	0.220	0.21	0.13	0.36	0.22	0.068
0.0	2.0	1.18	0.97	1.40	0.43	0.139	0.80	0.62	1.11	0.50	0.164	0.84	0.67	0.98	0.31	0.102	0.41	0.26	0.60	0.34	0.109
1.0	2.0	1.42	1.33	1.65	0.33	0.107	0.59	0.38	1.01	0.63	0.202	0.44	0.11	0.73	0.62	0.196	0.28	0.22	0.44	0.22	0.074
2.0	2.0	1.70	1.37	1.77	0.41	0.134	0.77	0.61	1.01	0.39	0.132	0.61	0.46	0.87	0.41	0.129	0.31	0.14	0.53	0.40	0.132
3.0	2.0	1.55	1.22	1.81	0.59	0.187	0.80	0.51	1.03	0.52	0.171	0.47	0.22	0.77	0.55	0.182	0.39	0.04	0.59	0.54	0.179
4.0	2.0	1.59	1.38	1.84	0.46	0.149	0.35	0.17	0.53	0.36	0.115	0.65	0.39	0.88	0.49	0.162	0.41	0.26	0.57	0.31	0.100
5.0	2.0	1.56	1.17	1.82	0.65	0.205	0.69	0.52	0.87	0.35	0.110	0.46	0.31	0.78	0.47	0.150	0.28	0.22	0.62	0.41	0.132
4.5	2.5	1.54	1.46	1.69	0.23	0.079	0.85	0.71	1.04	0.33	0.106	0.39	0.17	0.70	0.54	0.172	0.26	0.12	0.48	0.36	0.120
3.5	2.5	1.25	0.87	1.55	0.68	0.220	0.26	0.10	0.55	0.46	0.145	0.40	0.11	0.79	0.68	0.221	0.49	0.34	0.65	0.31	0.099
2.5	2.5	1.63	1.21	1.99	0.78	0.255	0.37	0.15	0.61	0.46	0.148	0.36	0.18	0.56	0.38	0.121	0.34	0.13	0.67	0.53	0.171
1.5	2.5	1.26	1.05	1.38	0.33	0.110	0.43	0.08	0.68	0.60	0.198	0.32	0.21	0.47	0.26	0.087	0.46	0.17	0.77	0.60	0.190
0.5	2.5	1.49	1.20	1.76	0.56	0.181	0.36	-0.11	0.53	0.63	0.202	0.47	0.19	0.62	0.43	0.135	0.30	0.15	0.49	0.34	0.107
0.0	3.0	1.32	0.94	1.59	0.65	0.208	0.80	0.56	1.05	0.49	0.157	0.81	0.21	1.11	0.90	0.290	0.62	0.18	0.88	0.69	0.229
1.0	3.0	1.16	1.25	1.74	0.49	0.163	0.60	0.27	0.69	0.42	0.139	0.26	0.05	0.48	0.43	0.137	0.35	0.17	0.58	0.42	0.138
2.0	3.0	1.40	1.20	1.55	0.34	0.108	0.62	0.41	0.90	0.48	0.158	0.50	0.24	0.69	0.45	0.141	0.73	0.37	1.12	0.75	0.241
3.0	3.0	1.19	1.00	1.46	0.46	0.152	0.72	0.43	1.02	0.59	0.192	0.63	0.20	0.94	0.74	0.237	0.80	0.02	1.28	1.26	0.413
4.0	3.0	1.30	0.91	1.45	0.54	0.174	0.27	0.21	0.46	0.25	0.083	0.55	0.25	1.44	1.19	0.383	0.47	0.18	0.68	0.50	0.162
5.0	3.0	1.39	1.30	1.83	0.53	0.170	0.65	0.55	0.98	0.43	0.144	0.27	0.19	0.41	0.22	0.070	0.23	-0.06	0.45	0.51	0.161
4.5	3.5	1.29	0.97	1.58	0.60	0.191	0.54	0.09	0.82	0.73	0.241	0.73	0.48	0.95	0.47	0.155	0.43	0.22	0.82	0.60	0.190
3.5	3.5	1.06	0.96	1.36	0.40	0.125	1.31	1.00	1.66	0.66	0.218	1.07	0.80	1.25	0.45	0.147	0.99	0.59	1.31	0.71	0.236
2.5	3.5	1.28	0.81	1.60	0.80	0.258	1.15	0.84	1.56	0.72	0.230	1.12	0.91	1.35	0.44	0.145	0.65	0.33	1.04	0.71	0.233
1.5	3.5	1.04	0.96	1.28	0.32	0.105	1.05	0.97	1.27	0.31	0.100	1.15	0.77	1.86	1.09	0.349	0.99	0.66	1.90	1.24	0.401
0.5	3.5	1.17	0.91	1.29	0.38	0.120	1.28	1.20	1.58	0.38	0.120	1.12	0.82	1.67	0.84	0.275	0.72	0.44	1.09	0.65	0.212
0.0	4.0	1.19	1.01	1.62	0.61	0.200	0.95	0.48	1.19	0.71	0.232	1.24	0.76	1.61	0.85	0.281	1.57	1.29	1.85	0.56	0.185
1.0	4.0	1.22	0.95	1.83	0.88	0.288	1.10	0.90	1.67	0.77	0.247	1.06	0.36	1.59	1.24	0.398	1.02	0.73	1.37	0.64	0.207
2.0	4.0	0.95	0.73	1.03	0.30	0.097	0.53	0.24	0.83	0.59	0.191	0.89	0.61	1.22	0.61	0.199	0.92	0.59	1.30	0.72	0.234
3.0	4.0	0.90	0.71	1.33	0.62	0.203	0.79	0.59	1.16	0.57	0.184	1.00	0.51	1.39	0.88	0.289	1.53	1.24	1.82	0.58	0.189
4.0	4.0	1.19	0.85	1.33	0.49	0.153	1.08	0.69	1.36	0.66	0.210	0.89	0.52	1.19	0.67	0.211	0.86	0.56	1.10	0.54	0.170
5.0	4.0	1.09	1.02	1.43	0.41	0.134	1.12	0.72	1.37	0.65	0.212	1.15	0.83	1.45	0.62	0.198	1.31	1.02	1.64	0.63	0.206
4.5	4.5	1.25	0.95	1.41	0.46	0.145	1.36	1.16	1.80	0.64	0.206	1.45	1.26	1.70	0.44	0.141	1.42	1.08	1.69	0.61	0.198
3.5	4.5	1.09	0.69	1.38	0.69	0.225	1.39	0.83	1.59	0.76	0.241	1.32	1.01	1.50	0.49	0.161	1.19	0.92	1.39	0.46	0.154
2.5	4.5	0.94	0.66	1.58	0.91	0.294	0.34	0.14	0.57	0.44	0.142	0.50	0.29	0.73	0.43	0.139	0.90	0.37	1.01	0.63	0.210
1.5	4.5	1.11	0.72	1.39	0.67	0.217	1.20	1.04	1.66	0.61	0.201	1.42	1.08	1.68	0.60	0.195	1.47	1.01	1.75	0.74	0.244
0.5	4.5	1.21	0.97	1.35	0.38	0.127	1.44	1.25	1.65	0.40	0.131	1.60	1.31	2.05	0.74	0.243	1.68	1.48	1.93	0.45	0.144
0.0	5.0	0.85	0.51	1.15	0.65	0.213	1.31	1.02	1.71	0.69	0.218	1.48	1.27	1.73	0.46	0.144	1.56	1.09	1.80	0.71	0.225
1.0	5.0	0.71	0.44	1.22	0.78	0.247	1.47	1.12	1.75	0.63	0.199	1.66	1.43	1.85	0.42	0.136	1.53	1.32	1.85	0.53	0.171
2.0	5.0	0.82	0.39	1.16	0.77	0.247	1.58	1.36	1.84	0.48	0.156	1.62	1.40	1.79	0.39	0.121	1.42	1.09	1.66	0.57	0.184
3.0	5.0	0.60	0.37	1.06	0.70	0.229	0.89	0.36	1.25	0.89	0.283	1.59	1.25	1.89	0.64	0.211	1.18	0.88	1.46	0.59	0.190
4.0	5.0	0.92	0.78	1.02	0.24	0.073	1.51	1.33	1.76	0.44	0.140	1.63	1.41	1.82	0.41	0.129	1.91	1.73	2.13	0.39	0.131
5.0	5.0	0.93	0.43	1.33	0.90	0.289	1.75	1.49	2.07	0.58	0.184	1.90	1.75	2.23	0.47	0.158	1.96	1.77	2.17	0.40	0.135
Averages:		1.18	0.92	1.48	0.56	0.180	0.93	0.71	1.17	0.46	0.149	0.94	0.70	1.18	0.48	0.156	0.86	0.63	1.10	0.47	0.153

Table E.10: Fully loaded chiller with delta wings set at 25 degrees in first configuration 1 - Air speed data for trial 3
Breed type loaded: Red deer

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)
0.0	0.0	0.71	0.61	1.07	0.46	0.151	1.56	1.18	1.95	0.78	0.250	1.85	1.51	2.12	0.61	0.193	1.66	1.34	2.22	0.88	0.288
1.0	0.0	0.87	0.72	1.01	0.28	0.087	1.73	1.53	1.94	0.41	0.128	2.03	1.88	2.25	0.37	0.123	2.02	1.77	2.13	0.36	0.111
2.0	0.0	0.80	0.38	1.05	0.67	0.214	1.74	1.57	1.94	0.37	0.116	1.93	1.79	2.10	0.30	0.099	2.05	1.80	2.06	0.26	0.084
3.0	0.0	0.66	0.49	0.89	0.40	0.127	1.56	1.21	1.95	0.74	0.242	1.94	1.78	2.12	0.34	0.109	1.88	1.66	1.99	0.33	0.109
4.0	0.0	0.90	0.75	1.11	0.36	0.113	1.76	1.51	1.94	0.43	0.141	2.05	1.86	2.23	0.38	0.121	1.95	1.69	2.10	0.41	0.134
5.0	0.0	0.43	0.26	0.71	0.45	0.145	1.25	1.05	1.46	0.41	0.137	1.85	1.75	2.05	0.29	0.093	1.39	0.95	1.63	0.68	0.219
4.5	0.5	1.32	0.96	1.51	0.55	0.183	0.91	0.52	1.41	0.88	0.285	1.36	1.10	1.64	0.54	0.171	0.87	0.51	1.02	0.51	0.168
3.5	0.5	0.86	0.41	1.15	0.74	0.238	1.43	1.08	1.81	0.73	0.242	0.37	0.29	0.62	0.33	0.100	1.42	1.06	1.61	0.55	0.175
2.5	0.5	1.22	1.02	1.39	0.38	0.124	1.77	1.42	2.07	0.65	0.211	1.36	1.02	1.62	0.60	0.190	0.93	0.46	1.22	0.76	0.247
1.5	0.5	1.05	0.82	1.28	0.46	0.146	1.49	1.33	1.65	0.31	0.102	0.54	0.30	0.69	0.39	0.121	0.68	0.51	0.77	0.26	0.080
0.5	0.5	1.23	1.04	1.38	0.34	0.111	1.30	1.06	1.56	0.50	0.159	0.88	0.34	1.18	0.84	0.268	1.12	0.87	1.42	0.55	0.174
0.0	1.0	0.99	0.66	1.26	0.60	0.190	0.67	0.50	0.76	0.25	0.084	1.02	0.85	1.20	0.35	0.115	0.91	0.46	1.14	0.68	0.218
1.0	1.0	1.32	1.10	1.65	0.55	0.177	0.67	0.47	0.76	0.28	0.087	0.95	0.77	1.05	0.28	0.090	0.86	0.52	0.95	0.43	0.134
2.0	1.0	1.41	1.14	1.64	0.50	0.158	1.33	1.06	1.66	0.60	0.192	0.76	0.60	1.00	0.40	0.133	0.51	0.29	0.72	0.43	0.136
3.0	1.0	1.21	0.80	1.40	0.60	0.194	1.35	0.99	1.68	0.69	0.220	1.10	0.90	1.29	0.39	0.126	1.11	1.00	1.16	0.16	0.049
4.0	1.0	1.48	1.07	1.74	0.68	0.216	1.29	0.92	1.69	0.77	0.246	0.99	0.76	1.09	0.34	0.107	0.75	0.60	0.86	0.26	0.083
5.0	1.0	0.99	0.51	1.48	0.97	0.311	0.79	0.34	1.04	0.70	0.227	0.83	0.58	1.05	0.47	0.158	0.71	0.47	0.88	0.41	0.136
4.5	1.5	1.55	1.30	1.70	0.40	0.131	1.36	1.18	1.77	0.60	0.195	0.54	0.29	0.84	0.55	0.172	0.28	0.16	0.43	0.27	0.090
3.5	1.5	1.42	1.18	1.78	0.59	0.191	0.22	0.08	0.42	0.34	0.112	0.41	0.30	0.55	0.24	0.083	0.23	0.16	0.37	0.21	0.068
2.5	1.5	1.84	1.60	2.19	0.59	0.186	0.66	0.45	1.05	0.60	0.194	0.17	0.03	0.26	0.23	0.072	0.19	0.15	0.29	0.14	0.045
1.5	1.5	1.46	1.24	1.65	0.40	0.126	0.12	0.02	0.27	0.25	0.077	0.26	0.02	0.31	0.29	0.092	0.23	0.16	0.29	0.13	0.047
0.5	1.5	1.72	1.61	2.03	0.42	0.140	0.35	0.16	0.46	0.30	0.094	0.32	0.16	0.45	0.29	0.096	0.18	0.02	0.29	0.27	0.088
0.0	2.0	1.23	0.90	1.46	0.56	0.179	1.32	1.06	1.50	0.44	0.142	1.22	1.05	1.42	0.37	0.122	0.48	0.30	0.72	0.42	0.139
1.0	2.0	1.51	1.39	1.65	0.26	0.082	0.72	0.28	1.02	0.73	0.235	0.49	0.13	0.76	0.63	0.204	0.20	0.16	0.29	0.13	0.038
2.0	2.0	1.62	1.47	1.73	0.26	0.088	0.95	0.76	1.18	0.42	0.140	0.82	0.62	1.04	0.42	0.134	0.21	0.02	0.35	0.33	0.104
3.0	2.0	1.54	1.25	1.87	0.63	0.201	0.66	0.35	0.82	0.47	0.151	0.71	0.46	1.05	0.59	0.187	0.45	0.21	0.67	0.46	0.145
4.0	2.0	1.59	1.40	1.72	0.32	0.107	0.23	0.15	0.44	0.29	0.092	0.67	0.43	0.94	0.51	0.162	0.45	0.30	0.56	0.26	0.081
5.0	2.0	1.57	1.30	1.82	0.52	0.165	0.86	0.59	1.20	0.61	0.192	0.52	0.30	0.74	0.44	0.142	0.20	0.16	0.33	0.17	0.053
4.5	2.5	1.59	1.46	1.72	0.27	0.091	1.21	1.00	1.49	0.49	0.164	0.43	0.16	0.74	0.59	0.187	0.21	0.10	0.45	0.35	0.114
3.5	2.5	1.32	0.93	1.67	0.74	0.240	0.15	0.02	0.27	0.25	0.084	0.50	0.17	0.76	0.59	0.195	0.35	0.30	0.44	0.14	0.042
2.5	2.5	1.63	1.30	1.93	0.63	0.204	0.39	0.16	0.67	0.51	0.168	0.17	0.02	0.30	0.28	0.094	0.33	0.16	0.73	0.57	0.186
1.5	2.5	1.29	1.17	1.41	0.24	0.072	0.21	0.05	0.45	0.40	0.127	0.26	0.16	0.44	0.28	0.093	0.36	0.16	0.70	0.54	0.178
0.5	2.5	1.46	1.18	1.80	0.61	0.195	0.29	0.16	0.50	0.35	0.108	0.69	0.30	0.90	0.60	0.191	0.27	0.09	0.51	0.42	0.132
0.0	3.0	1.39	1.16	1.66	0.50	0.164	0.78	0.60	0.93	0.34	0.113	0.93	0.68	1.19	0.50	0.163	0.61	0.06	0.86	0.80	0.258
1.0	3.0	1.19	1.29	1.85	0.56	0.182	0.76	0.45	0.92	0.47	0.155	0.23	0.16	0.35	0.19	0.061	0.37	0.16	0.58	0.42	0.137
2.0	3.0	1.26	1.12	1.49	0.37	0.118	0.63	0.45	0.90	0.45	0.142	0.41	0.05	0.66	0.61	0.198	0.62	0.16	0.97	0.81	0.263
3.0	3.0	1.13	0.92	1.33	0.42	0.139	1.06	0.81	1.41	0.60	0.191	0.63	0.37	0.97	0.60	0.191	0.74	0.40	1.25	0.85	0.278
4.0	3.0	1.28	0.90	1.42	0.52	0.169	0.26	0.16	0.55	0.39	0.129	0.56	0.34	0.86	0.52	0.169	0.65	0.24	0.86	0.62	0.196
5.0	3.0	1.36	1.20	1.70	0.50	0.163	0.93	0.70	1.20	0.49	0.158	0.21	0.16	0.30	0.15	0.050	0.22	0.02	0.49	0.47	0.156
4.5	3.5	1.20	1.02	1.52	0.50	0.166	0.62	0.40	1.05	0.65	0.211	0.82	0.62	1.11	0.49	0.158	0.41	0.19	0.63	0.44	0.145
3.5	3.5	1.18	1.03	1.40	0.37	0.117	1.28	0.91	1.65	0.73	0.235	1.49	1.16	1.80	0.64	0.208	1.02	0.41	1.41	1.00	0.327
2.5	3.5	1.24	0.98	1.51	0.53	0.168	1.18	0.90	1.44	0.53	0.178	0.93	0.72	1.15	0.43	0.138	0.62	0.42	1.14	0.72	0.234
1.5	3.5	1.08	0.99	1.25	0.26	0.087	1.16	0.94	1.36	0.42	0.135	1.35	1.05	1.74	0.69	0.226	0.77	0.47	1.13	0.66	0.210
0.5	3.5	1.07	0.90	1.31	0.42	0.132	1.54	1.26	1.69	0.43	0.135	1.22	1.05	1.78	0.73	0.239	0.78	0.34	1.26	0.92	0.298
0.0	4.0	1.19	0.93	1.49	0.56	0.185	1.19	0.95	1.46	0.50	0.160	1.27	0.76	1.80	1.05	0.335	1.62	1.35	1.79	0.44	0.141
1.0	4.0	1.16	0.94	1.47	0.54	0.171	1.42	1.18	1.70	0.52	0.165	1.08	0.49	1.50	1.01	0.322	1.06	0.66	1.47	0.81	0.266
2.0	4.0	0.97	0.73	1.08	0.35	0.113	0.54	0.23	0.90	0.67	0.217	1.00	0.69	1.47	0.78	0.250	0.88	0.67	1.19	0.52	0.164
3.0	4.0	0.96	0.75	1.30	0.54	0.174	0.53	0.30	1.04	0.73	0.233	1.18	0.78	1.76	0.99	0.318	1.48	1.06	1.88	0.82	0.268
4.0	4.0	1.06	0.78	1.22	0.44	0.138	1.28	1.05	1.51	0.46	0.144	1.08	0.60	1.47	0.87	0.281	1.09	0.68	1.27	0.59	0.191
5.0	4.0	1.12	0.94	1.32	0.37	0.122	1.47	1.08	1.63	0.55	0.177	1.46	1.04	1.76	0.72	0.238	1.47	1.19	1.67	0.48	0.157
4.5	4.5	1.24	1.01	1.42	0.41	0.130	1.41	1.18	1.63	0.45	0.145	1.51	1.27	1.69	0.42	0.138	1.59	1.40	1.73	0.33	0.108
3.5	4.5	1.12	0.67	1.36	0.69	0.228	1.35	0.95	1.77	0.82	0.266	1.33	0.97	1.51	0.55	0.174	1.12	0.79	1.29	0.50	0.167
2.5	4.5	0.99	0.73	1.22	0.49	0.162	0.44	0.17	0.77	0.60	0.189	0.57	0.30	0.85	0.55	0.180	1.00	0.51	1.14	0.63	0.200
1.5	4.5	1.05	0.74	1.22	0.48	0.160	1.38	1.23	1.73	0.50	0.161	1.60	1.27	1.85	0.58	0.185	1.57	1.05	1.81	0.76	0.250
0.5	4.5	1.16	0.94	1.23	0.30	0.098	1.49	1.29	1.80	0.51	0.161	1.72	1.48	1.94	0.46	0.148	1.82	1.51	2.06	0.55	0.180
0.0	5.0	0.87	0.57	1.19	0.62	0.206	1.26	0.79	1.65	0.86	0.276	1.54	1.28	1.79	0.51	0.164	1.46	1.03	1.65	0.62	0.198
1.0	5.0	0.82	0.56	1.27	0.71	0.235	1.60	1.22	1.79	0.58	0.189	1.68	1.49	1.87	0.38	0.119	1.65	1.38	1.78	0.40	0.123
2.0	5.0	0.62	0.27	0.92	0.65	0.214	1.62	1.46	1.85	0.39	0.123	1.83	1.61	2.14	0.54	0.176	1.81	1.42	1.94	0.52	0.165
3.0	5.0	0.55	0.36	1.27	0.91	0.298	1.07	0.90	1.29	0.39	0.123	1.75	1.42	2.12	0.70	0.228	1.16	0.76	1.34	0.58	0.192
4.0	5.0	0.72	0.57	0.79	0.22	0.069	1.65	1.49	1.94	0.45	0.142	1.66	1.47	1.86	0.39	0.125	2.01	1.79	2.16	0.37	0.120
5.0	5.0	0.91	0.41	1.18	0.77	0.246	1.91	1.59	2.25	0.65	0.215	2.18	1.94	2.40	0.46	0.148	2.03	1.84	2.13	0.29	0.095
Averages:		1.17	0.93	1.43	0.50	0.161	1.05	0.80	1.32	0.52	0.167	1.04	0.78	1.29	0.50	0.162	0.94	0.66	1.15	0.49	0.157

