final report

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Prepared by: Neil Brereton, Graham Treffone
JBS Australia
Dean Gutzke
Meat & Livestock Australia

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Locked Bag 991
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Commercial proving of spray chilling in Australian beef plants – Phase 2 (One beef plant evaluation)

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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. JBS Swift Australia commissioned and evaluated spray chilling at the Dinmore plant in order to investigate as processing combinations as possible.

A system was successfully installed to service one chiller and operational parameters were devised and tested.

The key outcomes were:

- Using a spray system that incorporates nozzles that delivers water flow rates between 19 and 48 litres per minute at 2 bar (200kpi). The water is delivered in a series of spray cycles for a specified time per cycle to reduce dehydration of the carcase during refrigeration eg 8 sprays for 24 seconds each / every 30 mins in the first 3.5 hours. The number of spray cycles per carcase is dependent on the expected duration of chilling, the chilling performance, the type of the carcases and the expected end target.

- Trials have been successfully conducted to introduce spray pattern variations, based on the type of carcases being chilled and the duration of the expected chilling. Depending on the length of refrigeration, carcases have been sprayed. As much as 3 spray cycles and as many as 16 spray cycles. Each spray pattern is delivered for approximately 24 secs. The refrigeration is switched off during spray cycles but do run between spray cycles for 24 – 30 mins. Depending on the chiller size water usage / cycle is approximately 400 litres.

- Water is now delivered via a heat exchanger to deliver spray water at 18'C. There has not been any noticeable change in any chilling, shrink or eating quality standard due to the reduction in spray water temperature.

- Comparative weighing of spray sides against the equivalent opposite sides (conventionally chilled) has again indicated significant reduction in weight loss. Recent trials in Nov 2009, on 4 categories of beef carcases have indicated that greater than 0.5% of HSCW. Reduction is

ending up as saleable meat. There were no noticeable increases in the trims and no increase in bone waste.

- There was no detriment to the shelf life, purge or eating quality characteristics of the product as detailed in the final report on P.PIP.0175 prepared & presented by Neil McPhail of CSIRO (Mar 09).

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

Executive Summary

Spray chilling is the intermittent spraying of carcases with water during the early stages of the cooling of hot sides. The commercial target set by Swift is to reduce the weight loss (shrink) of less than 0.5% hot standard carcase weight (HSCW) 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 a service chiller 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.

A key component of the design of the production trials is to enable a comparison of benefits associated with a) implementation of best practices in conventional chilling, compared with b) spray chilling (including cost of capital). In this respect, the outcomes of the first full production trial (at Swift's Dinmore site) include:

- Preliminary results from the first full production trial demonstrated yield benefits <0.6% on blast-chilled trade carcases which is within the expected range of 0.5% savings and demonstrates that the process has commercial viability.
- There are no adverse quality or safety issues shown through previous commercial proving trials.
- High fat coverage is a significant determinant factor; large grain-fed cattle yet be to evaluated
- Spray nozzle configuration, spray pattern and water cycle is critical to yield
- There are a number of R&D areas requiring work, specifically, high fat coverage, variable water sources, temperature of water and pre-chill treatment.
- There have been no adverse quality or safety issues reported since the application of spray chill at Dinmore, nor have there been any reported complaints from any customers.
- Trials have been successfully conducted to introduce a series of variations to spray chilling regimes based on the size & quality of the carcases and the expected chilling duration in each carcase chiller.

- Spray chilling produced reduction of shrink losses to within 0.5% of the original hot weight. Demonstrated across 4 separate commercial beef categories, spray chilling produced results indicating that the yield of saleable meat also increased by 0.5% whilst there was no noticeable gain in waste products. To achieve these benefits, depending on the chiller size the water consumption per spray cycle was less than 400 litres.
- There has been no detriment to the shelf life, purge & eating characteristics of an meat primal, sub-primal or trimming as a result of full scale spray chilling
- A conservative estimate of spray chill applied to Swift Dinmore beef processed would be $11 per head at 680,000 head killed in 2009 equates to approximately $7M pa to Swift.
- Swift project also included consultation with regulatory bodies with export approvals being obtained.

As anticipated, a number of issues could not be investigated within the production trial at Swifts Dinmore plant. The independent CSIRO expert has identified the following critical research areas still require evaluation:

- Impact of water quality sourced from alternatives to local supply
- Issues related to high temperature water
- Impact of heavy export carcases and variable chilling regimes and systems
- Impact of carcases with greater external surface fat coverage

In addition, while the current suite of projects relates specifically to beef, spray chilling in sheepmeat processing also requires further consideration. A project (anticipated budget of $225,688) related to production trialling of spray chilling in sheepmeat processing is also currently being considered by JBS Swift and MLA.

In summary, 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 and other processing plants similar to the Dinmore plant (with respect to carcase types & processing conditions) 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. Specifically, it is propose to undertake additional research at the Beef City plant for beef which has identified to be significantly different to warrant further investigation. It is also proposed to investigate lamb spray chilling, and Brooklyn has been identified as the site to undertake this preliminary work.

On conclusion of the R&D production trial, it is anticipated that MLA may need to undertake additional work to assist the remaining 85% of industry to adopt the technology over the next 5-10 years. A detailed adoption and commercialisation strategy will be prepared based on a successful R&D outcome from this pilot.

Contents

1 Background

Spray chilling is the intermittent spraying of carcases with water to minimise carcase weight losses (typically between 0.5 to 2% carcase shrinkage occurs during initial chilling). Spray chilling is commonly practised in North American meat processing however has had limited to no uptake in Australia. The main reasons for this are reported by scientists and processors to be:

- Perception that the shelf-life of vacuum-packaged meat is reduced
- Technical challenges associated with dripping condensation
- Concerns about loss of colour and presentation of product
- Unacceptable levels of drip
- Difficulty in obtaining regulatory approval
- Difficulty in controlling the amount of water added to the carcase
- The ability to consistently achieve a commercially viable level of yield improvement to warrant the investment.

It would appear that North American operators/regulators have higher tolerance levels in relation to the above issues. It is also noted that the application of spray chilling in US meat processing is commonly associated with hot beef carcases and is required because of the large evaporative losses experienced during 48 hour chilling cycles. Existing US spray chilling systems are not considered viable for application within Australia because of the vastly different meat processing methods used. This is evidenced by the fact that Australian processors that have sister companies in the US using spray chilling and yet they have not been able to successfully adopt the technology to their Australian processing conditions.

The benefits of improved yield between 0.5% and 2% are well documented from the US experience. While there is potential for some of the evaporative loss to be reduced if “best practice” chiller management principles are applied, it is considered that spray chilling may offer additional scope for improvement and greater flexibility within existing chilling designs. Detailed and specific cost-benefit analyses for spray chilling applications have yet to be undertaken within the Australian context. It is noted that MLA identified the significant potential benefits to the Australian industry of spray chilling several years ago but it has taken some time to identify suitable partners willing to undertake the high-risk research required.

A review of the literature and consultation with an independent expert advisor (CSIRO – Neil McPhail) identified the following critical technical issues need to be addressed if spray chilling is to be widely adopted by the Australian industry:

i) **Engineering -** while a spray water chilling and distribution system has been successfully developed for Dinmore (previous project), the distribution pipes and nozzles used at Dinmore require further development to adapt to vast differences in configuration of chillers across various plants in addition to trialling new pipe equipment.

ii) **Site specific issues -** spray chilling parameters are likely to need to be tailored for each chiller possibly resulting in higher water usage per head at some sites when compared with the original Dinmore trial.

iii) **Product mix –** a wide range of cattle types are processed in Australian plants that are likely to require different spraying types (e.g. Carcases from heavy grain-fed cattle are likely to require different spraying parameters to those from lean *Bos indicus* ox from Northern Australia, or dairy cows).

iv) Product quality – it must be confirmed that eating quality and quality specification requirements (across the various market demographics) are not negatively affected by spray chilling.

v) Shelf life – while preliminary assessment at Dinmore was conducted up to 13 weeks, there may be a higher expectation by customers of the storage life of product so this may need to be re-assessed for periods up to 16 weeks.

vi) Compliance – currently spray chilling is permitted in Australian plants but the procedure to be used by an export-registered abattoir must be approved in writing by AQIS. In the past, AQIS and state meat authorities (depending on the markets) may have had exception to spray chilling as sources of contamination and weights and measures issues. This needs to be addressed via rigorous scientific protocols and adequate consultation mechanisms. In addition, any specific consumer issues and FSANZ requirements also require clarification.

vii) Water quality & water usage – changes to legislation in water management in various states (e.g. fluoride in Qld, recycled water policies, quarantined assessable to table water, water restrictions) and variances in natural purity and temperature of water supply are significant variances in different geographic locations. It will be important to determine whether spray chilling imposes any additional impost in terms of water usage and/or disposal of waste water.

viii) Technical design of chillers – the factor which is considered to have the greatest influence on weight loss is evaporator capacity and geometry of the evaporator. Continuous air circulated systems can typically produce 2.1 to 2.4% carcase weight losses. More recent designs of hot beef carcase chillers have demonstrated that with appropriate selection of evaporators and control systems, 1% or less weight loss is achievable.

There is some literature already published, albeit most of which has been on studies conducted in the US and Canada. For reference below, here are some of these at hand:

1) "Effect of Spray Chilling on quality of Beef from leaner and fatter carcases" CL Hippe, RA Field, B Ray, WC Russell – University of Wyoming, Laramie 82071 – 1990

2) "Shrouding, Spray Chilling and Vacuum-packaged Aging effects on processing and eating quality attributes of Beef " - LaurenMLee, ZeniaJ Hawrysh,Lester E Jeremiah, Robert T Hardin – Journal of Food Science Vol 55 No 5 1990,

3) "Quality and Bacteriological Consequences of Beef Carcass Spray-chilling: Effects of Spray Duration and Boxed Beef Storage Temperature" GG Greer, SDM Jones - Agriculture and Agrifood Canada, Lacombe Research Centre, Lacombe, Alberta Canada 1996

4) "Microbiological verification of Spray Chilling in an Export Establishment" Ian Eustace, Neil McPhail, Bill Spooncer- Australia Meat Technology 1998

Some discussion has been had with engineers running Swift USA plants regarding the finer details of their installations, their experiences and findings regarding water nozzle selection, delivery pressures and temperatures. It was noted from these discussions that delivery of the water below 18° Celsius seemed to have no benefit regarding improving the chill as the contact time with the body was so short. Many sites had started off with spray chilling programs of 2° Celsius but have now reverted to 18° Celsius. It was also noted from the discussions that the sprays are showers not mists, i.e. larger droplet sizes. The concern with mists is fallout from rails and trolleys on to the bodies through condensation.

