final report

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Beef Trim Management & Blending System

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Executive summary

The objective of this project was to increase the value of beef trimmings by the incorporation of inline CL x-ray scanning technology into the grading/mixing process. Pre-sorted trim is automatically scanned, graded, blended, weighed and despatched in pre-programmed quantities for packaging. The technology utilised reduces the amount of labour required, reduces or eradicates CL understatement and CL overstatement and, as a result, reduces rejections, claims and potential loss of market that could arise from continued below par performance.

The Beef Trim Management and Blending System has proven to successfully improve CL accuracy of packed trim by 0.456% and removed CL rejects associated with manually grading trim. Furthermore, the system improves carton packing labour efficiency through the utilisation of a Multibatcher which has the throughput of 3 operators.

Key learning from the project are:

- Consistent product flow to the Eagle FA/3 x-ray is critical
- Smaller, sliced trim prices improve overall carton CL accuracy
- Consistent feed to the Cabinplant Multibatcher is critical
- Where possible, Intralox thermodrive belts can be used however 800 Series Nub Top belts are best for incline scenarios.

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1 Background

Across the Australian beef processing industry, beef trims are graded in-line by visual assessment as operators pack trimmings from conveying system or manual sortation stands. Accuracy of individual cartons / pallecons to the designated chemical lean (typical range 65 to 95 CL) are determined post the packing process by the use of x-ray or drill / microwave methods of verification. Typically, when packaging is being done by visual assessment, even with the most experienced operators there are numerous rejections while trying to achieve a given CL level.

These rejections can result in:

- Increased labour requirements by having to return product to the sortation table and re-blend with other pieces of trim to achieve the desired CL target.
- Increases in the quantity of consumables used i.e. cartons, labels, ink etc.
- Elevated potential for strains for operators while they carry up to 27kg cartons to sortation tables.

The objective of this project was to increase the value of beef trimmings by the incorporation of inline CL x-ray scanning technology into the grading/mixing process. Pre-sorted trim product are automatically scanned, graded, blended, weighed and despatched in pre-programmed quantities for packaging. The technology utilised reduces the amount of labour required, reduces or eradicates CL understatement and CL overstatement and, as a result, reduces rejections, claims and potential loss of market that could arise from continued below par performance.

2 Project objectives

The Beef Trim Management and Blending System project has been designed to deliver 3 key objectives:

1. Develop and implement a system the can automatically blend trim to achieve a pre-programmed CL grade
2. Automatically pack 27.2kg cartons of trim
3. Automatically pack 1,000kg bulk trim pallecon

3 Methodology – System Design & Functional Description

3.1 General Philosophy

The trim area processes cuts of meat based on visually estimated CL according to the production schedule downloaded from the site production system to the Conveyor PLC.

Trim is transferred from the boning and slicing area via Conveyor 5449 to CL Sorting Hoppers based on visual CL grades.

Trim paths are determined by a combination of the daily production schedules, operator selection and operating conditions.

Discharge of Trim from CL Sorting Hoppers depends upon downstream devices being ready to accept trim however manual operation of conveyors and equipment is provided via SCADA and the local supervisor HMI.

3.1.1 Trim Processing Details

Trim processing is divided into four separate processes.

3.1.1.1 Trim Transfer

Trim is transferred to CL Sorting Hoppers from the boning and slicing area via Conveyor 5449, Conveyor 5450, Conveyor 5451 and CL Sorting Conveyor 5452.

Trim is picked from Conveyor 5452 by an operator based on visual estimated CL and placed in the CL Sorting Hopper selected to store Trim with corresponding CL.

Each hopper is manually assigned a CL value using the local supervisor HMI.

Hopper design is critical to ensure consistent discharge of trim. The final Hopper design incorporates a screw to meter out trim onto the transfer conveyor.

3.1.1.2 Trim Grading

One of two modes of operation are possible;

a. Auto

When called by Trim Mixing, Trim is transferred from one of five CL Sorting Hoppers to achieve a target CL. Target CL is an estimated value based on the defined CL of each Hopper. Trim is discharged from CL Sorting Hoppers onto Conveyor 5458 and transferred to the Eagle FA/3 X-Ray machine where actual CL and accumulated weight is measured. If actual CL is above target CL, trim is taken from a Sorting Hopper with defined CL as less than target CL. If actual CL is below target CL, trim is taken from a Sorting Hopper with defined CL as greater than target CL. Trim is transferred to one of two selected Mixers to provide consistent mix of various CL Trims.

b. Manual

A manual process is necessary for the scenario where automatic operation of a CL Sorting Hoppers or downstream equipment is not possible (in case of equipment maintenance or malfunction) or not required.

Manual operation requires the associated discharge conveyor to be operated in reverse using a Foot Pedal. This allows trim to be packed directly from the CL Sorting Hoppers, thus bypassing the blending system.
Each CL Sorting Hopper has an associated auger to feed a bi-directional discharge conveyor as per Table 1.