Table E.11: Fully loaded chiller with delta wings set at 25 degrees in first configuration
Average air speed data for trials 1-3

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)
0.0	0.0	0.70	0.59	1.02	0.42	0.139	1.56	1.32	1.79	0.48	0.155	1.73	1.47	1.90	0.44	0.141	1.66	1.45	1.97	0.52	0.170
1.0	0.0	1.02	0.86	1.14	0.28	0.089	1.70	1.55	1.85	0.29	0.093	1.97	1.87	2.12	0.23	0.077	1.92	1.78	2.00	0.22	0.071
2.0	0.0	0.79	0.35	1.01	0.67	0.216	1.58	1.46	1.76	0.30	0.098	1.84	1.72	1.97	0.25	0.079	1.88	1.73	1.97	0.23	0.077
3.0	0.0	0.62	0.45	0.85	0.40	0.130	1.46	1.24	1.69	0.45	0.145	1.82	1.65	1.99	0.34	0.108	1.82	1.67	1.94	0.26	0.084
4.0	0.0	0.89	0.78	1.05	0.27	0.088	1.64	1.47	1.78	0.30	0.099	1.88	1.75	2.02	0.27	0.088	1.84	1.68	1.94	0.26	0.086
5.0	0.0	0.42	0.27	0.68	0.41	0.133	1.28	1.10	1.46	0.36	0.118	1.67	1.51	1.86	0.35	0.109	1.22	0.84	1.44	0.60	0.193
4.5	0.5	1.38	1.12	1.57	0.45	0.148	1.06	0.76	1.28	0.52	0.170	0.93	0.73	1.15	0.42	0.134	0.94	0.66	1.14	0.48	0.158
3.5	0.5	0.85	0.45	1.20	0.75	0.243	1.52	1.29	1.77	0.48	0.155	0.99	0.89	1.14	0.25	0.076	1.12	0.89	1.32	0.43	0.139
2.5	0.5	1.34	1.14	1.51	0.37	0.120	1.74	1.49	1.96	0.47	0.152	1.55	1.34	1.74	0.39	0.128	1.04	0.73	1.23	0.50	0.163
1.5	0.5	1.05	0.82	1.29	0.47	0.153	1.35	1.16	1.52	0.36	0.116	0.83	0.67	0.94	0.27	0.087	0.74	0.63	0.85	0.22	0.071
0.5	0.5	1.32	1.15	1.61	0.46	0.151	1.36	1.18	1.51	0.33	0.105	0.83	0.57	1.01	0.45	0.144	0.86	0.71	1.04	0.33	0.107
0.0	1.0	1.02	0.73	1.41	0.68	0.216	0.82	0.68	0.97	0.29	0.096	0.74	0.58	0.90	0.32	0.104	0.57	0.33	0.75	0.42	0.134
1.0	1.0	1.39	1.19	1.61	0.42	0.133	0.61	0.47	0.73	0.25	0.079	0.64	0.51	0.76	0.25	0.079	0.60	0.38	0.75	0.37	0.118
2.0	1.0	1.45	1.19	1.68	0.49	0.158	0.88	0.65	1.14	0.49	0.159	0.50	0.38	0.66	0.28	0.094	0.50	0.29	0.72	0.44	0.141
3.0	1.0	1.28	0.92	1.44	0.51	0.168	1.11	0.92	1.28	0.37	0.119	0.76	0.59	0.93	0.34	0.109	0.89	0.80	0.99	0.20	0.066
4.0	1.0	1.47	1.16	1.85	0.69	0.223	1.05	0.84	1.26	0.42	0.136	0.83	0.73	0.93	0.20	0.065	0.61	0.50	0.71	0.21	0.069
5.0	1.0	0.93	0.43	1.38	0.95	0.309	0.74	0.40	0.95	0.54	0.175	0.78	0.56	0.97	0.41	0.135	0.73	0.50	0.90	0.40	0.127
4.5	1.5	1.57	1.34	1.74	0.40	0.130	1.04	0.88	1.29	0.41	0.132	0.56	0.39	0.76	0.37	0.118	0.39	0.28	0.50	0.22	0.072
3.5	1.5	1.31	1.09	1.61	0.52	0.170	0.27	0.17	0.41	0.24	0.080	0.46	0.24	0.59	0.35	0.112	0.31	0.19	0.50	0.31	0.101
2.5	1.5	1.65	1.54	2.08	0.54	0.172	0.43	0.31	0.82	0.50	0.164	0.28	0.12	0.39	0.27	0.086	0.30	0.26	0.42	0.16	0.054
1.5	1.5	1.37	1.16	1.55	0.39	0.124	0.20	0.10	0.33	0.23	0.075	0.35	0.12	0.33	0.21	0.069	0.22	0.12	0.30	0.18	0.058
0.5	1.5	1.67	1.55	1.95	0.40	0.132	0.32	0.19	0.41	0.21	0.068	0.49	0.17	0.53	0.36	0.114	0.22	0.10	0.36	0.25	0.082
0.0	2.0	1.19	0.97	1.39	0.42	0.136	0.92	0.76	1.11	0.35	0.114	0.86	0.72	1.00	0.28	0.092	0.42	0.26	0.59	0.33	0.107
1.0	2.0	1.46	1.36	1.63	0.27	0.087	0.61	0.39	0.89	0.50	0.160	0.45	0.18	0.67	0.49	0.159	0.28	0.23	0.39	0.17	0.051
2.0	2.0	1.65	1.43	1.74	0.31	0.100	0.79	0.62	1.01	0.39	0.128	0.62	0.47	0.80	0.33	0.105	0.31	0.14	0.53	0.39	0.126
3.0	2.0	1.52	1.22	1.80	0.57	0.184	0.82	0.55	1.01	0.47	0.150	0.48	0.29	0.74	0.45	0.146	0.40	0.16	0.57	0.41	0.134
4.0	2.0	1.59	1.39	1.75	0.36	0.120	0.36	0.22	0.51	0.28	0.089	0.66	0.44	0.88	0.44	0.145	0.42	0.28	0.55	0.27	0.088
5.0	2.0	1.57	1.26	1.82	0.56	0.177	0.70	0.55	0.89	0.34	0.108	0.47	0.33	0.67	0.34	0.109	0.28	0.22	0.50	0.27	0.087
4.5	2.5	1.56	1.46	1.68	0.23	0.075	0.87	0.73	1.04	0.31	0.102	0.39	0.20	0.69	0.49	0.158	0.26	0.15	0.47	0.32	0.105
3.5	2.5	1.22	0.87	1.55	0.68	0.220	0.24	0.10	0.40	0.31	0.101	0.41	0.14	0.67	0.52	0.172	0.50	0.36	0.64	0.29	0.093
2.5	2.5	1.61	1.25	1.93	0.68	0.221	0.38	0.18	0.62	0.44	0.141	0.37	0.18	0.56	0.38	0.123	0.35	0.15	0.66	0.51	0.165
1.5	2.5	1.25	1.11	1.37	0.26	0.082	0.45	0.17	0.66	0.49	0.159	0.36	0.24	0.50	0.26	0.085	0.47	0.25	0.77	0.52	0.166
0.5	2.5	1.49	1.27	1.74	0.47	0.153	0.36	0.12	0.53	0.41	0.130	0.55	0.25	0.74	0.49	0.155	0.30	0.16	0.46	0.30	0.095
0.0	3.0	1.32	1.06	1.57	0.52	0.166	0.80	0.60	0.99	0.39	0.127	0.83	0.47	1.11	0.64	0.210	0.64	0.23	0.88	0.65	0.213
1.0	3.0	1.54	1.29	1.73	0.44	0.147	0.56	0.32	0.69	0.37	0.122	0.27	0.12	0.43	0.31	0.099	0.37	0.17	0.57	0.39	0.130
2.0	3.0	1.37	1.22	1.55	0.33	0.104	0.66	0.42	0.91	0.49	0.157	0.51	0.25	0.69	0.43	0.140	0.74	0.38	1.10	0.73	0.233
3.0	3.0	1.18	1.00	1.40	0.40	0.132	0.72	0.50	0.98	0.48	0.155	0.64	0.32	0.91	0.60	0.191	0.82	0.37	1.28	0.91	0.297
4.0	3.0	1.32	0.99	1.45	0.46	0.149	0.29	0.21	0.46	0.25	0.083	0.56	0.31	1.01	0.69	0.224	0.49	0.22	0.66	0.44	0.142
5.0	3.0	1.43	1.30	1.76	0.46	0.150	0.73	0.57	0.99	0.42	0.138	0.27	0.19	0.39	0.20	0.066	0.23	0.05	0.42	0.37	0.119
4.5	3.5	1.22	1.01	1.50	0.49	0.157	0.55	0.29	0.83	0.55	0.179	0.75	0.50	0.97	0.47	0.154	0.44	0.22	0.72	0.50	0.162
3.5	3.5	1.13	1.00	1.34	0.34	0.100	1.33	1.02	1.65	0.63	0.203	1.09	0.85	1.28	0.43	0.139	1.01	0.60	1.31	0.70	0.231
2.5	3.5	1.28	0.97	1.55	0.58	0.187	1.19	0.92	1.47	0.55	0.186	1.14	0.92	1.34	0.42	0.138	0.66	0.39	1.04	0.65	0.219
1.5	3.5	1.06	0.97	1.23	0.26	0.086	1.10	0.97	1.27	0.30	0.096	1.17	0.84	1.58	0.74	0.237	0.99	0.65	1.63	0.98	0.317
0.5	3.5	1.11	0.92	1.28	0.36	0.112	1.38	1.22	1.59	0.37	0.116	1.24	0.91	1.56	0.65	0.211	0.73	0.45	1.07	0.62	0.200
0.0	4.0	1.25	1.02	1.58	0.56	0.181	0.97	0.67	1.20	0.53	0.170	1.27	0.82	1.64	0.82	0.258	1.60	1.32	1.85	0.53	0.172
1.0	4.0	1.18	0.95	1.59	0.64	0.205	1.13	0.92	1.49	0.57	0.182	1.10	0.60	1.51	0.91	0.291	1.04	0.76	1.37	0.61	0.200
2.0	4.0	0.92	0.73	1.02	0.29	0.093	0.54	0.25	0.83	0.58	0.186	0.91	0.65	1.24	0.60	0.194	0.93	0.62	1.28	0.66	0.212
3.0	4.0	0.92	0.74	1.28	0.54	0.175	0.80	0.59	1.16	0.57	0.184	1.01	0.65	1.42	0.77	0.250	1.55	1.26	1.82	0.56	0.182
4.0	4.0	1.14	0.86	1.29	0.43	0.136	1.10	0.77	1.36	0.59	0.188	0.90	0.57	1.21	0.64	0.205	0.88	0.58	1.09	0.51	0.163
5.0	4.0	1.16	1.02	1.40	0.38	0.122	1.15	0.81	1.37	0.56	0.184	1.18	0.88	1.44	0.56	0.181	1.33	1.04	1.63	0.59	0.191
4.5	4.5	1.25	1.01	1.41	0.40	0.128	1.45	1.20	1.74	0.54	0.176	1.54	1.30	1.73	0.42	0.138	1.47	1.21	1.68	0.47	0.150
3.5	4.5	1.09	0.69	1.34	0.65	0.211	1.38	0.97	1.61	0.64	0.208	1.33	1.03	1.52	0.49	0.160	1.20	0.93	1.37	0.44	0.144
2.5	4.5	0.94	0.70	1.30	0.61	0.199	0.35	0.16	0.58	0.43	0.135	0.51	0.30	0.74	0.44	0.145	0.82	0.42	1.00	0.59	0.192
1.5	4.5	1.11	0.77	1.31	0.54	0.175	1.22	1.06	1.59	0.52	0.168	1.45	1.15	1.67	0.51	0.166	1.50	1.12	1.74	0.62	0.204
0.5	4.5	1.20	1.00	1.30	0.30	0.096	1.46	1.29	1.67	0.38	0.122	1.62	1.34	1.90	0.56	0.183	1.73	1.51	1.92	0.41	0.131
0.0	5.0	0.82	0.51	1.13	0.62	0.205	1.32	1.04	1.65	0.61	0.195	1.52	1.29	1.75	0.46	0.146	1.55	1.12	1.79	0.67	0.213
1.0	5.0	0.71	0.45	1.17	0.72	0.232	1.49	1.21	1.71	0.50	0.161	1.69	1.47	1.86	0.40	0.128	1.56	1.34	1.79	0.45	0.143
2.0	5.0	0.84	0.42	1.15	0.74	0.238	1.61	1.40	1.84	0.44	0.141	1.65	1.44	1.88	0.44	0.144	1.45	1.11	1.65	0.53	0.172
3.0	5.0	0.57	0.37	1.06	0.69	0.225	0.91	0.57	1.20	0.64	0.205	1.62	1.29	1.92	0.63	0.204	1.21	0.91	1.42	0.51	0.166
4.0	5.0	0.94	0.80	1.01	0.21	0.068	1.54	1.40	1.79	0.39	0.122	1.66	1.49	1.83	0.34	0.106	1.93	1.76	2.10	0.33	0.111
5.0	5.0	0.96	0.46	1.27	0.81	0.260	1.78	1.54	2.05	0.52	0.167	2.00	1.83	2.24	0.40	0.133	1.99	1.80	2.14	0.34	0.112
Averages:		1.18	0.95	1.44	0.48	0.156	0.98	0.77	1.20	0.43	0.140	0.97	0.75	1.18	0.43	0.140	0.90	0.68	1.12	0.44	0.142

Table E.12: Fully loaded chiller with delta wings set at 25 degrees in second configuration - Air speed data for trial 1
Breed type loaded: Red deer