It was determined that to demonstrate that spray chilling could be applicable to 90% or more of Australia's processors, a large-scale R&D project is warranted that addresses the risks identified above across a range of processing scenarios including :

- Breed
- Water source (quality and temperature)
- Cattle type (prime, veal, cow & bull)
- Feed-type (grass, grain)
- Processing interventions (e.g. decontamination)
- Climate (specifically across the diversity of humidity on the eastern sea board)
- Market destination (domestic and export)

To assist in undertaking and evaluating the research, an independent expert from CSIRO has been engaged by MLA to act as a third party scientific advisor to determine appropriate research methodologies and to validate outcomes and impacts on product. In addition, it is proposed that as the research progresses, third-party cost-benefit experts will be contracted to undertake detailed evaluation studies in the context of both commercial benefit to Swift and also to the broader industry. While general regulatory approval has been granted by AQIS as part of the export licence, the research design also includes consultation and engagement with key regulators and customers, which is a requirement for each installation site.

The project proposed with Swift in 1 Beef Plant will provide significant data that will assist in identifying the clear value proposition for spray chilling across a range of potential applications. It is proposed that the research is designed to enable a comparison of benefits associated with a) implementation of best practices in conventional chilling, compared with b) spray chilling (including cost of capital).

Collaborative research and development between JBS Swift Australia and Meat & Livestock Australia was undertaken 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. The specific aims of the project were to :

- Evaluate the benefit of spray chilling at 1 beef processing plants taking into account various characteristics including animal variances, chiller design and water characteristics
- 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.

At the conclusion of this project, Swift and MLA will review the project outcomes to determine what additional factors need to be qualified in order to operate spray chilling throughout all processing variances in Australia. Additional spray chilling studies may be necessary in other plants.

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. (Refer to previous project p.pip.0175 - Verification of the effect of spray chilling in preventing chiller yield loss).

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 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 trial spray chilling plant and a chiller nozzle layout drawing are presented in 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 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 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 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 (Appendix I) and the trial spray chilling system Operational Functional Description in 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.

The results from previous trials at Dinmore (refer to p.pip.0175) 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.

From this earlier work, 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.

The data set from earlier spray chilling trials at Dinmore (refert o p.pip.0175) may allow the opportunity to analyse the effect of some of these factors on chiller shrink at a later date if necessary.

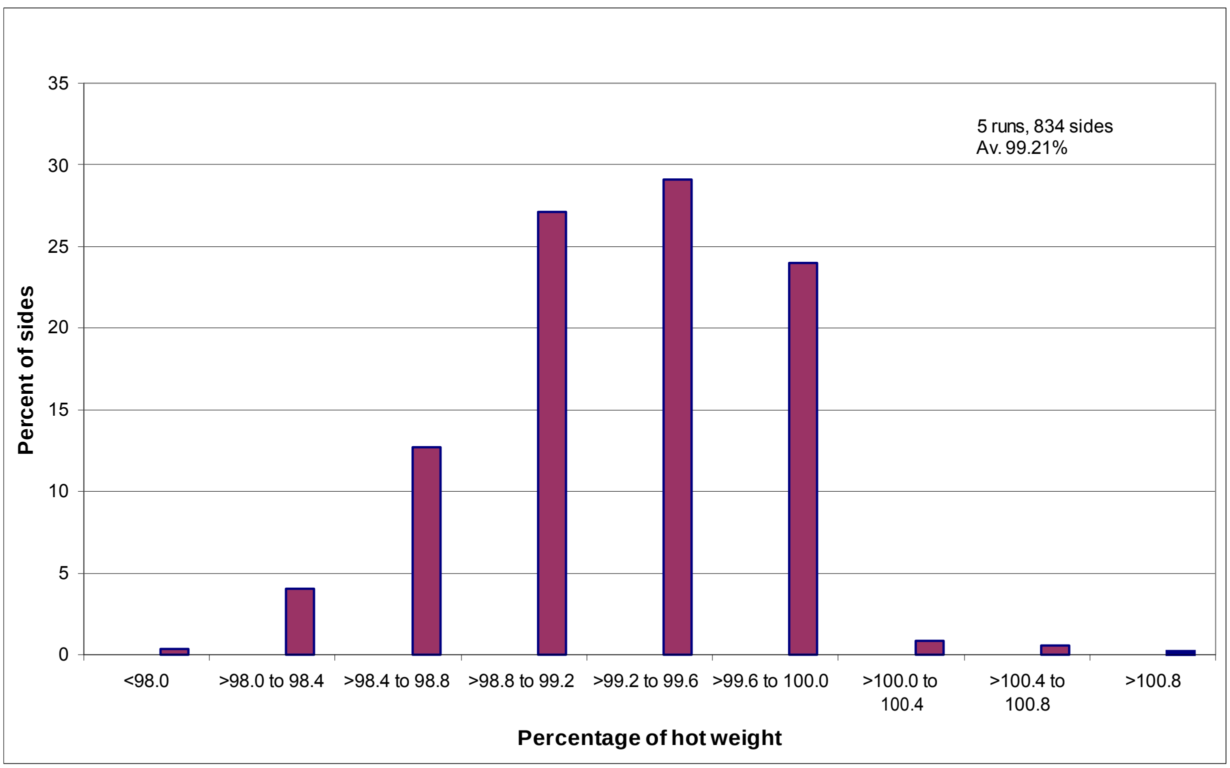

Figure 1: Weight loss distribution – 8 x 24 s sprays

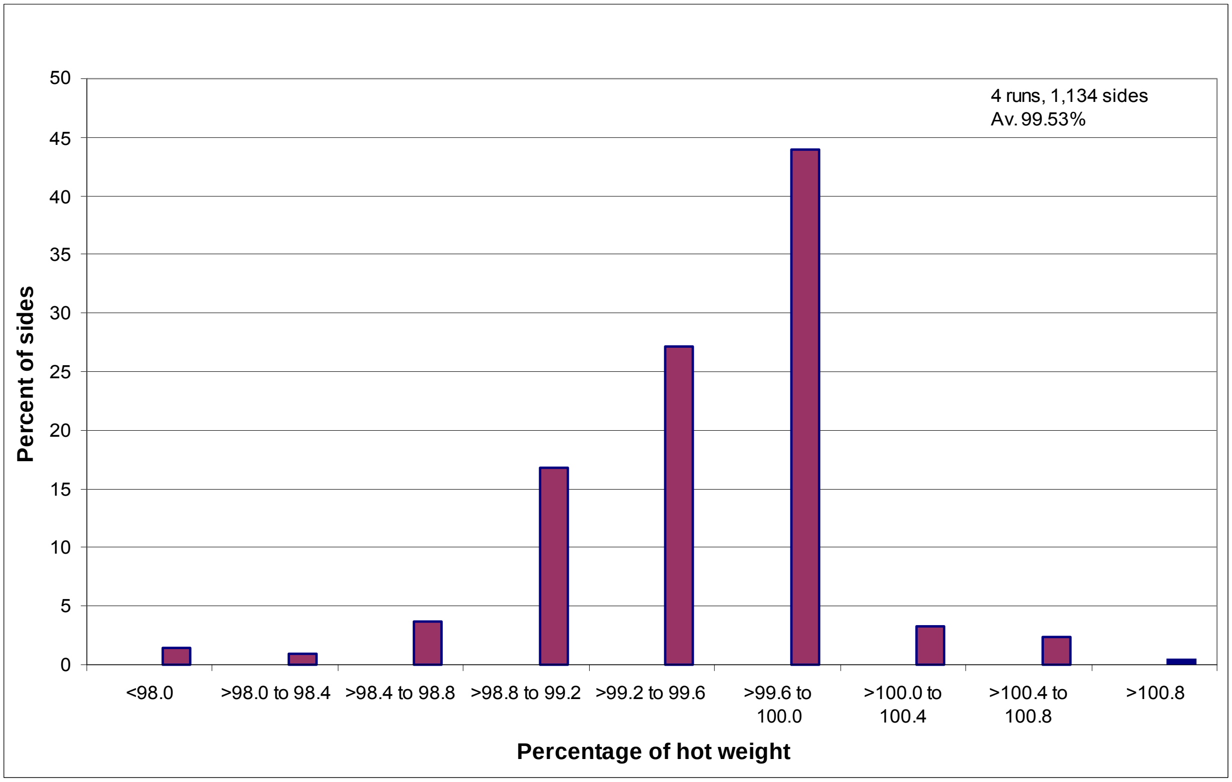

Figure 2: Weight loss distribution – 10 x 24 s sprays

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.

From earlier Djnmore spray chilling trials (refer to p.pip.0175) 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.

The current spray chilling trials have been completed and the system optimised for multiple carcase types. The key findings were:

- Using a spray system that incorporates nozzles that delivers water flow rates between 19 and 48 litres per minute at 2 bar (200kpi). The water is delivered in a series of spray cycles for a specified time per cycle to reduce dehydration of the carcase during refrigeration eg 8 sprays for 24 seconds each / every 30 mins in the first 3.5 hours. The number of spray cycles per carcase is dependent on the expected duration of chilling, the chilling performance, the type of the carcases and the expected end target.
- Trials have been successfully conducted to introduce spray pattern variations, based on the type of carcases being chilled and the duration of the expected chilling. Depending on the length of refrigeration, carcases have been sprayed …. As far as 3 spray cycles and as many as 16 spray cycles. Each spray pattern is delivered for approximately 24 secs. The refrigeration is switched off during spray cycles but do run between spray cycles for 24 – 30 mins. Depending on the chiller size water usage / cycle is approximately 400 litres.
- Water is now delivered via a heat exchanger to deliver spray water at 18'C. There has not been any noticeable change in any chilling, shrink or eating quality standard due to the reduction in spray water temperature.
- Comparative weighing of spray sides against the equivalent opposite sides (conventionally chilled) has again indicated significant reduction in weight loss. Recent trials in Nov 2009, on 4 categories of beef carcases have indicated that greater than 0.5% of HSCW. Reduction is ending up as saleable meat. There were no noticeable increases in the trims and no increase in bone waste.
- There was no detriment to the shelf life, purge or eating quality characteristics of the product as detailed in the final report on p.pip.0175 prepared and presented by Neil McPhail of CSIRO dated March 2009.

4.3 Evaluation of effect of spray water temperature on microbiology

Detailed microbiological findings of the earlier Dinmore spray chilling trials are presented in the final report on P.PIP.0175 prepared and presented by Neil McPhail of CSIRO dated March 2009. In this report, 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.

