final report

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Verification of the effect of spray chilling in preventing chiller yield loss

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Abstract

Spray chilling is the intermittent spraying of carcases with water to minimise carcase weight loss (shrink) during initial chilling. It is widely used in the USA but has not gained wide acceptance in Australia possibly due to the perception that the shelf life of vacuum-packaged meat is reduced. Swift Australia decided to quantify the benefits and determine whether shelf life is affected.

A system was successfully installed to service one chiller and operational parameters were devised and tested. Average carcase weight loss was reduced to 0.47% and boning trials confirmed an increase in saleable meat yield of 0.53%. Carcase cooling rate and microbiological status was not affected by spraying carcases with ambient (22°C) water. Storage trials with vacuum-packaged primal cuts showed that shelf life was not affected by spray chilling up to a storage period of 13 weeks.

It is recommended that Swift Australia extend spray chilling to the remaining chillers at Dinmore and consider it at their other sites.

Executive Summary

Spray chilling is the intermittent spraying of carcases with water during the early stages of the cooling of hot sides. The aim is to reduce the weight loss (shrink) of 1 to 2% due to evaporation of moisture from the surface tissue. Spray chilling is widely utilised in the USA but has not gained wide acceptance in Australia. This is thought to be due to the perception that the moist surface may lead to increase growth of micro-organisms and reduced shelf life of vacuum-packaged primal cuts.

Swift Australia obtained funding assistance to install spray chilling in one chiller at their Dinmore plant to evaluate its effectiveness in preventing yield loss. The aims of the project were:

- Determine whether spray chilling prevents yield loss in the chillers and that this yield gain is identified clearly as a primal yield gain or as render increased cost.
- Optimise the amount of water per head required to achieve at least 1.5% yield loss prevention.
- Verify the impact of spray chilling on product shelf life.
- Verify microbiological outcomes.

A spray chilling system, capable of supplying water at a temperature as low as 2 °C, was installed to service Chiller 5 at the Dinmore plant. It consists of a water storage tank with refrigeration plate heat exchanger, reticulation pipework and controls to supply three zones of nozzles above the sides. Each zone is sprayed in turn and then allowed to drain. The spray time, drain time and number of cycles can be adjusted to optimise chiller weight loss. Scales were installed in the passage to the boning room to allow chilled sides to be weighed on line.

Operating parameters have been developed for a normal overnight carcase chilling process that reduce chiller weight loss (shrink) to an average 0.47% compared with a shrink of 1.14% under conventional operating conditions. The following parameters were found to be suitable:

Spray zone 1	24 s
Spray zone 2	24 s
Spray zone 3	24 s
Drain time	24 minutes

There are 10 spray cycles for a total spraying time of 3 h 48 min. Carcases are allowed to dry for the remainder of the chilling cycle.

These spray chilling conditions resulted in an estimated increased water consumption of 22.3 L per head or 78 kL per day if fully implemented at the Dinmore plant.

Trials were carried out with spraying both ambient (22°C) temperature water and water chilled to 2°C. Carcase surface temperatures were logged and the ESAM sites were swabbed before and after chilling to determine whether water temperature had an effect on cooling rate and microbiological growth. The rate of cooling of the surface was similar for both runs and a refrigeration index (RI) of zero was calculated for both spray water temperatures. There was no

difference in microbiological quality of the carcases after spray chilling with ambient temperature water or chilled water compared with conventional chilling.

Boning yield trials, using the spraying parameters above, showed that over a range of body sizes and types, there was an increase in saleable meat yield of 0.53%. There was a significant increase in the yield of the Topside, Striploin, Blade and PE brisket primal cuts but a significant decrease in the amount of trimmings for manufacturing meat. There was no increase in the weight of the fat trim indicating that the increased carcase weight was not being trimmed off and sent for rendering. If these improved yield results are achieved for a daily throughput of 3,500 head at an average carcase weight of 300 kg, an additional 5,565 kg of saleable meat could be available. The cost of the increase in water consumed is insignificant compared with the potential return from yield improvement.

Storage trials with vacuum-packaged Outside flats, Striploins and Clods, showed that, for a storage period up to 13 weeks, there was no difference between the conventionally chilled and spray-chilled product in terms of microbiological quality, appearance, odour, quantity of drip and eating quality.

The following recommendations are made:

1. Undertake further chiller weight loss measurements to develop additional sets of spray chilling parameters for chilling periods longer than the normal overnight 16 – 20 hours and for shorter periods, such as warm boning.

2. Extend spray chilling to the remaining Dinmore chillers so that the benefits can be fully realised.

3. Investigate the requirements and implications of installing spray chilling at the other Swift Australia processing sites using the spray chilling design and operational parameters developed for Dinmore as a basis.

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1 Background

Beef carcases are normally chilled for 16 to 20 hours prior to boning into primal cuts and trimmings which are packed for further cooling and dispatch. During this carcase chilling process, carcases can lose 1 to 2% of their hot weight which is a potential loss of revenue for the processor. Spray chilling has been widely used in the USA for many years to reduce this weight loss (or shrink) but the practice has been used little in Australia. Spray chilling is the intermittent spraying of carcases with water during the first few hours of the chilling phase followed by a drying period prior to loadout and boning.

The limited application of spray chilling in Australia is thought to be due to concerns that it may result in a decrease in the shelf life of vacuum-packaged meat for which Australia has a high reputation in export markets. Spray chilling has been shown to reduce weight loss during overnight chilling to about 0.4% to 0.5% (Jones & Robertson, 1988, Strydom & Buys, 1995, Greer & Jones, 1997). However, there is little information in the scientific literature regarding the effect of spray chilling on the yield of saleable meat from the boned carcase. Greer & Jones (1997) showed that spray chilling had no detrimental effect on the shelf life of vacuum-packed beef up to 6 weeks, but Australian processors require vacuum packaged storage life of 10 weeks or more.

Although there is some published literature relating to meat industry spray chilling systems' water spray rates, most relate to studies conducted in either the US or Canada. As such there is no definitive data available as to what the optimal spray rates are in order to minimise the side shrinkage losses under typical Australian Meat Industry production conditions while still meeting all of the relevant Australian Meat Industry Standards & Regulations.

In an attempt to better understand the finer details of spray chilling system installations in the US, discussions were held with the engineers running the Swift plants in America regarding their experiences and their findings relating to their installed spray chilling systems. From these discussions, fairly high spray chilling system water usage figures of around 330 litres per carcase seemed to be the norm.

In addition, it was noted from these discussions that in the US, most spray chilling systems initially started off with a spray chilling water temperature of around 2°C, but that most systems had reverted to an 18°C spray chilling water temperature as the delivery of the spray water at temperatures below this seemed to have had little or no impact on improving the carcass chilling rate as the contact time of the water spray with the body was so short. It is however important to note that Australian regulations differ from those in the US and as such a spray chilling water temperature regime of 18°C needs to be proven to be accepted by AQIS in Australia.

In order to reduce 'shrink' losses during chilling, Swift Australia decided to trial a spray chilling system at one of their sites to determine the optimum parameters and the impact on chiller weight loss, boning room yield and any effect on the microbiological quality and storage life of their product.

Funding assistance was obtained from Meat & Livestock Australia to trial spray chilling at the Dinmore plant for evaluation and if it proved successful, extend it to other chillers and to other plants. This report presents the results of trials with the pilot spray chilling system.

2 Project Objectives

The overall objective of this project was to evaluate the effectiveness of spray chilling on the prevention of carcase yield loss. This included:

- Determination of whether spray chilling prevents yield loss in the chillers and that this yield gain is identified clearly as a primal yield gain or as render increased cost.
- Optimisation of the amount of water per head required to achieve at least 1.5% yield loss prevention.
- Verification of the impact of spray chilling on product shelf life.
- Verification of microbiological outcomes.

3 Methodology

The methods described in this section were followed to meet the project milestones below.

3.1 Construction of a trial spray chill water delivery system

Chiller 5 at the Dinmore plant was selected for installation of the trial spray chilling system. It is of identical design to all other hot carcase chillers at the plant except that it has 5 rails compared with 7 in the other chillers. The spray water distribution system was designed along the lines of systems installed in the Company's US plants. Australian refrigeration contractors, Gordon Brothers Industries were contracted to design and install the system for chilling and distributing the water.

3.2 Development of spray chilling parameters and calculation of water use

The system was designed so that the spray chilling parameters could be adjusted to ensure that the minimum carcase weight loss was achieved while complying with the AQIS Meat Notice 2002/18 'Compliance with retained water rules for carcases, meat and offals exported to the USA'. Parameters that could be adjusted were:

- water temperature;
- spray time;
- interval between sprays, and
- number of spray cycles.

Scales were installed in the loadout passage from the carcase chillers to record the weight of carcases from the test chiller and these were compared with the hot weights measured on the slaughter floor. Trials were initially undertaken with a small number of sides in the chiller and extended to full chiller loads. The parameters were varied and the effect on the weights of a range of body types assessed. The quantity of water used per spray cycle was calculated from the change in level of the spray water storage tank.

3.3 Evaluation of effect of spray water temperature on microbiology

When suitable spray chilling parameters had been confirmed as acceptable in minimising weight loss, they were evaluated for the effect on the microbiological status of the carcases. Trials were carried out with ambient (22°C) water and water chilled to 2°C. Thirty sides were selected at random and swabbed prior to loading into the chiller. The chiller load was sprayed for 24 seconds at 30 minute intervals a total of 10 times. On completion of chilling approximately 20 hours after loading, the same sides were again swabbed and the samples analysed for total viable count (TVC), total coliforms and *E. coli*.

The sides were swabbed at the ESAM sites of the butt, flank and brisket following the procedure described in AQIS Meat Notice 2003/06 Revised ESAM Program (2003).

For the runs at 22°C and 2°C, temperature probes attached to loggers were inserted under the surface of the foreleg of 3 sides located at the infeed end, middle and outfeed end of the chiller. On completion of the cycle, the loggers were removed and the data downloaded and the refrigeration index calculated.

3.4 Effect of spray chilling on boning room yield

The effect of spray chilling on yield of saleable meat was assessed for two different spraying cycles for a range of carcases. On eight separate days, five bodies were selected and one side was placed in one of the conventional chillers and the other in the spray chiller. Fifteen sides were sprayed with ambient (22°C) water for 24 s at 30-minute intervals, 8 times and 24 sides were sprayed 10 times at the same intervals. After overnight chilling, each side was weighed and conveyed to the boning facility where it was broken down into primal cuts, trim, fat and bone. Each item was weighed and the results recorded in a spreadsheet for statistical analysis.

3.5 Effects of spray chilling on storage life of chilled primal cuts

There has been a concern that spray chilling may have a detrimental effect on the storage life of vacuum packaged primal cuts. To evaluate this, three cuts were selected to represent different portions of the carcase. They were the outside flat from the butt, the striploin and the clod from the forequarter. Twenty-five bodies from grass-fed animals were selected. One side of each body was spray chilled with 22°C water while the other was conventionally chilled overnight. The nominated primal cuts were vacuum-packed, labelled and packed into cartons so that there were five sets of 15 cuts. The cartons were chilled and stored at approximately 0°C until they were opened for assessment at 0, 3, 9, 11 and 13 weeks after production.

At each assessment, the cuts were removed from a set of cartons, weighed and placed on a bench and rated on a nine-point scale of 0 to 8 for vacuum, appearance and odour on opening with a score of 8 representing a tight vacuum, no discolouration and no confinement or off odour. Two samples approximately 5 cm x 5 cm weighing at least 25 g each were excised from the surface fat using sterile procedures and placed into stomacher bags for microbiological analysis. The samples were analysed for TVC, total coliforms, *E. coli*, Lactobacillus sp, *Brochothrix thermosphacta* and *Salmonella*.

The amount of drip in each pack was weighed and a steak was cut from the butt end of each striploin, cooked on a griddle plate and assessed by an untrained taste panel of at least five people for off aroma and off flavour on nine-point scales.

4 Results and Discussion

4.1 Construction of a trial spray chill water delivery system

The trial spray chilling plant is located in Engine Room #2 at Swift Australia's Dinmore meat works and it supplies water from there to beef chiller #5 for spray chilling the beef sides during their primary side chilling phase. Chiller #5 was divided into 3 distinct spraying zones which would each spray independently one after the other Zone 1 sprays chilled water onto a single meat rail holding approximately 70 sides of beef while Zones 2 & 3 each spray chilled water onto two meat rails each holding approximately 70 sides of beef. A P&ID of the Dinmore chiller #5 trial spray chilling plant and a chiller #5 nozzle layout drawing are presented in Figures 1.1 and 1.2, Appendix I. As this was to be only a trial installation at Swift Dinmore, every effort was made to, where possible minimise the cost of the plant to be installed. The key components of the plant are:-

- An uninsulated food grade polyethylene 5,000 L plastic rain water tank located on the bare slab inside the existing engine room #2 to act as a system buffer and fresh water make-up point.

- A 1" copper make-up water line connected into the existing site potable water supply with pulse feedback flow meter to monitor and record back to the existing plant SCADA the spray chilling systems' water usage per primary carcase chilling batch.

- A 280 kW semi-welded NH_3/H_2O plate heat exchanger (PHE) capable of chilling 30 m^3/h of water down to a minimum of 2°C. On the NH_3 side, the PHE is connected into the existing engine room #2 -10°C NH_3 circuit complete with a Danfoss ICS 3-65 back pressure regulating valve which can control, via manual adjustment, the outlet water temperature from the PHE in a range between 2°C & 18°C. The specifications for the PHE are given in Figure 1.3, Appendix 1.

- A 2 pole 7.5 kW centrifugal pump rated at 30 m^3/h at a head of 47 m and with a 192 mm diameter impeller which supplies the spray chilling water to chiller #5 complete with 1,000 micron in line strainer at its inlet. The pump curve is shown in Figure 1.4 in Appendix 1.

- DN 80 Class 12 PVC reticulation piping mains insulated with 25 mm thick Armaflex which supplies the spray chilling water to and returns the excess water from chiller #5.

- Three spray chilling water supply valve stations, one for each spray zone, each consisting of an isolating valve, a solenoid valve, a pressure regulating valve with which a constant supply pressure to the various zones nozzles can be set complete with pressure gauge and a check valve.

- Two different types of nozzle arrangements are used to deliver the water chiller spray onto the beef carcases. The first nozzle arrangement (Type A) is used in the centre of zones 2 and 3 spray area, i.e. between the two meat rails covered by these two zones, and consists of a Promax® Clip-Eyelet connector, a Unijet®

polypropylene check valve strainer with 50 micron stainless steel mesh and a Promax® Quick Fulljet full cone QPHA-5.6W spray tip which will deliver 3.6 L/min at a water supply pressure of 2 bar. The second nozzle arrangement (Type B) is used on the sides of each of the three zones' spray areas, i.e. on the outer sides of the meat rails associated with each of these three zones, and consists of a Promax® Clip-Eyelet connector, a Unijet® polypropylene check valve strainer with 50 micron stainless steel mesh and a Promax® Quick Fulljet full cone QPHA-3 spray tip which will deliver 1.9 L/min at a water supply pressure of 2 bar. See Figure 1.5, Appendix 1 for the complete nozzle specifications.