Table 1: Manual Operation Conveyors

CL Sorting Bin 01	**CL Sorting Bin 02**	**CL Sorting Bin 03**	**CL Sorting Bin 04**	**CL Sorting Bin 05**
Conveyor 5453	**Conveyor 5454**	**Conveyor 5455**	**Conveyor 5456**	**Conveyor 5457**

3.1.1.3 Trim Mixing

Trim is transferred from the Eagle FA/3 X-Ray machine via conveyors where it enters one of two Mixers. Trim is mixed to create consistency across the batch, which could be drawn from various Sorting Bins. The mixing process has been optimised to prevent trim from snaring around the mixing paddles and to limit mixing time to prevent damage to the Trim. See Section 3.1.2 Trim Mixing for further details.

3.1.1.4 Trim Packaging

Analysed and blended trim is directed to one of four destinations; the Multibatcher or one of three pallecons/manual packing station

Trim Packaging destination is controlled by three pneumatic Diverters located along the Pallecon feed conveyor (5459). See Table 2 below;

Table 2: Packing destination configuration

Destination	**Pallecon 01**	**Pallecon 02**	**Pallecon 03**	**Multibatcher**
Diverter 01	**Opened**	Closed	Closed	Closed
Diverter 02	Closed	**Opened**	Closed	Closed
Diverter 03	Closed	Closed	**Opened**	Closed

I. Pallecon

Trim is transferred from mixing to the selected Pallecon Hopper. Trim is then transferred via conveyor to the pallecon until a set weight is achieved whereupon Trim transfer is halted. (Weight is set by production schedule downloaded from the Site Production System). Snowing commences until a set weight is achieved whereupon snowing is halted. Trim transfer resumes. (Weight is set by production schedule downloaded from the Site Production System)
The process of trim transfer and snowing continues until the required weight of Trim has been achieved. Once the Pallecon is complete, a message is sent from the Conveyor PLC to the Site Production System containing data shown Section 3.1.4

II. Pallecon Manual Mode – Packing Cartons

This manual process is necessary for the scenario where automatic filling of a pallecon is not possible or not required. Trim is transferred from mixing to the selected Pallecon Hopper, except an operator will carry out the required packaging operation using a Foot Pedal to reverse the direction of the associated Pallecon feed conveyor. This will allow operators to manually pack cartons of blended CL values. This mode of operation can be used to bypass the Multibatcher

Pallecon 01	Pallecon 02	Pallecon 03
Conveyor 5466	Conveyor 5465	Conveyor 5464

III. Multibatcher Auto

All devices are controlled by the Conveyor PLC except the Cabinplant Multibatcher which has its own internal OEM control system.

The Conveyor PLC has a hardwired interface, to the Multibatcher as follows;

- Digital Input - Ready
- Digital Input - Running
- Digital Input - Fault

Trim is transferred from mixing to the Multibatcher along Conveyor 5459 onto Multibatcher Feed Hopper. The Multibatcher Feed Hopper discharges trim into the Multibatcher whilst it continues to call for Trim, (Ready signal is on and the Fault signal is off).

3.1.2 Trim Mixing

Trim is delivered to the selected Mixer via Conveyor 5462 and a Diverter gate until a specific weight is achieved as defined by the SCADA or local supervisor HMI. Weight is logged by the Eagle FA/3 X-ray.

One mix cycle is defined as follows;

- Rotate forward for 10 seconds
- Pause for 2 seconds
- Rotate reverse for 10 seconds
- Pause for 2 seconds.

Each time period can be adjusted to suit requirements local supervisor HMI.

Once a mixing sequence is complete, Trim is discharged by pneumatic operated 'Bomber Bay' doors onto Conveyor 5463. The double acting pneumatic valves permit the 'Bomber Bay' doors to be opened incrementally. The 'Bomber Bay' doors are closed once the Mixer is empty prior to delivery of the next batch.

Trim is discharged in small portions over a period of time to prevent flooding the discharge conveyor with Trim and causing a conveyor jam. The discharge cycle is as follows:

- Open bomber doors 10% and hold 3 seconds
- Open bomber doors 20% and hold 3 seconds. Rotate forward
- Open bomber doors 30% and hold 3 seconds. Rotate forward
- Open bomber doors 50%
- Open bomber doors 100%

3.1.3 Pallecon Snowing

CO_2 is applied to pallecons according to the specification from the Site Production System. A CO_2 Extraction system is utilised to ensure the extraction of escaping CO_2 during the Snowing process. CO_2 can displace oxygen and is dangerous in large volumes to the health of personnel therefore a means of safely removing any excess CO_2 must be provided.