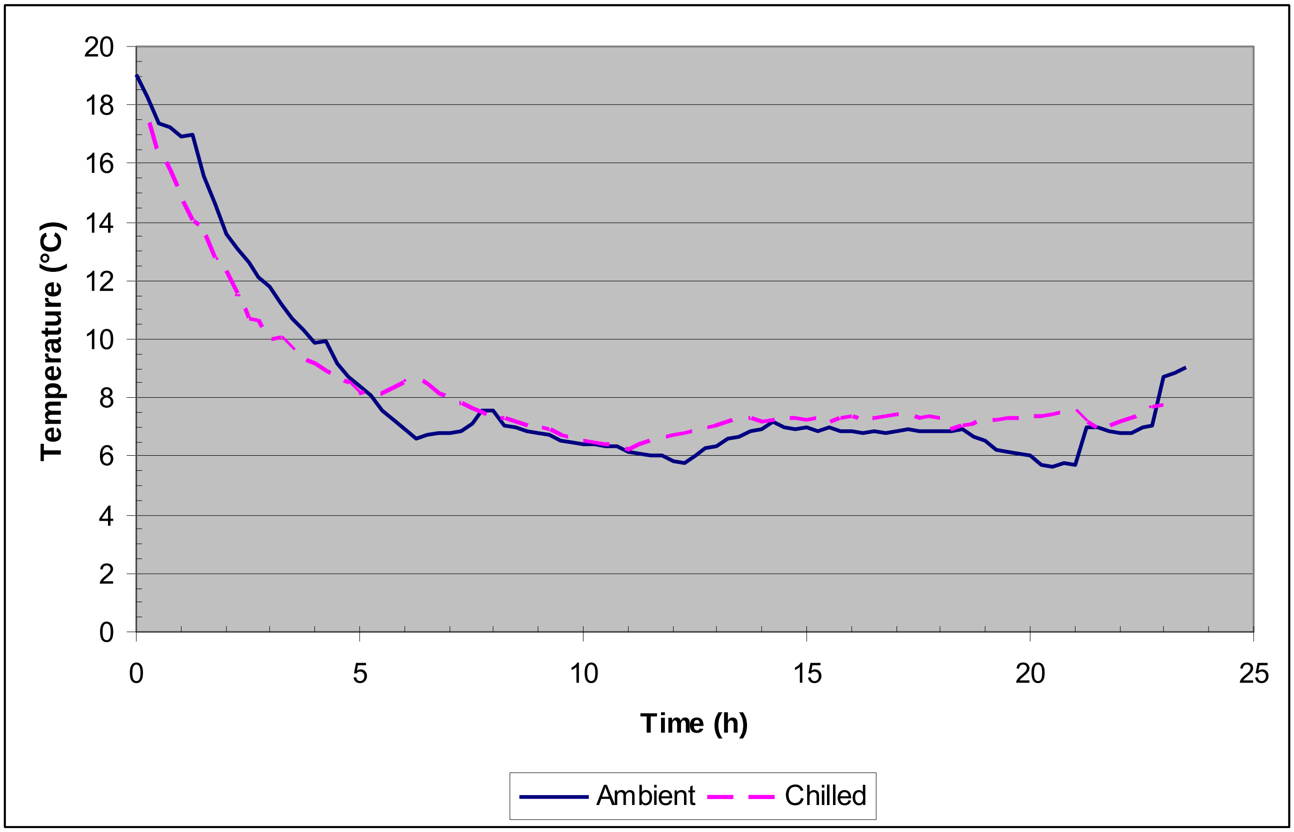

Figure 3: Average cooling rate of the surface of beef carcases in Chiller 5 for 22°C and 2°C spray water

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

Detailed boning room & saleable meat yields are shown in Appendix 3. These results are shown across a wide range of commercial cuts. The key findings are:

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.

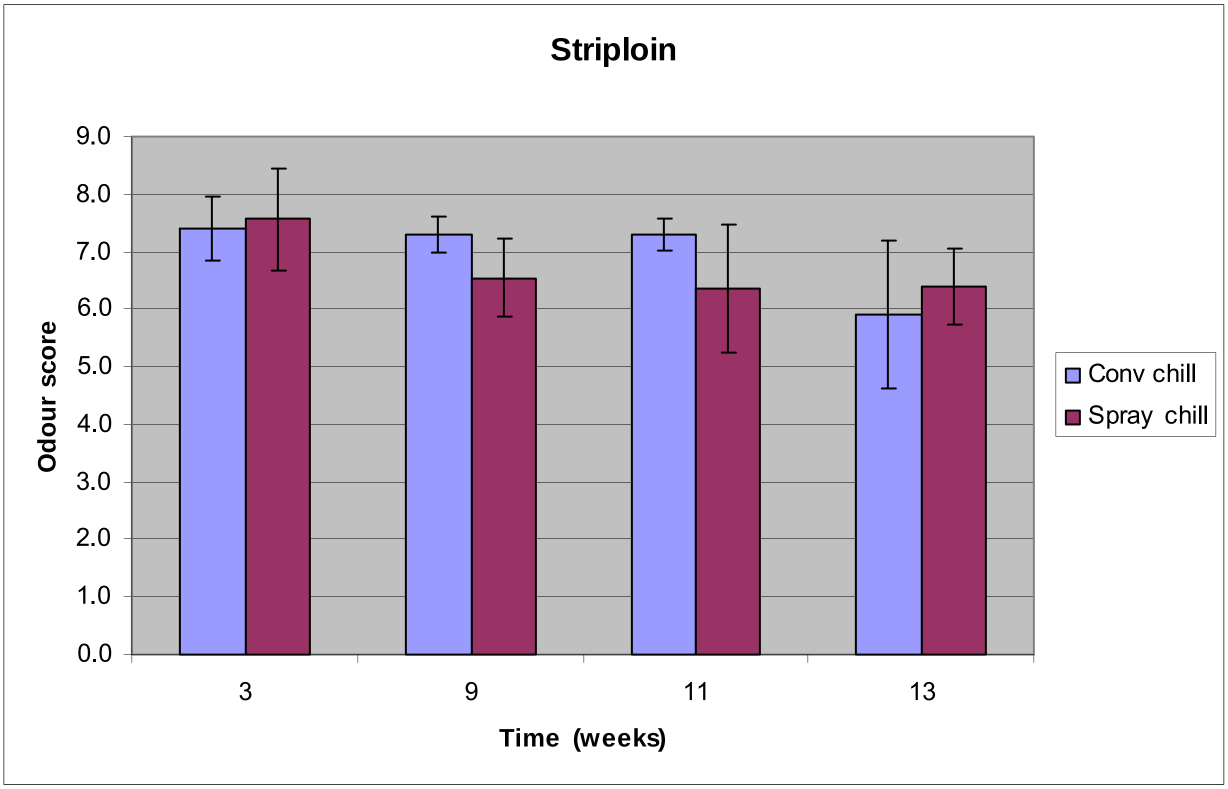

Figure 4: Odour scores for striploins (8: no odour, 0 – strong off odour, error bars show standard deviations)

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.

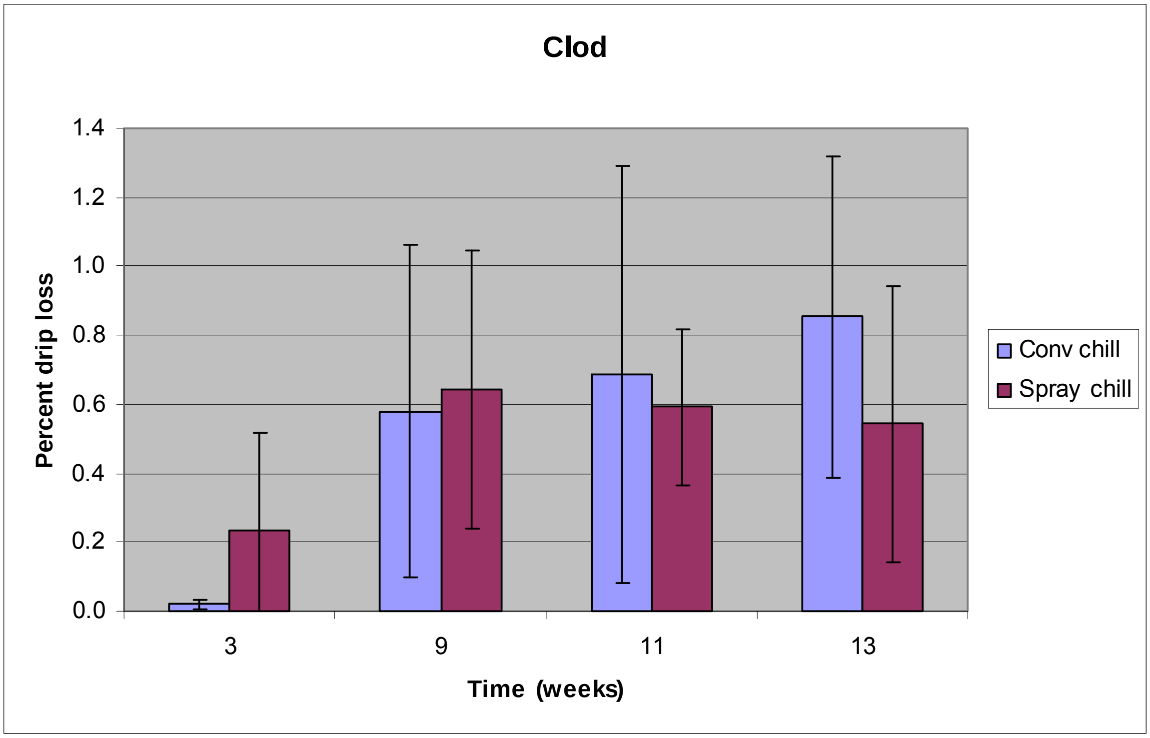

Figure 5: Drip in vacuum-packed clods (error bars show standard deviations)