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)
0.0	0.0	0.71	0.61	1.07	0.46	0.151	1.56	1.18	1.95	0.78	0.250	1.85	1.51	2.12	0.61	0.193	1.66	1.34	2.22	0.88	0.288
1.0	0.0	0.87	0.72	1.01	0.28	0.087	1.73	1.53	1.94	0.41	0.128	2.03	1.88	2.25	0.37	0.123	2.02	1.77	2.13	0.36	0.111
2.0	0.0	0.80	0.38	1.05	0.67	0.214	1.74	1.57	1.94	0.37	0.116	1.93	1.79	2.10	0.30	0.099	2.05	1.80	2.06	0.26	0.084
3.0	0.0	0.66	0.49	0.89	0.40	0.127	1.56	1.21	1.95	0.74	0.242	1.94	1.78	2.12	0.34	0.109	1.88	1.66	1.99	0.33	0.109
4.0	0.0	0.90	0.75	1.11	0.36	0.113	1.76	1.51	1.94	0.43	0.141	2.05	1.86	2.23	0.38	0.121	1.95	1.69	2.10	0.41	0.134
5.0	0.0	0.43	0.26	0.71	0.45	0.145	1.25	1.05	1.46	0.41	0.137	1.85	1.75	2.05	0.29	0.093	1.39	0.95	1.63	0.68	0.219
4.5	0.5	1.32	0.96	1.51	0.55	0.183	0.91	0.52	1.41	0.88	0.285	1.36	1.10	1.64	0.54	0.171	0.87	0.51	1.02	0.51	0.168
3.5	0.5	0.86	0.41	1.15	0.74	0.238	1.43	1.08	1.81	0.73	0.242	0.37	0.29	0.62	0.33	0.100	1.42	1.06	1.61	0.55	0.175
2.5	0.5	1.22	1.02	1.39	0.38	0.124	1.77	1.42	2.07	0.65	0.211	1.36	1.02	1.62	0.60	0.190	0.93	0.46	1.22	0.76	0.247
1.5	0.5	1.05	0.82	1.28	0.46	0.146	1.49	1.33	1.65	0.31	0.102	0.54	0.30	0.69	0.39	0.121	0.68	0.51	0.77	0.26	0.080
0.5	0.5	1.23	1.04	1.38	0.34	0.111	1.30	1.06	1.56	0.50	0.159	0.88	0.34	1.18	0.84	0.268	1.12	0.87	1.42	0.55	0.174
0.0	1.0	0.99	0.66	1.26	0.60	0.190	0.67	0.50	0.76	0.25	0.084	1.02	0.85	1.20	0.35	0.115	0.91	0.46	1.14	0.68	0.218
1.0	1.0	1.32	1.10	1.65	0.55	0.177	0.67	0.47	0.76	0.28	0.087	0.95	0.77	1.05	0.28	0.090	0.86	0.52	0.95	0.43	0.134
2.0	1.0	1.41	1.14	1.64	0.50	0.158	1.33	1.06	1.66	0.60	0.192	0.76	0.60	1.00	0.40	0.133	0.51	0.29	0.72	0.43	0.136
3.0	1.0	1.21	0.80	1.40	0.60	0.194	1.35	0.99	1.68	0.69	0.220	1.10	0.90	1.29	0.39	0.126	1.11	1.00	1.16	0.16	0.049
4.0	1.0	1.48	1.07	1.74	0.68	0.216	1.29	0.92	1.69	0.77	0.246	0.99	0.76	1.09	0.34	0.107	0.75	0.60	0.86	0.26	0.083
5.0	1.0	0.99	0.51	1.48	0.97	0.311	0.79	0.34	1.04	0.70	0.227	0.83	0.58	1.05	0.47	0.158	0.71	0.47	0.88	0.41	0.136
4.5	1.5	1.55	1.30	1.70	0.40	0.131	1.36	1.18	1.77	0.60	0.195	0.54	0.29	0.84	0.55	0.172	0.28	0.16	0.43	0.27	0.090
3.5	1.5	1.42	1.18	1.78	0.59	0.191	0.22	0.08	0.42	0.34	0.112	0.41	0.30	0.55	0.24	0.083	0.23	0.16	0.37	0.21	0.068
2.5	1.5	1.84	1.60	2.19	0.59	0.186	0.66	0.45	1.05	0.60	0.194	0.17	0.03	0.26	0.23	0.072	0.19	0.15	0.29	0.14	0.045
1.5	1.5	1.46	1.24	1.65	0.40	0.126	0.12	0.02	0.27	0.25	0.077	0.26	0.02	0.31	0.29	0.092	0.23	0.16	0.29	0.13	0.047
0.5	1.5	1.72	1.61	2.03	0.42	0.140	0.35	0.16	0.46	0.30	0.094	0.32	0.16	0.45	0.29	0.096	0.18	0.02	0.29	0.27	0.088
0.0	2.0	1.23	0.90	1.46	0.56	0.179	1.32	1.06	1.50	0.44	0.142	1.22	1.05	1.42	0.37	0.122	0.48	0.30	0.72	0.42	0.139
1.0	2.0	1.51	1.39	1.65	0.26	0.082	0.72	0.28	1.02	0.73	0.235	0.49	0.13	0.76	0.63	0.204	0.20	0.16	0.29	0.13	0.038
2.0	2.0	1.62	1.47	1.73	0.26	0.088	0.95	0.76	1.18	0.42	0.140	0.82	0.62	1.04	0.42	0.134	0.21	0.02	0.35	0.33	0.104
3.0	2.0	1.54	1.25	1.87	0.63	0.201	0.66	0.35	0.82	0.47	0.151	0.71	0.46	1.05	0.59	0.187	0.45	0.21	0.67	0.46	0.145
4.0	2.0	1.59	1.40	1.72	0.32	0.107	0.23	0.15	0.44	0.29	0.092	0.67	0.43	0.94	0.51	0.162	0.45	0.30	0.56	0.26	0.081
5.0	2.0	1.57	1.30	1.82	0.52	0.165	0.86	0.59	1.20	0.61	0.192	0.52	0.30	0.74	0.44	0.142	0.20	0.16	0.33	0.17	0.053
4.5	2.5	1.59	1.46	1.72	0.27	0.091	1.21	1.00	1.49	0.49	0.164	0.43	0.16	0.74	0.59	0.187	0.21	0.10	0.45	0.35	0.114
3.5	2.5	1.32	0.93	1.67	0.74	0.240	0.15	0.02	0.27	0.25	0.084	0.50	0.17	0.76	0.59	0.195	0.35	0.30	0.44	0.14	0.042
2.5	2.5	1.63	1.30	1.93	0.63	0.204	0.39	0.16	0.67	0.51	0.168	0.17	0.02	0.30	0.28	0.094	0.33	0.16	0.73	0.57	0.186
1.5	2.5	1.29	1.17	1.41	0.24	0.072	0.21	0.05	0.45	0.40	0.127	0.26	0.16	0.44	0.28	0.093	0.36	0.16	0.70	0.54	0.178
0.5	2.5	1.46	1.18	1.80	0.61	0.195	0.29	0.16	0.50	0.35	0.108	0.69	0.30	0.90	0.60	0.191	0.27	0.09	0.51	0.42	0.132
0.0	3.0	1.39	1.16	1.66	0.50	0.164	0.78	0.60	0.93	0.34	0.113	0.93	0.68	1.19	0.50	0.163	0.61	0.06	0.86	0.80	0.258
1.0	3.0	1.19	1.29	1.85	0.56	0.182	0.76	0.45	0.92	0.47	0.155	0.23	0.16	0.35	0.19	0.061	0.37	0.16	0.58	0.42	0.137
2.0	3.0	1.26	1.12	1.49	0.37	0.118	0.63	0.45	0.90	0.45	0.142	0.41	0.05	0.66	0.61	0.198	0.62	0.16	0.97	0.81	0.263
3.0	3.0	1.13	0.92	1.33	0.42	0.139	1.06	0.81	1.41	0.60	0.191	0.63	0.37	0.97	0.60	0.191	0.74	0.40	1.25	0.85	0.278
4.0	3.0	1.28	0.90	1.42	0.52	0.169	0.26	0.16	0.55	0.39	0.129	0.56	0.34	0.86	0.52	0.169	0.65	0.24	0.86	0.62	0.196
5.0	3.0	1.36	1.20	1.70	0.50	0.163	0.93	0.70	1.20	0.49	0.158	0.21	0.16	0.30	0.15	0.050	0.22	0.02	0.49	0.47	0.156
4.5	3.5	1.20	1.02	1.52	0.50	0.166	0.62	0.40	1.05	0.65	0.211	0.82	0.62	1.11	0.49	0.158	0.41	0.19	0.63	0.44	0.145
3.5	3.5	1.18	1.03	1.40	0.37	0.117	1.28	0.91	1.65	0.73	0.235	1.49	1.16	1.80	0.64	0.208	1.02	0.41	1.41	1.00	0.327
2.5	3.5	1.24	0.98	1.51	0.53	0.168	1.18	0.90	1.44	0.53	0.178	0.93	0.72	1.15	0.43	0.138	0.62	0.42	1.14	0.72	0.234
1.5	3.5	1.08	0.99	1.25	0.26	0.087	1.16	0.94	1.36	0.42	0.135	1.35	1.05	1.74	0.69	0.226	0.77	0.47	1.13	0.66	0.210
0.5	3.5	1.07	0.90	1.31	0.42	0.132	1.54	1.26	1.69	0.43	0.135	1.22	1.05	1.78	0.73	0.239	0.78	0.34	1.26	0.92	0.298
0.0	4.0	1.19	0.93	1.49	0.56	0.185	1.19	0.95	1.46	0.50	0.160	1.27	0.76	1.80	1.05	0.335	1.62	1.35	1.79	0.44	0.141
1.0	4.0	1.16	0.94	1.47	0.54	0.171	1.42	1.18	1.70	0.52	0.165	1.08	0.49	1.50	1.01	0.322	1.06	0.66	1.47	0.81	0.266
2.0	4.0	0.97	0.73	1.08	0.35	0.113	0.54	0.23	0.90	0.67	0.217	1.00	0.69	1.47	0.78	0.250	0.88	0.67	1.19	0.52	0.164
3.0	4.0	0.96	0.75	1.30	0.54	0.174	0.53	0.30	1.04	0.73	0.233	1.18	0.78	1.76	0.99	0.318	1.48	1.06	1.88	0.82	0.268
4.0	4.0	1.06	0.78	1.22	0.44	0.138	1.28	1.05	1.51	0.46	0.144	1.08	0.60	1.47	0.87	0.281	1.09	0.68	1.27	0.59	0.191
5.0	4.0	1.12	0.94	1.32	0.37	0.122	1.47	1.08	1.63	0.55	0.177	1.46	1.04	1.76	0.72	0.238	1.47	1.19	1.67	0.48	0.157
4.5	4.5	1.24	1.01	1.42	0.41	0.130	1.41	1.18	1.63	0.45	0.145	1.51	1.27	1.69	0.42	0.138	1.59	1.40	1.73	0.33	0.108
3.5	4.5	1.12	0.67	1.36	0.69	0.228	1.35	0.95	1.77	0.82	0.266	1.33	0.97	1.51	0.55	0.174	1.12	0.79	1.29	0.50	0.167
2.5	4.5	0.99	0.73	1.22	0.49	0.162	0.44	0.17	0.77	0.60	0.189	0.57	0.30	0.85	0.55	0.180	1.00	0.51	1.14	0.63	0.200
1.5	4.5	1.05	0.74	1.22	0.48	0.160	1.38	1.23	1.73	0.50	0.161	1.60	1.27	1.85	0.58	0.185	1.57	1.05	1.81	0.76	0.250
0.5	4.5	1.16	0.94	1.23	0.30	0.098	1.49	1.29	1.80	0.51	0.161	1.72	1.48	1.94	0.46	0.148	1.82	1.51	2.06	0.55	0.180
0.0	5.0	0.87	0.57	1.19	0.62	0.206	1.26	0.79	1.65	0.86	0.276	1.54	1.28	1.79	0.51	0.164	1.46	1.03	1.65	0.62	0.198
1.0	5.0	0.82	0.56	1.27	0.71	0.235	1.60	1.22	1.79	0.58	0.189	1.68	1.49	1.87	0.38	0.119	1.65	1.38	1.78	0.40	0.123
2.0	5.0	0.62	0.27	0.92	0.65	0.214	1.62	1.46	1.85	0.39	0.123	1.83	1.61	2.14	0.54	0.176	1.81	1.42	1.94	0.52	0.165
3.0	5.0	0.55	0.36	1.27	0.91	0.298	1.07	0.90	1.29	0.39	0.123	1.75	1.42	2.12	0.70	0.228	1.16	0.76	1.34	0.58	0.192
4.0	5.0	0.72	0.57	0.79	0.22	0.069	1.65	1.49	1.94	0.45	0.142	1.66	1.47	1.86	0.39	0.125	2.01	1.79	2.16	0.37	0.120
5.0	5.0	0.91	0.41	1.18	0.77	0.246	1.91	1.59	2.25	0.65	0.215	2.18	1.94	2.40	0.46	0.148	2.03	1.84	2.13	0.29	0.095
Averages:		1.17	0.93	1.43	0.50	0.161	1.05	0.80	1.32	0.52	0.167	1.04	0.78	1.29	0.50	0.162	0.94	0.66	1.15	0.49	0.157

Table E13: Fully loaded chiller with delta wings set at 25 degrees in second configuration - Air speed data for trial 2
Breed type loaded: Red deer

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)
0.0	0.0	0.71	0.61	1.07	0.46	0.151	1.56	1.18	1.95	0.78	0.250	1.85	1.51	2.12	0.61	0.193	1.66	1.34	2.22	0.88	0.288
1.0	0.0	0.87	0.72	1.01	0.28	0.087	1.73	1.53	1.94	0.41	0.128	2.03	1.88	2.25	0.37	0.123	2.02	1.77	2.13	0.36	0.111
2.0	0.0	0.80	0.38	1.05	0.67	0.214	1.74	1.57	1.94	0.37	0.116	1.93	1.79	2.10	0.30	0.099	2.05	1.80	2.06	0.26	0.084
3.0	0.0	0.66	0.49	0.89	0.40	0.127	1.56	1.21	1.95	0.74	0.242	1.94	1.78	2.12	0.34	0.109	1.88	1.66	1.99	0.33	0.109
4.0	0.0	0.90	0.75	1.11	0.36	0.113	1.76	1.51	1.94	0.43	0.141	2.05	1.86	2.23	0.38	0.121	1.95	1.69	2.10	0.41	0.134
5.0	0.0	0.43	0.26	0.71	0.45	0.145	1.25	1.05	1.46	0.41	0.137	1.85	1.75	2.05	0.29	0.093	1.39	0.95	1.63	0.68	0.219
4.5	0.5	1.32	0.96	1.51	0.55	0.183	0.91	0.52	1.41	0.88	0.285	1.36	1.10	1.64	0.54	0.171	0.87	0.51	1.02	0.51	0.168
3.5	0.5	0.86	0.41	1.15	0.74	0.238	1.43	1.08	1.81	0.73	0.242	0.37	0.29	0.62	0.33	0.100	1.42	1.06	1.61	0.55	0.175
2.5	0.5	1.22	1.02	1.39	0.38	0.124	1.77	1.42	2.07	0.65	0.211	1.36	1.02	1.62	0.60	0.190	0.93	0.46	1.22	0.76	0.247
1.5	0.5	1.05	0.82	1.28	0.46	0.146	1.49	1.33	1.65	0.31	0.102	0.54	0.30	0.69	0.39	0.121	0.68	0.51	0.77	0.26	0.080
0.5	0.5	1.23	1.04	1.38	0.34	0.111	1.30	1.06	1.56	0.50	0.159	0.88	0.34	1.18	0.84	0.268	1.12	0.87	1.42	0.55	0.174
0.0	1.0	0.99	0.66	1.26	0.60	0.190	0.67	0.50	0.76	0.25	0.084	1.02	0.85	1.20	0.35	0.115	0.91	0.46	1.14	0.68	0.218
1.0	1.0	1.32	1.10	1.65	0.55	0.177	0.67	0.47	0.76	0.28	0.087	0.95	0.77	1.05	0.28	0.090	0.86	0.52	0.95	0.43	0.134
2.0	1.0	1.41	1.14	1.64	0.50	0.158	1.33	1.06	1.66	0.60	0.192	0.76	0.60	1.00	0.40	0.133	0.51	0.29	0.72	0.43	0.136
3.0	1.0	1.21	0.80	1.40	0.60	0.194	1.35	0.99	1.68	0.69	0.220	1.10	0.90	1.29	0.39	0.126	1.11	1.00	1.16	0.16	0.049
4.0	1.0	1.48	1.07	1.74	0.68	0.216	1.29	0.92	1.69	0.77	0.246	0.99	0.76	1.09	0.34	0.107	0.75	0.60	0.86	0.26	0.083
5.0	1.0	0.99	0.51	1.48	0.97	0.311	0.79	0.34	1.04	0.70	0.227	0.83	0.58	1.05	0.47	0.158	0.71	0.47	0.88	0.41	0.136
4.5	1.5	1.55	1.30	1.70	0.40	0.131	1.36	1.18	1.77	0.60	0.195	0.54	0.29	0.84	0.55	0.172	0.28	0.16	0.43	0.27	0.090
3.5	1.5	1.42	1.18	1.78	0.59	0.191	0.22	0.08	0.42	0.34	0.112	0.41	0.30	0.55	0.24	0.083	0.23	0.16	0.37	0.21	0.068
2.5	1.5	1.84	1.60	2.19	0.59	0.186	0.66	0.45	1.05	0.60	0.194	0.17	0.03	0.26	0.23	0.072	0.19	0.15	0.29	0.14	0.045
1.5	1.5	1.46	1.24	1.65	0.40	0.126	0.12	0.02	0.27	0.25	0.077	0.26	0.02	0.31	0.29	0.092	0.23	0.16	0.29	0.13	0.047
0.5	1.5	1.72	1.61	2.03	0.42	0.140	0.35	0.16	0.46	0.30	0.094	0.32	0.16	0.45	0.29	0.096	0.18	0.02	0.29	0.27	0.088
0.0	2.0	1.23	0.90	1.46	0.56	0.179	1.32	1.06	1.50	0.44	0.142	1.22	1.05	1.42	0.37	0.122	0.48	0.30	0.72	0.42	0.139
1.0	2.0	1.51	1.39	1.65	0.26	0.082	0.72	0.28	1.02	0.73	0.235	0.49	0.13	0.76	0.63	0.204	0.20	0.16	0.29	0.13	0.038
2.0	2.0	1.62	1.47	1.73	0.26	0.088	0.95	0.76	1.18	0.42	0.140	0.82	0.62	1.04	0.42	0.134	0.21	0.02	0.35	0.33	0.104
3.0	2.0	1.54	1.25	1.87	0.63	0.201	0.66	0.35	0.82	0.47	0.151	0.71	0.46	1.05	0.59	0.187	0.45	0.21	0.67	0.46	0.145
4.0	2.0	1.59	1.40	1.72	0.32	0.107	0.23	0.15	0.44	0.29	0.092	0.67	0.43	0.94	0.51	0.162	0.45	0.30	0.56	0.26	0.081
5.0	2.0	1.57	1.30	1.82	0.52	0.165	0.86	0.59	1.20	0.61	0.192	0.52	0.30	0.74	0.44	0.142	0.20	0.16	0.33	0.17	0.053
4.5	2.5	1.59	1.46	1.72	0.27	0.091	1.21	1.00	1.49	0.49	0.164	0.43	0.16	0.74	0.59	0.187	0.21	0.10	0.45	0.35	0.114
3.5	2.5	1.32	0.93	1.67	0.74	0.240	0.15	0.02	0.27	0.25	0.084	0.50	0.17	0.76	0.59	0.195	0.35	0.30	0.44	0.14	0.042
2.5	2.5	1.63	1.30	1.93	0.63	0.204	0.39	0.16	0.67	0.51	0.168	0.17	0.02	0.30	0.28	0.094	0.33	0.16	0.73	0.57	0.186
1.5	2.5	1.29	1.17	1.41	0.24	0.072	0.21	0.05	0.45	0.40	0.127	0.26	0.16	0.44	0.28	0.093	0.36	0.16	0.70	0.54	0.178
0.5	2.5	1.46	1.18	1.80	0.61	0.195	0.29	0.16	0.50	0.35	0.108	0.69	0.30	0.90	0.60	0.191	0.27	0.09	0.51	0.42	0.132
0.0	3.0	1.39	1.16	1.66	0.50	0.164	0.78	0.60	0.93	0.34	0.113	0.93	0.68	1.19	0.50	0.163	0.61	0.06	0.86	0.80	0.258
1.0	3.0	1.19	1.29	1.85	0.56	0.182	0.76	0.45	0.92	0.47	0.155	0.23	0.16	0.35	0.19	0.061	0.37	0.16	0.58	0.42	0.137
2.0	3.0	1.26	1.12	1.49	0.37	0.118	0.63	0.45	0.90	0.45	0.142	0.41	0.05	0.66	0.61	0.198	0.62	0.16	0.97	0.81	0.263
3.0	3.0	1.13	0.92	1.33	0.42	0.139	1.06	0.81	1.41	0.60	0.191	0.63	0.37	0.97	0.60	0.191	0.74	0.40	1.25	0.85	0.278
4.0	3.0	1.28	0.90	1.42	0.52	0.169	0.26	0.16	0.55	0.39	0.129	0.56	0.34	0.86	0.52	0.169	0.65	0.24	0.86	0.62	0.196
5.0	3.0	1.36	1.20	1.70	0.50	0.163	0.93	0.70	1.20	0.49	0.158	0.21	0.16	0.30	0.15	0.050	0.22	0.02	0.49	0.47	0.156
4.5	3.5	1.20	1.02	1.52	0.50	0.166	0.62	0.40	1.05	0.65	0.211	0.82	0.62	1.11	0.49	0.158	0.41	0.19	0.63	0.44	0.145
3.5	3.5	1.18	1.03	1.40	0.37	0.117	1.28	0.91	1.65	0.73	0.235	1.49	1.16	1.80	0.64	0.208	1.02	0.41	1.41	1.00	0.327
2.5	3.5	1.24	0.98	1.51	0.53	0.168	1.18	0.90	1.44	0.53	0.178	0.93	0.72	1.15	0.43	0.138	0.62	0.42	1.14	0.72	0.234
1.5	3.5	1.08	0.99	1.25	0.26	0.087	1.16	0.94	1.36	0.42	0.135	1.35	1.05	1.74	0.69	0.226	0.77	0.47	1.13	0.66	0.210
0.5	3.5	1.07	0.90	1.31	0.42	0.132	1.54	1.26	1.69	0.43	0.135	1.22	1.05	1.78	0.73	0.239	0.78	0.34	1.26	0.92	0.298
0.0	4.0	1.19	0.93	1.49	0.56	0.185	1.19	0.95	1.46	0.50	0.160	1.27	0.76	1.80	1.05	0.335	1.62	1.35	1.79	0.44	0.141
1.0	4.0	1.16	0.94	1.47	0.54	0.171	1.42	1.18	1.70	0.52	0.165	1.08	0.49	1.50	1.01	0.322	1.06	0.66	1.47	0.81	0.266
2.0	4.0	0.97	0.73	1.08	0.35	0.113	0.54	0.23	0.90	0.67	0.217	1.00	0.69	1.47	0.78	0.250	0.88	0.67	1.19	0.52	0.164
3.0	4.0	0.96	0.75	1.30	0.54	0.174	0.53	0.30	1.04	0.73	0.233	1.18	0.78	1.76	0.99	0.318	1.48	1.06	1.88	0.82	0.268
4.0	4.0	1.06	0.78	1.22	0.44	0.138	1.28	1.05	1.51	0.46	0.144	1.08	0.60	1.47	0.87	0.281	1.09	0.68	1.27	0.59	0.191
5.0	4.0	1.12	0.94	1.32	0.37	0.122	1.47	1.08	1.63	0.55	0.177	1.46	1.04	1.76	0.72	0.238	1.47	1.19	1.67	0.48	0.157
4.5	4.5	1.24	1.01	1.42	0.41	0.130	1.41	1.18	1.63	0.45	0.145	1.51	1.27	1.69	0.42	0.138	1.59	1.40	1.73	0.33	0.108
3.5	4.5	1.12	0.67	1.36	0.69	0.228	1.35	0.95	1.77	0.82	0.266	1.33	0.97	1.51	0.55	0.174	1.12	0.79	1.29	0.50	0.167
2.5	4.5	0.99	0.73	1.22	0.49	0.162	0.44	0.17	0.77	0.60	0.189	0.57	0.30	0.85	0.55	0.180	1.00	0.51	1.14	0.63	0.200
1.5	4.5	1.05	0.74	1.22	0.48	0.160	1.38	1.23	1.73	0.50	0.161	1.60	1.27	1.85	0.58	0.185	1.57	1.05	1.81	0.76	0.250
0.5	4.5	1.16	0.94	1.23	0.30	0.098	1.49	1.29	1.80	0.51	0.161	1.72	1.48	1.94	0.46	0.148	1.82	1.51	2.06	0.55	0.180
0.0	5.0	0.87	0.57	1.19	0.62	0.206	1.26	0.79	1.65	0.86	0.276	1.54	1.28	1.79	0.51	0.164	1.46	1.03	1.65	0.62	0.198
1.0	5.0	0.82	0.56	1.27	0.71	0.235	1.60	1.22	1.79	0.58	0.189	1.68	1.49	1.87	0.38	0.119	1.65	1.38	1.78	0.40	0.123
2.0	5.0	0.62	0.27	0.92	0.65	0.214	1.62	1.46	1.85	0.39	0.123	1.83	1.61	2.14	0.54	0.176	1.81	1.42	1.94	0.52	0.165
3.0	5.0	0.55	0.36	1.27	0.91	0.298	1.07	0.90	1.29	0.39	0.123	1.75	1.42	2.12	0.70	0.228	1.16	0.76	1.34	0.58	0.192
4.0	5.0	0.72	0.57	0.79	0.22	0.069	1.65	1.49	1.94	0.45	0.142	1.66	1.47	1.86	0.39	0.125	2.01	1.79	2.16	0.37	0.120
5.0	5.0	0.91	0.41	1.18	0.77	0.246	1.91	1.59	2.25	0.65	0.215	2.18	1.94	2.40	0.46	0.148	2.03	1.84	2.13	0.29	0.095
Averages:		1.17	0.93	1.43	0.50	0.161	1.05	0.80	1.32	0.52	0.167	1.04	0.78	1.29	0.50	0.162	0.94	0.66	1.15	0.49	0.157