Each Pallecon station features an Extraction Hood secured above the pallecon scales to safely remove excess CO_2. CO_2 is delivered to the Pallecon at intervals defined by the production schedule downloaded from the Site Production System.
This process is known as Snowing. Snowing is controlled by a solenoid. Prior to energizing a stations solenoid, three conditions must be proven;

- Extraction system is running
- Hood is closed
- CO_2 Safety Valve is energized.

A manual purge function is also available to purge CO_2 that may have accumulated after periods of extended inactivity. Manual purge can be accessed from the local supervisor HMI.

Upon completion of a Pallecon packaging process, a message is sent to the Site Production System to state the current batch has been completed.

CO_2 monitors are installed around the pallecon area. A high CO_2 level in the surrounding area raises an alarm and activates an extraction system.

3.1.4 Site Production System

A high level production system is used for all inventory and product specification. A communications interface to the Conveyors PLC is required for product parameters, recipes, product tracking and management. Communications will be handled via Ethernet.

At the start of the day’s production, the production schedule is downloaded from the Site Production System to the Conveyor PLC using a push button located on a screen on both the local supervisor HMI. The production schedule, relevant to Trim, will contain, but not limited to, the following data set ‘Product Information to Tristar’;

Table 3: Site Production System interface

Title	Element	Data Type	Length (Max for Strings)	Example	Comments
Product Information to Tristar	Product Code	String	8	BD002	
	Product Descriptioin	String	25	CH BEEF *TRMG* 72CL	
	Target CL	Integer	4	72	
	Min CL	Integer	4	71	
	Max CL	Integer	4	75	
	Meat Layer Weight (kg)	Float	8	100	Not Used with Carton Product
	CO2 per Layer (kg)	Float	8	6	Not Used with Carton Product
	Max Weight	Float	8	1100	Not Sure if needed, but may be in the future
	Min Weight	Float	8	300	Not Sure if needed, but may be in the future
Batch Number to Tristar	Batch Number	Unsigned Integer	4	226	
Completed Pallecon to Daisy	Pallecon Station	String	4	PL1	
	Product Code	String	8	BD002	
	CL Value	Integer	4	74	This needs to be average of BOTH batches
	Total Meat Weight	Float	8	830.2	
	Total CO2 Weight	Float	8	48.1	
	Batch Number 1	Unsigned Integer	4	86000	
	Batch Number 2	Unsigned Integer	4	86001	

Once a batch is complete, the data set ‘Completed Pallecon’ will be transferred to the Site Production System. Batch Number is an unsigned integer that will begin counting at one, incrementing by one for the life of the system. In the event of communications loss, the data ‘Batch Number to Tristar’ is used to check the Batch Number in the Site Production System agrees with the Conveyor PLC.