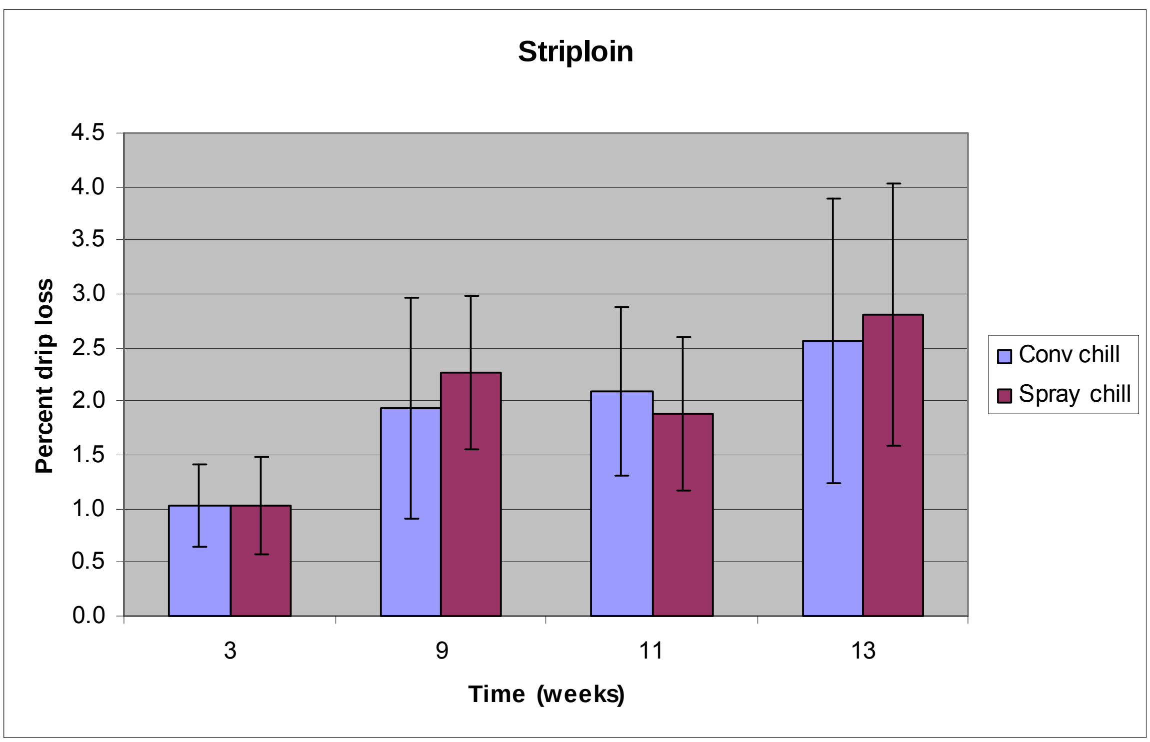

Figure 6: Drip in vacuum-packed striploins (error bars show standard deviations)

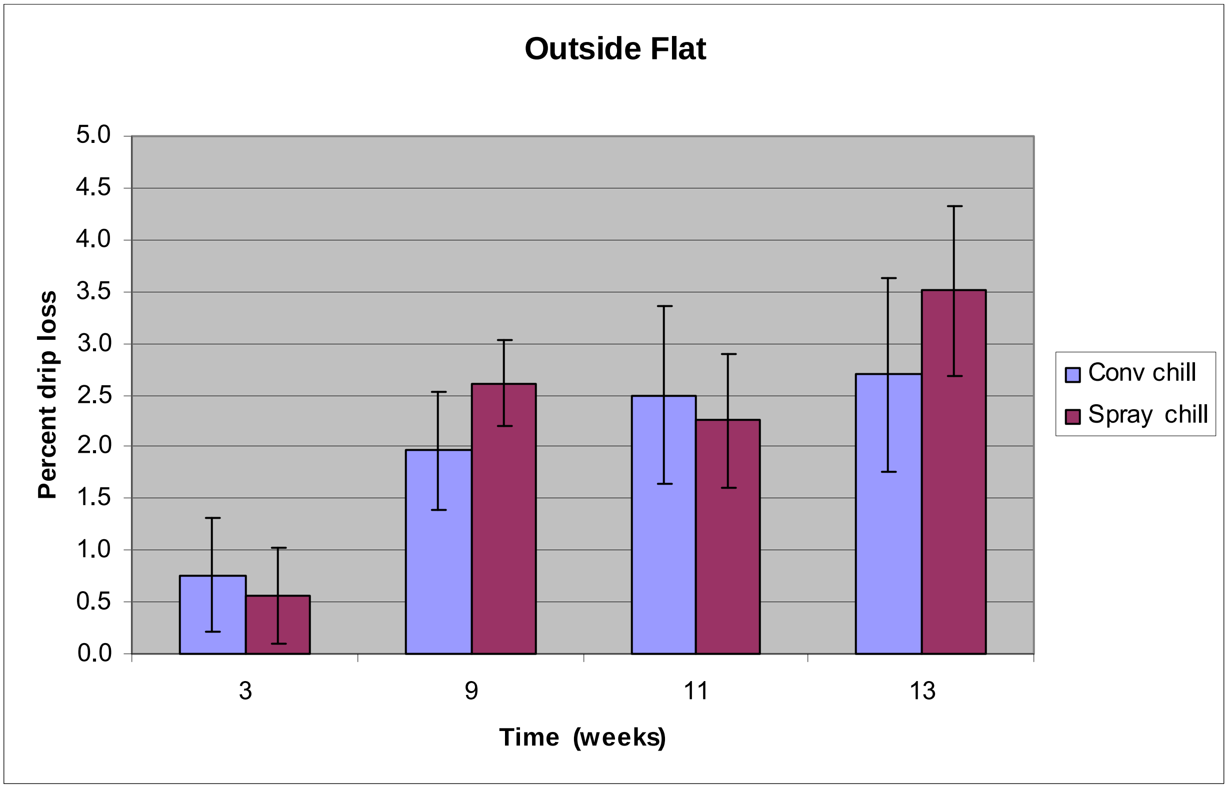

Figure 7: Drip in vacuum-packed outside flats (error bars show standard deviations)

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.

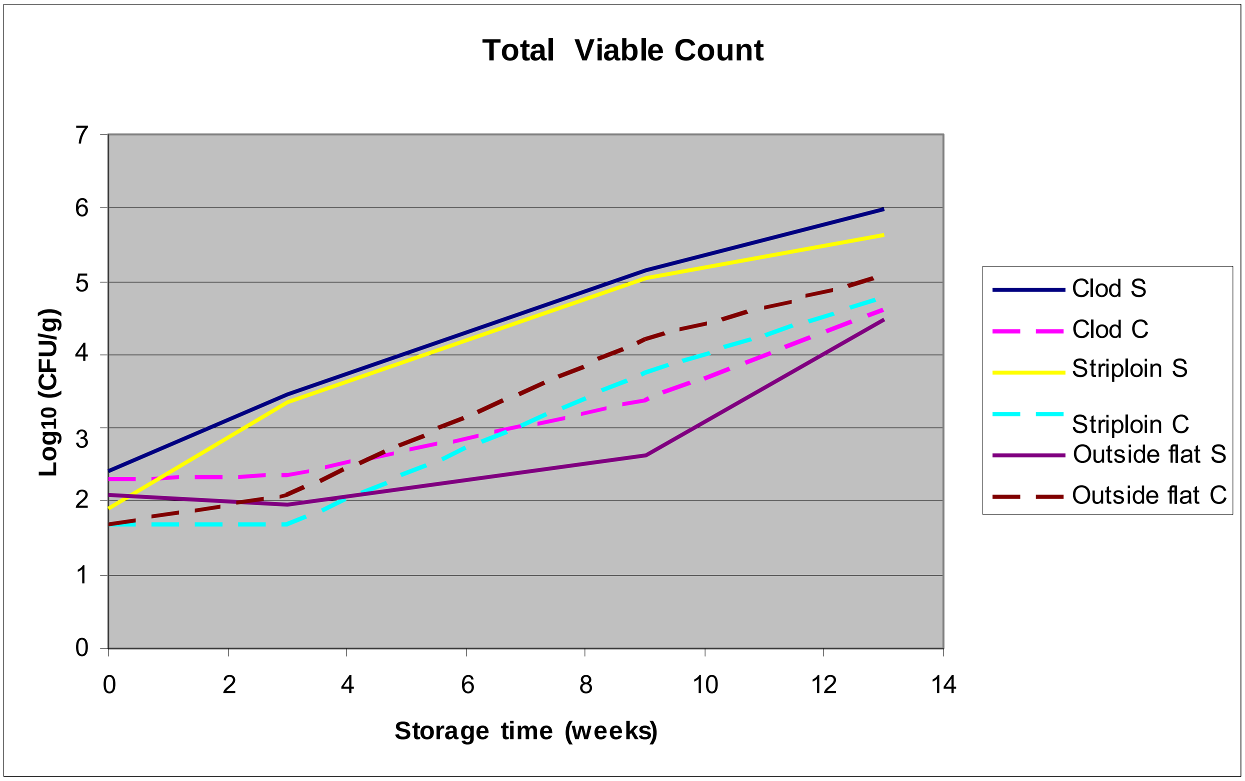

Figure 8: The growth of TVC during storage (S: spray, C: conventional)

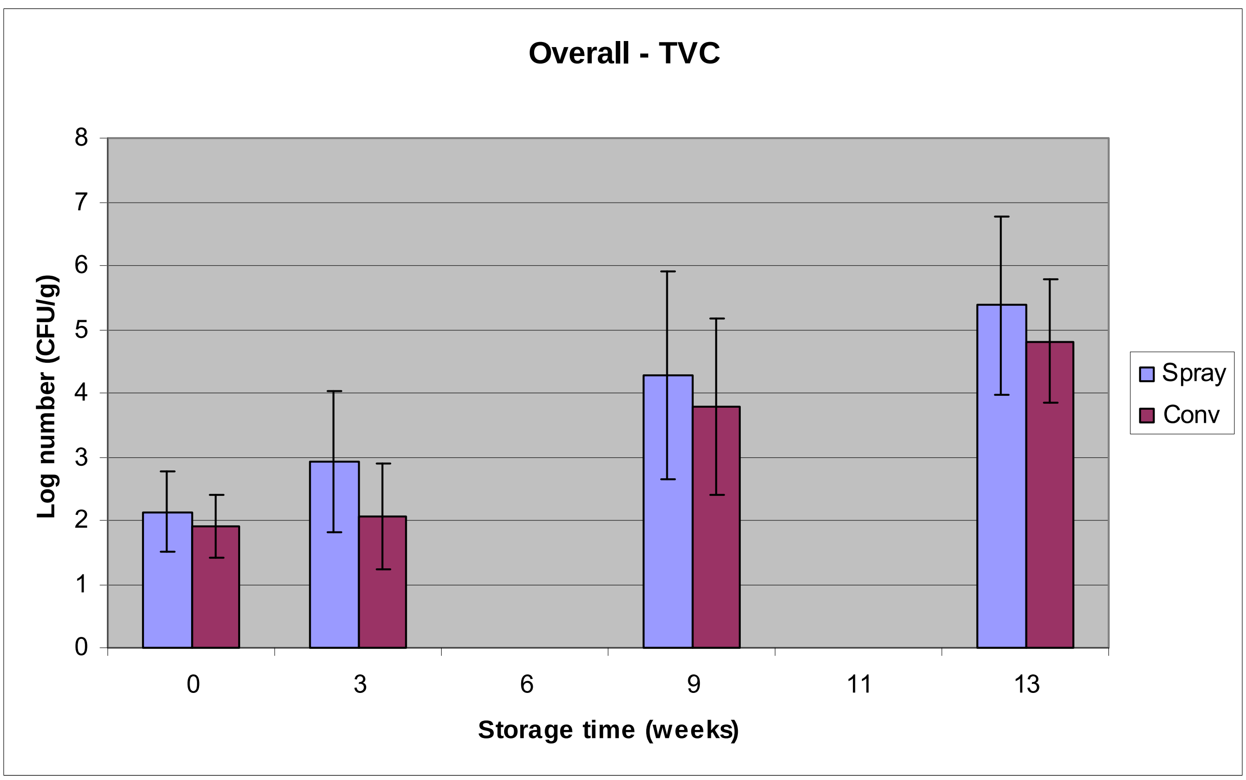

Figure 9: Mean TVC for clod, striploin and outside flat (error bars show standard deviation)

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.