Table E14: Fully loaded chiller with delta wings set at 25 degrees in second configuration - Air speed data for trial 3
Breed type loaded: Red deer

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)
0.0	0.0	0.69	0.49	0.99	0.50	0.159	0.86	0.73	1.01	0.28	0.084	1.36	1.21	1.48	0.27	0.086	1.52	1.40	1.61	0.21	0.062
1.0	0.0	0.79	0.63	0.94	0.31	0.103	1.42	0.86	1.68	0.82	0.233	1.69	1.10	1.83	0.73	0.220	1.70	1.21	1.88	0.67	0.183
2.0	0.0	0.72	0.41	0.90	0.49	0.162	1.70	1.56	1.87	0.30	0.100	1.86	1.68	1.99	0.30	0.092	1.87	1.70	2.06	0.36	0.104
3.0	0.0	0.58	0.38	0.78	0.39	0.129	1.42	1.25	1.65	0.41	0.114	1.70	1.46	1.88	0.42	0.118	1.74	1.58	1.82	0.23	0.068
4.0	0.0	0.68	0.55	0.80	0.25	0.082	1.34	1.15	1.60	0.46	0.139	1.68	1.50	1.72	0.22	0.075	1.69	1.46	1.88	0.42	0.138
5.0	0.0	0.36	0.24	0.50	0.27	0.083	0.77	0.45	1.05	0.61	0.214	0.82	0.38	1.15	0.77	0.266	1.11	0.90	1.28	0.38	0.116
4.5	0.5	1.06	0.83	1.38	0.56	0.180	0.62	0.49	0.72	0.23	0.087	0.68	0.15	1.10	0.94	0.317	0.51	0.27	0.81	0.54	0.178
3.5	0.5	1.06	0.62	1.33	0.71	0.225	1.24	1.01	1.44	0.43	0.154	1.21	0.92	1.42	0.50	0.169	1.07	0.65	1.32	0.67	0.218
2.5	0.5	1.29	1.11	1.47	0.36	0.115	1.25	0.99	1.44	0.45	0.144	0.88	0.72	1.04	0.32	0.112	0.99	0.73	1.25	0.52	0.146
1.5	0.5	1.30	0.99	1.52	0.54	0.170	0.75	0.58	0.87	0.29	0.103	0.85	0.72	1.15	0.43	0.118	0.85	0.51	1.15	0.64	0.191
0.5	0.5	1.39	1.10	1.60	0.50	0.159	1.08	0.88	1.30	0.42	0.122	0.98	0.77	1.39	0.62	0.188	1.15	0.86	1.47	0.61	0.201
0.0	1.0	1.41	1.12	1.65	0.53	0.175	0.45	0.26	0.62	0.36	0.117	0.62	0.54	0.71	0.17	0.077	0.56	0.31	0.72	0.41	0.138
1.0	1.0	1.44	1.18	1.70	0.53	0.169	0.85	0.73	0.99	0.26	0.088	0.44	0.15	0.61	0.46	0.138	0.70	0.54	0.86	0.32	0.126
2.0	1.0	1.13	0.78	1.41	0.63	0.200	0.50	0.36	0.69	0.33	0.103	0.65	0.44	0.88	0.45	0.184	0.50	0.34	0.70	0.36	0.114
3.0	1.0	1.38	1.13	1.56	0.42	0.137	0.57	0.42	0.72	0.30	0.108	0.41	0.28	0.62	0.33	0.114	0.26	0.15	0.43	0.27	0.102
4.0	1.0	1.41	1.14	1.63	0.49	0.156	0.54	0.22	0.78	0.56	0.204	0.95	0.59	1.15	0.56	0.152	0.46	0.22	0.72	0.50	0.153
5.0	1.0	0.76	0.43	1.05	0.62	0.204	0.60	0.32	0.96	0.64	0.198	0.68	0.45	0.94	0.50	0.159	0.98	0.74	1.17	0.43	0.174
4.5	1.5	1.40	1.21	1.60	0.39	0.131	0.85	0.65	1.02	0.38	0.123	0.52	0.20	1.03	0.83	0.235	0.61	0.29	1.01	0.72	0.293
3.5	1.5	1.22	0.94	1.54	0.59	0.187	0.29	0.16	0.44	0.27	0.080	0.52	0.44	0.70	0.26	0.095	0.47	0.33	0.56	0.22	0.068
2.5	1.5	1.39	1.06	1.68	0.62	0.204	0.21	0.02	0.55	0.53	0.156	0.29	0.15	0.55	0.40	0.123	0.52	0.29	0.76	0.47	0.171
1.5	1.5	1.25	1.01	1.59	0.58	0.191	0.62	0.48	0.76	0.28	0.088	0.25	0.14	0.44	0.29	0.107	0.29	0.15	0.44	0.28	0.105
0.5	1.5	1.58	1.36	1.80	0.44	0.146	0.27	0.15	0.48	0.32	0.103	0.42	0.29	0.58	0.28	0.075	0.48	0.30	0.69	0.39	0.117
0.0	2.0	1.18	1.06	1.34	0.29	0.091	0.80	0.47	1.11	0.64	0.188	0.15	0.07	0.19	0.12	0.034	0.71	0.44	0.89	0.46	0.179
1.0	2.0	1.37	1.21	1.54	0.33	0.109	0.23	0.15	0.29	0.14	0.064	0.76	0.48	1.00	0.53	0.172	0.48	0.33	0.60	0.26	0.086
2.0	2.0	1.37	1.14	1.57	0.43	0.137	1.19	1.07	1.28	0.21	0.078	1.02	0.79	1.16	0.37	0.119	0.45	0.29	0.58	0.28	0.083
3.0	2.0	1.37	1.13	1.60	0.47	0.148	1.06	0.84	1.30	0.46	0.166	1.26	1.04	1.44	0.40	0.115	0.95	0.51	1.16	0.65	0.182
4.0	2.0	1.41	1.21	1.58	0.37	0.122	0.75	0.46	1.00	0.55	0.157	1.09	0.92	1.28	0.36	0.123	0.81	0.44	1.26	0.82	0.257
5.0	2.0	1.12	0.91	1.34	0.43	0.144	1.09	0.87	1.30	0.43	0.139	0.89	0.68	1.13	0.45	0.131	0.94	0.51	1.11	0.60	0.178
4.5	2.5	1.52	1.30	1.68	0.38	0.128	0.38	0.20	0.52	0.31	0.093	0.75	0.58	0.88	0.30	0.112	0.50	0.19	0.81	0.62	0.208
3.5	2.5	1.02	0.76	1.35	0.58	0.188	1.03	0.90	1.12	0.21	0.055	0.36	0.17	0.59	0.42	0.129	0.75	0.46	1.00	0.55	0.150
2.5	2.5	1.46	1.12	1.81	0.69	0.222	1.15	0.89	1.41	0.52	0.169	0.62	0.39	0.90	0.52	0.175	0.33	0.16	0.52	0.36	0.122
1.5	2.5	1.21	1.10	1.37	0.27	0.087	0.96	0.74	1.20	0.46	0.130	1.10	0.95	1.22	0.26	0.087	0.32	0.16	0.48	0.31	0.112
0.5	2.5	1.47	1.32	1.62	0.30	0.102	0.33	0.16	0.63	0.47	0.163	0.57	0.23	0.89	0.66	0.218	0.49	0.25	0.73	0.48	0.165
0.0	3.0	1.13	0.96	1.42	0.46	0.147	0.47	0.15	0.73	0.58	0.155	0.65	0.33	1.16	0.82	0.259	1.08	0.32	1.69	1.37	0.513
1.0	3.0	1.17	1.09	1.48	0.39	0.129	0.35	0.15	0.53	0.38	0.138	0.48	0.16	0.70	0.54	0.171	0.53	0.15	0.96	0.81	0.255
2.0	3.0	1.15	1.04	1.31	0.27	0.085	0.79	0.43	1.15	0.72	0.220	0.99	0.71	1.35	0.64	0.204	1.07	0.74	1.43	0.69	0.218
3.0	3.0	1.20	0.95	1.36	0.41	0.137	0.37	0.18	0.61	0.43	0.126	0.45	0.29	0.58	0.28	0.115	0.43	0.29	0.69	0.40	0.137
4.0	3.0	1.15	0.92	1.35	0.43	0.136	0.18	0.04	0.34	0.30	0.080	0.45	0.27	0.72	0.45	0.138	0.32	0.22	0.44	0.21	0.076
5.0	3.0	1.05	0.87	1.25	0.39	0.125	0.92	0.39	1.27	0.88	0.252	0.61	0.40	0.92	0.53	0.192	0.46	0.27	0.73	0.46	0.162
4.5	3.5	1.13	0.94	1.38	0.44	0.145	0.09	0.02	0.15	0.13	0.065	0.23	0.15	0.29	0.14	0.061	0.36	0.12	0.58	0.46	0.155
3.5	3.5	0.93	0.69	1.14	0.45	0.145	0.61	0.29	0.88	0.59	0.236	0.22	0.12	0.44	0.31	0.097	0.38	0.29	0.44	0.14	0.054
2.5	3.5	1.16	0.79	1.50	0.71	0.230	0.85	0.55	1.01	0.47	0.144	0.96	0.71	1.15	0.44	0.130	0.48	0.28	0.60	0.31	0.099
1.5	3.5	0.85	0.72	0.96	0.24	0.072	0.70	0.50	1.00	0.51	0.147	0.65	0.34	0.87	0.53	0.180	0.81	0.55	1.07	0.52	0.174
0.5	3.5	1.06	0.92	1.22	0.30	0.101	0.72	0.54	0.85	0.31	0.076	0.80	0.59	1.01	0.43	0.135	0.60	0.31	0.89	0.58	0.219
0.0	4.0	1.22	0.88	1.52	0.64	0.212	0.66	0.50	0.77	0.27	0.093	0.87	0.65	0.95	0.30	0.089	0.62	0.34	1.11	0.76	0.219
1.0	4.0	0.95	0.77	1.15	0.38	0.123	0.64	0.41	0.72	0.31	0.107	0.54	0.29	0.72	0.43	0.144	0.39	0.09	0.63	0.54	0.175
2.0	4.0	0.88	0.69	1.06	0.37	0.119	0.53	0.31	0.72	0.41	0.122	0.53	0.41	0.65	0.24	0.093	0.41	0.17	0.63	0.46	0.145
3.0	4.0	0.91	0.66	1.17	0.51	0.170	0.17	0.02	0.29	0.27	0.087	0.47	0.37	0.65	0.28	0.092	0.57	0.33	0.72	0.39	0.128
4.0	4.0	0.84	0.67	1.02	0.36	0.111	0.15	0.03	0.29	0.26	0.067	0.09	0.02	0.15	0.13	0.063	0.11	0.02	0.15	0.13	0.058
5.0	4.0	1.10	0.90	1.33	0.43	0.136	1.15	0.80	1.57	0.77	0.234	0.86	0.59	1.15	0.56	0.186	0.97	0.73	1.32	0.59	0.185
4.5	4.5	0.72	0.55	0.96	0.41	0.135	1.02	0.76	1.49	0.73	0.240	1.25	0.99	1.49	0.50	0.174	1.40	1.11	1.62	0.52	0.187
3.5	4.5	0.87	0.57	1.07	0.50	0.158	0.57	0.18	0.76	0.58	0.193	0.72	0.43	0.92	0.50	0.167	0.56	0.29	0.77	0.48	0.152
2.5	4.5	0.61	0.39	0.81	0.42	0.140	0.61	0.40	0.82	0.43	0.156	0.78	0.59	0.94	0.36	0.109	0.77	0.30	1.15	0.84	0.288
1.5	4.5	0.84	0.59	1.03	0.44	0.143	0.43	0.15	0.60	0.45	0.144	0.41	0.15	0.68	0.53	0.163	0.71	0.41	1.02	0.62	0.197
0.5	4.5	0.99	0.83	1.13	0.29	0.091	0.87	0.72	0.98	0.26	0.086	0.79	0.44	1.13	0.69	0.242	0.82	0.68	1.01	0.33	0.109
0.0	5.0	0.63	0.35	1.00	0.65	0.211	1.12	0.42	1.48	1.07	0.338	1.09	0.78	1.43	0.65	0.228	1.09	0.87	1.29	0.42	0.118
1.0	5.0	0.55	0.31	0.82	0.51	0.162	0.82	0.50	1.10	0.60	0.174	0.82	0.33	1.28	0.94	0.243	1.03	0.84	1.24	0.40	0.138
2.0	5.0	0.58	0.34	0.76	0.43	0.134	0.43	0.13	0.72	0.59	0.156	0.66	0.26	1.01	0.75	0.259	0.84	0.44	1.17	0.73	0.259
3.0	5.0	0.45	0.23	0.80	0.57	0.185	0.70	0.45	0.86	0.42	0.153	0.98	0.73	1.23	0.50	0.155	1.17	0.73	1.33	0.60	0.178
4.0	5.0	1.22	1.07	1.37	0.30	0.097	1.43	1.16	1.85	0.69	0.210	1.35	1.10	1.48	0.39	0.119	1.43	1.29	1.60	0.31	0.117
5.0	5.0	1.23	0.94	1.46	0.52	0.168	1.59	1.45	1.68	0.23	0.080	1.58	1.30	1.87	0.57	0.151	1.62	1.45	1.94	0.49	0.147
Averages:		1.07	0.85	1.30	0.45	0.146	0.76	0.53	0.97	0.44	0.140	0.79	0.56	1.02	0.46	0.147	0.78	0.53	1.01	0.48	0.160

Table E15: Fully loaded chiller with delta wings set at 25 degrees in second configuration
Average air speed data for trials 1-3