3.2 System Configuration & Layout

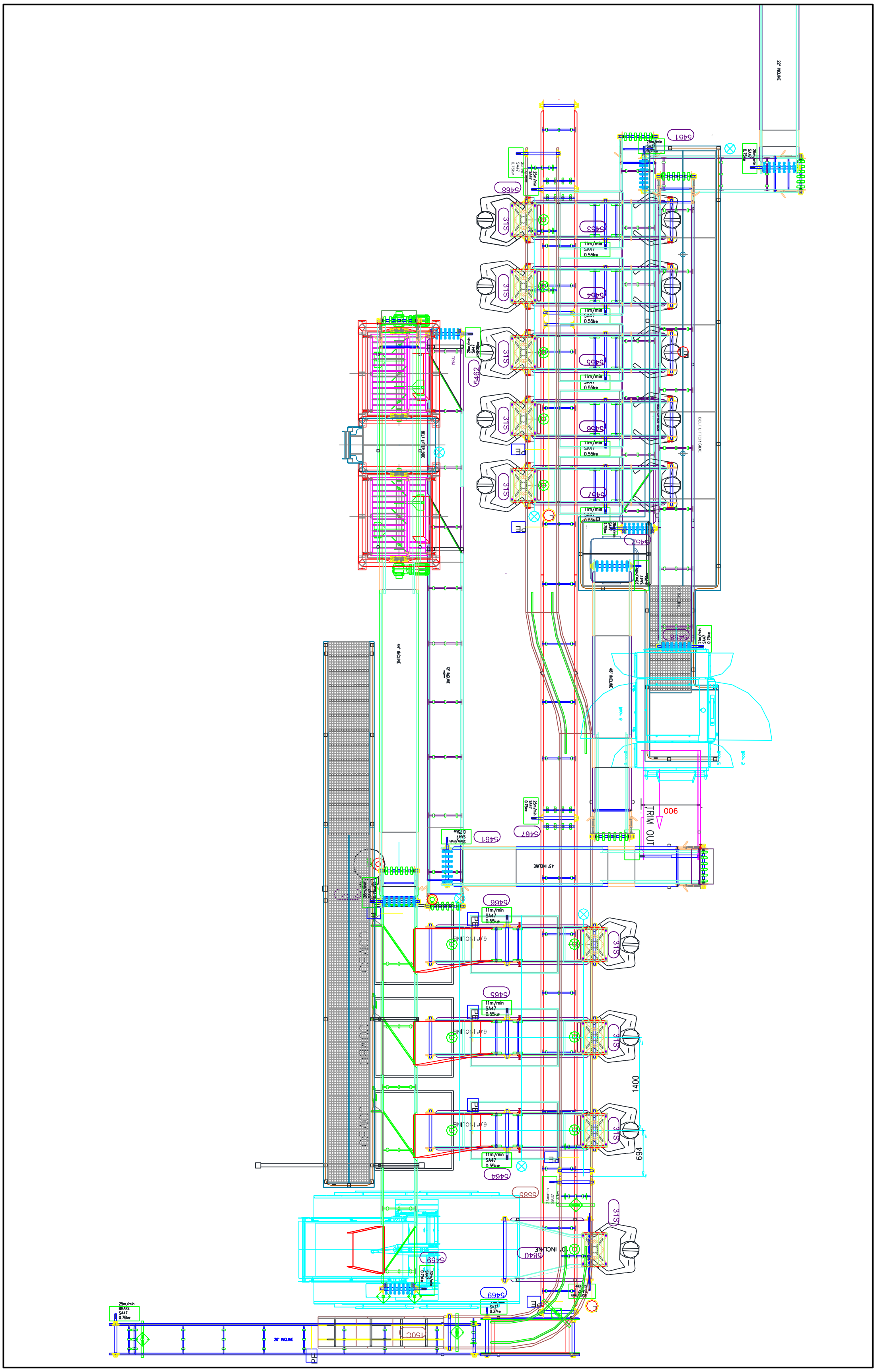

Figure 1 System Layout

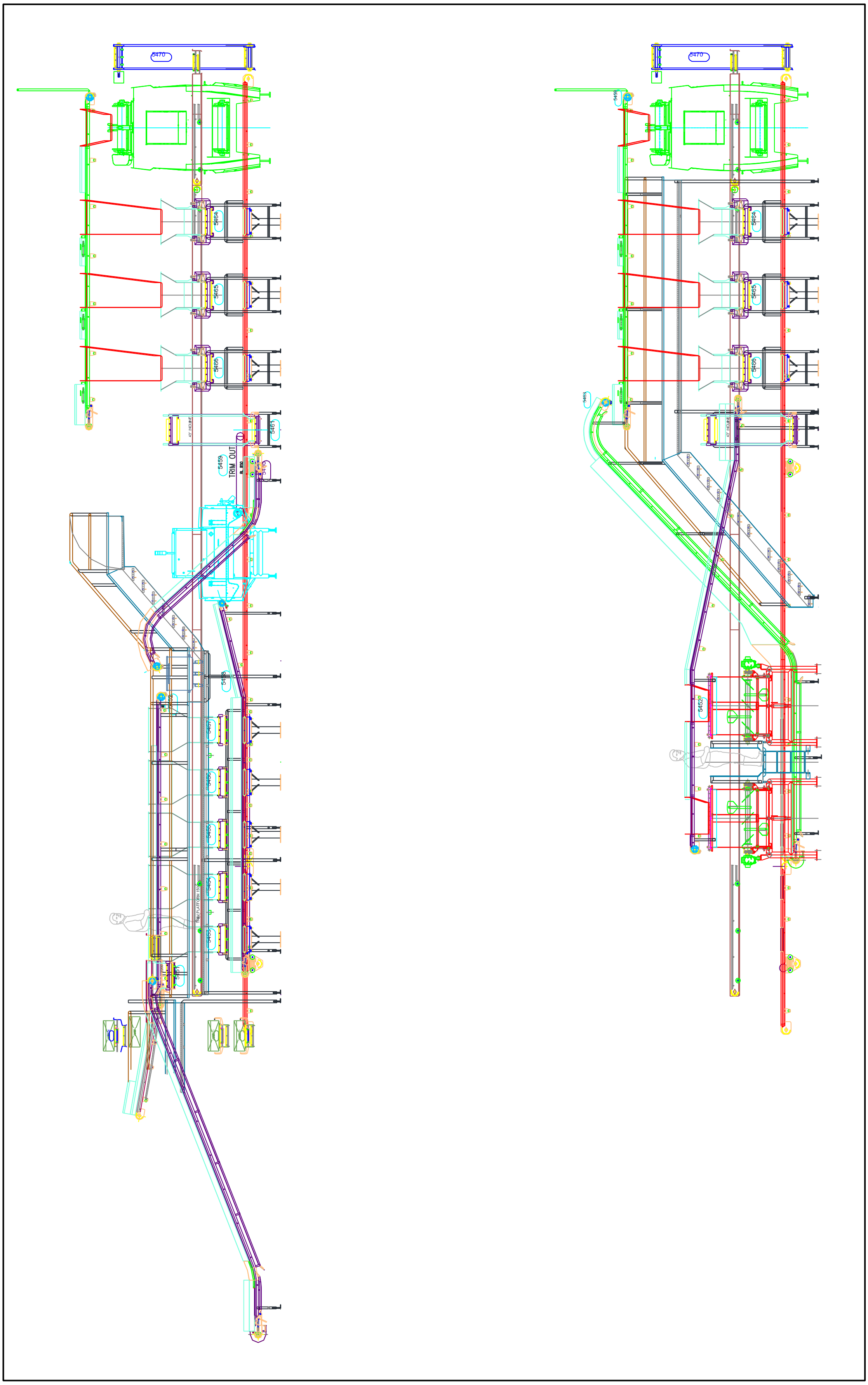

Figure 2: Elevation View

4 Commissioning & Performance Testing Results

Commissioning and performance testing of the Trim Management & Blending System was ongoing for approximately 18 months as the system was refined and issues were identified and subsequently resolved.

Commissioning and performance testing was divided into 4 key areas;

1. Trim Sortation
2. Trim Blending
3. Trim Mixing
4. Trim Packing

Furthermore, Trim Packing was divided into 4 packing scenarios;

1. Trim Packing – Multibatcher
2. Trim Packing – Pallecons
3. Trim Packing – Manual Cartons
4. Trim Packing – Manual Cartons Bypass Blending

4.1 Trim Sortation

Trim sortation consists of the manual 'pre-sortation' of trim pieces into baseline, lean and fat grades via visual inspection into 5 Sortation Hoppers. Mounted above each hopper is a digital display which provides real time feedback to the operators about the CL of trim that has been put into each hopper. To do this, the system has been programmed to draw small batches of trim (approximately 100kg) from each hopper through the Eagle FA/3 X-ray. Once the batch is analysed, its CL composition is sent to the display above the hopper trim was derived from. This provides the opportunity for the operator to adjust what they are putting into each hopper as required in real-time.

Initially, the CL feedback system would update the display each time a batch was sent through the Eagle FA/3 however it was determined that the CL value would change sporadically so a continuous average feedback method was introduced. This method displays the average CL drawn from each hopper over a 15 minute period and resulted in a far more consistent average CL displayed across each sortation hopper.

Figure 3: Trim Sortation CL Feedback Displays

4.2 Trim Blending

Trim blending is the key component of the Trim Management System. Extensive hours of commissioning, performance testing and programming were required to achieve a successful blend at production speed. The limiting factor for blending was the ability to discharge from the Sortation Hoppers at a consistent and reliable speed.