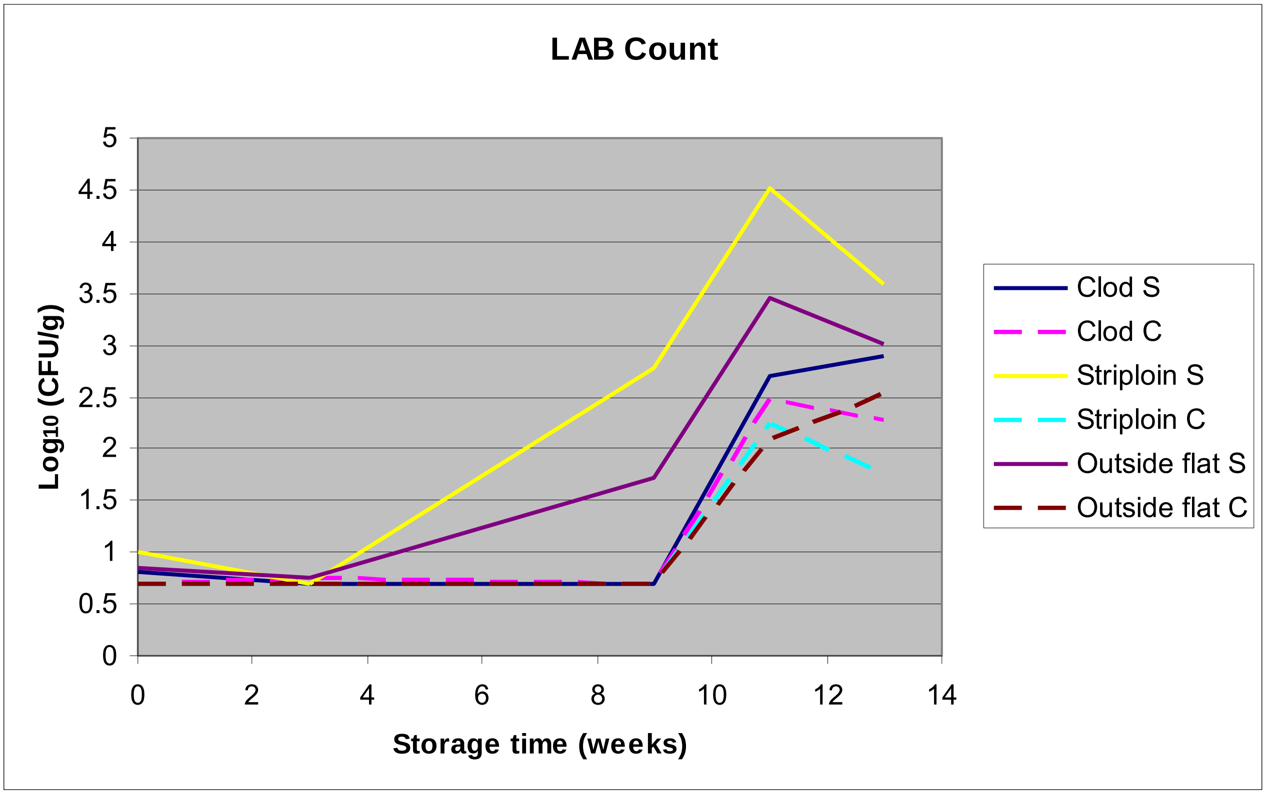

Figure 10: The growth of lactobacillus during storage (S: spray, C: conventional)

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.

4.6 Potential impacts & benefit of spray chilling

Swift benefits were estimated these benefits to be around $11 per head, which on last year's Dinmore kill (of approximately 688,000 hd) represented approximately AUD$7M value enhancement for Swift. The following assumptions have been applied to the cost benefit analysis :

- Swift confirmed their processing targets were 0.2%- 0.25% within H.S.C.W. The challenge was different processing conditions and carcase types, particular external fat covered warranted a dedicated resource to ensure optimal settings and programs were used. It was discussed that a lower level of shrink would be a risky proposition.

- It was confirmed that on average consistently achieving within 0.5% of the H.S.C.W using spray chilling (ie reduced shrinkage between 0.8 to 1.5%), the benefits to Swift's bottom line were significant. Other not commonly recognised benefits of spray chilling identified by Swift were recognised as being i) reduction of dark scabs which is trimmed & down-graded & ii) easier to bone (than conventionally chilled product). These benefits have not been factored in current cost analyses. MLA's proposition to have n independent involved in cost analyses was endorsed by Swift and important to Swift realising the true benefits of spray chilling. MLA proposed involving an independent of all future proposed R&D with spray chilling.

It should be noted (personal communication with key Swift operations staff) that other not commonly recognised benefits of spray chilling identified by Swift were recognised as being i) reduction of dark scabs which is trimmed & down-graded & ii) easier to bone (than conventionally chilled product). These benefits have not been factored in current cost analyses. MLA's proposition to have n independent involved in cost analyses was endorsed by Swift and important to Swift realising the true benefits of spray chilling. MLA proposed involving an independent of all future proposed R&D with spray chilling.

MLA advised that counting benefit was important to the project, and Swift supported the proposal to include a consultant in future proposed beef and lamb processing R&D to ensure general documentation and guidelines are developed. Swift was in principle supportive to circulate general spray chilling specifications and messages to the wider industry (subject to Swift & MLA approval).

4.7 Barriers to uptake of spray chilling, dedicated resourcing required

- In the light of commercial proving at Dinmore, Swift confirmed that roll out of spray chilling applications was planned as a priority to similar type plants (based on carcase types, processing parameters). Similar type Swift beef processes (to Dinmore plant) identified as Rockhampton, Longford & Brooklyn where spray chill had been rolled out and currently operable.
- MLA proposed that previous barriers to adoption of the technology may have been related to unknown risk factors related to processing conditions, reduced microbiological shelf-life and safety with no formal approval in place by regulatory authorities.
- Swift confirmed that general regulatory approval has been granted by AQIS as part of the export licence. The research design of the Dinmore trial included consultation and engagement with key regulators and customers. Swift advised that there had not been any adverse quality or safety issues reported since the application of spray chill at Dinmore, nor had there been any reported complaints from any customers.
- While all 4 spray chill Swift plants had regulatory approval, stringent measures are mandatory as part of the approval to ensure weight gains do not occur.
- Swift identified a critical regulatory issue was weight gain, and AQIS approval was granted on the basis that Swift had control measures in place to ensure pray chilling did not add weight (ie over and above H.S.C.W).
- Swift has dedicated and fully committed & trained personnel who co-ordinate spray chilling to ensure that each batch is compliant. This resource is also required to develop spray chilling protocols and specifications for each of the processing options that the plant experiences.

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

This project has shown that spray chilling is a viable means of increasing yield of saleable meat for Swift Australia. Increased yield will result in improved returns for the company, which should flow through to improved prices for the producer. 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. Swift benefits were estimated these benefits to be around $11 per head, which on last year's Dinmore kill (of approximately 688,000 hd) represented approximately AUD$7M value enhancement for Swift (Refer to Section 4.7).

The benefits of minimal carcase weight losses currently running at between 0.5% and 2% are well documented from the US experience. If these percentage improvements were applied to Australian production levels, the following table indicates a very significant commercial gain if the evaporative losses could be reduced (in terms of saleable meat yield).

Table 5: Cost to the Australian beef and veal supply chain from evaporative losses

Evaporative Loss %	Australia Beef production kgs/annum	Evaporative Loss kg/annum	Supply Chain Beef Value $/kg	Australian Lost Value $/annum
0.5	2200000000	11000000	$5.05	$55,550,000
1.3	2200000000	28600000	$5.05	$144,430,000
1.5	2200000000	33000000	$5.05	$166,650,000
2	2200000000	44000000	$5.05	$222,200,000

While there is potential for some of the evaporative loss to be reduced if "best practice" chiller management principles are applied, it is considered that spray chilling may offer additional scope for improvement and greater flexibility within existing chilling designs. Detailed and specific cost-benefit analyses for spray chilling applications have yet to be undertaken within the Australian context. It is noted that MLA identified the significant potential benefits to the Australian industry of spray chilling several years ago but previously has not been able to identify a suitable partner willing to undertake the high-risk research required.

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 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.

The outcomes of the first full production trial (at Swift's Dinmore site) include :

- Preliminary results from the first full production trial demonstrated yield benefits <0.6% on blast-chilled trade carcases which is within the expected range of 0.5% savings and demonstrates that the process has commercial viability.
- There have been no adverse quality or safety issues reported since the application of spray chill at Dinmore, nor have there been any reported complaints from any customers.
- There are no adverse quality or safety issues shown through previous commercial proving trials.
- High fat coverage is a significant determinant factor; large grain-fed cattle yet be to evaluated
- Spray nozzle configuration, spray pattern and water cycle is critical to yield
- There are a number of R&D areas requiring work, specifically, high fat coverage, variable water sources, temperature of water and pre-chill treatment.
- 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 have been successfully conducted to introduce a series of variations to spray chilling regimes based on the size & quality of the carcases and the expected chilling duration in each carcase chiller.
- Spray chilling produced reduction of shrink losses to within 0.5% of the original hot weight. Demonstrated across 4 separate commercial beef categories, spray chilling produced results indicating that the yield of saleable meat also increased by 0.5% whilst there was no noticeable

gain in waste products. To achieve these benefits, depending on the chiller size the water consumption per spray cycle was less than 400 litres.