On the basis of these plant components, the trial spray chilling system was originally designed, specified and selected to deliver an average of 180 L per side of spray chilling water at 2°C over the duration of the primary side chilling phase.

The original trial spray chilling system design parameters are provided in the Spray Chilling System Design Process Flow Diagram (Figure 1.6, Appendix I) and the trial spray chilling system Operational Functional Description in Figure 1.7, Appendix I.

4.2 Development of spray chilling parameters and calculation of water use

During preliminary trials it was found that the spray water was entrained in the upward flowing chiller air and deposited on the rails and ceiling which was unacceptable due to likely contamination of carcases. Modifications were made to the chiller program to stop the fans prior to the spray cycles commencing and re-start them on completion of spraying the three zones. This solved the issue.

Under the original arrangement the pneumatic line exhaust system did not completely clear the line and water continued to drip from the nozzles for some time after completion of each spraying cycle. To resolve this issue, a check valve strainer was installed behind each nozzle.

Trials were also restricted by difficulties in obtaining an accurate weight from the loadout scales. Sides needed to be double-spaced to allow sufficient time for a stable reading. This reduced the rate of processing over the scales, slowing production, so trials needed to fit with production schedules. The automated weight and side data collection system did not prove to be accurate enough and carcase weights needed to be collected manually.

Initial trials to optimise the spray chilling parameters suggested that between carcases there was a large variation in the percentage weight change during chilling. For example under the same conditions, some spray chilled carcases lost 1.2% whereas others gained 1.2%. Further investigation, however, showed that this was due to two main reasons: (1), scale errors, including calibration issues, and (2), neck bones being removed after weighing hot.

These initial trials did establish that spraying each zone in turn with 8 to 10 sprays of 24 second duration each with 24 minutes between spray cycles produced an acceptable result for the majority of carcases processed at Dinmore. The trials also showed the very lean bodies, such as bulls absorbed water much more readily than bodies with a good fat cover.

The trials also showed that ambient temperature water at 22°C did not result in a slower chilling rate than 2°C spray water (results presented in Section 4.3). Subsequent trials focussed on optimising the number of spray cycles using ambient water.

Nine trials were conducted in which a total of 1,968 sides were weighed after spray chilling. The results are summarised in Table 1.

Table 1: Results of spray chilling trials

	Chilling parameters		
	8 x 24 s sprays (2.96 h)	**10 x 24 s sprays (3.8 h)**	**No spray**
No. of runs	5	4	5
No. of sides	834	1,134	25
Av. side weight (kg)	147.3	153.6	155.8
Min side weight (kg)	87.0	66.0	116.0
Max side weight (kg)	268.5	296.5	214.0
Percent of HSCW	99.21	99.53	98.86
Weight loss (%)	0.79	0.47	1.14
Weight loss saving (%)	0.35	0.67	-

This shows that chilling shrink was reduced to 0.47% using 10 sprays of 24 s and to 0.79% using 8 sprays, which is a weight loss saving of 0.67% and 0.35% respectively over conventional chilling where there was 1.14% shrink. The data set represents a typical cross-section of the carcase type and weight range normally processed through the Dinmore plant.

Although the average shrink for the runs using 10 sprays of 24 s was 0.47%, the shrink for individual sides ranged from 2% to a slight weight gain with the majority of sides losing up to 1%. These distributions of weight change are shown in Figures 1 and 2 for 8 and 10 sprays respectively. This variation in weight loss between sides can be due to several factors including:

- Time in the chiller. The first sides loaded are likely to lose more weight than the last ones in.
- Location in the chiller. There are variations in air velocity which can affect evaporation.
- Fat cover. Very lean bodies, such as bulls absorb more water.
- Body size. Smaller sides are likely to lose more weight than larger sides.

This data set may allow the opportunity to analyse the effect of some of these factors on chiller shrink at a later date if necessary.

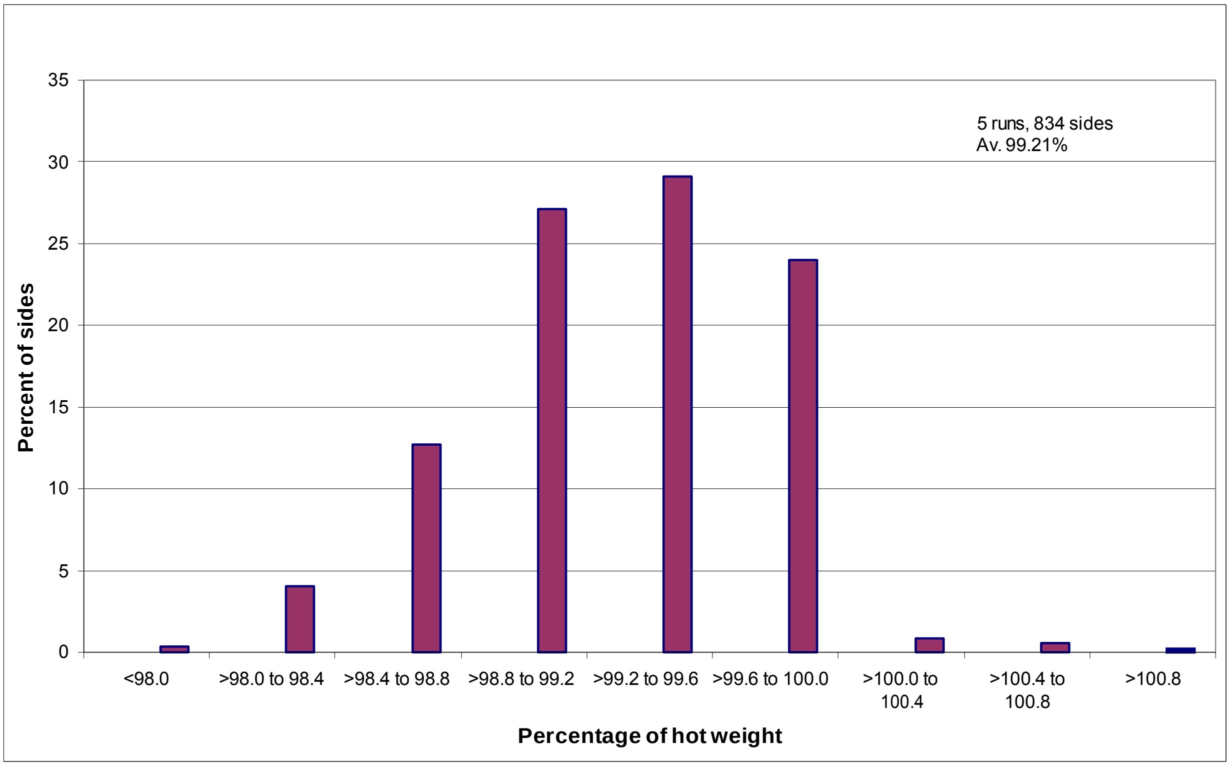

Figure 1: Weight loss distribution – 8 x 24 s sprays

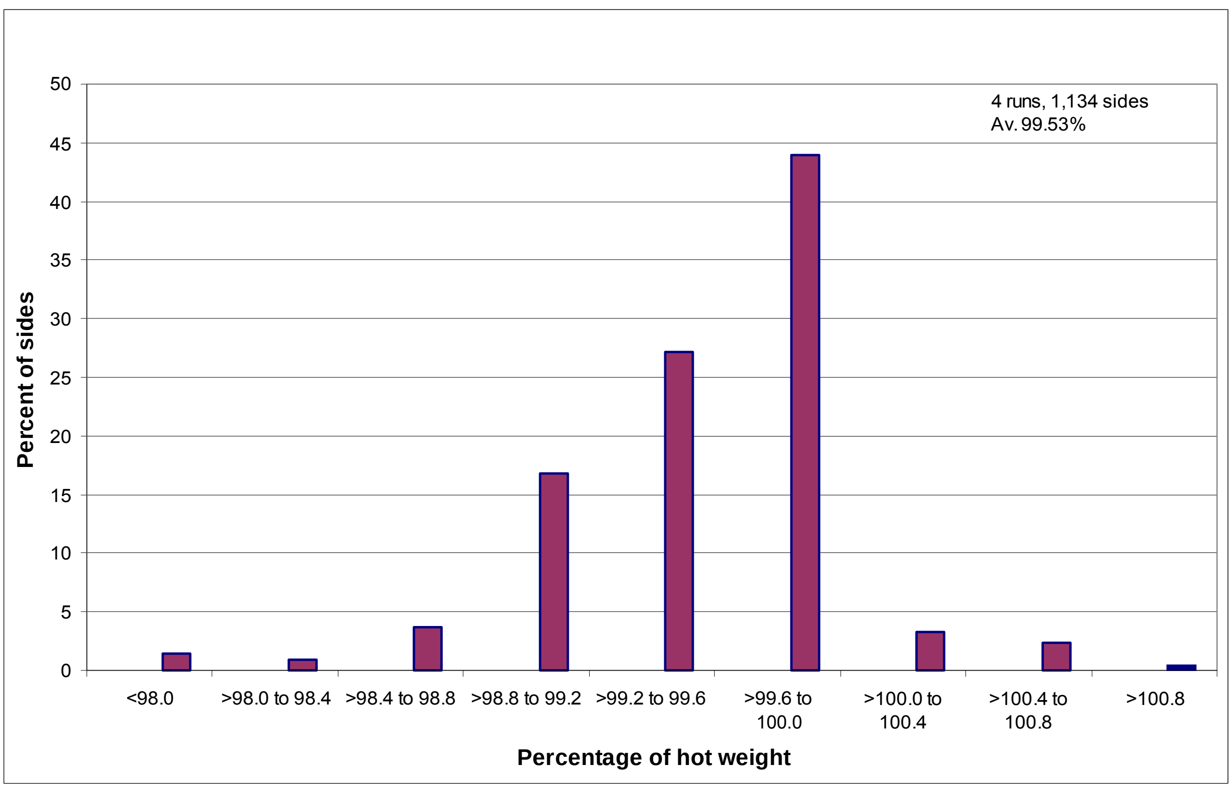

Figure 2: Weight loss distribution – 10 x 24 s sprays

Considering process variables and measurement uncertainties, these processes conform with the retained water rules for product exported to the United States. The recommended spray chilling parameters are:

Spray zone 1	24 s
Spray zone 2	24 s
Spray zone 3	24 s
Drain time	24 minutes

There are 10 spray cycles for a total spraying time of 3 h 48 min. Carcases are allowed to dry for the remainder of the chilling cycle.

The water consumption for one complete spray cycle totalling 72 seconds was 390 L or 3,900 L for a complete spray chilling run of 10 cycles. Chiller 5 holds on average 175 bodies, therefore the water consumption for spray chilling would be 22.3 L per head.

If spray chilling is implemented for the remaining chillers at Dinmore, water consumption for the plant would increase by approximately 78 kL per day, which is not considered to be significant for the plant.

4.3 Evaluation of effect of spray water temperature on microbiology

Overnight chilling with 22°C spray water and 2°C spray water both resulted in a refrigeration index (RI) of zero. This is to be expected with overnight chilling. In order to compare the two chilling regimes, the RIs were re-calculated for the average of the three measurements for each run using the starting temperature hot ‘No’ button on the MLA Calculator so that the lag phase was not deducted. This resulted in almost identical RI values of 0.45 for 22°C spray water and 0.46 for 2°C water. A plot of the average surface temperature for both spray water temperatures is presented in Figure 3 and confirms that there is very little difference in cooling rates.

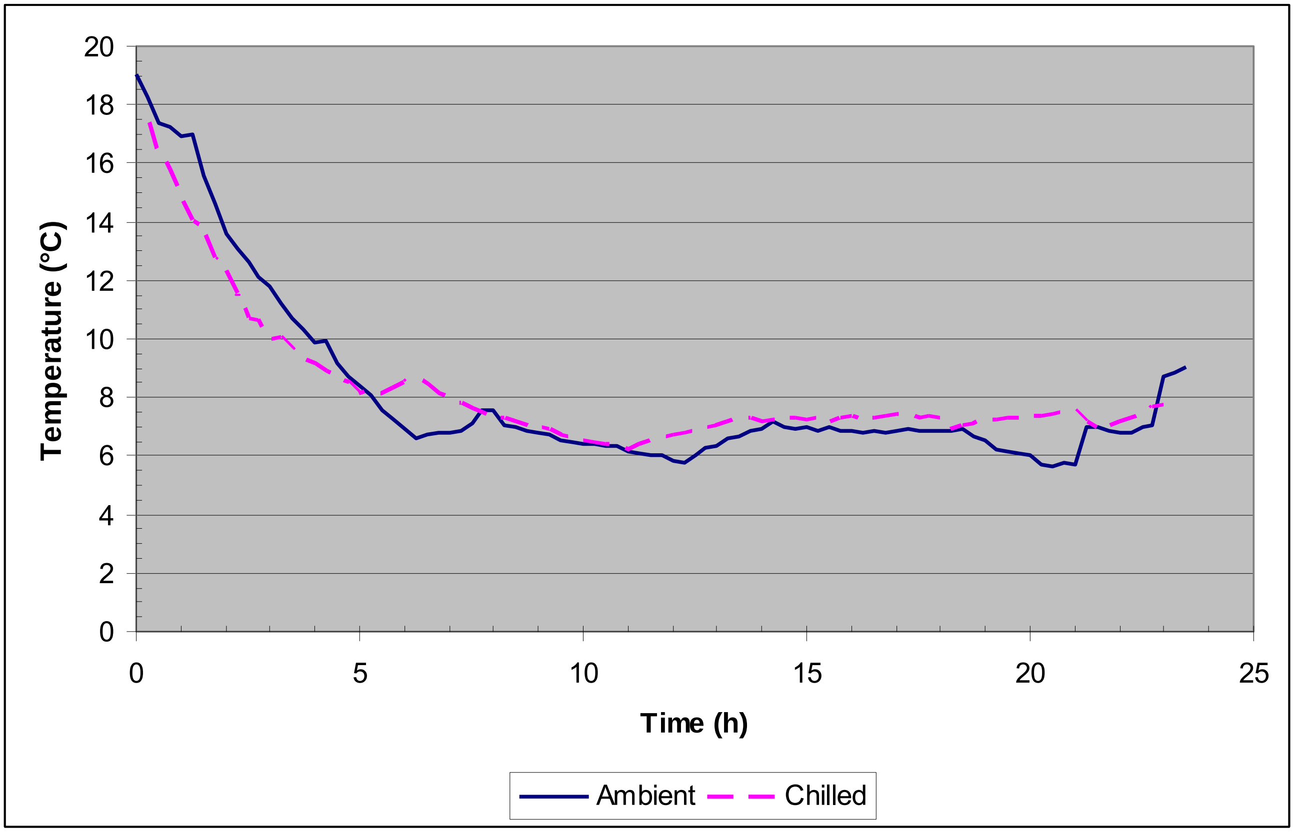

Figure 3: Average cooling rate of the surface of beef carcases in Chiller 5 for 22°C and 2°C spray water

Very low numbers of micro-organisms were recovered from the sides both before and after spray chilling. No *E. coli* were recovered from any of the samples and, at the limit of detection of 8.33 CFU/cm^2, TVC were measureable on less than half the sides. A summary of the mean TVC results for the two water temperatures, along with the average TVC of results for 2009 is presented in Table 2 and the complete microbiological results are in Appendix 2.