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)
0.0	0.0	0.68	0.46	1.01	0.55	0.178	1.11	0.92	1.34	0.42	0.147	1.39	1.13	1.67	0.53	0.162	1.67	1.49	1.86	0.36	0.117
1.0	0.0	0.67	0.51	0.83	0.32	0.106	1.51	1.17	1.79	0.62	0.158	1.81	1.45	1.99	0.54	0.162	1.90	1.49	2.08	0.59	0.172
2.0	0.0	0.70	0.44	0.88	0.44	0.144	1.65	1.51	1.82	0.31	0.110	1.91	1.72	2.07	0.34	0.102	2.01	1.82	2.24	0.42	0.121
3.0	0.0	0.57	0.37	0.77	0.40	0.125	1.37	1.22	1.54	0.31	0.102	1.65	1.48	1.84	0.36	0.109	1.76	1.63	1.87	0.24	0.082
4.0	0.0	0.60	0.47	0.74	0.27	0.097	1.29	1.05	1.49	0.44	0.117	1.56	1.33	1.71	0.38	0.116	1.62	1.48	1.75	0.27	0.090
5.0	0.0	0.35	0.22	0.46	0.24	0.078	0.81	0.58	1.05	0.47	0.139	1.17	0.89	1.41	0.52	0.171	1.00	0.74	1.28	0.54	0.166
4.5	0.5	0.94	0.67	1.30	0.63	0.190	0.81	0.63	1.04	0.41	0.158	0.89	0.60	1.18	0.58	0.189	0.82	0.56	1.13	0.57	0.194
3.5	0.5	1.10	0.67	1.37	0.71	0.222	1.11	0.84	1.30	0.46	0.154	1.22	1.01	1.45	0.44	0.149	1.22	0.98	1.38	0.40	0.133
2.5	0.5	1.24	1.05	1.43	0.38	0.116	1.36	1.13	1.62	0.49	0.179	1.27	1.09	1.44	0.36	0.117	0.93	0.68	1.17	0.49	0.153
1.5	0.5	1.37	1.04	1.60	0.56	0.182	1.00	0.82	1.14	0.31	0.146	1.07	0.93	1.28	0.36	0.112	0.88	0.66	1.06	0.40	0.135
0.5	0.5	1.39	1.04	1.62	0.57	0.196	1.31	1.03	1.53	0.50	0.205	1.27	1.01	1.60	0.59	0.178	1.14	0.90	1.36	0.46	0.151
0.0	1.0	1.53	1.23	1.79	0.56	0.174	0.63	0.52	0.77	0.25	0.118	0.75	0.61	0.87	0.26	0.096	0.62	0.42	0.80	0.38	0.119
1.0	1.0	1.44	1.14	1.75	0.62	0.188	0.65	0.53	0.79	0.25	0.100	0.54	0.37	0.68	0.32	0.098	0.58	0.41	0.73	0.32	0.112
2.0	1.0	1.01	0.61	1.31	0.70	0.210	0.50	0.32	0.78	0.46	0.160	0.57	0.43	0.73	0.30	0.119	0.61	0.50	0.76	0.25	0.087
3.0	1.0	1.41	1.14	1.58	0.44	0.149	0.68	0.51	0.95	0.44	0.123	0.53	0.34	0.71	0.36	0.129	0.49	0.30	0.66	0.36	0.108
4.0	1.0	1.38	1.10	1.60	0.49	0.153	0.72	0.48	0.94	0.46	0.140	1.03	0.67	1.25	0.58	0.166	0.68	0.46	0.91	0.45	0.151
5.0	1.0	0.73	0.43	1.01	0.58	0.177	0.65	0.30	0.96	0.66	0.224	0.84	0.60	1.09	0.49	0.161	0.94	0.66	1.19	0.53	0.192
4.5	1.5	1.33	1.12	1.56	0.44	0.157	0.98	0.73	1.26	0.52	0.166	0.74	0.49	0.98	0.49	0.143	0.55	0.34	0.78	0.45	0.169
3.5	1.5	1.23	0.92	1.57	0.65	0.191	0.30	0.16	0.48	0.32	0.132	0.37	0.25	0.56	0.31	0.100	0.38	0.22	0.52	0.30	0.103
2.5	1.5	1.28	0.91	1.58	0.67	0.204	0.34	0.15	0.62	0.47	0.140	0.31	0.16	0.52	0.37	0.120	0.44	0.25	0.64	0.39	0.133
1.5	1.5	1.24	0.98	1.63	0.65	0.205	0.47	0.31	0.66	0.35	0.144	0.26	0.15	0.42	0.26	0.098	0.29	0.16	0.43	0.28	0.096
0.5	1.5	1.57	1.31	1.78	0.47	0.145	0.24	0.15	0.40	0.25	0.133	0.35	0.25	0.49	0.24	0.074	0.33	0.20	0.56	0.36	0.107
0.0	2.0	1.19	1.06	1.35	0.29	0.097	0.91	0.69	1.11	0.42	0.129	0.75	0.60	0.88	0.28	0.089	0.46	0.21	0.69	0.48	0.183
1.0	2.0	1.34	1.16	1.52	0.37	0.125	0.76	0.68	0.83	0.15	0.086	0.90	0.69	1.14	0.45	0.151	0.52	0.26	0.79	0.53	0.169
2.0	2.0	1.28	1.03	1.53	0.49	0.161	1.14	1.01	1.25	0.24	0.112	0.93	0.76	1.08	0.32	0.110	0.43	0.26	0.62	0.36	0.112
3.0	2.0	1.34	1.11	1.57	0.46	0.130	1.06	0.86	1.27	0.41	0.115	1.05	0.79	1.25	0.46	0.131	0.59	0.31	0.81	0.51	0.154
4.0	2.0	1.36	1.15	1.54	0.39	0.124	1.04	0.77	1.29	0.52	0.132	1.12	0.92	1.37	0.45	0.138	0.68	0.38	0.97	0.59	0.176
5.0	2.0	0.97	0.77	1.18	0.41	0.130	1.03	0.87	1.21	0.34	0.109	0.97	0.81	1.11	0.29	0.093	0.64	0.32	0.92	0.61	0.184
4.5	2.5	1.51	1.25	1.70	0.45	0.146	0.43	0.22	0.64	0.43	0.130	0.60	0.41	0.75	0.34	0.123	0.53	0.24	0.80	0.55	0.197
3.5	2.5	1.00	0.75	1.32	0.57	0.174	0.63	0.45	0.80	0.35	0.087	0.49	0.24	0.75	0.50	0.167	0.62	0.35	0.99	0.65	0.191
2.5	2.5	1.42	1.08	1.79	0.71	0.223	0.84	0.62	1.04	0.42	0.188	0.63	0.40	0.98	0.58	0.176	0.38	0.16	0.57	0.41	0.141
1.5	2.5	1.22	1.09	1.39	0.30	0.097	0.66	0.46	0.86	0.40	0.136	0.83	0.66	1.02	0.36	0.116	0.37	0.16	0.62	0.46	0.158
0.5	2.5	1.45	1.28	1.60	0.32	0.111	0.35	0.21	0.53	0.32	0.110	0.59	0.33	0.87	0.53	0.179	0.75	0.49	1.08	0.59	0.202
0.0	3.0	1.09	0.93	1.40	0.48	0.140	0.55	0.23	0.96	0.73	0.158	0.64	0.34	1.06	0.72	0.220	1.11	0.53	1.63	1.10	0.370
1.0	3.0	1.20	1.02	1.44	0.42	0.128	0.46	0.24	0.66	0.42	0.132	0.37	0.13	0.55	0.42	0.128	0.71	0.37	1.14	0.78	0.246
2.0	3.0	1.05	0.94	1.21	0.27	0.080	0.89	0.58	1.23	0.64	0.159	0.93	0.63	1.24	0.61	0.208	0.94	0.67	1.21	0.54	0.174
3.0	3.0	1.19	0.90	1.35	0.45	0.136	0.55	0.37	0.81	0.45	0.160	0.55	0.38	0.71	0.34	0.115	0.49	0.28	0.77	0.50	0.166
4.0	3.0	1.08	0.84	1.31	0.47	0.147	0.31	0.07	0.50	0.43	0.136	0.40	0.23	0.66	0.43	0.148	0.39	0.21	0.73	0.52	0.153
5.0	3.0	0.88	0.69	1.09	0.40	0.125	0.73	0.41	0.95	0.54	0.186	0.69	0.49	1.02	0.53	0.173	0.51	0.29	0.78	0.48	0.159
4.5	3.5	1.11	0.91	1.37	0.46	0.150	0.26	0.12	0.43	0.31	0.079	0.29	0.17	0.50	0.33	0.095	0.59	0.25	0.90	0.65	0.203
3.5	3.5	0.86	0.58	1.10	0.52	0.157	0.87	0.63	1.05	0.42	0.171	0.61	0.34	0.86	0.51	0.168	0.42	0.26	0.54	0.28	0.094
2.5	3.5	1.10	0.67	1.49	0.82	0.272	0.74	0.43	1.00	0.57	0.227	0.86	0.58	1.11	0.52	0.163	0.60	0.43	0.75	0.32	0.107
1.5	3.5	0.79	0.64	0.89	0.24	0.073	0.83	0.59	1.09	0.50	0.110	0.89	0.61	1.20	0.59	0.179	0.83	0.51	1.18	0.67	0.207
0.5	3.5	1.05	0.91	1.22	0.31	0.103	0.85	0.56	1.03	0.47	0.103	0.67	0.43	0.98	0.55	0.186	0.72	0.50	1.01	0.52	0.179
0.0	4.0	1.16	0.80	1.49	0.69	0.213	1.00	0.81	1.16	0.35	0.173	0.88	0.69	1.14	0.45	0.148	0.77	0.45	1.09	0.64	0.190
1.0	4.0	0.88	0.70	1.05	0.35	0.112	0.76	0.48	1.03	0.55	0.172	0.68	0.46	0.89	0.44	0.141	0.47	0.27	0.70	0.43	0.145
2.0	4.0	0.89	0.67	1.09	0.43	0.139	0.75	0.54	0.91	0.38	0.127	0.76	0.48	0.94	0.47	0.149	0.62	0.40	0.86	0.46	0.150
3.0	4.0	0.91	0.63	1.16	0.53	0.164	0.58	0.42	0.73	0.31	0.126	0.78	0.64	1.05	0.42	0.123	0.61	0.38	0.81	0.43	0.153
4.0	4.0	0.73	0.57	0.92	0.36	0.122	0.40	0.17	0.60	0.43	0.118	0.30	0.17	0.52	0.36	0.124	0.57	0.40	0.76	0.36	0.114
5.0	4.0	1.05	0.83	1.30	0.47	0.144	1.29	0.91	1.64	0.73	0.196	1.02	0.70	1.27	0.57	0.182	1.08	0.85	1.39	0.54	0.176
4.5	4.5	0.54	0.38	0.81	0.43	0.155	0.94	0.64	1.30	0.66	0.228	1.28	1.05	1.59	0.54	0.177	1.25	0.93	1.45	0.52	0.162
3.5	4.5	0.81	0.52	1.00	0.48	0.141	0.72	0.45	0.89	0.45	0.137	0.80	0.48	1.00	0.53	0.171	0.77	0.44	1.03	0.60	0.193
2.5	4.5	0.51	0.28	0.70	0.42	0.137	0.78	0.53	1.03	0.50	0.144	0.84	0.62	1.02	0.41	0.129	0.79	0.45	1.17	0.72	0.237
1.5	4.5	0.74	0.50	0.93	0.43	0.155	0.64	0.39	0.83	0.43	0.143	0.72	0.42	0.93	0.51	0.158	0.91	0.55	1.23	0.68	0.213
0.5	4.5	0.91	0.75	1.07	0.32	0.109	0.93	0.64	1.10	0.46	0.144	0.91	0.63	1.17	0.53	0.180	1.03	0.83	1.30	0.47	0.164
0.0	5.0	0.59	0.32	0.98	0.66	0.231	1.08	0.59	1.50	0.91	0.308	1.36	1.07	1.63	0.56	0.180	1.17	0.87	1.41	0.55	0.158
1.0	5.0	0.53	0.30	0.75	0.45	0.140	0.92	0.65	1.18	0.53	0.144	1.03	0.65	1.30	0.65	0.180	1.07	0.74	1.28	0.54	0.173
2.0	5.0	0.41	0.25	0.55	0.30	0.108	0.61	0.26	0.91	0.65	0.138	0.78	0.42	1.15	0.74	0.260	1.04	0.68	1.36	0.68	0.223
3.0	5.0	0.41	0.17	0.78	0.61	0.201	0.54	0.25	0.81	0.56	0.187	1.07	0.73	1.42	0.70	0.222	1.34	1.04	1.56	0.52	0.170
4.0	5.0	1.23	1.08	1.42	0.34	0.112	1.47	1.19	1.77	0.58	0.169	1.51	1.26	1.66	0.40	0.123	1.49	1.30	1.70	0.40	0.130
5.0	5.0	1.29	1.08	1.52	0.44	0.139	1.68	1.49	1.83	0.34	0.093	1.79	1.59	2.05	0.46	0.133	1.77	1.59	2.04	0.45	0.138
Averages:		1.03	0.79	1.26	0.47	0.150	0.83	0.60	1.05	0.45	0.146	0.88	0.65	1.11	0.46	0.146	0.83	0.59	1.08	0.49	0.159

Table E.16: Fully loaded chiller with delta wings set at 35 degrees in second configuration
Breed type loaded: Red deer

Coordinates		Vertical Height in chiller - 0.5 metres					Vertical Height in chiller - 1.0 metres					Vertical Height in chiller - 1.5 metres					Vertical Height in chiller - 2.0 metres				
y - dir. (width) (m)	x - dir. (length) (m)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)	mean air speed (m/s)	min. air speed (m/s)	max. air speed (m/s)	range (m/s)	stdev (m/s)
0.0	0.0	0.99	0.80	1.25	0.45	0.155	1.69	1.40	1.88	0.48	0.137	1.54	1.41	1.71	0.30	0.088	1.87	1.70	2.02	0.31	0.090
1.0	0.0	0.92	0.73	1.01	0.28	0.106	1.72	1.49	1.88	0.39	0.118	1.79	1.61	1.98	0.37	0.103	1.90	1.71	2.05	0.33	0.119
2.0	0.0	0.88	0.72	1.04	0.32	0.109	1.56	1.32	1.73	0.42	0.127	1.66	1.44	1.82	0.38	0.113	1.79	1.69	1.88	0.18	0.062
3.0	0.0	0.84	0.63	1.01	0.39	0.126	1.50	1.25	1.70	0.46	0.144	1.52	1.23	1.71	0.49	0.168	1.71	1.52	1.81	0.28	0.096
4.0	0.0	0.58	0.34	0.83	0.49	0.145	1.29	1.09	1.48	0.40	0.138	1.37	1.30	1.53	0.23	0.082	1.54	1.39	1.59	0.20	0.075
5.0	0.0	0.47	0.19	0.69	0.50	0.164	0.69	0.44	0.87	0.44	0.138	0.79	0.58	1.01	0.44	0.143	0.98	0.78	1.15	0.37	0.118
4.5	0.5	0.65	0.36	0.93	0.58	0.187	0.36	0.29	0.46	0.16	0.064	1.01	0.79	1.25	0.46	0.151	0.92	0.46	1.15	0.69	0.194
3.5	0.5	0.81	0.60	1.02	0.43	0.132	1.54	1.36	1.67	0.31	0.104	1.43	1.24	1.59	0.36	0.138	0.96	0.65	1.15	0.50	0.139
2.5	0.5	1.12	1.00	1.30	0.29	0.096	1.30	0.97	1.58	0.61	0.194	0.98	0.72	1.20	0.48	0.143	0.73	0.42	1.00	0.59	0.188
1.5	0.5	0.64	0.40	0.87	0.48	0.146	1.24	1.13	1.44	0.31	0.096	0.58	0.44	0.73	0.29	0.086	0.59	0.38	0.80	0.43	0.154
0.5	0.5	1.17	0.90	1.50	0.60	0.166	1.28	0.90	1.47	0.57	0.168	0.52	0.22	0.73	0.51	0.169	0.57	0.19	0.85	0.66	0.181
0.0	1.0	1.17	0.88	1.31	0.43	0.145	1.10	1.01	1.25	0.23	0.079	0.34	0.16	0.44	0.27	0.086	0.41	0.26	0.70	0.44	0.127
1.0	1.0	1.05	0.45	1.36	0.91	0.257	0.46	0.20	0.69	0.49	0.168	0.46	0.23	0.68	0.45	0.134	0.51	0.29	0.83	0.54	0.209
2.0	1.0	0.89	0.59	1.14	0.55	0.160	0.72	0.44	1.03	0.60	0.206	0.39	0.15	0.56	0.41	0.112	0.49	0.18	1.11	0.92	0.267
3.0	1.0	0.90	0.73	1.15	0.42	0.136	0.51	0.29	0.75	0.46	0.153	0.43	0.15	0.67	0.52	0.171	0.71	0.33	1.05	0.72	0.191
4.0	1.0	0.89	0.75	1.01	0.26	0.097	0.78	0.70	0.87	0.17	0.072	0.64	0.48	0.88	0.41	0.136	0.43	0.29	0.80	0.51	0.152
5.0	1.0	0.74	0.52	0.87	0.36	0.129	0.70	0.29	1.01	0.72	0.204	0.80	0.42	1.29	0.87	0.330	0.87	0.39	1.14	0.75	0.193
4.5	1.5	0.88	0.74	1.07	0.32	0.119	0.47	0.25	0.75	0.50	0.178	0.52	0.19	0.71	0.52	0.180	0.95	0.52	1.31	0.79	0.245
3.5	1.5	1.19	0.87	1.42	0.55	0.186	0.54	0.33	0.72	0.39	0.114	0.46	0.29	0.72	0.43	0.107	1.00	0.73	1.41	0.68	0.195
2.5	1.5	0.72	0.58	0.95	0.38	0.136	0.50	0.17	0.89	0.72	0.210	0.62	0.36	0.78	0.43	0.131	0.42	0.27	0.60	0.32	0.114
1.5	1.5	1.15	1.01	1.36	0.34	0.094	0.48	0.30	0.92	0.62	0.180	0.80	0.29	1.25	0.95	0.247	0.63	0.47	0.89	0.43	0.135
0.5	1.5	0.98	0.73	1.38	0.65	0.176	0.58	0.29	0.87	0.58	0.189	0.27	0.15	0.38	0.22	0.068	0.62	0.33	1.11	0.77	0.237
0.0	2.0	0.87	0.71	1.01	0.30	0.089	0.60	0.26	0.87	0.61	0.228	0.92	0.80	1.08	0.27	0.079	0.72	0.29	1.25	0.95	0.289
1.0	2.0	0.54	0.32	0.73	0.41	0.159	0.77	0.64	0.85	0.21	0.073	0.91	0.72	1.38	0.66	0.195	0.45	0.29	0.65	0.36	0.116
2.0	2.0	0.55	0.37	0.72	0.36	0.122	0.93	0.67	1.28	0.61	0.184	0.48	0.29	0.80	0.51	0.180	0.75	0.30	0.96	0.66	0.192
3.0	2.0	0.73	0.45	0.87	0.43	0.115	0.62	0.27	1.01	0.74	0.275	0.88	0.58	1.11	0.53	0.169	0.44	0.18	0.70	0.52	0.173
4.0	2.0	0.78	0.69	0.87	0.18	0.070	1.25	1.14	1.43	0.29	0.101	0.93	0.68	1.13	0.45	0.134	1.12	0.81	1.36	0.55	0.162
5.0	2.0	0.74	0.47	1.24	0.77	0.215	0.64	0.40	0.97	0.58	0.177	0.86	0.69	1.07	0.38	0.133	0.73	0.30	1.05	0.75	0.231
4.5	2.5	0.43	0.34	0.45	0.10	0.038	0.53	0.36	0.79	0.44	0.132	0.94	0.71	1.33	0.62	0.215	1.17	0.87	1.67	0.80	0.285
3.5	2.5	0.72	0.51	0.95	0.45	0.124	0.42	0.22	0.58	0.36	0.122	0.43	0.16	0.68	0.52	0.164	0.45	0.20	0.71	0.51	0.165
2.5	2.5	0.66	0.30	0.91	0.61	0.199	0.81	0.43	1.10	0.67	0.240	0.26	0.05	0.66	0.61	0.168	0.31	0.16	0.52	0.36	0.129
1.5	2.5	0.44	0.29	0.63	0.33	0.131	0.67	0.31	0.81	0.50	0.159	1.06	0.73	1.36	0.63	0.227	1.58	1.27	2.01	0.74	0.224
0.5	2.5	0.69	0.54	0.79	0.25	0.085	0.35	0.18	0.71	0.53	0.168	0.89	0.62	1.19	0.57	0.170	0.75	0.39	1.25	0.86	0.280
0.0	3.0	0.64	0.58	0.76	0.18	0.067	0.61	0.45	0.76	0.31	0.110	0.81	0.39	1.04	0.66	0.203	1.51	0.84	2.17	1.33	0.354
1.0	3.0	0.56	0.45	0.74	0.29	0.124	0.45	0.15	0.66	0.51	0.162	0.37	0.15	0.72	0.57	0.184	0.55	0.15	1.25	1.10	0.340
2.0	3.0	0.77	0.41	1.22	0.81	0.317	0.73	0.55	1.00	0.46	0.154	0.18	0.03	0.34	0.31	0.098	0.21	0.03	0.41	0.38	0.121
3.0	3.0	0.53	0.29	0.73	0.44	0.173	0.44	0.15	0.75	0.60	0.227	0.29	0.15	0.44	0.28	0.071	0.23	0.12	0.34	0.22	0.076
4.0	3.0	0.52	0.30	0.68	0.38	0.113	0.62	0.30	1.01	0.71	0.193	0.19	0.03	0.38	0.34	0.105	0.48	0.24	0.77	0.53	0.183
5.0	3.0	0.21	0.02	0.42	0.40	0.110	0.45	0.30	0.72	0.42	0.131	0.43	0.27	0.60	0.32	0.121	0.43	0.16	0.66	0.50	0.179
4.5	3.5	0.27	0.15	0.30	0.15	0.049	0.12	0.01	0.15	0.14	0.057	0.15	0.06	0.25	0.19	0.049	0.36	0.15	0.65	0.50	0.171
3.5	3.5	0.39	0.16	0.73	0.57	0.188	0.31	0.15	0.51	0.36	0.086	0.14	0.02	0.28	0.26	0.075	0.10	0.02	0.24	0.22	0.081
2.5	3.5	0.73	0.16	1.17	1.00	0.302	0.32	0.15	0.56	0.41	0.174	0.26	0.12	0.60	0.48	0.155	0.10	0.01	0.16	0.15	0.061
1.5	3.5	0.37	0.16	0.56	0.40	0.124	0.28	0.15	0.44	0.28	0.098	1.00	0.79	1.22	0.43	0.143	1.13	0.58	1.63	1.05	0.384
0.5	3.5	0.72	0.28	1.10	0.81	0.227	0.24	0.15	0.44	0.28	0.107	0.62	0.45	0.83	0.39	0.128	0.41	0.17	0.56	0.39	0.134
0.0	4.0	0.75	0.58	0.91	0.33	0.132	0.20	0.10	0.34	0.24	0.082	0.63	0.39	0.87	0.49	0.185	0.53	0.15	0.89	0.74	0.247
1.0	4.0	0.58	0.44	0.79	0.36	0.106	0.30	0.15	0.44	0.28	0.109	0.66	0.45	0.87	0.43	0.167	0.44	0.23	0.86	0.63	0.167
2.0	4.0	0.77	0.45	1.02	0.58	0.204	0.32	0.09	0.57	0.48	0.186	0.58	0.31	0.88	0.57	0.186	0.73	0.16	1.41	1.25	0.364
3.0	4.0	0.37	0.20	0.59	0.39	0.119	0.53	0.31	0.73	0.42	0.126	0.16	0.02	0.29	0.27	0.077	0.21	0.11	0.29	0.18	0.068
4.0	4.0	0.47	0.17	0.69	0.52	0.169	0.04	0.02	0.11	0.09	0.038	0.11	0.01	0.15	0.14	0.059	0.07	0.02	0.15	0.13	0.067
5.0	4.0	0.37	0.17	0.64	0.47	0.175	0.35	0.15	0.71	0.56	0.170	0.56	0.42	0.86	0.45	0.144	0.77	0.45	1.11	0.66	0.250
4.5	4.5	0.16	0.05	0.29	0.24	0.058	0.20	0.02	0.29	0.27	0.107	0.70	0.52	0.94	0.43	0.128	0.84	0.74	0.93	0.19	0.069
3.5	4.5	0.79	0.48	1.01	0.54	0.165	0.52	0.15	0.92	0.77	0.235	0.37	0.15	0.70	0.55	0.172	0.29	0.15	0.65	0.50	0.180
2.5	4.5	0.32	0.16	0.54	0.38	0.125	0.43	0.13	0.87	0.74	0.216	0.32	0.15	0.57	0.42	0.139	0.90	0.62	1.07	0.45	0.141
1.5	4.5	0.38	0.18	0.60	0.42	0.140	0.49	0.17	0.72	0.55	0.143	0.38	0.14	0.72	0.58	0.178	0.54	0.29	0.81	0.52	0.207
0.5	4.5	0.32	0.16	0.62	0.46	0.129	0.77	0.33	1.23	0.89	0.256	0.79	0.44	1.26	0.82	0.293	0.45	0.15	1.17	1.01	0.385
0.0	5.0	0.54	0.30	1.01	0.71	0.199	1.23	0.75	1.53	0.78	0.253	1.44	1.18	1.70	0.53	0.190	1.16	0.66	1.38	0.72	0.217
1.0	5.0	0.19	0.15	0.29	0.14	0.058	0.36	0.15	0.78	0.63	0.218	0.38	0.13	0.58	0.45	0.147	0.32	0.12	0.59	0.47	0.161
2.0	5.0	0.81	0.46	1.14	0.68	0.173	0.26	0.02	0.68	0.66	0.201	0.74	0.34	0.99	0.65	0.193	0.57	0.45	0.75	0.30	0.110
3.0	5.0	0.86	0.55	1.04	0.50	0.156	0.40	0.16	0.60	0.44	0.148	0.63	0.54	0.73	0.19	0.079	0.73	0.31	1.17	0.85	0.232
4.0	5.0	0.90	0.73	1.16	0.43	0.148	1.38	1.16	1.53	0.38	0.100	1.39	1.20	1.58	0.39	0.119	1.32	1.13	1.55	0.43	0.125
5.0	5.0	1.00	0.83	1.26	0.43	0.162	1.49	1.27	1.72	0.46	0.159	1.61	1.29	1.78	0.49	0.154	1.46	1.21	1.72	0.52	0.162
Averages:		0.69	0.47	0.91	0.44	0.143	0.70	0.47	0.94	0.47	0.152	0.71	0.49	0.94	0.45	0.145	0.75	0.48	1.05	0.56	0.180