- There has been no detriment to the shelf life, purge and eating characteristics of an meat primal, sub-primal or trimming as a result of full scale spray chilling
- Swift project also included consultation with regulatory bodies with export approvals being obtained.
- Using a spray system that incorporates nozzles that delivers water flow rates between 19 and 48 litres per minute at 2 bar (200kpi). The water is delivered in a series of spray cycles for a specified time per cycle to reduce dehydration of the carcase during refrigeration eg 8 sprays for 24 seconds each / every 30 mins in the first 3.5 hours. The number of spray cycles per carcase is dependent on the expected duration of chilling, the chilling performance, the type of the carcases and the expected end target.
- Trials have been successfully conducted to introduce spray pattern variations, based on the type of carcases being chilled and the duration of the expected chilling. Depending on the length of refrigeration, carcases have been sprayed …. As far as 3 spray cycles and as many as 16 spray cycles. Each spray pattern is delivered for approximately 24 secs. The refrigeration is switched off during spray cycles but do run between spray cycles for 24 – 30 mins. Depending on the chiller size water usage / cycle is approximately 400 litres.
- Water is now delivered via a heat exchanger to deliver spray water at 18'C. There has not been any noticeable change in any chilling, shrink or eating quality standard due to the reduction in spray water temperature.
- Comparative weighing of spray sides against the equivalent opposite sides (conventionally chilled) has again indicated significant reduction in weight loss. Recent trials in Nov 2009, on 4 categories of beef carcases have indicated that greater than 0.5% of HSCW. Reduction is ending up as saleable meat. There were no noticeable increases in the trims and no increase in bone waste.
- There was no detriment to the shelf life, purge or eating quality characteristics of the product as detailed in the final report on p.pip.0175 prepared and presented by Neil McPhail of CSIRO dated March 2009.

As anticipated, a number of issues could not be investigated within the production trial at Swifts Dinmore plant. The independent CSIRO expert has identified the following critical research areas still require evaluation:

- Impact of water quality sourced from alternatives to local supply
- Issues related to high temperature water
- Impact of heavy export carcases and variable chilling regimes and systems
- Impact of carcases with greater external surface fat coverage

In addition, while the current suite of projects relates specifically to beef, spray chilling in sheepmeat processing also requires further consideration. A project (anticipated budget of $225,688) related to production trialling of spray chilling in sheepmeat processing is also currently being considered by JBS Swift and MLA.

In summary, the following recommendations are made:

i) 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.

ii) Extend spray chilling to the remaining Dinmore chillers and other processing plants similar to the Dinmore plant (with respect to carcase types & processing conditions) so that the benefits can be fully realised.

iii) 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. Specifically, it is propose to undertake additional research at the Beef City plant for beef which has identified to be significantly different to warrant further investigation. It is also proposed to investigate lamb spray chilling, and Brooklyn has been identified as the site to undertake this preliminary work.

On conclusion of the R&D production trial, it is anticipated that MLA may need to undertake additional work to assist the remaining 85% of industry to adopt the technology over the next 5-10 years. It is anticipated that this will include open days at Swift and various video and reporting outcomes. A detailed adoption and commercialisation strategy will be prepared based on a successful R&D outcome from this pilot.

8 Acknowledgements

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

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Shaun Johnston
Steve Smith
Tom Shillito
Kalyan Pandit

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Note key spray chilling literature sources;

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"Shrouding, Spray Chilling and Vacuum-packaged Aging effects on processing and eating quality attributes of Beef " - LaurenMLee, ZeniaJ Hawrysh,Lester E Jeremiah, Robert T Hardin – Journal of Food Science Vol 55 No 5 1990

"Quality and Bacteriological Consequences of Beef Carcass Spray-chilling: Effects of Spray Duration and Boxed Beef Storage Temperature" GG Greer, SDM Jones - Agriculture and Agrifood Canada, Lacombe Research Centre, Lacombe, Alberta Canada 1996

"Microbiological verification of Spray Chilling in an Export Establishment" Ian Eustace, Neil McPhail, Bill Spooncer- Australia Meat Technology 1998

10 Appendices

10.1 Appendix 1 – Spray chilling equipment & specifications

Introduction

The purpose of this report is to report on the technical aspects of the construction of the Spray Chilling setup for the commercial rollout of Spray Chilling to all production in a large Processing Plant.

In the preliminary evaluation of Spray Chilling conducted at the plant using temporary setups (– refer PIP 0175 Verification of the effect of spray chilling in preventing chiller yield loss – Neil McPhail Food Science Australia published March 2009) 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.

This PIP 0228 was to take these preliminary findings and establish Spray Chilling at a commercial scale in a large processing plant.

Technical Description of System and its Operation

In the first trials it was established that ordinary PVC piping was susceptible to cracking over time due to the water in the pipes and nozzles fluctuating in temperature and under certain conditions reaching freezing point. In point of fact in some cases individual spray nozzles froze and were unable to pass water on the next cycle. At this stage the trials were leaving the headers charged full of water between spray cycles in an effort to conserve water. However during the design team's Hazard and Operability study, it was identified that leaving the water in headers especially for plants on a 5 day week could mean the water could go stagnant and chlorine levels could drop. Also the freezing issue and the need to eliminate drip after spray chilling cycles were completed led to a change in programming such that air blowing of the pipework headers and nozzles between chiller cycles was implemented as a precaution.

Chilled water services

The chilled water service originates from a 500 litre stainless steel water tank. From the tank the water service is pumped by dual VSD pumps through a food grade Glycol to water heat exchanger (indirect cooling system adopted due to the potential food safety risk on a ruptured heat exchanger plate gasket) and then up into a ring main piping system above the chillers.

A George Fisher PPH (poly propelene) pipe material was selected to give long term reliability of performance in fluctuating water temperature conditions and being food safe. A 90mm OD main runs across all chillers with a 32mm OD return. In the ceiling space above each chiller individual manual isolation valves, pressure reduction valves, Siemens Magflow water meters, and individual spray zone solenoid valves together with air blow solenoid valves are set up. All the solenoid vales are an integral part of the spray system and are linked back to the main chiller system PLC

Once the chilled water solenoid is activated by the chilled water system, chilled water controlled to a maximum of 18 deg Celsius is fed to the spray ranges in a chiller bay to spray the carcases. After a predetermined spray duration the solenoid valve automatically closes. A wait period is then programmed where the refrigeration system in the carcase chiller is reactivated and after a predetermined duration, the spray is repeated for that chiller. During the spray, the fans to the chiller refrigeration are turned off to prevent the spray mist from circulating through the refrigeration coils and also across the over head structural steel. This is to prevent fallout from the overhead rails and stop the refrigeration coils from icing up. After a number of repetitions the spray system is turned off, the system headers within the chiller are air blown to clear water from lines (part of the final spray cycle to optimise water consumption) and the chiller cycle is allowed to "dry out and complete".

Colourbond safe trays were installed under each valve set in the ceiling space such that any leak from valve flanges or fittings would be prevented from damaging the ceilings. This also aids when servicing the valves to direct water to drain. Each safe tray was piped to floor down the walls inside the chiller passages in standard PVC piping

Spray Nozzles

A number of iterations of spray nozzles were experimented with. The final selection of nozzle proved successful and had an integrated diaphragm check valve built into the nozzle spring loaded to a rated pressure. Thus even when the header pipes were air blown, as the headers will never 100% drain, these check valves prevent any remaining water in the header from draining through the nozzles. This was discovered as being important, as initial trials showed bodies that were under dripping nozzles exceeded the programmed yield loss prevention target and in some cases gained weight leading to bodies having to be isolated and further chill/evaporation/weight loss time being required.

Spray Chilling Plant Control system functionality

This section details the functionality of the newly installed Spray Chilling Plants' Control System. The Spray Chilling System can be initiated, controlled & monitored via either the existing Hot Beef Passage HMI, the Chiller HMI or from any SCADA station. The functionality & screens on the HMI & SCADA are for the most part identical, however the SCADA system does have some additional screens & features which are used by management in setting up & monitoring the performance of the system; i.e. Spray Pattern Parameters & System Water Usage Figures. Both the PLC & SCADA systems are directly involved in the control of the Spray Chilling Plant. The PLC controls and directly interfaces with the field devices (i.e. motors, valves, flow switches etc), while the SCADA system directly interfaces with the PLC and acts as an interface between the PLC and the operator.

SYSTEM SCREENS & FUNCTIONALITY
CHILLER SPRAY PLANT
Figure A1.1: Chiller Spray Plant Screen