Table 2: Mean TVC at ESAM sites before and after chilling ($\log_{10}$ CFU/cm^2)

	Before chilling	After chilling
Ambient water	1.15 (37%)	1.27 (20%)
Chilled water	1.56 (13%)	1.02 (10%)
Conventional chill (2009 ESAM)	-	1.24 (58%)

The results are the means of the positive samples and the numbers in brackets indicate the percentage of samples from for which positive results were obtained.

The low numbers of positive samples makes it difficult to draw any firm conclusions, but after spray chilling there was very little difference in TVC between those sprayed with water chilled to 2°C and those sprayed with ambient temperature water of 22°C. The results were similar to the average TVC from 308 ESAM samples collected so far in 2009.

4.4 Effect of spray chilling on boning room yield

Three yield trials, with a total of 15 bodies were undertaken using 8 sprays of 24 s each and five trials for a total of 24 bodies using the spray conditions of 10 sets of 24 s sprays. The results of these boning yield trials are presented in Tables 3 and 4.

Table 3: Meat yield – 8 x 24 s

	Spray chill	Conventional chill
No. of sides	15	15
Av. Side weight (kg)	173.67	174.13
Fat (%)	8.18	8.09
Bone (%)	18.74	18.91
Saleable meat (%)	72.50	72.14
Yield improvement (%)	0.36	-

Table 4: Meat yield – 10 x 24 s

	Spray chill	Conventional chill
No. of sides	24	24
Av. Side weight (kg)	149.65	151.54
Fat (%)	7.57	7.74
Bone (%)	19.12	18.83
Saleable meat (%)	73.17	72.64
Yield improvement (%)	0.53	-

The trials revealed that there was a significant ($P<0.05$) improvement in saleable meat yield of 0.53 percentage points when the sides were given 10 x 24 s sprays. There also appeared to be a yield improvement after eight sprays, but this was not statistically significant ($P>0.05$). A significant difference may have been measureable if more sides had been included in those trials.

On a throughput of 3,500 head per day of cattle at an average dressed weight of 300 kg, nearly 5,600 kg of additional saleable meat could be available if spray chilling is fully implemented at Dinmore.

It is also important to note that there was no significant difference ($P>0.05$) in the weight of fat trim between the spray-chilled and conventionally chilled sides. Therefore the moisture appears to be retained within the saleable meat not the fat trim.

The yield of primal cuts and trimmings after spraying with 10 x 24 s sprays is presented in Table 5. The topside, striploin, blade and point-end brisket showed a significant improvement in yield ($P<0.05$). Primals such as the striploin, blade and PE brisket have a large surface area in relation to their volume, so may be expected to show the greatest yield benefit from spray chilling. The cube roll, which has no original external surface, would not be expected to show a yield increase and this was the case. Most of the other cuts, except for the tenderloin, showed small but non-significant increases in yield due to spray chilling. Allen *et al* (1987) found no difference between spray and conventionally chilled rib and inside round primal cuts.

Table 5: Yield of primal cuts & trimmings – 10 x 24 s sprays (percent of carcase weight)

Primal cut	Spray chill	Conventional chill	Statistically significant (*P<0.05*)
Topside scab on 12 mm	6.20	6.12	Y
Silverside 12 mm	7.27	7.15	N
Thick flank	4.23	4.19	N
Rump S/C	4.17	4.12	N
Striploin 3 rib	4.11	3.76	Y
Tenderloin S/on	1.70	1.78	N
Cube roll 5 rib	1.98	1.95	N
Chuck roll L/C	6.08	6.00	N
Blade fan cut 12 mm	5.84	5.48	Y
PE Brisket	4.01	3.77	Y
NE Brisket	3.32	3.23	N
Trmg	9.96	10.39	Y

It is noted that the yield of trimmings is significantly higher ($P<0.05$) for the conventionally chilled group than for the spray-chilled sides. Therefore some of the increased yield of primal cuts from spray-chilled sides may be attributable to excessive trimming of the conventionally chilled cuts.

Boners remarked during the yield trials that the spray-chilled sides were easier to bone and seam than the conventionally chilled sides.

4.5 Effects of spray chilling on storage life of chilled primal cuts

4.5.1 Assessment of intact packs

When the vacuum-packed clods, striploins and outside flats were evaluated after storage at 0°C for 3, 9, 11 and 13 weeks, no difference in appearance was detected by the panel between spray-chilled and conventionally chilled primals. Also there was no deterioration over the storage time as the scores at 13 weeks were not significantly different to the scores at 3 weeks. None of the packs showed signs of discolouration.

The majority of packs were considered to have a good vacuum with the score approximately the same at all sampling periods. There was no difference between spray and conventionally chilled packs. Three leakers were detected from the 60 packs sampled.

4.5.2 Odour on opening

Meat develops a distinctive cheesy odour as it ages in a vacuum pack and can be detected on opening. As it approaches the end of its storage life, this will develop into an unpleasant odour. Odour scores for each cut tended to decrease with time of storage but there was no difference between scores for spray-chilled and conventionally chilled samples. Figure 4 shows the odour scores for striploins.

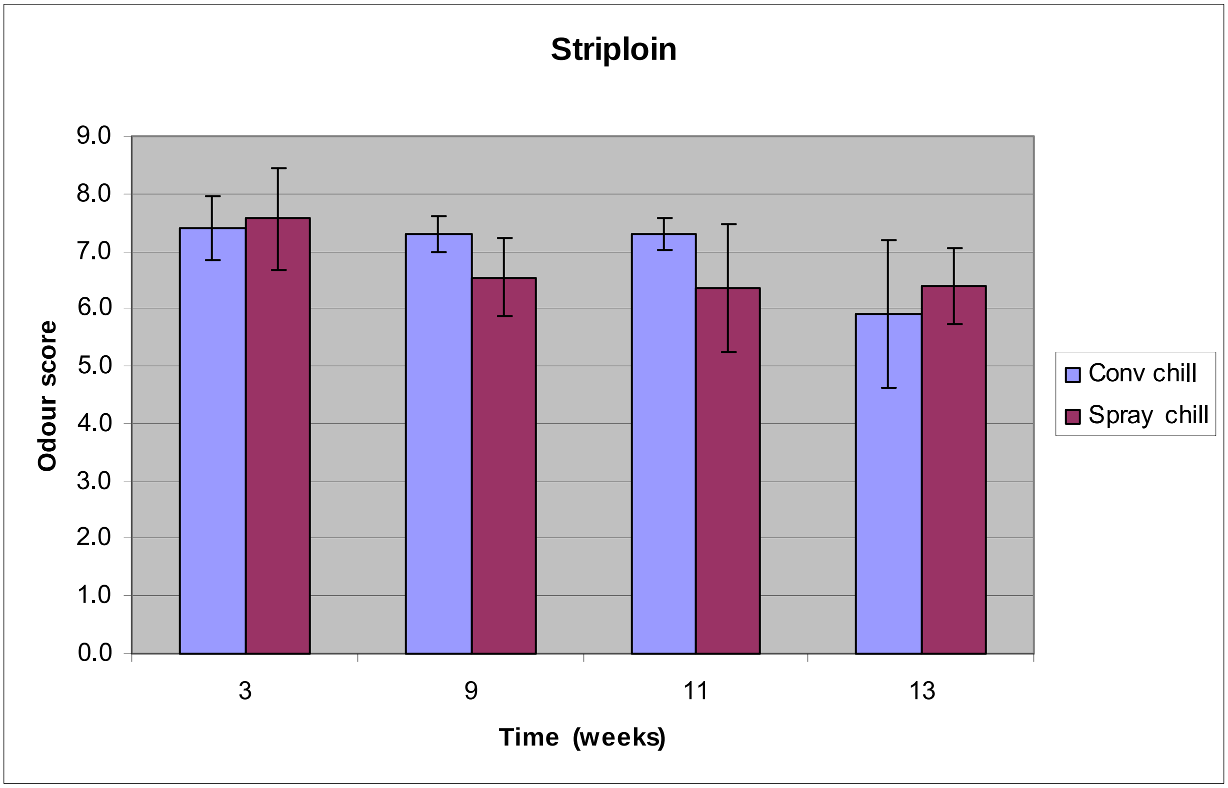

Figure 4: Odour scores for striploins (8: no odour, 0 – strong off odour, error bars show standard deviations)

4.5.3 Drip in vacuum packs

Spray chilling had no effect on the amount of drip or weep in vacuum packs. Drip was much lower in the clod packs than in the striploin and outside flat packs but increased with storage time to about 3% in the striploins and outside flats and less than 1% in the clods (Figures, 5, 6 and 7).

Some researchers have found evidence of increased drip in vacuum packs from spray-chilled carcases. Allen *et al* (1987) found that the inside rounds from spray-chilled carcases had 0.26% more purge than those from those conventionally chilled. The results of this investigation agree with those of Strydom & Buys (1995) and Greer & Jones (1997) who found no increase in drip due to spray chilling.

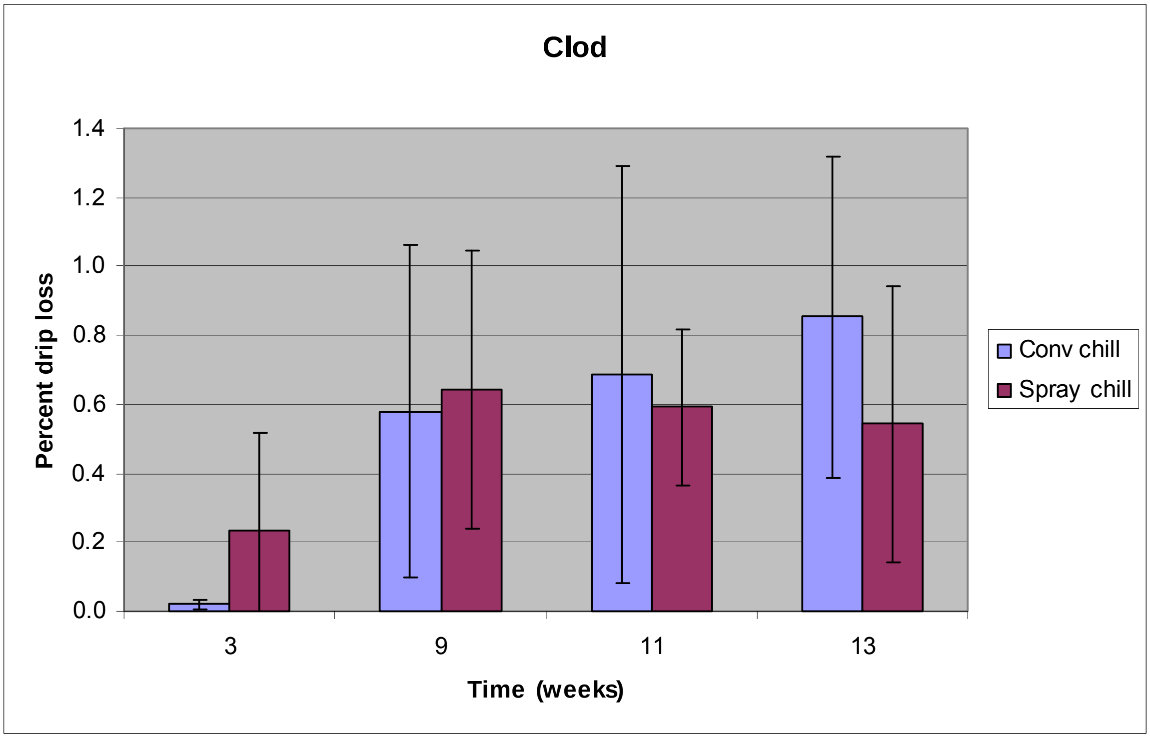

Figure 5: Drip in vacuum-packed clods (error bars show standard deviations)

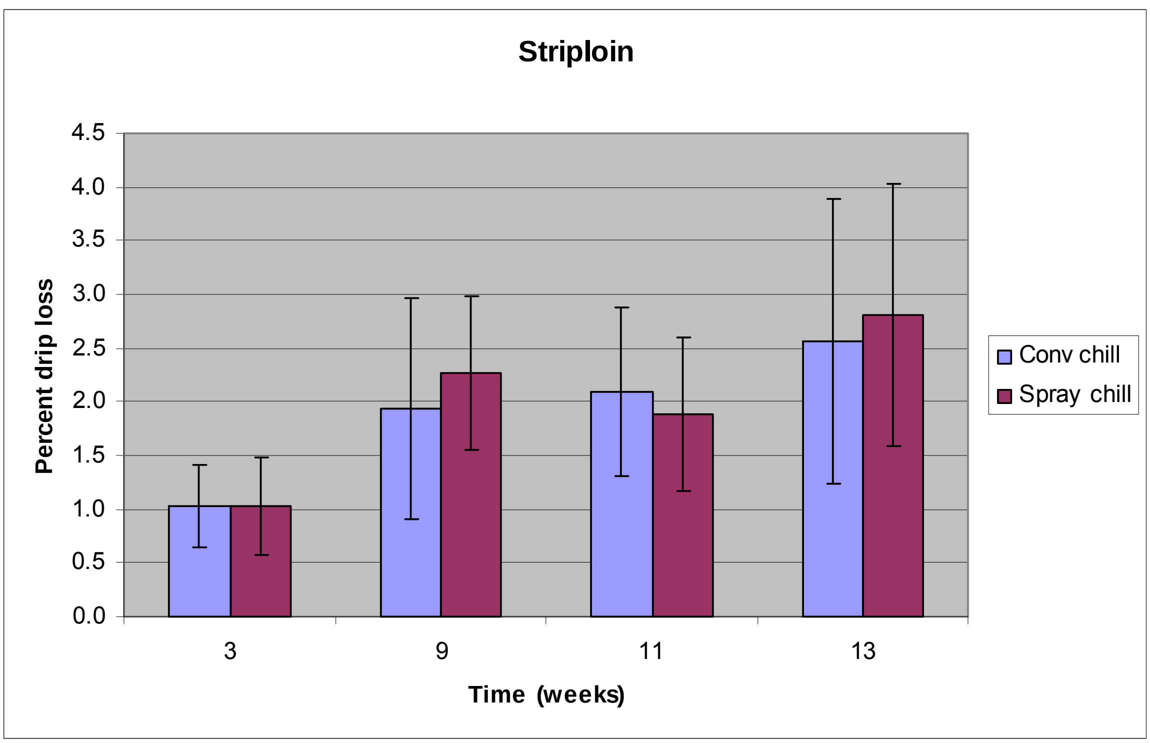

Figure 6: Drip in vacuum-packed striploins (error bars show standard deviations)