The original hopper design utilised a conveyor belt to transfer trim from the sortation hoppers. As individual trim pieces vary in size dramatically, the quantity of trim transferred to the Eagle FA/3 feed conveyor varied greatly despite the transfer time staying constant. This made predicting and correct trim adjustment very difficult and in some cases impossible.

Several modifications were made to the Sortation Hoppers to improve the discharge. A schedule of the changes is provided in Table 4. Continuous improvements were made to the initial prototype design until an optimal design was developed and implemented across all sortation hoppers

Design and consultation determined that an auger system would resolve the issues experienced however there are inherit work health and safety risks associated with augers in high traffic production areas. This concern was more so prevalent due to limitations in available space. To minimise the risk, the final design includes an auger within the hopper to meter trim on a belt which then transfers to the Eagle CL analyser feed. The auger within the hopper is guarded and inaccessible to operators eliminating safety risks. Guards around the auger include safety rated lock out switches which disable its operation during cleaning or maintenance.

Table 4 Trim Hopper Auger Outcomes

Date	**Item**	**Changes and Modifications**
August 2016	Installation of prototype auger to meter out product onto belt	• Upgrade of the motor size • Change of gear ratio to reduce RPM of auger • Changes to discharge chute size • Changes to auger and belt operating speeds. • Changes to auger flight sizing • Tapering of the end flight to ensure product doesn't wrap around the auger shaft • Changes to auger coupling
March 2017	New auger design	• Remove internal coupling to improve cleaning • Add paddle to push product out of hopper
June 2017	Reverse auger operation	• Move discharge to opposite end of hopper • Modify paddle • Cut back auger flights so they don't extend past discharge chute
July 2017	Implement across all hoppers	• Lift all augers by 100mm to create greater clearance for trim to discharge

Figure 4: Auger discharges onto belt

The final hopper design allows for consistent and predictable trim discharge from the sortation hoppers which allows the system to blend as required at production speeds.