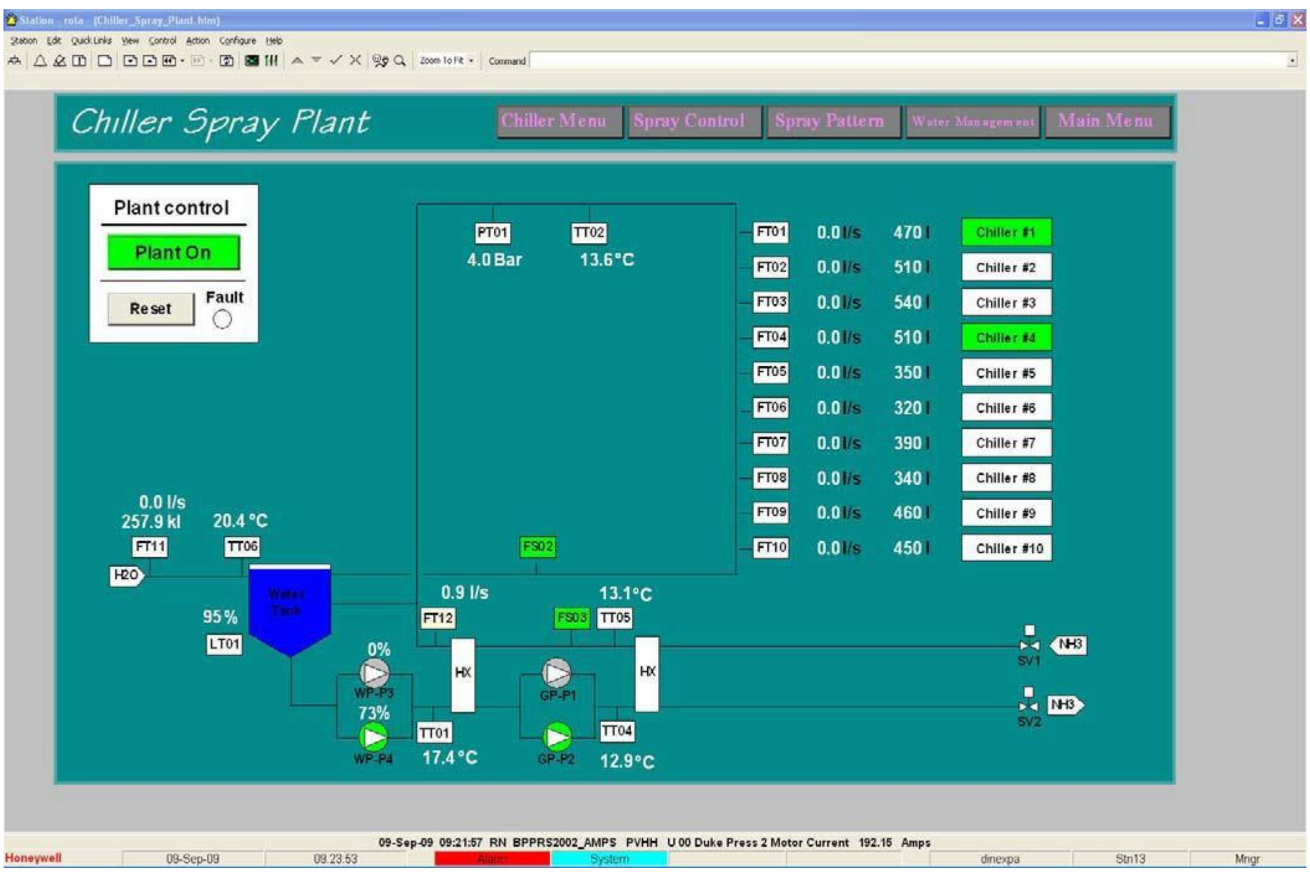

Figure A1.1 shows the main Chiller Spray Plant Screen. This is the screen which details the general layout and the current operational status & parameters of the Chiller Spray Plant. The only operator/management interface on this screen is the "Plant On/Off" Tab which turns the Spray Plant either **ON** or **OFF**. When the Chiller Spray Plant is turned **ON**, the "active" duty P-Glycol & Water pump will start and P-Glycol & Water will begin to circulate in their respective piping circuits. After an internal time delay of **30** seconds, to allow for the system to stabilise, the program will then “check” to see if flow has been established and is stable within the P-Glycol & Water circuits by ensuring that FS03 & FS02 (respectively) are “made”. If at this time, or any other time after another internal time delay of **15** seconds, either of these is not “made”, the Spray Plant will alarm & turn off. The status of these two (2) flow switches is indicated on the Chiller Spray Plant screen as either Green if “made” or Red if not “made”.

The operating philosophy of the respective Glycol & Water Pumps is for one (1) of each to be running at all times while the Chiller Spray Plant is **ON** while the other remains as a full standby. Change-over between the duty and standby pumps on both circuits occurs automatically in the event of a failure/fault with the duty pump, on an internal run-time clock (currently set to change over the respective duty pump weekly) and if the duty pump is turned off in the board or at its field isolator. When a pump is running it displays as Green, if faulted as Red else Grey. The two (2) water pumps are fitted with VSD’s which control the Chiller Spray Plant’s delivery pressure at a internally pre-set supply pressure (currently **4.0** bar) as measured & displayed by pressure transmitter PT01. The speed of the pump, as a percentage of its full capacity speed of **50**Hz, is also displayed on this screen.

There are a number of temperature transmitters installed in the system which will measure and display the temperatures at various “key” points within the P-Glycol, Spray Water & Make-up Water circuits. The only one of these which is used in any control loop is TT02 , which at internally pre-set measured Spray Water temperatures (currently **17.5**0C & **16.0**0C), will energise (open) & de-energise (close) respectively both NH3 solenoid valves SV1 & SV2 indicated on the Chiller Spray Plant screen.

In addition, there are also a number of flow transmitters installed in the system which will measure and display the current fluid flow rates and the accumulated to-date fluid flow rates at various “key” points within the PGlycol, Spray Water & Make-up Water circuits . The accumulated to-date fluid flow rates are automatically reset to zero at the end of each spray batch in each Chiller (FT01 to FT10) and at **06:00**am each morning for the Make-up Water flow transmitter (FT11).

Furthermore, there is a single level transmitter, LT01, installed on the Spray Water Buffer Tank, which measures and displays the tanks’ current water level as a % .

The Chiller Spray Plant screen in Figure **1** also includes a fault indication “light” and a fault reset button which provides fault indication and reset capabilities for any major fault within the Chiller Spray Plant, such as tripped pumps, flow switch “failure” etc and provides an indication, by having a Green background, which of the Beef Chillers is currently cycling through a Spray Batch .

CHILLER 1 to 10 SPRAY CONTROL

Figure A1.2: Chiller 1 to 10 Spray Control Screen

Figure A1.2 shows the Chiller 1 to 10 Spray Control Screen. This is the screen from which Spray Chilling of each individual Chiller is started, paused and monitored. Each of the ten (10) individual Beef Chillers' has its own identical "block" on the Chiller 1 to 10 Spray Control Screen, so the functionality of only one (1) of these Beef Chillers' "blocks", i.e. Chiller #1, will be discussed and detailed further herein.

It should be noted here that at any time whilst either Water or Air is being discharged into a Chiller, the respective Chiller Fans' will have their "Run" signal removed and as such be "OFF" during this time.

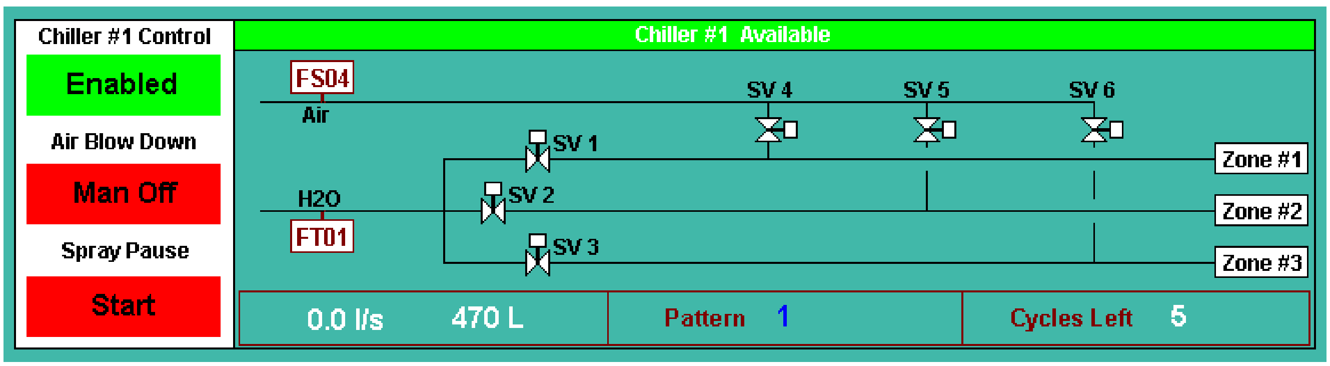

Figure A1.3: Chiller #1 Spray Control "Block"

Before Spray Chilling is initiated in any of the individual Chillers, the operator must first establish if the individual Chiller in which Spray Chilling is to be initiated is able to be Sprayed. This is done by ensuring that the "Chiller Available" Tab is highlighted Green and NOT Red . For this Tab to be Green, the following conditions must be met:-

1. The Chiller Spray Plant MUST be **ON**
2. The Chiller itself MUST be in "Cycle" Mode (in existing Chiller Control Screen)

If any of the "Chiller Available" Tabs' are highlighted Red, Spray Chilling in those Chillers will NOT be able to be initiated. Once the required Chillers' Spraying Availability is confirmed, and prior to Spray Chilling being
initiated, the operator must secondly ensure that the correct Spray Pattern is selected .

There is a choice of five (5) different "approved" Spray Patterns (1 to 5) from which the operator can select. These 5 Patterns have their own Screen (SCADA only) on which the various parameters which make up a complete Pattern can be inputted or changed. This can however only be done on the SCADA "*Spray Pattern*" Screen by someone with the necessary access to this Screen. This Screen (see Figure **5**) is discussed in more detail later.

Once the Chillers' Spraying Availability is confirmed and the correct Pattern has been selected, then Spray Chilling in that Chiller is initiated by selecting the "Disabled" Tab on the Chiller on which Spray Chilling is to be initiated. This Tab will change from saying "Disabled" on a Red background to

"Enabled" with a Green background . Once this Tab displays "Enabled" on a Green background, the corresponding Chillers' Tab on Figure **1** will also display Green.

Once Spray Chilling in a specific Chiller is "Enabled", Spray Chilling in that Chiller occurs in a Spray Batch, which consists of a number of Spray Cycles. As each Chiller is divided into a number of Spraying Zones, of which there are three (3) in ALL Chillers EXCEPT Chiller #5 which has two (2), each of these Spray Cycles consists of a consecutive Water Spray into each of the Chillers' Spray Zones for the designated Zone Spray Time followed by a designated Spray Step Time (these times vary depending on which Spray Pattern is selected) during which time NO water is sprayed into the Chiller. This then completes one (1) Spray Cycle.

Spray Chilling in the "Enabled" Chiller will continue to "cycle" through in this manner until ALL of the Spray Pattern dependant number of Spray Cycles have been completed. At any time during the operation of Spray Chilling in an "Enabled" Chiller, the number of remaining Spray Cycles for the Spray Batch to be completed is displayed on each individual Chillers' Spray Control "Block" .

While H_2O is being sprayed into each of the individual Chillers' Spray Zones, the Zone associated Solenoid will "indicate" that water is being supplied into that Zone by "highlighting" Green . At the same time, the Chillers' Water Flow Transmitter (FT01 in this case), will also "highlight" Green & display the current water flow rate as well as the cumulative water flow, thus far, for the Spray Batch
.

On completion of the "last" Spray Cycle, the system will AUTOMATICALLY do a Compressed Air Blow-Down of the Spray Chilling Piping Headers in the "Enabled" Chiller in order to "purge" all of the H_2O from them, thus ensuring that these headers are "empty" when the specific Spray Batch in that Chiller is completed. It should be noted that the "purging" of these headers in this manner will discharged water from these headers onto the Beef in the Chiller and as such we in effect have one (1) additional Spray Cycle (Purge Cycle) over & above the Spray Pattern dependant number of Spray Cycles originally selected for the "Enabled" Chiller.