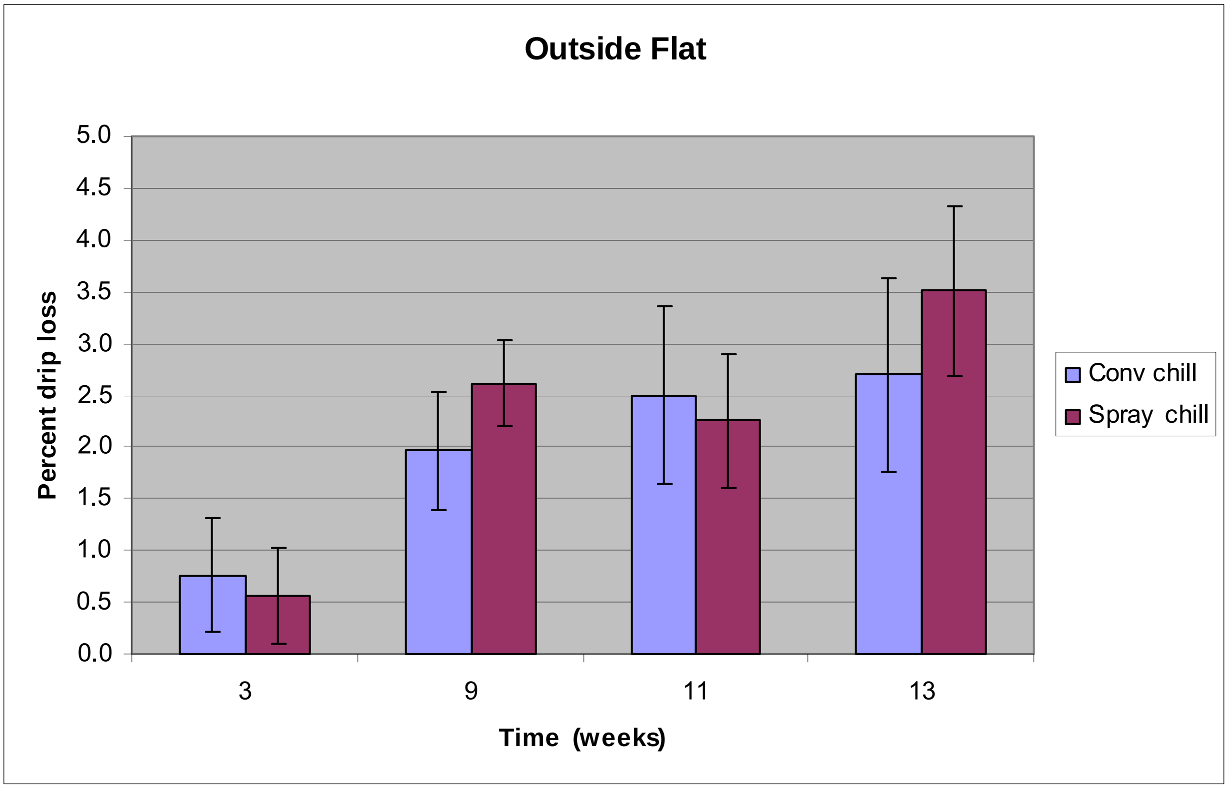

Figure 7: Drip in vacuum-packed outside flats (error bars show standard deviations)

4.5.4 Sensory assessment

Sensory evaluation of steaks from the striploins found no differences in aroma or flavour between those that had been spray chilled and the conventionally chilled ones. There was no decrease in acceptability with increased storage time.

4.5.5 Microbiological quality

The total viable count (TVC) gradually increased throughout the 13 week storage period (Figure 8) to a mean of 4 to 6 log_{10} CFU/g. The counts on spray-chilled clods and striploins appeared to be slightly higher, but the differences were not significant. This is in agreement with Greer & Jones (1997) who found no differences in bacterial count during storage for up to 6.5 weeks. The results for the means of the three cuts sampled are presented in Figure 9. Plots of the growth on each cut are provided in Appendix 2. The counts were highly variable between cuts, at week 13 ranging from <2.7 log_{10} CFU/g to 7.5 log_{10} CFU/g.

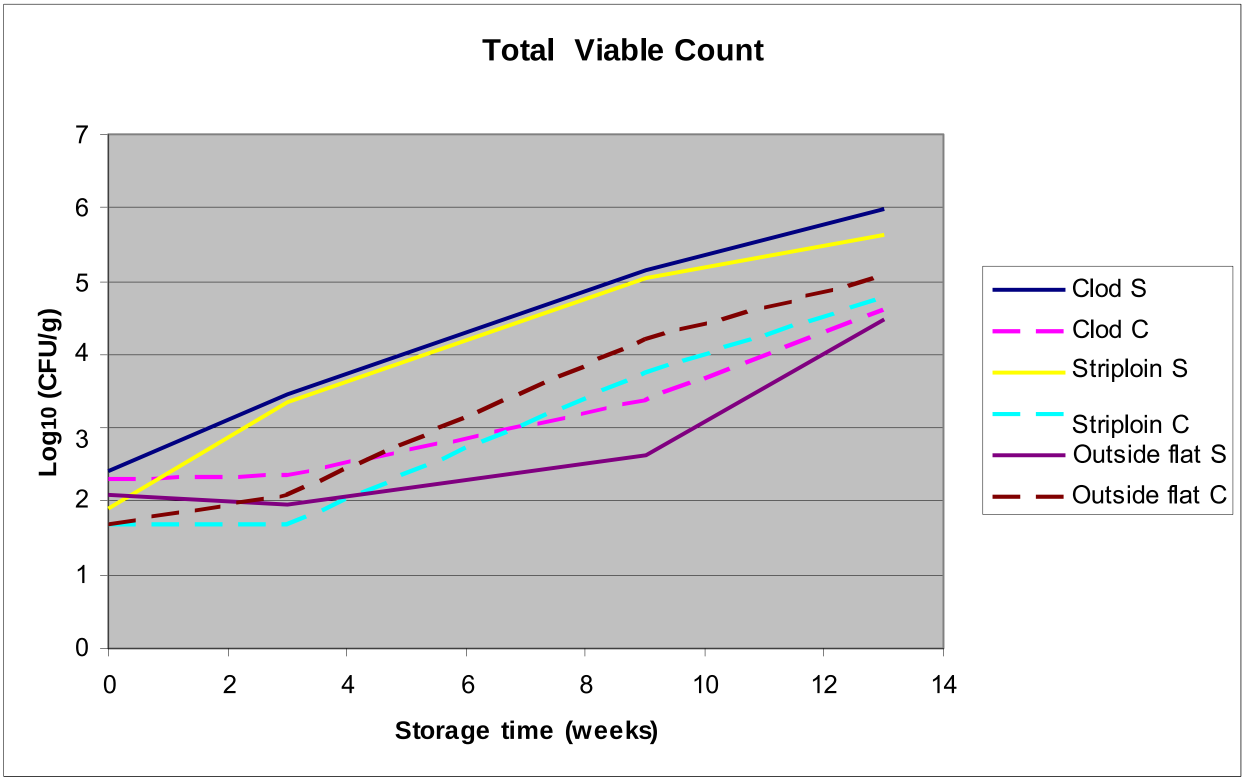

Figure 8: The growth of TVC during storage (S: spray, C: conventional)

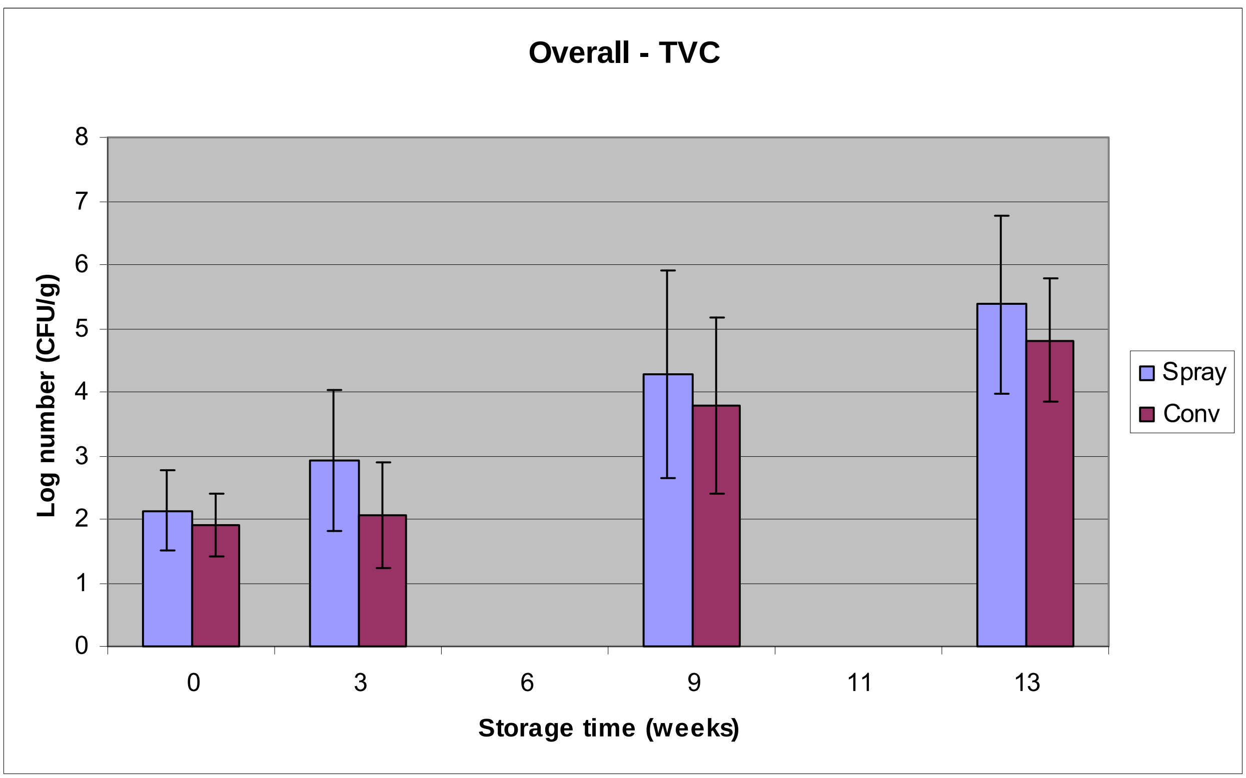

Figure 9: Mean TVC for clod, striploin and outside flat (error bars show standard deviation)

Counts of *Lactobacillus* were barely detectable during the early stages of vacuum storage but rose to an average of 2.0 to 4.0 log_{10} CFU/g by week 13 (Figure 10). However counts were variable between samples, ranging from <3.0 log_{10} CFU/g to 4.2 log_{10} CFU/g at week 13. There was a tendency for spray chilled samples to have higher counts than those conventionally chilled but they were below the level considered to cause spoilage.

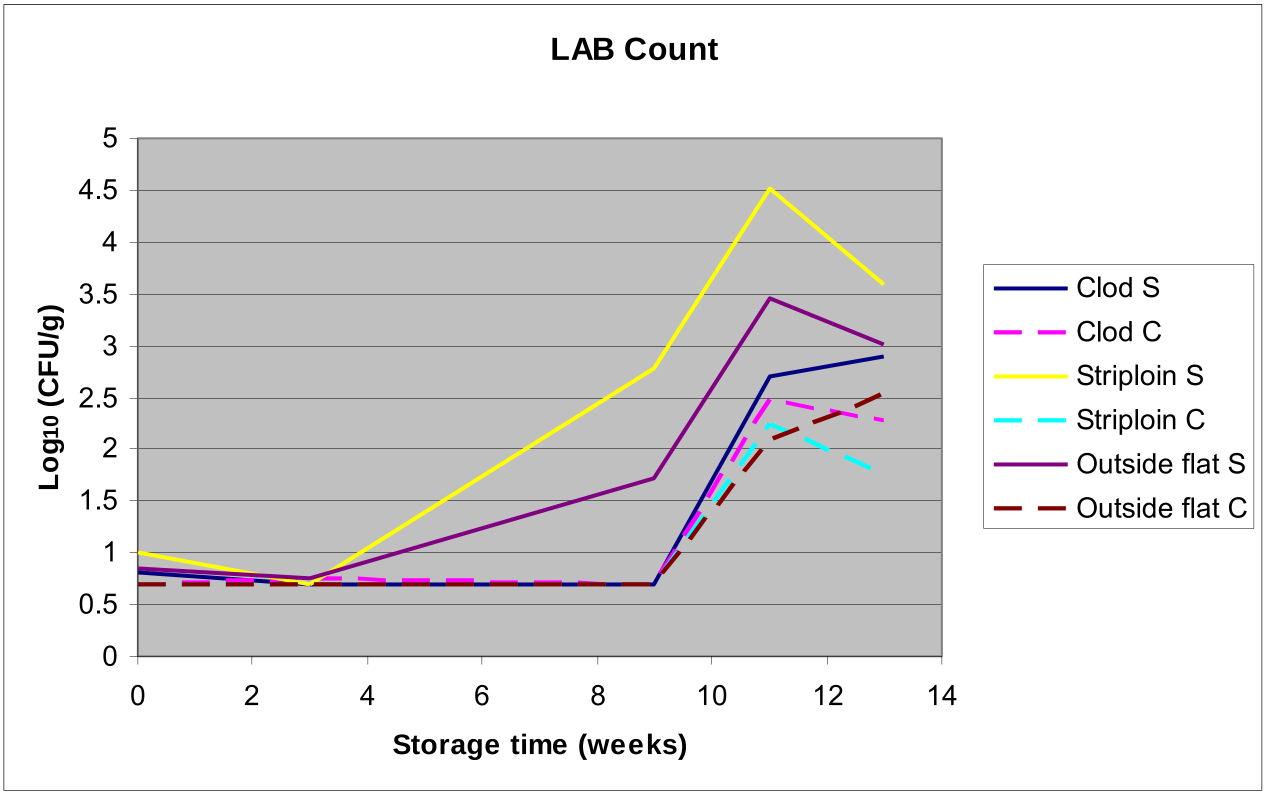

Figure 10: The growth of lactobacillus during storage (S: spray, C: conventional)

The spoilage organism, *Brochothrix thermosphacta* were recovered intermittently, at levels that were not likely to cause spoilage. Neither *E. coli* nor *Salmonella* were detected in any samples.

The results of microbiological sampling and analysis indicate that both the spray-chilled and conventionally chilled primal cuts were of acceptable microbiological quality and there was no indication of spoilage. A storage life was at least 13 weeks was achieved.

5 Success in Achieving Objectives

This project has successfully achieved all objectives. A spray chilling system has been installed in a chiller at the Dinmore plant of Swift Australia, its operation optimised and the effects on product evaluated. Specifically:

- Spray chilling parameters have been developed that reduce average carcase weight loss to less than 0.5% and it has been shown that an increase in saleable meat yield after boning of 0.53% can be obtained.
- The spray chilling parameters developed result in a much lower water consumption than reportedly used in plants in the United States. Spray chilling resulted in an increase in water consumption of approximately 22 L per head.
- The shelf life of three representative vacuum-packaged primal cuts was shown to be not affected by spray chilling up to a storage time of 13 weeks at 0°C.
- The microbiological quality of carcases was similar after spraying chilling with 22°C ambient temperature water and after spraying with 2°C water. The spray-chilled vacuum-packaged primal cuts from spray chilled and conventionally chilled carcases were of similar microbiological quality after storage.

6 Impact on Meat and Livestock Industry – now & in five years time

This project has shown that spray chilling is a viable means of increasing yield of saleable meat for Swift Australia. If this process is extended to other Swift plants and to other processors over the next few years, Australia as a whole will benefit from increased export earnings.