Table E.17: Full chiller with wings set at 25 degrees in second configuration
Double the number of readings
Breed type loaded: Red deer (same conditions as trial 1)

		Vertical Height in chiller - 1.5 metres							Vertical Height in chiller - 1.5 metres				
Coordinates		mean air	min. air	max. air	range	stdev	Coordinates		mean air	min. air	max. air	range	stdev
y - dir.	x - dir.	speed	speed	speed			y - dir.	x - dir.	speed	speed	speed		
(width)	(length)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(width)	(length)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)
0.0	0.0	1.77	1.45	2.12	0.67	0.169	2.0	2.5	0.63	0.46	0.88	0.42	0.104
0.5	0.0	1.97	1.85	2.06	0.21	0.085	1.5	2.5	0.57	0.30	0.98	0.68	0.207
1.0	0.0	2.04	1.72	2.16	0.44	0.133	1.0	2.5	0.63	0.39	0.86	0.47	0.110
1.5	0.0	2.14	1.89	2.33	0.45	0.169	0.5	2.5	0.23	0.02	0.58	0.56	0.183
2.0	0.0	2.03	1.89	2.15	0.26	0.089	0.0	2.5	0.59	0.16	0.79	0.63	0.191
2.5	0.0	1.99	1.81	2.18	0.38	0.107	0.0	3.0	0.23	0.14	0.45	0.30	0.091
3.0	0.0	1.72	1.58	1.88	0.29	0.095	0.5	3.0	0.38	0.15	0.92	0.77	0.223
3.5	0.0	1.67	1.57	1.82	0.24	0.077	1.0	3.0	0.56	0.29	1.23	0.93	0.269
4.0	0.0	1.63	1.46	1.86	0.40	0.126	1.5	3.0	0.22	0.14	0.42	0.27	0.091
4.5	0.0	1.64	1.36	1.92	0.56	0.185	2.0	3.0	0.41	0.19	0.79	0.60	0.176
5.0	0.0	1.62	1.23	1.95	0.72	0.168	2.5	3.0	0.69	0.29	1.14	0.84	0.280
5.0	0.5	1.02	0.92	1.46	0.54	0.204	3.0	3.0	0.68	0.56	0.86	0.30	0.110
4.5	0.5	0.75	0.51	0.95	0.44	0.170	3.5	3.0	0.54	0.32	0.86	0.54	0.178
4.0	0.5	1.15	0.97	1.39	0.42	0.142	4.0	3.0	0.40	0.06	0.60	0.54	0.174
3.5	0.5	1.41	1.17	1.60	0.44	0.151	4.5	3.0	0.51	0.31	0.81	0.50	0.134
3.0	0.5	1.23	1.03	1.54	0.51	0.097	5.0	3.0	0.38	0.21	0.57	0.36	0.126
2.5	0.5	1.08	1.31	1.85	0.54	0.146	5.0	3.5	0.68	0.53	0.77	0.24	0.089
2.0	0.5	1.36	1.22	1.45	0.23	0.078	4.5	3.5	0.31	0.15	0.55	0.40	0.099
1.5	0.5	1.06	0.88	1.15	0.26	0.079	4.0	3.5	0.38	0.16	0.72	0.56	0.173
1.0	0.5	1.31	1.12	1.44	0.32	0.112	3.5	3.5	0.22	0.15	0.29	0.14	0.067
0.5	0.5	1.22	0.96	1.46	0.50	0.125	3.0	3.5	0.46	0.26	0.70	0.44	0.140
0.0	0.5	1.49	1.31	1.64	0.33	0.112	2.5	3.5	0.42	0.15	0.91	0.76	0.236
0.0	1.0	0.59	0.44	0.74	0.30	0.086	2.0	3.5	0.82	0.58	1.11	0.53	0.142
0.5	1.0	0.72	0.59	0.82	0.23	0.053	1.5	3.5	0.71	0.32	1.01	0.69	0.179
1.0	1.0	0.49	0.34	0.62	0.27	0.089	1.0	3.5	0.81	0.50	0.98	0.48	0.139
1.5	1.0	0.55	0.44	0.71	0.27	0.089	0.5	3.5	0.93	0.73	1.21	0.48	0.162
2.0	1.0	0.51	0.33	0.72	0.39	0.120	0.0	3.5	0.75	0.44	1.07	0.63	0.196
2.5	1.0	0.55	0.45	0.61	0.16	0.046	0.0	4.0	0.82	0.59	1.01	0.43	0.163
3.0	1.0	0.73	0.46	0.87	0.42	0.127	0.5	4.0	0.89	0.50	1.16	0.66	0.246
3.5	1.0	0.92	0.73	1.13	0.40	0.154	1.0	4.0	0.82	0.51	1.07	0.56	0.165
4.0	1.0	1.07	0.88	1.35	0.48	0.202	1.5	4.0	0.66	0.44	0.94	0.51	0.175
4.5	1.0	0.79	0.44	1.56	1.13	0.345	2.0	4.0	0.75	0.58	0.95	0.38	0.102
5.0	1.0	0.51	0.30	0.72	0.42	0.115	2.5	4.0	1.00	0.80	1.29	0.49	0.147
5.0	1.5	0.79	0.57	1.09	0.52	0.147	3.0	4.0	0.74	0.37	1.08	0.71	0.197
4.5	1.5	0.57	0.41	0.70	0.29	0.108	3.5	4.0	0.82	0.45	0.98	0.54	0.146
4.0	1.5	0.39	0.22	0.58	0.36	0.098	4.0	4.0	1.12	0.88	1.43	0.55	0.186
3.5	1.5	0.60	0.31	0.99	0.68	0.188	4.5	4.0	0.44	0.30	0.68	0.38	0.110
3.0	1.5	0.49	0.33	0.62	0.28	0.094	5.0	4.0	0.14	0.07	0.29	0.22	0.063
2.5	1.5	0.22	0.15	0.29	0.14	0.066	5.0	4.5	1.22	1.02	1.44	0.42	0.132
2.0	1.5	0.30	0.15	0.44	0.28	0.090	4.5	4.5	1.44	1.21	1.64	0.43	0.305
1.5	1.5	0.40	0.29	0.46	0.16	0.066	4.0	4.5	1.64	1.38	1.86	0.48	0.155
1.0	1.5	0.26	0.16	0.34	0.18	0.059	3.5	4.5	1.03	0.73	1.46	0.73	0.266
0.5	1.5	0.24	0.12	0.44	0.31	0.083	3.0	4.5	0.76	0.53	1.00	0.48	0.132
0.0	1.5	0.34	0.19	0.46	0.26	0.087	2.5	4.5	0.90	0.75	1.07	0.31	0.095
0.0	2.0	0.88	0.73	1.05	0.32	0.107	2.0	4.5	0.89	0.49	1.32	0.83	0.273
0.5	2.0	0.92	0.71	1.13	0.42	0.131	1.5	4.5	0.72	0.43	0.96	0.54	0.163
1.0	2.0	1.06	0.87	1.26	0.39	0.128	1.0	4.5	0.66	0.38	1.00	0.63	0.213
1.5	2.0	1.00	0.85	1.16	0.30	0.090	0.5	4.5	0.88	0.49	1.03	0.55	0.156
2.0	2.0	0.98	0.76	1.26	0.50	0.142	0.0	4.5	0.58	0.29	0.85	0.56	0.180
2.5	2.0	1.36	1.19	1.51	0.32	0.095	0.0	5.0	0.81	0.45	1.14	0.69	0.188
3.0	2.0	1.17	1.04	1.30	0.25	0.072	0.5	5.0	1.26	0.91	1.38	0.46	0.089
3.5	2.0	1.35	1.20	1.50	0.30	0.092	1.0	5.0	1.44	1.04	1.91	0.86	0.281
4.0	2.0	1.09	0.89	1.23	0.33	0.109	1.5	5.0	1.30	1.02	1.44	0.42	0.140
4.5	2.0	1.10	0.99	1.21	0.21	0.069	2.0	5.0	1.10	1.00	1.16	0.15	0.063
5.0	2.0	0.89	0.78	1.01	0.23	0.069	2.5	5.0	1.01	0.87	1.15	0.27	0.097
5.0	2.5	0.86	0.73	1.01	0.28	0.119	3.0	5.0	0.95	0.53	1.15	0.62	0.184
4.5	2.5	0.44	0.29	0.61	0.31	0.106	3.5	5.0	1.23	0.89	1.58	0.69	0.233
4.0	2.5	0.35	0.28	0.48	0.19	0.065	4.0	5.0	1.20	1.03	1.58	0.55	0.165
3.5	2.5	0.44	0.26	0.73	0.47	0.165	4.5	5.0	1.42	1.18	1.61	0.44	0.137
3.0	2.5	0.43	0.18	0.68	0.50	0.149	5.0	5.0	1.86	1.56	2.15	0.59	0.172
2.5	2.5	0.63	0.46	0.88	0.42	0.104	Averages:		0.88	0.67	1.12	0.45	0.140

Table E.18: Replicate readings at 1.5 m
Breed type loaded: Red deer

Coordinates		Reading 1	Reading 2	Difference
y - dir.	x - dir.	mean air	mean air	mean air
(width)	(length)	speed	speed	speed
(m)	(m)	(m/s)	(m/s)	(m/s)
0.0	0.0	1.699	1.770	0.071
1.0	0.0	1.992	2.041	0.049
2.0	0.0	1.947	2.033	0.087
3.0	0.0	1.659	1.724	0.065
4.0	0.0	1.618	1.628	0.009
5.0	0.0	1.411	1.620	0.209
4.5	0.5	0.990	0.754	0.236
3.5	0.5	1.234	1.413	0.179
2.5	0.5	1.316	1.080	0.236
1.5	0.5	1.055	1.061	0.006
0.5	0.5	1.262	1.220	0.041
0.0	1.0	0.797	0.588	0.208
1.0	1.0	0.543	0.493	0.050
2.0	1.0	0.399	0.515	0.115
3.0	1.0	0.527	0.731	0.204
4.0	1.0	0.895	1.071	0.176
5.0	1.0	0.783	0.509	0.274
4.5	1.5	0.763	0.565	0.197
3.5	1.5	0.314	0.603	0.289
2.5	1.5	0.196	0.223	0.027
1.5	1.5	0.308	0.399	0.091
0.5	1.5	0.267	0.244	0.022
0.0	2.0	0.973	0.877	0.096
1.0	2.0	1.075	1.061	0.014
2.0	2.0	1.079	0.976	0.103
3.0	2.0	0.876	1.167	0.291
4.0	2.0	0.917	1.092	0.175
5.0	2.0	0.871	0.889	0.018
4.5	2.5	0.256	0.436	0.180
3.5	2.5	0.433	0.440	0.006
2.5	2.5	0.731	0.629	0.102
1.5	2.5	0.701	0.631	0.070
0.5	2.5	0.589	0.593	0.004
0.0	3.0	0.566	0.384	0.183
1.0	3.0	0.303	0.218	0.086
2.0	3.0	0.854	0.687	0.167
3.0	3.0	0.591	0.538	0.053
4.0	3.0	0.326	0.506	0.181
5.0	3.0	0.756	0.675	0.081
4.5	3.5	0.305	0.378	0.073
3.5	3.5	0.630	0.459	0.171
2.5	3.5	0.687	0.818	0.131
1.5	3.5	1.015	0.812	0.203
0.5	3.5	0.584	0.749	0.165
0.0	4.0	0.803	0.885	0.082
1.0	4.0	0.742	0.661	0.081
2.0	4.0	0.955	0.998	0.042
3.0	4.0	1.004	0.823	0.182
4.0	4.0	0.264	0.441	0.177
5.0	4.0	1.334	1.222	0.112
4.5	4.5	1.238	1.438	0.199
3.5	4.5	0.747	0.764	0.018
2.5	4.5	0.919	0.885	0.034
1.5	4.5	0.890	0.661	0.229
0.5	4.5	1.010	0.882	0.128
0.0	5.0	1.450	1.262	0.187
1.0	5.0	1.211	1.297	0.086
2.0	5.0	0.963	1.009	0.046
3.0	5.0	1.135	1.234	0.099
4.0	5.0	1.601	1.422	0.179
5.0	5.0	2.014	1.856	0.158
	Averages:	0.908	0.902	0.122

APPENDIX F

Carcass weightloss data - Trial 1, No wings - 26 hour chill cycle

Table F.1: Carcass rails 1-3

1st Rail - Red Deer				2nd Rail - Red Deer				3rd Rail - Read Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
				51	56.5	54.5	3.5	73	46.2	44.1	4.5
29	N/A	N/A	N/A	52	62.9	60.9	3.2	74	47	45.4	3.4
30	N/A	N/A	N/A	53	62.0	60.1	3.1	75	45	43.3	3.8
31	N/A	N/A	N/A	54	60.0	58.2	3.0	76	50.4	48.8	3.2
32	N/A	N/A	N/A	55	68.4	66.5	2.8	77	54.2	52.6	3.0
33	N/A	N/A	N/A	56	62.6	60.7	3.0	78	42.7	41.2	3.5
34	N/A	N/A	N/A	57	49.6	48.1	3.0	79	46.1	44.5	3.5
35	N/A	N/A	N/A	58	43.0	41.5	3.5	80	47.3	45.7	3.4
36	59.9	58.1	3.0	59	36.4	35.2	3.3	81	48.3	46.6	3.5
37	58.0	55.8	3.8	60	48.0	46.5	3.1	82	45.8	44.1	3.7
38	60.3	58.3	3.3	61	51.1	49.3	3.5	83	45.3	43.8	3.3
39	64.1	61.8	3.6	62	51.5	49.8	3.3	84	42.3	41.0	3.1
40	63.2	61.2	3.2	63	45.5	43.9	3.5	85	54.3	52.4	3.5
41	64.1	62.1	3.1	64	47.0	45.4	3.4	86	49.7	48.2	3.0
42	63.7	61.5	3.5	65	58.6	56.8	3.1	87	59	57.0	3.4
43	61.7	59.5	3.6	66	48.6	46.9	3.5	88	60	58.0	3.3
44	50.2	48.1	4.2	67	47.2	45.5	3.6	89	58.4	56.5	3.3
45	58.6	56.0	4.4	68	42.9	41.6	3.0	90	56.1	54.3	3.2
46	57.8	55.4	4.2	69	43.9	42.3	3.6	91	54.8	53.3	2.7
47	59.7	57.1	4.4	70	50.0	48.2	3.6	92	60.8	58.8	3.3
48	60.0	57.5	4.2	71	48.7	46.8	3.9	93	57.1	55.1	3.5
49	73.5	70.8	3.7	72	46.9	44.9	4.3	94	61.4	59.6	2.9
50	76.7	74.0	3.5								
Average weight loss along rail 1:			3.8%	Average weight loss along rail 2:			3.5%	Average weight loss along rail 3:			3.2%

▭ = Carcasses in test zone

Table F.2: Carcass rails 4-6

4th Rail - Red Deer				5th Rail - Red Deer				6th Rail - Red Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
95	58.0	55.9	3.6	117	84.9	81.8	3.7				
96	56.5	54.9	2.8	118	56.3	54.6	3.0				
97	52.0	50.3	3.3	119	67.3	65.2	3.1	140	42.9	40.1	6.5
98	55.6	53.8	3.2	120	61.9	59.8	3.4	141	37.2	36.0	3.2
99	55.3	53.8	2.7	121	74.9	72.5	3.2	142	44.5	43.2	2.9
100	61.0	59.3	2.8	122	40.4	38.9	3.7	143	38.3	37.2	2.9
101	56.3	54.6	3.0	123	60.8	59.0	3.0	144	42.3	41.1	2.8
102	55.3	53.7	2.9	124	65.6	63.4	3.4	145	46.0	44.5	3.3
103	57.8	56.1	2.9	125	62.1	60.1	3.2	146	44.1	42.8	2.9
104	59.7	58.0	2.8	126	59.8	58.0	3.0	147	82.1	79.0	3.8
105	58.1	56.2	3.3	127	55.4	53.7	3.1	148	82.3	79.6	3.3
106	58.2	56.3	3.3	128	70.2	68.1	3.0	149	74.6	72.0	3.5
107	57.3	55.4	3.3	129	66.8	64.6	3.3	150	96.4	92.9	3.6
108	61.9	60.0	3.1	130	44.5	42.8	3.8	151	84.0	80.8	3.8
109	56.6	54.7	3.4	131	67.2	65.1	3.1	152	65.6	63.2	3.7
110	58.0	56.1	3.3	132	57.1	55.1	3.5	153	57.3	55.3	3.5
111	59.5	57.5	3.4	133	48.6	47.0	3.3	154	73.1	70.1	4.1
112	60.3	58.2	3.5	134	66.9	65.0	2.8	155	89.0	85.1	4.4
113	52.2	50.4	3.4	135	58.8	56.5	3.9	156	89.7	86.1	4.0
114	47.5	45.9	3.4	136	48.9	47.0	3.9	157	83.8	80.2	4.3
115	57.4	55.4	3.5	137	56.6	54.6	3.5	158	150.4	144.8	3.7
116	48.0	46.0	4.2	138	70.2	67.4	4.0	159	45.9	44.2	3.7
				139	57.3	54.9	4.2	160	43.0	41.8	2.8
Average weight loss along rail 4:			3.4%	Average weight loss along rail 5:			3.5%	Average weight loss along rail 6:			3.8%

▭ = Carcasses in test zone

Average carcass weight loss in test zone:	3.5%

Carcass weightloss data - Trial 2, No wings - 14 hour chill cycle

Table F.3: Carcass rails 1-3

1st Rail - Fallow Deer				2nd Rail - Fallow Deer				3rd Rail - Fallow Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
6	22.0	21.3	3.2								
7	24.4	23.7	2.9					67	23.5	22.9	2.6
8	20.9	20.3	2.9	37	22.7	22.1	2.6	68	25.0	24.4	2.4
9	22.1	21.5	2.7	38	22.3	21.7	2.7	69	20.9	20.4	2.4
10	20.7	20.1	2.9	39	21.1	20.5	2.8	70	23.0	22.5	2.2
11	21.0	20.4	2.9	40	21.5	21.0	2.3	71	22.7	22.2	2.2
12	22.4	21.8	2.7	41	22.8	22.2	2.6	72	21.3	20.8	2.3
13	21.5	20.9	2.8	42	22.7	22.2	2.2	73	22.1	21.6	2.3
14	23.2	22.6	2.6	43	22.0	21.3	3.2	74	22.6	22.1	2.2
15	22.3	21.6	3.1	44	21.1	20.5	2.8	75	24.8	24.3	2.0
16	21.7	21.1	2.8	45	21.6	21.1	2.3	76	18.4	17.9	2.7
17	22.7	21.9	3.5	46	20.4	19.8	2.9	77	21.3	20.8	2.3
18	21.9	21.3	2.7	47	22.0	21.5	2.3	78	22.5	21.8	3.1
19	22.9	22.3	2.6	48	22.0	21.5	2.3	79	24.1	23.6	2.1
20	22.5	21.9	2.7	49	22.1	21.6	2.3	80	N/A	19.6	N/A
21	22.4	21.5	4.0	50	21.2	20.7	2.4	81	20.6	20.1	2.4
22	23.2	22.5	3.0	51	21.6	21.2	1.9	82	22.8	22.3	2.2
23	22.0	21.3	3.2	52	23.2	22.5	3.0	83	21.0	20.5	2.4
24	22.9	22.0	3.9	53	22.0	21.5	2.3	84	19.9	19.5	2.0
25	22.4	21.8	2.7	54	22.2	21.7	2.3	85	19.9	19.4	2.5
26	21.4	20.7	3.3	55	21.6	21.1	2.3	86	20.0	19.5	2.5
27	21.7	21.1	2.8	56	21.6	21.1	2.3	87	21.0	20.5	2.4
28	21.7	21.0	3.2	57	20.5	20.2	1.5	88	22.1	21.5	2.7
29	21.7	20.8	4.1	58	21.3	20.8	2.3	89	21.7	21.2	2.3
30	21.4	20.7	3.3	59	21.1	20.6	2.4	90	21.8	21.3	2.3
31	21.9	21.2	3.2	60	22.0	21.5	2.3	91	19.2	18.7	2.6
32	22.4	21.7	3.1	61	22.0	N/A	N/A	92	20.5	19.9	2.9
33	22.0	21.3	3.2	62	18.7	18.2	2.7	93	20.1	19.6	2.5
34	22.6	21.9	3.1	63	21.8	21.2	2.8	94	21.2	20.7	2.4
35	22.5	21.8	3.1	64	20.0	19.4	3.0	95	20.0	19.6	2.0
36	22.3	21.6	3.1	65	22.7	22.1	2.6	96	21.8	21.2	2.8
				66	18.9	18.4	2.6	97	19.2	18.6	3.1
Average weight loss along rail 1:			3.2%	Average weight loss along rail 2:			2.5%	Average weight loss along rail 3:			2.5%