4.3 Trim Mixing

Trim is transferred from the Eagle FA/3 to one of two Mixers. Several deficiencies were experienced during commission of the mixers. The system was designed to send 400kg of batched analysed trim to each mixer prior to starting a mix cycle. It was found that 400kg was difficult to mix in the required timeframe to keep up with production throughput. Mixing at a faster rate caused motor overloading issue. Furthermore, controlling the discharge of 400kg of trim from the mixer was difficult. As the 'bomber bay' mixer doors were incrementally opened, trim would hang up and not release from the machine.

The following actions were undertaken to resolve these issues:

- The drive and gearbox were increased to provide greater torque for mixing the heavier volume
- Mixer paddles were trimmed to reduce resistance through product
- Mixer paddle angles were modified to reduce mechanical stress while ensuring adequate mixing. Paddles were changed to draw product to the centre of the mixer rather than push towards one end.
- Discharge program was optimised to provide more consistent and even discharge from the mixers by adjusting the door opening sequence and keeping the mixer running while discharging.
- The pneumatic cylinders were increase to be able to support the weight of a full mixer during discharge.

Furthermore, an automated trim slicer was installed to reduce the size of trim pieces moving through the system. By slicing trim prior to mixing, carton CL accuracy improved dramatically.. Slicing trim has further downstream benefits by allowing more accurate weights to be achieved by the Cabinplant Multibatcher, reducing rejects.

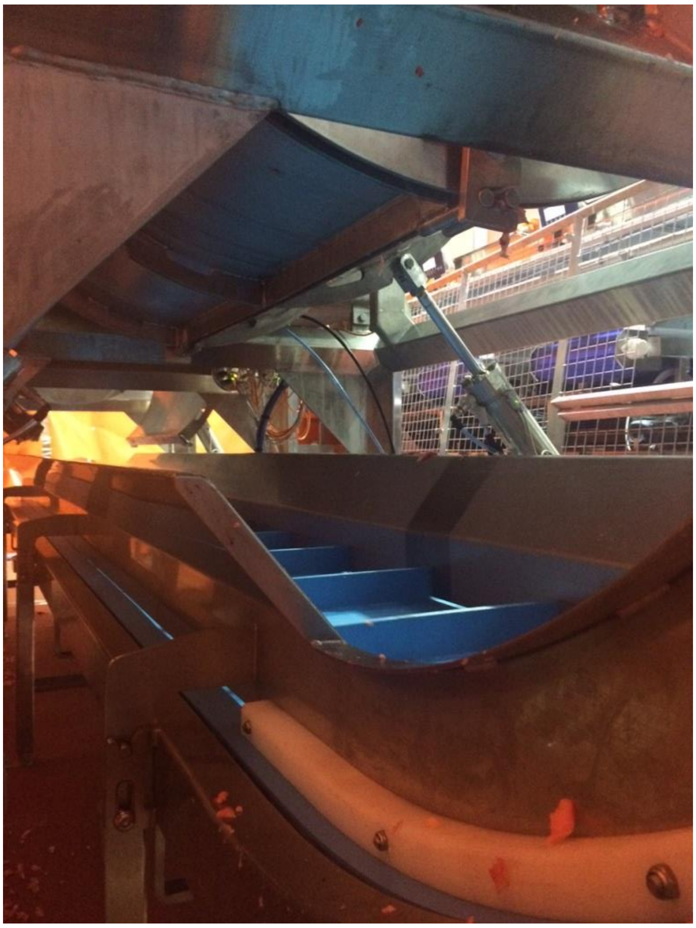

Figure 5: Mixer "Bomber Door" configuration

Figure 6: Larger motor/gearbox

4.4 Trim Packaging

Analysed, blended and mixed trim is directed to one of four destinations; the Multibatcher or one of three pallecons/manual packing station

4.4.1 Trim Packaging – Multibatcher

The Multibatcher installed in Trim Management & Blending system is the first of its kind in the industry and is designed to improve carton packing efficiency and accuracy, reducing labour requirements. TFI utilised the expertise of the suppliers, Cabinplant from Denmark, to assist with the commissioning and performance testing of the machine.

During the commissioning period, Cabinplant engineers made the following observations;

1. Uneven product distribution across the top infeed conveyor of the Multibatcher caused by uneven product flow and transfer to the Multibatcher. The uneven distribution caused large variations in the amount of product entering the weighing pans on each side of the machine which leads to a large variation in the amount of product distributed to the buckets used for weight combination calculations. This cause's a large amount of product rejects as the machine could not create the target weight range batch.

2. Overfilling of Multibatcher infeed conveyor which leads to product blocking up the infeed to the weighing pans. This is further exacerbated by larger trim cuts which block the infeed to the weighing pan. When this occurs, the weighing precision and speed of the machine is reduced because the one weigh pan gets overfilled while the other pan infeed is blocked.