7 Conclusions and Recommendations

A spray chilling system, capable of supplying water at a temperature as low as 2 °C, has been successfully installed to service Chiller 5 at the Dinmore plant of Swift Australia Pty Ltd. It consists of a water storage tank with refrigeration system, reticulation pipework and controls to supply three zones of nozzles to apply a spray of water in cycles to the beef carcases during the first few hours of chilling.

Operating parameters have been developed for a normal overnight carcase chilling process that reduce chiller weight loss (shrink) to an average 0.47% compared with a shrink of 1.14% under conventional operating conditions. The following parameters were found to be suitable:

Spray zone 1	24 s
Spray zone 2	24 s
Spray zone 3	24 s
Drain time	24 minutes

There are 10 spray cycles for a total spraying time of 3 h 48 min. Carcases are allowed to dry for the remainder of the chilling cycle.

These spray chilling conditions resulted in an estimated increased water consumption of 22.3 L per head or 78 kL per day if fully implemented at the Dinmore plant.

Trials were carried out with spraying both ambient (22°C) temperature water and water chilled to 2°C. Carcase surface temperatures were logged and the ESAM sites were swabbed before and after chilling to determine whether water temperature had an effect on cooling rate and microbiological growth. The rate of cooling of the surface was similar for both runs and a refrigeration index (RI) of zero was calculated for both spray water temperatures. There was no difference in microbiological quality of the carcases after spray chilling with ambient temperature water or chilled water and conventional chilling.

Boning yield trials, using the spraying parameters above, showed that over a range of body sizes and types, there was an increase in saleable meat yield of 0.53%. There was a significant increase in the yield of the Topside, Striploin, Blade and PE brisket primal cuts but a significant decrease in the amount of trimmings. There was no increase in the weight of the fat trim indicating that the increased carcase weight was not being trimmed off and sent for rendering. The cost of the increase in water consumed is insignificant compared with the return from yield improvement.

Storage trials with vacuum-packaged Outside flats, Striploins and Clods, showed that, for a storage period up to 13 weeks, there was no difference between the conventionally chilled and spray-chilled product in terms of microbiological quality, appearance, odour, quantity of drip and eating quality.

The following recommendations are made:

1. Undertake further chiller weight loss measurements to develop additional sets of spray chilling parameters for chilling periods longer than the normal overnight 16 – 20 hours and for shorter periods, such as warm boning.

2. Extend spray chilling to the remaining Dinmore chillers so that the benefits can be fully realised.

3. Investigate the requirements and implications of installing spray chilling at the other Swift Australia processing sites using the spray chilling design and operational parameters developed for Dinmore as a basis.

8 Acknowledgements

The significant contribution to this project of the production team from Dinmore is gratefully acknowledged. In particular:

Neil Brereton
Graham Treffone
Shaun Johnston
Steve Smith
Tom Shillito
Kalyan Pandit

The spray chilling system was ably designed and installed by Gordon Brothers Industries Pty Ltd.

Funding was provided by Swift Australia Pty Ltd, Australian Meat Processor Corporation Ltd and Meat & Livestock Australia.

9 Bibliography

Allen, D. M., Hunt, M. C., Luchiari Filho, A, Danler, R. J. & Goll, S. J. (1987). Effects of spray chilling and carcass spacing on beef carcass cooler shrink and grade factors. *Journal of. Animal Science*, 64, 165-170.

AQIS (2002). Meat Notice 2002/18, Compliance with retained water rules for carcases, meat and offals exported to the USA.

AQIS (2003) Meat Notice 2002/6, Revised ESAM program.

Greer, G. G. & Jones, S. D. M. (1997). Quality and bacteriological consequences of beef carcase spray-chilling: effects of spray duration and boxed beef storage temperature. *Meat Science*, 45, 61-73.

Jones, S. D. M. & Robertson, W. M. (1988). The effects of spray-chilling carcasses on the shrinkage and quality of beef. *Meat Science*, 24, 177-188.

Strydom, P. E. & Buys, E. M. (1995). The effects of spray-chilling on carcass mass loss and surface associated bacteriology. *Meat Science* 39, 265-276.

10 Appendices

10.1 Appendix 1 – Spray chilling equipment

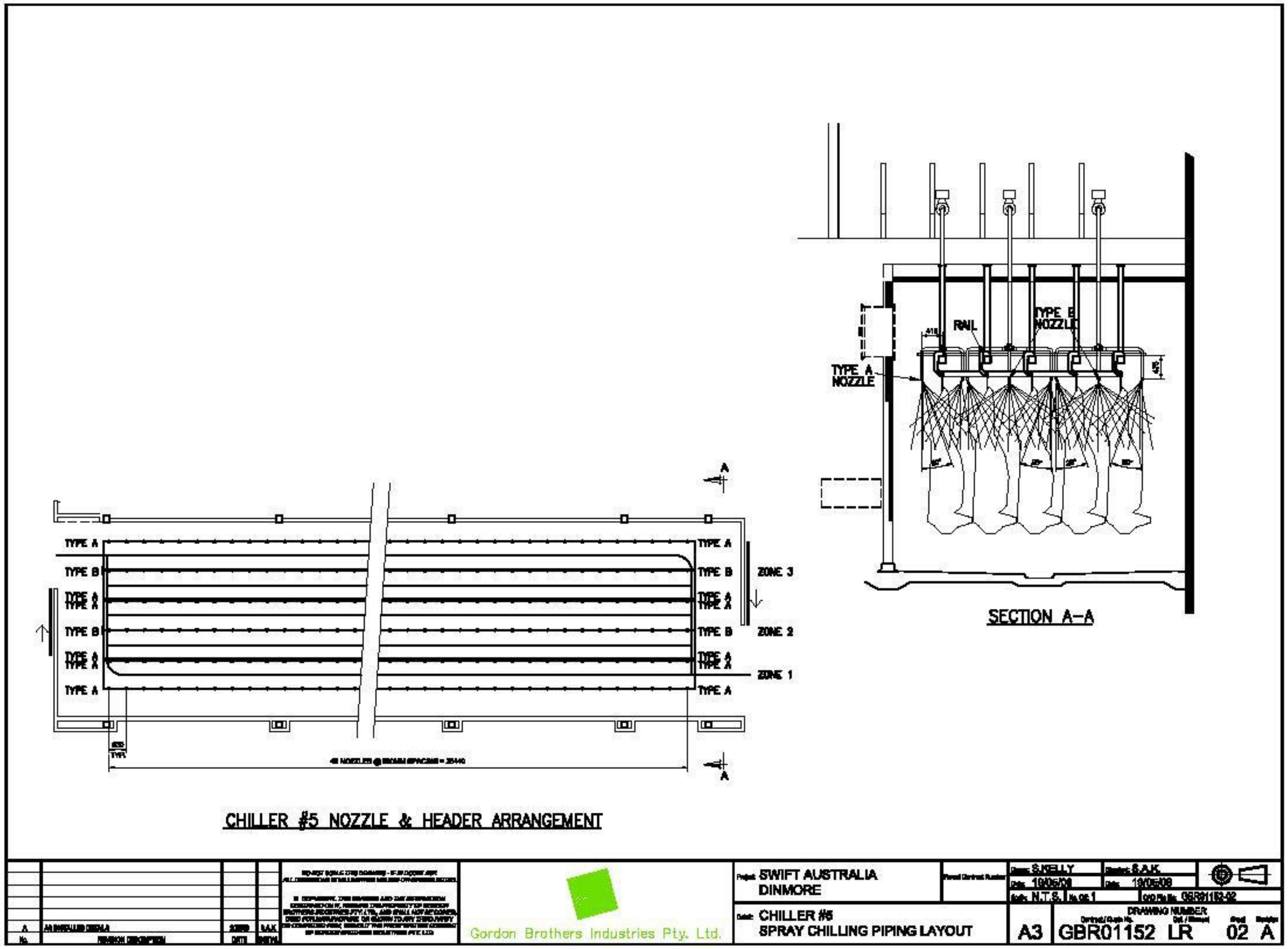

Figure 1.1: Piping and nozzle layout – Chiller 5

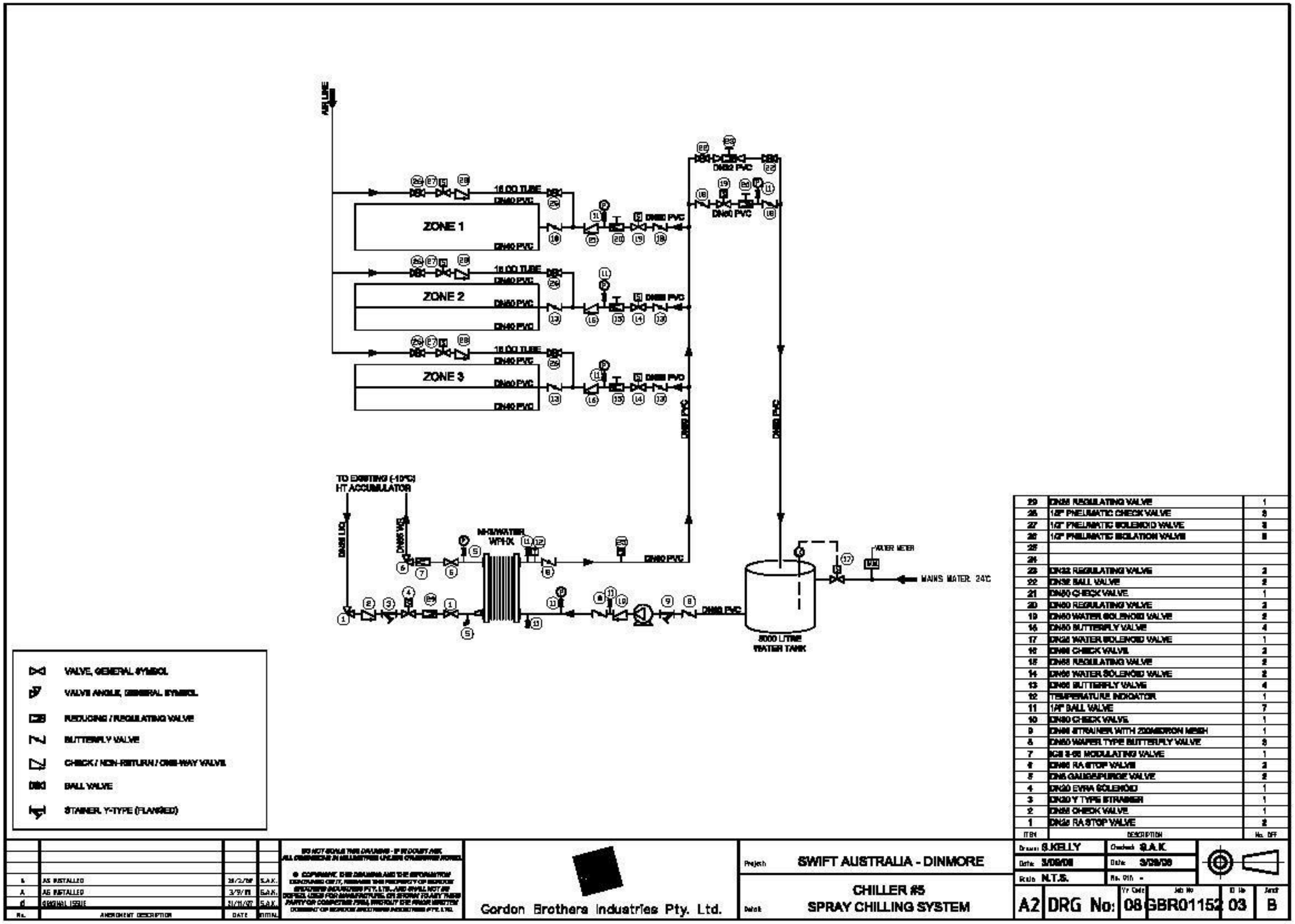

Figure 1.2: Spray chilling arrangement

Plate Heat Exchanger

Technical Specification

Customer : **Gordon Brothers Industries Pty Ltd**
Model : **M10-BWFD**
Project: : **AUSYSMEL-181(a)/Flooded PHE**
Item : **Date** : **1/05/2008**

Fluid		**Water**	**Ammonia**
Mass flow rate	kg/s	8.333	0.3193
Fluid Condensed/Vapourized	kg/s	0.000	0.2235
Inlet temperature	°C	10.0	0.0
Outlet temperature(vapor/liquid)	°C	2.0	0.0
Operating pressure (In/Out)	bar	/	4.29/4.24
Pressure drop (Perm/Calculate)	kPa	100/14.0	7.50/5.37
Velocity Connection (In/Out)	m/s	1.06/1.06	0.0639/8.61
Heat Exchanged	kW	280.6	
Relative directions of fluids		Cocurrent	
Number of passes		1	1
Plate material / Thickness		ALLOY 316 / 0.60 mm	
Sealing material		NBRP	Welded
Ring Gasket		CR	
Connection material		Stainless steel	Stainless steel
Connection diameter	mm	100	100
Nozzle orientation		S2 -> S1	S3 -> S4
Pressure vessel code		AS 1210	
Flange rating		ASME 150	
Design pressure	barg	16.0	16.0
Test pressure	barg	24.0	24.0
Design temperature	°C	70.0/-10.0	70.0/-10.0
Overall length x width x height	mm	1205 x 470 x 981	
Liquid volume	dm³	29.0	29.6
Net weight, empty / operating Flooded	kg	500 / 532 / 548	
Packed weight (BOX(OCEAN))	kg	530	
Internal volume	m³	0.8	
length x width x height	mm	1100 x 600 x 1190	

Performance is conditioned on the accuracy of customers data and customers ability to supply equipment