As the Spray Chilling Piping Headers will be "empty" when the next Spray Batch is "Enabled", there is a fixed "*Priming Time*" (currently **20** seconds) allocated as part of the very first Spray Cycle of a Spray Batch to allow for the "filling" (Priming) of the piping headers to thereby ensure that the first Spray Cycle of a Spray Batch is not affected in any way by improper Water distribution onto the Beef due to the piping headers being "empty". Just as in the case of Water Spraying, Air Blow-Down is also done on a Zonal basis with ALL Chillers, EXCEPT for Chiller which has two (2) Zones, having three (3) Zones. The Compressed Air used in Air Blow-Down is delivered into each of the "Enabled" Chillers respective Zones consecutively for an adjustable "*Air Blow-Down Time*" period, which can be inputted or changed in the SCADA system by someone with the necessary access to the SCADA "*Spray Pattern*" Screen (see Figure **5)**

There also exists the facility on each Chiller Spray Control "Block" to MANUALLY initiate an Air Blow-Down in an individual Chiller should the need arise. A Manual Air Blow-Down follows the same logic as that of an Auto Air Blow-Down and can only be initiated when Spray Chilling is "Disabled" in that Chiller . When Compressed Air is supplied into each of the individual Chillers' Zones, the Zone associated solenoid will "indicate" that air is being supplied into that Zone by "highlighting" Green . At the same time, the common system Air Flow Switch (FS04) will also "highlight" Green when it registers any flow.

At any time whilst Spray Chilling is "Enabled" in a Chiller, the Spray Batch can be "Paused" for a period not exceeding **30** minutes after which time if the Spray Batch is not "Un-Paused". Spray Chilling in the associated Chiller will AUTOMATICALLY "Disable" itself.

Figure A1.4: Typical Chiller Spray Chilling Program Hierarchy

Figure A1.4 above shows the current Spray Chilling Program Hierarchy/Logic for the Beef Chillers.
SPRAY CHILLING SPRAY PATTERNS

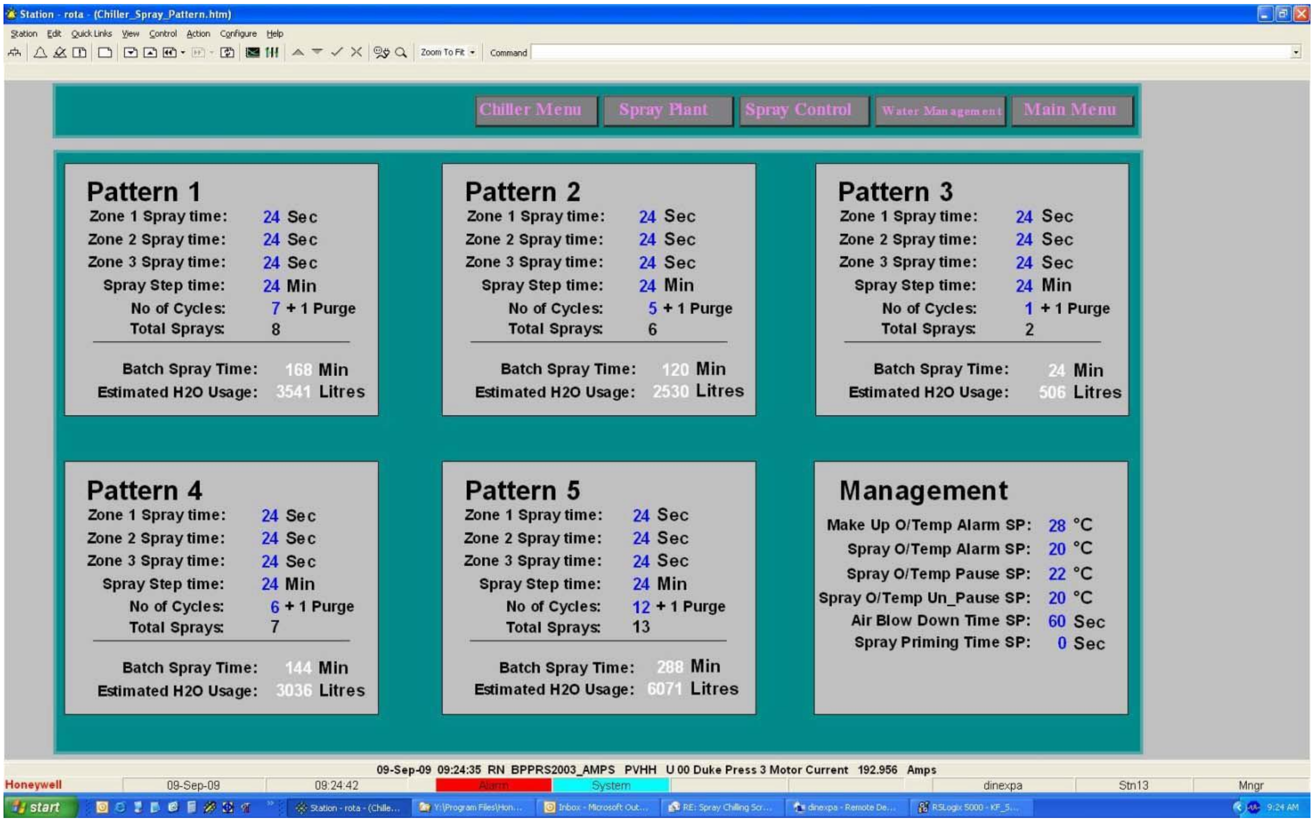

Figure A1.5: Chiller Spray Pattern Screen

Figure **5** shows the Chiller Spray Pattern Screen. This is the screen in which the five (5) different “approved” Spray Patterns’ parameters can be inputted & changed; i.e. Zonal Spray Time , Spray Step Time, # of Spray Cycles (excluding the Purge Cycle), Air Blow-Down Time & **1st** Spray Priming Time. This Screen is ONLY available on the SCADA system and can ONLY be viewed & changed by someone with the necessary access.

In addition, on this Screen the parameters associated with the Make-up & Spray Water Temperature Alarm/Hold Points can be inputted & changed.

These are:-

- Make-up H2O Over Temperature Alarm Set-point, which is the value at which an ALARM is raised in the SCADA that the Make-up Water Temperature is above a “set” value
- Spray H2O Over Temperature Alarm Set-point, which is the value at which an ALARM is raised in the SCADA that the Spray Water Temperature is above a “set” value
- Spray H2O Over Temperature System Pause Set-point, which is the Temperature value at which the Spray Chilling System will go into a HOLD/PAUSED state

- Spray H2O Over Temperature System Un-Pause Set-point, which is the Temperature value at which the Spray Chilling System, once in a HOLD/PAUSED state, will UNHOLD/UNPAUSE itself & continue/proceed with its normal operation. It should be noted that the system can only Un-Pause itself if this Temperature is reached within a maximum of **30** minutes from the time at which it initially Paused, else the entire Spray Plant will shut down.

SPRAY CHILLING WATER MANAGEMENT

Figure A1.6: Chiller Water Management Screen

Figure A1.6 shows the Chiller Water Management Screen. This screen, which is ONLY available on the SCADA system and can ONLY be viewed by someone with the necessary access, gives management a synopsis of the Spray Chilling Water Usage for each Chiller as well as the Total Spray Chilling Water Usage for ALL the Chillers combined. There are no parameters/values on this Screen which can be inputted or changed, it is purely an "Indication Only" Screen for Management purposes.

On each individual Chiller, the following is displayed/recorded:-

- The Currently selected Spray Pattern
- The Current & Previous Spray Cycles' H2O Usage
- The Current & Previous Spray Batches' H2O Usage
- The Current Total Chiller H2O Usage since 6am that morning

For the Entire Spray Chilling System, the following is displayed/recorded:-

- The Total Spray Chilling System H2O Usage
- The Current Total Spray Chilling System H2O Usage since 6am that morning

Photographs of the System

Photo A1.1 – Water tank – water-Glycol HEX and Glycol-NH3 HEX

Photo A1.2 – Chiller pipework

Photo A1.3 – Above Ceiling Valve station

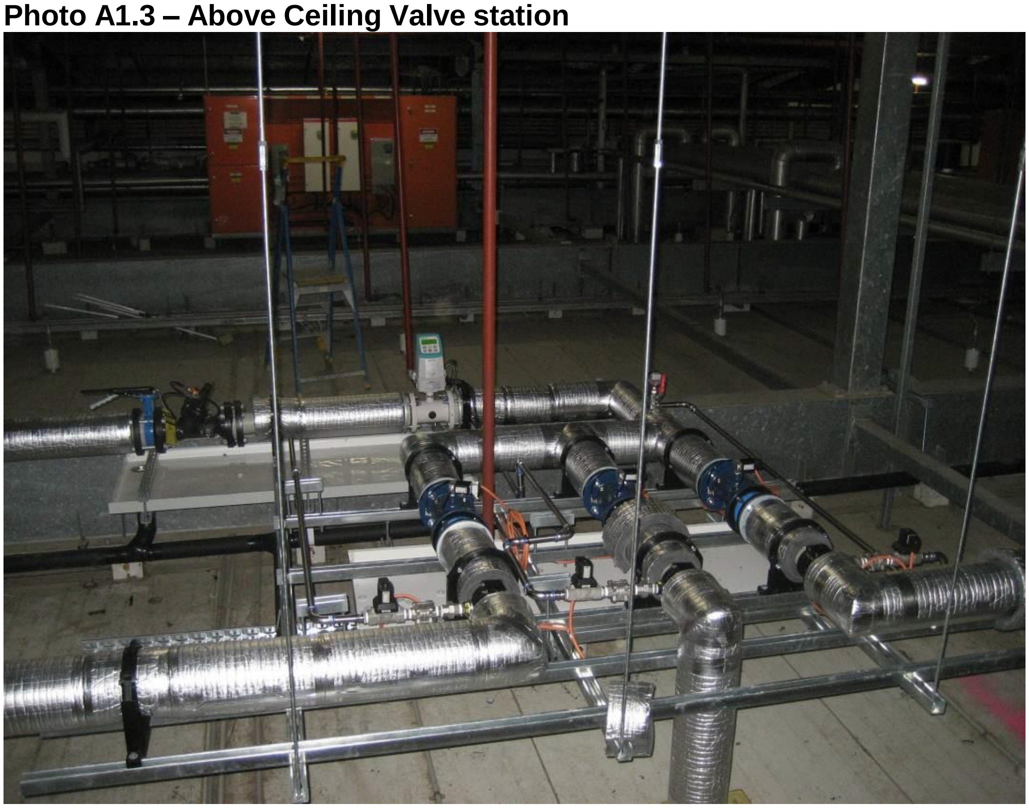

Photo A1.4 Above Ceiling Valve station