= Carcasses in test zone

Table F.4: Carcass rails 4-6

4th Rail - Fallow & Red Deer				5th Rail Red Deer				6th Rail - Red Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
98	19.5	19.1	2.1								
99	19.7	19.2	2.5	13	45.1	43.8	2.9				
100	19.8	19.5	1.5	14	57.7	56.2	2.6	37	49.9	48.8	2.2
101	20.9	20.4	2.4	15	32.7	31.8	2.8	38	42.6	41.5	2.6
102	22.3	21.7	2.7	16	51.3	49.9	2.7	39	49.9	48.6	2.6
103	20.4	20.0	2.0	17	55.6	54.4	2.2	40	51.5	50.5	1.9
104	20.5	20.1	2.0	18	47.6	46.3	2.7	41	55.2	54.1	2.0
105	20.1	19.6	2.5	19	45.3	44.2	2.4	42	53.5	52.4	2.1
106	20.7	20.2	2.4	20	47.3	46.1	2.5	43	42.6	41.5	2.6
107	19.4	18.9	2.6	21	48.6	47.4	2.5	44	41.8	40.6	2.9
108	20.4	19.9	2.5	22	50.8	49.5	2.6	45	54.6	53.4	2.2
109	21.9	21.4	2.3	23	47.1	45.8	2.8	46	45.8	44.5	2.8
110	19.2	18.7	2.6	24	54.4	53.1	2.4	47	58.2	56.8	2.4
1	45.8	44.5	2.8	25	55.5	54.1	2.5	48	46.7	45.2	3.2
2	45.8	44.6	2.6	26	37.6	36.5	2.9	49	45.5	44.2	2.9
3	49.9	48.7	2.4	27	49.5	48.5	2.0	50	60.6	58.6	3.3
4	37.7	36.6	2.9	28	49.0	47.9	2.2	51	40.8	39.6	2.9
5	47.0	45.7	2.8	29	40.3	39.2	2.7	52	37.8	36.7	2.9
6	45.0	43.8	2.7	30	57.5	56.1	2.4	53	55.9	54.3	2.9
7	54.4	53.0	2.6	31	45.0	43.8	2.7	54	45.5	44.3	2.6
8	51.2	49.9	2.5	32	53.4	52.1	2.4	55	42.8	41.5	3.0
9	51.8	50.3	2.9	33	56.5	55.1	2.5	56	48.7	47.3	2.9
10	48.7	47.4	2.7	34	41.7	40.5	2.9	57	40.6	39.3	3.2
11	58.7	57.1	2.7	35	49.7	48.5	2.4	58	69.4	66.8	3.7
12	45.1	43.9	2.7	36	51.7	50.3	2.7				
Average weight loss along rail 4:			2.7%	Average weight loss along rail 5:			2.5%	Average weight loss along rail 6:			3.1%

= Carcasses in test zone

Average carcass weight loss in test zone:	2.7%

Carcass weightloss data - Trial 3, No wings - 14 hour chill cycle

Table F.5: Carcass rails 1-3

1st Rail - Red Deer				2nd Rail - Red Deer				3rd Rail - Read Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
1	53.5	52.1	2.6								
2	51.6	50.3	2.5	25	39.4	38.1	3.3	48	55.5	53.6	3.4
3	54.3	52.9	2.6	26	38.1	36.9	3.1	49	53.2	51.7	2.8
4	51.5	50.2	2.5	27	53.7	52.2	2.8	50	54.9	53.8	2.0
5	57.5	56.2	2.3	28	51.2	49.7	2.9	51	52.3	50.9	2.7
6	49.0	47.8	2.4	29	51.5	50.0	2.9	52	55.5	54.0	2.7
7	49.6	48.2	2.8	30	50.4	48.9	3.0	53	54.4	52.9	2.8
8	69.1	67.5	2.3	31	54.4	52.8	2.9	54	48.6	47.3	2.7
9	58.2	56.9	2.2	32	55.6	54.1	2.7	55	52.8	51.3	2.8
10	53.4	52.1	2.4	33	50.3	48.7	3.2	56	53.7	52.1	3.0
11	57.5	56.1	2.4	34	54.2	52.7	2.8	57	54.1	52.5	3.0
12	46.4	45.1	2.8	35	48.8	47.2	3.3	58	43.4	42.1	3.0
13	44.1	42.6	3.4	36	51.2	49.7	2.9	59	56.1	54.5	2.9
14	43.2	41.9	3.0	37	47.2	45.8	3.0	60	44.6	43.3	2.9
15	41.8	40.5	3.1	38	44.4	43.0	3.2	61	42.0	40.8	2.9
16	41.2	39.7	3.6	39	47.2	45.8	3.0	62	51.9	50.4	2.9
17	39.7	38.7	2.5	40	50.8	49.4	2.8	63	50.7	49.2	3.0
18	41.1	39.7	3.4	41	46.7	45.3	3.0	64	53.8	52.3	2.8
19	39.4	37.9	3.8	42	51.2	49.5	3.3	65	55.8	54.2	2.9
20	41.5	40.1	3.4	43	51.6	50.0	3.1	66	51.4	49.9	2.9
21	39.8	38.6	3.0	44	43.6	42.2	3.2	67	55.9	54.3	2.9
22	43.0	41.6	3.3	45	44.4	42.9	3.4	68	51.9	50.5	2.7
23	38.8	37.6	3.1	46	50.5	48.9	3.2	69	45.8	44.6	2.6
24	41.3	39.8	3.6	47	50.5	49.0	3.0	94	57.8	56.2	2.8
70	41.8	40.3	3.6	93	47.5	46.1	2.9				
Average weight loss along rail 1:			3.3%	Average weight loss along rail 2:			3.1%	Average weight loss along rail 3:			2.8%

= Carcasses in test zone

Table F.6: Carcass rails 4-6

4th Rail - Red Deer				5th Rail - Red Deer				6th Rail - Red Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
				95	47.6	46.4	2.5	119	52.1	50.6	2.9
71	50.4	49	2.8	96	56.9	55.5	2.5	120	48.5	47.1	2.9
72	47.9	46.3	3.3	97	54.7	53.0	3.1	121	59.1	57.5	2.7
73	54.8	53.3	2.7	98	54.0	52.4	3.0	122	51.2	49.9	2.5
74	43.2	41.9	3.0	99	47.5	46.4	2.3	123	55.7	54.2	2.7
75	55	53.5	2.7	100	52.6	51.2	2.7	124	51.6	50.3	2.5
76	54.1	52.5	3.0	101	49.6	48.2	2.8	125	49.0	47.6	2.9
77	47.7	46.2	3.1	102	48.5	47.2	2.7	126	49.0	47.7	2.7
78	51	49.5	2.9	103	51.9	50.3	3.1	127	54.9	53.5	2.6
79	51.9	50.4	2.9	104	53.7	52.1	3.0	128	45.8	44.4	3.1
80	53.6	52	3.0	105	45.9	44.5	3.1	129	52.4	51.0	2.7
81	54.1	52.6	2.8	106	53.7	52.0	3.2	130	47.7	46.3	2.9
82	44.4	43.1	2.9	107	60.6	59.2	2.3	131	63.9	61.8	3.3
83	52.1	50.5	3.1	108	56.2	54.6	2.8	132	65.0	62.7	3.5
84	48.1	46.6	3.1	109	44.5	43.2	2.9	133	49.0	47.1	3.9
85	55.5	53.8	3.1	110	50.9	49.4	2.9	134	52.7	51.0	3.2
86	51.5	50	2.9	111	53.4	51.8	3.0	135	68.2	66.0	3.2
87	56.7	55	3.0	112	51.8	50.4	2.7	136	59.3	57.1	3.7
88	53.4	51.7	3.2	113	55.4	53.8	2.9	137	50.6	49.0	3.2
89	48.8	47.3	3.1	114	50.9	49.2	3.3	138	39.3	38.1	3.1
90	52.1	50.6	2.9	115	53.1	51.5	3.0	139	60.3	58.7	2.7
91	52.5	50.8	3.2	116	52.0	50.5	2.9	140	51.9	50.4	2.9
92	52.8	51.3	2.8	117	50.4	48.7	3.4	141	52.5	50.9	3.0
118	48.3	46.9	2.9	143	50.5	48.8	3.4	142	62.1	60.1	3.2
				144	60.8	58.9	3.1	145	44.6	43.2	3.1
Average weight loss along rail 4:			3.0%	Average weight loss along rail 5:			3.0%	Average weight loss along rail 6:			3.2%

= Carcasses in test zone

Average carcass weight loss in test zone:	3.1%

Carcass weightloss data - Trial 1, wing configuration 1 - 14 hour chill cycle

Table F.7: Carcass rails 1-3

1st Rail - Fallow & Red Deer				2nd Rail - Red Deer				3rd Rail - Red Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
1	24.7	24.1	2.4								
2	19.1	18.5	3.1								
3	17.2	16.8	2.3								
4	16.4	15.9	3.0								
5	18.9	18.4	2.6								
6	19.3	18.7	3.1					28	55	53.8	2.2
7	17.5	16.9	3.4	7	65.2	63.8	2.1	29	49.6	48.3	2.6
8	15.4	14.9	3.2	8	64.2	62.5	2.6	30	48.4	47.1	2.7
9	17.5	16.9	3.4	9	42.5	41.3	2.8	31	57.9	56.7	2.1
10	20.8	20.2	2.9	10	48.6	47.2	2.9	32	50.1	48.8	2.6
11	15.6	15.1	3.2	11	43.8	42.5	3.0	33	50.9	49.6	2.6
12	18.3	17.8	2.7	12	45.9	44.8	2.4	34	57.3	55.9	2.4
13	19.2	18.7	2.6	13	39.0	37.9	2.8	35			
14	17.9	17.3	3.4	14	46.3	45.0	2.8	36	49.5	48.2	2.6
15	19.2	18.6	3.1	15	54.3	52.8	2.8	37	55.6	54.1	2.7
16	17.6	17.1	2.8	16	55.5	53.9	2.9	38	46.3	45.0	2.8
17	18.1	17.6	2.8	17	53.5	52.0	2.8	39	43.4	42.2	2.8
18	18.0	17.4	3.3	18	51.0	49.5	2.9	40	41.0	39.9	2.7
19	16.6	16.0	3.6	19	53.7	52.4	2.4	41	48.7	47.4	2.7
20	22.1	21.3	3.6	20	54.3	52.6	3.1	42	41.2	40.0	2.9
21	21.0	20.3	3.3	21	46.5	45.0	3.2	43	32.9	31.8	3.3
22	18.0	17.5	2.8	22	62.3	60.6	2.7	44	45.2	43.9	2.9
23	16.1	15.6	3.1	23	49.7	48.1	3.2	45	46.0	44.7	2.8
1	52.2	50.6	3.1	24	46.8	45.2	3.4	46	37.1	35.8	3.5
2	70.9	69.0	2.7	25	59.3	57.4	3.2	47	54.4	52.7	3.1
3	56.7	55.2	2.6	26	55.7	54.0	3.1	48	43.4	42.0	3.2
4	48.6	46.9	3.5	27	51.3	49.9	2.7	49	46.1	44.7	3.0
5	40.9	39.6	3.2	52	46.2	45.7	1.1	50	48.7	47.3	2.9
6	58.6	56.9	2.9					53	48.6	47.3	2.7
51	47.3	46.8	1.1								
Average weight loss along rail 1:			3.0%	Average weight loss along rail 2:			2.8%	Average weight loss along rail 3:			3.0%

= Carcasses in test zone

Table F.8: Carcass rails 4-6

4th Rail - Red Deer				5th Rail - Red Deer				6th Rail - Red Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
54	45.1	44.8	0.7	76	48.7			99	45.1	43.6	3.3
55	48.1			77	46.3	45.0	2.8	100	50.4	48.8	3.2
56	50.3	48.9	2.8	78	45.3	43.9	3.1	101	47.7	46.3	2.9
57	40.9	39.7	2.9	79	60.4	58.9	2.5	102	56.2	54.4	3.2
58	40.2	38.9	3.2	80	53.8	52.3	2.8	103	56.6	55.0	2.8
59	46.1	44.7	3.0	81	45.2	43.9	2.9	104	46.6	44.4	4.7
60	43.8	42.3	3.4	82	43.8	42.4	3.2	105	58.3	56.7	2.7
61	43	41.6	3.3	83	49.7	48.2	3.0	106	45.6	44.3	2.9
62	55.8	54	3.2	84	49.1	47.6	3.1	107	52.6	51.1	2.9
63	49.3	47.9	2.8	85	54.6	53.0	2.9	108	51.0	49.4	3.1
64	55.1	53.4	3.1	86	47.3	45.9	3.0	109	40.0	37.8	5.5
65	48.5	47	3.1	87	51.5	50.0	2.9	110	48.6	47.1	3.1
66	47.3	45.9	3.0	88	45.8	44.3	3.3	111	51.4	49.7	3.3
67	55.1	53.1	3.6	89	48.7	47.1	3.3	112	52.1	50.5	3.1
68	49.8	48.2	3.2	90	47.0	45.4	3.4	113	61.2	59.5	2.8
69	46.3	45	2.8	91	46.2	44.6	3.5	114	53.1	50.9	4.1
70	55.2	53.4	3.3	92	48.0	46.2	3.7	115	51.4	49.7	3.3
71	40.8	39.2	3.9	93	54.1	52.2	3.5	116	40.4	38.9	3.7
72	54.5	52.5	3.7	94	45.1	43.5	3.5	117	37.5	36.0	4.0
73	49	47.3	3.5	95	60.3	58.5	3.0	118	40.4	38.8	4.0
74	53.2	51.2	3.8	96	52.8	50.9	3.6	119	41.3	39.7	3.9
75	48.5	47.3	2.5	97	52.8	51.1	3.2	120	32.0	30.8	3.8
				98	44.5	42.9	3.6	121	45.0		
Average weight loss along rail 4:			3.3%	Average weight loss along rail 5:			3.3%	Average weight loss along rail 6:			3.7%

= Carcasses in test zone

Average carcass weight loss in test zone:	3.2%

Carcass weightloss data - Trial 2, wing configuration 1 - 14 hour chill cycle

Table F.9: Carcass rails 1-3

1st Rail - Red Deer				2nd Rail - Red Deer				3rd Rail - Read Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
1	39.8	38.6	3.0								
2	53.3	51.7	3.0					49	43.9	42.5	3.2
3	47.9	46.4	3.1	25	53.2	51.7	2.8	50	39.6	38.3	3.3
4	40.8	39.4	3.4	26	40.9	39.5	3.4	51	43.7	42.3	3.2
5	46.0	44.6	3.0	27	45.3	44.0	2.9	52	44.7	43.2	3.4
6	34.8	33.4	4.0	28	55.2	53.8	2.5	53	49.4	48.0	2.8
7	50.6	49.2	2.8	29	42.8	41.5	3.0	54	61.2	59.4	2.9
8	47.9	46.5	2.9	30	47.6	46.3	2.7	55	48.2	46.5	3.5
9	45.2	43.8	3.1	31	43.7	42.3	3.2	56	58.0	56.3	2.9
10	41.4	40.1	3.1	32	68.4	66.6	2.6	57	40.7	39.3	3.4
11	37.2	36.0	3.2	33	46.1	44.7	3.0	58	36.8	35.4	3.8
12	50.3	49.0	2.6	34	41.0	39.8	2.9	59	53.2	51.6	3.0
13	49.1	47.6	3.1	35	42.2	40.9	3.1	60	41.2	39.8	3.4
14	41.0	39.6	3.4	36	56.0	54.6	2.5	61	38.5	37.1	3.6
15	50.5	49.0	3.0	37	39.2	37.9	3.3	62	51.4	49.7	3.3
16	46.5	45.1	3.0	38	60.3	58.9	2.3	63	51.3	49.8	2.9
17	44.7	43.3	3.1	39	42.1	40.7	3.3	64	45.0	43.4	3.6
18	40.9	39.6	3.2	40	42.6	41.2	3.3	65	50.3	48.5	3.6
19	55.2	53.4	3.3	41	45.2	43.8	3.1	66	45.4	43.7	3.7
20	51.1	49.4	3.3	42	41.3	39.9	3.4	67	37.2	35.8	3.8
21	47	45.5	3.2	43	48.4	46.9	3.1	68	40.5	39.0	3.7
22	50.5	48.9	3.2	44	45.6	44.1	3.3	69	45.4	43.8	3.5
23	46.1	44.6	3.3	45	39.6	38.1	3.8	70	53.7	51.8	3.5
24	42.2	40.9	3.1	46	40.7	39.4	3.2	71	47.1	45.4	3.6
47	49.4	47.8	3.2	48	43.0	41.5	3.5	72	50.8	49.0	3.5
								97	56.8	54.7	3.7
Average weight loss along rail 1:			3.2%	Average weight loss along rail 2:			3.2%	Average weight loss along rail 3:			3.5%

= Carcasses in test zone

Table F.10: Carcass rails 4-6

4th Rail - Red Deer				5th Rail - Red Deer				6th Rail - Red Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
74	46.9	45.5	3.0	99	56.8	55.2	2.8				
75	42.9	41.4	3.5	100	54.9	53.3	2.9	123	57.0	55.4	2.8
76	45.9	44.5	3.1	101	59.4	57.6	3.0	124	54.1	52.5	3.0
77	54.5	52.7	3.3	102	56.1	54.4	3.0	125	55.7	54.0	3.1
78	52.7	51.1	3.0	103	58.9	57.2	2.9	126	48.0	46.5	3.1
79	54.1	52.4	3.1	104	52.4	50.7	3.2	127	54.6	52.9	3.1
80	44.4	42.9	3.4	105	54.4	52.7	3.1	128	102.6	99.8	2.7
81	47.3	45.7	3.4	106	59.6	57.9	2.9	129	56.1	54.6	2.7
82	45	43.4	3.6	107	63.1	61.2	3.0	130	85.2	82.7	2.9
83	52	50.3	3.3	108	59.6	57.7	3.2	131	85.5	82.9	3.0
84	45.5	44	3.3	109	63.2	61.4	2.8	132	57.8	56.0	3.1
85	48.1	46.4	3.5	110	56.4	54.5	3.4	133	50.7	49.2	3.0
86	53.2	51.4	3.4	111	51.5	49.9	3.1	134	64.7	62.7	3.1
87	88.4	85.7	3.1	112	71.9	69.9	2.8	135	69.3	67.2	3.0
88	72.7	70.5	3.0	113	79.6	77.0	3.3	136	44.8	43.3	3.3
89	76.3	74.2	2.8	114	55.8	54.1	3.0	137	53.5	51.6	3.6
90	54.9	53.3	2.9	115	52.6	50.7	3.6	138	49.6	47.8	3.6
91	60	58.1	3.2	116	60.0	57.9	3.5	139	39.8	38.1	4.3
92	57.9	56	3.3	117	60.0	57.8	3.7	140	57.0	54.9	3.7
93	52.2	50.3	3.6	118	53.2	51.7	2.8	141	57.1	55.1	3.5
94	59.2	57.3	3.2	119	55.4	53.5	3.4	142	53.4	51.5	3.6
95	53.4	51.5	3.6	120	58.1	56.0	3.6	143	56.9	54.9	3.5
96	59.5	57.4	3.5	121	55.3	53.1	4.0	144	56.2	54.0	3.9
98	63	60.7	3.7	122	53.5	51.4	3.9	145	48.5	46.6	3.9
Average weight loss along rail 4:			3.3%	Average weight loss along rail 5:			3.4%	Average weight loss along rail 6:			3.6%