Figure 1.3: Plate heat exchanger specifications

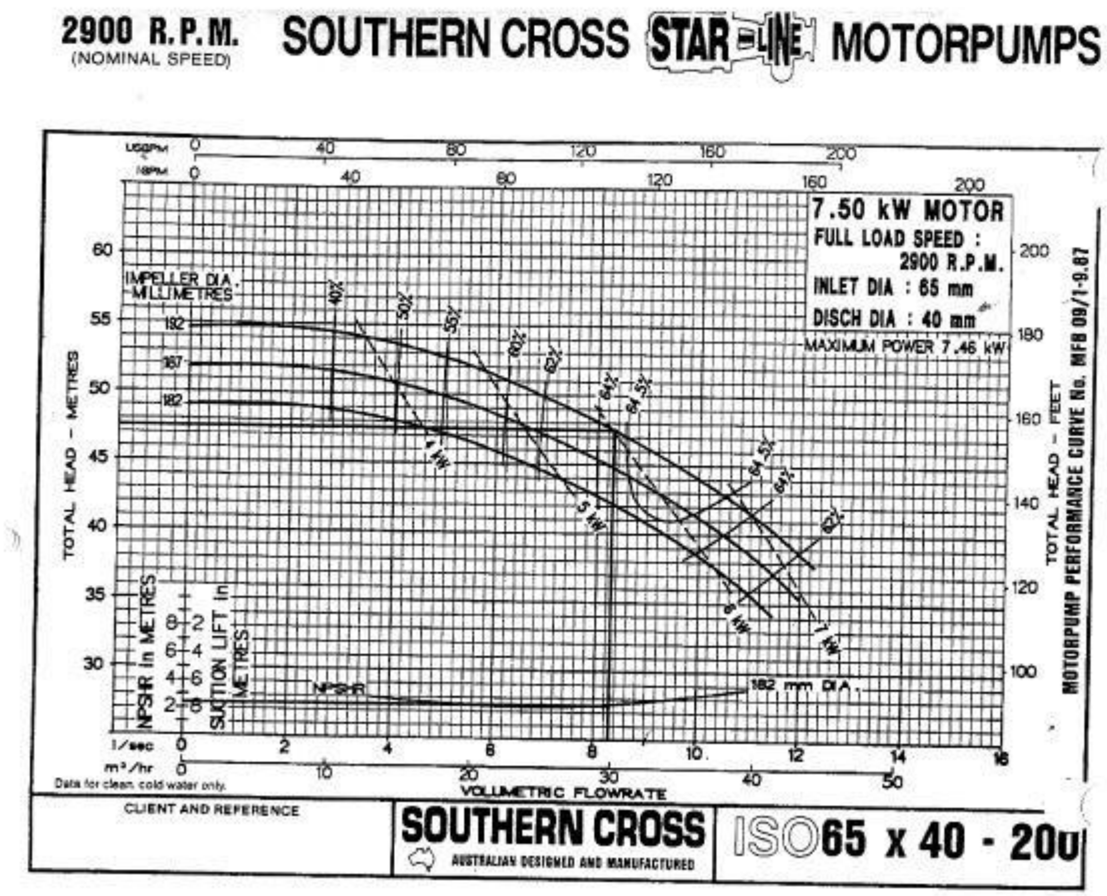

Figure 1.4: Pump curve

METAL PRETREATMENT

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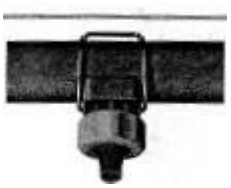
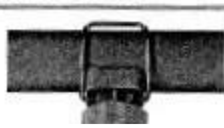
ADJUSTABLE BAL..L•TYPE SPRAY NOZZLES

CLIP-EYELET" SPRAY NOZZLES



PROMAX® CLIP-EYELET SPRAY NOZZLES



FEATURES AND BENEFITS

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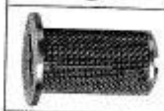
K18

UniJet® STRAINERS

L

SPECIFICATIONS

Strainers	Model	Construction	Screen
	5053	Brass	Stainless steel with 24, 50, 100, 200 mesh
	8079	Polypropylene	Stainless steel with 24, 50, 100, 200 mesh
	6051	Stainless steel	Stainless steel with 24, 50, 100, 200 mesh
	4514 Slotted	Brass	Milled slot equivalent 16, 25, 50 mesh
		Aluminum	Milled slot equivalent 16, 25 mesh
		Nylon	Milled slot equivalent 16, 25, 50 mesh
	4067 Cup	Stainless steel	Stainless steel with 50, 100, 200 mesh
	7830 Disc	Stainless steel	Stainless steel with 50, 100, 200 mesh
	4193A with check valve*	Aluminum Brass Stainless steel Polypropylene	Stainless steel with 24, 50, 100, 200 mesh

*Built-in check valve and stainless steel springs with opening pressures of 5, 10, 20 or 40 psi (0.35, 0.7, 1.5 or 2.8 bar).

ORDERING INFO

UNIJET STRAINER

6051 - SS - 50
(Strainer Type - Material Code - Mesh Size)

UNIJET STRAINER

4067 - 200
(Strainer Type - Mesh Size)

UNIJET STRAINER

4193A - SS - 5 - 50SS
(Strainer Type - Material Code - Spring Opening Pressure (psi) - Mesh Size)

UNIJET STRAINER

4514 - NY - 10
(Strainer Type - Material Code - Slot Width)

MATERIALS

Material	Material Code	Strainer Type: 5053	8079	6051	4514-10 (50 Mesh)	4514-20 (25 Mesh)	4514-32 (16 Mesh)	4193A
Brass	(none)	•			•	•	•	•
Aluminum	AL					•	•	•
Nylon	NYB				•	•	•	
Stainless Steel	SS			•				•
Polypropylene	PP		•					•

Other materials available upon request.

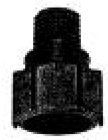
B

QUICK *FullJet*® AND PROMAX® QUICK FULLJET SPRAY NOZZLES, WIDE ANGLE SPRAY

FULL CONE NOZZLES

PROMAX QUICKJET® BODIES

• QPPA male inlet connections



QPPA nozzle body

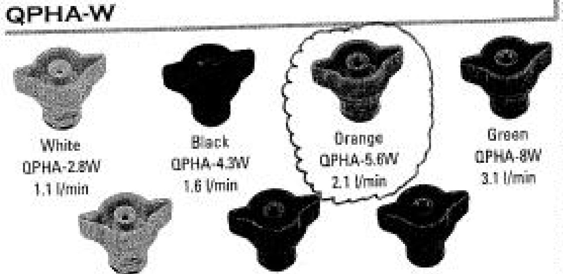
Optional external O-ring (CP7712-2/17-VI)

Spray tip

PROMAX QUICK FULLJET SPRAY TIPS

ProMax Quick FullJet nozzles are comprised of two components, a body and a spray tip. Available tips are shown below. In addition, there is an optional O-ring recommended for harsh environments.

QPHA-W



White QPHA-2.8W 1.1 l/min

Black QPHA-4.3W 1.6 l/min

Orange QPHA-5.6W 2.1 l/min

Green QPHA-8W 3.1 l/min

Yellow QPHA-10W 3.8 l/min

Blue QPHA-12W 4.6 l/min

Red QPHA-14W 5.3 l/min

Capacities at 10 psi (0.7 bar)

OPTIMIZATION TIPS

• See page B2 for optimization tips.

APPLICATIONS

Standard Quick FullJet Spray Nozzles

• Cooling and rinsing
• Dust control
• Gas scrubbing, washing, cooling
• Product washing/rinsing

ProMax Quick FullJet Spray Nozzles

• Chemical manufacturing
• Coating
• Cooling
• Food processing
• Metal finishing
• Parts washing/rinsing
• Printed circuit board manufacturing

SEE ALSO

• Accessories
– ProMax QuickJet nozzle adapters
– QuickJet adjustable ball fitting bodies
– QuickJet nozzle system adaptors
– QuickJet nozzle system plugs
– QuickJet nozzle system plugs for ProMax bodies
– QuickJet split-eyelet bodies
– UniJet® nozzle system adapter for QuickJet systems

ORDERING INFO

QUICK FULLJET COMPLETE NOZZLE

Nozzle body			Spray tip		
1/4	QJJA –	SS	+ QHA –	SS	8W
Inlet Conn.	Body Type	Material Code	Tip Type	Material Code	Capacity Size

PROMAX QUICK FULLJET COMPLETE NOZZLE WITHOUT EXTERNAL O-RING

Nozzle body		Spray tip	
1/4	QPPA	+ QPHA –	14W
Inlet Conn.	Body Type	Tip Type	Capacity Size

PROMAX QUICK FULLJET COMPLETE NOZZLE WITH EXTERNAL O-RING

Nozzle body		Spray tip	
3/8	QPPA	+ QPHA –	2.8W
Inlet Conn.	Body Type	Tip Type	Capacity Size

BSPT connections require the addition of a "B" prior to the nozzle body inlet connection.

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B22

QuickFulfler AND PRoMAX<8 QUICK FuLL.JET SPRAY NOZZLES, WIDE ANGLE SPRAY

PERFORMANCE DATA

Maximum Free Passage Diameter is the maximum diameter as listed of foreign matter that can pass through the nozzle without clogging.

DIMENSIONS AND WEIGHTS

Based on lightest/heaviest version of each type.

MATERIALS

Spraying Systems Co.
Experts in Spray Technology
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B23

QUICK*Futgev* AND PROMAX* QUICK FULWET SPRAY NOZZLES, STANDARD SPRAY

B

PROMAX QUICKJET" BODIES

• QPPA male inlet connections

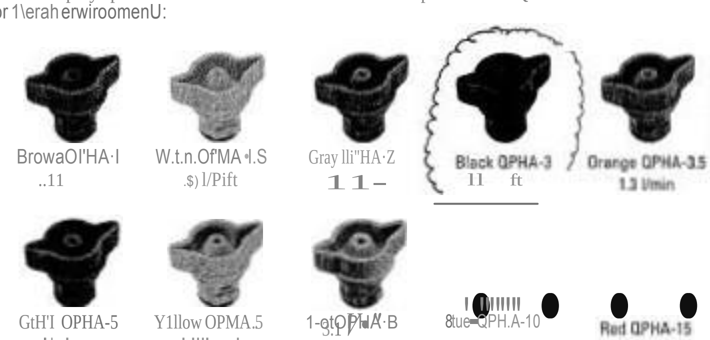
Q.PPA noz:dl body

Optional external O-ring (CP7717-2/17-VI)

Spray tip

PROMAX QUICK FULWET SPRAY...;.;PS: ol

ProMax Quidt fuiiJet no.tllts art co nprlstd ot two componer.u. bQdy •rlll •lptty Of ; Anilblt sptay tips are shown below htdd!ciOf\.thtft is 111 oprior.alO·MQ recomment:td :lor 1\erah erwiroomenU:



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Black QPHA-3 11 ft

Orange QPHA-3.5 1.3 l/min

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8tue QPH.A-10

Red QPHA-15 5.7 l/min

Capacities at 10 psi (0.7 bar)

OPTIMIZATION TIPS

• See page B2 for optimization tips.

APPUCATIONS

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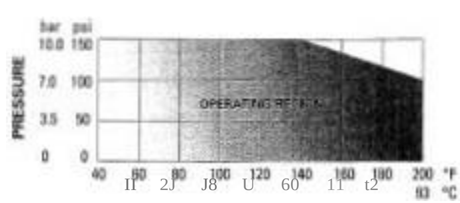

B

QUICK FullJet AND PROMAX® QUICK FULLJET SPRAY NOZZLES, STANDARD SPRAY

FULL CONE NOZZLES

PERFORMANCE DATA

*At the stated pressure in bar.

Inlet Conn. (in.)	Nozzle Type					Capacity Size	Orifice Dia. Nom. (mm)	Max. Free Passage Dia. (mm)	Capacity (liters per minute)*										Spray Angle (°)*		
	QGA	QLGA	QHA	QLHA	QPHA				0.4	0.5	0.7	1.5	2	3	4	6	7	10	0.5	1.5	6
1/8, 1/4, 3/8, 1/2 (QPHA 1/4, 3/8 only)	•				•	1	.83	.64	–	–	.38	.56	.64	.79	.91	1.1	1.2	1.4	–	58	53
	•				•	1.5	1.2	.84	–	.48	.57	.84	.97	1.2	1.4	1.7	1.8	2.2	52	65	59
	•				•	2	1.2	1.0	.58	.64	.76	1.1	1.3	1.6	1.8	2.2	2.4	2.9	43	50	46
	•					2.5	1.35	1.0	.72	.81	.95	1.4	1.6	2.0	2.3	2.8	3.0	3.6	43	50	46
	•				•	3	1.5	1.0	.86	.97	1.1	1.7	1.9	2.4	2.7	3.4	3.6	4.3	52	65	59
	•		•		•	3.5	1.6	1.3	1.0	1.1	1.3	2.0	2.3	2.8	3.2	3.9	4.2	5.0	43	50	46
	•					4	1.7	1.3	1.2	1.3	1.5	2.2	2.6	3.2	3.8	4.5	4.8	5.8	48	55	50
	•				•	5	2.0	1.3	1.4	1.6	1.9	2.8	3.2	3.9	4.6	5.6	6.0	7.2	52	65	59
1/4, 3/8, 1/2 (QPHA 1/4, 3/8 only)	•		•		•	6.5	2.4	1.6	1.9	2.1	2.5	3.6	4.2	5.1	5.9	7.3	7.8	9.4	45	50	46
					•	8	2.4	1.6	2.3	2.6	3.1	4.5	5.2	6.3	7.3	8.9	9.6	11.5	54	65	61
	•		•		•	10	3.2	1.6	2.9	3.2	3.8	5.6	6.4	7.9	9.1	11.2	12.1	14.4	58	67	61
					•	15	3.6	2.4	4.3	4.8	5.7	8.4	9.7	11.8	13.7	16.8	18.1	22	60	65	60
3/8, 1/2	•					9.5	2.6	2.4	2.7	3.1	3.6	5.3	6.1	7.5	8.7	10.6	11.5	13.7	45	50	46
	•			•		15	3.6	2.4	4.3	4.8	5.7	8.4	9.7	11.8	13.7	16.8	18.1	22	64	67	61
	•					20	4.0	2.8	5.8	6.4	7.6	11.2	12.9	15.8	18.2	22	24	29	76	80	73
	•			•		22	4.5	2.8	6.3	7.1	8.4	12.3	14.2	17.4	20	25	27	32	87	90	82
1/2		•				16	3.5	3.2	4.6	5.2	6.1	8.9	10.3	12.6	14.6	17.9	19.3	23	48	50	46
		•				20	4.1	3.2	5.8	6.4	7.6	11.2	12.9	15.8	18.2	22	24	29	62	65	59
		•		•		25	4.6	3.2	7.2	8.1	9.5	14.0	16.1	19.7	23	28	30	36	64	67	61
		•				30	4.8	3.6	8.8	9.7	11.4	16.8	19.3	24	27	34	36	43	69	72	66
		•				32	5.2	3.6	9.2	10.3	12.2	17.9	21	25	29	36	39	46	72	75	68
		•				40	6.2	3.6	11.5	12.9	15.3	22	26	32	36	45	48	58	88	91	83
		•				50	6.8	4.0	14.4	16.1	19.1	28	32	39	46	56	60	72	91	94	86

Maximum Free Passage Diameter is the maximum diameter as listed of foreign matter that can pass through the nozzle without clogging.