3. The speed of the manual packing process once product is released from the Multibatcher to be packed into the carton is limiting the output of the machine. The operator cannot pack the pre-weighed batches into cartons as quickly as the machine can produce them.

To resolve these issues, 2 key modifications were made to the system.

1. Installation of a Multibatcher Feed Hopper to create a buffer of trim prior to feeding the Multibatcher. The hopper includes a counter-rotating twin screw augers to discharge trim at a metered rate evenly across the Multibatcher feed belt. The modification had an immediate effect on Multibatcher operation and instantly resolved items 1 and 2 above. Configuration of the Multibatcher Feed Hopper is shown in Fig. 5.

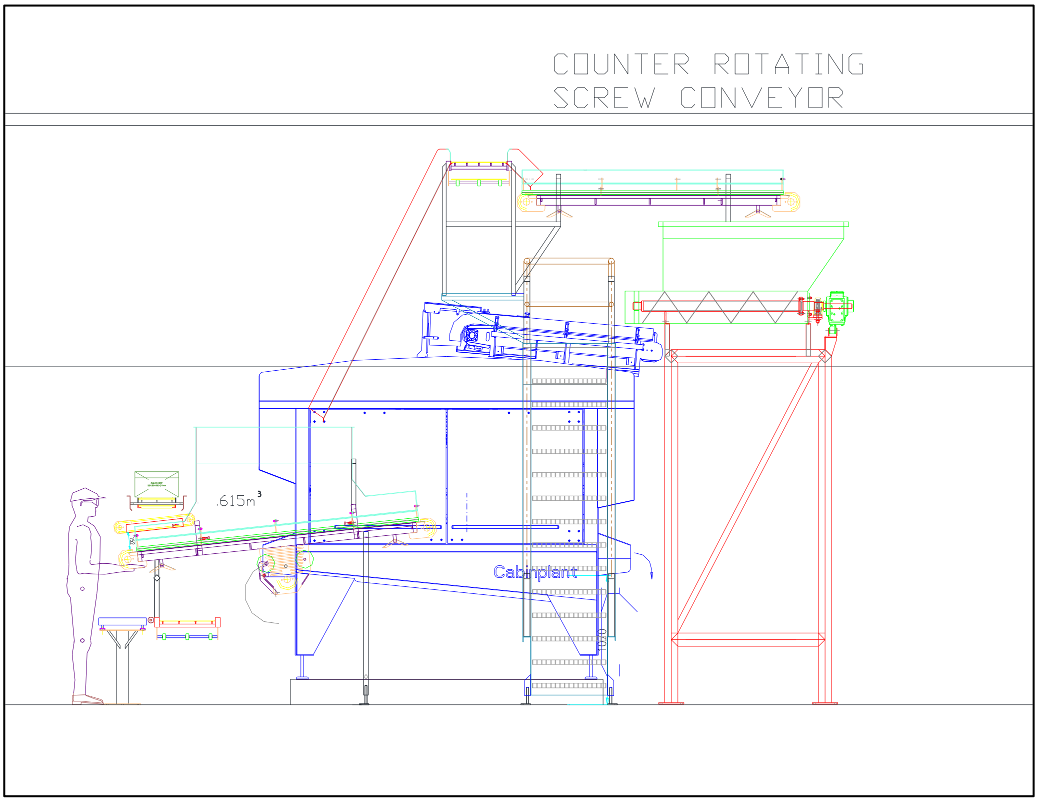

Figure 7: Multibatcher Feed Hopper

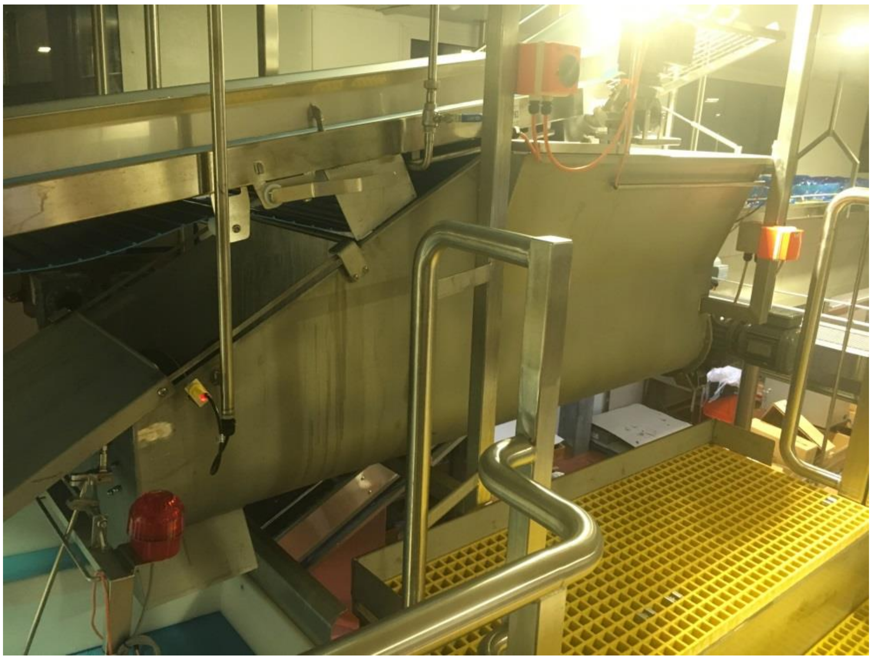

Figure 8: Multibatcher Feed Hopper

Figure 9: Counter-rotating twin screws

Figure 10: Trim distributed evenly across multibatcher feed belt

2. Optimise packing process to achieve the required packing rate by developing a carton delivery and production line system. The process is as follows:
   i. Empty cartons are presented to the packing operator on a conveyor belt.
   ii. The carton is held in place by a gate.
   iii. Once the operator has packed the carton, a foot pedal is used to activate the gate. When the gate drops the full carton moves along the line and an empty carton presents itself ready for packing.

iv. Another operator then labels the carton, validates the weight and tucks in the liners.

Figure 11: Multibatcher carton delivery system

Figure 12: Packing pre-weighed 27.2kg batch into a carton

The Multibatcher system has the ability to accurately generate six 27.2kg portions per minute or 10t of trim per hour. Manually packing and weighing a carton takes an experienced operator 30 seconds. The Multibatcher has the ability to consistently perform the function of 3 labour units.

4.4.2 Trim Packaging – Pallecons

Commissioning of the trim pallecon packaging system proved straight forward and successful. Pallecon scales were integrated with the control system and provided real time weight feedback. Trim would transfer from the pallecon packing hoppers into the pallecon. Once 100kg of trim was in the pallecon, transfer would stop and snowing would commence until a predetermined weight of snow was added to the pallecon based on the product specification selected by the operator on the HMI. Snow application was automatic and controlled by the change in scale weight during application.

4.4.3 Trim Packaging – Manual Cartons

The manual carton packing process was installed as a bypass to the Multibatcher in the event that the machine was not operating. This would allow the facility to continue to pack blended trim using conventional methods. When packing manually into cartons, operators control the flow of trim from the pallecon hopper to a carton on a scale using a foot pedal.