= Carcasses in test zone

Average carcass weight loss in test zone:	3.4%

Carcass weightloss data - Trial 3, wing configuration 1 - 14 hour chill cycle

Table F.11: Carcass rails 1-3

1st Rail - Red Deer				2nd Rail - Red Deer				3rd Rail - Read Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
1	50.8	49.3	3.1								
2	61.2	59.3	3.3	25	42.1	41.1	2.5	48	56.6	55.0	3.0
3	74.3	71.9	3.3	26	45.4	44.1	3.0	49	55.3	53.7	2.9
4	53.9	52.2	3.2	27	46.2	44.9	2.8	50	43.4	42.3	2.7
5	66.5	64.3	3.5	28	44.6	43.4	2.7	51	59.3	57.7	2.7
6	45.2	43.9	3.0	29	41.5	40.3	3.0	52	52.9	51.5	2.7
7	45.2	44.0	2.8	30	45.1	44.0	2.6	53	58.2	56.5	3.0
8	41.6	40.4	2.9	31	38.7	37.6	3.0	54	54.5	52.9	2.9
9	40.5	39.2	3.2	32	43.5	42.3	2.7	55	56.2	54.5	3.0
10	32.0	31.0	3.2	33	44.6	43.3	2.9	56	46.9	45.4	3.3
11	62.1	60.5	2.7	34	42.2	41.0	2.9	57	56.0	54.4	2.9
12	63.3	61.5	2.9	35	69.3	67.3	2.9	58	50.7	49.2	3.1
13	74.1	71.7	3.4	36	44.6	43.4	2.7	59	76.6	74.3	3.2
14	69.0	66.8	3.3	37	45.5	44.2	2.9	60	45.6	44.3	3.0
15	66.3	64.2	3.3	38	43.5	42.3	2.7	61	48.0	46.6	2.9
16	73.3	71.0	3.2	39	45.2	43.8	3.3	62	50.7	49.0	3.4
17	60.2	58.5	3.0	40	43.3	42.0	3.0	63	32.4	31.4	3.2
18	81.2	78.7	3.2	41	34.5	33.4	3.2	64	35.9	34.8	3.3
19	79.4	76.9	3.2	42	38.4	37.1	3.4	65	34.7	33.4	3.9
20	69.3	67.3	2.9	43	46.2	44.8	3.2	66	34.1	32.9	3.7
21	65.0	63.2	2.9	44	36.8	35.7	3.2	67	44.1	42.7	3.4
22	40.8	39.5	3.4	45	32.9	31.9	3.3	68	41.8	40.5	3.3
23	41.7	40.4	3.1	46	36.4	35.6	2.1	69	43.2	41.8	3.2
24	45.1	43.8	3.1	47	34.7	33.5	3.5				
Average weight loss along rail 1:			3.2%	Average weight loss along rail 2:			3.0%	Average weight loss along rail 3:			3.3%

= Carcasses in test zone

Table F.12: Carcass rails 4-6

4th Rail - Red Deer				5th Rail - Red Deer				6th Rail - Red Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
71	46.7	45.7	2.1	94	43.4	42.2	2.9	117	46.7	45.3	3.1
72	51.9	50.4	3.1	95	53.5	52.0	2.9	118	41.2	40.0	3.1
73	47.4	46	3.0	96	47.3	45.9	3.1	119	43.6	42.3	3.0
74	46.9	45.5	3.0	97	52.1	50.7	2.7	120	48.3	46.8	3.2
75	49.8	48.3	3.2	98	46.6	45.2	3.0	121	41.5	40.3	3.0
76	54.4	52.7	3.2	99	47.3	45.9	3.0	122	47.4	45.7	3.7
77	49.8	48.2	3.4	100	47.9	46.5	3.0	123	56.5	55.0	2.7
78	41.2	39.8	3.4	101	52.7	51.2	3.0	124	43.4	42.2	2.9
79	48.8	47.3	3.2	102	45.0	43.6	3.1	125	47.0	45.7	2.9
80	48.8	47.3	3.1	103	50.5	49.1	2.9	126	45.6	44.2	3.1
81	54.9	53.1	3.3	104	46.7	45.3	3.2	127	52.6	51.0	3.1
82	62.0	60.1	3.2	105	46.5	45.1	3.0	128	52.3	50.7	3.1
83	60.9	59.1	3.0	106	44.9	43.6	3.0	129	46.6	45.2	3.2
84	60.2	58.3	3.3	107	49.4	47.8	3.3	130	49.3	47.8	3.2
85	60.6	58.8	3.0	108	48.9	47.4	3.2	131	55.3	53.6	3.2
86	70.8	68.8	2.9	109	44.7	43.2	3.5	132	51.9	50.0	3.9
87	45.4	44	3.2	110	42.3	40.8	3.6	133	52.1	50.2	3.8
88	41.2	39.8	3.6	111	51.3	49.5	3.6	134	46.0	44.4	3.7
89	59.2	57.1	3.7	112	52.1	50.5	3.2	135	45.0	43.4	3.8
90	71.5	69.2	3.3	113	46.1	44.7	3.2	136	41.1	39.6	3.8
91	50.4	48.6	3.7	114	45.0	43.4	3.6	137	47.4	45.7	3.7
92	48.1	46.7	3.0	115	41.0	39.6	3.6	138	50.5	48.6	3.8
93				116	47.4	45.7	3.8	139	44.9	43.2	3.9
Average weight loss along rail 4:			3.3%	Average weight loss along rail 5:			3.4%	Average weight loss along rail 6:			3.6%

= Carcasses in test zone

Average carcass weight loss in test zone:	3.3%

Carcass weightloss data - Trail 1, wing configuration 2 - 62 hour chill cycle

Table F.13: Carcass rails 1-3

1st Rail - Red Deer				2nd Rail - Red Deer				3rd Rail - Red Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
1	54.5	53	2.8								
2	58.7	57.1	2.7	24	39.6	38.2					
3	56.3	54.6	3.0	25	40.9	39.4	3.7	48	55.0	53.2	3.3
4	50.7	49.3	2.8	26	36.5	35.2	3.6	49	47.1	n/a	n/a
5	55.0	53.4	2.9	27	39.1	37.6	3.8	50	50.2	n/a	n/a
6	62.5	60.5	3.2	28	42.7	41.2	3.5	51	47.8	46.5	2.7
7	54.0	52.2	3.3	29	36.0	34.7	3.6	52	48.7	47.3	2.9
8	66.1	64.4	2.6	30	43.7	42.3	3.2	53	47.0	45.5	3.2
9	52.1	50.5	3.1	31	42.0	40.5	3.6	54	47.6	46.2	2.9
10	43.0	41.5	3.5	32	40.1	38.6	3.7	55	52.1	50.6	2.9
11	50.0	48.2	3.6	33	44.8	43.2	3.6	56	48.7	47.3	2.9
12	53.6	52.0	3.0	34	42.0	40.5	3.6	57	48.4	46.9	3.1
13	44.0	42.4	3.6	35	43.4	41.9	3.5	58	50.0	48.5	3.0
14	53.7	52.1	3.0	36	33.6	32.2	4.2	59	53.5	51.6	3.6
15	42.8	41.0	4.2	37	42.6	41.1	3.5	60	49.0	47.0	4.1
16	41.1	39.4	4.1	38	42.0	40.3	4.0	61	49.0	47.2	3.7
17	40.0	38.1	4.8	39	47.4	45.4	4.2	62	52.8	50.8	3.8
18	42.0	40.2	4.3	40	54.7	52.8	3.5	63	49.3	47.2	4.3
19	41.1	39.4	4.1	41	39.0	37.1	4.9	64	48.1	46.2	4.0
20	41.5	39.8	4.1	42	47.2	45.5	3.6	65	49.7	47.6	4.2
21	42.6	40.7	4.5	43	45.0	43.1	4.2	66	53.8	51.5	4.3
22	38.8	37.1	4.4	44	38.7	36.9	4.7	67	47.1	45.3	3.8
23	40.0	38.1	4.8	45	40.8	38.9	4.7	68	50.7	48.6	4.1
46	46.6	45.1	3.2	70	51.0	49.0	3.9	69	48.5	46.7	3.7
47	50.0	48.5	3.0					92	54.1	52.0	3.9
Average weight loss along rail 1:			4.0%	Average weight loss along rail 2:			4.1%	Average weight loss along rail 3:			3.9%

= Carcasses in test zone

Table F.14: Carcass rails 4-6

4th Rail - Red Deer				5th Rail - Red Deer				6th Rail - Red Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
				93	60.2	58.4	3.0				
72	53.7			94	50.0	48.3	3.4	116	48.5	46.9	3.3
73	49	47.9	2.2	95	45.1	43.7	3.1	117	60.3	58.4	3.2
74	49.3	n/a	n/a	96	58.4	56.5	3.3	118	67.4	65.5	2.8
75	54.6	53.1	2.7	97	49.0	47.5	3.1	119	62.6	60.8	2.9
76	50.2	48.7	3.0	98	42.1	40.6	3.6	120	60.7	58.7	3.3
77	51.7	50.3	2.7	99	39.5	38.5	2.5	121	58.0	56.1	3.3
78	48.7	47.3	2.9	100	44.4	43.3	2.5	122	54.8	53.0	3.3
79	51	49.4	3.1	101	43.7	42.6	2.5	123	74.5	72.3	3.0
80	47.4	45.9	3.2	102	45.4	44.0	3.1	124	56.5	54.9	2.8
81	74.8	72.4	3.2	103	42.5	n/a	n/a	125	54.6	52.9	3.1
82	73.8	71	3.8	104	42.5	n/a	n/a	126	60.1	58.1	3.3
83	83.7	80.5	3.8	105	45.7	44.4	2.8	127	69.5	67.2	3.3
84	67.3	64.7	3.9	106	45.5	44.0	3.3	128	49.3	47.3	4.1
85	81.6	78.2	4.2	107	46.0	44.6	3.0	129	51.8	49.8	3.9
86	65.8	63.3	3.8	108	45.5	43.8	3.7	130	72.0	69.4	3.6
87	71.3	68.6	3.8	109	42.0	40.5	3.6	131	86.0	82.9	3.6
88	50.1	48.3	3.6	110	67.4	64.9	3.7	132	88.7	85.2	3.9
89	54.5	52.3	4.0	111	68.7	66.1	3.8	133	88.7	84.9	4.3
90	50.5	48.5	4.0	112	55.5	53.5	3.6	134	98.8	94.6	4.3
91	59.7	57.5	3.7	113	65.6	63.0	4.0				
114	71.6	68.7	4.1	115	71.6	68.7	4.1				
				98	42.1	40.6	3.6				
Average weight loss along rail 4:			3.9%	Average weight loss along rail 5:			3.6%	Average weight loss along rail 6:			3.8%

= Carcasses in test zone

Average carcass weight loss in test zone:	3.9%

Carcass weightloss data - Trial 2, wing configuration 2 - 14 hour chill cycle

Table F.15: Carcass rails 1-3

1st Rail - Red Deer				2nd Rail - Red Deer				3rd Rail - Red Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
1	90.4	88.1	2.5					44	51.2	50.0	2.3
2	98.9	96.3	2.6	23	44.0	42.7	3.0	45	53.0	51.5	2.8
3	103.5	100.9	2.5	24	48.8	47.4	2.9	46	57.6	56.4	2.1
4	113.5	110.8	2.4	25	45.1	43.8	2.9	47	51.1	49.9	2.3
5	47.4	46.1	2.7	26	59.9	58.6	2.2	48	56.8	55.4	2.5
6	53.8	52.6	2.2	27	60.5	59.1	2.3	49	48.2	47.1	2.3
7	62.3	60.8	2.4	28	69.0	67.3	2.5	50	49.0	48.0	2.0
8	41.8	40.4	3.3	29	59.0	57.6	2.4	51	54.4	53.0	2.6
9	46.0	44.7	2.8	30	58.6	57.1	2.6	52	61.6	60.2	2.3
10	64.6	63.1	2.3	31	60.4	58.9	2.5	53	55.7	54.2	2.7
11	52.0	50.6	2.7	32	47.6	46.1	3.2	54	45.1	43.8	2.9
12	55.4	53.9	2.7	33	55.1	53.5	2.9	55	38.3	37.1	3.1
13	54.0	52.6	2.6	34	52.1	50.7	2.7	56	43.8	42.6	2.7
14	60.8	59.3	2.5	35	67.0	65.1	2.8	57	50.1	48.5	3.2
15	62.3	60.2	3.4	36	47.1	45.8	2.8	58	44.1	42.8	2.9
16	60.8	52.2	14.1	37	45.2	43.9	2.9	59	52.1	50.7	2.7
17	60.2	58.7	2.5	38	51.0	49.5	2.9	60	50.0	48.6	2.8
18	70.8	69.1	2.4	39	49.3	47.9	2.8	61	51.2	49.7	2.9
19	59.5	57.6	3.2	40	45.6	43.6	4.4	62	46.6	45.2	3.0
20	48.7	47.2	3.1	41	47.9	46.2	3.5	63	45.2	44.1	2.4
21	50	48.4	3.2	42	62.9	61.3	2.5	64	54.5	53.0	2.8
22	70.7	68.8	2.7	43	43.6	42.2	3.2	65	53.6	52.0	3.0
Average weight loss along rail 1:			3.8%	Average weight loss along rail 2:			3.0%	Average weight loss along rail 3:			2.9%

= Carcasses in test zone

Table F.16: Carcass rails 4-6

4th Rail - Red Deer				5th Rail - Red Deer				6th Rail - Red Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
66	37.9	36.6	3.4								
67	48.9	47.7	2.5								
68	61.8	60.4	2.3								
69	56.4	55	2.5								
70	53.7	52.5	2.2								
71	56	54.7	2.3								
72	61.6	60.1	2.4								
73	56.9	55.5	2.5								
74	50	48.4	3.2								
75	46.2	44.8	3.0								
76	53.2	51.6	3.0								
77	45.6	44.3	2.9	88	43.1	42.1	2.3	98	38.4	37.5	2.3
78	46.4	45	3.0	89	48.4	47.3	2.3	99	43.4	42.3	2.5
79	47.6	46.2	2.9	90	44.4	43.3	2.5	100	45.9	44.7	2.6
80	47.6	46.2	2.9	91	47.9	46.7	2.5	101	44.4	43.3	2.5
81	44.2	43	2.7	92	46.3	45.2	2.4	102	42.7	41.6	2.6
82	42.5	41	3.5	93	46.6	45.4	2.6	103	48.7	47.4	2.7
83	43.4	42.2	2.8	94	46.8	45.5	2.8	104	47.3	46.1	2.5
84	44.3	43.1	2.7	95	43.6	42.5	2.5	105	45.3	44.0	2.9
85	35	34	2.9	96	42.1	41.0	2.6	106	43.7	42.5	2.7
86	49.1	47.8	2.6	97	44.5	43.3	2.7	107	35.2	34.1	3.1
87	45.6	44.5	2.4								
Average weight loss along rail 4:			2.9%	Average weight loss along rail 5:			2.5%	Average weight loss along rail 6:			2.6%

= Carcasses in test zone

Average carcass weight loss in test zone:	3.0%

Carcass weightloss data - Trial 3, wing configuration 2 - 14 hour chill cycle

Table F.17: Carcass rails 1-3

1st Rail - Red Deer				2nd Rail - Red Deer				3rd Rail - Red Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
1	69.7	68.0	2.4								
2	63.5	61.8	2.7	25	47.8	46.8	2.1				
3	56.1	54.5	2.9	26	44.4	43.2	2.7	47	62.4	60.8	2.6
4	59.6	57.9	2.9	27	55.2	53.8	2.5	48	60.0	58.4	2.7
5	63.9	62.3	2.5	28	46.1	45.0	2.4	49	62.3	60.8	2.4
6	61.6	60.0	2.6	29	60.6	59.1	2.5	50	60.8	59.2	2.6
7	56.6	55.1	2.7	30	59.5	57.9	2.7	51	55.8	54.3	2.7
8	62.0	60.4	2.6	31	57.5	55.9	2.8	52	67.4	65.6	2.7
9	62.0	60.3	2.7	32	65.2	63.2	3.1	53	62.7	60.9	2.9
10	61.0	59.4	2.6	33	58.0	56.2	3.1	54	58.1	56.5	2.8
11	64.1	62.1	3.1	34	63.8	61.8	3.1	55	67.5	65.6	2.8
12	57.2	55.3	3.3	35	65.1	63.4	2.6	56	59.0	57.2	3.1
13	67.0	65.0	3.0	36	56.2	54.7	2.7	57	61.2	59.5	2.8
14	61.0	59.0	3.3	37	61.6	59.8	2.9	58	62.0	60.2	2.9
15	56.4	54.7	3.0	38	65.1	63.2	2.9	59	66.9	65.0	2.8
16	60.3	58.4	3.2	39	61.8	60.0	2.9	60	57.2	55.7	2.6
17	60.1	58.2	3.2	40	58.3	56.7	2.7	61	60.3	58.5	3.0
18	72.8	70.5	3.2	41	64.3	62.4	3.0	62	69.5	67.3	3.2
19	57.2	55.5	3.0	42	62.0	60.3	2.7	63	58.0	56.2	3.1
20	58.7	57.0	2.9	43	56.8	55.2	2.8	64	54.5	52.7	3.3
21	63	61.0	3.2	44	70.5	68.6	2.7	65	70.9	69.0	2.7
22	59.4	57.6	3.0	45	66.3	64.4	2.9	66	58.6	56.9	2.9
23	61.9	59.8	3.4	46	62.6	61.0	2.6	89	80.8	78.5	2.8
24	39.1	37.7	3.6	68	43.6	42.3	3.0				
67	42.4	41.1	3.1								
Average weight loss along rail 1:			3.2%	Average weight loss along rail 2:			2.8%	Average weight loss along rail 3:			2.9%

= Carcasses in test zone

Table F.18: Carcass rails 4-6

4th Rail - Red Deer				5th Rail - Red Deer				6th Rail - Fallow Deer			
Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)	Carcass Number	weight in (kg)	weight out (kg)	weight loss (%)
								112	22.7	22.1	2.6
								113	21	20.5	2.4
								114	24.2	23.7	2.1
								115	21.8	21.2	2.8
								116	22.2	21.6	2.7
								117	21.1	20.5	2.8
69	57.3	55.7	2.8					118	21.0	20.4	2.9
70	76.2	74.6	2.1	90	72.1	70.4	2.4	119	21.8	21.3	2.3
71	56.4	54.9	2.7	91	72.7	70.8	2.6	120	21.6	21.0	2.8
72	75.7	74.1	2.1	92	90.6	88.3	2.5	121	21.2	20.7	2.4
73	55.5	54	2.7	93	63.1	61.6	2.4	122	21.3	20.7	2.8
74	58.3	56.8	2.6	94	82.7	80.6	2.5	123	21.7	21.2	2.3
75	52.7	51.3	2.7	95	82.1	79.8	2.8	124	21.0	20.5	2.4
76	77.7	75.9	2.3	96	75.3	73.4	2.5	125	21.8	21.2	2.8
77	57.1	55.6	2.6	97	57.0	55.5	2.6	126	20.9	20.3	2.9
78	55	53.6	2.5	98	71.4	69.5	2.7	127	22.0	21.5	2.3
79	59.5	57.8	2.9	99	68.0	66.2	2.6	128	21.5	20.9	2.8
80	53.6	52.1	2.8	100	80.7	78.7	2.5	129	21.5	21.0	2.3
81	58.8	57.2	2.7	101	72.5	70.5	2.8	130	22.7	22.1	2.6
82	50.5	47.9	5.1	102	80.0	77.7	2.9	131	20.8	20.3	2.4
83	61.3	59.6	2.8	103	82.2	80.0	2.7	132	22.7	22.2	2.2
84	54.4	53.1	2.4	104	79.6	77.3	2.9	133	22.1	21.5	2.7
85	60	58.4	2.7	105	66.2	64.4	2.7	134	22.6	22.0	2.7
86	45.5	44.1	3.1	106	70.7	68.5	3.1	135	24.6	23.4	4.9
87	58.1	56.5	2.8	107	88.5	86.2	2.6	136	20.6	20.0	2.9
88	53.9	52.1	3.3	110	74.7	72.6	2.8	137	21.1	20.5	2.8
108	90.2	87.7	2.8	111	78.7	76.3	3.0	138	21.8	21.1	3.2
109	92.1	89.5	2.8					139	22.8	22.1	3.1
								140	22.8	22.2	2.6
								141	20.6	19.9	3.4
								142	22	21.4	2.7
Average weight loss along rail 4:			3.0%	Average weight loss along rail 5:			2.8%	Average weight loss along rail 6:			2.9%

= Carcasses in test zone

Average carcass weighl loss in test zone:	2.9%