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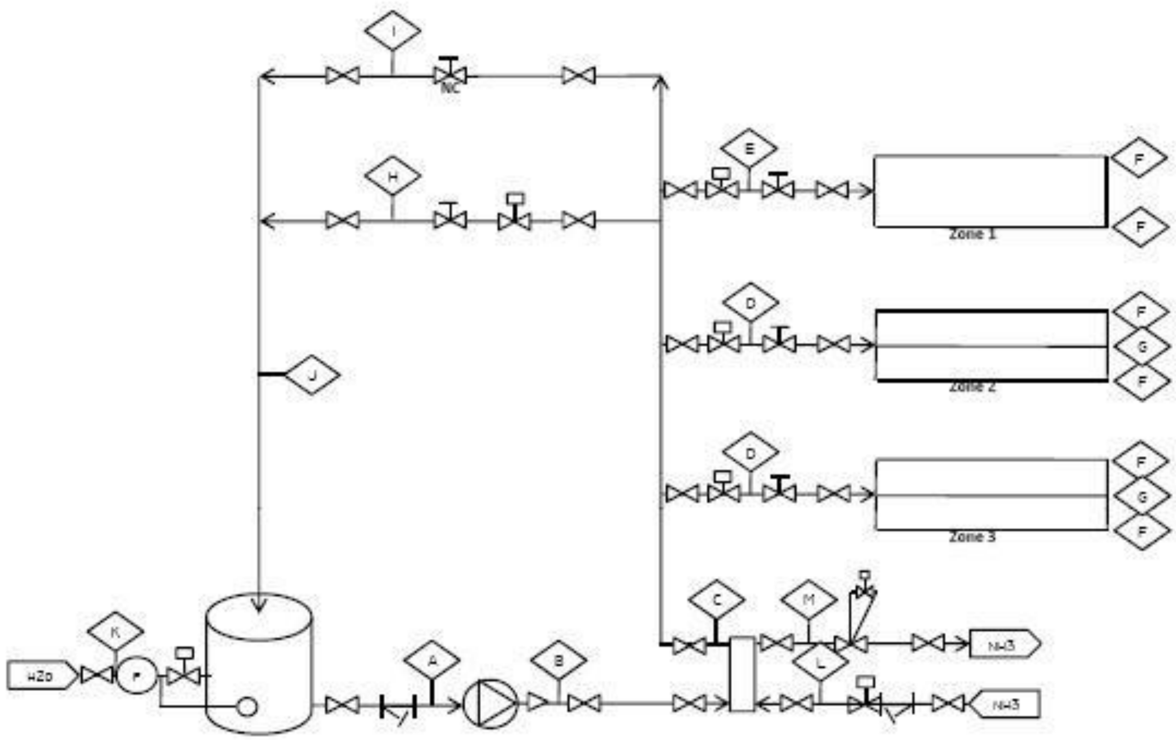
Figure 1.5: Spray nozzle specifications

SWIFT DINMORE SPRAY CHILLING SYSTEM FOR CHILLER #5



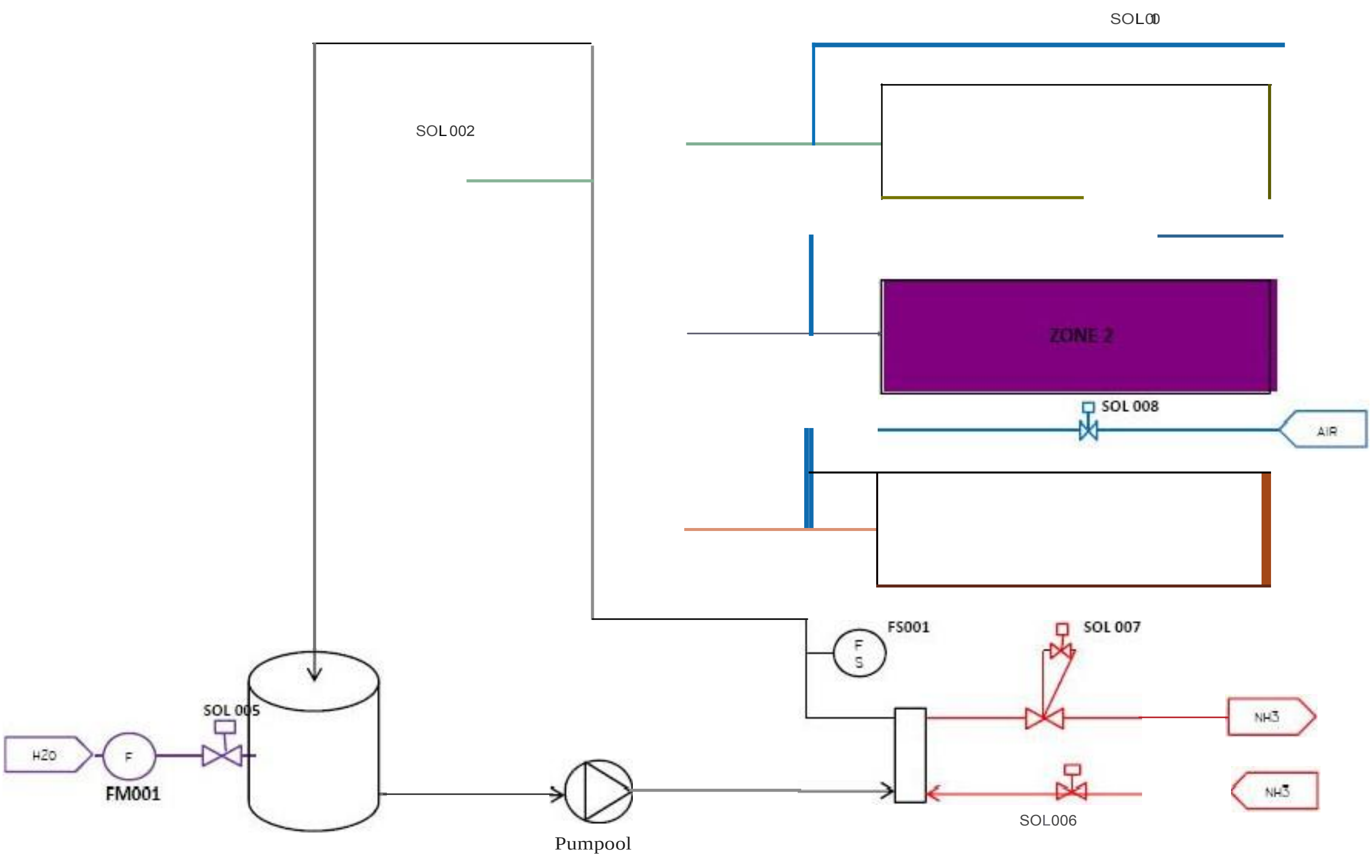
		A	B	C	D	E	F	G	H
Service		H2O	H2O	H2O	H2O	H2O	H2O	H2O	H2O
Flow	*kg/h*	30,000	30,000	30,000	21,756	11,172	5,586	10,584	30,000
Pressure	*kPag*	40	515	470	300	200	200	300	300
Temp	*deg C*	9.5	10	2	2.5	2.5	2.5	2.5	2.5
Size	*NB*	80	80	80	65	50	40	50	65
Veloc	*m/s*	1.7	1.7	1.7	1.8	1.6	1.2	1.5	2.5

		I	J	K	L	M*			
Service		H2O	H2O	H2O	NH3-L	NH3-G			
Flow	*kg/h*	0	30,000	6,310	1150	805			
Pressure	*kPag*	300	250	500	330	330			
Temp	*deg C*	2.5	2.5	25	0	0			
Size	*NB*	32	65	40	25	65			
Veloc	*m/s*	0.0	2.5	1.4	1.0	19.5			

* Denotes Gas Mass Only

Figure 1.6: Spray chilling process flow diagram

FUNCTONAL DESCRIPTON- SWIFT DINMORE- CHILLER #5 SPRAY CHILLING SYSTEM



Verification of the effect of spray chilling in preventing chiller yield loss

Step	Item	Initial values	Units	System action
1	Initiation of spray system			When any of Chiller #5 cycle's are initiated from the SCADA, the Spray Chilling System will go into "*Standby*" mode.
2	Starting of system			The Spray Chilling System is then started via the "*Start*" tab on the Spray Chilling SCADA page allocated for the Chiller #5 Spray Chilling System.
3	Spray delay time	0	hours	Once the Spray Chilling System is started from the SCADA page, a Spray Delay Time will begin its countdown before the actual water spraying cycle begins. The Spray Delay Time is an adjustable parameter which allocates a delay time for the Chiller prior to the commencement of actual water spraying. After the Spray Delay Time has elapsed, Pump001 will start & SOL002 will energise (open). After a further internal delay of (60secs) NH3 solenoids SOL006 & 007 will energise (open), but if & only if flowswitch FS001 is "high" and indicating flow. If FS001 is "low" or at any time during the operation of the system loses flow for > (60 s), SOL006, 007 & 002 will de-energise (close), PUMP001 will stop and an alarm will be raised on the SCADA. If FS001 "allows" SOL006, 007 & 002 to remain energised and PUMP001 to remain running, then after another internal delay of (60secs) the process proceeds to the next step. SOL006 & 007 and Pump001 will remain active throughout until the Spray Cycle Run Time is completed.
4	Zone 1 spray time	1.5	minutes	At the start of step 2, SOL002 will de-energise (close) & SOL004 will energise (open). SOL004 will remain energised for the entire Zone 1 spray cycle time and then de-energise (close). Immediately after SOL004 de-energises, the process proceeds to the next step.
5	Zone 2 spray time	1.5	minutes	At the start of step 3, SOL003 will energise (open). SOL003 will remain energised for the entire Zone 2 spray cycle time and then de-energise (close). Immediately after SOL003 de-energises, the process proceeds to the next step.
6	Zone 3 spray time	1.5	minutes	At the start of step 4, SOL001 will energise (open). SOL001 will remain energised for the entire Zone 3 spray cycle time and then de-energise (close). Immediately after SOL001 de-energises, the process proceeds to the next step.
7	Drip cycle time	8.5	minutes	At the start of step 5, SOL002 will energise (open) and will remain energised for the entire Drip Cycle Time. During this cycle all other solenoids will remain de-energised (closed) except for the Solenoids SOL006 & 007 which will remain energised. Pump001 will remain running.
8	Spray system run time	10	hours	The system will continue to run through steps 4-7 until either the Spray system run time elapses or the Spray System is switched off, paused or interrupted.
9	Spray system paused or chiller Cycle is interrupted	30	minutes	If the Spray Chilling System is paused via the "Pause" tab on the allocated Spray Chilling SCADA page, or if the Chiller Cycle is interrupted or stopped for any reason, then irrespective of whichever step the Spray Chilling System is in, the system will go into "*Hold*" mode, i.e. ALL active solenoids will de-energise (close), except for SOL002 which will energise (open). PUMP001 will remain running, if and only if FS001 permits this. If the Spray Chilling System is "re-started/unpaused" in less than (30min), then the system will "re-start" in Step 4 and continue running through Steps 4-7 until the remainder of the Spray System Run Time has elapsed. If the system is "re-started/unpaused" after more than (30min), then the system will automatically "Stop" itself, i.e. SOL002 will de-energise (close) and PUMP001 will stop.
10	Elapsed spray system run time	3	minutes	Once the Spray Chilling System "Run Time" has elapsed, or the System has been interrupted for longer than 30 minutes (as per step 9) and SOL002 has de-energised & PUMP001 has stopped, then solenoids SOL008, 009 & 010 will energise (open) for the duration of the Elapsed Run Time Cycle allowing High Pressure Air to "blow-down" the Spray Chilling System piping to completely empty the pipes of water ready for the next system "start-up".

Figure 1.7: Spray chilling operational functional description

10.2 Appendix 2 – Results of carcase microbiological sampling

Table 2.1: Results from sampling sides before and after spray chilling - 22°C water

Side No.	Before spray chilling (CFU/cm^2)			After spray chilling (CFU/cm^2)		
	TVC	Total coliforms	*E. coli*	TVC	Total coliforms	*E. coli*
780 R	nd	nd	nd	nd	nd	nd
780 L	8.33	nd	nd	nd	nd	nd
781 R	nd	nd	nd	nd	nd	nd
781 L	16.67	nd	nd	nd	nd	nd
782 R	nd	nd	nd	nd	nd	nd
782 L	nd	nd	nd	8.33	nd	nd
783 R	nd	nd	nd	nd	nd	nd
783 L	nd	nd	nd	nd	nd	nd
784 R	nd	nd	nd	nd	nd	nd
784 L	nd	nd	nd	nd	nd	nd
786 R	108.33	nd	nd	nd	nd	nd
786 L	nd	nd	nd	nd	nd	nd
787 R	8.33	nd	nd	nd	nd	nd
787 L	8.33	nd	nd	8.33	nd	nd
788 R	16.67	0.08	nd	nd	nd	nd
788 L	8.33	nd	nd	nd	nd	nd
789 R	nd	nd	nd	nd	nd	nd
789 L	nd	nd	nd	nd	nd	nd
790 R	nd	nd	nd	nd	nd	nd
790 L	nd	nd	nd	nd	nd	nd
791 R	8.33	nd	nd	100	nd	nd
792 R	nd	nd	nd	nd	nd	nd
792 L	8.3	nd	nd	8.33	nd	nd
793 R	nd	nd	nd	nd	nd	nd
793 L	50	nd	nd	83.33	0.58	nd
794 R	nd	nd	nd	nd	nd	nd
794 L	nd	nd	nd	8.33	nd	nd
797 R	8.33	nd	nd	nd	nd	nd
797 L	nd	nd	nd	nd	nd	nd

Nd = Not detected

Table 2.2: Results from sampling sides before and after spray chilling - 2°C water

Side No.	Before spray chilling (CFU/cm^2)			After spray chilling (CFU/cm^2)		
	TVC	Total coliforms	*E. coli*	TVC	Total coliforms	*E. coli*
447 L	nd	nd	nd	nd	nd	nd
459 R	nd	nd	nd	nd	nd	nd
462 R	nd	nd	nd	nd	nd	nd
463 R	nd	nd	nd	nd	nd	nd
464 R	8.33	0.17	nd	nd	nd	nd
465 R	nd	nd	nd	nd	nd	nd
466R	250	nd	nd	nd	nd	nd
467 L	nd	nd	nd	nd	nd	nd
467 R	nd	nd	nd	nd	nd	nd
471 R	100	0.25	nd	nd	nd	nd
473 L	nd	nd	nd	nd	nd	nd
473 R	nd	nd	nd	nd	nd	nd
474 R	nd	nd	nd	nd	nd	nd
474 L	nd	nd	nd	nd	nd	nd
488 L	nd	nd	nd	nd	nd	nd
488 R	nd	nd	nd	nd	nd	nd
495 L	nd	nd	nd	nd	nd	nd
495 R	nd	nd	nd	8.33	nd	nd
496 L	nd	nd	nd	nd	nd	nd
496 R	nd	nd	nd	nd	nd	nd
502 L	nd	nd	nd	nd	nd	nd
502 R	nd	nd	nd	nd	nd	nd
518 L	nd	nd	nd	16.67	nd	nd
518 R	nd	nd	nd	8.33	nd	nd
574 L	nd	nd	nd	nd	nd	nd
574 R	nd	nd	nd	nd	nd	nd
575 L	8.33	nd	nd	nd	nd	nd
575 R	nd	nd	nd	nd	nd	nd
577 L	nd	nd	nd	nd	nd	nd