4.4.4 Trim Packaging – Manual Cartons from Sortation Hopper

This packing area is also utilised for trim cuts that do not require blending or in case of any issue with the Trim Management System. Minor adjustments to chutes and guides were made to assist operators with packing cartons.

4.5 Conveyor Belt Selection

Due to the various pieces of equipment and processes throughout the Trim Management System, there are several requirements to transfer trim on an incline. During commissioning and performance testing of the system, several areas were identified to have unacceptable levels of 'dropped meat' as a result of carry-over from incline belts.

Where possible, Intralox Thermodrive belts were selected from the trim area due to their high level of hygiene and cleaning ability. It was identified that smaller pieces of trim had a tendency to stick to the cleats of the inclined Thermodrive belts, resulting in it carrying over to the return side. These would subsequently fall off the belt.

A trial was conducted using an Intralox 800 Series Nub Top polypropylene belt. It was found that this belt resulted in better transfer of trim and also reduced the occurrence of trim falling back down the inclines as it travelled up. It is estimated that this belt reduced trim carry over by 90%.

To ensure the new belt had the same hygiene level of the thermodrive belt, micro analysis was conducted. High risk contact surfaces should have a total aerobic plate count of <1 cfu/cm^2 using the swab method (Sentance & Husband, 1993). Based on this criterion, the Intralox 800 Series Nub Top polypropylene belt passed 48 individual tests.

As a result, thermodrive incline belts were replaced with 800 Series Nub Top belts.

5 Conclusion

The Beef Trim Management and Blending System has proven to successfully improve CL accuracy of packed trim by 0.456% and removed CL rejects associated with manually grading trim. Furthermore, the system improves carton packing labour efficiency through the utilisation of a Multibatcher which has the throughput of 3 operators.

Key learning from the project are:

- Consistent product flow to the Eagle FA/3 x-ray is critical
- Smaller, sliced trim prices improve overall carton CL accuracy
- Consistent feed to the Cabinplant Multibatcher is critical
- Where possible, Intralox thermodrive belts can be used however 800 Series Nub Top belts are best for incline scenarios.

6 Appendix

6.1 OEM Equipment List & Specifications

Data Sheets Attached

- X-ray: Eagle FA3/B with Retracting nose reject (Both units manufactured by Eagle PI)
- Slicer: Magurit Galan 930 (Manufactured by Magurit)
- Multi-Batcher: MB30 (Manufactured by Cabinplant)