Nd = Not detected

10.3 Appendix 3 – Results of storage life tests

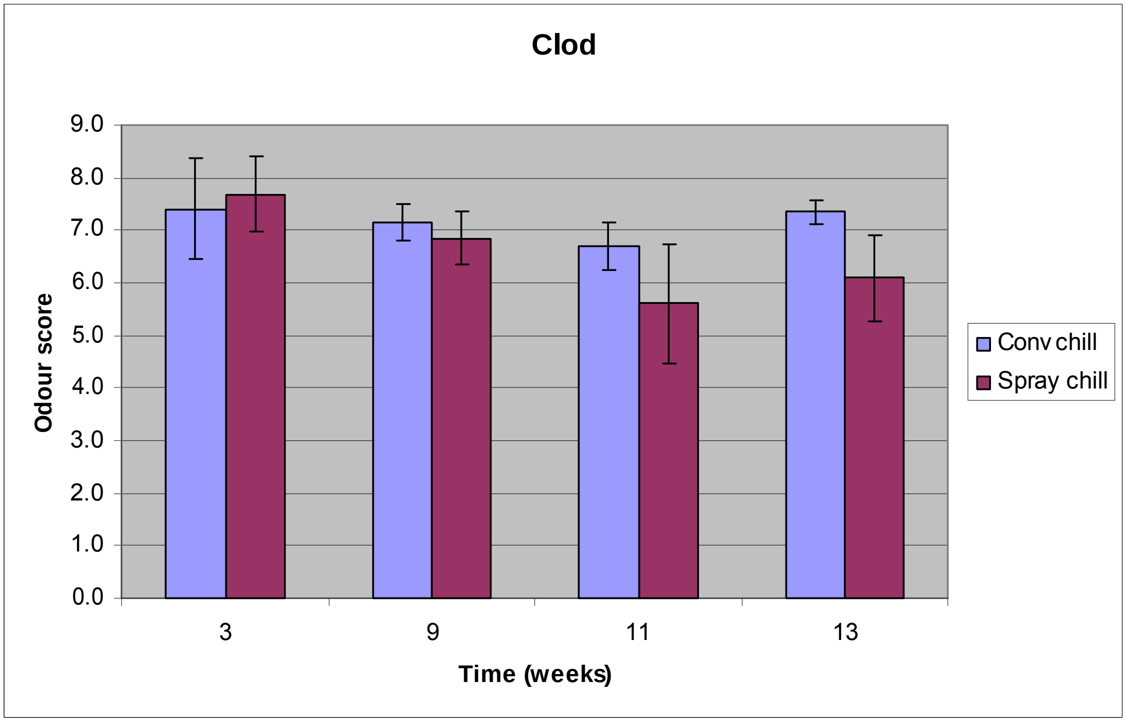


Figure 3.1: Odour scores for clod packs

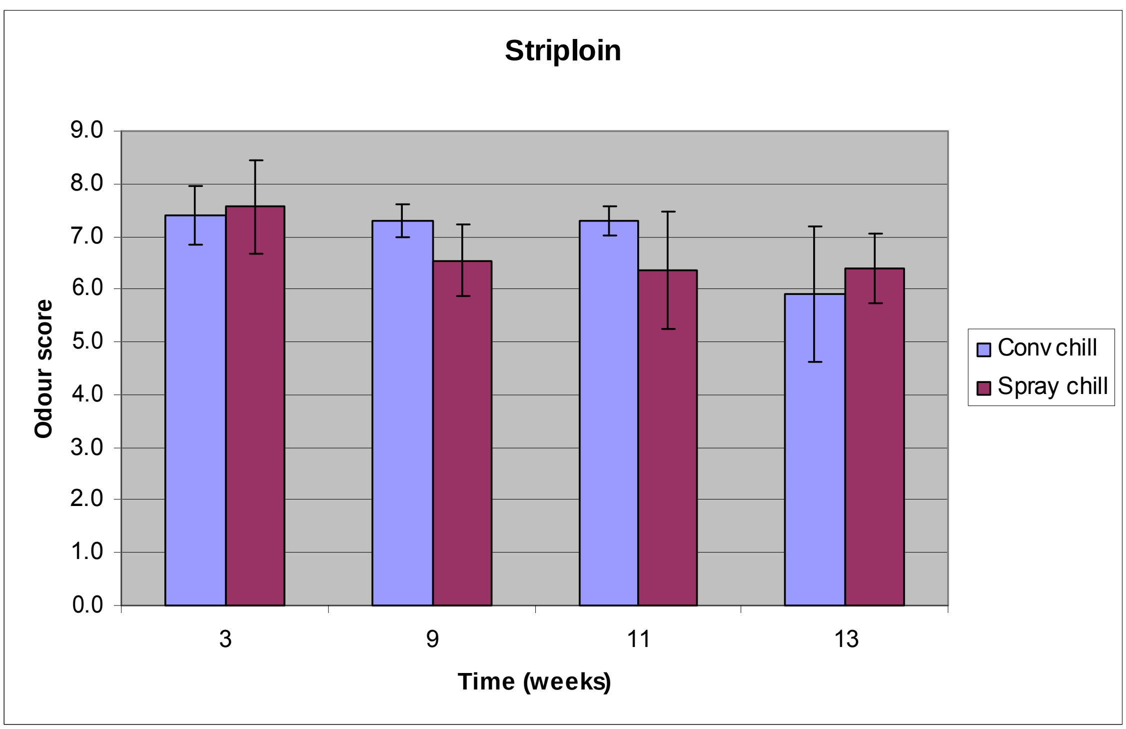


Figure 3.2: odour scores for striploin packs

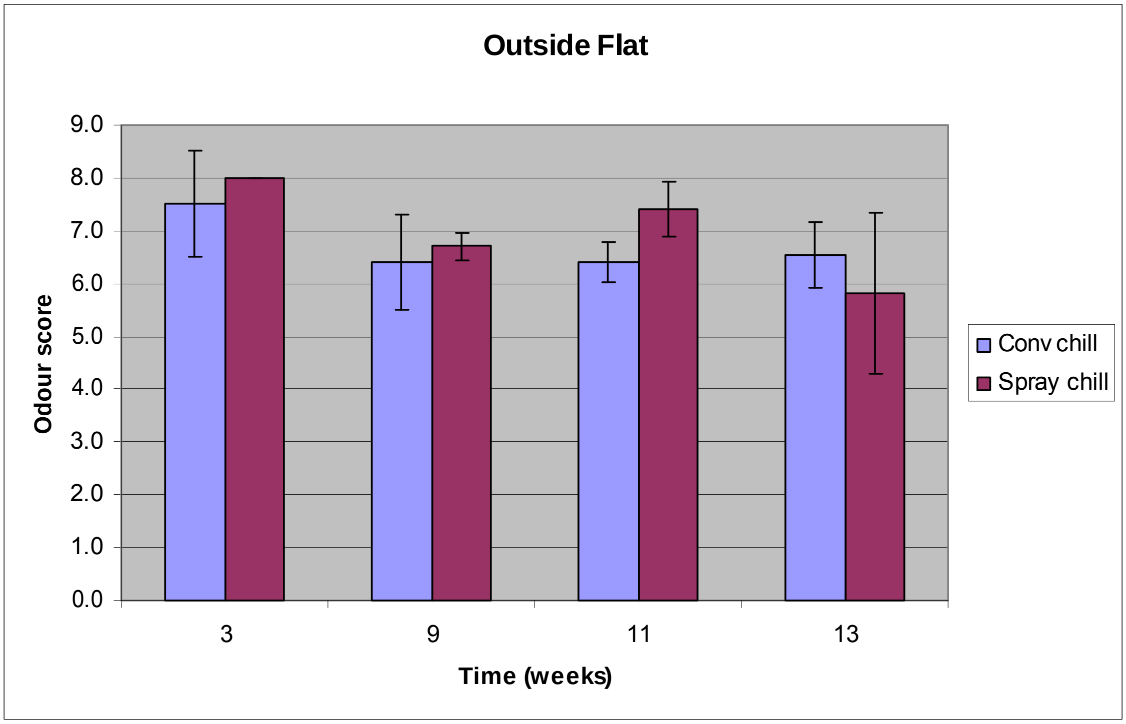


Figure 3.3: Odour scores for outside flat packs

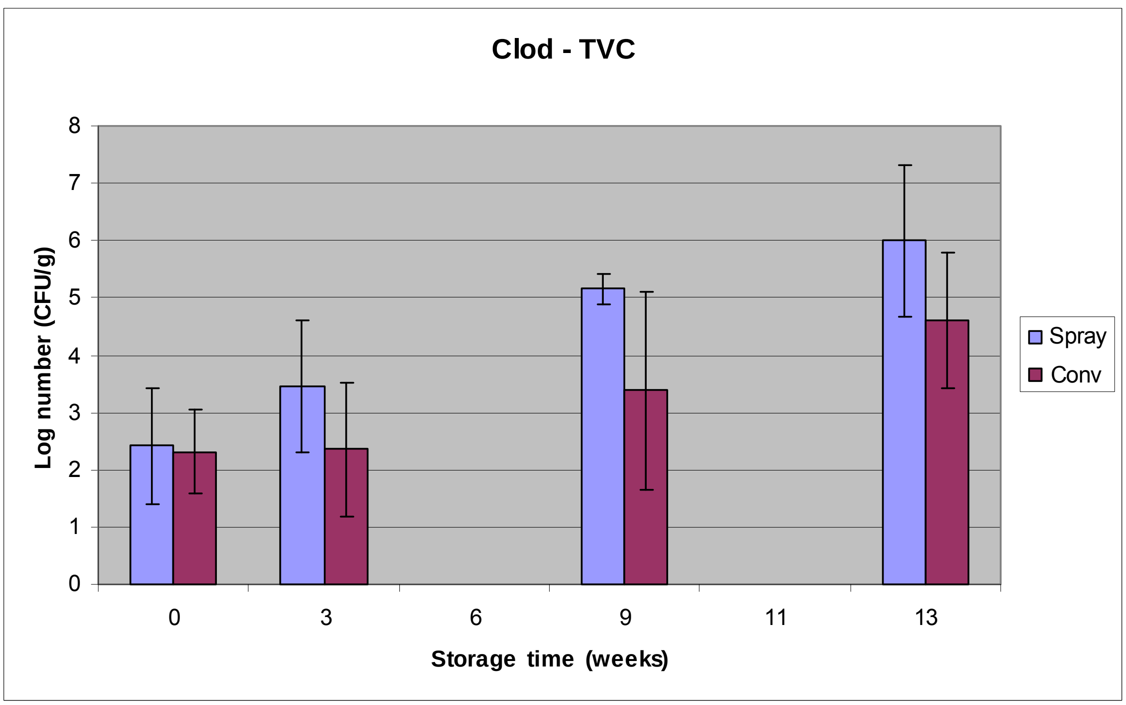


Figure 3.4: Total viable count for clod packs

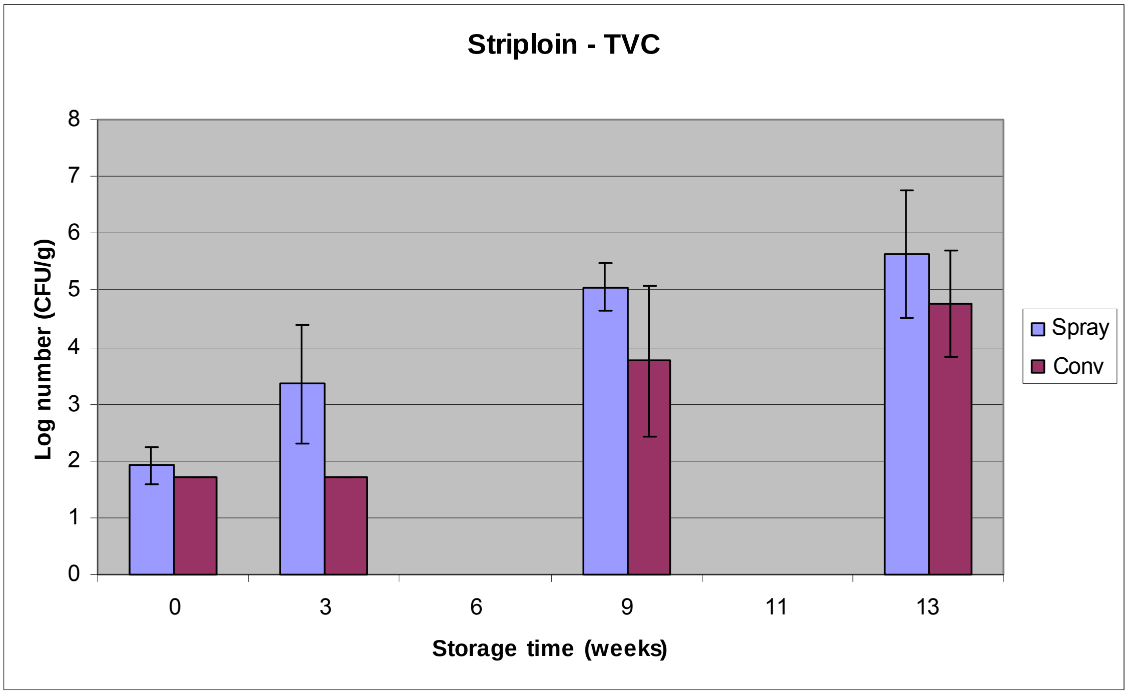


Figure 3.5: Total viable count for striploin packs

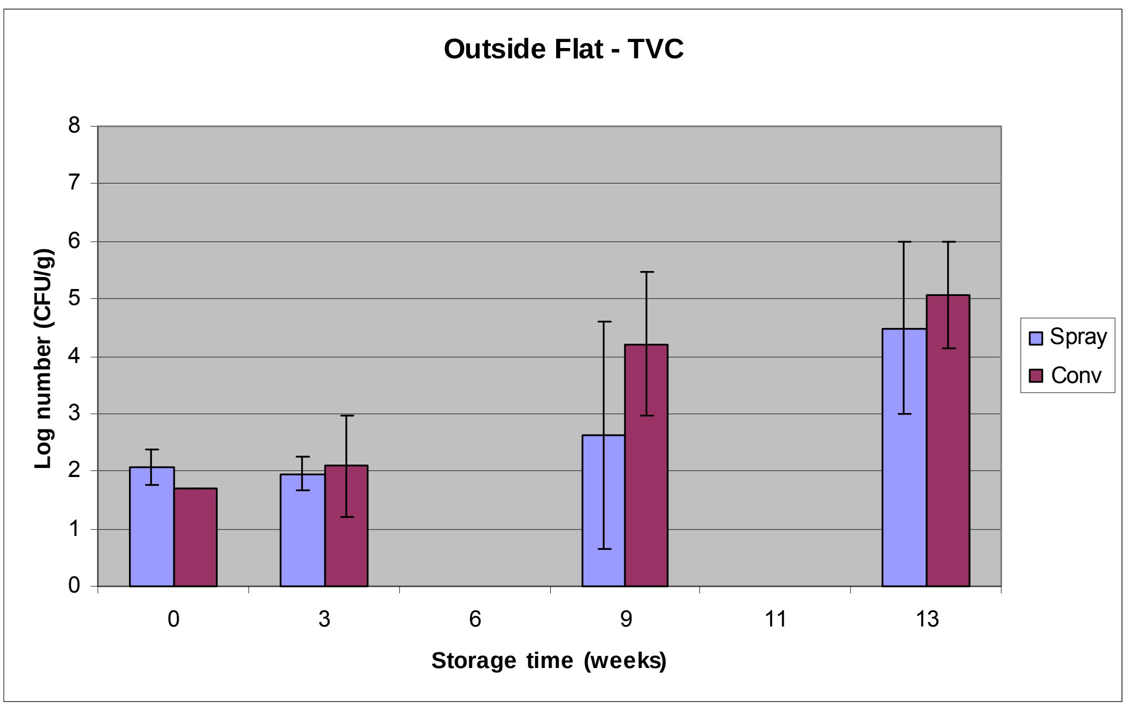


Figure 3.6: Total viable count for outside flat packs